



UTAH Master Naturalist

Mountain Adventures Manual



utahmasternaturalist.org

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Welcome to Utah Master Naturalist!

Utah Master Naturalist was developed to help you initiate or continue your own personal journey to increase your understanding of, and appreciation for, Utah's amazing natural world. We will explore and learn about the major ecosystems of Utah, the plant and animal communities that depend upon those systems, and our role in shaping our past, in determining our future, and as stewards of the land.

Utah Master Naturalist is a certification program developed by Utah State University Extension with the partnership of more than 25 other organizations in Utah. The mission of Utah Master Naturalist is to develop well-informed volunteers and professionals who provide education, outreach, and service promoting stewardship of natural resources within their communities. Our goal, then, is to assist you in assisting others to develop a greater appreciation and respect for Utah's beautiful natural world.

*"When we see the land as a community to which we belong,
we may begin to use it with love and respect." - Aldo Leopold*

Participating in a Utah Master Naturalist course provides each of us opportunities to learn not only from the instructors and guest speakers, but also from each other. We each arrive at a Utah Master Naturalist course with our own rich collection of knowledge and experiences, and we have a unique opportunity to share that knowledge with each other. This helps us learn and grow not just as individuals, but together as a group with the understanding that there is always more to learn, and more to share.

This manual is your literary companion as you journey through a Utah Master Naturalist course. **Ideally, you'll become familiar with the contents of this manual before the course starts.** That way, we can focus on applying this knowledge while we are out on field excursions. I hope you enjoy your time as a participant in a Utah Master Naturalist course, and that it truly helps you on that journey through our natural world.

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UTAH MASTER NATURALIST MOUNTAIN ADVENTURES

Introduction

The primary goal of Utah Master Naturalist is to promote stewardship of Utah's natural world. In doing so, Utah Master Naturalist will train and inspire its participants to not only become better stewards themselves, but also to help inspire others to their own roles as stewards of the land. Becoming a better steward can involve physically managing land more sustainably, but for most of us, it usually includes developing an appreciation for and curiosity about Utah's natural world, considering how our use of resources in our daily lives affects this natural world, and making informed decisions to live in a more sustainable way.

Goals of Utah Master Naturalist:

- To inspire people to have a lifelong commitment to explore and learn about Utah's natural world, as well as share those experiences and that knowledge with others
- To promote an increased awareness of and stewardship for Utah's natural systems
- To develop a growing population of well-trained naturalists in Utah
- To disseminate relevant science-based information and effective interpretive techniques
- To connect professional and volunteer naturalists to organizations that need them.

What is a naturalist, and what is their role or responsibility? Each Utah Master Naturalist class begins with a discussion that is an opportunity for participants to shape the idea of what it means to be a naturalist. There are many tools that aid a naturalist. Perhaps the greatest tools are our five senses, for it is with these senses that we observe nature. Many naturalists use other tools to capture a particular moment in nature in order to revisit it again. These tools might include writing in journals, taking photographs, painting landscapes, or even collecting and identifying parts of nature to possibly learn more about at a later time using reference materials. Each one of us has interests and abilities that are brought out and enhanced by using these tools.

In 2006, we conducted a needs assessment survey of agencies and organizations around Utah that include professional and volunteer naturalists as part of their staff. Results indicated that there is a need for a program such as Utah Master Naturalist to provide well-trained volunteers. Ninety-one percent of Utah organizations that responded to the survey use volunteers to deliver their programs. Although 55% of the respondents had volunteer training programs in place, 95% of the respondents stated that the UMNP would be valuable training for new volunteers. The majority of organizations provide only 1-5 hours of training for their volunteers.

In addition to a greater need for more knowledgeable volunteers, an enormous change has been occurring in Utah for much of the past two centuries. As we will discuss throughout this section, the viewpoint of Utah's inhabitants, with respect to the value of conserving Utah's natural world, has changed with each group that has inhabited the state. Differing ideas about land use, conservation, and connection to the land have shaped where we are today.

Aldo Leopold, "Father of Modern Conservation," believed that, in regard to being a naturalist, "personal satisfactions...are more important than fame." That is, being a naturalist should be enjoyable- it should provide a level of personal satisfaction in addition to being a learning process. Aldo Leopold often thought that the 1940s educational system did little, if anything to promote "personal amateur scholarship in the natural-history field."

Aldo Leopold believed that one of the greatest downfalls of humanity is the idea that either humans are not part of nature, or that nature's sole purpose is to serve the needs of humans. In order to treat the natural world with love and respect, we must first feel like we belong to it, that we are a part of it. In order

to feel a sense of belonging to our natural world, we must begin to understand it, even just a small part of it. To begin understanding our natural world, we must first learn about it. An essential part of learning about our natural world is experiencing it.

The Utah Master Naturalist Program aims to help us experience, learn about, and understand Utah's natural world. By doing so, we will become more aware of how our actions affect the land, or community, in which we live. We will become better stewards of the land. We will develop what Aldo Leopold referred to as the "land ethic."

Important Naturalists

Knowledge of natural history helps us understand and explain what we see, but a lack of knowledge does not necessarily exclude someone from being a naturalist; the only requirement for becoming a naturalist is curiosity. No naturalist, living or dead, was born with in-depth knowledge of the natural world. The pursuit of knowledge via learning about the biosphere, a pursuit all of you, and the people discussed below, were willing to initiate.

Claude T. Barnes

Claude T. Barnes was a naturalist with whom few people are likely familiar. Barnes was an attorney who lived in Salt Lake City, by the mouth of City Creek Canyon, and for nearly 40 years from the early 1920s to the late 1950s recorded his observations on nature. He ventured into the Wasatch Mountains on nearly a daily basis to record bird sightings, observe animals in their natural habitats, and develop a large collection of plants and insects. Barnes' daily natural history notes were compiled into the book *The Natural History of a Mountain Year: Four Seasons in the Wasatch Range*, which is out of print, but can still be found through used book sellers. He prefaced that "the writing of this book... is but a token of love of a naturalist for the beauties and mysteries of the wildwoods."

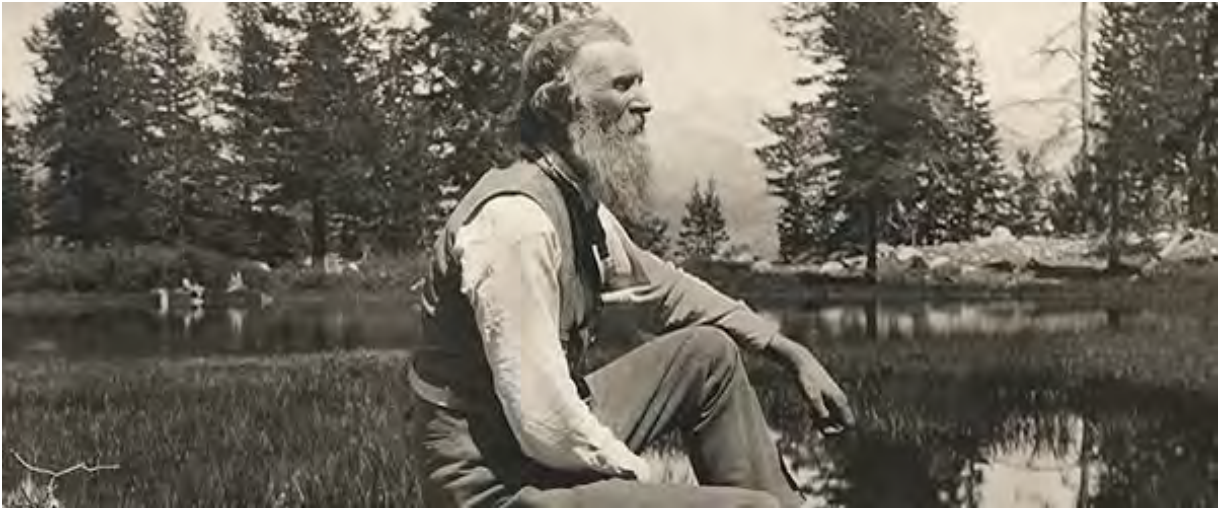
Barnes wrote about many plants, animals, and places with which we are still familiar today, from flocks of yellow-headed blackbirds at Farmington Bay, to the ripening elderberry of Ogden Canyon, and the rarity of wolverines in the Wasatch and Uinta Mountains. His writings also serve as a historical record of our natural world, revealing that "seldom now do we of these once untraveled mountains hear a wolf; indeed, not since 1919 have we seen the tracks of one." On July 15, 1943, Barnes first saw a European starling in the Salt Lake Valley, proposing that its numbers had diminished in the east, and it moved west to find a more suitable home. We know from historical accounts that the European starling was first introduced into Central Park in New York City in 1890, and Barnes' account tells us that it took 63 years for the species to expand across the country to Utah.

Reading Barnes' daily accounts of nature remind us of the importance of using our skills of observation, being present in the moment, and, simply, "getting out there." There is something beautiful in nature to see every day, right in our back yards.

"Whatever the weather, whatever the time of year, to learn the secrets of nature one must go to the wild places" - Claude T. Barnes

John Muir

John Muir was born in Dunbar, Scotland, in 1838, and when he was 11, his family moved to Wisconsin. Young John was an avid reader, and a fairly successful inventor. Although he worked long hours on the family farm, he spent his free time roaming the woods and eventually studied natural sciences in college.



While working in a carriage factory on 1867, Muir was temporarily blinded when an awl pierced his right eye. When his sight returned after several months, he became determined to see as much of the natural world as possible and, at age 30, embarked on a walking journey of over 1000 miles to the Gulf of Mexico. Eventually, his wanderings led him to California, the Sierra Nevada, and Yosemite Valley. It was soon evident that Muir's heart and spirit became a part of Yosemite.

“Then it seemed to me that the Sierra should be called, not the Nevada or Snowy Range, but the Range of Light. And after ten years of wandering and wondering in the heart of it... it still seems above all others the Range of Light.”

Muir discovered glaciers in that area, and determined that ancient glaciers were responsible for the formation of the famous valleys. His discoveries, and remarkable writing skill, soon brought prominent citizens, such as Ralph Waldo Emerson and Asa Gray, to visit the area. By 1890, Muir became instrumental in prompting Congress to establish Yosemite National Park. Two years later, he organized the famous Sierra Club to help protect wild places. His influence continued to grow as he authored 10 major books and published 300 articles dealing with natural history and travels. In 1903, President Theodore Roosevelt came to see Muir in Yosemite to discuss ideas about national conservation policies.

John Muir also believed in the idea that being in nature provided a much more effective learning experience than any book could. For most of his adult life, Muir was adamantly against books of any kind. Luckily for us, his views changed in the latter part of his career, and he began writing about his own adventures in nature. John Muir was voted the Greatest Californian by the California Historical Society in 1976.

“One day's exposure to mountains is better than cartloads of books.”

Inhabitants of Utah's Mountains

The earliest inhabitants of Utah were the nomadic hunter-gatherer **Paleoindians**, from around 12,000 B.C. to 6,500 B.C. Their successors, the **Archaic** people, lived in Utah from that time forward until around the 1st Century A.D. Both groups lived in caves or wood shelters throughout the state. Because of their hunter-gatherer lifestyle, they moved each season to places where food was abundant. Mountains were invaluable in the summer for collecting berries and finding plentiful game animals. In the winter, native peoples would live in the lower desert valleys to escape the harsh mountain winters. Starting around 400 B.C., farming societies, including the **Ancestral Puebloan** and **Fremont** people, occupied the Great Basin

and Colorado Plateau. As a result, the mountains became a less important food source during the summer as permanent villages aided in growing crops.



The Fremont were hunter-gatherers and agricultural people. (Image from Utah State History)

When Europeans first arrived in Utah, there were five American Indian tribes living in the state: the **Utes, Paiutes, Goshutes, Shoshone, and Navajo**. The Navajo lived in plateau country of southern Utah, and believed that Mother Earth, and her offerings (the mountains, vegetation, animals, water, etc.), were sacred and could not be owned by any man. The Utes occurred throughout most of the state, and were a hunter-gatherer society. They built shelters called tepees, which were made with long poles built in a cone shape and covered in animal skins. These structures could easily be taken down and moved when food became scarce or when harsh weather came. The Northwestern Shoshoni resided in the valleys of northern Utah, especially in the Weber and Cache Valleys, as well as along the shores of the Great Salt Lake. Most Indian tribes in the state, especially the Utes and Shoshone, only utilized the mountains of Utah during the summer, and descended to the lower-elevation valleys during the winter.

The earliest Europeans to come to Utah were the Spanish from Mexico, who mostly traded horses, firearms, and liquor to the Indians for furs and Indian slaves. Horses allowed many Indian tribes more mobility. The next Europeans to come to Utah were the mountain men and trappers. These men trapped beavers in the mountain streams, as well as hunted other various animals for meat and furs to sell. Their livelihood relied on the mountains of Utah, as well as those of other western states. However, by the 1840s, beavers were nearly extinct throughout most of the western United States. An additional role of mountain men in Utah was their discovery of trails that would be used to settle the west, including the Oregon Trail, California Trail, Old Spanish Trail, as well as trails in Utah that led into the Uinta Basin and the Wasatch Front.

When early **Mormon pioneers** came to Utah in the mid-1800s, the population grew fast with over 11,000 settlers in the first 3 years. Although these settlers mostly farmed in the valleys, they also utilized the mountains resources during the year. Settlers began grazing livestock in the mountains during the summer, hunted the wild game, grew crops and established settlements in many mountain valleys, and logged mountain forests for building materials. As a result, resource use and a decrease in the amount of available game animals caused considerable conflicts between the Indians and Mormon settlers. The growing population led to expansion and settlement throughout the entire state under the direction of church leaders. Some mountain valley towns, such as Scofield and Fairview, were established for agricultural purposes. Later, towns like these also became locations for coal mining and timber operations. Many of the mountain towns that started as agricultural areas still exist today and carry on the farming and ranching traditions.



A 1912 reenactment of early Mormon pioneers travel through Mountain Dell in the Wasatch Range.

Although industry in Utah started as and continues to be largely agriculture-based, other types of commercial activities began soon after settlement. With the California Gold Rush of 1849, there was an influx of miners passing through the territory in search of gold. The Mormon settlers were mostly interested in mining coal for fuel instead of precious minerals during the latter part of the 1800s, because the church did not generally support mineral mining. Instead, men were counseled to practice farming and provide food for their families. The foundation of commercial mining in Utah started with Patrick Edward Connor. After the start of the Civil War in 1861, which required most of the military that was stationed in Utah during the Utah War (1857-1859) to go back east to fight in the south, Connor volunteered for service in the Union army and was appointed Colonel of the Third California Infantry. In 1862, he moved his command to Salt Lake City, where he founded Camp Douglas. Connor was ordered to protect the overland mail route and keep an eye on the Mormons to make sure they did not aid and support the Confederacy. During this period, many members of his army were experienced prospectors who participated in the California Gold Rush, and were granted leave to explore the nearby Wasatch and Oquirrh Mountains for gold and silver deposits. The first mining claims began in Bingham Canyon in 1863, which led to further exploration. By 1866, Connor and his army were discharged from Utah, but mining exploration continued. From that time until Connor's death in 1891, he devoted himself to the development of mining property in Utah and Nevada.

The most productive mining districts in Utah during the late 1800s were the Bingham, Park City, Tintic, and Big and Little Cottonwood Canyons. The newly acquired mining wealth helped stimulate Salt Lake City's economic base. Park City was one mountain valley mining area that flourished due to mineral mining in the Ontario, Silver King, Daly-West, Daly-Judge, and Silver King Consolidated mines. As the mines flourished, houses began springing up around them. Although the Panic of 1893 slowed economic growth throughout the state, Park City's expansion was halted by a devastating fire in 1898. It raged through Park City's commercial district, with losses estimated over \$1,000,000, and over 200 businesses and homes were destroyed. The community rebuilt, but the mountain mining town declined again prior to and during the Great Depression in the 1930s. By the 1950s, Park City was almost dead and abandoned. In the 1960s, the town experienced a rebirth due to the increase leisure time for winter recreational activities. The mining town of Park City then became a key ski resort city in northern Utah. In the 1980s, Deer Valley recreational area added to the area's development, and it is still considered to be one of the greatest winter recreational areas in the state. Similar to Park City, the silver mining town of Alta had fluctuations throughout the late 1800s and early 1900s, but by 1930 it was practically a ghost town. In the late 1930s,

Alta received funding from a group of businessmen and skiers, who organized the Salt Lake City Winter Sports Association and built their first ski lift. As skiing grew in popularity, the resort started expanding in the 1960s around the same time that the Park City winter recreational area began.



Early Utah miners explored the mountains, looking for precious metals. (Image from Utah Historical Society)

Some mountain mining towns in the state were not as lucky. One town, called Bullion City, was located in Bullion Canyon on the eastern slope of the Tushar Mountains in central Utah. Bullion Canyon stretches from about 6,000 feet in elevation near Marysville, to its highest mountain peaks up to 12,000 feet. Mining expeditions started in the canyon in 1868, and by 1872 there were several hundred people living in the canyon in search of precious metals. Bullion City then became the county seat of Piute County in 1873. Because of the expense to transport ore, the risk from Indian attacks, and the decline in high grade ore, the population in the canyon began to decline thereafter. By the 1880s, Bullion City became a ghost town. In 1921, the Bully Boy Mines Corporation from Delaware ushered in another mining boom similar in size to the first, but with the additional aid of more modern equipment, such as electricity and jackhammers. By 1923, mining again dwindled significantly, but a few small mining operations remained until the early 1950s. Today, only remnants of Bully Boy Mill, some log cabins, and a few other mining structures remain to remind visitors of the historic past of this lost mining community.

During the 20th century, industrial advances allowed for more leisure time for Americans. As a result, other types of recreational resorts opened up throughout the state. A few of these resorts were located in Utah's mountains, such as in the Scenic Ogden Canyon and up Emigration Canyon. In the early 1900s, Ogden Canyon had a man-made waterfall, an electric trolley, the Oak's Resort, Idlewild Lodge and Restaurant, and the world-famous Hermitage Hotel. Emigration Canyon had the Pinecrest Inn, which was completed in 1915 after requests for lodging when visiting the canyon. The original Hermitage Hotel, trolley systems, and Pinecrest Inn no longer exist today. In recent years, more and more recreational resorts have again opened in mountainous areas, largely as an escape from development along the Wasatch Front.



