Ecological Concepts

Chapter Goals:
After completing this chapter, volunteers should be able to:

- Explain the ecological principles that apply to individual organisms, populations, communities, and ecosystems
- Explain the balances that exist between ecosystems and what factors are necessary to keeping ecosystems in balance
- Explain how different ecosystems are determined largely by different environmental factors
- Describe the hydrologic cycle, the nitrogen cycle, and the carbon cycle
- Explain what is meant by succession and climax and list the factors responsible for each
- Illustrate a food web and explain the importance of trophic relationships
- Define biodiversity and understand the importance of managing for biodiversity
- Identify ecological factors that are relevant to a threatened species
- Understand the laws and procedures necessary for protecting species

Defining Ecology

The term “ecology” is derived from the Greek words, oikos, for house or household, and *logos*, which refers to “the study of” some particular topic. Literally translated then, ecology means the study of households, in this case, the households of nature. German zoologist Ernst Haeckel, who is credited with coining the word in 1870, defined it as follows: “By ecology we mean the body of knowledge concerning the economy of nature – the investigation of the total relations of the animal both to its inorganic and its organic environment.” If you peruse modern texts for a more current definition, you will find that they still focus on the key importance of *relationships* and *interaction*s. “Ecology is the study of the relationships of organisms to their environment and to one another” (Brewer, 1994). “Ecology is the scientific study of the interactions that determine the distribution and abundance of organisms” (Krebs,

“The Laws of Ecology:
1. *Everything is connected.*
2. *Everything must go somewhere.*
3. *Nature knows best.*
4. *There is no such thing as a free lunch.”*

-Barry Commoner, 1971

1972). A somewhat different definition, offered by Odum in 1963, stressed the then emerging systems approach; “Ecology is the study of the structure and function of ecosystems.”

Given the fact that you are embarking on a lifelong journey to becoming a Master Naturalist, you might find the definition offered by the early English ecologist, Charles Elton (1927), an especially appealing one. He defined ecology as “scientific natural history.” Natural history – the observations and descriptions of the behavior and adaptations of organisms – especially as collected by naturalists of the 17th, 18th, and 19th centuries, provided a good background for the emerging field of ecology in the 20th century. What allowed for the transition to “scientific” natural history was Darwin’s theory of evolution. Specifically, his concept of natural selection provided a mechanism to explain how populations of organisms change, adapt, evolve, to an ever-changing environment. Within the unifying framework of natural selection, ecologists can now go beyond just describing the many varied and amazing behaviors and adaptations of organisms to provide us with logical explanations of their evolutionary origin and purpose.

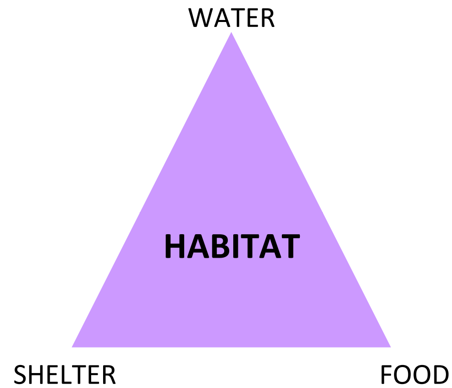
Levels of Biotic Organization

While early naturalists were primarily interested in describing individual organisms, ecologists frequently investigate higher levels of biotic organization (Note that these terms have very specific ecological meanings that differ from their common usage):

- *Population* – A group of organisms belonging to the same species occupying a particular area at the same time.
- *Community* – An association of interacting populations usually associated with a given place in which they live.
- *Ecosystem* – An ecological system. The biological community of a given area and the physical environment with which it interacts.
- *Landscape* – Interacting ecosystems on a relatively small geographic scale.
- *Biosphere* –That portion of the earth and its atmosphere in which life occurs and the physical-chemical environment in which it is embedded.

A cautionary note: The above levels of biotic interaction are often so ordered and imply a sense of increasing scale. Excluding the “biosphere,” which clearly does encompass the entire planet, any of the other terms may apply equally well to a variety of physical scales. You are perhaps familiar with the concept of an “ecosystem” within a **drop of pond water.** While it would be erroneous to think that the numerous organisms you might find in such a drop would be self-sustaining over any length of time, it is nevertheless true that functioning communities, ecosystems and landscapes can be found within small confines, including individual organisms!

Two other commonly used terms with which you will become familiar are *niche* and *habitat*. An organism's niche is best thought of as its "occupation" or ecological role in the community.
Important aspects of a species' niche would include its position in the food web, which species it relies on for food and which species prey on it, as well as its relative importance in the flow of energy and the cycling of nutrients. Ecologists more broadly define the niche of a species as the sum total of all its interactions within a given community, or the ranges of conditions and resource qualities within which the organism or species can persist.



If niche defines an organism's occupation, *habitat* describes its address. It is the place where a plant or animal normally lives, and is often characterized by a dominant plant form or physical characteristic. For example, boreal forest is the habitat for the woodland caribou while cold mountain streams are the habitat for cutthroat trout. For any organism to survive in a particular area, the habitat must provide it with three important resources – food, water and shelter. In order for a habitat to be suitable, however, these three resources must be easily accessible. If water was located at too great a distance from food and shelter, for instance, a particular species might not find that habitat acceptable. Space is yet another important component of habitat. Beyond the fact that most species have minimal home range requirements, that amount of area necessary to provide all necessary resources for survival, many are also territorial, defending their space from being utilized by others of their own species. Thus habitat must provide each species with easily accessible food, shelter and water within a space large enough to secure those resources for the individual or social group.

Ecosystem Characteristics

During your Master Naturalist training, you will be introduced to a number of ecosystems distinct to your region of Idaho. We want you to become better acquainted with both the structure and functioning of those systems, and the ways in which each major component of the system interacts and depends on the rest to maintain the overall health of that system.

Early ecologists soon became aware of the fact that regardless of where they were, be it arctic tundra, prairie grassland, tropical rain forest, or coral reef, there were a number of underlying principles and relationships which seemed to provide a foundation for the understanding of all ecological systems.

Climate and Weather

When any ecosystem is examined, it is clear that we can first organize it on the basis of its *biotic* (living) vs. *abiotic* (non-living) components. Two important abiotic features are climate and nutrients. We'll examine the role of nutrients in more detail a little later on, but first, let's look at climate. *Climate* is defined as the long-term patterns of temperature, precipitation, wind and humidity that exist for a given area. Short-term changes in these atmospheric conditions are referred to as *weather*. On a large geographic scale, it is interesting to note that the world's major terrestrial ecosystems, often referred to as *biomes*, can be delineated almost entirely on the basis of mean annual temperature and precipitation. Not unexpectedly, tropical rain forests are found where both average annual precipitation and average annual temperature are high. Perhaps less expected is the fact that both deserts and tundra are characterized by very low average precipitation. What role do you think temperature and precipitation play in determining the eco-regions of Idaho?

Five Eco-regions of Idaho

1.

2.

3.

4.

5.

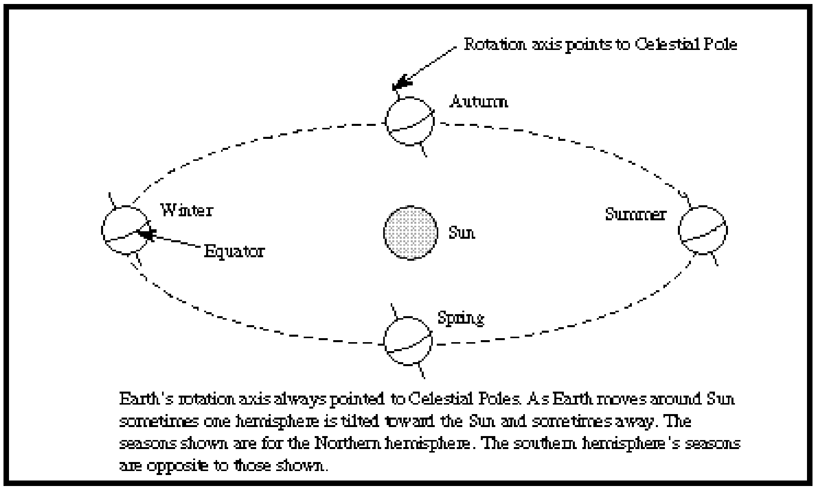
The plants and animals that comprise the biotic component of a given biome often exhibit unique adaptations that are reflective of their abiotic environment. For example, can you think of at least three features of high desert plants (such as sagebrush) that have evolved in response to arid conditions? What adaptations do high desert animals exhibit? Plants and animals that are not closely related often exhibit similar adaptations to similar environmental conditions. This is known as *convergent evolution*.

Sunlight and Heat

Heat and light received from the sun, collectively known as *solar radiation*, does not reach all parts of the Earth in equal amounts or for equal lengths of time. Heat and light vary in intensity during the course of a day as the Earth rotates on its axis, and throughout the year as it revolves in an orbit around the sun.

Polar Regions receive much less solar radiation than do tropical regions because the sun is farther from the poles than from the equator, and because of the Earth's tilt on its axis. This tilt prevents direct sunlight from reaching the poles for long periods each year. As a result of the daily, seasonal, and annual distributions of solar radiation, we assign the Earth specific *climatic zones*—ranging from polar to temperate to tropic—which relate primarily to temperature differences.

We measure solar heat, as a form of energy, in degrees of relative warmth called *temperature*. Plants and animals tolerate certain high and low limits of temperature. Beyond those limits, each organism cannot survive.



The sun's rays do not strike the Earth evenly, as seen in this diagram of the sun and the earth's axis. This uneven radiation creates different climates on Earth. Permission for diagram usage pending Nick Strobel.

