In its most simple form, biodiversity is 'Life on Earth'. It refers to a variety of life forms including plants, animals and microorganisms, the genes that they contain and the ecosystems that they form. de Fontaubert et al (1996) defines biodiversity more specifically as ‘the variability among living organisms from all sources including terrestrial, marine and other aquatic inter alia ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.’ Indeed, as this definition illustrates, biodiversity is composed of three main categories: (1) genetic diversity, (2) species diversity and (3) ecosystem diversity. These different components portray how biodiversity encompasses a number of different scales ranging from the gene to the ecosystem.

**MODULE 3: OCEAN CONNECTIONS**

**SECTION 1: MARINE BIODIVERSITY**

**SUNSHINE STATE STANDARDS**


**OBJECTIVES**

Students will be able to:

- Define biodiversity
- List different functions that organisms can provide to an ecosystem
- Identify important ecosystem services
- Perform simulations of different ecosystem services
- Calculate diversity indices of different ecosystems
VOCABULARY

Biodiversity- the variability among living organisms from all sources, including, among other things, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

Species diversity- diversity among species present in different ecosystems; the diversity of populations of organisms and they way they interact.

Genetic diversity- diversity of genes within a species and processes, such as mutations, gene exchanges, and genome dynamics that occur at the DNA level and generate evolution.

Ecosystem diversity- genetic, species, and ecosystem diversity of a given region; the diversity of species interactions and their immediate environment.

Ecosystem Services- Services provided by ecosystems that benefit humans and other organisms, and are necessary for a healthy planet.

Biotic- the living components of an ecosystem.

Abiotic- The non-living components of an ecosystem.

Diversity Index- a statistic which is intended to measure the biodiversity in an ecosystem.

BACKGROUND

Introduction

Biodiversity is the degree of variation of life forms within a given ecosystem, biome, or an entire planet. Biodiversity is a measure of the health of ecosystems. Greater biodiversity implies greater health. Biodiversity is in part a function of climate. In terrestrial habitats, tropical regions are typically rich whereas Polar Regions support fewer species.

Rapid environmental changes typically cause extinctions. One estimate is that less than 1% of the species that have existed on Earth are extant.
Biodiversity is defined as “the variability among living organisms from all sources, including, among other things, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (United nations Convention on Biological Diversity). There are three distinct levels of biodiversity:

- **Species diversity** – diversity among species present in different ecosystems; the diversity of populations of organisms and the way they interact.
- **Genetic diversity** – diversity of genes within a species and processes, such as mutations, gene exchanges, and genome dynamics, that occur at the DNA level and generate evolution.
- **Ecosystem diversity** – genetic, species, and ecosystem diversity of a given region; the diversity of species interactions and their immediate environment.

Today's biodiversity is the result of billions of years of evolution, natural processes, and in more recent years, human activity. Human activity has had a tremendous impact on biodiversity due to the use of Earth's resources and exponential population growth. The total number of species on Earth today is estimated to be around 10 million different species. New species are discovered often, and many that have been discovered have not yet been classified. The ocean, along with the tropical rainforest, is one of the richest sources of biodiversity on Earth.

**Distribution**

Biodiversity is not evenly distributed. Flora and fauna diversity depends on climate, altitude, soils and the presence of other species. Diversity consistently measures higher in the tropics and lower in polar regions generally. In 2006 many species were formally classified as rare or endangered or threatened; moreover, scientists have estimated that
millions more species are at risk which have not been formally recognized. About 40 percent are now listed as threatened with extinction—a total of 16,119.

Even though terrestrial biodiversity declines from the equator to the poles, this characteristic is unverified in aquatic ecosystems, especially in marine ecosystems. In addition, several assessments reveal tremendous diversity in higher latitudes. Generally terrestrial biodiversity is up to 25 times greater than ocean biodiversity.

A biodiversity hotspot is a region with a high level of endemic species. Many hotspots have large nearby human populations. Most hotspots are located in the tropics and most of them are forests.

The ocean is a complex ecosystem where every biotic and/or abiotic factor influences every other factor either directly or indirectly. All species are an integral part of their ecosystem by performing specific functions that are often essential to their ecosystems and often to human survival as well. Some of the functions different species provide are:

- Capture and store energy
- Produce organic material
- Decompose organic material
- Cycle water and nutrients
- Control erosion
- Control pests
- Regulate climate and atmospheric gases.

Removing species from ecosystems removes these important functions. And because of the interlaced structure of these systems, the loss of one species or habitat can have drastic impacts on others. Thus, the greater the diversity of an ecosystem, the better it can maintain balance and productivity while withstanding environmental stressors.

What is Marine Biodiversity?

Biodiversity is now commonly defined as the variety of life in genes, species and habitats. According to the definition of the Convention on Biological Diversity, biodiversity is the variability among living organisms from all sources, including inter alia, terrestrial, marine and other aquatic
ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

The three domains of life, bacteria, archaea and eukarya are present in the marine environment. In addition there are viruses. About 230,000 species of marine plants and animals have been scientifically described and a few thousand bacteria and archaea. This known biodiversity only represents a small fraction of the number of species existing, except for the macrophytes and seagrasses which are living in coastal environments and, in general, for the pelagic environment.

The distribution of marine biodiversity varies widely throughout ocean basins. The abundance and diversity of most taxa tends to be highest near continental and island margins that are less than 2,000 meters deep.

These areas experience nutrient enrichment from upwelling processes and terrestrial runoff. Areas where significant upwelling occurs are often extraordinarily productive in tropical, temperate, and polar regions. Within major habitat types, species richness and endemism also vary enormously around the globe.