The old Hermitage Hotel, built in Ogden Canyon in 1905, was destroyed by fire in 1939.

Physical Characteristics and Processes

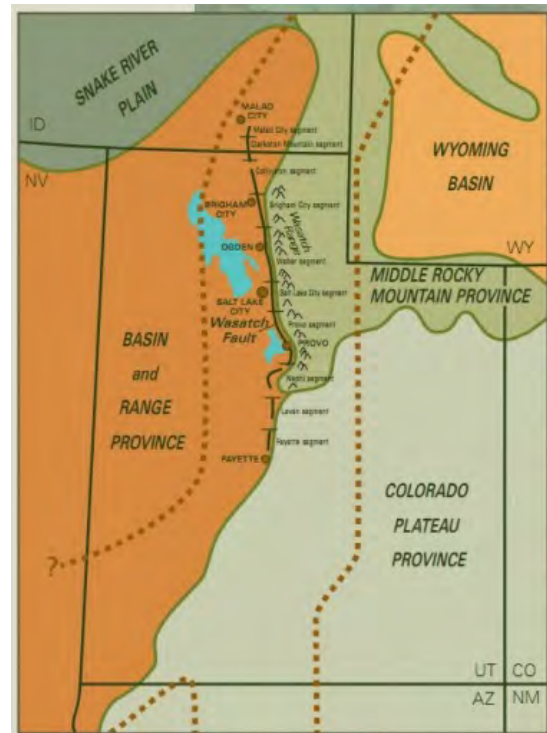
Geography

Utah has a vast geologic history that is often considered very unique. Its landscape is separated into three general physiographic provinces, which include the Middle Rocky Mountains, the Central Basin and Range (i.e., Great Basin), and the Colorado Plateau. Each major landform has its own spectacular characteristics and aesthetic charm. The Middle Rocky Mountains includes the magnificent Wasatch and Uinta mountain ranges; Utah's Basin and Range is characterized by tan-colored desert floors and isolated gray-limestone mountain ranges; and the Colorado Plateau includes spectacular redrock country, the Uinta Basin, and the high plateaus of south-central Utah. Each landscape has its own unique geological history, which extends back billions of years within the bedrock.

Middle Rocky Mountain Ranges

The Middle Rocky Mountains includes the Wasatch and Uinta Mountain ranges, as well as other numerous smaller ranges including the Bear River, Raft River, Stansbury, Oquirrh, and Crawford Ranges. The region's two major mountain ranges, the Wasatch and Uinta Mountains, have little in common. The Wasatch is relatively young, 12-17 million years old and still forming, and runs north to south from central to northern Utah. Elevations range from 4,330 feet to 11,928 feet at its highest peak, Mt. Nebo. This range rises more than a mile above the desert floor, and is 15 miles wide at the widest point. It is a product of the displacement from the Wasatch fault zone, which it parallels, as well as other faults, volcanic activity, and glacial erosion. Because of the complexity of the formation of the Wasatch Mountains, all rock types (igneous, metamorphic, and sedimentary) are well represented throughout the range.

The Uinta Mountains are a classic Rocky Mountain-type range with some unique characteristics. The Uinta Mountain Range has an east-west orientation that coincides with the location of an east-west Precambrian belt, which has its origin over 2 billion years ago. The current mountain range dates back to around



Major physiographic regions of Utah
(Image from Utah Geological Survey)



Major mountain ranges of Utah.

60-65 million years ago (mya), with additional formation occurring around 15 mya. In Utah, it extends from the Utah-Colorado border westward, intersecting the Wasatch Mountains. The Uintas include some of the highest mountains in the state, including Utah's highest peak, Kings Peak, which reaches 13,528 feet in elevation. They contain the headwaters to many of Northern Utah's rivers and streams, and are central to the historic and economic development of Northern Utah.

Colorado Plateau Region

The **Colorado Plateau** takes its name from the Colorado River and its tributaries, which run through this region. It encompasses 130,000 square miles of the Four Corners states. The elevation of these plateaus averages about 6,500 feet, but reach higher elevations in the high southern plateaus. The plateaus are made up mostly of flat-lying layers of sedimentary rocks, but are also covered by volcanic rocks and ash that has eroded away in some areas. The simple layer cake structure of rock of the Colorado Plateau is exposed, in part, due to harsh climate of the area, allowing it to be easily traced across the landscape. The Colorado Plateau is located in the south-eastern half of the state, and is broken up into three regions, the true Colorado Plateau, the High Southern Plateaus, and the Uinta Basin.

The origin and timing of the uplift of the Colorado Plateau is a subject still heavily debated among geologists. But the deep canyon incision of the region by the greater Colorado River system is known to have begun about 6 million years ago. Miraculously, it reached its current height with little deformation of the sedimentary rock layers from which it is made. Although the bedrock layer is mostly unbroken throughout the plateau, the Colorado River has numerous sculpted canyons, buttes, mesas, and other geological features that were created by water's erosive power. The major mountain ranges in this region include the La Sal, Abajo, and Henry Mountains, which are geological exceptions because they are made extensively of igneous intrusions after the uplift of the Rockies, rather than sedimentary in origin. The highest peak in the La Sal Range reaches 12,721 feet at Mt. Peale, the highest peak in the Abajo Range reaches 11,360 feet at Mt. Abajo, and the highest peak in the Henry Range reaches 11,615 feet at Mt. Ellen.

The High Southern Plateaus of Utah's Colorado Plateau include the mountain ranges that are a continuum of the Wasatch Range, and is considered the transitional zone that separates the Great Basin from the Colorado Plateau. The southern sections of this range are blanketed by Tertiary volcanic rocks, a result of volcanic activity in the area around 15 to 30 mya. However, this area is relatively tectonically active, with some volcanic rocks as young as a few thousand years old. This range also reached its current elevation within the last 10 million years. This region consists of the Wasatch Plateau, Sevier Plateau, Tushar Mountains, Pahvant Range, Brian Head, and various other mountains and plateaus that extend to the southern Utah border.

The Uinta Basin area on the northern end of the Colorado Plateau is a distinctly bowl-shaped landform that is relatively flat with many rivers that flow through it. Valleys throughout the basin range 4,000-5,000 feet in elevation. The Uinta Basin's southern edge, which separates it from the rest of the Colorado Plateau, is characterized by rugged cliffs that reach elevations from 8,000 to 10,000 feet. The cliffs were created during the Mesa Verde Formation as long as 90 million years ago, and consist mostly of sandstone, but also with some shale and limestone. The Book Cliffs are an erosional feature that is much younger, though, at only 6 million years old.

Basin and Range Mountains

The **Central Basin and Range** covers the western third of Utah. It is primarily covered by deserts and salt flats, but is broken up by small, narrow mountain ranges. Many of the small mountain ranges of the Central Basin and Range were created by the tilting of fault blocks that were created by the stretching of the earth's crust between the Wasatch Mountains and Sierra Nevada. This is the same normal faulting that has created the Wasatch Range itself. In western Utah, the mountains we see today expose rocks of nearly

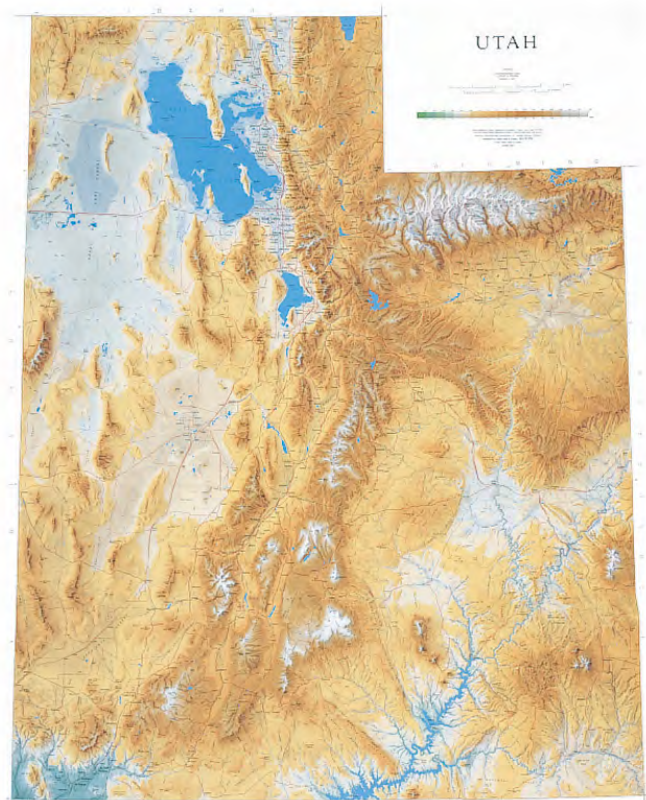
every geologic age, from Precambrian to Paleozoic to Mesozoic to Cenozoic. Activity in this region began as early as 570 mya and continues to occur today. The mountain ranges contain thick deposits of fossil-bearing marine strata of all seven Paleozoic Periods, and therefore are made of mostly carbonate rocks (limestone and dolomite). Although carbonate rocks are not easily eroded in dry climates, flash floods and heavy rainfall events often accumulate sediment deposits in the basins, and slopes can often be half-buried by their own eroded debris. Some of the major mountain ranges in this area include the Raft River Mountains and the Deep Creek Range.

Topography

The topography of the **Wasatch Mountains** is generally characterized by craggy, steep-walled canyons and precipitous cliffs, with the existence of various glaciated cirques and canyons. However, the Wasatch is less rugged farther to the east as it transitions to the Colorado Plateau or Green River Basin. Some smaller spurs of the Wasatch Range, such as the Bear River Range, are generally considered to be less steep and rugged. The elevation of the Wasatch Mountains ranges from approximately 4,300 feet at the foothills to 11,928 feet at Mt. Nebo, its tallest peak. It covers approximately 160 miles from southeastern Idaho to Central Utah, and is typically no more than 10 miles wide at any point. Although the Wasatch Mountains is a singular range between Salina and Price, the Wasatch Plateau continuation nearly extends the Wasatch fault zone to the state's southern border.

Although the **Uinta Mountains** are the tallest mountain range in Utah, the topography is generally smoother than the Wasatch Range due to (1) more extensive glaciation that has occurred, and (2) the fact that they are tectonically inactive, unlike the Wasatch Range. This range is located in the northeastern corner of the state, and is oriented on an east-west axis, atypical of most western mountain ranges. The recognized mountains of the Uinta Range are approximately 70-80 miles long, and over 40 miles wide in some areas. The entire Uinta anticlinal formation is up to 150 miles long, reaching from western Colorado border to the Wasatch Mountains at the Salt Lake Valley. The landscape is generally characterized by broad, flat basins, abundant lakes and ponds, glacial cirques, and steep walled mountains. The entire range is an anticline, which was formed as a result of upward buckling of the earth's crust under the forces of compression. The range averages 10,000-11,000 feet in elevation, and contains the state's highest peak, King's Peak, at 13,528 feet tall. King's Peak is located just south of this range's central spine. The range is highest and most heavily glaciated on the west end, and gradually declines in elevation moving east.

The **La Sal and Abajo Mountains** are both small isolated ranges within the Colorado Plateau Region. These ranges were created by laccolithic intrusions that bulged layers of sedimentary rock upward as liquid magma cooled beneath the earth's surface. It is debated that the intrusions began the uplift of the Colorado Plateau. The La Sal Mountains are the second highest range in the



The diverse topography of Utah.
(Image from U.S. Geologic Survey)

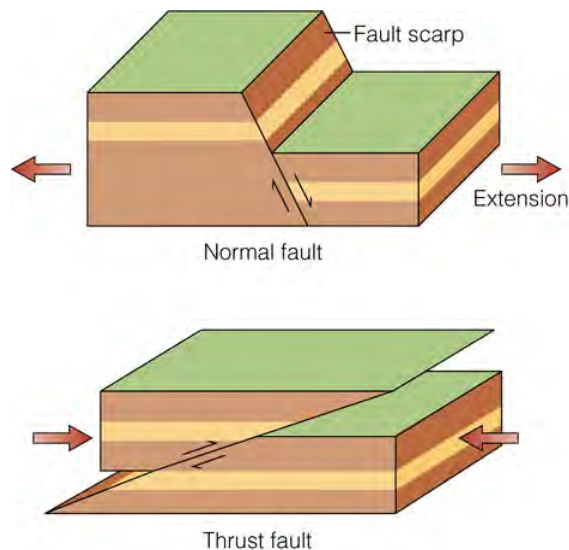
state, and generally considered to be fairly steep-sided mountains. They are about 10 miles wide, and reach 12,721 feet at the highest peak, Mt. Peale. The Abajo Range is more subtle and hidden, with sculpted canyons and gentle peaks. These mountains reach their highest point at Abajo Peak, at 11,360 feet above sea level.

Mountain Formation

Thirty million years ago, the distance from Salt Lake City, Utah, to Reno, Nevada, was about two-thirds of what it is today. The earth's crust around Utah is constantly being stretched east to west. This stretching creates tension that results in either a slow, continuous movement or a sudden movement along a fault, creating a break in the earth's crust that results in an earthquake. During an earthquake, the mountains rise and the valleys drop along faults and the two cities are stretched about ½ inch farther apart each year. As the landscape is stretched, the down-dropping of valleys during this extension is adding up to 1mm of relief per year across mountain fronts. This uplifting is more commonly in the form of infrequent sudden earthquakes rather than during slow continual movements. After millions of years of such movements, complex series of faulting and folding has resulted in many mountain ranges throughout the state. This section will review the basic fault types that are critical for the formation of Utah's mountains, followed by how some of the major mountain ranges were formed.

Basic Fault Types

A fault is a break in the earth's crust where blocks of earth slip past each other due to the build-up of pressure beneath the surface. There are two basic fault types that are responsible for mountain formations within the state, a **normal fault** and a **thrust fault**. In a normal fault, the mountain block, also known as the foot wall, moves diagonally upward as the valley block, also known as the hanging wall, falls diagonally downward. A thrust fault happens when two blocks move toward each other, resulting in the hanging wall being pushed up and over the foot wall as a result of compression.



Basic fault types involved in mountain formation.

Earth movements do not usually occur continually, but instead as episodic events that result in **earthquakes**. These earthquakes typically originate approximately 10 miles below the surface, at a point called the focus. The point on the earth's surface, directly above the focus is called the epicenter, where the greatest amount of ground shaking occurs. The best-known faults in Utah are those associated with the

Wasatch fault zone, a collection of normal dip-slip faults that runs 240 miles along the Wasatch Front. It is capable of producing earthquakes with magnitudes up to 7.5 on the Richter Scale. On average, the Wasatch fault zone has produced an earthquake with a magnitude equal to or greater than 3 each year since 1847, but only one has been strong enough to break the surface of the ground.

The Wasatch Fault Zone

The **Wasatch fault zone** divides the state in half, with the Great Basin to the west and the Colorado Plateau to the east. This fault system is less than 25 million years old. It is made up most notably by the Wasatch fault, which runs from Malad City, Idaho, to just north of Fayette, Utah. The Elsinore, Sevier, and Hurricane faults, which continue south from the end of the Wasatch fault to the Utah-Arizona border, are a continuation of this line. These faults, as well as other smaller faults that surround them, are normal faults that have created the Wasatch Mountain Range and the High Mountain Plateaus of southern Utah (also referred to as the Wasatch Plateau). In addition to normal faults, in the southern plateaus there are monoclines, which are one-sided folds of sedimentary rocks that are draped over deep-seated faults, and are responsible for landforms such as the San Rafael Swell and Capitol Reef National Park. The Colorado Plateau is relatively un-deformed compared to other regions in the state, but is easily eroded by fast moving streams that leave behind bare rock formations. This erosion has resulted in spectacular scenery within the state, such as the Monument Valley, Rainbow Bridge, and Canyonlands National Park. Eroded sediments from this region are carried down the Colorado and Green Rivers and are deposited into Lake Powell.

The western half of the state, the Central Basin and Range, is different. Rather than being eroded away, it is a large basin that collects sediment from the surrounding mountain ranges. The majority of the river systems in the Uintas and Wasatch Mountains, as well as the isolated mountain ranges of the Central Basin and Range, all terminate within this region. It is therefore called a terminal basin, where no water leaves the system except through evaporation, which leaves behind all of the minerals and sediment that have been eroded and carried downstream. Salt is a major mineral deposit that is left behind when water evaporates from this region, and has led to the creation of the salt flats and Great Salt Lake.

Formation of the Wasatch Mountains

The Wasatch Mountains are generally considered to be a product of 20 million years of geologic faulting, volcanic activity, glaciations, and erosion. The Wasatch Range began uplifting only 12 to 17 million years ago; however, compressional forces in the earth's crust began to stacking and thrusting large sheets of rocks during the Cretaceous Period (138-66 mya), which were then heavily eroded by magma intrusions about 38 to 24 mya. Afterward, older sedimentary rocks uplifted the Wasatch Range as it is seen today, extending from the mountains near Nephi, northward to the Utah-Idaho border. The more recent uplifting



The Wasatch fault zone divides northern Utah in half.
(Image from Utah Geological Survey)

was mostly due to the Wasatch fault, which is currently considered one of the most active normal faults in the world. This fault mostly follows along the western edge of the Wasatch Range. It is considered a transitional fault zone within the intermountain seismic belt, which separates the Central Basin and Range to the west, and the Middle Rockies and Colorado Plateau to the east. It is broken up into 10 individually-named faults, each averaging about 25 miles long, and each fault has a few mechanical segments. This fault zone moves an average of 1mm per year, but at infrequent intervals that result in earthquakes. The large fault movements can result in surface-breaks called scarps. Each scarp may be up to 20 feet high. Over time, combinations of multiple earthquake events can create scarps over 100 feet high. In addition to the movements of this normal fault, the Wasatch Mountains are a result of other complex fault types, volcanic activity, and glacial activity. The characteristic sharp ridge lines, U-shaped valleys, glacial lakes, and piles of debris called moraines were caused by mountain glaciers that eroded the landscape beneath their massive weight within a few hundred thousand years.

