Life In The Watershed
Part I: Watershed Ecology

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"When one tugs at a single thing in nature he finds it attached to the rest of the world..." --John Muir

INTRODUCTION

Ecosystems include the living, non-living and energy components of a watershed. By now you will have learned about the physical and chemical (water) environment. The study of ecosystems will introduce the biological elements of a given environment—in this case, the watershed.

The term ***ecology*** was first introduced to the science community in 1866, by a German biologist, Ernst Haeckel. It is derived from the Greek *oikos* ("household') & *ology* ("the study of"). If we apply the meaning in a more familiar, root-usage, economics, it refers to the economy of nature. Keeping with that analogy, we might look at energy as the "currency" of Ecology.

THE BASICS OF ECOLOGY

Let's start with a simple dichotomy. If we look around us there are basically two types of living things—plants and animals. Most plants are considered **producers**, organisms which can produce their own food using the sun as a source of energy to manufacture food (photosynthesis). Most animals are considered **consumers**, organisms which are dependent on producers—or other consumers—as a source of their food.

The majority of producers are green plants. Using **chlorophyll**, plants have the ability to **photosynthesize** (or produce carbohydrates utilizing sunlight as the primary energy source) and are recognizable to most of us as algae, mosses and ferns, grasses, **forbs**, shrubs and trees. For the most part, these organisms are all dependent on sunlight for energy.

Consumers may include bacteria, mammals, birds, fish, insects, spiders, snails, and worms. All are dependent on consuming some other organism for energy.

In this section you will learn about:

- Basic ecosystem concepts.
- Ecological dynamics.
- Terrestrial ecosystems.
- Arizona's ecological divisions.

Ecology often involves the study of systems—hence the term **ecosystem**. A system is an aggregate of things, forming a complex whole, that are tied together by relationships. These systems are made up of a hierarchy of interconnecting relationships, such as in a food web. For example some of the food web relationships in the desert southwest might include: a population of coyotes that feed on a population of field mice that consumed the fruits of some grasses. The energetic and genetic relationships between these different organisms are at the heart of ecology.

ECOLOGICAL STRUCTURE

Natural systems are usually considered parts of hierarchies—an ordering from biggest to smallest (or vice-versa). For our purposes, ecological hierarchy will be discussed from the largest to the smallest scale.

Biome: Biomes are the earth's distinct ecological regions. The names of terrestrial biomes are named by their dominant plant life. Arizona examples include: *Desert, Grasslands, Chaparral, Woodland, Coniferous Forest, Semi-Tropical Scrub, Alpine Tundra*. Generally water bodies are considered an integral part of each terrestrial biome.

Ecosystem: An ecosystem is made up of individuals or groups of different plants and animals (biotic components) interacting with each other and all associated non- living or **abiotic** components such as rocks, soils, water, and climate. Ecosystems function via the cycling of matter (such as carbon or minerals) and energy flowing through.

Community: If we focus only on the interactions between different groups of plants and animals, excluding the **abiotic** (non-living) components of an ecosystem, we are dealing with an ecological community**.**

Population: A population is the fundamental unit of an ecosystem through which energy and nutrients move. A population is the number of individuals of the same kind, living in the same area, at the same time.

Individual organism: Individuals are relatively independent, distinct and different from other types of organisms in a community. Individuals respond independently to the environment presented.

HOW ECOSYSTEMS WORK

Recall that ecosystems consist of all living things interacting directly or indirectly in a given area with their environment. Energy is considered the "currency" of the ecosystem's economy, and the relationships between living things in an ecosystem are often categorized by patterns and behaviors regarding energy flows throughout.

The flow of energy is commonly described as passing through a **food chain.** Food chains consist of a specific producer and a number of consumers that are dependent upon the availability of energy, it produces. A consumer which eats a producer is labeled a **1^{st} Order Consumer**, a consumer which eats the 1^{st} Order Consumer is labeled a **2^{nd} Order Consumer,** and so on.

In reality, food chains are not simple, but occur as part of a **food web**. Rabbits seldom eat just a single species of grass but many other plants. The coyote eats other things besides rabbits. Hawks and bobcats eat rabbits as well. Bacteria and molds decompose dead plant materials and animal wastes as well as animals when they die.

The underlying ecological theme involves following the energy pathways through living, ecological systems from the ultimate source, the sun. Ecologists categorize organisms into **trophic levels** in an ecosystem. Producers—plants, that is—are the principal direct accumulators of solar energy on earth, Available and transferable energy to the 1^{st}, 2^{nd}, and 3^{rd} order consumers is reduced by around 90% for each step up in tropic level. The amount lost is released as heat and work. This progressively declining energy relationship and inefficiency is often represented as an **energy pyramid.**

ECOLOGICAL ROLES

The way organisms go about getting food is equally important as who eats whom. Consumer-Producer relationships are usually unique and species-specific. An organism which tends to be exclusively a plant consumer is an **herbivore.** An organism which eats the flesh of other consumers is a **carnivore.** Some creatures eat both plants and animals and are called **omnivores.**

Specialized relationships often warrant even more descriptive labels.

- Herbivores tend to be further categorized as **grazers** or **browsers**.
- There are also **predator-prey** relationships, in which one organism benefits, while the other is killed. Culling of the population by predators may be beneficial for the prey species.
- If one organism benefits and the other is harmed but not killed, the relationship is **parasitism.**
- If one organism is benefited but the other is neither benefited, harmed, injured nor killed the relationship may be described as **commensalism**.
- If both organisms benefit from a relationship we would describe it as **mutualism.**
- If two species are so closely ecologically intertwined and would die if separated, we are looking at the most extreme case of

mutualism, called **symbiosis.**

- Other groups to consider are **scavengers** and **decomposers;** an essential and diverse group of plants, animals, fungi, and bacteria responsible for recycling all dead organisms.

COMPETITION

In an ecological setting, many important relationships between organisms are categorized as intra- or interspecific competition. If the interactions are between members of the same species within a community it is called **intraspecific competition**. Reproduction, food gathering, and nesting behaviors are often unique for each species. Nevertheless, within an ecological community there are often interactions and competition between species for the same space, food, etc. These are examples of **interspecific competition**.

It is very important, as we observe and analyze competitive behaviors, that we recognize subjective or premature judgments. Not all competition is good and not all competition is bad.

BOUNDARIES

If a community is defined "within a given area and time", how are boundaries established and/or maintained? Boundaries are probably best defined as being "flexible". Most communities overlap in their interactions with neighboring communities. Some species may become active participants in communities a considerable distance from their primary community due to boundary affects.

COMMUNITY STRUCTURE

Organisms live together in communities. These communities are usually organized in specific ways that depend on each organism's ability to adapt to conditions created by its fellow community members and other environmental conditions. For example, in forested areas, different types of plants may occur in layers—herbs, shrubs and trees forming successively higher canopies. Another example of community structure occurs in aquatic systems as light penetrates the water column and different types of algae or aquatic plants flourish or disappear.

One important rule of thumb is that as the **biological diversity** of a community increases (greater amounts and types of life), then so too does the complexity of the community's structure. Also, as environmental stress decreases, so does the complexity of the community structure. Think of arctic tundra compared to a tropical rainforest—the latter has a more consistent environment. Hence, it also has more complex community structure. This is one of the reasons that **Riparian** communities (see Part II) are more complex than surrounding desert areas—they usually have constant sources of water which relieves stress on the organisms in them.