In general, marine ecoregions associated with isolated islands and enclosed seas tend to display higher levels of endemism.

Moreover, knowledge of biogeographic boundaries and biodiversity information for marine habitat is limited at this time. The pelagic major habitat types are characterized by widespread distribution of many species. In contrast, sizable proportions of the ocean trench biotas (hadal) surveyed to date are endemic to single trenches. Our limited knowledge reduces our confidence to undertake comparative analyses.

Species diversity in the oceanic pelagic environment is extremely low. The number of species in the upper 200 meters (m) of the pelagic oceanic environment is well known for four groups of animals, the Euphausiacea, Chaetognatha, Pteropoda and Copepoda, which dominate the biomass everywhere. There are only 80 species of euphausiids, 50 of chaetognaths, about 40 of pteropods and less than 2000 for the most diverse group, the calanoid copepods. These data
are based on more than 20,000 net tows and, although new species will certainly continue to be discovered, it is obvious that pelagic biodiversity is of another order than both terrestrial and marine benthic diversity.

This low number of (animal) species is in striking contrast with the diversity of animals in sediments. About 200,000 species are currently known from benthic environments. Most of them have been described from coral reefs, and only about 60,000 are known from soft bottom habitats that cover most of the Earth’s surface. Benthic species from the temperate shallow waters of Europe are reasonably well known, especially in the larger macro- and megafauna. The smaller meiofauna (mm-sized animals) is less well described and, as an example, a survey of the benthos in the North Sea in 1986 yielded about 40% of benthic copepod species new to science.

For both animals and microbes, the exploration of environments that are difficult to access, such as the deep-sea floor or marine caves, and the application of new technologies, are constantly yielding new species and higher taxonomic categories, even up to phylum level. Especially the availability of rapid sequencing technologies has shown that variability in the microbial domain, including the small eukaryotes, is extremely high and that tens of thousands of ‘species’ may co-occur in a single liter of sea water.

Life originated in the sea and is much older in the sea than on land. As a consequence, animal and plant diversity at higher taxonomic levels are much greater in the sea where there are 14 endemic (unique) animal phyla whereas only 1 phylum is endemic to land. For plants the situation seems to be different—almost all algal groups have representatives in both fresh and marine waters and higher plants are nearly exclusively terrestrial. There is also a remarkable diversity of life-history strategies in marine organisms. The sum total of genetic resources and physiological diversity in the sea is therefore expected to be much more diverse than on land.

Habitat diversity and the number of marine habitats is difficult to define. Studies of zonation have typically demonstrated the existence of very narrow zones in intertidal areas, where direct observation is possible, and broader and broader zones as one goes deeper. However, it is recognized that this is due to our
limited possibilities of observation and with increasing technological capability, finer discontinuities are revealed even in the water column. Besides zonation bands, a number of very specific habitats often linked to tectonic activities have been discovered over the last decades, starting with the hydrothermal vents in 1977 and followed in later years by cold seeps of gases and fluids, carbonate mounds, mud volcanoes, etc. Multibeam sonar has allowed much more detailed analysis of the sea floor showing fine-grained features in sediments that were previously thought to be rather uniform, or the very complex topology of marine canyons in the continental slope. With increasing potential of observation, the number of marine habitats on many different scales will certainly increase, and, as these habitats often contain species which are specifically adapted to their environmental conditions, so will species diversity.

**Types of Diversity**

**Genetic Diversity**

Genetic diversity is the variation in the amount of genetic information within and among individuals of a population, a species, an assemblage, or a community. It is reflected by the level of similarity or differences in the genetic makeup of individuals, populations and species. These similarities and differences may evolve as a result of many different processes: e.g. chromosomal and/or sequence mutation, and physical or behavioral isolation of populations. Although genetic diversity is not always obvious, it is extremely important as it is a requisite for evolutionary adaptation to a changing environment. Therefore, genetic diversity can be thought of as insurance, which allows adaptation to changing environmental conditions.

To understand many ecological and evolutionary processes, one must understand something of the genetic diversity of the species, population, or individual of interest. Further, it is desirable to understand the mechanisms for creating and maintaining the observed patterns of diversity. Thus, studies of genetic diversity have the potential to provide insight in many fields including conservation biology, population and community ecology, and evolutionary biology.
Species Diversity

Species diversity is the variation in the number and frequency of species in a biological assemblage or community. Species diversity is the most commonly used synonym for biodiversity, where species richness (number of species in a given habitat) is the main index used for its measurement. The working estimate of the total number of species on earth is 12.5 million, however, the total number that could exist ranges from 5-100 million. Grassle and Maciolek (1992) suggest that there may be 10 million undescribed species in the deep sea alone!

In both marine and terrestrial realms, diversity of the smaller organisms is much less established than the larger organisms. For example, in the ocean, there is a plethora of information on whales, dolphins, porpoises and fish while only recently are scientists understanding the extreme diversity present in microorganisms such as bacteria and phytoplankton (i.e. the plants of the sea).

It is the origin and extinction of species that are the main components which determine biological diversity. However, the contribution of species to the overall diversity is not equal. Organisms that differ widely from each other will have a higher contribution to the overall diversity as compared to species that are more similar to each other. This illustrates that species richness may not be the best estimate for species diversity and it may be essential to use a different index in the future.