Temperature also influences rate of reproduction, growth, and survival of living things. For example, in a temperate climate, persistent cold weather late into the spring prevents most plants from developing properly, as well as the insects and rodents that feed upon them. A poor supply of insects and rodents then decreases the well-being of hawks, foxes, and other animals. Therefore, temperature—as a component of weather— influences the strength or weaknesses of food chains and webs.

A warm blooded fisher. Photo courtesy, IDFG.

Warm-blooded animals, such as birds and mammals, have insulated bodies that regulate internal temperatures regardless of the amount of heat in their environments. *Cold-blooded* animals, such as reptiles, fishes, amphibians, and insects, have no way to regulate their own body temperatures. So, their bodies usually assume the same temperature as their environments.

A cold blooded wood frog. Photo courtesy, Steve Kozlowski. USFS.

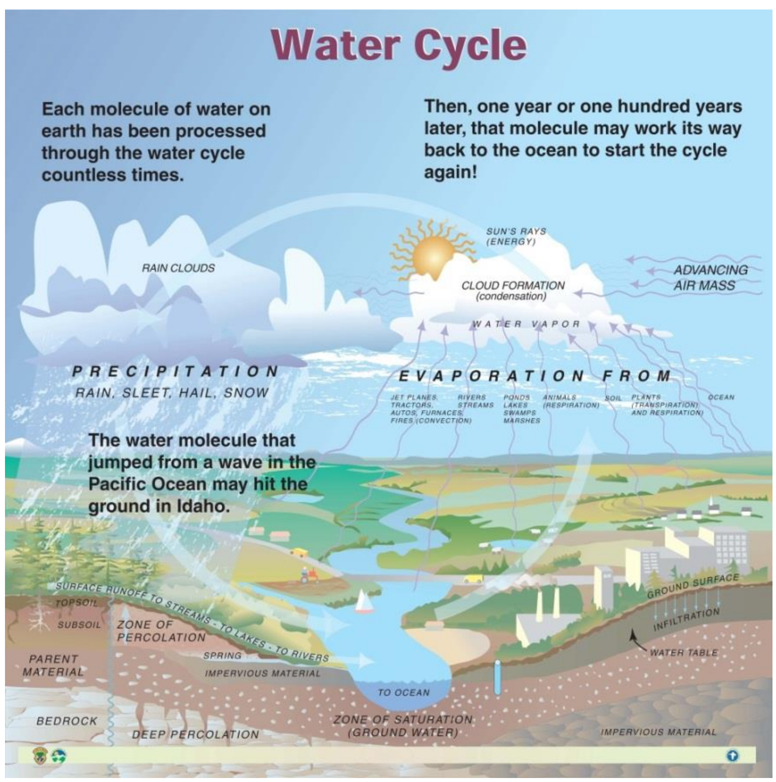
The amount of moisture in the air, known as *humidity*, influences the tolerance of most warm- and cold blooded animals to external temperature extremes. Hot or cold temperatures in dry climates generally are easier for most animals to cope with than similar extremes in wet climates.

Soil

Soil is the Earth's loose surface material in which most plants are rooted. In large measure, the quality and abundance of life in any region is a reflection of its soil's characteristics. More than just "dirt," soil is itself a complex ecosystem. It is composed of fragments of inorganic material (minerals), organic matter derived from living organisms in various stages of decomposition, soil water and the minerals and organic compounds dissolved in it, soil gases and living organisms. The development of a mature soil may take hundreds of years to complete through the complex interactions of climate, parent material (bedrock), topography and organisms. The abundance of life in any environment depends, to a great extent, on the characteristics of its soil. Soils classified as loams are a mixture of fine, medium, and coarse (clay, silt, sand) particles and often contain significant amounts of organic matter (humus). These soils are often more fertile than either heavy clay or very sandy soils and generally support a greater number and diversity of plants and hence, a greater diversity of animals. More information on soils can be found in section 11 of the Geology chapter.

Water and Air

The sun drives movements of water and air over the surface of our planet. Differential heating of the atmosphere, based on latitude and season, sets in motion generally recognized global wind patterns which circulate both heat and water. Together with topography, these atmospheric movements play a dominant role in determining the location of the Earth's major biomes, as well as the regional availability of water.



This diagram of the hydrological cycle shows how water is circulated around the globe. Graphic by Renai Brogdon, IDFG.

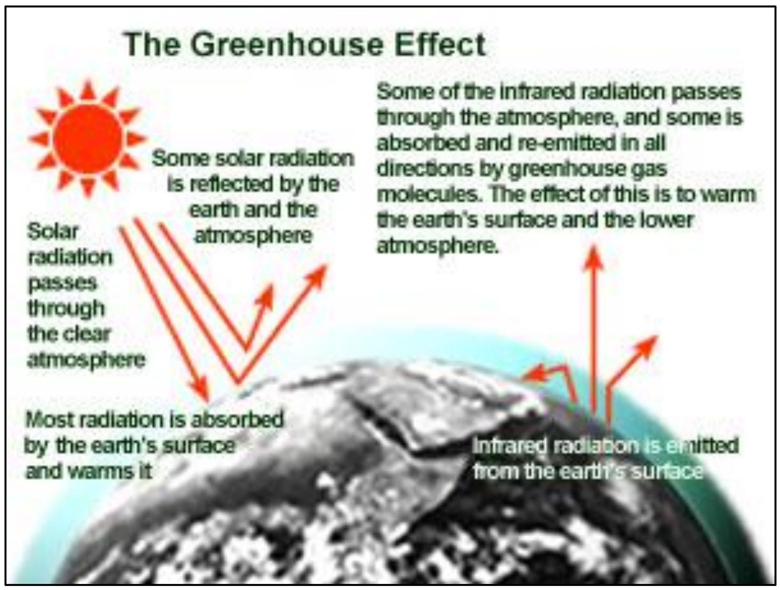
Water

Water takes many forms in the environment: water vapor is a gas; standing water is liquid; and frozen water or ice is a solid. In the atmosphere, water is humidity. We call water *precipitation* when it falls to the ground as snow, sleet, rain, or hail. In oceans, lakes, and streams, we call it surface water; and it is part of every cell making up the bodies of plants and animals. No matter where or in what form it occurs, water eventually recycles through processes of evaporation from streams, lakes, and oceans; transpiration from plants; and respiration from animals.

Similar to solar radiation, water differs in amount and availability from place to place throughout the world. For example, deserts are almost always dry. Tropical forests tend to be very wet. Determined by annual precipitation, many other climatic zones include humid, sub humid, semiarid, and others

Air

While we sometimes use the words "air" and "oxygen" interchangeably, our atmosphere is actually 78% nitrogen and only 21% oxygen. The remaining one percent is comprised primarily of carbon dioxide, CO2, and water vapor. These two gases are very important in creating the "greenhouse effect." By absorbing much of the sun's infrared radiation, these gases trap the sun's heat and act as the Earth's warming blanket. Without them, our planet would be uninhabitable, much like our moon or the planet Mars. Scientists are concerned that our present rate of fossil fuel consumption will raise atmospheric levels of carbon dioxide enough to significantly increase global temperatures over the next 50-100 years. If this were to occur, it would have profound effects on both the distribution and survival of many species, including our own!



Oxygen, given off by plants and other sources, is taken in by animals through lungs, gills, and other specialized breathing mechanisms. Animals transport oxygen in their blood to many cells of the body, to be used for every life-support process.

At high elevations, air contains less oxygen, so animals' hearts must pump harder to get blood and, therefore, oxygen to all parts of their bodies. Animals must adapt to different conditions of the air, move to a different environment, or perish. For example, animals living at high altitudes have larger hearts than do their relatives at lower elevations. Air also supplies plants with nitrogen and carbon dioxide as well as oxygen. When traveling through the mountains or in an elevator you may notice an increasing or decreasing pressure in your head as you go up or down. Your ears probably pop. This occurs as the result of rapid changes in atmospheric pressure.

The atmosphere is denser close to the Earth; at sea level, than higher in the sky. Unlike water in oceans, that is nearly incompressible and weighs the same at the ocean floor as it does at the surface, air at sea level weighs more than air at the top of mountains. Although there is air in our atmosphere hundreds of mile above the Earth, more than one-half of our breathable air stays within 3 ½ miles (5 3/5 kilometers) of Earth's surface. Because air is highly compressible, air at or near the Earth's surface is much heavier, and less stable than air higher up. This condition determines weather changes. Therefore, air pressure refers to the density of air at a given time in a given place.

The Hydrological Cycle

The continuous process involving the circulation of water between the atmosphere, the ocean, and the land is called the hydrologic cycle. Solar radiation and gravity are the driving forces that "run" the cycle. It has been calculated that there is a mass of around 13,967 X 10^{20} grams of water on the accessible areas of the earth's surface. This water may be found on the surface as liquid or ice, and in the atmosphere as vapor. Approximately 99% of the total is in the oceans and seas, and most of the remainder is locked in glaciers, snow and ice. Water vapor in the atmosphere amounts to only a minor fraction of 1 percent of the total. The remainder, the inland waters of lakes, rivers, and wetlands, constitutes only about 0.25 X 10^{20} g, or 0.000018% of the total. Not only is water a key constituent of life in its own right, but it also serves as the medium through which many other nutrients are carried.

