Why: Does the Forest Look Like This? – Basic Ecology

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Ecology is the study of the world around us, the interactions of plants, animals, water, soil, climate and other factors that make this place where we live – look and work like it does. Learning some key ecological concepts helps us describe our property to ourselves and others and enables us to put the property in context and better manage our resources.

Some Key Concepts

- **Ecosystems have boundaries.** A scientist sets these boundaries to efficiently study ecosystem characteristics and processes.
- **Energy flows in one direction through an ecosystem.** These energy flows can be used to understand how ecosystems work.
- **Chemical elements are cycled and recycled within an ecosystem.** While some materials may move into or out of an ecosystem, most of the elements that make up that ecosystem are constantly recycled.
- **Ecosystems are dynamic and always changing.** Many changes are predictable based on principles common to all ecosystems. Natural disturbances are responsible for initiating changes in ecosystems called succession.

Ecosystems Have Boundaries

John Muir once wrote that "everything is hitched to everything else." In our attempt to study and understand ecological processes we always have to be aware of the fact that the boundaries we place on the ecosystems we study are artificial. While some scientists study processes like global warming which affect the entire planet, others are interested in interactions of microscopic organisms in a few drops of water.

Scientists study ecosystems of all sizes and many levels of complexity. The processes that shape ecosystems often work beyond the boundaries we establish. We can think of your property boundaries as the boundaries of a specific ecosystem. The forests and streams on your property, which we may think of as part of an ecosystem, are affected by regional climate and even the ways in which our neighbors manage their properties. It is rare indeed that property boundaries make sensible ecological boundaries. It is more likely that the watershed which completely encompasses your property is a logical ecosystem boundary.

Scientists choose ecosystem boundaries to simplify the study of complex relationships and facilitate comparison of similar types of ecosystems. Choosing the right scale is an important step. For landowners, understanding ecology at the scale of an organism, community, or watershed are important.

The Ecology of Organisms

Every plant or animal has specific life history requirements. In a garden or in the wild, some plants grow best in full sunlight and others grow well in full shade; the majority are able to tolerate and grow in conditions somewhere in between. Recognizing differences in light requirements and shade tolerance amongst plants helps us understand why plants grow in some places and not others, giving us tips on management. For example, ponderosa pine grows best in full sunlight, though it can tolerate growing in shade for years and still survive. If grown in shade for too long, a ponderosa pine will eventually decline in health and die. On the other hand, white fir can grow for many years in deep shade, and can respond with increased growth if and when an opening in the forest allows full sunlight to reach it. Plants differ not only in their tolerance to shade but in their tolerance to moisture stress (drought), disease, and soil nutrient status. Since plants cannot move to better environmental conditions like animals, relative stress tolerance is a critical determinant of plant community composition and structure.

The Ecology of Plant Communities

Rarely are California's forests made of only one species of tree. It is more common that they are composed of numerous tree, shrub and herb species. These plant associations or communities occur because of specific environmental and historical conditions.

Ecosystems are commonly described in terms of plant communities. Communities array themselves along significant environmental gradients. For many landowners it is very helpful to position your property on an ecological transect that traverses an important environmental gradient. In California, one of the most important environmental gradients is elevation or altitude. Another is latitude and a third is distance from the Pacific Ocean. Knowing where you are on the "ecological transect" or environmental gradient provides an understanding of the ecological context and potential of your property. Below, we illustrate this with an ecological transect from the Sacramento Valley to the eastern slope of the Sierra Nevada.

If you were to drive from Sacramento to Lake Tahoe you would travel through several plant communities. Along the banks of the Sacramento river, you would find a community of plants that is adapted to periodic flooding including cottonwood, willows, alders, sedges and cattails. These riparian communities often have abundant and diverse plant, animal and insect life.

As you traversed the urban environment you would encounter an ecosystem that has been highly modified by human activity. Plant communities in urban areas are a collection of native and exotic vegetation often intentionally planted for ornamental reasons. Native wildlife like raccoons, skunks and birds can thrive in this artificial environment, sometimes becoming pests.

Continuing the journey, you would pass through agricultural fields, another ecosystem that is highly modified by people. Agricultural fields are very simple ecological systems manipulated by mechanical and chemical treatments to produce very specific products. Agricultural fields clearly demonstrate a concept that will be discussed in more detail later **-** disturbance. By deliberately "disturbing" the natural progress of native vegetation, we manipulate this ecosystem to meet specific needs.