Formation of the Uinta Mountains

The Uinta Mountains are considered a folded and faulted anticlinorium (i.e., succession of anticlines and synclines). The mountain range itself dates around 60-65 mya when the mountains were first uplifted due to compressional forces that created upward (convex) buckles in the earth's crust, called **anticlines**, and downward (concave) buckles, called **synclines**. This geological activity resulted in a 150 mile, east-west oriented, mountain range in the northeast corner of the state. These anticlinal faults can be found within the Wasatch Mountains, suggesting that partial Uinta Mountain formation occurred prior to the formation of the Wasatch Range. The mountains that were created by this anticline were then eroded down before being raised again about 15 mya to their current height. The Uintas are separated into three general subsections, the High Uintas, Eastern Uintas, and marginal benches. Even more so than the Wasatch Mountain Range, the High Uintas show significant characteristics caused by mountain glaciers during the Pleistocene Era, which created steep slopes, gently sloping valleys, glacial lakes, and moraines. This specific subsection includes the headwaters of the Provo, Weber, Duchesne, Uinta, and Bear Rivers, and contains hundreds of rock-rimmed, glacial-carved lakes. The Eastern Uinta subsection does not contain such glacial features of the High Uintas, instead, it is characterized by wide, shallow valleys with very few lakes.

Formation of the Colorado Plateau Mountains

Unlike the rest of the Colorado Plateau, the La Sal, Abajo, and Henry Mountain Ranges were created as a result of a specific type of volcanic activity, known as **laccolithic intrusions**. As liquid magma made its way from the earth's mantle to upper layers of the earth's crust, it pushed overlying sedimentary rock layers upward as it cooled to form a dome-shaped mountain. Unlike a volcano, the magma typically did not reach the earth's surface, but was instead injected beneath the layers of sedimentary rocks. This pushed up the existing surface layers, contouring them in a dome shape around the magma, and resulted in an igneous core once the magma cooled. The igneous intrusions occurred somewhere between 20 to 25 mya. Ever since these mountains were formed, millions of years of erosion have removed the overlying sedimentary rock layers, revealing the igneous core beneath.

Utah's Geologic Timeline

Paleozoic Era

The Paleozoic Era lasted from 550 to 240 mya, and included the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods. During this era, Utah was the western shore of North America, with nearly half of the state covered by water. Vast coral reefs, which occurred along the

western coastlines, accumulated thick layers of limestone that are now exposed within the Wasatch Mountains. Some rock layers formed during this era have abundant oil and gas, specifically those from the Mississippian and Pennsylvanian periods. The remaining half of the state was characterized by low-lying flatlands with elevations barely above sea level. During this era, temporary, oscillating, shallow seas occurred upon these eastern flatlands, and were very rich in life. With little relief upon the landscape at this time, there was little erosion. The small amount of sediments that did occur was usually quartz sand, and accumulated within underwater basins such as the Oquirrh and Paradox Basins. During this period, the first invertebrates, amphibians, and reptiles originated.

Mesozoic Era

The Mesozoic Era lasted from 240 to 66 mya, included the Triassic (240-205 mya), Jurassic (205-138 mya), and Cretaceous (138-66 mya) periods, and was known as the age of the dinosaurs. During this era, the Paleozoic flatlands underwent many significant changes. During the Triassic period, shallow seas covered the northern and western half of the state, and occasionally overlapped with the mudflats of the eastern and southern half of Utah. Erosion during this period created a system of lakes and rivers. The accumulations of such eroded sediments contained high amounts of petrified wood. During this period, the first dinosaurs and primitive mammals appeared.

The second period within the Mesozoic Era, the Jurassic period, was broken up into the Early Jurassic and Late Jurassic. In the Early Jurassic, Utah was covered extensively by wind-deposited sandy deserts, which were blown in from the northwest. These sands formed dunes that were eventually cemented into tan rock that is known as Navajo Sandstone. It is visible in places like Arches and Canyonlands National Parks, Checkerboard Mesa in Zion National Park, and the San Rafael Swell. Little water was present during this time. During the Late Jurassic, water from the northern seas invaded the state twice, resulting in meandering river, lakes, and lowlands that were inhabited by dinosaurs. It was at this time that rivers washed large amounts of iron-rich sands originating from the Uncompaghre Mountains throughout eastern and southern Utah. These red sands eventually formed the Entrada sandstone layer that is now visible throughout the Colorado Plateau, and most notably forms Delicate Arch. During the Late Jurassic, there was also high amounts of sedimentation that filled the Arapien Basin with gypsum and salt. The Arapien Basin is located in central Utah between the Wasatch Plateau and the Canyon and Pavant Ranges. During this period, mountains and volcanoes occurred along the northern and western edge of the state.

The final period, the Cretaceous period, was characterized by formation of high mountains in western Utah from the thrust faulting, as well as declining lake and river systems. The western thrust faulting peaked during this period, which was caused by east-west compressional forces as a result of a collision of the North American and Pacific tectonic plates. This faulting became known as the Sevier Thrust System. During this period, Eastern Utah was covered by an inland sea, spanning from the Gulf of Mexico into the Arctic, and was surrounded by dinosaur-inhabited coal swamps. The extinction of dinosaurs marked the end of the Cretaceous Period and the Mesozoic Era. Rock layers from this period contain high levels of uranium in the Colorado Plateau region, and large amounts of oil and gas in Northern Utah.

Cenozoic Era

The most current era of earth's history, the Cenozoic Era, occurred from around 66 mya to the present. It includes two periods, the Tertiary (66-1.6 mya) and Quaternary (2.56 mya to present), which consists of seven epochs, the Paleocene (66-55 mya), Eocene (55-38 mya), Oligocene (38-24 mya), Miocene (24-5 mya), Pliocene (5-1.6 mya), Pleistocene (1.6-0.1 mya), and the Holocene (0.1 mya to present). In the Paleocene Epoch, erosion wore down the mountains of western Utah and deposited large amounts of sediments into the inland sea to the east. Continued pressure from the collision of the Pacific Plate caused the Uinta Mountains to uplift.

In the second epoch of the Cenozoic Era, the Eocene, Utah began to rise from its near sea level elevation to nearly a mile above sea level (approximately 5,000 feet). As warping continued in the Colorado Plateau region, large basins were created and filled with water. The largest of such basin lakes was called Lake Uinta. Lake Uinta was part of a larger Green River Lake system, which stretched into Wyoming and Colorado. The lake gradually contracted and was replaced, instead, by a river system. Upon these lake bottoms, thousands of feet of organic-rich sediments accumulated, resulting in well-preserved fish fossils and oil shales. During this epoch, the western mountains continued to erode until they were reduced to relics of their past, but during the later part of this epoch, granitic intrusions and volcanic flows again occurred in northwestern Utah.

During the Oligocene Epoch, the Colorado Plateau basins were filled in with sediments, creating broad plains that separated isolated mountain uplifts across the entire state. The beginnings of modern rivers ran across these plains. At this time, the continental divide passed through northeastern Utah, so the Green River of Wyoming drained to the Mississippi River to the east rather than its present-day flow to the west. With the beginning of the extension of western Utah, which eventually led to the Basin and Range region, extensive volcanic activity occurred. As a result, igneous rocks that formed the Henry, La Sal, and Abajo Mountains began to intrude, as well as igneous intrusions in northern Utah and volcanoes in southwestern Utah. The majority of Utah's copper is probably associated with these Oligocene-age volcanic intrusions throughout the state, including the copper in the Bingham mining district that is located west of Salt Lake City.

During the next period, the Miocene, volcanic activity continued forming three great metallic mineral belts until around 15 mya. These mineral belts are known as the Park City-Oquirrh, Deer Creek-Tintic, and the Wah Wah-Tushar belts. Continual uplift within the Rocky Mountains and the Colorado Plateau, rejuvenated major river systems that continue to carve out the landscape. Although previous compression from plate collisions had moved the location of San Francisco closer to Salt Lake City, extensions during this period moved the locations of the two cities farther apart. These extensions separated uplifting mountain blocks from down-dropped basins, resulting in the Basin and Range region that makes up the majority of western Utah today. This Basin and Range faulting created mountain-valley-mountain topography and created the Wasatch Fault zone.

The Pliocene Period began approximately 5.3 mya, marking a distinct change in the Colorado Plateau, from a broad, low-relief landscape to one in which rivers incised the landscape, creating diverse topography. The volcanic activity of southwestern Utah, which began during the Oligocene Epoch, continues into this time period. The basin and range faulting and regional uplifts of the Miocene also continue into this epoch. The one defining characteristic of the Pliocene Period is that it had a warmer climate than that which exists today. This allowed species of the Northern Hemisphere to exist hundreds of miles north of their current range and distribution. Melting ice near the poles caused by these warmer temperatures may have caused sea levels to rise up to 90 feet higher than their present day levels. Current knowledge about this epoch still remains largely incomplete because of some difficulties in gaining accurate environmental data from this specific time period.

One of the most famous epochs of this era is the Pleistocene. During this epoch, glaciers blanket the high-elevation Uinta, Wasatch, and Colorado Plateau mountain ranges. The geography of Utah during this epoch is very similar to its present geography, with landscape features such as mountains, canyons, and rivers were all in place, but glacial movement carved surface features upon the landscape that are still present today. The climate during this time included many periods that were especially wet and cold, resulting in 20 different "Ice Ages." Lake Bonneville formed during this period, covering many northern and western valleys throughout the state. It stretched east to west from the Wasatch Mountains to Nevada, and north to south from the Utah-Idaho border to Cedar City. Eroded sand and gravel accumulated along the shoreline, creating distinct shorelines, or benches, throughout time. Humans first arrived in Utah during the later part of this epoch, migrating in from Asia with the formation of Bering Land Bridge in the

north. This land bridge also allowed some species of ice age wildlife to immigrate to North America from Asia; the most famous of which is the extinct woolly mammoth (*Mammuthus primigenius*).

The final epoch of the Cenozoic Era is the Holocene, which includes present day Utah. The basin and range fault continues to be active, and the Great Salt Lake is a remnant of Lake Bonneville, which continually diminishes and accumulates vast quantities of salt. Volcanic eruptions continued into this epoch, occurring as recently as 660 years ago in Western Utah. Utah's vast and complicated geologic history has left permanent marks on the landscape across the state. It explains the brightly colored rocks of the east, the somber colors of the west, the spectacular canyons of the Colorado Plateau, the high mountain chains of northern and central Utah, and the basin and range topography with no external drainage. The entire geologic history of Utah has played an underlying role in the locations of human settlement, industry, and recreation throughout the state, and will continue to have such influences well into the future.

Erosion

Erosion has had a tremendous influence on Utah's mountains for millions of years. As mountains are uplifted through plate tectonics, the process of erosion is continually, but very slowly, tearing them down. Over vast amounts of time, mountains are eroded, creating a vast network of canyons, to alluvial fans in the valleys and plains below.

Erosion Types, Effects, and Causes

Erosion is the process by which the land is worn away by water, wind, ice, or gravity. Bare soil has the highest erosion potential, and bedrock and vegetated soils generally have the least. Frozen soils are relatively erosion resistant, but as they thaw they are easily eroded. There are two general categories of erosion that occur today, natural and human-influenced. Natural erosion is generally considered to be influenced by climatic forces on the earth's surface, and is largely uncontrollable. This type of erosion has shaped our landscape in the past, and will continue to into the future. Such erosional forces can be accelerated by poor management of the landscape, such as unrestricted development, vegetation removal, overgrazing or other types of soil disturbance. In contrast, large efforts are more commonly being directed at reducing human influences on soil erosion.

Erosion occurs most commonly due to the force of water flowing across soil or rock. Some common types of water erosion include raindrop erosion, sheet erosion, rill erosion, gully erosion, and channel erosion. Raindrop erosion is the displacement of surface sediments caused by the impact of the gravitational force of raindrops. This type of erosion happens everywhere and is more gradual than other types of water erosion. Sheet erosion is caused by shallow sheets of water that flow over the soil surface. As it moves, the water picks up and relocates sediment downhill. Rill erosion is the result of concentrations of water that create small channels on the soil surface. Gully erosion is similar to rill erosion, but is much larger and may result in a combination of multiple rills. Sheet, rill, and gully erosion are usually caused by heavy precipitation events as water makes its way to into streams or rivers in the canyon bottoms and valleys below. Channel erosion occurs when channels become unstable due to increased flows or changes in upstream sediment loads. This type of erosion is common in streams and rivers during flooding events, and is considered a rapid form of water erosion that clouds the water with sediment, which can lead to stress and mortality in aquatic species.

Water in the form of ice can also be highly erosive. The constant freezing and thawing of water can break apart rocks and soil particles. Such effects are seen in the spring when rocks are broken apart from the soil surface and roll down hillsides or cliff faces onto roads. Erosion from ice formation most often occurs at higher elevations, and the hoodoos of Bryce Canyon National Park is a great example.

Another type of ice erosion occurs from the movement of glaciers. Glaciers erode the landscape as the extreme weight of a glacier progresses downhill due to the force of gravity. As it moves, it pulls rocks and soil along with it, depositing them in moraines as the glacier melts at lower elevations or as the temperature rises. Although glaciers had a significant effect upon the landscape thousands of years ago, they do not exist in Utah today.

Wind, in contrast, is caused by airflow between areas of high and low pressures. It is another common type of erosion, especially in areas where soils are lighter or unstable, such as the sand dunes of Little Sahara Recreational Area in central Utah. These dunes form from remnant sands of Lake Bonneville as they are carried and deposited by the prevailing winds. They continually move northeast by about 5-10 feet each year. Wind also plays a role in mountainous areas, affecting snow distribution, vegetation growth, and soil erosion. It is a critical factor in determining where vegetation is able to grow, which then affects the stability of the soil surface to resist erosion.

There are five primary factors that contribute to erosion. They include rainfall and climate, soil erodibility, slope length and steepness, cover, and land use. As slope steepness increases, the gravitational eroding force is also greater; as slope length increases, increased distance increases erosive forces caused by momentum; and as plant cover increases, roots hold the soil together and prevent sediments from being lost. Soil erodibility is a measure of how easily a substance is moved or broken free from the soil surface. Lastly, land use practices may include wildlife management, livestock grazing, road construction techniques, recreational activities, or urban development.

Future of Erosion

Although many things can be done to reduce the amount of erosion (e.g., beaver dams that slow stream flow and trap sediments, stabilizing the soil by increasing plant cover, or limiting the amount of disturbance), erosion will always happen. Erosion continues to shape the landscape today as it has in the past, and its effects will be greatly seen upon the mountains that surround us. Over millions of years, erosive forces will continually alter slopes and carve out canyons, transporting vast amounts of sediment to the valley floors below, just as it has throughout Utah's geologic past.

Erosion will alter habitats, affect wildlife and ecosystem functions, and change the appearance of the landscape over time. There is uncertainty, though, as to how much human-caused actions will affect erosional processes in the future. This is difficult to determine because of the large amount of variation in climate (e.g., precipitation and flooding) and other factors (e.g., vegetation cover, soil composition).

Glaciation

What are Glaciers?

A **glacier** is a persistent body of ice that is largely made up of re-crystallized snow, and shows evidence of downward or outward movement due to gravitational forces. During periods of colder temperatures and higher snowfall, glaciers can form in high mountain ranges. If there is enough snow accumulation, the mass of the glacier causes it to flow slowly downhill through existing canyons. Glaciers are semi-permanent because they do not melt each year. But, over thousands of years, climate change can result in warmer temperatures that will facilitate melting. The two general glacial categories are **temperate glaciers** and **polar glaciers**. Temperate glaciers have internal ice temperatures that are near the melting point, but polar glaciers always maintain a temperature well below its melting point. Most glaciers that still occur today are found within the polar regions.

Mountain glaciers are relatively small glaciers that can occur at high elevations. The smallest of such glaciers originate in and help to create bowl-shaped depressions called cirques near mountain peaks. As the glaciers grow in size, they may spread down canyons and into the valleys and are called **valley glaciers**.

If these valley glaciers extend to sea level, they can carve steep, but narrow, valleys called fjords into the coastline, and are called **fjord glaciers**. If a valley glacier extends onto a gentle slope beyond the mountains, it is called a **piedmont glacier**. When glaciers cover an entire mountain range, it is considered to be ice capped. **Ice sheets** are the largest type of glaciers on the earth. Modern ice sheets cover both Greenland and Antarctica, and contain 95% of the world's glacial ice. Ice shelves are the last type of glacier, and are characterized as floating ice sheets that can be over 3,000 feet thick.

Glaciers often fluctuate in size, but annual change is usually gradual. Glaciers increase in size due to accumulations of snowpack with increased levels of compaction. Glaciers can also decrease in size through ablations, resulting in a loss of mass due to melting. Glacial movements are gradual, but are categorized into two groups- internal flow and basal sliding. Internal flow is caused by a deformation of ice crystal structure, resulting in the sliding of individual layers across other layers, and can occur in both polar and temperate glaciers. Basal sliding is caused by melt water at the base of a glacier, which lubricates and reduces friction between the layers. This type of glacial movement only occurs in temperate glaciers.

Glaciation

Glaciation is the modification of the Earth's surface due to the movement of glaciers. The evidence of glaciation in our relatively recent history is still present on the landscape. As glaciers move, they pick up and transport sediments that are deposited when the glacier recedes. Landscapes that have been shaped by glaciations have characteristics of both glacial erosion and glacial deposits. **Glacial cirques** are semi-circle basins that are formed on mountainsides, and mark the start of glacial advances. These cirques often fill with melted glacial or snowmelt water and form kettle lakes. **Glacial canyons** are formed when canyons that contained glacial ice are eroded into a U-shaped canyon (e.g., Little Cottonwood Canyon), rather than a V-shaped canyon that is caused by stream erosion (e.g., Mill Creek Canyon). As these U-shaped canyons are formed, sharp knife-edge-like ridges called **arêtes** are formed as two glaciers erode adjacent canyons.