If we step back and look at the ecological communities found on earth, we have little difficulty in seeing there are changes which occur on a daily, weekly, monthly, and yearly basis. More dramatically, if there is a major disturbance such as a fire, flood or human construction leaving degraded conditions behind, we can observe a very slow process by nature where plants and animals return and slowly change the disturbed area through a series of stages that can lead back toward the original pre-disturbance conditions. This sequential and somewhat orderly process of ecological recovery over time, is called **succession**.

Succession follows a unique pattern which might be different based on the larger climatic and physical characteristics of an area. Typically invader species are the first to occupy a disturbed area. As supportive soils and other ecological changes accumulate, the complexity of the community increases. Very little in nature is static, however. Plant and animal communities may change constantly over time, particularly with climate variability that is a frequent characteristic of the Arizona environment.

It is important to realize many communities are maintained by reoccurring fires, flood, grazing, and other disturbances in non-climax conditions. Lodgepole pine forest, which dominates the Rocky Mountains, the grasslands of central North America, the sagebrush prairies, and brush-scrub forests are representative examples of fireperpetuated, “climax” communities. Another example, closer to home, would be a residential yard. Human intervention and regular mowing will maintain a yard in a relative steady or “climax” state. If neglected, it would eventually be overrun and the grass would be replaced with “weeds” from the surrounding, natural community. The appearance of “weeds” marks the beginning of a new stage of succession in the community.

ECOLOGICAL SETTINGS

Biotic communities exist within the context of the **abiotic** (non-living) environments. The environmental conditions in each biotic community support particular plants and animals. Each plant, for example, has an upper limit, the **altitude** or elevation where it’s too wet or too cold for the plant to grow, and a lower limit, where it’s too dry or too hot.

Aspect (the direction a slope faces) can modify the effects of temperature. Southwest facing slopes and mountainsides are warmed by exposure to full sunlight during the hottest part of the day. Northeast facing slopes are cooler since they receive less direct sunlight. For a good example of this, merely look across a valley; notice that on some hillsides trees, shrubs or cacti are taller and may be quite different than other areas. This is probably due to the direction the slope faces and the amount of heat and light and water it received because of that aspect. Warmer slopes will also be drier.

Living organisms, regardless of their level of biological sophistication and presumed importance by humans, play a significant role in the ecological direction, success or failure of an ecosystem. Abiotic factors play an equally important role. Climate, weather, precipitation, soils, water, wind, fire, temperatures are but a few abiotic factors we tend to take for granted as we see a beautiful forest, prairie or herd of antelope. Yet, these are the very factors which make it possible for them to be there and survive. In Arizona, it is often that we find elevation and precipitation play important roles in the type of plant community found in a particular area.

Three important concepts related to ecological setting include niche, habitat and range. A **niche** is the way an organism occupies its environment. Where a species is found and what physical environment it requires is its **habitat**. An organism’s **home range** is distance a species can move within a given environment. Physical environmental conditions influence an organisms range.

Lastly, we need to mention the frequently used term **ecological site**. An ecological site describes a combination of the biotic and abiotic characteristics in a particular location. While it has some of the qualities of an ecosystem, it also takes into account slope, aspect, climate, nutrients, soil type, water, etc. When scientists discuss management of ecosystems, they often study a particular ecological site to gain a baseline for understanding the whole ecosystem and how local abiotic factors might influence it.

ARIZONA’S ECOLOGICAL REGIONS

Arizona can be divided into at least 13 distinct ecological regions that are determined by climate, latitude, and elevation. These divide the state into large-scale landscapes (such as Sonoran or Great Basin regions) and **biomes** (such as tundra, oak forest, or desert grassland).

There are four desert ecological regions in Arizona: Sonora, Chihuahua, Mohave and Great Basin. Elevation, geographic location and precipitation patterns separate the four deserts. The first three deserts are “hot deserts”, while the Great Basin is a “cold desert.” Most of these deserts have some overlap in characteristics, but there are unique plants and animals in each.

Covering most of southwestern Arizona, the **Sonoran Desert** region is the hottest of the four. Of the common plants in this region, cacti and succulents have adapted by modifying their leaves so they don’t lose water. Small leaves, waxy coverings and green **bark** allow trees and shrubs to tolerate extreme temperature and limited moisture. The small leaves and waxy coverings help reduce the amount of moisture lost to **transpiration** and in addition to the leaves; the green bark is able to capture sunlight for photosynthesis. Many animals have adapted by being active at night or only coming out of burrows during certain seasons. Common animals in this desert include mountain lions, bobcats, gray and kit foxes, coyotes, three varieties of skunk, bats, bighorn sheep, javelina, mule deer, pronghorn antelope, coati, ringtails, raccoons, a wide diversity of reptiles and amphibians, kangaroo rats, packrats, mice, and birds. Insects and arachnids (spiders, scorpions, etc.) are numerous and highly diverse. Most of the precipitation takes place in two rainy periods, one in the summer and one in the winter.

The **Chihuahuan Desert** region lies in southeastern Arizona, usually above 3,500 feet in elevation. This desert is a shrub desert with fewer succulents and cacti than the Sonoran desert. The Chihuahuan Desert in Arizona receives more rain than the Sonoran desert because of its elevation, and can support more grasses. Rainfall occurs mainly during the summer months. This desert also supports some wildlife species that are more commonly found in Mexico. These include cats such as mountain lion, bobcats, jaguars, ocelots, and jagarundi; as well as a variety of deer, antelope and bighorn sheep; abundant, diverse birdlife; bats; coatimundi, skunks, badgers, raccoons; javelina; coyotes and possibly wolves in higher elevations. Bear are also more common in the Chihuahuan desert.

The **Mohave Desert** is in the northwestern part of the state. It is a transitional desert between the higher and cooler Great Basin desert and the lower, hotter Sonoran desert. While many of the same plants found in the other deserts occur here, there are a few that are characteristic of the Mohave Desert such as the Joshua tree. Wildlife in this desert is not as diverse as in the neighboring Sonoran, it draws on animals from both that desert and the Great Basin (see below) giving it a rich assemblage of wildlife. Rainfall in the Mohave Desert primarily occurs during the winter and is among the lowest of all North American landscapes.

The **Great Basin Desert** is the only "cold desert" in Arizona. It occurs in northern Arizona, mostly at elevations of 4,000 to 6,500 feet. Rainfall, about 7-12 inches annually, is fairly evenly distributed during the year. This desert primarily supports shrubs and grasses. Sagebrush is often a good indicator that you are in the Great Basin desert. Wildlife tends to be better adapted to cold temperatures and includes mule deer, elk, coyotes, wolves (historically), prairie dogs, skunk, badgers, bear, raccoons, ferrets, packrats, wild horses, more cold-adapted reptiles or amphibians, and less-diverse bird life (when compared to the other deserts).

The state is divided by a mountainous region that runs along the Mogollon Rim, the edge of the Colorado Plateau, includes the White Mountains. This higher-altitude environment receives the most precipitation in rain and snow, and so contains the majority of the state's forests as well as rich grasslands and chaparral plant communities. It is also the source for most of the state's surface water. Wildlife in the transition zone include bear, wolves, coyotes, mountain lions, bobcat, bighorn sheep, elk, mule deer, abundant rodents, skunks, badgers, raccoons, and diverse bird populations. Mountains in this region are also home to a variety of amphibians and reptiles, insects and arachnids.