As the flat agricultural fields give way to rolling hills, the plant community changes to a grassland. Although not readily apparent to the casual observer, California's grasslands, or rangelands, have been highly altered by people. Prior to European settlement of California, light frequent fires and Indian land management practices maintained a perennial bunch grass community sometimes with light cover of oak trees in savannas. Before the 1700's, most of this landscape would have been green year-round instead of brown in autumn. Introduction of European livestock and exotic grasses from the Mediterranean had dramatic effects on the California grasslands. Over a relatively short period, Mediterranean grasses and herbs displaced the perennial grasses and came to dominate the grassland plant communities. Annual grasses grow quickly in spring, capturing soil moisture and nutrients, set seed, then die. They are much more effective competitors than the native bunch grasses.

Further up in elevation the rolling hills get steeper, soils change, and the vegetation changes accordingly. Gray pine, blue oak and live oak become common, grassland diminishes, and understory shrubs become more common. Soils tend to be shallow and rocky, rainfall is relatively limited and snowfall is rare. This transition zone between valley grasslands and conifer forests at higher elevations is home for over 200 species of wildlife. It is also a zone of increasingly intense human development.

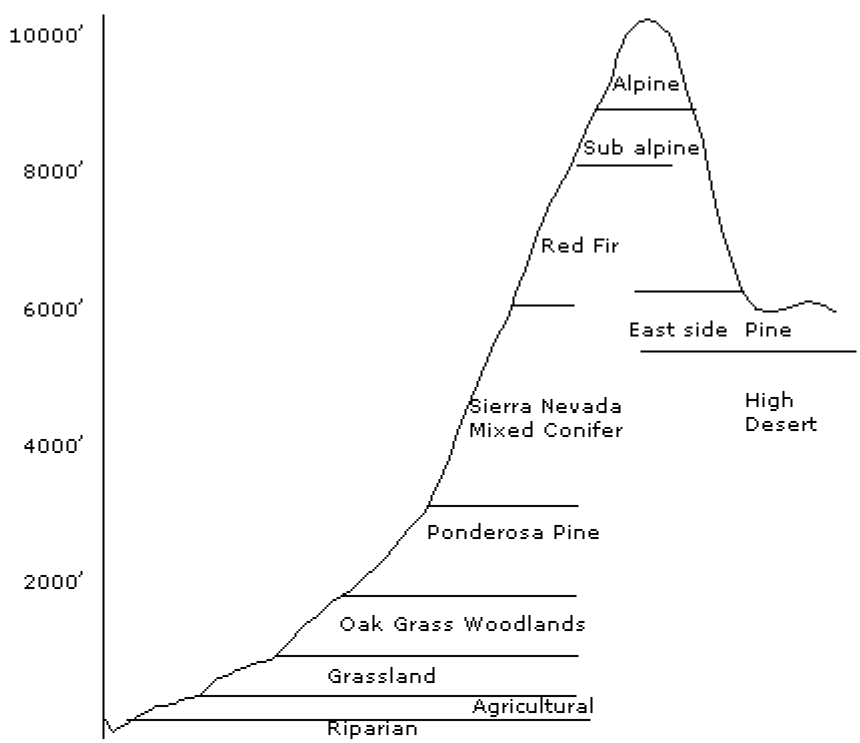
At about 2000 feet elevation, the vegetation changes again to nearly pure ponderosa pine forest for a narrow belt. Precipitation is still inadequate for supporting the more diverse mixed conifer forests that we associate with the Sierra Nevada range. Temperatures are too low in winter to support abundant oaks but the Kellogg black oak becomes a common understory plant.

The mixed conifer community found at elevations from about 2000 to 6000 feet are well-adapted to the relatively harsh winters of the Sierra Nevada. Precipitation is higher here than in the ponderosa pine belt and much of it falls as snow. Snow melt during the spring recharges soil moisture allowing tree growth to occur well into the summer drought period. The mixed conifer community is dominated by ponderosa pine, sugar pine, Douglas-fir, white fir, and incense cedar with a large array of shrub and herb species.

In the sub-alpine higher elevations the mixed conifer community gives way to communities dominated first by white and then by red fir and lodgepole pine. Soils are thin because of the very harsh climate and they are highly susceptible to erosion. At the Sierra crest, alpine rock fields comparable to Arctic tundra dominate. Alpine settings are characterized by unique tree communities, such as bristlecone pine, and by meadows which have spectacular wildflower shows in summer. Most alpine settings in the Sierra Nevada are within protected wilderness areas.