The characteristic U-shaped glacial Little Cottonwood Canyon. (Image by M. Larese-Casanova)

Common types of glacial deposits include till, moraines, and glacial erratics. **Till** is a heterogeneous mixture of sediments that is deposited directly from the ice. There are multiple types of **moraines**, but moraines are generally considered till deposits that are different from the underlying bedrock. They commonly create small rocky ridges at the bottom of a mountain. Ground moraines are deposited directly beneath glaciers; lateral moraines are deposited along the sides of moving glaciers; arcuate moraines, also known as terminal moraines, are low-elevation deposits that were formed at the end of a glacier as it recedes; and medial moraines are deposits formed where two valley glaciers merge. Glacial moraines are

common at the mouth of Little Cottonwood Canyon. **Glacial erratics** are large rocks that have been carried down slope by glacial ice, and range in size from a pebble to a house.



Large glacial erratics can be seen along the sides of Little Cottonwood Canyon. (*Image by M. Larese-Casanova*)

Other types of glacial evidence that are common in Utah include glacial striations and hanging canyons. **Glacial striations** are a series of long, straight, parallel grooves that have been scratched into the bedrock by rock fragments that were lodged at the base of a moving glacier. **Hanging canyons** occur where shallower side canyons meet the deeper main glacial canyon. Waterfalls can often be found at these locations. These features can be seen in many places throughout Utah, including in the Uinta Mountains, Big Cottonwood Canyon, Little Cottonwood Canyon, and other areas of the Wasatch Range.

Glaciers in Utah

Although glaciers have occurred multiple times throughout Utah's history, the most recent glacial period occurred between 30,000 to 10,000 years ago. During this time, glaciers advanced and retreated as a result of climate fluctuations. Lake Bonneville reached its highest point around 18,000 years ago. At that time, the climate was 15-18°F (8-10°C) cooler, likely with more annual precipitation than what currently exists. Lake effect precipitation from Lake Bonneville contributed largely to the glaciers of the Uinta and Wasatch Mountains during this time period. Large snow accumulations, which formed above 8,200 feet in the north and 10,000 feet in the south, advanced down-slope over time to elevations as low as 5,000 feet. The Uinta Mountains claim the largest glacial coverage, around 1,000 square miles, with individual glaciers as long as 27 miles. The Wasatch Mountains had the second largest glacial coverage, with over 60 glaciers throughout the range. During the Pleistocene, at least 50 glaciers occurred in the Wasatch and Uinta Mountains that were larger than a mile in length. Many other smaller glaciers also occurred. The Aquarius Plateau, located east of Cedar City in south-central Utah, was another major glaciated area that covered over 50 square miles. Because younger glacial advances typically scour away older glacial deposits, glacial records are remarkably incomplete.

The largest alpine glaciers were once found in Utah's highest range, the Uinta Mountains. Evidence of such glacial activity is seen in the vast number of moraines, U-shaped glacial canyons, hanging valleys, striations, glacial erratics, and cirque basins with kettle lakes. The north side of the range held numerous long-valley glaciers, while the south side was dominated by larger, but shorter glaciers. The larger glaciers

of the south were due to larger snow accumulations as a result of gentle dips in the bedrock and a gentler slope, which had resulted in less movement to lower elevations. The steeper dips in the northern bedrock, did not allow for such accumulations to occur, but spread out over longer distances instead.



The soft, rounded peaks of the Uinta Mountains are remnants of an active glacial past.

Similarly to the Uintas, parts of the Wasatch Mountains were also sculpted by glacial ice. The most dramatically affected areas include Little Cottonwood Canyon, Big Cottonwood Canyon, and Bell's Canyon, with significant evidence of many types of glacial erosion and deposits. These glaciers filled the canyons and tributaries with hundreds of feet of ice. Unlike Big Cottonwood Canyon, Little Cottonwood Canyon glaciers reached Lake Bonneville and calved large icebergs into the lake. More southern mountains in the state also show some glacial evidence, such as the La Sal, Henry, Abajo, Boulder, Sevier, Pahvant, and Tushar Mountains. However, glaciation in these southern mountains was limited and glaciers were small. Glaciers largely disappeared from Utah around 7,000-8,000 years ago during the most recent warming trend. Some small glaciers may have occurred within the state during the Little Ice Age 150-500 years ago. Currently, only snowfields occur in the state. Unlike glaciers, snowfields typically do not move, are usually only a few feet thick, and can sometimes completely melt during peak summer temperatures.

Interesting Ice Age Animals

Technically speaking, an ice age spans over millions or tens of millions of years and is separated by glacial periods and interglacial periods that coincide with temperature fluctuations. The last major ice age occurred during the Pleistocene Epoch, lasting from 2 mya to about 10,000 years ago. This was an interesting period of Utah's history largely because of the wildlife that occurred here. During this period, the Bering Land Bridge connected Eurasia to North America, allowing the migration of animals between the two continents. Some of the large and interesting animals that once occurred here as a result of this ice bridge included the mammoth, mastodon, saber-toothed cat, giant ground sloth, camels, musk ox, long-horned bison, short-faced bear, and horses. These species are known as the **Pleistocene Megafauna**, which went extinct around the end of the ice age, about 10,000 years ago. Many of the species that occur in Utah today are smaller relatives of these extinct Megafaunal species.



Ice Age mammals that once roamed Utah. (Image from USU Eastern Prehistoric Museum)

Climate

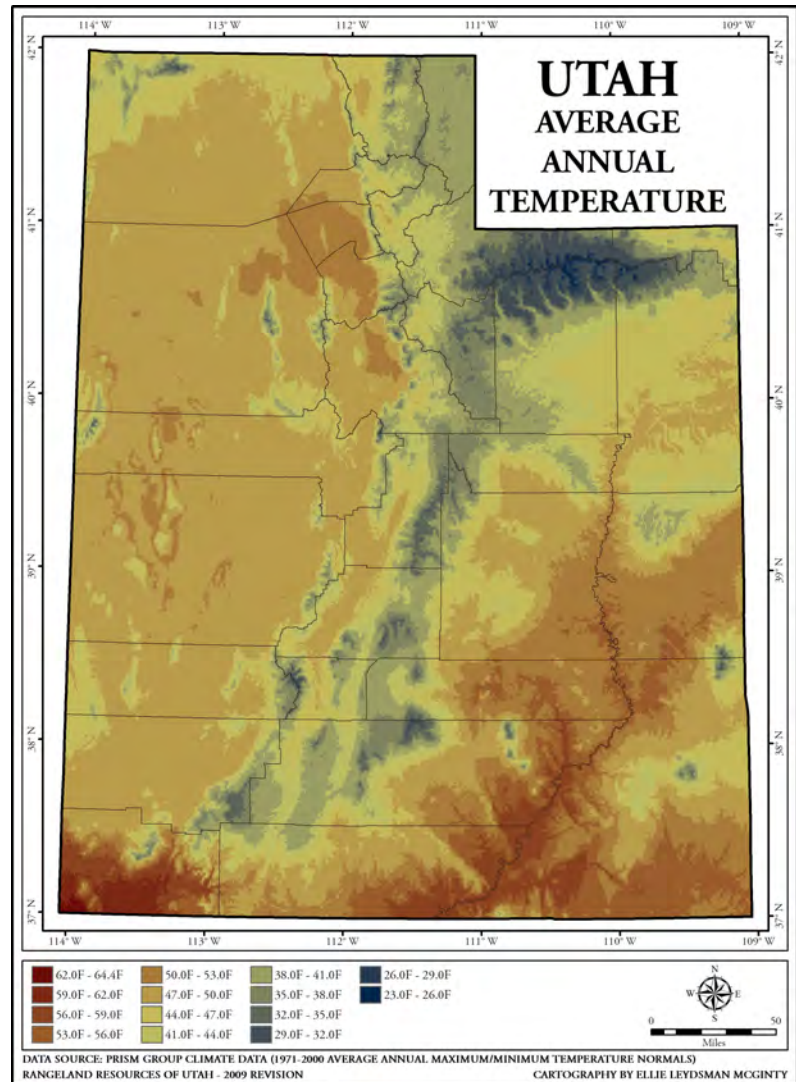
Throughout the history of the earth, Utah's climate has been warmer and colder, as well as wetter and drier than it is today. The major determinants of climate in Utah include the distance from the equator, the elevation above sea level, the location with respect to the Intermountain storm path, which includes rain shadow effects, and the distance from a principal water source, such as the Pacific Ocean. Utah's climate largely controls the vegetation, habitats, and animals that can exist on the landscape. Today, Utah's climate is relatively variable, usually with a large amount of variation from daytime highs to nighttime lows. A variety of extreme weather phenomena are known to occur within the state including flash floods, snowmelt floods, hailstorms, tornadoes, blizzards, and droughts. Hurricanes are probably one of the only weather related disasters that have not significantly affected the state.

Mid-elevation mountains have particularly cold winters and cool summers. Above treeline, these landscapes have a tundra climate that is too cold to promote plant growth. Alpine climates are usually characterized by exaggerated climatic conditions, even during the summer months. Mean monthly summer temperatures in these mountainous climates are usually below 72°F, however in a single day, alpine temperatures can range from above 90°F to below freezing. Because Utah is situated between 37° and 42° north latitude, it receives less solar energy than the equator but more solar energy than the poles. Because of the earth's axis, this results in distinct seasons throughout the year. Utah is also in the zone of the prevailing Westerly Winds.

Temperatures

Utah is a state full of sunshine. Salt Lake City, on average, receives 67% of all possible sunshine annually, with an average of 125 clear days, 101 partly cloudy days, and 139 cloudy days a year. July is Salt Lake City's sunniest month, receiving 83% of all possible sunshine. Typically, temperatures will reach above 100°F in many of Utah's valleys at least once during the summer, but areas over 10,000 feet will seldom ever reach over 80°F. Nighttime temperatures during the summer, above 10,000 feet, are commonly around 30-40°F, reaching freezing temperatures regularly. Alpine tundra has the coldest climates, where temperatures are too cold to permit the growth of trees. Sub-zero temperatures occur during most winters in all but the warmest, southernmost areas of the state. January is generally considered to be the coldest month of the year. The lowest, recorded, minimum temperature in the state was on February 1, 1985, at Peter Sinks, which is located at the top of Logan Canyon, with a temperature of -69° F. The highest, recorded maximum temperature in the state was on July 5, 1985, in St. George, with a temperature of 117°F.

Utah's temperature varies greatly between different seasons, elevations, and latitudes, and can even have large variations between daytime and nighttime temperatures. Daily fluctuations are usually caused by the amount of cloud cover. Clouds can moderate the amount of temperature variation, keeping daytime temperatures lower and nighttime temperatures higher. Maximum daily temperatures are reached around 2 p.m. throughout Utah's mountains, and daytime lows at approximately sunrise. Utah's mountains and mountain valleys are relatively cooler than the rest of the state. At Alta in Northern Utah, 8,700 feet in elevation, mean annual temperature is 37.9°F. Mean annual temperature in the Salt Lake Valley near Alta, at around 4,220 feet in elevation, is 51.6°F. At Brian Head in Southern Utah, 9,770 feet in elevation, mean annual temperature is 34.6°F. Mean annual temperature in the Cedar City Valley, at 5,610 feet in elevation, is 50.4°F. Generally, there is an average of 3-5°F decrease in average yearly temperature for every 1,000 feet increase in elevation, and 1°F decrease in average yearly temperature for every 1 degree



increase in latitude. Generally, this leads to an average of 6°-8°F warmer in southern mountains and valleys than northern ones of the same elevation. During the summer in the Uinta Mountains, nighttime temperatures commonly drop below freezing and high daytime temperatures may never exceed 65°F.

However, there are many exceptions to the rule in Utah. Strong **inversions** that occur in many of Utah's valleys occur when the air near the ground radiates heat, resulting in warmer, lighter air above the colder, heavier air. This creates a stable and stagnant weather condition at lower elevations, up to 2000 feet above the valley floor, and traps pollution and extensive fog in the valleys. During the winter months, this cold valley air created by such inversions can often be cooler than the mountain air found at higher elevations. Also, urban areas are usually warmer because they absorb more of the sun's heat than rural areas, and areas near water are moderated by the water's temperature. For example, five different sites in the Cache Valley had average freeze-free periods ranging from 111 days to 159 days; and five different sites in the Salt Lake City area had average freeze-free periods ranging from 167 days to 214 days. Higher up in elevation, the effects of external factors are less significant. In the Ephraim area, three mountain sites ranging from alpine meadows to oak forests, significantly larger elevation differences than in Logan and Salt Lake City, had average freeze-free periods ranged from 81 days to 87 days.

Aspect also has an effect on temperature because of how the sun is reflected, radiated, and absorbed by the earth's surface and surrounding vegetation. Southern and western slopes tend to be warmer and

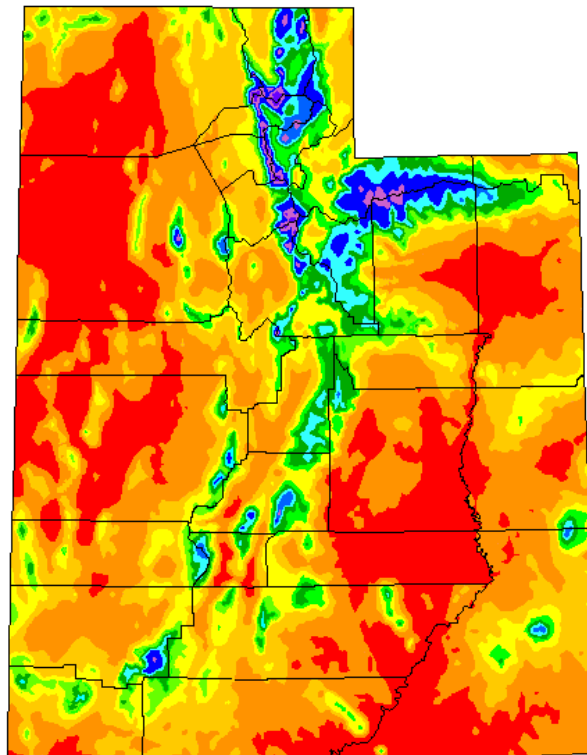
drier due to the greater amount of exposure to direct sunlight. The hillsides absorb solar radiation during the day, and radiate it back into the atmosphere at night. Some southwestern aspects can be free of snow for the entire year, providing important winter habitat and forage for birds and mammals during this harsh season. Northern and eastern aspects receive limited direct sunlight, and radiate less heat back to the atmosphere. At higher elevations, some northeastern aspects can be covered with snow for the entire year, especially within glaciated cirques, which tend to trap colder air.

Precipitation

Precipitation in Utah is extremely variable, ranging from 2-3 inches per year in parts of the Mojave Desert to over 60 inches in parts of the high northern Wasatch Mountains. The majority of precipitation occurs from late-summer to early spring, and peaks during the coldest month of the year, January. The mountains of Utah receive the majority of their precipitation in the form of snow. This winter precipitation usually originates from low-pressure systems coming out of the northwest, where cold arctic air encounters the relatively warmer pacific waters. Because Utah is the second driest state in the nation, high altitudes and lower temperatures commonly produce the cold, dry dendrite flakes, also known as powder. These light, fluffy snowflakes have given Utah the title of having the “Greatest Snow on Earth.” The state’s snowpack is usually present from November to June, with some areas retaining snowpack throughout the summer. The Great Salt Lake has a unique influence on its local climate, called the lake effect. In the Wasatch and Uinta Mountains, lake effect snowfall significantly contributes to the local annual snowpack.

Unlike winter precipitation, summer precipitation is mostly a result of localized storm systems. As the sun warms the mountains and valley floors during the day, warm air rises up the mountains in the afternoon. This moist, warm air cools as it rises, causing condensation and precipitation. In most cases, summer precipitation is irregular and isolated, and usually occurs between July and September.

Similar to temperature, elevation significantly affects the amount of precipitation Utah mountains receive. Mountains on average receive from 100 to 500 inches of snow, and from 25 to over 60 inches of precipitation each year. Some areas of southwestern Utah only receive 10 inches of snowfall annually, while other areas within the Wasatch Range have had a maximum of 700 inches of snow pack during the high precipitation year of 1983-1984. Areas throughout the state that are less than 4,000 feet in elevation, receive less than 10 inches of precipitation annually, and agricultural lands generally receive between 10-16 inches. Because precipitation increases with elevation, precipitation and snowfall maps tend to resemble topographic maps. Although precipitation in alpine areas is



Legend (inches per year)			
Red	Less than 8	Green	24 to 28
Orange	8 to 12	Cyan	28 to 32
Yellow	12 to 16	Blue	32 to 40
Light Green	16 to 20	Purple	40 to 50
Dark Green	20 to 24	Dark Purple	More than 50

Average Annual Precipitation

Utah

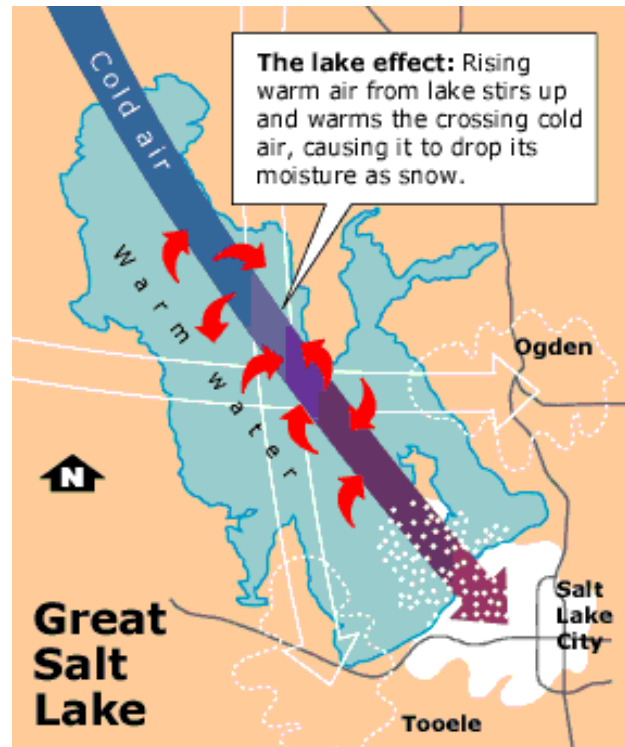
Period: 1961-1990 Units: inches

plentiful, freezing temperatures make it unavailable to plants for 8-10 months of the year. Typically, slow snowmelt in the spring and summer provide water during the dry season. As a result, 85% of the state's residents live along the Wasatch Front, and receive their water from the numerous snowmelt-fed rivers and streams. Occasionally, rapid spring warming can cause excessive flooding or even drought.