In addition to the mountainous central part of the state, southeastern Arizona also encompasses some of the "sky island" mountains. These isolated ranges are home to some unique plants and animals that would not normally survive in the surrounding desert "seas".

Arizona Vegetative Communities

Arizona can also be more finely divided into specific vegetative communities, defined largely by their dominant vegetation. Broadly, these include deserts, grasslands, chaparral, woodlands, forests, and tundra. These communities are dependent upon their slope or aspect, soil type, temperature, and most importantly, precipitation.

Arizona's **grasslands** occur throughout the state in all but the lowest and driest regions. They provide homes for animals adapted to wide-open spaces. As you might guess from the name, grasses dominate. Shrubs and trees are also found in many grassland areas. The three major grassland types in Arizona are mountain, plains and desert grasslands.

Mountain grasslands are relatively small, natural openings in forests. They are usually in spots too wet or too rocky to grow trees.

Figure 1. Plains grasslands near the Huachuca Mountains. Photo courtesy of David Bly.

These areas extend from the pine forests well into the higher elevation fir forests. The mountain grasslands occur above 6,000 feet with annual precipitation averaging between 20 and 30 inches or more. These grasslands are in the mountain ranges of northern Arizona and the isolated mountains ("sky islands") of southeastern Arizona.

Plains grasslands occur in the eastern half of the state between 5,000 and 7,000 feet elevation and receive between 11 and 18 inches of annual precipitation. This is considered a semi-arid grassland habitat that sometimes extends up into the lower portion of the ponderosa pine forest in northeastern Arizona. The juniper-pinyon woodland and the great basin desert are often intermixed with this grassland.

Figure 2. Interior Chaparral. Photo Courtesy of the National Park Service.

Figure 3. Oak and Juniper woodland. Photo Courtesy of the National Park Service.

The **desert grasslands** occur between elevations of 3,500 and 5,000 feet and receive annual precipitation of 10 to 15 inches. They usually lie in basins and valleys. Most desert grasslands are located in the southeastern portion of the state, but some are also found in the northwestern portion. Desert grasslands contain a mixture of grasses, shrubs and small trees.

Interior **Chaparral** occurs in the central part of Arizona between 4,000 and 6,000 feet elevation and receives 13 to 23 inches of annual precipitation. Small stands of chaparral vegetation may occur as low as 3,500 feet or as high as 7,000 feet. Plants in the chaparral are dense, shrubby and grow to around the same height, 4-6 ft. Occasionally there are taller shrubs or small trees. Chaparral shrubs typically have small, thick leaves as adaptations to drought.

The **Oak and Juniper woodlands** occupy the foothills and mountains in the southeastern and central parts of Arizona between 4,500 and 6,000 feet elevation. The annual precipitation is from 12 to 18 inches. They are usually open woodlands of evergreen oaks and/or junipers with a variety of grasses, shrubs, succulents and few cacti.

The **Oak-Pine woodlands** lie between the oak woodland and the ponderosa pine forest. They are characterized in part by the presence of two large mid-elevation conifers, Chihuahua pine and Apache pine. They are primarily situated in the southeastern part of the state between 4,000 and 6,500 feet. Annual precipitation is usually between 12 and 22 inches.

Figure 4. Ponderosa pine forest. Photo Courtesy of the National Park Service.

Pinyon-Juniper woodlands cover large areas below ponderosa pine forest in central and northern Arizona. They are between 5,500 and 7,000 feet with 12 to 20 inches annual precipitation. At lower elevations there are usually more junipers than pinyon pine. At higher elevations the pinyons reach their greatest size and sometimes grow in large pure stands.

The **Pine forests** are often dominated by ponderosa pine. In fact, Arizona has the largest continuous stand of ponderosa pine in the United States. Mature trees may be 200 to 400 years old and can grow to 125 feet tall. Elevation of this forest is between 6,000 and 9,000 feet, varying according to northern or southern facing slope (aspect). Precipitation is approximately 18 to 26 inches annually.

The **Spruce-Fir forests** receive the most precipitation in Arizona. They receive from 25 to 35 inches of annual precipitation (much of it as snow). Very little sunlight reaches the ground because trees grow close together. The closeness of the trees helps them brace against strong winds. The major trees found between elevations of 7,500 to 9,500 feet are Douglas fir and white fir. Spruce and alpine fir trees are found at elevations of 8,500 to 11,500 feet.

The only true **Alpine Tundra** in Arizona is isolated on the top of the San Francisco Mountains about 10 miles north of Flagstaff. Along the irregular crest line there are six peaks and the mountain is known locally as the San Francisco Peaks. Elevation is from 11,000-12,670 feet. Precipitation is about 33 to 40 inches annually. Alpine tundra plants are small and low growing, rarely more than a few inches above ground level, but many have large or showy flowers.

The most iconic of Arizona's vegetative communities is **Sonoran Desertscrub** with its tall columnar cacti, ocotillos and low forests of mesquites, ironwood and palo verde trees (see Figure 5). This vegetative community is dominated by semi-tropical plants that have recently colonized the region after a post-ice age drying period. With both summer and winter precipitation (between 3 and 12 inches annually), and an elevation below 3,000 feet, the community supports a structural diversity similar to that of tropical thorn forests in Mexico.

Figure 5. Sonoran Desertscrub. Photo courtesy of the National Park Service.

Adjacent to the Sonoran Desertscrub ecosystem are important **Sonoran Riparian Decidious Forests**. These are characterized by Cottonwood-Willow associations or sometimes by Arizona Ash and Sycamore trees (see Figure 6). Uplands directly adjacent to these areas are often dominated by velvet, honey and screwbean mesquites. When these are the dominant tree and attain fairly large stature, these woodlands are often referred to as **Mesquite Bosques**, utilizing the archaic Spanish term for forest (see Figure 7). These unique, **riparian** ecosystems will be discussed in greater detail in the next section.

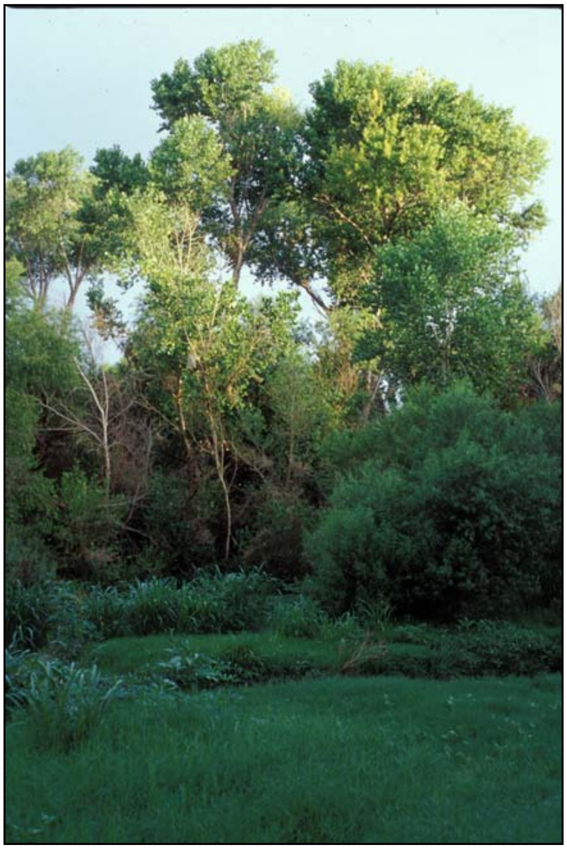

Figure 6. Sonoran Riparian Deciduous Forest. Photo courtesy of Brian Powell.