Ecosystem/Habitat Diversity

An ecosystem consists of all living and non-living things in an area. Ecosystems include a unique combination of animals, plants, microorganisms and physical characteristics that define the location. Ecosystem diversity is the variation in the collection of assemblages, communities, and habitats within a region. Currently, there is no universal classification or unique definition of ecosystems at a global scale, however, this area of research is evolving quickly. Inherent in ecosystem diversity are both biotic (living) and abiotic (non-living) components, which differs from both genetic and species diversity.
There are a number of habitats that continue to be discovered at an alarming rate and there may be more ecosystems of this nature waiting to be revealed. In the ocean, hydrothermal vents were discovered less than 25 years ago! They are known to be extremely unique habitats with many endemic species (Grassle, 1986; Tunnicliffe, 1991). Furthermore, whale carcasses have been discovered to be a unique microhabitat (Smith et al, 1989) and they may also be connecting points between hydrothermal vent communities allowing these organisms transverse vents.
It should be noted that in some of the literature, ecosystems and habitats are considered as separate phenomena. Gray (1997) amalgamates community and ecosystem diversity, arguing that one cannot separate the community and ecosystem. He concludes that 'no ecological system, whether individual, population or community, can be studied in isolation from the environment in which it exists'. In this report, habitat diversity considers habitats as physical areas and the biotic components they contain and thus, habitat diversity is actually more useful than ecosystem diversity.

**Other types of diversity**

It is evident from the above discussion that biodiversity encompasses many levels including genes, species, ecosystems and habitats. Although these are the main components of biodiversity, there are two other kinds of biological diversity that have been suggested. They include (1) higher taxonomic diversity and (2) functional diversity (Norse, 1993).

Phyletic or taxonomic diversity involves the variation and variability of the working body plans (phyla) of organisms. An example of a phylum includes Arthropoda of which the class Insecta is part. Phyletic diversity can result in a higher diversity of phyla without requiring a high diversity of species. For example, in the marine environment there are 32 out of the 33 animal phyla present (Norse, 1993) and this is considered a high phyletic or taxonomic diversity.

Functional diversity is a grouping of species on the basis of how similar their functions are. For example, in the ocean, all organisms that deposit feed may be amalgamated into one functional group just like all filter feeders would compose another group based on that particular function. This can also extend to reproduction methods or biochemical diversity.

**Goods and Services Provided by Marine Biodiversity**

Marine organisms play a crucial role in almost all biogeochemical processes that sustain the biosphere, and provide a variety of products (goods) and functions (services) which are essential to humankind’s well-being. Goods include the production of food (about 100 million tonnes annually) and natural substances, ingredients for
biotechnology and pharmaceuticals, and even land (e.g., the carbonate platforms that make up the Bahamas). These goods are mainly delivered by macroscopic organisms.

Besides goods, marine ecosystems deliver a series of services that are essential to the proper functioning of the Earth. These include the production and mineralization of organic material, the storage of carbon, the storage of pollutants and waste products from land, the buffering of the climate and of climate change, coastal protection (mangroves, dune-beach systems, coral reefs). Most of these services are delivered by microscopic organisms.

The rate and efficiency of any of the processes that marine organisms mediate, as well as the range of goods and services that they provide, are determined by interactions between organisms, and between organisms and their environment, and therefore by biodiversity. These relationships have not yet been quantified, and we are at present unable to predict the consequences of loss of biodiversity resulting from environmental change in ecological, economic or social terms.

The economic valuation of goods and services has been a subject of much research and debate recently. Although it is possible to attribute monetary value to many goods and services (and to show that this value can be extremely high) it is also important to recognize that non-use values such as intellectual interest, aesthetic pleasure and a general sense of stewardship towards the non-human life of our planet are important prerequisites for public support of the conservation and sustainable use of the marine environment.

**Resistance and Resilience to Change**

The diversity-stability hypothesis suggests that diversity provides a general insurance policy that minimizes the chance of large ecosystem changes in response to global environmental change. Microbial microcosm experiments show less variability in ecosystem processes in communities with greater species richness, perhaps because every species has a slightly different response to its physical and biotic environment. The larger the number of functionally similar species in a community, the greater is the probability that at least some of these species will survive stochastic or directional changes in the environment and maintain the current properties of the ecosystem.

Even the loss of rare species may jeopardize the resilience of ecosystems. In the marine environment this is particularly relevant for species at the top of the food web, such as tuna and sharks, whales, sea lions and sea otters and perhaps some birds. Species diversity also reduces the probability of outbreaks by pest species by diluting the availability of their hosts.

**Resistance to Invasions**

Biodiversity can influence the ability of exotic species to invade communities through either the influence of traits of resident species or some cumulative effect of species
richness. Early theoretical models and observations of invasions on islands indicated that species-poor communities are more vulnerable to invasions because they offer more empty niches. However, studies of intact ecosystems find both negative and positive correlations between species richness and invasions.

**Marine Food Webs**

The main marine primary producers are very small and often mobile. In the oceans cyanobacteria are the main primary producers: species from the genera *Synechococcus* and *Prochlorococcus*, about 1-2 μm in diameter, are responsible for about two thirds of oceanic primary production, i.e., one third of the total primary production of organic material on Earth.

Oceanic primary production is limited by nutrients, including iron in large areas of the oceans. A large part of the organic material produced is internally recycled. The microbial food web, based on dissolved organic matter, includes photoheterotrophic bacteria, using sunlight as an energy source but without the production of oxygen, and viruses which are responsible for control of the bacterial populations. The very small picoeukaryotes, both autotrophs and heterotrophs, many of which are grazers on bacteria, are extremely diverse but very poorly known. Marine food webs are very long in most areas and include many species.

