The Ecosystem Concept and Project WILD

The *Project WILD K–12 Curriculum and Activity Guide* and *Aquatic WILD K–12 Curriculum and Activity Guide* are designed to invite students of all ages to ask questions about how ecosystems work. To address these questions, educators need not be professional ecologists nor have extensive backgrounds in biology or wildlife management. This appendix serves as a reference to help educators develop a few simple and powerful ecological concepts with students.

The Ecosystem

Ecosystem combines two words: ecology and system. "Eco" comes from the Greek word "household" and can be thought of as the household of nature. A system is any group of parts that work together as a unit. Ecology regards a system as a set of living and nonliving parts that interact over time. Ecologists have offered a number of definitions of this concept. A question that often arises is the size and scope of an ecosystem. Some have seen pictures of Earth from space and heard the entire planet referred to as an ecosystem. This ecosystem is called the "global ecosystem" or "biosphere." Essentially, there is no closed natural ecosystem, even the biosphere, but scientists often create boundaries to study relationships between a set number of living and nonliving things.

The term ecosystem helps to categorize different sections of the natural world and identify differences in how each system operates. The redwood forests in California and the bottom of the Atlantic Ocean both have an energy source, but one uses the sun while the other uses hydrogen sulfide from thermal vents. We can draw an imaginary line around a section of the larger world, decide to treat its elements separately from the rest, and call it an ecosystem. When describing how organisms in the system behave, interact, grow, adapt; what they eat; how long they live; what happens to them when they die; and what they require to stay healthy or to reproduce, we are studying how the household system operates—and thinking SYSTEM-atically.

Connections between elements of a system are often subtle and hard to see or understand. Quite frequently, this is because they take a long time to happen. The life cycle of certain tree species in North American west coast forest ecosystems is 300 to 500 years. In an average human life span, we might see little change in those forests. But the life cycle of an ecosystem in a pond that dries up during the summer and is frozen in the winter might be 12 months. Life cycles in a jar of microbes might be measured in hours.

An ecosystem represents a concept rather than a place or set of things. When students set up a wide-mouth jar in the classroom with pond water, a few small animals, and some plants, then cap the bottle tightly, they have established an ecosystem. The jar contains biotic and abiotic elements. The biotic elements are all the living things in the jar: plants, snails, microbes, and so forth. The abiotic elements are the nonliving elements: air, water, rocks, and bottom debris. Both the biotic and abiotic elements will interact with each other in the ecosystem. The animals might use plants for food or shelter, while the plants recycle nutrients from their waste to grow.

This little ecosystem in a jar will quickly turn into a gooey mess unless placed under indirect sunlight. The system in the bottle is not going to operate without a source of energy, namely light energy. If there are not too many animals, or consumers, in the jar, the bottle can be sealed, even "air tight", and may operate as a self-contained environment for many years. It will slowly change over time as some organisms will die and decompose. Slow hatching eggs or spores may develop and germinate. The acidity of the water may change. The color of the water may change and absorb more heat and light. The system will undergo a life cycle of its own, slowly aging and changing. Throughout all these fluctuations the key to any self-sustaining, successful ecosystem is a balance of inputs and outputs. When the term ecosystem is used in Project WILD and Aquatic WILD, it describes a system in which there are living and nonliving components, and a primary source of energy interacting over time within a defined area. In most systems, the primary source of energy is the sun. We could establish organisms in various environments, but unless there was an appropriate balance or set of relations among them, the system would quickly or slowly go into crisis and die. Many people have seen examples of changed systems when they have cleaned out refrigerators or discovered last month's uneaten lunch in the bottom of their lockers.

One ecosystem often studied in school is a pond. "Pond" is not a word typically used with a precise definition and is similar to the word ecosystem in many ways. In some parts of the world, a pond is a small body of freshwater. In other places, a pond can be a lake quite reasonable in size and depth or a small bay with narrow entrances to the ocean. Here we use the term to refer to small, shallow, freshwater waterbody.