Utah's wettest water year on record since 1895, occurred in 1994-1995 when the state as a whole averaged 16.67 inches of precipitation. Utah's driest period since 1899, was recorded in 1976, when the state as a whole averaged only 7.7 inches of precipitation. Utah's most severe winter since 1899, occurred during 1948-1949. It was the coldest winter on record, with an accumulation of 78 inches of snow at the Salt Lake City Airport, and resulted in the deaths of 10 people due to the direct effects of the weather.

Lake Effect

The Great Salt Lake has a noticeable effect on the local climate of Northern Utah. The high salt content of the lake, 15-25%, prevents most of the lake surface from freezing during the winter months. Open water naturally adds moisture to the air flowing over the lake, which enhances precipitation over the Wasatch Mountains as the moist air rises over the mountains. **Lake effect** snowstorms usually occur 5-6 times per year during the late fall or early spring. This usually occurs when cold northwest storms move over the warmer Great Salt Lake, where the warmer, moist lake air rises into the cooler storm air. One of the largest lake effect storms occurred in October 1984, when up to 2 feet of snow fell on the benches of the Salt Lake City area, causing over 1 million dollars in damage. The lake is also responsible for the valley's average 8-12 mph daytime winds that occur, which can lower afternoon temperatures by 2-4° F.



Lake effect snow in the Salt Lake area.
(Image from Salt Lake Tribune)

Floods and Droughts

The majority of agricultural areas within the state require irrigation water to adequately grow most crop species. Fortunately, most of these areas are adjacent to mountains, which usually provide adequate amounts of stored mountain runoff to irrigate. During periods of extreme drought, which occur every 24 years and last for about 5-10 years on average, limiting water resources presents a major problem to irrigating farmers, as well as the general population. Scientists have discovered five droughts similarly to the Dust Bowl period of 1929-1940, and 12 droughts similar to the dry spell of 1946-1956, which have occurred within the United States, and include Utah, during the last 500 years.

On the other end of the spectrum to drought, flooding is also a serious problem. On average in the United States, 300,000 people are driven from their homes, 135 people are killed, and around \$2 billion worth of property is damaged or destroyed each year. In Utah, most flooding occurs seasonally during spring snowmelt and runoff, but can also occur as flash floods. Snowmelt floods usually reach their peak during May or June, and are usually caused by a mix of high snowpack and warm springtime temperatures. Dramatic warming during the spring of 1983 caused rivers to rise dramatically throughout Utah, which resulted in flooded, sandbagged streets in Salt Lake City and inundated highways in Juab, Utah, and Millard Counties.

Flash floods are another type of natural danger in Utah. When areas are subjected to heavy, localized rainfall that accumulates in a very short time period during summer thunderstorms, flash floods can occur in dry stream channels and perennial streams. These flash floods rip through river beds, urban streets, and mountain canyons, moving boulders, uprooting trees, washing away roads and automobiles, and destroying buildings and bridges. Most flash floods in the state cause minimal damage, but a few have been significantly destructive and deadly. One in particular, which occurred in the Sheep Creek area of Flaming Gorge in June of 1965, killed seven people. In Utah alone, over 360 flash floods and 170 snowmelt floods have occurred since 1853. Since 1950, flooding has resulted in 26 deaths, making it the second greatest weather-related killer in the state.

Avalanches

Utah's mountains have another serious risk that is created by climatic factors—avalanches. **Avalanches** form as successive layers of snow deposit throughout time. The dissimilar physical properties of each layer, such as density and water content, create weak points that result in the sliding of two different layers across each other to create an avalanche. Factors such as fluctuating temperatures, wind speed, and wind direction contribute to avalanche formation. There are multiple types of avalanches, but the two general types are dry slab and wet avalanches. **Dry slab avalanches** are when large cohesive plates of snow slide as a unit on the snow underneath, and can reach speeds of around 80 mph. These avalanches can lie patiently for months until triggered by something or someone. **Wet avalanches** are usually caused by increasing air temperatures or rain that causes water to percolate through the snowpack and weaken the snowpack. Once initiated, wet avalanches travel at about 20 mph, significantly slower than dry-slab avalanches. The dangers of many avalanches can be avoided by staying away from high-risk areas where they occur. Avalanches most often occur on slopes between 25 and 45 degrees, because of drifts and cornices created by wind deposits; during snowstorms (about 90% of avalanches), and when triggered by the weight of humans or their activities (about 90% of avalanches). Since 1958, approximately 110 people have died in avalanches in Utah.

Relative Humidity

Although Utah is the second driest state in the country, and generally has a low relative humidity due to its desert climate, Utah's mountains create a mid-latitude highland climate. The relative humidity of Utah's mountain ranges is high compared to the rest of the state, which contributes to the characteristic cold winters and cool summers that occur in these areas. On average, the relative humidity of the state's mountain ranges is generally highest in the morning, and lowest around noon. Broad leaf forests and woodlands are the exception, where increased transpiration from the larger leaf area, increases the daytime relative humidity. A narrow belt of relatively humid climate exists along the Wasatch Front, where annual precipitation exceeds the potential evapotranspiration rate. As a result, the majority of Utah's population, industry, and agriculture occur in this area. One interesting fact about Utah's humidity is that the average Utah home has a relative humidity of less than 15% during the winter months, which is drier than the Sahara Desert.

Wind

Winds are a result of unequal heating and cooling of the earth's surface, pressure differences, and topography. The direction of Utah's prevailing winds varies with latitude and topography. Winds are generally strongest on higher, exposed ridges, and least severe on leeward slopes and protected sites. General canyon winds follow a daily pattern, where cold air from mountain tops travels downward in the

mornings to mix with the warmer valley air below. In the evenings, flow reverses and warm air from the valleys moves upslope to mix with cooler mountain air.

Other than general canyon winds, there are six other major types of wind including Southerly, Northerly, Easterly Canyon, Westerly, Thunderstorm, and Tornadic winds. Southerly winds, also called desert winds, usually occur in the western valleys of Utah. They bring warm air up from the southwestern deserts ahead of an approaching storm or cold front. One of the highest desert wind speeds was a 93 mph wind gust. Average wind speeds calculated for an elevation of 10,000 feet above sea level, ranged between 25 and 35 mph depending upon location.

Northerly winds usually occur during or just after the passage of a strong cold front or low-pressure system. One of the highest northerly wind gusts at a mountain location was 124 mph at Snowbird's Hidden Peak (11,000 feet above sea level). Easterly Canyon winds are a form of topographic wind that creates serious problems several times each year. These winds usually occur when a strong high pressure develops over southern Wyoming and a deep low pressure develops over southeastern Nevada. Surface pressure differences between the two areas can create winds in excess of 74 mph gusts out of canyon mouths along the western slopes of the Wasatch Mountains. The highest recorded Easterly Canyon winds, 120 mph, were recorded in Ogden, Bountiful, Sundance, and Park City at different times. Westerly winds usually occur during the passage of a strong cold front. These winds are common throughout the year in the Wasatch Mountains, but are relatively uncommon in the Uintas during the summer. Westerly wind gusts have been recorded up to 77 mph. Thunderstorm winds are associated with lines of thunderstorms called squall lines. These large thunderstorms can produce strong downdraft winds called microbursts, which flow out in all directions once they reach the ground. The highest wind-gust microburst ever recorded was 121 mph. Tornadic winds are rare in Utah, but are the winds associated with tornado activity. The highest wind speed associated with a Tornadic wind was 89 mph.

Hydrology

The hydrologic cycle is the continuous circulation of water between oceans, continents, and the atmosphere. It can be thought of as a machine of endless motion, powered by the sun's energy, and assisted by gravity. The same water has been circulating since the first rains fell on the earth, with very little water ever lost or gained. Continental water consists of only 2.5% of our planet's water, mainly in polar ice caps and groundwater, and atmospheric water consists of as little as 0.0001%. The remaining 97.5% of our planet's water is in the oceans. Evaporation, which uses the sun's energy or heat to convert liquid water molecules into gas, is the primary outlet for water movement from the world's oceans. Evaporated water stays in the atmosphere for an average of 10 days before being dropped as rain, snow, or condensation back to the earth's surface. In general, land water will inevitably infiltrate groundwater, flow across the surface of the earth, or become glacial ice, which will eventually flow back to the sea.

This is, however, a simple description of a complex system, and not all water finishes the complete cycle every time. In Utah, a significant portion of the state's precipitation does not end up in the oceans; instead it ends up in the Great Salt Lake's terminal basin. This Wasatch Front hydrologic sub-cycle requires evaporation to continue the complete hydrologic cycle. Many factors, such as temperature and wind, control the rate of such hydrologic functions. Evaporation, however, typically only transports water molecules, and leaves behind accumulations of nutrients, minerals, and even toxic substances in the Great Salt Lake ecosystem. About 2.5 million tons of minerals flow into the Great Salt Lake each year, and approximately 2 million tons of those minerals are extracted by private companies to be used in making products such as fertilizers, water softener salt, road salt, bleach, and detergents.

As mentioned previously, the majority of Utah's precipitation is received during the winter months as snow. In some mountain areas, high precipitation totals can last from August to April. However, mountain locations can receive as much precipitation during the summer as valley locations receive during the winter months. Because mountains are higher in elevation, summer clouds have to increase in altitude to pass

over them, and cannot hold as much moisture as they did at lower elevations. Mountain snowpack totals can reach up to 700 inches/year in some areas, but averages range between 100-500 inches depending on the location and year. This snowpack provides a unique annual hydrograph that does not necessarily follow a graph of annual precipitation. Although the snow is generally received from December through March, the majority of water does not show up in Utah's lakes and streams until May and June. This can be seen by comparing annual precipitation graphs to annual river flow graphs, which are called hydrographs. Hydrographs plot the changes in discharge of a river over time, and discharge units are measured in either m^3/s or $feet^3/s$. Although the moist conditions and cooler temperatures at higher elevations are critical for providing growing conditions in Utah's mountains during the summer, the precipitation stockpiled within the mountains is more critical to sustain life at lower elevations. The water received by Utah's mountains supply significant resources to the wildlife, plant communities, and human communities that occur from the alpine zone to the desert valleys below.

Stream Flow and Reservoirs

Surface water and groundwater are constantly interacting. As water seeps into the soil, it replenishes the water table. When the water table is level with the surface water, ground water feeds back into the surface water. Vegetation also has an impact on watershed function. Upland areas, which do not grow directly on the river's shore, can intercept the water to be used by plants, slow the flow and collection of water in order to reduce erosion, and allow more time for groundwater recharge to occur. Riparian vegetation, which grows directly by a water source, has the same properties as upland sites, but it also provides support to the banks of the stream channel in order to prevent massive erosion events during high flows.

Water accumulates via surface flow exponentially from higher elevations to lower elevations as smaller tributaries progressively empty into larger rivers. These major rivers accumulate large quantities of water that are often stored in reservoirs, and used for multiple purposes. These reservoirs were largely created to store water for irrigation and drinking throughout drier portions of the year. Many of these dams can also provide hydroelectric power, create various recreational opportunities, provide sediment traps for eroded materials, and help mitigate the effects of flooding by slowing the flow rate and keeping the discharge rate constant. However, dams have negative consequences as well. Reservoirs increase surface area of the water, which increases the amount of water lost through evaporation. They also interfere with the natural flow cycle of a river, remove the natural ecosystem services of flooding that will result in a loss of natural river channel characteristics, and negatively affect native plant and animal species, such as blocking migrating salmon. The impacts of dams can be managed by manipulating the discharge to more closely resemble the natural flow of these rivers.

Utah's Hot Springs

Although Utah is not particularly known for its hot springs, over 100 occur throughout the state. Many of these springs occur along the Wasatch fault line, at the base of the Wasatch Range. The ultimate source of this water is the precipitation that falls on the mountains above. As this water melts, a portion of the runoff water percolates into the ground, and slowly migrates downward through the bedrock. Heat that originates within the earth's interior slowly warms this descending ground water. This heated ground water can then quickly reach the surface again, from depths of over 5,000 feet, through faults and fractures in the earth's crust. The temperature of the water depends upon how deep the water circulates, and the thermal gradient of the earth's crust at different layers.

Soils

Soils are a complex product of (1) mechanical and chemical breakdown, erosion, and transportation of parent material by moving water, ice, or wind, (2) leaching and deposition of chemicals and nutrients, and (3) organic growth and decomposition. Along with water and air, soil is also a particularly important natural resource to ecosystems. It provides physical support, minerals, and a home for billions of microbes, plants, and animals. In general, soils of the mountain regions in Utah are slightly alkaline to neutral, with thick, dark-colored organic horizons at the surface.

Soil Types

Mollisol soils make up the majority of mountainous soils within the state. These soils are characterized as thick, dark, and relatively fertile. They typically form under grassland vegetation in sub-humid woodland zones, or under aspen and understory forbs and grasses in forested zones. Mollisols are considered rich in dead and decaying plant matter called **humus**. Humus stores mineral nutrients, contributes to the nutrient and water holding capacity of the soil, and gives the soil its dark color. These soils usually occur where annual precipitation exceeds 12 inches per year and at elevations above 5,000 feet. General sites include lake terraces, alluvial fans, foothills, mountains, high plateaus, and valley bottoms. The pH levels in Mollisol soils are generally moderately alkaline due to the high levels of calcium and magnesium in the parent material— the limestone from ancient coral reefs. These soils are among the most productive agricultural soils, and at higher elevations, they support various rangeland and wildlife habitat types.

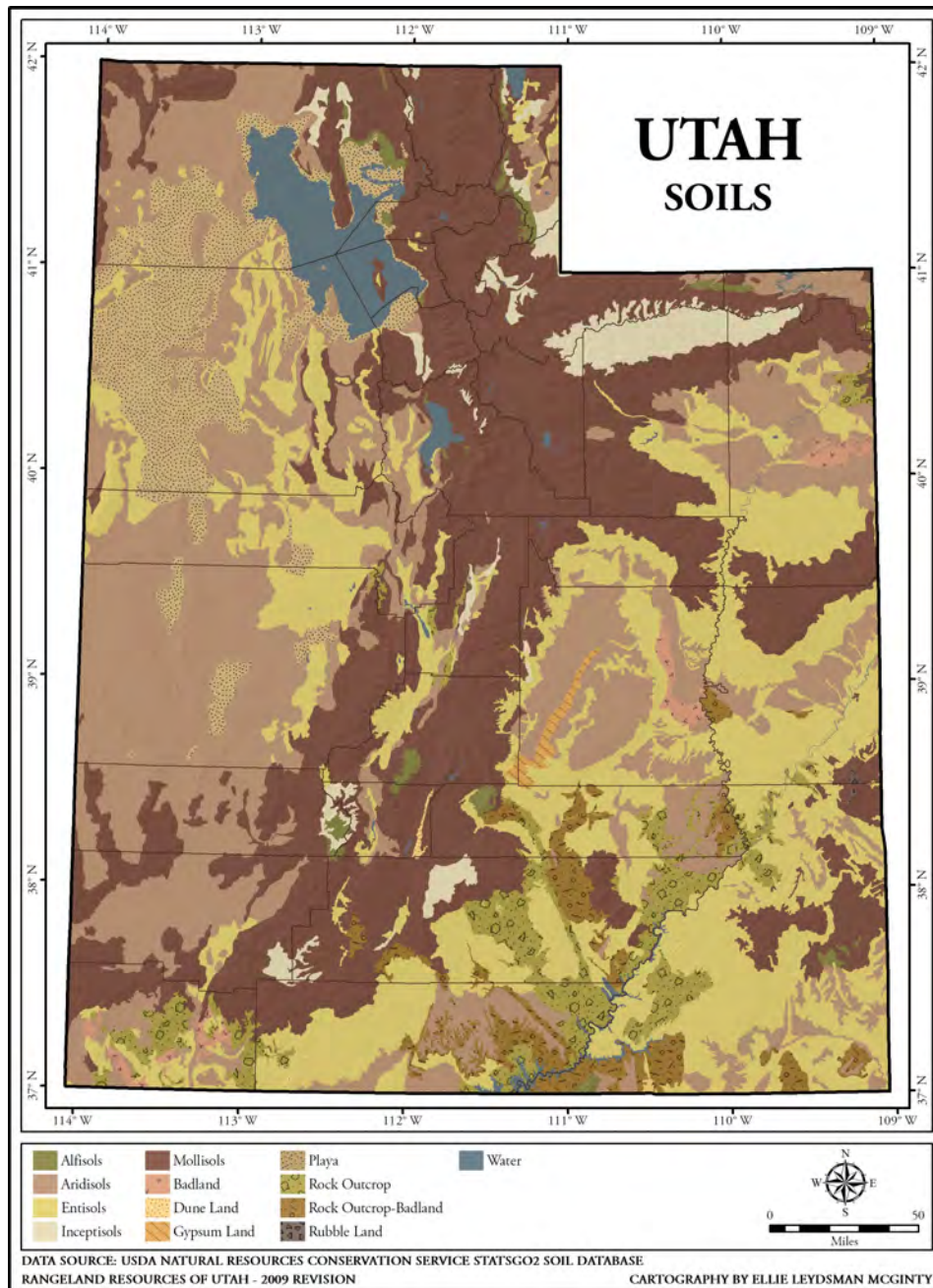
Inceptisol soils make up the majority of soils in the alpine zone. The soils in this order are poorly developed, and are found on relatively young geomorphic surfaces. They are generally found in semiarid, sub-humid, and cool humid climates. A sizeable portion of Utah's inceptisol soils occur in mountainous areas, occupying steep slopes with south or west aspects. Sub-surface horizon layers, in Inceptisol soils, are characterized by translocating carbonates, brighter soil colors, and more development than the surface layers.