Figure 7. Mesquite Bosque. Photo courtesy of Robert Emanuel.

Figure 8. Wet Meadow. Photo courtesy of Robert Emanuel.

Figure 9. Mountain Grassland. Photo courtesy of Robert Emanuel.

Figure 10. Rocky Mountain montane riparian forest. Photo courtesy of Robert Emanuel.

Part II: Aquatic Ecosystems & Riparian Areas

By Robert Emanuel

"To the lost man, to the pioneer penetrating a new country, to the naturalist who wishes to see the wild land at its wildest, the advice is always the same -- follow a river." -- Edwin Way Teale

In this section you will learn about:

- Aquatic, riparian and wetland ecosystems.
- Riparian area functions.
- Human impacts on watershed ecosystems.
- Riparian area management

SPECIAL ECOSYSTEMS: JUST ADD WATER

Even though Arizona is perceived as lacking water, there are a significant number of natural and human-made aquatic ecosystems in the state. In many cases, communities and ecosystems fluctuate in vigor as water is or is not available through the seasons.

Water quality, quantity as well as duration may determine the type of aquatic ecosystem. Some examples of these types include:

- Ponds & pools;
- Lakes & reservoirs;
- Springs, streams & rivers;
- Riparian areas & wetlands;
- Irrigation canals & stock tanks.

The term **riparian** is used as an inclusive term to describe the area adjacent to a water body. The term **wetland** is used as an inclusive term to describe an area which is frequently subject to persistent flooding or in close proximity to elevated ground water**.** These are transitional ecosystems that demonstrate characteristics and life forms associated with both terrestrial and aquatic ecosystems. Both riparian areas and wetlands occur naturally or may be a product of human design or activity.

We will explore riparian areas, wetlands, lakes, and streams in greater detail.

RIPARIAN AREAS

As we will note repeatedly throughout the Arizona Watershed Stewardship Guide, the water bodies at the heart of a watershed are really just products of processes, individual events, or land-use practices across the watershed. In other words, the health of the water body is a telling part of the report card for the rest of the watershed. That said, another key indicator for watershed health is the state of the riparian areas within them. Like canaries in the coal mine, the presence or absence of healthy stands of vegetation and animals dependent upon them indicate whether there is sufficient clean water in the whole system.

Riparian areas are centers of Arizona's biological diversity (diversity of life). That means that the diversity of life is often greatest in association with these ecosystems. The drier the surrounding landscape, the more distinct the riparian zone. In the desert or grassland a flowing stream and its adjacent riparian area supports a conspicuous oasis with forests and wildlife that would not otherwise occur in the area. Even in higher-elevation biotic communities, the riparian area often can be distinguished from surrounding plant communities by a greater abundance of deciduous trees and shrubs.

In Southern and Central Arizona at elevations between 3,000 and 6,500 feet, riparian areas tend to be characterized by cottonwoods, willows, ash, sycamore, walnut trees, and other trees. The cottonwood-willow forest that characterizes riparian areas below 3,000 feet is one of the most endangered forest-types in North America. It also supports some of the highest biodiversities of the continent.

Riparian areas in higher elevations (6,500 feet or higher) are characterized by willow, chokecherry, boxelder and Rocky Mountain maple. Aspen, blackberries, conifers and other vegetation are sometimes present.

In most cases, riparian areas occur in any biome whenever there is perennial water near or on the surface. However, some ecologists broaden the concept to include the banks of ephemeral washes in our deserts. These are streams where water is generally present only during rainfall events. Here, a riparian area consisting of ironwoods, palo verdes, and desert willows is clearly distinct from broad expanses of creosote bushes around it. These areas, though dry most of the year are considered very important to bird and other animal life in these driest landscapes. We will refer to them as dry riparian areas (or xeroriparian areas) to distinguish them from wet ones.

Lastly, **mesquite bosques**, which are drier than cottonwood willow, and wetter than dry wash riparians, exist along many streams in the Southwest. They are among the richest, yet most degraded Southwestern environments. For example, in 1776, Tucson was built on the site of mesquite bosque originally growing along the Santa Cruz River. Many mesquite bosques were reduced or destroyed by fuelwood cutting to support mining or other fuel needs in the late 19th or early 20th century.

Why Are Riparian Ecosystems Important?

Riparian areas occupy less than 2% of the total land area in the Southwestern United States (an area including Arizona, New Mexico, southern Utah and Southwestern Colorado). These ecosystems are quite often the most productive and valuable of all of these lands. One estimate from researchers at the Arizona-Sonora Desert Museum states that up to 90% of all desert vertebrate animal species are dependent upon riparian areas for some portion of their life-cycles (such as breeding, nesting, feeding or migrating). For example, riparian areas such as those along the San Pedro, Colorado, Hassayampa, Verde, Gila, and Santa Cruz rivers provide critical habitat for millions of birds migrating across North America from Mexico and Central America.

Riparian areas provide habitat and travel corridors for many mammals, including mule deer, rabbits and elk. Some species depend upon riparian areas for most of their lives including otter, ringtail, raccoon, beaver, and muskrat. Other mammals, such as bats, are also

Key Riparian Area Functions

Aquatic Habitat

- Contributing large wood that creates pools and hiding cover for some fish and macroinvertebrates.
- Creating a vegetation **canopy** to provide hiding areas for fish and macroinvertebrates.
- Providing organic matter and nutrients that serve as food for fish and other aquatic life.
- Stabilizing stream banks to reduce erosion and **siltation** of gravel streambeds. Siltation is the filling in or covering of a stream bottom with fine sediment or silt.
- Slowing floodwaters to create areas for fish to hide during high flows.
- Altering how much sunlight reaches the aquatic ecosystem for photosynthesis.

Terrestrial Habitat

- Providing various microclimates to accommodate many types of wildlife.
- Contributing large wood that provides hiding places and cool areas for wildlife such as amphibians or small mammals.
- Creating travel corridors that allow wildlife to move around the landscape and to have access to water.
- Providing food for various types of wildlife.
- Contributing standing snags for cavity-nesting birds and other wildlife.

Water Quality

- Slowing floodwaters and creating areas for sediment deposition during the high flows.
- Creating shade to cool water temperatures.
- Filtering pollutants such as nutrients from overland runoff and subsurface flow to prevent them from entering the aquatic system.

Adapted with permission from: Oregon State University Extension Service publication EM 8714, Watershed Stewardship: A Learning Guide (Oregon State University, Corvallis, Oregon, new July 1998, revised January 2002), 485 pp. $42.00.

found in riparian areas because of increased cover and food.

Beaver are particularly important for riparian areas in that they may create small and large-scale changes in the adjacent water body by damming it, causing flooding, slowing floodwaters and increasing the amount of water that infiltrates into the neighboring landscape. **Silts** and fine **sediments** are often held back by beaver dams which contribute to improved water quality. Beaver are thought to be responsible for the formation and maintenance of many of the Southwest's original wetlands.

For humans, riparian areas provide important recreation opportunities for hiking, picnicking, fishing, wildlife watching, and hunting. For thousands of years, riparian areas have provided medicines, food, and building materials for many different societies in the region. As late as the 1930s, riparian areas provided wood for construction and fuel. Today, Arizona's riparian areas are important places for anglers, hunters and wildlife watchers. These activities are economically important: fishing alone is worth over $85 million a year and bird-watching is worth over $342 million per year for the state.