The standing stock of grazers is higher than that of primary producers in the sea, which is the opposite of the situation on land. Ocean productivity is on average far lower than land productivity. In the largest part of the ocean, beneath the shallow surface layers, no photosynthesis occurs at all and the largest part of the Earth’s biosphere is therefore dependent on external subsidies of organic matter.

High-level carnivores often play key roles in structuring marine biodiversity and yet are exploited heavily with unquantified but cascading effects on biodiversity and on ecosystem functions. This does not occur on land, where the ecosystems are dominated by large herbivores and, of course, increasingly by humans which monopolize about 40% of the total world primary production. Top down control of marine food webs implies that the fisheries of top predators have to be considered as a potential mechanism directly dependent on humans that may change the ecology of the entire ocean.
Threats to Marine Biodiversity

It is often argued that changes in biodiversity will be mainly restricted to land and consequently attention to biodiversity changes in the oceans is limited. However, humans do impact the oceans already to a considerable degree, especially in the coastal areas but increasingly in the open ocean as well.

The effects of fisheries, focusing on the top predators and herbivores of the food web, is globally visible in the disappearance of large fish, sharks, turtles, crustaceans and plants, and consequent increases in smaller fish species, sea urchins, etc., and their phytoplanktonic or macrophyte food. Global climate change is increasing sea-surface temperature and northward migrations of species have been documented from fisheries and the unique data from the Continuous Plankton Recorder. Increasing carbon dioxide ($CO_2$) levels reduce the pH of sea water and increase the solubility of calcium carbonate with potentially dramatic consequences for calcifying organisms, such as corals, mollusks, coccolithophorids, pteropods and forams.

A greater variety of species at a higher trophic level is exploited in the sea than on land: humans exploit over 400 species as food resources from the marine environment; whereas on land only tens of species are harvested for commercial use. Exploitation of
maritime biodiversity is also far less managed than on land and amounts to the hunter-gatherers stage that humans abandoned on land over 10,000 years ago, yet exploitation technology is becoming so advanced that many marine species are threatened to extinction. Insufficient consideration has been given to the unexpected and unpredictable long-term effects that such primitive food-gathering practices engender.

Most if not all pollution (air, land and freshwater) ultimately enters the sea. Marine biodiversity is thus most exposed to and critically influences the fate of pollutants in the world. Yet marine species are probably least resistant to toxicants. The spread of pollutants in marine food chains and therefore the quality of marine food is uncontrollable by humans.

Protection of Marine biodiversity

Human attention rightly focuses on the decline of biodiversity on land, but this should not happen at the expense of the oceans—attention to marine biodiversity is also urgently needed if we want to maintain a stable relationship between humans and the sea. The oceans have no owner and no single nation or international organization is liable for their health. As a consequence, the seas are under increasing pressure. Humankind is destroying the coastline and its protection against flooding, polluting coastal waters and critically changing the oceanic food webs by overfishing of the top predators over large parts of the world. Marine Protected Areas and Nature Reserves are now being established rapidly but not in areas beyond national jurisdiction which remain vulnerable to uncontrolled exploitation. This includes most of the open ocean and deep-water habitats on Earth and so, in fact, most of the planet.

Marine Biodiversity Research

We know more about the Moon than about the oceans and more money is spent on space research than on exploration of the deep sea, the last unknown habitat on Earth and one where exciting discoveries can still be made. As an example, since 1980 two new animal phyla have been discovered that are endemic to the marine environment and a whole series of new habitats have been found and explored in the last ten years. Even more recently is the exploration of the vast genetic and microbial diversity. The
need for extended exploration is exemplified by programs such as the Census of Marine Life, a worldwide effort to explore and understand the biodiversity of the oceans.

An important product of marine biodiversity research should be the necessary knowledge and tools for adequately managing and protecting marine biodiversity. This requires knowledge on genetic and ecological mechanisms that control biodiversity (gene flow, dispersal, adaptive value of genetic polymorphisms, determination of dispersal and recruitment, species interactions including invasions, sediment transport, natural and human-induced catastrophes, etc.). It also requires knowledge on the functional role of biodiversity: what is the variability in genes, species and communities that is required for ‘normal’ or desirable ecosystem functioning; and models on dispersal of genes and organisms, species interactions and food webs, the interaction between food webs and biogeochemical fluxes, and impact assessment of diffuse and point source pollution, coastal constructions, mass tourism and global climate change.

**Technology and Data Information Systems**

Support of conservation and sustainable exploitation of biodiversity will require development of rapid assessment techniques for monitoring marine biodiversity (genes, species and biotopes), including the use of molecular techniques, rapid identification techniques, assessment of difficult species (microbes, sibling species, multispecies complexes), pictural taxonomic and identification keys accessible on the World Wide Web and CD-ROM, remote sensing techniques (Satellite Imagery, Side Scan Sonar, multibeam, LIDAR, etc.). It must also provide for the development of data bases and Geographic Information Systems (GIS) for genes, species and habitats.
ACTIVITY: SECRET SERVICES

Perform simulations that demonstrate some of the important ecosystem services provided by biodiversity.

DURATION: 2 days (45 min-1hr each day)

OBJECTIVES
- Perform simulations that demonstrate some of the important ecosystem services that biodiversity provides.
- Perform a series of simulations that demonstrate ecosystem services. Identify and discuss the services illustrated in the simulations.