When all the water on Earth is represented in a 5-gallon bucket …

1,244.16 Tablespoons = Ocean water

25.6 Tablespoons = icecaps and glaciers

7.93 Tablespoons = groundwater

.11 Tablespoons = Freshwater lakes

.1 Tablespoons = Inland seas and salt lakes

.0128 Tablespoons = Atomospheric water

.0012 Tablespoons = Rivers

The hydrological cycle details the circulation of water between ocean, earth, and atmosphere. Atmospheric water falls on the earth as ***precipitation*** in the form of rain, snow or fog. About five-sixths of the water ***evaporated*** in the cycle comes from the oceans, but only three-fourths of global precipitation falls on them. The difference is that which is exported to the land. In heavily vegetated areas, much of the precipitation is intercepted by plants and released back to the atmosphere as evapotranspiration. That which does not, soaks into the ground or becomes surface ***runoff***, creating our streams and rivers. Water that percolates through the soil may eventually reach an impermeable layer and reside there as ***groundwater***. Its upper surface is referred to as the water table. Geological formations that yield water in usable (in human terms) quantities are referred to as ***aquifer**s*. If not used somewhere along the way, all ground and surface water eventually returns to the sea, completing the cycle. Carried in solution will be many nutrients either leached from the soil or derived from the weathering of parental rock. These nutrients will eventually be deposited as ocean sediments and their biogeochemical cycle will not be completed unless, and until, these deposits are again raised above sea level in a geological uplift.

Implications for Management

"Everybody talks about the weather, but nobody ever does anything about it" is a popular saying. Despite our best efforts to bring needed rains through chanting, dancing, or seeding clouds, we have had limited success in changing, or even predicting, short-term weather. Our discussion of the implications for management of the hydrological cycle is therefore going to focus on the management of water (aquatic systems) once it's on the ground. How we manage aquatic systems is based on the values we assign to them. Some of those values might include flood storage and conveyance, water supply, pollution and sediment control, recreation, aquifer recharge and fish and wildlife habitat. Managing aquatic systems for recreation (swimming, boating, and water skiing) may involve methods different from those employed if managing for fish and wildlife habitat. As is true for any system, management objectives will determine management guidelines.

All aquatic systems are affected by the status of the terrestrial (land) systems that surround them. Controlling erosion throughout the watershed is of primary importance to maintaining the health of aquatic systems. Excessive run-off following storm events is a primary cause of both stream bank erosion and stream sedimentation. Improving groundwater infiltration by reducing the amount of impervious surfaces and increasing the use of deep-rooted native species of grasses and wildflowers can greatly reduce damaging run-off. Surrounding urban or agricultural lands also contribute significant levels of point source and nonpoint source pollution to aquatic systems. Reduction of these pollutants should be an important management objective in terms of increasing water quality of the affected aquatic systems.

Appropriate management of aquatic vegetation can enhance many of the benefits provided by aquatic systems. Restoration of native aquatic plants (including submerged, emergent and shoreline species) can improve infiltration, reduce erosion, and filter out many harmful pollutants, while increasing habitat for fish and wildlife. In some cases, aquatic systems may benefit by the removal of aquatic plants, especially invasive non-natives such as Eurasian watermilfoil (*Myriophyllum spicatum*).

Controlling water levels is another management tool that can improve the value of aquatic systems, particularly those involving constructed wetlands. Reducing water levels creates mudflats that are attractive to a variety of birds, allows for improved soil aeration and growth of new food-producing plants. Such "drawdowns" are frequently performed in the fall to provide migratory birds with critical food resources along their routes. Conversely, increasing water levels simulates flood conditions, bringing in additional nutrients and stimulating aquatic plant growth.

Mineral and Nutrient Cycling

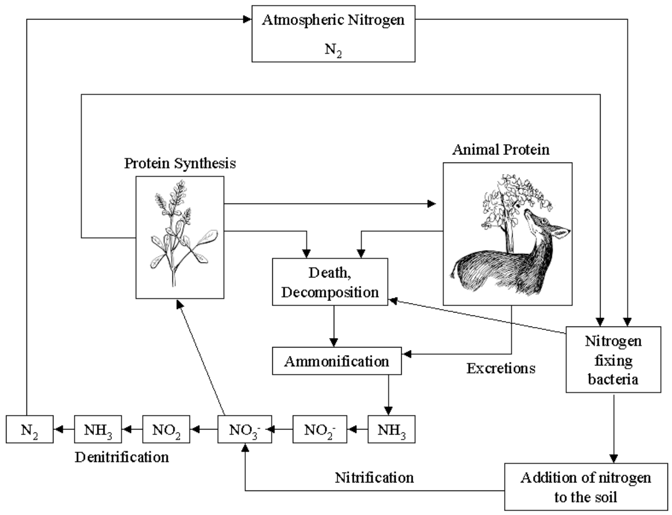
The never-ceasing quest for energy among all living organisms is an important determinant of many of the unique and peculiar traits of organisms. Entire books have been written about the adaptations related to either acquiring food or avoiding becoming food. But energy needs aren't the only consideration for organisms. In addition to the basic building blocks of organic matter (carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur), at least 20 other elements are considered essential to life. These elements move freely between the abiotic (non-living) and biotic (living) portions of an ecosystem as plants take in carbon dioxide from the air, and water and minerals from the soil to produce carbohydrates, fats, and proteins. They are then passed along the food chain to both herbivores and carnivores. Nutrients are eventually returned to their elemental form and again take up residency in the abiotic environment upon decomposition of both excretory waste and dead plant and animal tissue.

This circulation of elemental materials is thus another important aspect of ecosystem function. Note that unlike energy, which *flows through* an ecosystem, matter is continually recycled. Some elements that currently (and temporarily) make up your body may well have resided in a dinosaur a hundred million years ago, or in the primordial bacteria that first colonized the planet almost 4 billion years ago!

Nutrient cycles are more formally referred to as *biogeochemical cycles*. It emphasizes the fact that the biological (bio) realm and the rest of the earth (geo) are inextricably interconnected through the movement of essential chemical elements. Biogeochemical cycles have no starting point. They are not for the ultimate benefit of plants or consumers any more than they are for detritivores or bacteria.

Of the many existing biochemical cycles, those most frequently detailed include the cycling of carbon, nitrogen, phosphorus and sulfur. Common to all are the presence of either a gaseous or sedimentary reservoir, and a change in the chemical nature of the element as it passes from one step to the next. We will examine the nitrogen cycle in more detail. Those wishing to learn more about the cycling of other nutrients are encouraged to do so by consulting any ecology text.

The Nitrogen Cycle



The Nitrogen Cycle, Courtesy of G.T. Miller.

Nitrogen, in the form of NH_2 (one nitrogen atom and two hydrogen atoms), is the building block of all plant and animal proteins. However, it does not exist in this form in nature, and outside of biological processes, it exists almost entirely in its non-reactive molecular form, N2 gas. The earth's atmosphere, which is 79% nitrogen, is the vast reservoir for this important nutrient. Plants need nitrogen, but they cannot absorb it in its gaseous form (N2). They only take up nitrogen as either ammonia (NH3) or nitrate (NO3), so even though life is bathed in nitrogen, it can't use any of it unless it is first transformed or "fixed."

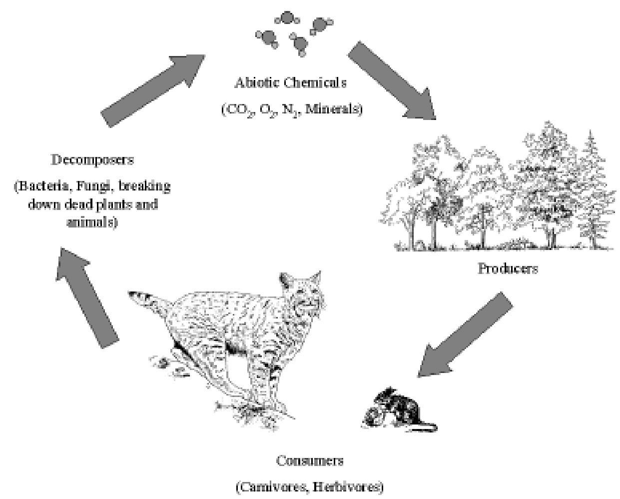
Nitrogen Fixation

Nitrogen fixation, the process of converting atmospheric N2 to ammonia (NH3), although energetically expensive, is accomplished by a wide variety of terrestrial and aquatic microorganisms, especially by both free-living and symbiotic bacteria. In many terrestrial environments, leguminous plants (members of the pea and bean family) often harbor the bacterium, *Rhizobium*, in root nodules. This is a *symbiotic* arrangement; that is, both organisms benefit from the relationship. The bacteria tap into the plant's stored food, acquiring the energy necessary to carry out fixation, while the legume benefits by having access to the excess of ammonia produced beyond the needs of the bacteria. This is why legumes are often high in protein. It is also why legumes like vetch, clover and alfalfa are often planted as cover crops. *Rhizobium* not only provides for the needs of itself and its symbiont, it may actually result in as much as 250 pounds of nitrogen compounds being added annually to each acre planted.

This wildflower, growing in the Boise Foothills, is a type of vetch. As a member of the pea family, these plants are nitrogen fixators.

Ammonification

Animals and decomposers produce their proteins from the plant or animal proteins in their diet. When these proteins are broken down in respiration, a waste product, ammonia, is produced. This may be excreted directly (fish) or it may first be converted to a less toxic form. Most mammals, us included, convert it to urea, while most birds, reptiles, and invertebrates convert it to a more solid form, uric acid. These compounds are the source of energy for another group of bacteria, which convert the nitrogen compounds to ammonia in a process known as *ammonification*. Upon death, this same process will break down an organism's body proteins.



The nitrogen cycle, courtesy TX Master Naturalist Program.