Riparian Area Functions

Riparian areas are sites of great dynamism, where hydrologic (water-related), geologic, and ecologic factors come together to influence the type of life in them. Another way to think about riparian areas is as areas of *interaction between terrestrial and aquatic ecosystems as well as between bottomland and upland landscapes*. Because of this, riparian areas can be thought of as performing some critical functions for the watershed.

The characteristics of riparian vegetation—types, distribution, and other attributes—either directly or indirectly can provide key functions and building blocks for fish and wildlife habitat and water quality (see box on page 10). In the aquatic system, riparian vegetation provides cover and shade. When large trees fall into the stream they create pools and structure that hold materials in place, giving variety to this watery environment. Especially in the driest deserts of the state, riparian areas often provide the only habitat with trees and cover, providing access to cooler air temperatures, travel corridors and most importantly—water.

Even though it uses water in the stream, riparian vegetation also slows flood flows, allowing for seepage of floodwaters into adjacent soils and causing to drop its **sediment** into the channel or floodplain. In some parts of Sonora, Mexico, savvy farmers actually take advantage of this by planting riparian trees along the edges of their floodplain fields. The additional sediment makes for rich soils and larger farm fields.

Arizona riparian vegetation is in fact often dependent upon this new sediment and the frequent flood events. In places where floods take place, large and medium-sized trees may be removed, but the **scouring** of the floodplain yields hundreds of cottonwood and willow seedlings and contributes to regeneration of the riparian area. Places downstream where sediment—often mixed with all of that **organic** matter from the plants—is deposited will be rich new habitat for a variety of plants.

Lastly, riparian vegetation can filter pollutants such as excess sediment, fertilizers or pesticides that travel into streams in runoff from upland areas. If these pollutants enter the water body, they may negatively impact aquatic life and make water less useful for humans. Vegetative buffers may prevent them from entering the aquatic ecosystem. Humans will very often create riparian areas to specifically perform this function.

STREAM ECOLOGY

Creeks, rivers, brooks, washes—all these can be considered streams in a generic sense of the word. In fact, hydrologists, watershed managers and aquatic ecologists use the term to talk about

Figure 1. Microscopic filaments of algae

flow (stream flow), about conditions (stream condition), and form (stream morphology). These three terms also describe aspects of the streams abiotic environment that influence life. Keep in mind that not all streams are alike and that conditions for life in one may be drastically different than another, or even between different reaches of the same stream.

Streams present unique conditions for life. Water quality in streams is important because, it influences the type of organisms and variety of options they may have for survival and reproduction. For example, in sluggish streams or stream reaches, the amount of dissolved oxygen may be low, restricting the types of fish, insects and macroinvertebrates that can survive there, especially in warm areas. Likewise, in fast moving streams, oxygen is high and temperatures are lower, but the stream morphology (or form) may be such that only a few well-adapted forms of life can cling to the rocks in the bed and not be swept away. Streams provide what ecologists call **microhabitats** that provide specific conditions for a single type of organism or group of organisms. Hence, deep pools are good habitat for some species of fish, while mossy rocks may provide habitat for a spider that feeds just above the water. Next time you visit a stream, try to identify some of these microhabitats.

Figure 2. Mayfly larva living in the substrate of a stream. Photo courtesy of Jan Benda.

Like terrestrial ecosystems, streams require inputs of energy, recycle nutrients, and depend upon a mix of biotic and abiotic elements working in synch. The basis for the food web of aquatic ecosystems is sunlight (the same as in terrestrial systems). Shoreline plants produce leaves, stems, flowers and fruit that then make their way into the stream by floods or leaf-fall. The mix of organic matter is food for scavengers to break down. These scavengers are then consumed by other forms of life.

The other major converter of sunlight in streams is by **algae** and **cyanobacteria**, simple plant and plant-like life forms that live suspended in water or attached to the substrate. See Figure 1, on the previous page. This transformation of sunlight to food takes place during the day and when light is greatest. The process both produces and uses oxygen from the surrounding water and releases or consumes dissolved carbon dioxide. Generally, oxygen is used in the night while carbon dioxide is used during the day.

While algae and cyanobacteria are important food sources for aquatic life, when they are overabundant, they may consume too much oxygen and kill other life forms. Generally, this happens when these tiny organisms begin to build up to such density that light is reduced in lower areas of the water column. The algae at that level then die, are broken down by bacteria, which then consume oxygen. When oxygen levels are too low to sustain some other forms of aquatic life, the condition is called hypoxia, or where there is no oxygen left at all, **anoxia**.

The overabundance of these plants may be caused by input of too many nutrients into the water. When plant growth overwhelms other life in the water due to nutrients or other causes, the condition is called **eutrophication.** Anoxia is often a consequence of eutrophication. Other submerged (underwater) vegetation can also play a role in this process. Generally, the slower the stream moves and the warmer the season, the more likely that plant life will respond to an overabundance of nutrients leading to eutrophication and anoxia. Slower, warmer water already has less oxygen and nutrients may be

Figure 3. Dragonfly larva. Photo courtesy of Beat Oertli.

Figure 4. Chiricahua leopard frog. Photo courtesy of Arizona Game and Fish.

present for longer periods before being moved downstream. Lakes, ponds and stock tanks are thus highly susceptible to this process. Nutrients may come from a variety of sources including urban runoff (fertilizers, oils/grease), sewage and effluent, returning flows of irrigation water (fertilizers), animal waste (nitrate), or natural sources.

Streams with high velocity flows, or those with high fluctuation of flows (from very high scouring flows to nearly dry) will tend to have low density of vegetation and hence not suffer problems of eutrophication.

Other fundamental members of the aquatic food web are the **macroinvertebrates** that feed on plant life, each other, and accumulated organic matter.

Macroinvertebrates are organisms without backbones, but that are large enough to be visible without the aid of a microscope. Snails and crayfish are examples, although aquatic insects are far more common. Macro-invertebrates may be scrapers, filterers, shredders or predators. Scrapers remove food from rocks, wood, leaves or other hard surfaces. Filterers collect tiny particles floating in the water through elaborate filtration systems. Shredders will break down organic matter by eating their way through it (like earthworms in terrestrial ecosystems). Predators, such as the dragonfly larva illustrated in Figure 3, feed on other macroinvertebrates as well as small fish and young amphibians.

Amphibians, fish, aquatic mammals (such as otters, muskrat or beaver) round out the aquatic ecosystem. Reptiles such as turtles and snakes are also common. Waterfowl such as ducks, geese, egrets, or herons will contribute organic matter, feed on macroinvertebrates, fish, and amphibians.

Native amphibians such as Sonora tiger salamander and several species of the leopard frogs are currently struggling for survival in many areas due to habitat loss, disease, as well as competition or predation by non-native species.

Arizona Fish

Most of us don't think of Arizona and immediately make an association with fish. However, from tiny desert springs to the raging torrents of the Colorado River, fish have adapted to the arid and semi-arid environment of our state quite well. Their ability to adjust to periods of drought and flash floods is a marvel of nature and has been the key to their survival. Arizona is home to many types of **endemic** species of fish found nowhere else in the world, some uniquely adapted to just one stream or pond. Some examples include:

- The Quitobaquito pupfish is found in a few ponds in the heart of the Sonoran Desert just feet from the Mexican border as well as in the nearby Rio Sonoyta. Ground water pumping, habitat alteration, and pesticides in neighboring Mexico threaten it.