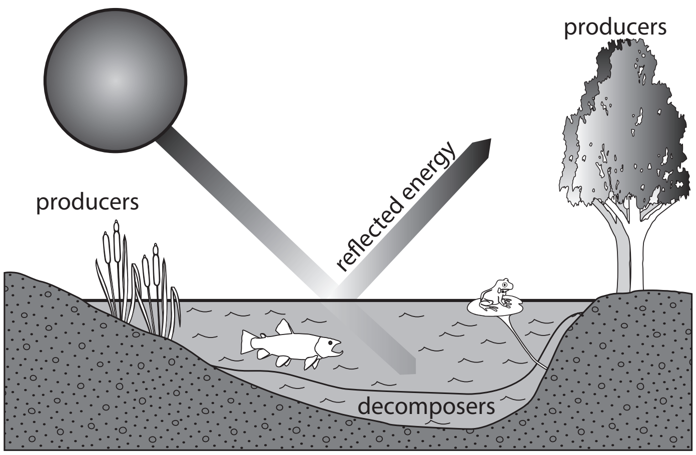

Diagram A

Diagram A shows a simple illustration of a pond and includes the basic elements of most ecosystems. The sun is the energy source and acts as the "engine" which drives the rest of the system. The biotic components are the green plants and animals. The green plants are direct "sun catchers." The wonderful process of capturing the sun's energy is known as photosynthesis—photo (light) and synthesis (assembly, connection, manufacture). The energy of the sun is stored in the form of chemical bonds in molecules. During photosynthesis, plant cells store solar energy by assembling complex molecules with six carbon atoms from building blocks of CO_2 and water. Animals are not capable of photosynthesis but rely on green plants to catch solar energy and to use it to assemble food materials. Known as producers, green plants are the food factories in natural systems. Equally important, plants also provide oxygen as a byproduct of this process.

Not all animals eat plants directly. Those that eat plants and only plants are known as primary consumers, or herbivores. They are one step away from producers. Animals that eat other animals are two steps away from the sun, so they are often called secondary consumers, or carnivores (meat eaters). The sequence becomes more complex if we add animals that prey on other meat eaters: tertiary consumers (three steps away from the sun). **Diagram B** illustrates some of those relationships.

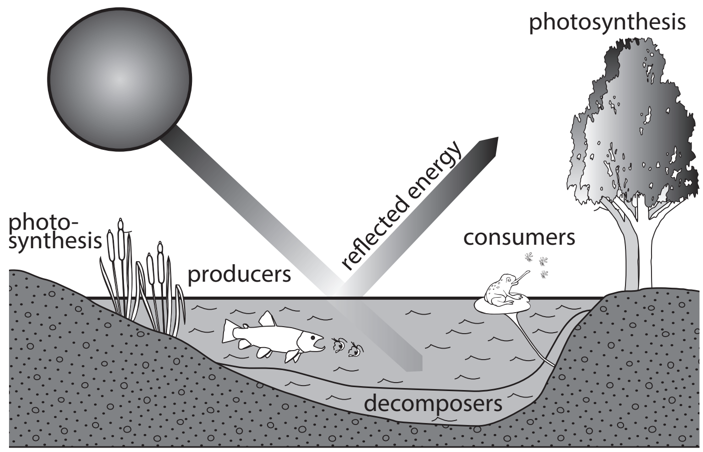

Diagram B

A diagram linking some of these organisms as producers and consumers is illustrated as a food chain. **Diagram C** shows a simple food chain that might be associated with a pond. In this diagram, the eagle eats the fish that eats the frog. In turn, the frog eats spiders and the spiders eat insects.

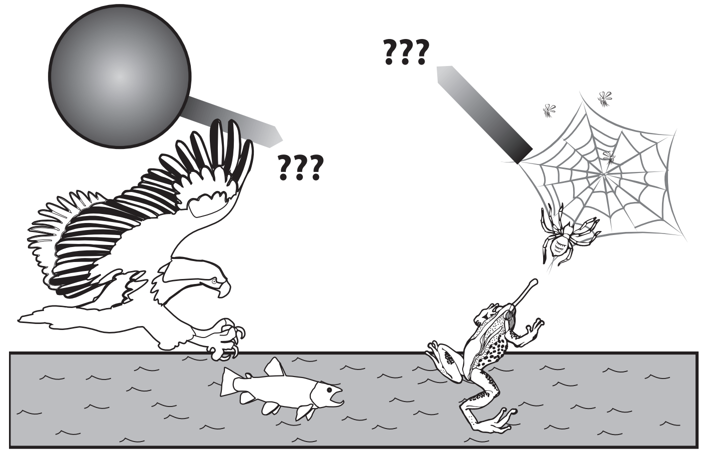

Diagram C

This food chain is not an ecosystem as important elements are missing. There are no direct producers capable of photosynthesis. The eagle cannot capture energy from the sun directly. It is at least three steps away from the sun's input of energy. In its tadpole stage, the frog eats plant material. The insect might feed on plant nectar, or its larval stage might eat leaves. The food chain describes only a portion of the connections in a pond ecosystem. If the diagram were more complex, then a food web would be produced. Food webs balance inputs and outputs in the ecosystem, allowing it to exist for long periods of time. It would include all the producers and consumers in the pond and introduce a new set of special consumers, called decomposers.