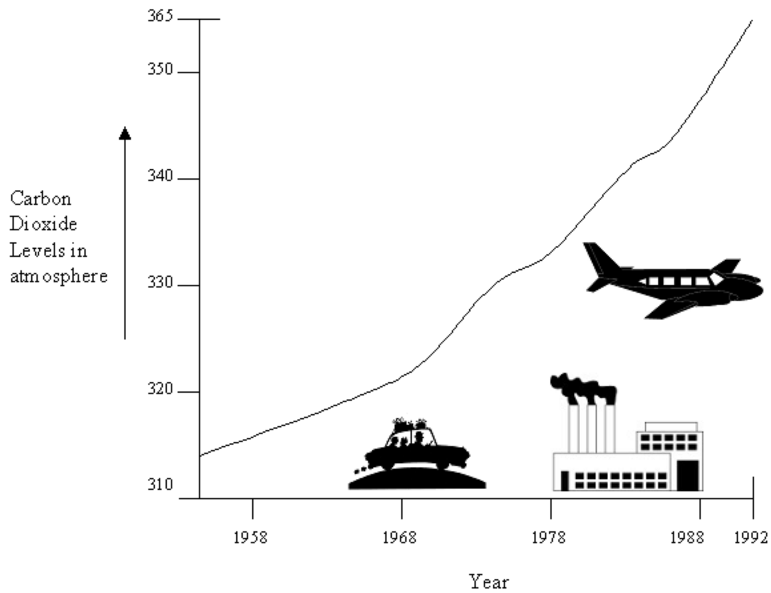
Nitrification

While ammonification returns nitrogen once again into a form immediately utilizable by plants, ammonia is often further acted upon by two separate groups of bacteria (again as a means of obtaining energy) in a two-step process known as nitrification. The first group of bacteria converts ammonia to nitrite (NO2) and the second group converts nitrite to nitrate (NO3). Both of these compounds are negatively charged (anions) and often precipitate out as various salts when bonded to positively charged cations, such as potassium or magnesium. As such they can be retained in soils for a much longer time than ammonia, and are therefore important components of a soil's fertility. Like table salt, these nitrogenous salts readily dissociate in water, thus making nitrate available for uptake by plants after a rain.

Denitrification

The above reactions will only take place under aerobic conditions, that is, where oxygen is present. Soils that have been compacted, waterlogged, or are otherwise anaerobic, will often set the stage for a loss of utilizable nitrogen in soils. Yet another group of bacteria, all anaerobes, will obtain significant energy by converting nitrate or nitrite back to elemental nitrogen, N2. Although this may be looked at by some as a "negative" or harmful process (well-aerated soils are more productive), denitrification does bring the nitrogen cycle full circle, insuring that atmospheric concentrations of nitrogen are maintained and that the system as a whole remains in balance.

The Carbon Cycle



As all good Trekkies know, we here on Earth are carbon-based life forms. Carbon is not only one of the major building blocks of all life (known to date), but it is inextricably bound to the way most all organisms obtain their energy. For that reason the carbon cycle is sometimes referred to as the energy cycle. Plants take in carbon dioxide (CO_2) and water, and through the process of photosynthesis, create glucose, a simple carbohydrate or sugar. Simple sugars, the most basic form of food energy, can be further modified to form complex carbohydrates (starches), various fats and oils and proteins. Plants use some of these organic compounds for their own metabolic needs, thereby returning some carbon back to the environment as CO_2, but most is retained in the plant body. Herbivores (plant eaters) obtain their carbon (energy) from the plants they eat and higher level consumers (carnivores) from the animals they eat. Decomposers obtain their carbon from the dead plants and animals they consume. Ultimately, all consumers and decomposers return most of the carbon back to the atmosphere (or water) as CO_2 in the process of respiration, thus making it available once again to plants.

That's the simple part of the cycle. The more interesting part has to do with the amount of carbon that *isn't* returned to the system as gaseous CO_2. Organic matter that escapes immediate decomposition may enter long-term storage as fossil carbon. This doesn't happen to any appreciable degree today, but vast quantities of carbon entered such long-term storage 285-350 million years ago during the Carboniferous Period. This carbon is now being returned to the environment as CO_2 at the rate of about 7 billion tons per year in the process of burning our fossil fuels of coal, oil and gas. About half that amount seems to be accumulating in the atmosphere. An estimated one to two billion tons is being absorbed by oceans and the remaining amount has most likely gone into increased plant biomass. The great majority of un-oxidized carbon is not found in fossil fuels, but in various carbonate rocks deposited as sediments on the bottom of lakes and oceans. Oceans are actually the single largest reservoir for CO_2, storing 60% more than the atmosphere. When CO_2 dissolves in water, some of it forms carbonic acid that, in turn, may form various carbonates and bicarbonates. Because they are not very soluble, carbonates usually precipitate out and form sediments. One of the most common examples that everyone is familiar with is calcium carbonate or limestone.

Implications for Management

Most everyone has heard of the greenhouse effect and global warming. The greenhouse effect refers to the fact that gases (most prominently CO2) in our upper atmosphere (troposphere) trap and hold radiant heat, much like the glass in a greenhouse. Increasing the concentration of greenhouse gases increases this heat retention. The vast majority of climatologists are now convinced that human activity, primarily the burning of fossil fuels, is directly responsible for the significant increases in greenhouse gas concentrations measured over the last 50 years. If this trend continues, CO2 levels could double by 2050, leading to a possible increase in global average temperature between 3.5-9o F. The implications of such a temperature increase, at a rate 10-100 times faster than has occurred during the past 10,000 years, are profound. Hotter, drier conditions will negatively impact food production and water resources, increase the frequency and severity of storms and hurricanes, raise sea levels 2-3 feet (flooding coastal communities) and have a severe impact on most plant and animal communities. If, for example, CO2 levels do double by 2050, hardwood trees (and the entire assemblage of hardwood forest species) east of the Mississippi would have to shift 300 miles northward to find suitable climatological conditions. Plants and animals can, of course, shift their distributions in response to climate change, but following the retreat of the last ice age, northward movement of hardwood trees was only 12 miles per 100 years. The implication is that many members of those forest communities will simply not survive.

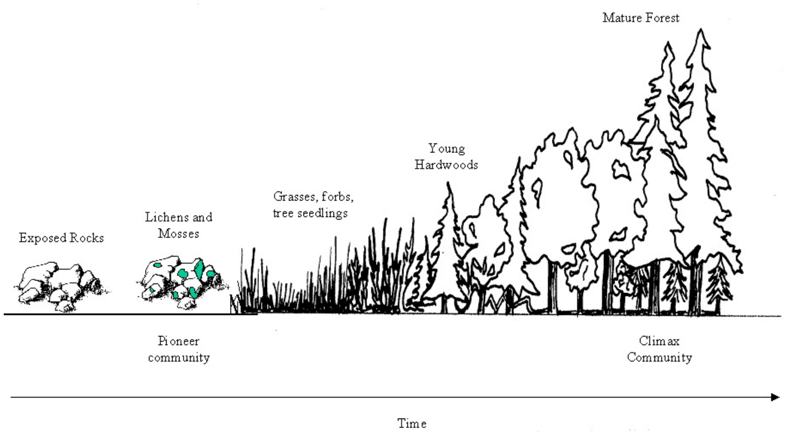
As severe as these outcomes are, there is concern that rising temperatures may set in motion a dangerous

10 things you can do to reduce your carbon footprint

1. Drive less (combine trips, ride your bike, carpool, use public transportation, and walk)!
2. Replace your incandescent light bulbs with compact fluorescent lights (CFLs).
3. Put one-sided faxes and printed reports back into the printer for re-use on the other side.
4. Unplug phone, radio, and cell phone chargers when not in use. These use energy regardless of if they are charging.
5. Buy local. Reduce trucking and shipping pollution.
6. Replace single-pane windows with double-pane windows.
7. Buy “green” energy from your power company.
8. Rid yourself of junk mail. Take the time to call, email or write to the companies that send you junk mail and get your name off their list!
9. Hang your clothes on the line to dry.
10. BYOCSB-bring your own cloth shopping bags. Put empty shopping bags in your car, so you have them for when you go to the grocery store.

positive feedback or "runaway greenhouse" effect. We mentioned that the oceans serve as an important reservoir or sink for carbon dioxide. However, as global temperatures rise, the ocean's ability to dissolve and hold CO2 falls. Release of this oceanic CO2 into the atmosphere will further accelerate the rate of change. Likewise, increasing temperatures on land will melt continental ice sheets, adding to rising ocean levels and exposing more dark, heat-absorbing landmass. It will also speed up decomposition rates, resulting in the release of even more CO2. Lastly, the continued destruction and burning of tropical forests exacerbates the problem two-fold. Deforestation directly contributes about one-fourth of the annual release of carbon dioxide. In addition, loss of these trees removes their ability to absorb excess CO2. To at least partially offset rising CO2 production, many countries have embarked on significant reforestation programs. Most experts agree, however, that significant reduction in the threat of global warming will not come without significant reduction in our use of fossil fuels. We need to greatly increase the efficiency with which we continue to use coal, oil and gas and switch as soon as possible to alternative, renewable energy sources.

Ecological Succession



One of the overarching themes to your Master Naturalist training should be the fact that nature is dynamic. The natural world is constantly undergoing change. Everyone living in Idaho is familiar with the phrase, "If you don't like the weather, stick around a few minutes, it's bound to change." We can all relate to the fact that not only is our weather unpredictable on a day to day basis, but that even seasonal patterns vary from year to year. Last winter may have brought record snowfall, while this year hardly any fell. Weather is just one of many factors that are subject to change within any organism's environment. Changes in the distribution and abundance of species may be in response to changes in either short or long-term weather patterns, other species, random events, human disturbance, or ecological succession.