Alfisol soils are generally found in temperate humid or subhumid regions of the world, but some suborders of Alfisol soils occur in the high mountains of Utah, specifically under conifers and other timber. These soils are characterized by a thin organic layer, a thin dark surface horizon, and an underlying pale sub-surface horizon where clay has moved to the subsoil layers. These soils are generally strongly alkaline.

Entisols are soils of recent origin and do not have discernible horizon layers, with exception of some darkening of the surface. These soils usually occur on younger alluvial areas, along some valley bottoms, and on stream floodplains.

Wasatch Range and Plateau Soils

The Wasatch Mountains are very complex, which often make them hard to generalize. Although the soils within this range primarily originated from sedimentary rocks such as limestone or sandstone, other types of parent materials, such as quartzite, are locally present throughout the range. The majority of soils are considered to be Mollisols, but some Inceptisols occur on the highest elevation sites. Alfisol and Entisol soils do exist, but occupy localized areas such as flood zones. The pH of this mountain range is generally considered to be near neutral or slightly alkaline, although most high alpine areas are usually considered to be acidic (this is true for most mountain ranges in Utah). The Wasatch Plateau soils generally have a clay texture, with a dark organic soil layers, and are generally slightly acidic. Bedrock on the top of Utah's high plateaus generally originated from lava, and soils are therefore usually thin and rocky.



A general soil map of Utah. (Image from USDA Natural Resource Conservation Service)

Uinta Mountain Soils

The soils of the upper Uinta Mountains originate primarily from metamorphic quartzite, but various sedimentary rocks, such as sandstone and limestone, also occur. Because the Uinta mountains primarily consist of quartzite bedrock, soils are usually underdeveloped and are deficient in available nitrogen for plant growth. The range has a large number of Inceptisol soils at high elevations and Mollisol soils at lower elevations. The soils that make up this range are slightly acidic, and generally have poor drainage characteristics, which commonly result in acidic, surface-water accumulations. These surface waters result in the formation of Sphagnum bogs, which are otherwise quite uncommon throughout Utah. Some of the major soil formations in this region consist of glacial cirques and rock outcrops. Alpine soils, like the ones

near King's Peak, were generally very sandy and are usually considered sandy loams. Lower elevation willow and meadow communities had a variety of soil types ranging from meadow Histosols to coarse-textured Molisols near streams.

Colorado Plateau Soils

The La Sal, Abajo, and Henry Mountain soils generally originate from sedimentary rocks such as sandstone. However, as those layers have eroded away to lower elevations, igneous rocks like quartz, which formed because of the magma intrusions during this ranges formation, have become more prominent in some areas. Soils in these mountains are usually characterized as Mollisols, similarly to those of the other ranges. Rocky outcrops, badlands, and rubble landforms are more common throughout this region than any other. Soils of the Henry Mountains are generally well-drained and loamy, but range from shallow to deep in structure.

Soil Landforms

Glacial cirques commonly result in large catchment of surface soil material from erosion. These soil accumulations allow for broad, montane meadows to form and persist on nutrient-poor sites where very little soil development has occurred since glaciations. Because of cool temperatures, abundant moisture, and relatively deep soils, cirque meadows are some of the best places to view wildflowers in summer.

Rock outcrops consist of exposures of bare rock and vary from rocky summits and talus slopes of the Uinta and Wasatch Mountains, to the sandstone outcrops of the Colorado Plateau, or to recent lava flows on the high plateaus. The surface area of rock outcrops consists of 50-75 percent bare rock, with the remainder being shallow soils. While rocky outcrops are often harsh environments, unique species including bristlecone pine, pika, and mountain goats, are well adapted to survive there.

Badlands are arid-land formations of softer sedimentary rocks and clay-rich soils that have been extensively eroded by wind and water. Badlands are associated with complex geological formations, including canyons, ravines, and gullies. The erosional processes of these formations tend to create irregular, jagged, and extraordinary landscapes. Portions of southern Utah are characterized by badland formations, such as Grand Staircase-Escalante National Monument.

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Mountain Communities

Soil Communities

Soil communities play a significant role as the foundation of ecosystems, providing structure for plants, and holding moisture and nutrients that drive productivity. Five ecological functions of soils have been identified, and include promoting plant growth, holding and releasing water, recycling minerals and other nutrients, transferring energy through the food chain, and acting as an environmental buffer. In mountainous regions, soil communities vary widely as a result of differences in parent material, topography, plant communities, and wildlife communities.

Parent materials of the soil provide a chemical backbone, which can affect soil pH, nutrient composition and fertility, soil type, and many other soil properties. In the Wasatch Mountains, soils tend to be neutral to alkaline in nature, and are composed largely of limestone rock. The tendency for a more basic pH soils is due to the chemical properties of limestone, which contains large quantities of an acid neutralizing agent called calcium carbonate (CaCO_3). The soils of the Uinta Mountains, on the other hand, tend to be more acidic because carbonate-based, acid neutralizing agents are not common. Instead, these soils are largely composed of pre-Cambrian quartzite rock, which resulted after sandstone was metamorphosed. The soils of the Uinta Mountains are also more poorly drained than the soils in the Wasatch Range. This is largely due to the particle size of the soil (sand vs. clay), which is controlled by the erosion properties of the parent material.

Topography can have a large impact on the development and function of a soil community. Steeper slopes, which are common in mountainous areas, prevent soil development of more than about 1 foot deep, largely because avalanches and landslides can strip the top-layer of soil from the slope. Since smaller soil particles are more easily erodible, steeper topography is usually comprised of coarse soil and rocks. Steeper slopes are also well-drained, because water is more likely to run off the surface layer or infiltrate through the coarse soil. This results in drier soils that limit plant growth and establishment that would help to stabilize the soil from excessive erosion. Similarly, upper montane forests also have shallow soils because of a shortened growing season during which development occurs. As a result, the shallow soils result in higher elevation forests being more susceptible to wind-thrown trees. Conversely, flatter slopes, bowl-shaped glacial cirques, and mountain benches tend to have deeper, moister soils. In these areas, runoff and erosion is limited, and large amounts of moisture and sunlight result in more vegetation and deeper soil layers. Fine-sediments, which have been eroded from adjacent steeper slopes, tend to accumulate in these areas. The finer sediments result in a greater water and nutrient holding capacity in these soils.

Plant species and communities, in turn, have a considerable influence on soil communities. Plant communities help determine soil composition largely by the amount of organic material that is produced on the soil surface. Conifer forests tend to have a shallow organic layers comprised mostly of needle litter and duff. Aspen forests produce more litter content than conifers, but do not have a very thick litter layer because leaves are decomposed and incorporated into the soil much quicker than conifer needles. This results in a thicker organic layer with less litter content. Upper montane forests usually have less leaf litter compared to lower montane forests because plant growth is limited by a shorter growing season. Upper montane forests often have little more than a thin veneer of organic material over the bedrock layer.

Additionally, many wildlife species contribute to soil structure and composition of mountain ecosystems. All animals (e.g., deer, elk, rabbits, squirrels) excrete waste that contribute to the organic layer of the soil surface. Solid waste is broken down by soil biotic organisms (e.g. worms, bacteria), and is again made available for plant uptake and growth. Animals are also critical in the dispersal of many other nutrients from one site to another, which creates a mosaic of sites with different soil compositions. For

example, red squirrels create piles of cone scales at the base of conifer trees, flickers and woodpeckers remove the tree bark in search of insects, and jays and other small animals hide nuts in ground caches. Animals also provide the key service of soil turnover. Small mammals, such as gophers and squirrels burrow through the soil, can overturn over 1/3rd of the upper soil layers each year, loosen the soil structure, and increase aeration and drainage properties of the soil. This service is more prominent in aspen forests than conifer forests. Even small insects, such as ants and termites play an important role in soil composition. They break down dead, woody debris, resulting in the accelerated decomposition of litter material.

Although humans tend to have less of a general effect on mountain soil communities, people have recently had a large impact on some local soil communities, through recreational and commercial activities. Soil surface and plant community disturbances can result in increased erosion and nutrient loss. Also, a loss of wildlife trophic level interactions, caused by overutilization of specific species, can result in a major alteration in the function and composition of any mountain soil community.

Oak-Maple Woodland

Abundance in Utah

Gambel oak and bigtooth maple can be found throughout most of Utah's mountains from 5,000-8,000 feet. These dense, low woodlands make up about 5-6% of Utah's forests. Although both species can grow together, oaks prefer southern aspects and maples prefer northern and eastern aspects. At their lower elevational limits, they may grow in conjunction with pinyon-juniper or sagebrush ecosystems. At the upper limit, they merge with aspen, ponderosa pine, or mountain mahogany. Oak dominate most sites, making up an estimated 25% of all the individual trees in Utah. Maples are only estimated as 3% of Utah's trees. Gambel oak is absent from Cache and Rich Counties in Northern Utah, due to their northern latitudinal or climatic limit on seedling establishment and survival, and sites are therefore dominated by maples in these areas.



A characteristic dense oak-maple woodland in Utah. (Image by M. Larese-Casanova)

Structure

Oak-maple woodlands are usually characterized by a dense and diverse understory in areas with moisture and deeper soils. However, dense stands can reduce the abundance of understory plant species

due to insufficient sunlight penetrating the canopy. Gambel oak tends to be less than 30 feet in height, but can grow as tall as 60 feet, and bigtooth maple tends to have several stems and can reach 50 feet in height. Neither species tend to grow more than 12 inches in diameter. They are adapted to a range of soil depths and soil textures which include silt loam, clay loam, sand, gravel, and cobble, and can grow in both moderately acidic and alkaline soils (pH range 6-8). Historically, more extensive grass cover allowed for more frequent fires, which inhibited oak and maple seedling and sapling establishment. Due to longer fire intervals, increased livestock grazing, and changing climatic conditions, increased oak and maple establishment has resulted in higher densities. This has caused a reduction in sunlight, decreasing understory production.

Composition

Oak and maple prefer moist, deep, well-drained soils, and are usually oak-dominated. These sites have more herbaceous understories with snowberry, serviceberry, chokecherry, big sagebrush, and wild rose as common shrubs. Drier sites, with shallower soils, have less understory vegetation and are often interspersed with stands of curl-leaf mountain mahogany. The understory can include an average of 25 different plant species including cheatgrass, rabbitbrush, bitterbrush, yarrow, and blue grama. Average annual precipitation is usually less than 15 inches for most sites.

Ecology

With an average of 25 understory species, oak-maple woodlands are very important habitat for a wide variety of birds and mammals. Oak and maple provides important forage, breeding habitat, and cover for a variety of small game (which collect seeds and nuts for winter food), birds (providing nesting sites for sharp-shinned hawks), and big game (such as acorns and browse for mule deer and elk). Lower elevation oak-maple communities in Utah are regularly used by big game animals for winter range, located in the transitional zone between mountain and desert.

Oaks and maples are adapted to fire, heavy grazing, and logging, often resprouting as quickly as 10 days after disturbance. Sprouting can occur by way of crown, lignotubers, layering, or rhizomes. The regenerative capacity of oak is attributed to numerous adventitious buds situated on lignotubers and rhizomes throughout the upper meter of soil. Research suggests that the buds on the lignotubers are the most important regenerative structure, but consider rhizomes to be the primary means of clonal expansion. Maples have similar root systems to oak, but are without rhizomes. Vegetative reproduction through layering is typical, and effective, in older maple trees.

Changes throughout history

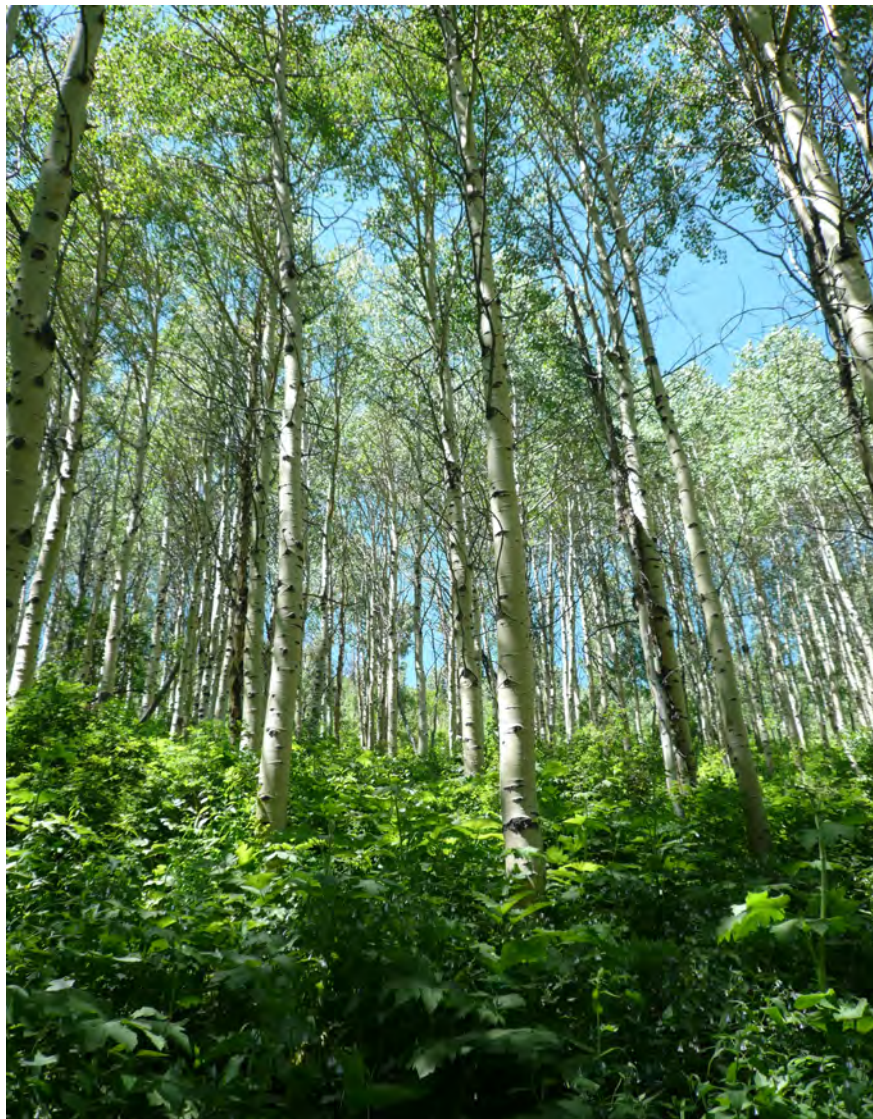
As urban expansion continues along the Wasatch Front, residential development continually encroaches upon oak-maple woodlands. This leads to increased wildfire risk, putting more pressure on managers to reduce fuel loads and create fire breaks to prevent wildfires from reaching homes. In Emigration Canyon and on Camp Williams military training grounds, intense goat grazing is being used to create fire breaks to protect nearby areas. Maple leaves turn fiery orange in the autumn while oak leaves offer less vibrant yellow and rusted red hues.

Montane Forests

Aspen Forests

Abundance in Utah

Aspen forests can be found from canyon bottoms and riparian areas to upper elevation slopes, occurring on relatively moist sites. In many areas, aspen often grow in conjunction with conifers, such as subalpine fir and Engelmann spruce, acting as a nurse tree to provide a shady establishment spot for the shade tolerant conifers. Because aspen are not a shade-tolerant species, lack of disturbance leads to overstories that become dominated by conifer species, which results in limited regeneration and survival of aspen stands. In Utah, aspen forests are found from 7-10K feet, most common at mid-elevations, and cover over 1.6 million acres. Aspen forests are Utah's most common montane forest community, comprising approximately 22% of Utah's mountain forests.



A healthy aspen forest has a varying age structure and dense understory. (Image by M. Larese-Casanova)

Structure

Quaking aspen get their name from the sound and appearance of their fluttering leaves in even the gentlest breeze, and are affectionately called quakies by native Utahns. Aspens grow in thick stands of groves, expanding **clonally** through vegetative reproduction (sprouting) into open areas such as meadows. The open canopy of aspen forests allows more light to penetrate to the forest floor, resulting in understories that are usually dense. Overstories can range from pure aspen stands, (i.e., those without any other tree species) to all levels of mixed-stands, where aspen occur in conjunction with conifer species such as spruce and fir. In other areas where aspen are adjacent to meadows or openings, sprouting aspen continually establish along the edges, using the available sunlight to create a dome-like structure with older trees in the middle, and smaller, younger trees toward the outside. On sites with less than optimal conditions, aspen are smaller and occasionally stunted with a decreased herbaceous understory. The structure varies greatly depending upon environmental conditions and stand history. Aspen are fragile species that are especially susceptible to wind throw and snow damage. Under the weight of deep snowpack, saplings will bend at the bases downhill, causing a deformity called a pistol-butted lower trunk.

Composition

Because of aspen's great ability to vegetatively reproduce after disturbance, thick stands with even-aged, genetically identical aspen are common. If varying aged aspen are present in the understory, densities are low enough to allow adequate light for replenishment, but this is not usually the case. Increased light availability and high organic content of the top layer of soil, caused by the rapid decay of nutrient-rich aspen leaves, can lead to herbaceous understories with 10 times more diversity than those of conifer forests. These forests are highly variable, and composition is determined by environmental conditions, age structure, stand history, tree density, and adjacent vegetation types. Understories are usually dominated by shrubs, including species such as mountain snowberry, western serviceberry, chokecherry, shrubby cinquefoil, Oregon-grape, Wood's rose, and dogwood. They are also home to many wildflowers including the sego lily, Fendler's meadowrue, Colorado blue columbine, shooting star columbine, heartleaf arnica, western coneflower, and wild geranium.