Decomposers are the garbage collectors of nature, breaking down a variety of materials into simpler compounds. Similar to consumers, decomposers receive their energy from other organisms and cannot perform photosynthesis. Decomposers produce CO_2 and release needed elements into the system. Without these recyclers, the entire ecosystem would gradually run down. Imagine a forest in which none of the fallen trees, branches, dead animals, and leaves ever rotted. Soon it would be impossible to move through the debris and nothing new could grow. Without decomposition in ponds, the accumulation of materials falling to the bottom would result in the pond's rapidly becoming so shallow that it would no longer hold water.

As a general principle, students should understand that both energy and materials constantly circulate in all ecosystems. Plants, through the process of photosynthesis, are the major point of entry of the sun's energy into the natural system. However, that energy works in other ways throughout the ecosystem. Solar heating of the atmosphere and oceans produces winds and great patterns of air circulation in the atmosphere. The absorption of solar energy in the oceans is expressed in the flow of ocean currents. In a way, the entire planet is a great solar-powered engine. All materials cycle—some slowly, some quickly.

Carbon dioxide, for example, is a byproduct of respiration in plant and animal cells. The carbon of CO_2 is used by green plants in photosynthesis and becomes the building block of many biological molecules, including sugars, proteins, and fats. Once assembled into these materials, the carbon can be taken in by animals when they eat food materials—whether from plant or animal sources. Food is both a source of energy and a source of raw materials for biological construction.

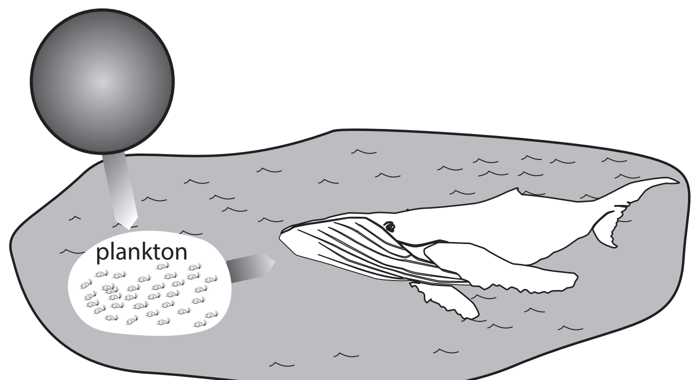

Diagram D

The carbon cycle is one of the great cycles in natural systems. Nitrogen, water, and elements such as phosphorus are also involved in cycles. The passage of materials along food chains and through cycles is responsible for the concentration of chemicals such as pesticides. Small amounts of pesticide molecules passed along a food chain may accumulate when they reach the top consumer, whether that be an eagle or a human. Sometimes animals like the Humpback Whale "shorten" the steps between the input of solar energy and themselves by feeding directly on millions of small animals and plants that are closer to the source of solar energy. (See **Diagram D**.)

An ecosystem, therefore, may be viewed as a set of living and nonliving elements interacting over time within a defined locale. Ecologists attempt to define ecosystems in terms of sets of elements that directly or indirectly interact with each other. At a global level, all elements on the planet interact. The rain that falls today on the plains may have evaporated yesterday from the leaf of a tree in a coastal forest. But in practical terms, for studying and understanding the interactions among organisms in the environment it is useful to draw boundaries around certain groups of organisms that are normally interacting in a relatively direct way, as a community or neighborhood grouping. This grouping may be considered an ecosystem.

Within these biological neighborhoods, it is possible to assign organisms both an "address," describing their typical location in space, and an "occupation," or role that they play in the system. An organism's address is its habitat. The occupation of an organism in an ecosystem is called its niche. For many people, the term niche describes a location or group. Ecologists use the term to describean organism's role or activities in the system. This definition can often be a source of confusion.