Succession can be defined as the replacement of populations on a site through a regular progression until a relatively permanent or *climax* community is established. Succession occurs both on land and in the water. The former is usually referred to as *xerarch* (dry) succession and the latter as *hydrarch* succession. When this process occurs on a site previously devoid of life, such as on bare rock or in a sterile body of water, it is called *primary succession*. *Secondary succession* occurs on areas that have recently supported an ecological community, but have been disturbed. Secondary succession would be observed on a forested area following a fire, on an area inundated by floodwaters, or on abandoned cropland.

Primary Succession

Primary succession may take hundreds, or thousands, of years before a stable climax community is attained. Much of that time may be involved in the creation of a soil substrate substantial enough to support the climax plant species. *Pioneer* species are the first to occupy a barren site. They typically share the following characteristics: strong powers of dispersal, high reproductive rates and the ability to persist under the extreme environmental conditions often encountered at such sites. They are usually short-lived "fugitives" which can quickly establish a foothold, but are competitively inferior to species that may take longer to establish their presence. Many well-known "weed" species are good examples of such fugitive pioneers. Over time, increasing deposition of organic matter provides resources for a greater diversity of plants. Succeeding communities, known as *seres*, frequently exhibit an increase in the both the number and size of species.

Whereas succession was once viewed as a very orderly process whereby each sere "paved the way" for the one that followed, we now know that succession is neither so altruistic nor so predictable. While earlier plant species *may* make the environment more suitable for later successional species, it is equally possible that they may inhibit later species from invading or have little or no effect either way. In forest habitats, plant species replacement may be based, in part, on individual germination tolerances for light or shade or levels of soil moisture. Ultimately, succession for any geographic region may vary considerably from site to site. Not only may it proceed along a variety of pathways, it may not always end up at the same end-point. Local conditions and chance events may produce any number of "climax" communities. Changes in the composition of animal species also occur over time, with animal species usually reflecting changes in the plant community. An example of the plants that might dominate the seral stages of primary succession is shown (pg. 19). The climax community is one that is capable of self-replacement, achieving some level of steady-state stability as long as climatic patterns remain unchanged.

Secondary Succession

Disturbances that remove all or most of the members of a community often do not remove the soil substrate necessary for their existence. This soil also serves as a seed bank and will often contain viable seeds from previous communities. Thus, secondary succession may progress much more rapidly than primary succession and may skip entirely many of the earlier seral stages. While second-growth forests may not immediately share all of the characteristics of the forest it replaced, it may be possible to re-establish most members of a forest community within 80-100 years following a fire or other such disturbance.

Disturbance and Recovery

If undisturbed, what plants dominate your ecosystem?

An ecological disturbance can best be thought of as an interruption of a settled state. The magnitude and frequency of disturbances, be they natural or otherwise, will determine the rate and degree to which a community will return to its pre-disturbed state. Small-scale disturbances, such as the loss of several trees in a forest due to high winds, may not alter the community composition at all; those individuals lost being replaced by saplings of the same species "waiting their turn" in the understory. On the other hand, a mature, climax forest, unaltered for many years, may be completely devastated by an intense fire. Recruitment may have to come from seeds arriving from a distant source, perhaps from a forest of different species composition. In this case, secondary succession may proceed along any number of pathways and recovery of the original forest may take many decades if it happens at all. Communities subjected to frequent disturbance, such as in a floodplain, are more likely to contain species with adaptations favoring their rapid recovery.

Implications for Management

As you might surmise from the above, disturbance regimes can have profound effects on the level of species diversity present at a given site. At low levels of disturbance, climax communities may exhibit relatively low levels of diversity, since competition will be high and the community will be primarily composed of a few dominant species. At high levels of disturbance, diversity will also be low, since relatively few species will be adapted to survive under those conditions. It follows that species diversity is actually highest at both intermediate stages of succession as well as under moderate levels of disturbance. If one wishes to manage an area for maximum species diversity, it will be necessary to create or maintain these conditions. Middle successional stages, where habitat is varied, will foster species diversity.

On the other hand, certain animals may be on the threatened or endangered species list because they are tied to a particular successional stage that is no longer abundant due to human interference. For example, flammulated owls and white-headed woodpeckers need large tracks of mature and old growth ponderosa pine trees. According to a Forest Service and Bureau of Land Management study, 75% of ponderosa pine ecosystems have been lost in the interior Columbia River landscape due to fire exclusion, logging, and grazing of livestock. (Idaho Department of Fish and Game, 2000)

Current estimates indicate that greater than 75% of the historical old growth ponderosa pine ecosystems have been lost across the Interior Columbia River Basin landscape (USFS and USBLM 1997). The primary effect of past forest management activities on overall acres of ponderosa pine has been the significant change in the historical fire regime. Three types of management activities have had the most influence on changing the historical fire regime: 1) fire exclusion policies; 2) grazing of livestock; and 3) harvesting of trees. (Covington and Moore 1994, Agee 1996)

Trophic Relationships

To early ecologists, it became apparent that the most obvious *functional* relationship linking plants and animals together in any ecosystem was food based. Feeding or *trophic* relationships delineated who ate whom in order to obtain the energy and nutrients necessary for survival. Hence, any community of organisms could be organized on the basis of the following *trophic levels*:

- Producers – Those organisms capable of producing their own food, primarily by fixing energy from the sun via photosynthesis. These *autotrophs* (self-feeders), most of which are plants, then serve as the primary energy source for the rest of the biosphere!

- Herbivores (primary consumers) – Those organisms obtaining their energy directly from plants, also referred to as primary consumers.

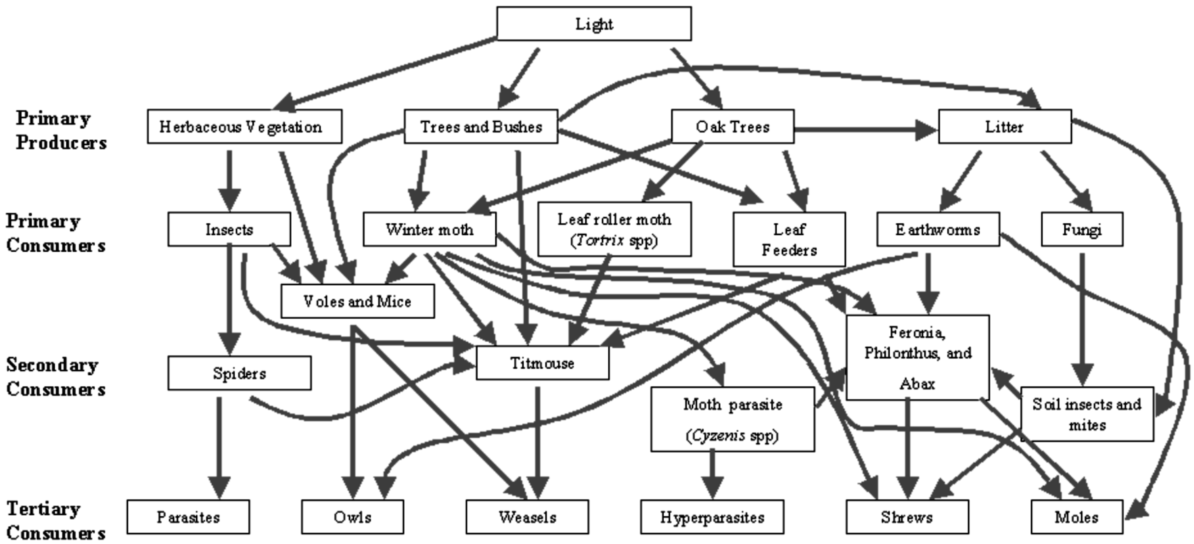
- Primary Carnivores (secondary consumers) – Those organisms obtaining their energy from herbivores.

- Secondary Carnivores (tertiary consumers) – Those organisms obtaining their energy from other carnivores. While one could conceivably continue "stacking up" carnivores in this fashion indefinitely, most ecosystems rarely exceed 4 or 5 trophic levels.

- Detritivores – Also known as decomposers, these organisms obtain their food from dead plants and animals. Through their actions, the building blocks of life are returned to the environment in elemental form to be used yet again. While often not considered a distinct trophic level, they are indispensable members of the biotic community.

Food Webs

A sequence of organisms, each of which feeds on the one preceding it, form a *food chain*. An Idaho example would be grass-insects-songbirds-raptor.