MATERIALS
- Clear funnel
- 3 Clear plastic cups
- 3 glass jars
- Celery stalks with leaves
- Cotton balls
- Activated charcoal
- Sand
- Potting soil
- Water
- Red food coloring
- Paring knife
- Magnifying glass
- 4 sponges
- Small doormat
- 2 flat sheets of wood or plastic similar in size to doormat
- 2 shallow aluminum trays
- 2 rectangular plastic containers
- Wax paper (cut to a 6 in x 6 in square)
- Geranium plant leaf with stem
- Cobalt chloride paper
- Petroleum jelly
- Paper clip
- Tape
- Large bowl
- Measuring cup
- Tablespoon
- Baking soda
- Lamp
- Water plant (such as Elodea – purchase at aquarium store)
Ecosystems and the variety of species within them provide many important services that help make life possible or at least more livable. These services are happening all the time—they are so common that we often don’t notice them or think about how important they are. This activity is a series of five simulations that illustrate a variety of these services. (More advanced students can try to develop their own simulations after learning more about ecosystem services.)

1. Before class begins, arrange the stations for each simulation. Place a copy of the directions and necessary materials at each station
   - Station 1: Dirty Water
     - Clear funnel
     - 1 clear plastic cup
     - 1 jar
     - Cotton balls
     - Activated charcoal
     - Sand
     - Potting soil
     - Water
   - Station 2: Treatment Plants
     - Celery
     - 1 jar
     - Food coloring
     - Water
     - Paring knife
     - Magnifying glass
   - Station 3: Runoff Race
     - 4 sponges
     - Doormat
     - 2 sheets of wood or plastic
     - 2 aluminum trays
     - Soil
     - Water
     - 2 rectangular containers
     - Additional props to tilt models (books, magazines, blocks, etc)
   - Station 4: Natural Climate Control
     - 2 clear plastic cups
     - Wax paper
     - Geranium plant leaf with stem
     - Cobalt chloride paper
     - Petroleum jelly
     - Paper clip
2. Divide students into 5 groups and assign each group to a station
   - Explain to students that they will work together to complete a simulation
   - Each simulation illustrates one way that ecosystems provide important services for the environment
3. Distribute the “The Secret’s Out” worksheet
4. Explain that each group will run one simulation and then present that simulation to the class.
   - When they arrive at a station, all team members should read the directions completely
   - After they have read and understood the directions, they can set up the simulation.
   - The group should discuss the expected outcome of the simulation
   - Next, they can run the simulation. **Remind groups at stations 2, 4, and 5 that their simulations will take about 24 hours to complete.**
   - Each student should answer the questions listed under “Think About It”
5. On day 2, explain to students that each team will have a few minutes to present their simulation to the class
   - Each team should briefly review its procedures, perform the simulation (or explain the results of the overnight simulations), and discuss the results
   - Each group should provide information to the class that answers the “What Happened?” and “Think About It” sections on the worksheet
6. After watching all the simulations, students must identify the ecosystem service being demonstrated in the simulation on their worksheet
7. Lead a class discussion around their answers
   - Review and summarize the different ways ecosystems provide important services to people and the planet
   - What are some other ecosystem services that were not covered during this activity?
8. **Possible Extensions**
   - Have students identify different places in the community where the ecosystem services they simulated are occurring. Students can create brochures that highlight and advertise these services
   - Allow students to identify other types of ecosystems services, and then create their own simulations that can model those services.
9. Review and summarize.
   - When all the teams have completed their presentations, review and summarize the different ways ecosystems provide important services to people and to the planet. The list should include flood control, water filtering and purification, erosion control, oxygen production and climate control.
STATION 1: DIRTY WATER

Soil is a mixture of mineral particles, air, water, microorganisms and other organic matter (material derived from living things). The materials that make up soil form layers. Hundreds of years may be required to form just a few inches of soil. Soil helps to purify water by filtering out some of the suspended solids (floating “dirt” particles) as they flow through the different soil layers. The makeup of the soil determines how well it will act as a filter. Soil also helps to remove chemical contaminants such as fertilizers and pesticides.

Many minerals in the soil can chemically bond with contaminants, which are then stored in the soil and prevented from flowing into nearby waterways. As a result of chemical reactions, the soil can also help “detoxify” certain chemicals, making them less harmful to living things.

MATERIALS

- clear funnel or clear plastic soda bottle with the bottom cut off and the label removed
- clear plastic cup
- tall jar or flask
- cotton balls or toilet paper
- activated charcoal
- sand
- potting soil
- water

WHAT TO DO

1. Pack the funnel approximately one-third full with cotton balls.

2. Place a layer of charcoal on top of the cotton balls. Then place a layer of sand on top of the charcoal.

3. Place the funnel into the jar or flask. The mouth of the jar should be small enough to keep the funnel off the bottom of the jar. (See diagram.)

4. Mix one-fourth cup of potting soil with one-half cup of water in the plastic cup. Then slowly pour the water into the funnel.
**WHAT HAPPENED?**

Describe the appearance of the water after filtering and any changes that you can see. Look at the different layers in your funnel.