- The Little Colorado sucker is now found in only two sections of the Little Colorado River.

- Yaqui chub are found in the far southeastern corner of the state on the San Bernardino Wildlife Refuge and in very restricted locations in adjoining Mexico.

- Santa Cruz pupfish were once endemic to a spring near Tucson and at Monkey Spring, near Sonoita, in Santa Cruz County. It was lost to habitat degradation very early at Tucson, but survived at Monkey Spring until introduced largemouth bass wiped them out in 1971.

Like the Santa Cruz pupfish, native fish populations have not fared well due to historic and contemporary demands for water. Because they are literally at the “bottom” of most watersheds, what occurs upstream or up-land has the potential to adversely impact fish populations. Habitat loss and alteration have been the principal causes for the extinction or sharp decline in most native populations. This includes dams, impairment of natural water quality, loss of instream flow due to overuse or ground water pumping, or the introduction of non-native animals that consume or out-compete the natives. Crayfish, bullfrogs, non-native catfish, bass, and mosquito fish are all exotic non-native species that threaten the balance for native fish, as well as native amphibians and aquatic reptiles.

More than half of Arizona’s fish species are on the **Federal Endangered Species** list. The recovery of viable Apache and Gila trout populations are promising indicators of what can happen with concerted effort, but for other species such as the Colorado humpback chub, desert pupfish, or razorback sucker, the future still looks grim. The key to recovering Arizona’s native fish populations is habitat restoration and protection.

OTHER WETLAND ECOSYSTEMS

Many wetlands in Arizona have a special name—*ciénega.* The word probably dervives from the combination of *cien* or “hundred” with *agua* or “water” by Spanish explorers who found these water and food sources vital in their travels—as well as focal points for native human settlement. *Ciénegas* are low to mid-elevation (2,000-6,000 feet) wetlands characterized by permanently saturated, highly organic, sometimes acidic soils. Wetland or *ciénega* plants include low sedges, cattails, rushes, grasses, as well as many forbs and flowers. *Ciénegas* may have riparian areas surrounding them in dryer soils with forests of cottonwoods, velvet ash, willows, walnut trees, mesquites, and other trees and shrubs.

According to some ecologists, the marsh-like plants of the ecosystem represent a climax community. Although wetland or *ciénega* plant life is relatively uniform, they are habitat for diverse wildlife and include ducks, geese, migratory birds, beaver, fish, frogs, reptiles, insects, and other macroinvertebrates. *Ciénegas* are among the most threatened ecosystems in Arizona and the New Mexico.

Wet mountain meadows are another, important wetland ecosystem in Arizona and the Southwest. As the name suggests, these ecosystems are characterized by sedges, grasses, rushes, and herbaceous plants. While meadows may occur because of poor soil conditions, wet meadows have soils that are saturated with water all or part of the year, making tree establishment impossible.

In some cases, wet meadows may be flooded for long periods, leading to the growth of submerged vegetation in the deepest areas. But unlike lakes or marshes, wet meadows always dry out enough to support terrestrial plants during some period of time on a regular or frequent basis. Like *ciénegas* at lower elevations, wet mountain meadows are threatened or have disappeared in some parts of the state.

HUMAN IMPACTS IN WETLANDS, STREAMS & RIPARIAN AREAS

Wetlands, streams and adjacent riparian areas face an uncertain future in Arizona after centuries of abuse. Humans have always depended upon these special places for their water, hydropower, medicinal plants, food sources, fuel-wood, livestock production, construction materials, and recreational opportunities. In many cases—especially since the middle of the 19th century, our overuse of these resources has resulted in serious threats to the long-term sustainability of aquatic ecosystems.

Logging, draining, diverting and building adjacent to wetlands and streams has contributed to the largest detrimental impacts on these areas. In the late 19th century, as settlers from the eastern United States moved into Arizona, floodplain farming became a priority along perennial and intermittent streams. The impact was greatest along the lower Gila, lower Salt, middle Verde and Santa Cruz rivers. Head cuts made by irrigators incised during floods, causing the water table to drop and the stream to lower, or, at times, to disappear entirely. With lowered flows and lowered water tables, farmers in many areas became dependent upon ground water pumping by the middle of the 20th century. But ground water pumping meant that underground water that normally flowed into the streams—hence kept them flowing—was drained.

Often in response to declining flows, the state, companies such as the Salt River Project, and the federal government constructed dams on many of Arizona's streams to store water for irrigators, cities, and others. So most streams—such as the Gila—no longer flow unimpeded throughout their entire length. Without regular flows, the lower reaches of streams dried up completely, and the deposits of nutrient-rich sediment in the riparian-dominated floodplains stopped. Rich riparian, wetland and stream ecosystems literally collapsed in most areas. In Arizona, the headwaters streams continue to flow, but the lower reaches are generally far poorer in biological diversity due to a lack of regular water and fresh nutrients.

The cycle that replenished desert streams has ended in many areas, and the flows that continue are usually from upstream dam releases, flooding, or effluent from waste water treatment plants. The latest trend is the replacement of floodplain farms with new suburban homes—also dependent upon ground water or upstream reservoirs but rarely ever from surface flows.

In the late 19th century, the removal of riparian vegetation and diversion of surface water was also accompanied by an increased demand for fuel and construction wood. In areas where mining was heaviest, such as the upper San Pedro watershed, the demand for fuel-wood soared to power steam-generator pumps and equipment as well as for constructing mine tunnels. Huge mesquite bosques (or forests), or forests of cottonwoods, willow, and sycamores were cut along nearby streams to feed the demand for wood. In some places wood cutters came from as far away as Sonora, Mexico to supply the mines with a steady supply.

Livestock grazing became a newly invigorated activity during the late 19th century in many of Arizona's watersheds. While Spaniards and Mexicans brought cattle, sheep, and other livestock to settlements along the major rivers in Southern Arizona, the impact was kept in check by Apache raids, poor communications with the more populated south and political instability. But in the late 19th century, droughts in the southern plains drove large and small-scale cattle operations westward to new territory. The newly established railroads through the state also allowed ranchers to send their cattle to market cheaply and easily. Unlike today's approach to carefully managed grazing, livestock operators in the late 19th century overstocked the open, unfenced ranges, leading to a devastating loss of vegetation, soil erosion, and stream bank erosion. In some locations, such as southeastern Arizona, the process resulted in less upland infiltration. The water table subsequently dropped below the roots of most riparian vegetation, which then died. Other research holds that ground water pumping near streams resulted in lowered water tables as well.

Climate played an important role in this process because the period when overstocking occurred coincided with good precipitation and lush range plant growth. A few years later, after the stocking was at an all-time high, a decade-long drought parched the land and caused cattle to graze down grasses, trees and shrubs to nothing. Many range operators were forced sell their emaciated cattle cheaply, kill them on the spot, or move on. When the drought ended, the rains that fell were intense and washed away the exposed soils, and gouged out the washes.

21st Century Challenges

While some areas have recovered or were restored through human efforts, modern pressures continue to bear down on most of the state's watershed ecosystems. Especially in central areas, urban development has replaced farming or ranching as the chief challenge to maintaining healthy watershed life. Once houses replace agriculture, runoff and infiltration may be impaired. **Runoff** is the flow of water over the surface of the land and **infiltration** is the movement of water into the soil from the surface. When the landscape is paved by driveways, rooflines, sidewalks and roads, the ability for water to infiltrate is vastly reduced because of an increase in **impervious** surface areas. It then runs over the surface of the land. These flows impact riparian areas, streams and wetlands by carrying pollutants and also causing excessive soil erosion and scouring of vegetation and aquatic animals. Riparian vegetation is largely dependent upon ebbs and flows of water and sediments, and may be less able to handle fast flows from urban areas with the pollutants they carry.