As we dip into the Lake Tahoe basin, we encounter communities dominated by jeffrey pine and ponderosa pine. The dominance of pines reflects the lower precipitation on the lee side of the Sierra Crest.

If we continue past Lake Tahoe onto the eastern slope of the Sierra Nevada we enter an even drier environment which is dominated by pure stands of widely spaced ponderosa pine. Finally, in the intermountain basins of Nevada we would encounter high desert dominated by sagebrush. Streams in the eastern Sierra Nevada are often vegetated with riparian shrub and tree communities dominated by cottonwood, willows and water birch. Wetlands are diverse and important wildlife habitat in the high desert and foothills of the eastern Sierra Nevada.



If we were to stop to explore any of these ecosystems closely we would find other ecosystems contained within the larger plant communities: meadows, lakes, brush fields, rivers and streams. Locally distinctive microclimates and soils create conditions suitable for unique and interesting plant communities.

This ecological transect illustrates several environmental conditions which control the distribution and composition of plant communities. These include the effects of elevation change on climate and soil conditions and the related effects on plants. Although we have presented this transect in a simplistic way, it is in fact very complex. When the effects of management on both communities and the environment are considered, it becomes apparent why the study of ecology commands so much interest among scientists. Some of the cause-effect relationships reflected in our ecological transect can be understood by exploring some of the underlying ecological processes.

Energy Flows Through Ecosystems

One way to understand and compare ecosystems is to trace the flow of energy through them. Energy flows from the sun as light, is converted to chemical energy by plants, used by animals, and eventually released to the environment as heat through decomposition. None of these processes create energy, they only convert it to forms usable for biological activity.

Let’s look at a single tree as an example. The tree absorbs sunlight through its leaves, and converts it to chemical energy (i.e., carbohydrates and plant tissues) through the process of photosynthesis. Some of that energy is stored in the trunk, roots, and leaves for the tree’s later use, or is used to support the process of gathering more sunlight. Indeed the tree is breathing, burning chemical energy in its cells, and giving off heat. An animal, such as a deer might browse the foliage for its own energy needs. When leaves or branches fall to the ground, decomposers, worms, insects, fungi – take over, breaking the leaves down to smaller and smaller components, eventually to be taken up by the roots again.

The energy from those leaves can flow through the ecosystem through many other pathways. For example, the worm that helped decompose leaves may be eaten by a robin. An owl could feed on the robin. The fungi which grew on the worm’s castings could form a mushroom, eaten by a squirrel. The squirrel may in turn be eaten by a hawk. The hawk eventually dies and feeds scavengers, insects and fungi.

At each stage, some of the energy is used in the life processes of the predator. The prey takes energy from one source, converts it to its needs, loses some to the environment as heat, and eventually is fed upon by another or decomposed. Understanding how energy flows through these complex, interdependent processes helps us understand how changes in the environment can effect energy flow through it.

Chemicals are Cycled and Recycled Within Ecosystems

While energy flows through an ecosystem, chemical elements necessary for life are recycled within it. Carbon, hydrogen, oxygen, nitrogen, and other elements are used by plants, animals, and microbes and cycled amongst them. These elements are combined in various ways to support life processes, broken down into simpler forms, and recombined into other forms.

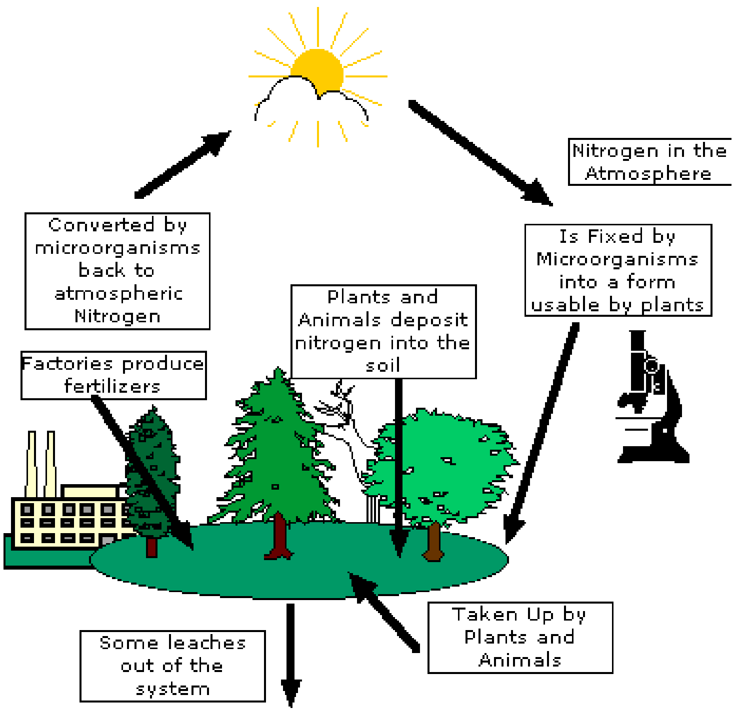
The cycling of nitrogen, an element essential to plant growth and a constituent of all proteins, provides an excellent example. Take a deep breath and exhale. You just took about one quart of nitrogen into your lungs and expelled it, a little bit warmer, but relatively unchanged. Nitrogen is abundant in the atmosphere as nitrogen gas. About 78% of our atmosphere is nitrogen. As a gas, nitrogen is very stable; the nitrogen atoms are so tightly bound that they do not react easily with anything else. Nitrogen gas is used to preserve the taste of stored food and wine. In its gaseous form however, nitrogen is unavailable to plants and animals.