Where did most of the large soil particles get trapped? ______________________

Where did the fine particles get trapped? ______________________

What do you observe about your samples?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

**THINK ABOUT IT**

How do you explain the results of the experiment?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

Why do you think some materials are more effective filters than others?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

How would you describe the “services” that soils provide?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

Can you list a local example of this service?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________
STATION 2: TREATMENT PLANTS

Plants have fine “tubes” inside them that carry water from their roots to their leaves. When water contains toxic pollutants (such as pesticides or heavy metals) those pollutants may also be carried up and through the plant. Many wetland plants store toxic materials in their tissues. This doesn’t mean that the toxins disappear—usually they are excreted later. But they are released slowly, in small amounts that are less damaging than a large dose of toxins entering a river, lake or pond all at once. When the wetland plants die, the toxins are released back into the water and soil of the wetland where they may be “captured” by other plants or by soil particles. Even though wetland plants can help absorb and alter some toxins, they aren’t able to absorb all toxins. Just as there’s a limit to how much water a sponge can absorb, there’s a limit to what wetland plants can absorb—especially if toxins enter the wetland in large amounts.

MATERIALS

- fresh celery stalks with leaves
- a jar or beaker
- red or blue food coloring
- water
- paring knife
- magnifying glass

WHAT TO DO

1. Add several drops of food coloring to a water-filled beaker or jar. The food coloring represents pollution from a toxic substance (pesticides, oil or heavy metals, such as mercury, for example).

2. Cut one-half inch from the bottom of a celery stalk and place the stalk in the colored water. Leave overnight. The celery stalk represents plants such as cattails, sedges and grasses that grow in wetlands. The colored water represents the water that flows through the wetland.

3. On the following day, cut the celery stalk into one inch pieces so that each team member has a piece.
4. Examine the celery closely.

**WHAT HAPPENED?**

Describe what you see.

________________________________________________________________________________________

________________________________________________________________________________________

Observe the tubules (tubes that transport the water). Where do you see the colored water?

________________________________________________________________________________________

________________________________________________________________________________________

Do you notice anything interesting about the celery leaves? (As you cut through the celery, you should see colored lines in the stalk. The colored lines are the xylem that transports water and minerals to all parts of the plant. Because the xylem distributes water throughout the plant, you should see color at the edge of the leaves. If you look carefully with a magnifying glass, you should also see the veins in the leaves tinted with color.)

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

**THINK ABOUT IT**

Communities are increasingly using wetlands as natural water treatment facilities. How do wetlands plants help purify water?

________________________________________________________________________________________

________________________________________________________________________________________

Why is the water remaining in the beaker still “polluted”?

________________________________________________________________________________________

________________________________________________________________________________________
What do you think happens to the pollutants?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Why can’t we dump all our waste into wetlands? How does your community treat its wastewater?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Where does the water from storm drains in your community go?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
STATION 3: RUNOFF RACE

As water flows through wetlands, the grasses slow the speed of the water by simply being in the way. When the water slows, particles of soil and other solids are deposited in the grass, making the water clearer. Larger particles usually settle out first and the smallest particles usually travel the farthest. Wetlands help protect streams, lakes, bays and other downstream water bodies from a heavy build-up of sediment. They also help protect many aquatic plants and animals. Muddy water covers filter feeders such as clams and mussels, clogs fish gills, smothers fish eggs, "blinds" aquatic animals that hunt for food by sight and blocks sunlight that aquatic plants need to grow.

MATERIALS
- several sponges
- a doormat or a piece of artificial turf
- two flat sheets of wood or plastic similar in size to the doormat
- two shallow aluminum trays
- soil
- two containers of water
- props to tilt the models

WHAT TO DO

1. Set up both boards (and sheets of plastic) on a slant. They need to be at the same angle.

2. Place the doormat (or artificial turf) on one of the boards. Then set the trays at the base of each board. (See diagram.) These boards represent wetlands. The board with the doormat represents a healthy wetland filled with plants. The other board represents an unhealthy wetland where the plants have died or have been removed.

3. Fill both water containers with equal amounts of water and soil, then mix.

4. Get a team member to stand behind the high end of each board. Now have each of them pour a container of the soil/water mixture down the board at the same time and at
the same rate. This flow represents water entering the wetland as a stream, flowing through the wetland and emptying into a lake (the tray).

**WHAT HAPPENED?**

Which wetland had the faster water flow?

______________________________________________________________________

In which wetland did more soil settle out? (The model with the doormat or artificial turf should have slowed the water down and trapped more of the larger particles, keeping them from settling out into the tray.)

______________________________________________________________________

**THINK ABOUT IT**

Based on your observations of this model, how do healthy wetlands help provide cleaner water?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

How could muddy water be harmful to wildlife?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Why do scientists recommend natural planting along the edges of streams, rivers, ponds and lakes?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________
STATION 4: NATURAL CLIMATE CONTROL

Water is necessary for life on earth. In the water cycle, water moves from the oceans to the atmosphere, to the land, through lakes, streams and rivers back to the ocean. Living things also take part in the water cycle. Plants absorb water through their roots and release water into the atmosphere through their leaves in a process called transpiration. Transpiration is the evaporation of water through tiny openings in the leaves. When the water evaporates, any impurities that might be in it stay behind in the plant. In this way water entering the atmosphere is purified. Water released into the atmosphere also contributes to the formation of clouds. In ecosystems, plants play an important role in determining the amount of water entering the atmosphere, which has a great effect on the climate in an area.

MATERIALS

- two large, clear-plastic cups
- six-inch square piece of waxed paper
- geranium plant leaf with stem
- cobalt chloride paper (available from science supply catalogs)
- petroleum jelly
- paper clip
- tape
- water

WHAT TO DO

1. Place a drop of water on a piece of cobalt chloride paper. Observe the change in color. Cobalt chloride paper is used to detect the presence of water.