Urban growth also results in increased use of ground water resources. As our population increases, our ability to make choices about where to protect riparian areas is limited by urban growth and declining water availability.

Figure 5. Tamarisk or saltcedar. Photo courtesy of the National Park Service.

Flood control has also placed big constraints on aquatic ecosystems and riparian areas. As houses, roads, farm fields, or businesses grow too close to the edges of streams, floods—a normal and natural process for healthy watersheds—become unacceptable. Hence, in many urban watersheds, governments have built channels to keep the water inside the stream banks. The result is a largely nonfunctioning riparian system. Worse, restoring these streams is even more difficult because of the concerns of surrounding property owners.

In some locations, the discharge of treated effluent into the channel from wastewater treatment plants have allowed some stretches of rivers to return to some semblance of their former selves. While fish, invertebrates and other aquatic life may be much less diverse than in the previously flowing stream, year-round flows allow riparian vegetation to return. These areas are called **effluent-dominated streams** and make up a significant part of restoration efforts in Arizona. If, however, the cities that generate wastewater run out of other options, full water recycling may take place—thus removing the perennial stream flows from these newly restored areas. This is yet another example of how competing water uses impacts what can be achieved in protecting, maintaining or restoring watersheds.

Invasive Species

Lastly, humans have intentionally or accidentally introduced more than a few **invasive species** into these ecosystems. Invasive species are plants and animals that out-compete the locals to such an extent that they dominate ecosystems. Most—but not all—invaders are from other parts of the planet. Two examples that are particularly problematic for Arizona's aquatic ecosystems are tamarisk (also called saltcedar) and the bullfrog. Tamarisk is a tree originating in North Africa or Eurasia that was brought into Arizona for planting windbreaks along railroads and farms as well as for ornamental purposes. Tamarisk is an aggressive, woody invasive plant species that has become established over as much as a million acres of floodplains, riparian areas, wetlands and lake margins in the western United States. Tamarisk trees may quickly out-compete native cottonwood, willow, or mesquite forests, especially after the area has been disturbed by changes in stream flow, salt content of the soil, or other abiotic factors. They are thirsty plants that can lower the water table by sending down deep taproots into ground water—leading to reduced stream flows. Once the ground and surface water is gone, they can survive on only rainfall and occasional floods. Tamarisk eradiation involves spraying strong herbicides and mechanical removal of the trees. In some areas of Arizona, this alone is a huge, expensive task, but key to restoring native riparian vegetation to many watersheds throughout the state.

Figure 6. American Bullfrog. Photo courtesy of Cecil Schwalbe.

Bullfrogs are one of the "best" examples of an invasive animal species for aquatic ecosystems. They can move long distances between water sources, generally using stock tanks, ponds, or lakes for reproduction and habitat. Adult bullfrogs are voracious predators, feeding on everything within reach, including other bullfrogs if no other prey is present. Because of this behavior, bullfrogs have **extirpated** (or removed) many other amphibians, and reptiles from their native ecosystems. Because a bullfrog can have as many as 20,000 eggs per clutch and has multiple clutches each year, the bullfrog has been nearly uncontrollable without concerted effort. One simple solution is to help remove the local population by learning to identify and eat bullfrog legs! But truly eradicating these pests requires large-scale effort to eliminate populations.

In addition to bullfrogs, another destructive invader to aquatic ecosystems is the crayfish. These were introduced to control lake vegetation, and were spread by fishermen as live bait. Unfortunately, they are also voracious predators of native species. Do <u>not</u> use them for fish bait in waters where they don't already exist.

Many introduced fish—while good for sport fishing—have become invaders from the perspective of protecting native fish species. For example, the small-mouthed bass consumes many smaller fish as part of its diet, including our native minnows. Bluegill, sunfish, and channel catfish have also become problematic in large parts of the state.

From the standpoint of protecting aquatic and riparian ecosystems, some other problematic invasive plant species include:

- Bermuda grass
- Johnson grass
- Lehmann lovegrass
- African sumac
- Eurasian watermilfoil
- Giant salvinia
- Hydrilla
- Water hyacinth
- Russian olive

SOME MANAGEMENT GOALS

Now we have introduced you to the life in a watershed and how that life takes advantage of abiotic conditions. We need to discuss **management** of those living systems, especially riparian areas. Management means actively manipulating nature to achieve positive results for humans, wildlife, or other values. We focus upon riparian areas because they are often the linchpin for a healthy or unhealthy watershed. When you can create the conditions that foster the growth of healthy plants and animals along a stream, you have protected or regenerated the heart of the watershed.

Riparian area management usually focuses on a range of goals for protecting or creating fish and wildlife habitat and enhancing water quality. Goals also might emphasize other values such as creating attractive views from nearby homes.

Riparian management goals often are based on **desired conditions**: the number, size, and species of plants; the location of the stream; the size and location of woody debris; or other factors. However, this approach tends to view riparian conditions as unchanging.

An alternative approach is to focus on the desired ecological **functions**. Functions refer to the processes that support life: providing in-stream structure, shading a stream, filtering **pollution**, capturing sediment, etc. This approach is likely to succeed in the long term because it enables the riparian area to work without constant human intervention.

Riparian restoration emphasizes improving these functions to achieve a range of goals for fish and wildlife habitat, water quality and humans. Focusing on ecological functions also provides management flexibility because it opens the door to more than one approach to meet these goals.

It is important to keep in mind that we are working with living systems that change over time. Very little is static in nature. Plant and animal communities change over time.

It is also critical to remember that these ecosystems work within non-living conditions to survive. Any alteration of the abiotic factors that influence these ecosystems—such as stream flow, water quality, or soil fertility—may cause unforeseen changes. In this regard, humans are among the most powerful agents of ecosystem change!

General Management Concepts

Ecosystem diversity is important. This means the richness of different species is often as important as the presence or absence of a particular species. **Structural diversity** is important as well. There are two components to structural diversity: **horizontal** and **vertical**. Horizontal refers to the patterns and structure of vegetation as you move upslope from the edge of an aquatic system. Vertical diversity focuses on the height and structure of the vegetation. Different ages of trees, snags and other types of trees influence vertical diversity and shrubs and vines are also critical.

Riparian management can be "active" or "passive." Active management refers to creating vegetation planting sites or actually planting seedlings, cuttings or **seeds**. This also includes removing exotic species. Passive management addresses the causes of riparian vegetation loss, allowing natural processes to revegetate a site. An example of the passive approach is fencing a riparian area from livestock grazing to permit natural seeding and growth of vegetation, or allowing natural flooding back on a channelized floodplain.

It is important to remember that streams have a big impact on riparian ecosystems along their shores. For example, a meandering channel might move to far to allow seedlings to take in a particular year. For this reason, a restoration project should work within the stream's "zone of influence" and be wide enough to encompass the area where future channel changes could occur. A riparian fencing project, for example, should consider the area of long-term channel migration.

All management projects should take into account the dominant uses of the surrounding watershed. For example, urban areas require different treatment than rural rangelands. Or likewise, farmers who use water from a stream may have something to say about planting more competition for water along the banks of an over-allocated stream (since trees and other riparian vegetation will consume water through a process called **evapotranspiration**).