The nitrogen found in every living cell is found in a less stable form that is high in chemical energy. Think of nitroglycerine or TNT - the N is nitrogen. The explosive nature of these chemicals is well known. This is the same type of energy that drives cells - though on a smaller and less dramatic scale. When nitrogen molecules are split and the individual atoms paired with other elements like carbon, hydrogen and oxygen-a process, known as "fixing" nitrogen-it is put into a form that is usable by plants.

Nitrogen is fixed naturally in two ways. A very small amount is fixed by lightning. The bulk of natural fixing is done by bacteria. Most nitrogen-fixing bacteria live independently in the soil or water, but a large number live in swollen tissues called nodules on plant roots. These bacteria get water, nutrients and protection from the plant and in return supply fixed nitrogen to it.

People also put nitrogen into the environment deliberately. Fertilizers made from nitrogen gas subjected to high heat and pressure have been available since the early 1900's. When excessive fertilizer is applied to agricultural fields the highly soluble nitrogen may run off into rivers, lakes and streams causing pollution. Oxides of nitrogen are a product of automobile exhaust and burning fossil fuels.

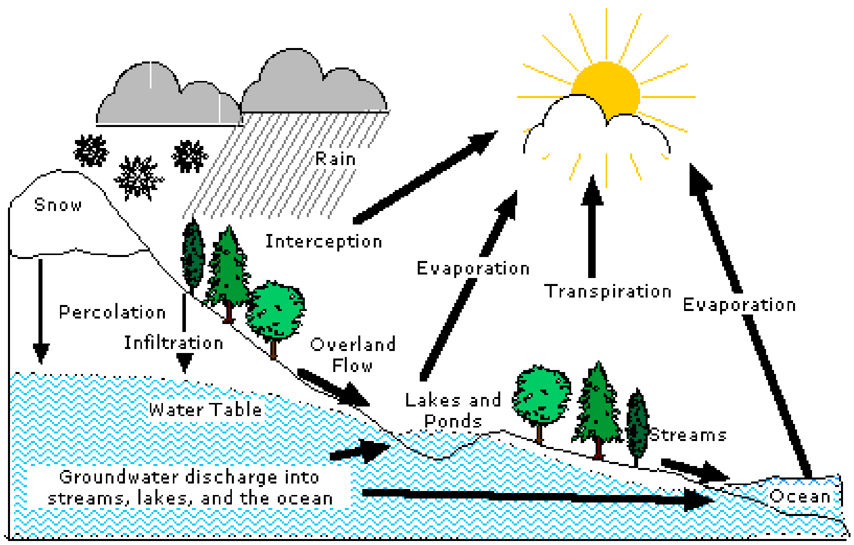
Once nitrogen enters the plant it is transformed into various compounds that compose plant tissues. If the plant tissues are eaten by animals, the nitrogen is transformed into their tissues. Eventually the plant or animal dies and insects, fungi, and bacteria, termed decomposers, break down the tissues. The nitrogen compounds go through a decomposition process called denitrification eventually becoming nitrogen gas and returning to the atmosphere.



Other chemical elements cycle through ecosystems in similar ways. Carbon, phosphorous, potassium and other chemicals absorbed by plants are eaten by animals and insects and eventually decomposed. Studying the paths of elements through the ecosystem, called nutrient cycles, highlights important ecological processes. Often an element might not be in sufficient supply for maximum ecosystem productivity. For example on serpentine soils, calcium is often deficient. Since calcium is a key element in many tissues and biological activities, when it is deficient there are limits to the plant species which can survive and productivity is low. When a chemical element is not in adequate supply in an ecosystem it is termed a limiting factor.