2. Fill one of the cups with water and apply petroleum jelly to the rim.

3. Straighten the paper clip and use one end of it to poke a small hole in the center of the square of waxed paper.
4. Insert the geranium leaf stem through the hole in the waxed paper square. Apply petroleum jelly around the stem where it emerges from the waxed paper. Apply enough petroleum jelly to cover any extra space in the hole and make an airtight seal.

5. Position the leaf and waxed paper combination directly over the water-filled cup. Gently press down on the waxed paper around the rim so the waxed paper is held in place by the petroleum jelly. The stem should be in the water.

6. Tape a piece of cobalt chloride paper to the inside bottom of the other cup. Apply petroleum jelly around the rim of the cup.

7. Invert the cup with the cobalt chloride paper over the geranium leaf setup. Gently press the cups together. Do not allow the leaf to touch the cobalt chloride paper.

8. Observe the setup for five minutes. Pay particular attention to the color of the cobalt chloride paper. Leave the setup undisturbed for 24 hours.

9. On the following day make your final observations about the cobalt chloride paper.

**WHAT HAPPENED?**

How do you explain the change in color of the cobalt chloride paper? (As the water made its way through the stem and leaf, it entered into the air of the second cup. Because cobalt chloride paper turns pink in the presence of water vapor, the cobalt chloride paper changed color.)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

**THINK ABOUT IT**

Using the results of the demonstration, what role do you think plants play in the water cycle?

________________________________________________________________________

________________________________________________________________________

How do plants affect local climates?

________________________________________________________________________

________________________________________________________________________
Describe the differences in climate between two ecosystems (e.g. forest, prairie, wetland, etc.).

Do you think the climate would be different in a community with many trees compared to a community with few trees?
STATION 5: PRODUCING OXYGEN

Green plants, like animals, need food. But unlike animals, plants make their own food through a process called photosynthesis. Photosynthesis uses carbon dioxide (CO2), water (H2O) and energy from the sun to produce food and oxygen. Common indoor plants used in homes and offices may help to fight the rising levels of indoor air pollution. NASA scientists are finding plants to be useful in absorbing potentially harmful gases and cleaning the air inside modern buildings.

MATERIALS
- large bowl
- water
- measuring cup
- tablespoon
- baking soda
- drinking glass
- lamp
- water plant such as Elodea or Anacharis (available from stores that sell live fish)

WHAT TO DO

1. using a measuring cup, fill a bowl with fresh water. Write down the number of cups of water used.

2. Mix in one tablespoon of baking soda for every two cups of water. (Baking soda is also known as bicarbonate of soda. It contains carbon and in this experiment it will provide the CO2 that a plant needs in order to create its own food—to photosynthesize.)

3. Place a water plant, such as Elodea, inside a drinking glass. Add enough water to fill up half the glass.

4. Lower the glass sideways into the bowl of water until the glass fills with water and no air bubbles are left in the glass. Then turn the glass upside down in the bowl without letting in air. The top of the glass should rest on the bottom of the bowl.

5. Set up a light near the bowl and aim the light toward one side of the glass.

6. Leave the light on the plant overnight.
7. Observe the plant and the glass of water the next day.

**WHAT HAPPENED?**

What formed the next day? Why? (You should see a bubble the next day. The light stimulates photosynthesis in the plant. As a plant goes through photosynthesis to make food, it releases oxygen. Since oxygen is lighter than water, it rises to the top and is trapped by the glass. After 24 hours, enough oxygen has gathered to form a bubble.)

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**THINK ABOUT IT**

How do you explain the results you see?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Why might a city planning board be interested in planting trees in their community, or the people in an office building be interested in having house plants?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Using the results of the demonstration, what role do you think plants play in all ecosystems?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

What other factors are necessary for the process of photosynthesis?

______________________________________________________________________
STATION 5: PRODUCING OXYGEN

Elodea

Glass

Water

Bowl
MATCH THE NUMBER OF THE STATION TO THE ECOSYSTEM SERVICE THAT IS DESCRIBED HERE.

A. ______ Plants have fine “tubes” inside them that carry water from their roots to their leaves. When water contains toxic pollutants (such as pesticides or heavy metals) those pollutants may also be carried up and through the plant. Many wetland plants store toxic materials in their tissues. This doesn’t mean that the toxins disappear—usually they are excreted later. But they are released slowly, in small amounts that are less damaging than a large dose of toxins entering a river, lake or pond all at once. When the wetland plants die, the toxins are released back into the water and soil of the wetland where they may be “captured” by other plants or by soil particles. Even though wetland plants can help absorb and alter some toxins, they aren’t able to absorb all toxins. Just as there’s a limit to how much water a sponge can absorb, there’s a limit to what wetland plants can absorb—especially if toxins enter the wetland in large amounts.

B. ______ As water flows through wetlands, the grasses slow the speed of the water by simply being in the way. When the water slows, particles of soil and other solids are deposited in the grass, making the water clearer. Larger particles usually settle out first, and the smallest particles usually travel the farthest. Wetlands help protect streams, lakes, bays and other downstream water bodies from a heavy build-up of sediment. They also help protect many aquatic plants and animals. Muddy water covers filter feeders such as clams and mussels, clogs fish gills, smothers fish eggs, “blinds” aquatic animals that hunt for food by sight and blocks sunlight that aquatic plants need to grow.