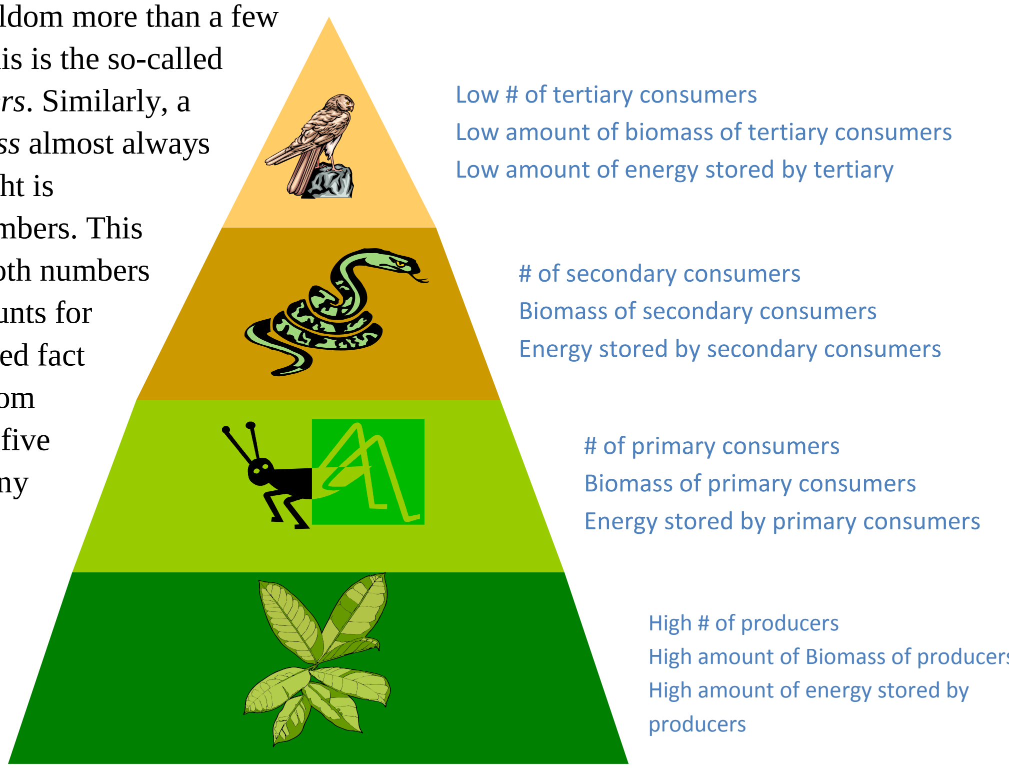


This is an attempt to draw a food web using broad categories of animals and plants.
Graphic courtesy of Texas Master Naturalist Program and Varley, Gradwell, and Hassel.

In most communities, several to hundreds of such food chains exist, and are interconnected in such a way as to form *food webs*. Were all organisms to be included, such food webs would be too complex to actually draw. Thinking of examples of food chains and webs reveals the "complexities" about trophic organization. First, not all organisms fit neatly into a single trophic level. Voles and mice, for example eat both herbs and insects, and like many other animals, including us, are considered *omnivores*. Second, while detritivore food webs are often considered separately, in reality the so-called herbivore food web and detrivore food webs usually interdigitate in a complex fashion. Finally, such food webs do not tell us much about which species are the most "important" to the stability of that particular community.

Pyramids of Numbers and Biomass

A general pattern emerges from observing community structure based on trophic relationships. There are usually many more plants than herbivores, greater numbers of herbivores than carnivores, and seldom more than a few top carnivores. This is the so-called *pyramid of numbers*. Similarly, a *pyramid of biomass* almost always results if dry weight is substituted for numbers. This rapid decline in both numbers and biomass accounts for the previously noted fact that there are seldom more than four or five trophic levels in any community.



Energy Flow

In order to understand the patterns in the graphic (right), we need to examine *energy* and *energy flow* within an ecosystem. Without getting sidetracked by a physics lesson, we're going to define energy as the capacity to do work. When you are "out of energy," your capacity to do work certainly feels limited. Work, however, isn't confined to just physical labor. It also includes maintaining basic metabolic functions, such as biochemical transformations, biosynthesis, secretion, and cell maintenance. Thus, as long as they're alive, all organisms continually lose energy in the form of heat. Lying in bed in a coma still requires energy! Unless an organism can replenish that energy which is constantly being lost, it will die.

The original source of all energy utilized by organisms is the sun. Unfortunately, the sun's energy or *solar radiation* cannot be used directly by most organisms to meet their constant energy needs (sun bathing would otherwise be looked at in a whole different light, so to speak). Only those organisms capable of photosynthesis can accomplish this. Interestingly, less than 1% of the solar radiation reaching the Earth's atmosphere is fixed in the form of chemical bonds in photosynthesis, yet this is sufficient to produce all of the plant and animal biomass on the planet! Unless this chemical form of energy in plant and animal tissue enters long-term storage (as was the case in the formation of oil, gas and coal), all of it is eventually degraded to heat, a form of energy no longer capable of performing biological work. That is why we say that energy *flows* through an ecosystem. The daily influx of energy from the sun that is fixed by the producers is roughly balanced by the daily outflow of heat produced by the myriad of living, metabolizing organisms, ultimately radiating back into outer space.

Ecological Efficiencies

Let's now go back and more closely examine the basic pattern we find in nature with regard to the pyramid of numbers and biomass. Why is it that most ecosystems support only three to five trophic levels? Why not 10 or 20 or 100? Is that picture we've all seen of a tiny minnow being swallowed by a larger fish and that by a still larger fish, and it in turn by a yet larger fish, and on and on until the last is swallowed by the giant whale false? In a word, yes! In order to see why, we need to understand what happens to a "packet" of energy as it makes its way from one trophic level to the next. Let's imagine 1,000 square meters of grassland and assume, for purposes of illustration, that our initial packet of solar energy fixed by all of the plants in that ecosystem has a value of 10,000 units. As we shall see, only a small percentage of this energy is going to end up in the next trophic level, the herbivores. First, some of that energy will be needed by the plants to meet their own metabolic needs. For plants, that figure lies between 20 and 75%, thus leaving between 25-80% of the energy plants fix in photosynthesis for growth or *net production*. Put another way, we can say that the *net production efficiency* of plants is between 25-80%. This is the new plant biomass (energy) available for consumption by the herbivores.

If we take an average *net production efficiency* of 50% (actually typical for grassland plants) we now have 5,000 units of energy available to the herbivores. But herbivores are not going to consume every last shred of plant material available. The *harvesting efficiency* of grassland herbivores varies between 5-30%. Let's assign a value of 20% to our herbivores. That means they will eat (ingest) only 1,000 units of energy (5,000 x 20% = 1,000). As you can see, we have already "lost" 90% of the energy we started with!

Let's continue to follow our packet of energy, now 1,000 units, as it proceeds through the herbivores. First, we have to be aware that most consumers don't digest, or *assimilate* everything they eat. Because plant material contains a lot of indigestible parts, *assimilation efficiencies* for herbivores are typically low, ranging between 30-60%. Thus, we are now left with between 300-600 units of energy that are actually digested (assimilated) by the herbivores, the remainder leaves the animal as fecal material, or *egestion*. Can all of the energy assimilated by an herbivore be applied towards growth? No. A significant amount of this energy must also be used to take care of an animal's basic metabolic needs.

Here is where we see a large difference between *ectotherms* and *endotherms*. You may know the former as "cold-blooded" and the latter as "warm-blooded" animals. Whereas ectotherms can put 20-50% of their assimilated energy towards growth, endotherms (birds and mammals) can only muster 1-3%. Why is this *tissue growth efficiency* so low for birds and mammals? Because most of their assimilated energy must be used to maintain an elevated body temperature (high metabolic rate). Since ectotherms simply assume the temperature of their surroundings, their metabolic needs are substantially less and they can put more of their available energy directly into growth.

Let’s apply the above tissue growth efficiencies to an average value of 500 units of energy assimilated by the grassland herbivores. Ectotherms, such as grasshoppers, will produce between 100-250 units of new tissue (500 x 20-50%), while endotherms, such as mice or rabbits) will produce only 5-15 units (500 x 1-3%). Out of our original 10,000 units of energy, we have managed to produce only 100-250 units of herbivore tissue if we’re talking grasshoppers and the like, and very scant 5-15 units of herbivore “meat” if we’re considering birds and mammals. This is all that will be available to the next trophic level, the primary carnivores. We have lost somewhere between 97.5 to 99.95% of the energy originally fixed by plants in photosynthesis!

Having “crunched the numbers,” you can begin to appreciate the rather drastic reduction in numbers and biomass usually portrayed in the third and fourth levels (carnivores) of the respective pyramids (refer again to pg.19). This is why the fourth trophic level only represents a few individual carnivores for the size of our illustration.

As a simplification, ecologists often employ the “10% rule” to illustrate the decline in available energy from one trophic level to the next. Thus, only .01% of the original amount of energy fixed by the plants in photosynthesis would be available to tertiary carnivores in any given area! It is this low trophic-level efficiency that accounts for the small number of trophic levels observed in any ecosystem.

Implications for Management

The exceedingly small amount of energy available to the highest trophic level accounts for the fact that “big, fierce animals,” those top carnivores, are exceedingly rare. In fact, most top carnivores need to be highly mobile to cover the vast amount of ground needed to supply their energy needs. Home ranges of wolves and mountain lions, for example, are on the order of hundreds of square miles! Their predatory activities often form crucial energy links between neighboring ecosystems or landscapes. It also explains why many of these top carnivores are often on endangered species lists. Never existing in large numbers, encroaching development and increasing levels of habitat fragmentation are compromising their need for large expanses of suitable habitat. It is also putting them in more frequent contact with human activities, often with negative consequences.

The territorial needs of these predators are also posing a dilemma to conservation biologists. As wildlife habitat continues to shrink, biologists are recognizing that the long-term survival of many species may ultimately depend on our willingness and ability to set aside sufficiently large tracts of land as biological reserves. The important question is – "How large of an area is needed to maintain a viable population of that region's largest carnivore?" Is there the financial and political wherewithal to create at least one park or preserve on the magnitude of thousands of square miles? If not, we might not only lose those magnificent large predators but also the long-term stability of entire biological community of which they are important, perhaps critical, members.

Ecological Relationships

Species Interactions

So far, we have learned that the structure and function of all ecosystems is based on the concepts of energy flow and nutrient cycling. An organism's trophic relationships, and its relative importance in the flow of energy and the cycling of nutrients, are important aspects of its role, or niche in the community.

Another key element in describing an organism's niche is the way it interacts with other species within its community. What kinds of interactions exist among species? One way of answering this question is to determine the effect that one species has on another's ability to survive and reproduce. In the table to the right, types of interactions are listed along with their effects on the two species involved. In a predator-prey interaction, for instance a plus indicates that species one (the predator) benefits from the interaction. For species two (the prey), the negative sign signifies a negative impact on its population. Note that this particular type of interaction would also include herbivores eating plants and host/parasite interactions.