The Pattern of Water Movement in Ecosystems

In California, water is often the most important factor that limits plant growth and ecosystem productivity. The hydrological cycle is a physical and biological process that dramatically shapes the environment. It begins when water is evaporated from oceans, lakes, rivers and other water bodies. The movement of water through plants from the soil to the leaves and then to the atmosphere is called transpiration. Atmospheric water derived from evapotranspiration condenses in clouds which are transported by winds. When the clouds cool the water falls as rain or snow. Mountains in the way of the moving clouds cause the water vapor to rise, cool and fall as precipitation. Because in California the prevailing winds come from the west, west-facing slopes usually receive more precipitation. East-facing slopes are dryer. When precipitation reaches the ground as rain or snow, most water that is not taken up by plants returns to streams and lakes eventually reaches the ocean. Some is stored as ground water.



Ecosystems are Dynamic

It is not always evident to humans that ecosystems are always changing. Forests change over the course of a human life time. Unless there is a dramatic event like a fire, these changes happen slowly and are often not recognized. However, they are happening and can be predicted.

The process by which an ecosystem changes from one vegetation type to another is called ecological succession. If we begin with a forest that has been converted to bare land following a catastrophic event, the land may be quickly colonized by grasses and herbs. Or, the bare land may be colonized by shrubs and trees that are capable of invading open sites. In the absence of another disturbance, the original community of invaders may gradually give way to the forest that occupied the site before the disturbance. As the forest canopy develops, plants that can survive in low light conditions become more common. Eventually, shade tolerant plants can come to dominate the ecosystem.

Disturbance is a natural ongoing event in ecosystems. Fire, insects, disease, and logging disturb the ecosystem, opening up the canopy and allowing plants that need full sunlight to thrive. Understanding processes such as succession and disturbance helps us to predict the effects of management activities. Recognizing that ecosystems are dynamic helps us anticipate changes.

One of the key values of ecosystem science is that it provides a basis for predicting the effects of people's actions on ecosystems. Most of what we do, timber harvesting, grazing, wildlife habitat improvement, even fire control is aimed at influencing ecological succession. When we cut down the forest to create shrub or grassland for domestic animals or livestock we are producing an early successional stage. Grazers or browsers will maintain the community at that stage if their level of use is sufficient to keep trees from re-invading.

Forestry techniques such as thinning may be used to develop forest conditions suitable for wildlife. If thinning is done properly, it can cause a forest to grow bigger trees faster. Presence of large trees provides habitat for species such as the pileated woodpecker or the spotted owl. In that case we are trying to speed the rate of succession. When we use controlled burns to reduce dense fuel loads in shrub communities we are attempting to suspend succession.

If we view our activities in an ecological context – that we are actually affecting succession – it provides a basis for understanding our effects on other ecosystem processes. For example, when we convert forest to grassland we change fundamental nutrient cycles in ecosystems. Instead of annual inputs of decay-resistant, acidic pine needles there are annual inputs of easily decomposed grass leaves and stems. The effects on the ecosystem's hydrologic cycle may be very pronounced. The tree canopy which formerly intercepted rainfall is gone. Demand of plants for water is less for grass than it is for trees. The net result may be that more precipitation runs off to streams.

Changing vegetation means changing ecosystem food webs. Natural successional changes in vegetation are accompanied by shifts in the numbers and kinds of animals. Interfering with those changes creates an immediate demand on the existing animals to either adapt, move or die. Large mobile animals may be capable of relocating to nearby suitable habitat. It is rare that suitable habitat in the wild is unoccupied and migrant animals may have to compete with existing animals. Some animals, especially some birds and smaller mammals may be able to adapt to the changes. Other animals, with specific habitat requirements and limited mobility will simply die.

Most things that people do to influence ecological succession are aimed at improving the production of goods and services for people's benefit. Even wildlife habitat improvements or stream restoration projects usually have goals ultimately related to people's well-being; production of more game or wildlife for recreational purposes, restoration of sport and commercial fisheries, etc. There is no good or bad associated with one or another activity except when the results have unexpected, negative ecological effects. Evaluating activities in an ecological context can provide insight into those effects and perhaps lead to the proper weighing of the human benefits against the ecological costs. An ecosystem orientation is also a broadening of vision to include not just the human community and its needs but the entire ecological community and the many ecological processes.

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