C. ______ Soil is a mixture of mineral particles, air, water, microorganisms and other organic matter (material derived from living things). The materials that make up soil form layers. Hundreds of years may be required to form just a few inches of soil. Soil helps to purify water by filtering out some of the suspended solids (floating “dirt” particles) as they flow through the different soil layers. The makeup of the soil determines how well it will act as a filter. Soil also helps to remove chemical contaminants such as fertilizers and pesticides. Many minerals in the soil can chemically bond with contaminants, which are then stored in the soil and prevented from flowing into nearby waterways. As a result of chemical reactions, the soil can also help “detoxify” certain chemicals, making them less harmful to living things.

D. ______ Green plants, like animals, need food. But unlike animals, plants make their own food through a process called photosynthesis. Photosynthesis uses carbon dioxide (CO2), water (H2O) and energy from the sun to produce food and oxygen. Common indoor plants used in homes and offices may help to fight the rising levels of indoor air pollution. NASA scientists are finding plants to be useful in absorbing potentially harmful gases and cleaning the air inside modern buildings.
Water is necessary for life on earth. Through the water cycle, water moves from the oceans, to the atmosphere, to the land and back to the ocean. Living things also take part in the water cycle. Plants absorb water through their roots and release water into the atmosphere through their leaves in a process called transpiration. Transpiration is the evaporation of water through tiny openings in the leaves. When the water evaporates, any impurities that might be in it stay behind in the plant. In this way water entering the atmosphere is purified. Water released into the atmosphere also contributes to the formation of clouds. In ecosystems, plants play an important role in determining the amount of water entering the atmosphere, which has a great affect on the climate in an area.
ACTIVITY: THE VALUE OF BIODIVERSITY

Students explore the monetary cost of preserving biodiversity and discover which organisms they “value”.

DURATION: 45 minutes

MATERIALS:
- The Value of Biodiversity Table
- Pictures of a variety of different organisms (one for every student; organisms should include all types, including mold, bacteria, algae, plants, invertebrates, vertebrates, etc.
- Cardstock
- String/yarn

PROCEDURE
1. Before Class:
   - Print and cut the pictures of each organism
   - Place on cardstock. Write the name of the organism beneath it’s picture.
   - Use string to make cardstock into a name tag
   - Record student statements on the board.
2. As students enter the classroom, assign each a different organism by having them wear the cardstock name badge.
3. Distribute the Value of Biodiversity Table
4. Explain to students that they each have $3 million to put toward the conservation of species and their habitats.
   - Each student must decide which species will benefit from their investment by determining how their money will be spent.
   - The class will have 10 minutes to walk around to “meet” the other organisms.
   - As students meet the organisms they must decide which is worth spending money on.
5. Encourage students to review the entire handout before the meet and greet begins, so that they understand how to complete the table.
6. Give the class 10 minutes to meet all the organisms.
7. After the meet and greet, ask students to return to their seats to allocate their $3 million.
   - Stress the importance of recording how the money will be spent and why they chose each organism.
   - Give the class about 5 minutes to complete.
8. Have each student present their top 3 choices of organisms
   - Find out how much money was spent on each organism.
   - What are some of the ways the money will be spent and the justifications for the spending.
9. After each student has presented their top choice, identify the organisms that no money was spent on.
   - List these organisms on the board.
   - Why were these organisms neglected?
   - Allow students to brainstorm why some organisms were chosen more than others.

10. Choose a species that was not well funded and ask the student representing that organisms to come to the front of the class
    - Explain to the class that there has been a recent scientific discovery that has determined that this organism has an extract that can raise the SAT score of anyone who drinks or eats it by 500 points. However, this plant can only grow in desert habitats.
    - Ask if anyone is willing to pull their funding from one of their top choice organisms to put towards habitat conservation for this organism.
    - Lead a discussion that examines that if all organisms on Earth play an important role, why are some cared for more/less by humans. What would it take to change perceptions?

11. Possible Extension: As a homework assignment, students can research more about their assigned organism.
    - Students should write a brief bio of the organism that contains its habitat, place in the food chain, and its niche.

THE VALUE OF BIODIVERSITY

It is estimated that there are approximately 12,250,000 species living on Earth. When most people think about biodiversity, plants and vertebrates come quickly to mind. A healthy planet requires a much broader spectrum, with a far greater variety of life.

DIRECTIONS

You have $3 million to put toward the conservation of species and their habitats. As a point of reference, $9.7 million was spent on the conservation plan for the endangered northern spotted owl. The price of undisturbed rain forest habitat in South America is $35 an acre through the Adopt-an-Acre program sponsored by The Nature Conservancy.

Decide which species will benefit from your investments. List them in order from highest amount to lowest.

Decide how the money will be spent.
- Will it go to buying up native habitat and turning it into a preserve?
- Will the remaining individuals be collected from the wild and put in a zoo or botanic garden for captive breeding?
- Will the money go towards collecting fungal specimens from all around the world to be used in cancer research?
- Would you start a biodiversity garden project at schools in your community and collect species locally?
- Do you have other ideas about how the money could be used to preserve biodiversity?

Write a justification for each expense. Why would you spend money on that particular species?

<table>
<thead>
<tr>
<th>Species</th>
<th>Amount of $ to be spent</th>
<th>How will the money be spent?</th>
<th>Why did you spend money on this species?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESOURCES

http://www.marinebiodiversity.ca/cmb/education/what-is-marine-biodiversity

http://www.eoearth.org/article/marine_biodiversity


http://cmbc.ucsd.edu/

http://en.wikipedia.org/wiki/Biodiversity

http://wwf.panda.org/about_our_earth/ecoregions/about/habitat_types/selecting_marine_ecoregions/