INTERACTION SPECIES

	1	**2**
Neutralism	0	0
Competition	-	-
Amensalism	0	-
Predation	+	-
Commensalism	+	0
Protocooperation	+	+
Mutualism (obligatory)	+	+

Types of Interactions their effects on the species involved:

- *+ is a positive effect*
- *- is a negative effect*
- *0 is no effect*

Neutralism - the state of being neutral.

Competition - The simultaneous demand by two or more organisms for limited environmental resources, such as nutrients, living space, or light.

Amensalism - A symbiotic relationship between organisms in which one species is harmed or inhibited and the other species is unaffected.

Predation - The capturing of prey as a means of maintaining life.

Commensalism - A symbiotic relationship between two organisms of different species in which one derives some benefit while the other is unaffected.

Protocooperation - the first in time association of organisms working together for common benefit

Mutualism -An association between organisms of two different species in which each member benefits.

Competition is defined as the use of a limited resource by two or more individuals, either of the same species (intraspecific competition) or different species (interspecific competition). Competition is negative for both because use or defense of a resource by one (individual or species) always reduces availability of that resource for any other.

For much of the past 130 years, most ecologists believed that the old dictum "nature, red in tooth and claw" succinctly described the dominant forces shaping and controlling the natural world. We discovered that the concepts of trophic interaction and energy flow were pivotal in developing an ecological framework. They also influenced thinking about the way in which biological communities were structured. Predation and competition, (killing and fighting for resources) were seen as the key to understanding how communities were organized. They were also viewed as important determinants of population size and stability of natural systems. As one famous study put it, "Are populations limited primarily by what they eat or by what eats them?" (Hairston, Smith and Slobodkin, 1960) As a result, the ecological literature is especially rich in articles detailing predator-prey interactions and competition. Over the years, observation, theory and experiments have clearly demonstrated that both do play important roles in structuring biological communities. More recently, ecologists have turned their attention to other types of interactions. Within the last several decades, they have begun to elucidate the importance of win-win interactions, such as symbiotic relationships among plants and their pollinators and the mycorrhizal association of fungi with plant roots, to similarly shape community structure.

Species-Community Relationships

Interspecific (between species) interactions often have a significant effect on the number of species present in a community and their relative abundance. Evolutionary ecologists believe, for example, that much of the great diversity in life we see has come about through *competitive exclusion*. The *Competitive Exclusion Principle* states that two or more species cannot coexist on a single limited resource. Competition thus leads to one of two scenarios. Either one species will "out compete" the other(s) and gain sole possession of that resource *or* natural selection will, over time, select for those individuals that exploit different resources, thereby avoiding competition. Ultimately, characteristics of species diverge sufficiently to allow for coexistence with each species occupying a unique niche in the community.

In some habitats, ecologists have identified *keystone species*, species whose addition or removal may lead to major changes in community structure.

Think of examples in Idaho of effects of removing a keystone species. What happened?

Population Dynamics

As illustrated in the preceding section, species interactions can have profound effects on the numbers of individuals in a given population. Obviously, many other environmental factors, both abiotic and biotic, affect population size. Ultimately, though, we can track changes in *population density*, the number of individuals per unit area, as a resultant of four factors:

- **Natality** – the production of new individuals through either sexual or asexual reproduction
- **Mortality** – loss of individuals through death
- **Immigration** – new individuals moving into a population
- **Emigration** – residents moving out of a population.

All the fancier models of population growth (which we happily won't go into) are based on this simple equation:

$$N_{(t+1)} = N_t + B + I - D - E$$

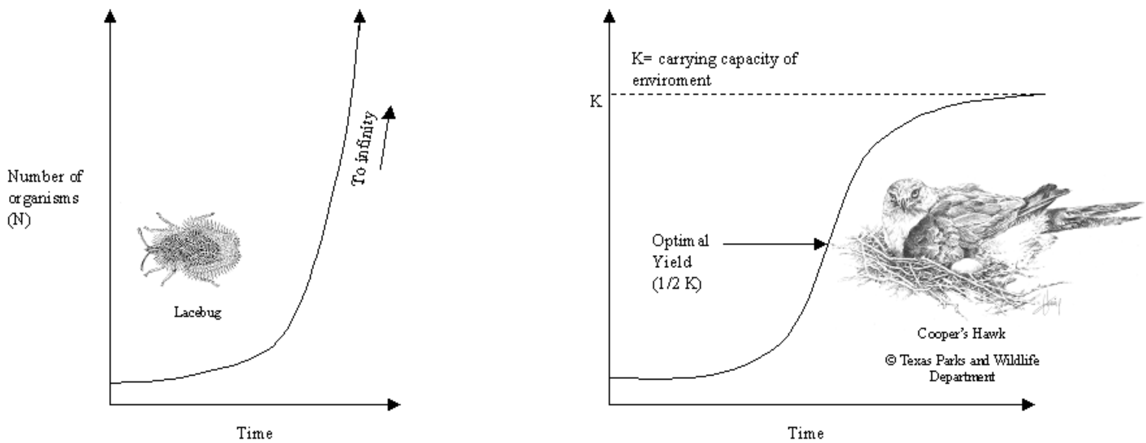
Verbally this reads: The number (N) of individuals in a population at some unit of time in the future (Nt+1) is equal to the current number of individuals (Nt) plus the number of new individuals recruited via reproduction (B) and immigration (I), minus the number lost to death (D) and emigration (E) over that unit of time. If recruitment exceeds losses, the population grows; if not, the population declines.

In part, the job of population biologists and wildlife managers involves assigning values to each of these four variables to better predict future population trends. *Intrinsic* (internal) factors affecting population growth include its sex and age distribution, age-specific fecundity (rate at which an individual produces offspring), and social structure. A population comprised mostly of young, pre-reproductive individuals is going to have a different growth pattern than one that has a high percentage of older, post-reproductive individuals. Certain populations, such as some species of salamanders, need a critical minimal number of individuals in order for successful breeding to occur. Territorial species, such as many of our songbirds, will behaviorally limit the number of breeding pairs allowed in a given habitat.

There are also many *extrinsic* (external) factors affecting population growth, including competition, predation, disease, pollution, hunting, and *carrying capacity* of the environment.

Carrying Capacity

Carrying capacity is a very important ecological concept. It is defined as the maximum number of individuals of a given species that a habitat can sustain indefinitely. When habitat quality improves, its carrying capacity increases. If habitat declines so does the carrying capacity. This is why both the *quantity* and *quality* of wildlife habitat is so critical to maintaining wildlife populations and why wildlife managers "manage" habitat, not wildlife.



Two growth forms - exponential (first graph) and logistic (second graph). Courtesy of E.O. Wilson and W.H. Bossert, 1971.

Population Growth Models

For many species (most invertebrates), populations may exhibit *exponential growth* **(**first graph) After starting slowly, numbers begin to accelerate rapidly, increasing at an ever-increasing rate, mimicking the way money grows in an account earning compound interest. Populations often continue to grow exponentially until a sudden change in environmental conditions causes them to "crash." An insect population growing exponentially throughout the spring and summer may be brought to a sudden halt by the first cold snap. This is *density-independent* growth, the growth rate of the population is independent of the population density. Other species, especially long-lived vertebrates, may exhibit a *logistic growth* pattern, as idealized in the second graph. Their populations show the effects of increasing *environmental resistance*. The greater the population size, the more the environment "pushes" against further growth. As numbers of individuals approach the habitat's carrying capacity (K), the population growth rate gradually slows until, at K, it becomes zero, thus stabilizing the population at carrying capacity. This *density-dependent* growth is the result of both intrinsic factors (greater social stress leads to lower natality rates, lower survivorship rates, higher emigration rates, etc.) and extrinsic factors (increased predation, disease).

No species in nature follows either pattern exactly or indefinitely. The logistic growth model, for example, assumes that populations are capable of immediately changing their growth rates in response to environmental resistance. The reality is that there is usually a lag effect, or time delay. A population at carrying capacity may continue to grow for some time before environmental factors leading to zero population growth take effect. Thus, rather than leveling out at K, a population may overshoot it, leading to over-exploitation of resources and an eventual decline below the original carrying capacity. The long-term result may either be a population that oscillates around K in an increasing tighter pattern (damped oscillation) or one that exhibits more or less regular periodic cycles of abundance. Periodic fluctuations in numbers have often been documented in northern habitats such as the classic 10-year cycle exhibited by snowshoe hare, lynx, ptarmigan and ruffed grouse and the 4-year cycles exhibited by various species of voles and lemmings.

Implications for Management

Despite their apparent limitations, these basic models have served as the foundation for more sophisticated attempts to understand population dynamics. Population models are the primary tools of today's resource managers. The objective of all natural resource management is to produce the greatest *yield* without endangering the resource being harvested. Whether we are discussing forestry, fisheries, or wildlife, the resource manager must know enough about the population dynamics of the species in question to accurately set appropriate harvest rates on a year to year basis. Sadly, much of human history is strewn with examples of how poor management has led to the destruction of a once abundant resource. An application of the logistic population growth model has been the basis of scientific resource management since the 1930s. The model predicts that the *maximum sustained yield* for any population is obtained not at the highest population size, but rather at a point much below K. In its simplest form, the logistic model reveals that the highest rate of population increase occurs at the mid-point of the growth curve, or when N = ½ K. Thus the maximum sustained yield for a game species would be obtained by cropping that population back to one half the carrying capacity, prior to the next breeding season. To determine actual hunting or "bag" limits, wildlife managers must collect and analyze both population and habitat data to determine the relationship between a population's current size and its potential for future growth set by the carrying capacity of the habitat.