Ecology

Quaking aspen are one of the most widespread organisms in the world. Aspen occurs from Newfoundland west to Alaska and south to Virginia, Missouri, Nebraska, and northern Mexico. It is listed as a dominant species in over 100 habitats or plant communities. In Utah, aspen grow in every ecological zone, with the exception of the alpine tundra, occupying more land than any other forest type other than pinyon-juniper forests, which comprise nearly half of Utah's forests. Aspen is a small-medium sized tree, typically shorter than 50 feet. It usually grows in areas with mean annual temperatures around 45°F (7°C), with annual precipitation exceeding evapotranspiration, and soils ranging from shallow and rocky, deep loamy sands, or heavy clays. Aspen prefers soils that are well drained, loamy, and high in organic matter and nutrients. Most aspen sites naturally have a high level of rich organic matter, due to the rapid rate of leaf litter decay.

Aspen is considered an **early successional** (seral) species, or colonizer, after disturbance in most areas. It grows faster and initially outcompetes conifer species. Because conifers are shade tolerant, they can slowly work their way into the overstory, shading out the less tolerant aspen. However, on some sites where moisture, dense understories, or limited seed banks limit conifer establishment, aspen may persist over time. On other sites, succession to conifer dominated stands can range from one generation to more than 1,000 years, depending upon soil, site, and conifer species type. Two soil types in Utah showed succession ranging from 75-100 years for one site, and over 140 years for the other.

Aspen regularly exist as clones where multiple stems are connected to a common parent by their root system. Each stem can live for up to 150 years. The average number of sprouts-per-acre, 1 year after a major disturbance, is around 20,000-30,000, but this depends upon the effect of diseases, insects, defoliation, and snow damage. Some clones in a stand can be identified by the timing of leaf growth, flowering, or leaf color change in the fall, although these methods are not particularly accurate. Even though a single aspen can produce over 1 million seeds, seedling regeneration is usually thought to be very rare in Utah, where dry conditions can kill germinating seeds. In the Pando study, after removing 141 samples with the Pando genetics, researchers found 40 other genotypes in the remaining 63 samples, which they recognized as being a possible result from seedling establishment. Various research has reported hundreds or even thousands of seedlings per hectare after fire, which is contradicting to other studies showing just a few seedlings. However, the survival rate for the millions of seeds produced by each tree is relatively small.

Aspen forests provide important breeding, forage, and resting habitat for a large variety of birds and mammals. Wildlife species that inhabit aspen forests include deer, elk, moose, bears, rabbits, squirrels and other small rodents, porcupines, beavers, forest grouse, and well over 30 small bird species. Aspen stands, in general, provide animals with a banquet of energy and protein forage. Beavers use aspen to build dams; deer use quaking stands as fawning grounds; they provide good hiding and thermal cover for mammals and birds; and birds use them to nest and roost.

Quaking aspen are considerably more important to the function and biodiversity of an ecosystem than most tree species. Aspen forest communities generally have a higher diversity and abundance than most other habitat types. For example, breeding bird surveys rank aspen forest diversity 8th out of 95 different physiographic community types. However, the diversity in aspen forests is somewhat dependent upon patch size. Larger connected forests have higher bird diversity than small patches. Understory plant species diversity is high, but understory communities are often dominated by forb or shrub species. Although over 100 understory plant species were recorded in aspen stands located in the central and southern Rocky Mountains, most of those stands had only a tenth of that diversity.

Because of its significant range in tolerance and adaptations, aspen is the most widely distributed tree in North America. Aspen are more tolerant of changes in plant community structures, which allows them to live in a variety of habitats and elevations. For example, aspen growth form ranges from twisted, dwarfed bushes to 90 foot tall trees; they exist commonly as early successional species that establish after disturbance, but they may also persist as a stable late-successional community in areas where conifers and heavy grazing does not occur; and they can be found from the mountains of Mexico to northern Alaska, from the Atlantic to the Pacific shorelines, and from sea level to 12,000 feet in elevation.

Unlike most plants, the seeds of aspen trees mature in the early spring rather than in the fall. Aspen commonly produce enormous quantities of seeds in structures called catkins. Some individual trees have been known to produce catkins with over 54 million seeds in a single season; seeds have an average of 90% viability. Despite the enormous seed production and viability, aspen rarely successfully reproduce from seeds in the semiarid west. Although most seeds are capable of germinating, other factors significantly limit successful establishment. Seedlings that do establish commonly wither and die before they find a reliable source of water or adequate sunlight. Because seedling establishment is so limited, aspen have adapted a very successful form of asexual reproduction to facilitate establishment. Aspen commonly reproduce through **suckering**, where lateral roots send up vertical stems. During spring growth or when roots are damaged from disturbance, many new stems sprout due to a reduction of hormones that suppress growth. Even though sexual reproduction is rare, and the majority of individual trees are genetically clonal stems, quaking aspen are the most genetically diverse organism investigated to date.

In Utah, asexual reproduction has produced the largest known living organism in the world. It is a single aspen clone that covers over 107 acres with more than 47,000 genetically identical stems. This single male clone nicknamed **Pando**, which is the Latin term for "I spread," is located in the southernmost portion of Utah's Wasatch Mountains on the Fishlake National Forest. It has persisted for at least 80,000 years, but

some hypothesize it to be more than 1 million years old; this would make it the oldest living organism on earth. In addition, Pando is calculated to weigh more than 13,000,000 lbs. If this is correct, it is suspected to be the heaviest organism in the world as well. There are suggestions that fungal growths in the Northwestern U.S. may be larger, but they remain unproven. Most aspen clones, on the other hand, cover a significantly smaller area because they are limited by competition from shade-tolerant conifer species.



Pando, the largest known organism on Earth. (Image from US Forest Service)

Wildlife and livestock have significant effects on aspen forests. In fact, herbivory of young stems (i.e., suckers) by deer and cattle has recently been implicated though research at USU to be responsible for the decline of Pando due to lack of understory replacement of older stems. Although aspen communities generally produce as much forage as grasslands, they are equally sensitive to overgrazing that can significantly alter plant community composition. Heavy grazing shifts the dominant understory species to those that are less palatable, and prevents the regeneration of aspen saplings. Although all livestock and ungulates affect the growth of aspen saplings, larger herbivores are suspected to have a greater effect because they are able to reach higher trees and eat more browse. In addition to large herbivores, small mammals and birds are responsible for eating aspen bark and buds. Grouse, rabbits, other small rodents, and birds rely on aspen buds in their winter diet. In one Utah study, aspen buds comprised up to 85% of the winter diet of ruffed grouse. Some insectivorous birds such as woodpeckers and sapsuckers peck holes in the bark of aspen to look for insects and sap. They also excavate nest cavities for laying and incubating their eggs. The excavated holes may then become portals for pathogen entry, but the benefits of controlling forest pests probably outweigh the negative effects of creating holes in the tree bark. The interactions between wildlife, livestock, and plant communities can result in alterations to the structure and composition of an aspen community, but may in turn lead to local adaptations.

There are many diseases that attack aspen throughout its range, but very few will severely injure or kill a living tree. Fungi cause the greatest threat of infection to aspen. Although there are 250 species of wood-rotting fungi that can affect aspen, only about a dozen significantly affect living trees. Wood-

decaying fungi mostly impact the roots of a tree; therefore, damage to the root system of an aspen clone increases the risk. Damage to the tree will commonly result in black cankers on the bark. that appear to be a result of fungi which are hypothesized to produce toxins that kill living cells. Cankers are common, especially in areas where livestock and ungulate cause browsing damage to the lower tree stems. The susceptibility of aspen to various types of tree infections increases with age.

Black leaf spot is the most common leaf-fungal disease in the west. Generally, it is considered to have little effect on the host tree. Under epidemic conditions, however, mortality of entire trees may occur, but twig and branch death is more common. Locally, a variety of insect species also affects the growth and survival of aspen. Leaf miners also affect aspen throughout the west. They leave trails on the surface of leaves that show where they have damaged the leaf as they have eaten it. Even though these insects are common, most years they do not significantly affect the well-being of their host tree. Other common insects in Utah include sawflies, leafhoppers, and aphids.

An interesting fact about the sex ratio of aspen is that female clones are more prominent at lower elevations and male clones are more prominent at higher elevations. As elevations increase, the ratio of females to males decreases, until male clones make up 90% of individuals above 10,500 feet. Although the mode of sex-determination remains a mystery, it makes sense that males would live at higher elevations than females so that wind and gravity can carry pollen downhill to the female clones for pollination. In addition, the growth rates of female clones surpass that of male clones by 12%. This may also be an adaptation to keep related males that live within the same area from pollinating females. Instead, females can be pollinated by other male clones that live at higher elevations.

Changes Throughout History

The commercial logging of aspen forests, especially for saw-logs, is not very common in Utah. Few of Utah's aspen stands produce merchantable lumber; they tend to be smaller and more twisted than industry prefers. However, there are exceptions and most of our small local sawmills do cut some aspen for siding. Approximately 650,000 feet³ of aspen was removed in 1992, with over 600,000 feet³ of it used as excelsior fiberwood (shredded wood fibers commonly used in swamp coolers). Aspen forests are also used for extensive recreational purposes including hunting, hiking, horseback riding, skiing, recreational vehicle riding, and camping.

As mentioned, aspen cannot tolerate shade and also have a relatively short lifespan compared to conifer species. Frequent fires eliminate encroaching conifers, creating areas where single-aged aspen stands regenerate. While grazing and fire suppression have occurred since the 1800s, it is difficult to know how much the amount of aspen in Utah has changed since the pioneers first arrived. Utah's Forest Inventory Analysis shows that the amount of aspen forest has increased approximately 14% between the inventories of 1993 and 2012. Based on several measures (e.g., area, volume), The Forest Inventory Analysis stated that there has been no significant net change in aspen distribution in Utah. However, the amount of growing stock (i.e., volume of live trees) has declined slightly, possibly due to drought, fire, herbivory, or other disturbances.

Douglas-Fir and White Fir Forest Types

Abundance in Utah

Douglas-fir and white fir are the next most common forest type in Utah consisting of about 7-8% of Utah's forests. It is a mid-elevational community, ranging from 5,000 to over 9,000 feet in elevation, and covers more than 1 million acres in the state. Annual precipitation ranges from 20-35 inches, with the majority in the form of winter snowpack at higher elevations and fall or spring rains in lower elevations. It occurs on a variety of soils ranging from shallow and rocky soils to deep and well-drained loams. Mixed fir

forests can occur from canyon bottoms to all aspect hillsides to high-elevation ridge tops. Douglas fir dominate northern and lower elevational sites, with white fir becoming increasingly more co-dominant to the south or at higher elevations. Similar to Gambel oak, white fir does not occur in the northernmost part of the state.



A typical Douglas-fir forest, with a dense canopy and minimal understory. (Image by M. Larese-Casanova)

Structure

The forest densities are variable and highly dependent upon moisture availability. Young stands may be quite dense, becoming more open with maturity. Under undisturbed conditions, mature forests will have a closed canopy, with sparse understory vegetation consisting of mostly shrubs. When moisture conditions favor, moss and lichen flourish on rock outcrops or rotting stumps. Douglas-fir tend to occur on steep, north-facing slopes, with ponderosa pine on south-facing slopes at lower elevations. White fir is a co-dominant in the southern half of the state. The mixture of sparse understory vegetation and steep slopes provide conditions with bare ground, which can then be easily eroded during spring snowmelt.

Composition

Douglas-fir is very common, dominating most sites they grow on, and tend to grow in pure stands on north-facing slopes from 5,000-8,000 feet. White fir on the other hand, is less prevalent, usually scattered throughout the landscape on north aspects, with increasing dominance at higher elevation and lower latitudes. Other tree species that may coexist include aspen, lodgepole pine, ponderosa pine, subalpine fir, and Engelmann spruce, with bigtooth maple, Gambel oak, or even Utah Juniper at lower elevations. Some understory species include western serviceberry, chokecherry, snowberry, forest willows, common yarrow, blue wild rye, elk sedge, green-leaf manzanita, in addition to various ferns, lichens, and mosses.

Ecology

Douglas-fir and white fir are long-lived species that can grow 100-130 feet tall. They are both relatively **shade-tolerant** species, but if disturbance does not occur Douglas-fir can be outcompeted by more shade-tolerant species such as subalpine fir or Engelmann spruce. White fir typically occupies cool and dry northern exposures whereas Douglas-fir is adapted to cool and moist northern exposures, but both species can occupy a variety of sites. Both species are limited to reproduction by seed. White fir can bear cones at 40 years of age, with medium to heavy crops every 2-4 years, and 185-295 seeds per cone. Douglas-fir bears cones at age 12-15, with abundant seed crops every 2-11 years, and 20-30 seeds per cone. Douglas-fir cones have bracts that are three-pronged, often referred to as mouse tails, which distinguish it from any other conifer cone.

Seeds of both species are an important food source for small mammals such as squirrels, chipmunks, mice, and shrews, as well as many bird species such as Clark's nutcrackers, mountain chickadees, black-capped chickadees, red-winged crossbills, and dark-eyed juncos. It also provides excellent cover and forage opportunities for other wildlife species including the great horned owl, northern goshawk, Mexican spotted owl, Steller's jay, blue grouse, tiger salamander, deer mouse, long-tailed weasel, red fox, porcupine, elk, mule deer, and black bear.

Fire suppression has caused a reduction in fire disturbance and has led to stand replacements by more shade-tolerant species on some Douglas-fir sites. Fire return intervals usually range from 25-100 years but can range from 7-400 years depending upon location, precipitation, fuel accumulation, and ground fuel continuity. In Bryce Canyon National Park for example, mixed-conifer communities historically burned every 7.5 years, but have only hosted a fire every 45 years since the year 1900. The chance of survival for both Douglas-fir and white fir during a fire depends on the age of the tree. Young trees have thin, smooth bark that provides little protection from fire. Douglas-fir saplings were shown to survive temperatures of 140°F for only 1 minute. Mature Douglas-fir trees have a bark that can be more than 4 inches thick, and as a result can usually survive moderate to severe fires if flames do not scorch the canopy.

Douglas-fir have mycorrhizal associations with a recorded 2,000 fungal species, usually ectomycorrhizal relationships (the fungi do not penetrate the cell walls of roots), or sometimes ectendomycorrhizal relationships (the fungi penetrates cell wall, but not the cell membrane like in endomycorrhizal).

Changes Throughout History

The taxonomy of Douglas-fir was debated for more than 100 years. While it is not a true fir, Douglas-fir has some qualities of firs, but is more similar to yews. Its genus, *Pseudotsuga*- meaning "false hemlock," was first assigned to it in the mid-1800s.

Ever since early pioneer settlement Douglas-fir has been valued as lumber for construction. Its straight, thick trunks would yield relatively large amounts of strong, but light, lumber. Douglas-fir was historically called red pine due to its reddish heartwood, and there are dozens of red pine site names in Utah. Due to extensive historic logging, some mature stands of Douglas-fir have disappeared. Although, dense stands of Douglas-fir as old as 100 years can be found in Utah's canyons.

Ponderosa Pine Forest Type

Abundance in Utah

Ponderosa pine forests are uncommon throughout Utah (only about 4% of Utah's forests), occupying dry, south-facing slopes from the Uinta Mountains south. They usually border shrublands or pinyon-juniper woodlands occurring from 7,000-9,000 feet in elevation, most common at 6,000-8,500 feet. In Bryce

Canyon National Park they can be found throughout the park with their red bark complimenting the background of red rock. They usually occur in small patches on sandy or granitic soils, with mid to low pH, but can be found on a variety of loams, loamy sand, and gravel soils with pH range of 4.9 to 9.1. Occurring in the transition zone between the dry foothills and wet forests, denser and wetter stands can often be replaced by Douglas fir. In Northern Utah, ponderosa pine occurs in less common, intermittent stands.

Structure

Ponderosa pine is often called “yellow pine” due to the orange-yellow bark it eventually develops and the yellow colored wood it produces. As the trees get older, the brown or even black bark turns to a reddish-yellow color. Ponderosa pine is considered the tallest pine species in Utah, growing up to 150 feet tall, and lives for 300 to 500 years. Historically, stand structure is open and park-like, resulting from frequent low-intensity fires occurring every 3 to 47 years. In Zion National Park, fire intervals were even lower, ranging from 3-12 years; large fires on the Horse Pasture Plateau burned more than 1,000 acres nearly every 3 years.



A dense stand of Ponderosa pine in the Uinta Mountains.
(Image by M. Larese-Casanova)

Composition

Ponderosa pine forests can occur in a variety of forms depending on precipitation, elevation, disturbance, and the occurrence of other species. Single species stands, which tend to exhibit open park-like characteristics, occur in drier areas with more frequent fires. Wetter sites with less frequent fires can exhibit a mixed conifer community with small patches of ponderosa pine mixed with Douglas-fir, white fir and spruce. Understory vegetation consists of mostly grasses, typically Idaho fescue, bluebunch wheatgrass, sheep fescue, and mutton grass. Dominant understory shrubs include curl-leaf mountain mahogany, greenleaf manzanita, black sagebrush, Gambel oak, bitterbrush, wild rose, and mountain snowberry. A variety of wildlife species including silver-haired bats, mountain cottontails, porcupines, wild turkeys, western bluebirds, Northern flickers, common ravens, Steller’s jays, canyon wrens, great horned owls, tiger salamanders, Albert’s squirrel, and mule deer inhabit ponderosa pine forests.

Ecology

Being drought tolerant, ponderosa pine is best adapted to sunny and dry mid-elevations where winters are cold and summers are warm and dry. Mean annual precipitation ranges from approximately 11 to 25 inches, mostly in the form of snow, but summer rains can be important in some areas. In drier areas, roots up to 40 feet deep and lateral roots up to 100 feet long are critical in capturing available water. Extremely long needles, usually in a bundle of three, are adapted to increase the capture of sunlight for photosynthesis, remaining green year-round. A heavy waxy coating on each needle reduces the amount of moisture lost to transpiration. Symbiotic relationships with mycorrhizal fungi aid trees in water absorption and nutrient uptake. In return trees provide fungi with food (i.e., sugar).