Lastly, it is critical that any management have monitoring at its heart. All projects should have a monitoring plan. Monitoring plans will tell you whether your riparian project met your original goals. They often include benchmarks or intervals in time, when you evaluate how your project is progressing toward your goals.

Portions of the previous sub-section were adapted with permission from the Oregon State University Extension Service publication EM 8714, Watershed Stewardship: A Learning Guide (Oregon State University, Corvallis, Oregon, new July 1998, revised January 2002), 485 pp. $42.00.

WORDS TO KNOW

Abiotic – refers to non-living components of ecological systems.

Adaptation - characteristics/behaviors acquired by organisms in response to external changes (stimuli) in their environment).

Algae – a primitive, usually aquatic organism that converts solar energy to food through photosynthesis. Can grow singly, in mats, as filaments, balls, or "slime" on rocks.

Alpine - ecological life zone associated with higher elevations, cold temperatures, relatively high levels of precipitation (snow), short growing season.

Altitude - physical elevation above sea level; as distance measured above and expressed in reference to mean sea level (MSL).

Anoxia – the absence of oxygen; the total deprivation of oxygen, as in bodies of water, lake sediments, or sewage.

Aspect - the physical direction a landform faces; example: the south-facing slope of a mountain.

Biome - large scale climatic regions of the biosphere with unique vegetation, plant and animal characteristics.

Biota - a term used to refer to the living components of an ecosystem (see also abiotic).

Biotic – an adjective referring to "living" or life.

Browser - an animal with a preference for fibrous/woody forbs, shrubs, trees.

Canopy - the highest overlaying vegetation layer in a forest.

Carnivore - a consumer which primarily consumes meat/flesh as a source of food.

Chapparal - dense, woody, shrub/brush- land type ecosystem.

Chlorophyll - green pigment found in plants which allows for the conversion of solar energy to chemical energy. Green plants/producers

Ciénega – Southwestern U.S. or Spanish term referring to a swamp or marsh, especially one fed by springs.

Climate - long-term meteorological qualities characteristic of a region. What you expect or want, weather is what you are getting.

Community - an ecological group consisting of different populations of organisms and which excludes non-living components.

Competition - species and/or populations of living things designed to provide advantage in reproduction, space, food, etc.

Consumer - an organism which is dependent on other organisms for their source of energy (food).

Cyanobacteria – similar to algae these primitive, single-celled organisms convert energy through photosynthesis; also called blue-green algae. Occasionally found in aquatic populations large enough to be toxic to humans, livestock and wildlife.

Ecology - the study of living things (biotic) as they interact with each other and their environment (abiotic).

Ecosystem - an ecological unit, with distinct, identifiable and unique characteristics consisting of different, interacting, individuals and/or populations (biotic communities), including the non-living environment.

Ecological Site - an ecological site describes a combination of biotic and abiotic characteristics in a particular location.

Effluent – the state-regulated treated outfall from wastewater treatment plants that includes mostly water, but also some of the residual chemicals and contaminants from treatment.

Effluent-dominated stream – a stream where effluent is the main source of surface flows.

Endemic – a unique organism (species) found no where else but in one specific location. Example of common usage: this plant species is *endemic* to the Huachuca Mountains.

Equilibrium – balance or status of balance between different parts of a system.

Eutrophication – the process of nutrient enrichment leading to dense plant growth, especially algae.

Evapotranspiration - the water loss by plants due to transpiration and evaporation.

Extinction – process of losing species through their failure to successfully function and/or to reproduce.

Extirpation – permanently removing a species from its normal area.

Food Web - a complex collection of interconnected/related food chains with multiple producers and consumers involved.

Forbs - broad-leaf (non-grass), green plants used as food by grazers/browsers.

Genus - a very distinct and critically descriptive taxonomical unit; the binomial systems “first’ name of an organism; genetically a very similar grouping.

Grassland - a large ecosystem /biome dominated by the presence of grasses and grass dependent organisms.

Habitat - the ecological surroundings required by an organism.

Herbivore - an organism who primarily prefers plant material as a food source.

Impervious surface – A surface that has been covered with a material that water cannot normally penetrate.

Infiltration - The entry of water into the soil.

Invasive - any organism species which tends to displace and replace native species within an ecosystem.

Invertebrate - an animal lacking an internal skeleton; may or may not possess an exoskeleton.

Macroinvertebrate – organisms without backbones, but that are large enough to be visible to the naked eye. Examples include amphipods, shrimp, snails, spiders, insects.

Microhabitat – the smallest locations in a landscape that provide specific conditions for an organism to survive.

Montane - reference to ecosystem variations and characteristics related to the influence of mountains and/or elevation.

Niche - the specific role an organism plays in the environment; dealing with function.

Perennial – year-round; also refers to a plant which can live and reproduce repeatedly over several years.

Photosynthesis – A complex chemical process powered by solar energy whereby plants produce sugars and other organic matter by combining different nutrients.

Pollution - any substance, condition or degradation capable of diminishing the quality and function of an ecosystem.

Population - an identifiable number of the same species within a given area and time.

Producer - an organism capable of producing its own food (energy) and not dependent on other organisms as a source of food; green, photosynthetic, plant.

Range - the distance/extent of the area of movement by individuals within their ecosystem; a term used by livestock operators to describe the area where animals are grazed.

Riparian - a term used to describe the area adjacent to flowing water; enhance bio-diversity associated with vegetative areas along flowing rivers and streams.

Scavenger - an organism which seeks out the remains of dead plant and animal life for its source of food.

Scouring – the act of a stream clearing, digging or removing sediment, organic matter, and other light materials by a powerful current of water.

Sediment - Material deposited by wind, water or glaciers.

Silt - fine grained particulate carried by water; particles between .002 and 0.05 mm in diameter.

Slope - the change in elevation of terrain; expressed as a percentage of elevation increase or decrease.

Species - a subdivision of a **genus**; considered the most basic biological classification; individuals closely resemble one another; interbreed and successfully produce fertile offspring; individuals share similar ecological and biological traits, offspring, in nature.

Succession - a process where plant and animal populations demonstrate a series of natural changes leading to a relatively stable ecosystem. Example: bare ground and rocks to a mature forest.

Symbiosis - an extreme example of mutualism; two individuals become so dependent upon each other neither would survive if separated.

Transpiration - the physical release of water vapor from photosynthetic plants.

Wetland – an area which is frequently subjected to persistent flooding or has an elevated water table.

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http://www.thearb.org/

Arizona Game and Fish Department
http://www.azgfd.com/

Arizona Native Plant Society
http://aznps.org/

Arizona Partners in Reptile and Amphibian Conservation http://www.reptilesofaz.com/

Arizona Riparian Council
http://azriparian.asu.edu/

Arizona-Sonora Desert Museum
http://www.desertmuseum.org/

Audubon Society
http://www.audubon.org/

Bat Conservation International
http://www.batcon.org/

Boyce-Thompson Arboretum
http://ag.arizona.edu/BTA/

Bureau of Land Management
http://www.blm.gov/nhp/index.htm

Desert Botanical Garden
http://www.dbg.org/

DesertUSA
http://www.desertusa.com/index.html

Invasivespecies.gov
http://invasivespecies.gov/

National Wildlife Federation
http://www.nwf.org/

Rangelands West
http://rangelandswest.org/index.html

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