Species Diversity

Species diversity refers to the number of different species found in a community. One of the most striking global patterns is the marked increase in biological diversity (commonly referred to as *biodiversity*) as one proceeds towards the equator. Greenland, for example, is home to 56 species of breeding birds, New York has 105, Guatemala 469, while Colombia boasts 1,395!

Turf grass (far above) can be replaced with native flowers and plants (above) to increase diversity and attract wildlife.

There have been many hypotheses proposed to explain this phenomenon. Tropical habitats are older, more productive, are structurally more complex (hence have a greater number of ecological niches), and have greater numbers of predators, thereby decreasing competition among prey species. Ecologists are currently examining each of these factors to see which best explains the observed latitudinal gradient.

As noted previously, we often see species diversity increase as we proceed through succession (recall that the greatest number of species often occurs prior to the climax community). In general, ecologists have observed that disturbed sites exhibit low species diversity, usually comprised of a few broadly adapted generalists, while undisturbed sites are comprised of a richer diversity of species, many of whom may specialize on a rather narrow group of resources. *Monocultures*, communities dominated by a single plant species, such as we frequently establish in growing our crops and landscaping our urban environment, are often unstable with regard to community structure, and often exhibit wide fluctuations in the population densities of the few species they support. Outbreaks of "pest" species and diseases are much more frequently encountered in these habitats than in more diverse communities. The "balance of nature" is more likely to be a reality within communities featuring complex food webs and numerous interspecific interactions. It is one reason we support homeowners replacing the typical "turf and trimmed trees" look with native landscaping, or wildscaping.

Fragmentation and Edge Effects

As the human population continues to increase both locally and globally, we continue to reduce remaining "undisturbed" habitat. As these natural habitats become smaller and increasingly fragmented, the ratio of an area's border to its interior rises. Smaller plots are subject to greater light intensities, higher wind velocities, and a variety of biotic factors associated with the relatively greater amount of perimeter or *edge*.

Cutting holes in a forest to create more edge was once looked upon by game managers as the premier technique for increasing the density of almost any game species. Stature of this "edge effect" was further increased by some ecologists who touted its ability to also increase overall species diversity. This was true, but only up to a point, the point at which interior species began to be lost. In the case of forest habitats, the species added by increasing edge are the generalist species common everywhere – such as the white-tailed deer, raccoon, grackles and song sparrow. When used now, "edge effect" usually carries a strong negative connotation. Many forest species, such as our songbirds, are harmed by edge in one or both of two ways.

- Many interior species not only avoid the edge, but the space from a few to many meters interior to an edge. A 4-acre cut from a forest tract actually removes a considerably larger area from use of these species.

- Reproductive success of interior species is often adversely affected by increasing edge because nest-parasitizing cowbirds and many native and domestic predators enter forests via edges. For particularly vulnerable species, such as ground nesters, forests with large amounts of edge may be "ecological traps" – attractive habitat, but deadly to them or their eggs and young.

A dramatic decline in the populations of many Neotropical songbirds has been documented over the past three decades. Members of this group of birds typically breed in the United States and Canada, but winter in Central and South America. While the initial focus of attention was on the continuing loss of breeding habitat in the north, destruction of tropical forests and other key habitats in their wintering grounds have also been implicated, especially since many of these birds actually spend two-thirds or more of their time in the tropics. Recognizing the seriousness of this issue, new initiatives on the national and international level, backed by significant funding, are underway to reverse this trend. The emphasis is on the identification, preservation and restoration of both breeding and wintering habitats, as well as those critical stop-over habitats used during migration.

Endangered Species

Why do some species become rare and go extinct while others thrive? First, we must remember that extinction is a natural process. The species that exist today represent only a tiny fraction of all the species that have ever existed. Aside from geologically rare instances of mass extinction (such as the apparent asteroid impact that brought an end to the 140 million year reign of the dinosaurs), extinction rates for any given group are usually low. For mammals, the fossil record indicates this rate was between .002 and .02 species per year. In the 20th century, 25 mammals are known to have gone extinct, or .25 per year, or 12.5 to 125 times the "background" rate. In fact, given the current rate of loss of all species worldwide, we may be in the midst of one of the fastest extinction rates of all time. The primary cause of this sharp rise in extinction rates is, first and foremost, habitat loss. As already mentioned, our burgeoning human population continues to occupy, clear and degrade more and more previously undisturbed land. Other factors, all related to human activity, include commercial hunting and fishing, predator and pest control, the exotic pet and plant trade, the introduction of alien species and pollution.

Which species are we losing? Primarily those species whose habitat is being fragmented or destroyed. These species tend to be habitat specialists rather than generalists. In Idaho, these species include the Woodland Caribou, Grizzly Bear, Lynx and Northern Idaho Ground Squirrel.

In contrast, generalists, those species with broad diets capable of surviving in a wide variety of habitats (especially those created by human activity), are common and often increase under conditions of disturbance.

So why should we care? What difference could it possibly make if we lose the woodland caribou or the lynx? There are three broad categories of arguments that are usually made to address such questions – aesthetic, practical and moral or ethical (Brewer, 1994).

The aesthetic argument is simply that the natural world has much to offer in terms of beauty, inspiration and wonder. John Burroughs said, "I go to nature to be soothed and healed, and to have my senses put in tune once again." Destroying the natural world impoverishes us all. A 2006 survey by the U.S. Fish and Wildlife service found that over 71 million Americans identify themselves as "wildlife watchers" and spent over $45 billion in pursuit of their hobbies. There are more active birders than golfers and birding has become one of the country's fastest growing outdoor activities.

Birding at Heyburn Marsh, Idaho.
Photo courtesy, Jennifer Miller, WREN Foundation.

On the practical side, all species are part of the web of life that sustains human life. There is no such thing as an "unnatural resource." Nature is the ultimate provider of all the goods and services that make our highly technological lives possible. Despite our ability to manufacture synthetic compounds, over 25% of all prescription drugs still rely on compounds derived directly from plants. A much higher percentage of drugs we have developed to treat everything from various types of cancer to HIV to malaria are modified derivatives of naturally occurring substances. An antiviral drug proven effective against a previously lethal form of herpes encephalitis was derived from a previously obscure Caribbean sponge and is now saving thousands of lives annually. When we lose any species, we lose forever the genetic information that is uniquely theirs and the opportunities to even test them for potentially useful compounds. As far as services are concerned, there is simply no replacing the roles countless organisms and communities play in maintenance of the atmosphere, biogeochemical cycling, soil formation, watershed management pest control and pollination.

Finally, there is a moral or ethical argument that can be made. Whether or not it is deemed "beautiful" or "economically beneficial" the decision to destroy another species can be thought of as simply "not the right thing to do" in the same way that murdering another human is morally and/or ethically wrong. If we come to the understanding that humans are a part of nature, not apart from nature, we will appreciate the fact that all living things are members of one biotic community. In Aldo Leopold's words, "We are all kin."

Threatened and Endangered Species Lists

The federal Endangered Species Act of 1973 committed the United States to preventing the extinction of plant and animal species. Most states, including Idaho, have enacted their own legislation with similar provisions. *Endangered species* are those in imminent danger of extinction throughout their range. *Threatened species* are those likely to become endangered within the foreseeable future. Many states also include a third category, *rare species*, which recognizes species that, because of their low or declining numbers and other special features, such as shrinkage of critical habitat, need special attention. At the federal level, the primary authority to list, delist or change the status of any species resides with the Secretary of the Interior.

Endangered species in Idaho as of 4/3/2008	Threatened species in Idaho as of 4/3/2008
Mammals Woodland Caribou	**Mammals** Grizzly Bear (sans the Yellowstone distinct population) Lynx Northern Idaho Ground Squirrel
Fish Sockeye Salmon White Sturgeon	**Fish** Bull Trout Chinook Salmon Steelhead
Invertebrates Banbury Springs Limpet Bruneau Hot Springsnail Desert Valvata Idaho Springsnail Snake River Physa	**Invertebrates** Bliss Rapids Snail

Endangered species in Idaho as of 4/3/2008	Threatened species in Idaho as of 4/3/2008
	Plants MacFarlane's Four-o'clock Spalding's Silene Ute Ladies' Tresses Water Howellia

(for an updated list, visit the Idaho Conservation Data Center website at http://fishandgame.idaho.gov/cdc/t&e.cfm)

Protection

Under both state and federal law, it is illegal to take, possess, transport or sell any animal species designated as endangered or threatened without the issuance of a permit. State laws and regulations also prohibit commerce in threatened and endangered plants and the collection of listed plant species from public land without a permit. Endangered species receive additional federal attention. Their essential habitats are also protected and a recovery plan is supposed to be devised, based on knowledge of the ecology of the species. It outlines procedures designed to build up populations to a level where the chance of extinction is minimal, allowing the species to be delisted. Well known success stories include the Bald Eagle, American Alligator and Peregrine Falcon.

Species of Greatest Conservation Need

In early 2006, the U.S. Fish and Wildlife Service (USFWS) approved Idaho's Comprehensive Wildlife Conservation Strategy (CWCS). This strategy was mandated by USFWS for each state. The strategy identifies Species of Greatest Conservation Need and what actions need to be taken to keep these species from becoming eligible for listing on the Endangered and Threatened Species list. A list of Species of Greatest Conservation Need in Idaho is located on page six of the following document.

http://fishandgame.idaho.gov/cms/tech/CDC/cwcs_pdf/appendix%20b.pdf

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