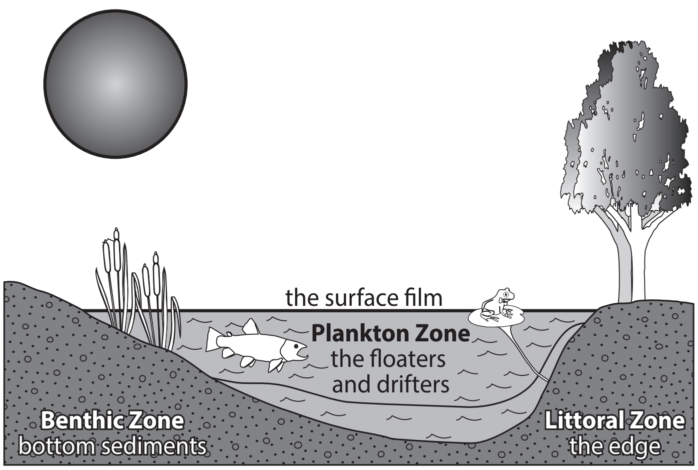

Diagram E

Although there are many different aquatic ecosystems, all can be divided into a set of zones which are usually categorized by depth. **Diagram E** illustrates some of the zones that can be found in a typical pond ecosystem. Organisms occupying the edge or margins of the pond live in the littoral zone. The planktonic zone is named for microscopic organisms, plants or animals, that float and drift through the water without means of locomotion. Other organisms like catfish or aquatic insects live around or in the bottom sediments of the pond. Though few, organisms like water-striders use surface tension to inhabit the narrow surface film zone at the top of the waterbody. Sometimes organisms inhabit different zones during different stages in their lives.

It is important to explore a variety of zones in multiple habitats because students might encounter quite different sets of organisms. Often, people tend to overlook certain zones—possibly because at first glance they seem devoid of life. It may seem tedious to sift through the muck on a pond bottom when dip nets are filled with interesting things found in the water or on rushes at the shore line. However, to develop an understanding of the diversity of life forms that inhabit an ecosystem we need to explore the whole range of addresses where they might be found.

Tips for Studying Ecosystems

A major purpose in having students study ecology is to develop an awareness and understanding of relationships. This process entails developing the ability to see systems, or sets of interactions, and think about how they have changed and will change with time. With enough exposure, students will begin to understand living systems as complex mosaics in which all the parts fit together to make a whole. The removal of one seemingly unimportant component can often have major consequences on the health and function of the ecosystem.

Building miniature ecosystems in jars or small glass aquariums can help students to begin thinking about what elements are needed to keep an ecosystem healthy. Foster an understanding of interactions by asking students to sketch a web connecting a natural object to as many other things, including themselves, they can think of. A dead leaf floating on the surface of a pond might be seen as unimportant to the ecosystems until—by drawing connections in as many directions and dimensions as possible—the student starts to see it as food, habitat, and former harvester of the sun's energy. These exercises help students appreciate all abiotic and biotic components in a habitat, even a dead leaf.

Individual organisms can be strange, beautiful, or even humorous. The next step in developing an ecosystem mindset is to try to appreciate the role played by an organism in the community of which it is a part. Is this a predator, or prey? Ultimately all organisms are "food" even if for microbes. Does one organism provide a home for other organisms? Do two different species work together to obtain resources they need but the other provides? Is it a producer that captures and stores solar energy? An important part of the activities in Project WILD and Aquatic WILD is asking students to think about these connections, and ultimately to connect themselves to the system as well.

Naming is often both an asset and an obstacle to the study of natural systems. When students visit a community, they want to know the names of the organisms they encounter. This is a good time to learn and recognize some plants and animals. But often it is enough to appreciate differences and similarities, and encourage students to assign names of their own making to the things they see. Do not let a lack of detailed knowledge of names discourage study. Instead, use this opportunity to pose the "How can we find out?" questions. Emphasize characteristics of plants and animals and their interactions, rather than losing sight of those attributes in a quest to label the parts.

Finally, it can be a powerful experience for students to visit and revisit a natural setting at various seasons of the year. Spring is an ideal season to study ponds and streams. But it is a mistake for students to think of nature as dead, or even as largely dormant, in the winter. Seasonal changes are important to the economy of nature. Ecosystems change over time. The changes of the seasons are an important expression of continuing natural change in natural systems.

Have students follow an ecosystem—perhaps a pond, stream, lake, or river—through the seasons from late summer to fall, through winter and into spring and summer. School grounds can also provide useful opportunities of this kind. Some schools have adopted a local pond or stream and use it as the focus of studies by classes over many years. If the past data is saved, students can appreciate what is happening to their local ecosystems.