Reproduction is a fairly unusual event in ponderosa forests and occurs via seed production with seedling success highest on bare mineral soils and lowest in shaded areas. Ponderosa pine is less shade tolerant and more drought tolerant than other coniferous species, which allow it to establish in the transition zone between dry scrublands and wet forests. Because of the dry nature of most ponderosa sites, mature trees have evolved with a thick bark that can protect the cambium from most fires. Increased fuel and heat loads caused by fire suppression has resulted in an increased fire mortality of mature trees. In wetter areas, fire suppression can lead to invasion by less fire-tolerant and more shade-tolerant species like Douglas-fir.

Changes Throughout History

Fire is historically important in ponderosa pine forests, occurring every 3–40 years, resulting in low-intensity understory burns; a ground fire as opposed to a crown fire. This reduces the competition and density of individual trees. Recently, the lack of fires has resulted in dense stands that are completely destroyed with larger, more intense fires that burn the crowns of the trees and are not confined to burning on the ground.

Approximately 200 insect species and many different diseases are thought to affect ponderosa pine, but just a few of them are common. Overcrowded stands are more susceptible to diseases (e.g., dwarf mistletoe) and insect infestation (e.g., pine beetles) due to unhealthy conditions. Mountain and western pine beetles (*Dendroctonus ponderosae*) infest dense, unhealthy stands, sometimes leaving large amounts of standing dead wood. Recently, with dense stands that are partially the result of fire suppression, pine beetle outbreak epidemics are more common.

Before the 1900s frequent fire limited understory ladder fuels, allowing for low-intensity ground fire to limit sapling survival without damaging large trees with thicker bark. Beginning in the 1800s, livestock grazing eliminated the fine fuels, such as grasses, that carry a fire. Fire suppression has also allowed for increased fuels accumulations including large numbers of standing dead trees, setting the stage for large, potentially catastrophic fires.

Limber and Bristlecone Pine Forest

Abundance in Utah

The Great Basin bristlecone pine (*Pinus longaeva*), and the limber pine (*Pinus flexilis*), are considered the late-successional community within Engelmann spruce and Douglas-fir zones. In Utah, limber pine can be found from 6,000-11,500 feet in elevation, and bristlecone can be found from 7,200-10,700 feet in elevation. Both forests make up around 1% of the forests in Utah. Both species are highly drought tolerant, occupying some of the driest sites capable of supporting trees, many at high elevations forming the upper treeline. They typically occur on steep, rocky, well-drained, windswept, nutrient poor soils or talus slopes, and often occur near the alpine zones, or treeline, of many of Utah's highest peak.



A limber pine, sitting atop a rocky, windswept ridge. (Image by M. Larese-Casanova)

Limber pine can be found throughout most of Utah's mountain ranges, with a significantly broader range than bristlecone pine. Bristlecone pine is restricted to small areas throughout southern and western Utah including the western edge of the Colorado Plateau in Millard County; the Uinta Mountains of Summit, Wasatch, and Duchesne counties, the Southern Wasatch Mountains, the Pine Valley Mountains of Washington County and northern Kane County; and the Wasatch Plateau of Emery County. In areas where both species occur, they are considered to be co-dominant on the landscape. Some of the best places to view these forests include the Manti-La Sal National Forest, Bryce Canyon National Park, Cedar Breaks National Monument, and Great Basin National Park.

Structure

Limber pine dominates south-facing slopes with few bristlecone, and is characterized by denser stands, with upright trees. In contrast, bristlecone dominates north-facing slopes, sometimes forming pure stands that are very open, with twisted and gnarled trees. At higher elevations, these forests are more open, with sparse understories; one study recorded only bristlecone and dwarfed Indian paintbrush at one site. At lower elevations, they are denser, and create a mixed forest structure with species such as Engelmann spruce.

With limited water and nutrients, trees are slow growing, long-lived, and can take hundreds of years to reach maturity. Mature trees on these harsh sites can cease height growth after only 15-30 feet. Factors

affecting growth include high elevation, extreme temperatures, dry conditions, nutrient-poor soils, strong winds, and the amount of solar radiation. Limber pines have deep taproots and mycorrhizal interactions to obtain water. In contrast, bristlecone root systems are shallow and branched to maximize water absorption when it is available. Secondly, harsh winds and freezing temperatures can leave trees gnarled and deformed at tree-line or on ridge-tops (also known as a krummholz form).



An ancient, gnarled bristlecone pine living at treeline in Great Basin National Park. (Image by M. Larese-Casanova)

Composition

In southern Utah or lower elevations, limber pine and bristlecone pine forests are usually more diverse, with more open structure, and can merge with juniper, mahogany, or aspen woodland communities. In Bryce Canyon National Park and Dixie National Forest, these forests can include blue spruce, Engelmann spruce, ponderosa pine, Colorado pinyon pine, Douglas-fir, Rocky Mountain juniper, Utah juniper, and Gambel oak. In some cases, Ponderosa pine can dominate the overstory, with white fir and bristlecone in the subcanopy.

In northern Utah and higher elevations, bristlecone/limber pine stands can range from pure stands to mixed stands with Engelmann spruce, subalpine fir, blue spruce, lodgepole pine, and white fir included. In areas disturbed by fire, lodgepole pine or quaking aspen can dominate the site. In pure bristlecone pine stands, understories can be species-poor, limited in some cases to only one species. Some common shrub species include true mountain-mahogany, curl-leaf mountain mahogany, wax current, and Wood's rose. Some herbaceous species include Ross's sedge, silver sagebrush, heartleaf arnica, slender wheatgrass, western yarrow, dwarfed paintbrush, and timber milkvetch.

Ecology

Both tree species are extremely long lived, but bristlecone pine has the longest life span of any non-clonal species in the world. Studies of the age of bristlecones in the Inyo and Dixie National Forests, and the White Mountains of California, ranged from 14 to 5,065 years, with some dead trees aging at over 5,000 years. The oldest recorded bristlecone pine in Utah was approximately 4,900 years old, but it was unfortunately cut down in 1964 before the age of the tree was known. Limber pine, although not as impressive as the bristlecones, have been aged at over 2,500 years old in Utah.

Both species are considered less shade-tolerant than many other conifers, which explains the mixed stand structure at lower elevation and higher precipitation sites. Without dry conditions or extreme disturbance, other conifers can suppress the growth of both bristlecone and limber pines. In these areas, bristlecone/limber pine forests are considered an early successional community, where other shade-tolerant spruce, fir, and pine species will eventually dominate the forest. In higher elevations where extreme wind, temperature, or drought are present, bristlecone/limber pine forests are able to outcompete other tree species, and are therefore considered the late successional community.

Regeneration of bristlecone/limber pine forests is highly variable. Trees can produce seeds to extremely old ages, but the total number of seeds produced decreased with age. In the White Mountains, one bristlecone pine over 4,300 years of age still produced viable seeds. Seed production may not be a problem in these forests, but poor wind pollination and seed dispersal has led to closely related stands in some areas. This is due to the inability of wind to disperse seeds over long distances. Clark's nutcrackers have adapted a mutualistic relationship with limber pine, and possibly also bristlecone pine, where birds harvest and bury seeds in caches throughout the forest. Some of these caches will be eaten throughout the winter, but others will not be used, resulting in increased dispersal distances for seedling establishment. Regeneration depends heavily on these seed caches to protect and disperse seeds. Other small mammals and birds, including the pinyon jay, can also aid in dispersal. Even if seeds are dispersed, favorable conditions for seedling establishment is often rare due to the dry, nutrient-poor soils that are characteristic of their habitat.

Bristlecone/limber pine forests are considered high-use and good cover habitats for a variety of animals including mule deer, elk, coyotes, a variety of small birds (e.g., chickadees, flycatchers, finches, dark-eyed juncos, mountain bluebirds, pine siskin), and also small mammals (e.g., chipmunks, ground squirrels, American pika). The browse is rated poor to fair in nutritional value, and is unpalatable to livestock and large mammals. The seeds from these trees are used only by small birds and mammals.

Changes throughout history

Both the limber pine and bristlecone pine are considered to be white pines. Limber pine was commonly called white pine due to the light gray color of its bark, but their bark can range from light grey, to dark gray or brown. Because of the irregular growth form, slow growth, and harsh environments, there is little commercial value for either species. In some areas, trees were locally harvested and used for mine shaft supports or railroad ties, because they were considered denser and harder than most conifer species. With such a gnarled growth form, they are considered to have great aesthetic value.

Lodgepole Pine Forest

Abundance in Utah

Rocky Mountain lodgepole pine (*Pinus contorta* var. *latifolia*), can grow on a wide range of sites from low-high elevations, dry-wet conditions, warm-cold temperatures, and nearly every soil condition found in the western U.S. In Utah, lodgepole pine covers nearly half a million acres (about 3% of Utah's forests)

within and north of the Uinta Mountains of Utah. It grows from 6,000-11,000 feet in elevation. Growth is best on gentle slopes with greater than 18 inches of annual precipitation and soils that are moist, medium-textured, and derived from granitic, shale, or coarse-grained lava parent materials. Lodgepole pine can also grow on rough and rocky terrain with steep slopes and ridges, with a minimum of 10 inches of precipitation annually, and soils that are young, poorly developed, or shallow with a pH<8. They can grow well on nutrient poor sites, often with nitrogen deficiencies due to slow litter decay and nitrogen immobilization, but will not grow well in soils high in calcium or magnesium. Trees grow best with moderate temperatures, but can withstand temperatures as low as 15°F when shoots are actively growing.



The characteristic tall, straight trunks of a lodgepole pine forest. (Image by M. Larese-Casanova)

Structure

Lodgepole pines are characterized by a long, slender trunk and a high, thin crown. In Utah, they usually grow 70 feet tall, but up to 150 feet, with average diameters of 24 inches, but up to over 30 inches. They generally have deep root systems (i.e., up to 11 feet), with a taproot dominating during the seedling and sapling stage, transforming to vertical sinkers off the lateral roots as the tree matures. These vertical roots provide major support for the tall trees. There have relatively few fine roots, and rely heavily on mycorrhizal associations for nutrient uptake.

Stand structure is determined by disturbance type. Large disturbances such as fire usually result in even-aged, single-story, dense forests. Lodgepole pine is not shade-tolerant, so continued seedling establishment is not possible under such a dense canopy. These even-aged forests can appear to be a tree farm due to their uniform growth structure. Wind, insects, or diseases can create multi-aged, multi-story, open stands. This is caused by the gradual deterioration of older trees, along with the establishment of seedlings in areas with an opened canopy.

Composition

In areas where other conifer species do not occur, lodgepole pine forests are considered the late-successional community and form pure stands. These communities occur on sites with extreme temperatures; soils that are well-drained, infertile, and experience droughts; soils that are poorly-drained with high organic content; sites that are cold and dry; or soils that are saturated in the spring or very dry in late summer.

Sites that have experienced recent fires also grow in pure stands. These sites can be persistent lodgepole pine stands with frequent fire intervals, or become dominated by other shade-tolerant spruce and fir species in the absence of fire. In persistent stands, fire intervals should be less than 100 years in order to eliminate competitive tree species such as Douglas-fir, subalpine fir, Engelmann spruce, and white fir. Lodgepole maintain their dominance by outcompeting other seed sources, obtaining high densities to shade other species, and allow for low-severity surface fires that remove seedlings without killing overstory trees. In stands that become dominated by shade-tolerant species, lodgepole pine regenerates rapidly after fire to dominate the site. Then, after about 20 years, species such as subalpine fir and Engelmann spruce will establish in the understory and replace lodgepole communities within 150-400 years in subalpine habitats without disturbance.

Lodgepole pine are susceptible to dwarf-mistletoe, mountain pine beetles, other insect pests (moths, jack pine budworm, and lodgepole terminal weevil), and multiple fungi including mycelium, three types of blister rusts (sweetfern, stalactiform, and comandra), and western gall rust. Dwarf-mistletoe is very common in lodgepole pine and reduces growth, seed production, and causes mortality (the young trees die quickly, but older trees may not show any effects for years).

Ecology

Annual precipitation ranges from a minimum of 10 to over 30 inches, with the majority received as snowfall during the winter. In some areas, there is no true frost-free season, with summer temperatures regularly falling below freezing. Lodgepole pine are moderately drought tolerant and moderately to highly frost tolerant. They are relatively short-lived, with an average life span of 150-200 years, but have been recorded to live up to 400 years.

There are two types of cones for regeneration— **serotinous** and non-serotinous genotypes. Most stands are composed of trees containing both regeneration genotypes, with the ratio determined by the fire history of the stand. Stands originating from fire disturbance generally have a high percentage of trees with serotinous cones, while those originating after other disturbance are likely to have a greater proportion of non-serotinous cones. Serotinous cones are sealed shut by a resin, requiring temperatures of 113-120°F to melt the resin, open the cones, and release the seeds. The characteristic serotinous cone can only occur on mature trees, over the age of 30-60 years, that have the serotinous genotype. The cones remain on the tree for 15-30 years, or until fire opens them. The cones protect the seeds until fire creates suitable sites for germination, and seeds remain viable for up to 80 years in the cone. Younger trees, with the serotinous genotype can start producing seeds at approximately 10 years of age, but cones do not contain the resins. Even though serotinous seeds are adapted to withstand fires, severe crown fires, caused by extreme temperatures and elevated fuel loads, have been known to destroy most of the stored serotinous seeds in the canopy. There is also a genotype that produces non-serotinous cones, which release seeds every year. These cones produce higher seed yields than serotinous cones, with more investment for seeds rather than resin, and can obtain annual productions exceeding 600,000 seeds/acre. Lodgepole pine seeds are winged, and are wind dispersed, on average, about 200 feet, and are also dispersed by runoff and small mammals.

Lodgepole pine thrives under the influence of fire, and it is an essential stage of regeneration for serotinous trees. Fire exposes mineral soil, increases available light, decreases competition, and increases water availability, which are all critical for enhanced germination and seedling establishment. The intensity

of fire also affects the germination rate of viable seeds. For non-serotinous seeds, germination was greatest (80%) with no exposure to flame or only 10 seconds of exposure to flame. For serotinous cones, germination was greatest (37% to 64%) after 10 to 20 seconds of flame exposure. Seedling establishment and density can be very high after fire, depending upon the intensity. After a stand-replacing fire in Montana, densities reached as high as 159,000 seedlings/acre, averaging 34,000 seedlings/acre, with a 52% survival rate over the first 12 years. In contrast, after a severe fire in Colorado, densities ranged from 0 to 4,800 seedling/acre. In areas where aspen is available, lodgepole pine has to compete with it following disturbance, because they share similar niches.

The mountain pine beetle is the most serious insect pest of lodgepole pine, periodically killing most of the large diameter trees (over 14 inches diameter), with low mortality in the younger trees. This cycle occurs every 20-40 years, unless interrupted by fire. Dwarf-mistletoe is also very common, with mortality depending upon the age of the tree and the density of trees. Young trees die quickly, while older trees may not show effects for years. Dense stands of lodgepole pine are particularly susceptible snow breakage, windthrow, dwarf-mistletoe, and mountain pine beetle attack, as well as insects and diseases.

Changes throughout history

American Indians first used lodgepole pine for tipi poles. Today, it is harvested for saw timber, paneling, pulpwood, firewood, fence posts and fence rails. It is also important for plywood, fiberboard, and composite/laminate products. It is an important forest community throughout Utah for hunting, fishing, riding recreational vehicles, hiking, and camping.

Spruce/Fir Forest

Abundance in Utah

Covering approximately 750,000 acres (about 5-6% of Utah's forests) from elevations 8,000-11,500 feet, most commonly from 9,000-11,000 feet, spruce/fir forest is the fourth most common coniferous forest in Utah. At lower elevations, spruce/fir forest is limited to northern exposures. As elevation increases, it occupies westerly and easterly aspects, occupying all aspects at timberline. Spruce tends to be more abundant at higher elevations and wetter sites, while subalpine fir is more abundant on lower elevation and drier sites. Soils are commonly rocky and shallow, with little soil development.



A sparse spruce/fir forest near treeline. (Image by M. Larese-Casanova)

Structure

Subalpine fir is the smallest of the eight fir species native to the western U.S., with many different growth forms, including: extremely narrow with dense crowns of short branches to somewhat broad-crowned and bullet-shaped, growing up to 60-100 feet; flag-form at timberline where individuals have an upright trunk above a krummholz-like mat, with branches growing only along the leeward side; and a typical krummholz form above timberline caused by severe winds and cold temperatures. Subalpine fir is slow growing, and is often only 10-20 inches in diameter after 150-200 years. They rarely live over 250 years largely due to their vulnerability to heart rot, which can kill them, but also makes them susceptible to windthrow.

Engelmann spruce is one of the largest of the high montane conifers. It often lives 350-450 years, with 500-600 year-old trees not uncommon. Mature individuals range from 45-130 feet tall, depending upon site conditions, averaging 15-30 inches in diameter. Mature trees have a narrow, pyramid form with short branches below treeline, or have a krummholz form above treeline.

Closed canopies are common in these forests due to the shade tolerance of both dominant coniferous species, allowing for continual regeneration and canopy closure. However, spruce-fir forest can have an open canopy near treeline where growing conditions are particularly challenging.

Composition

Engelmann spruce commonly makes up 70 percent of the overstory, while subalpine fir commonly dominates the understory trees. Even under the shade of mature trees, subalpine fir is very shade-tolerant and can easily establish on many substrates. Engelmann spruce can establish on mineral soils in the understory, but is less shade-tolerant. Growth is severely suppressed in dense overstories for both species. In the absence of large-scale disturbances, Engelmann spruce are thought to continually increase their dominance owing to their much longer life span. However, subalpine fir will continuously prolifically regenerate and can rapidly take advantage of small canopy gaps created by small-scale disturbances and individual tree mortality.

Other species that grow in association with these dominant species include lodgepole pine, Douglas-fir, aspen, blue spruce in drainages, white fir at lower elevations, limber pine, and bristlecone pine. The community composition varies by latitude, elevation, exposure, and, most importantly, soil moisture. After fire or disturbance, in present aspen or lodgepole pine can re-establish where spruce/fir forest existed. Aspen can persist for decades or even centuries if the seed bank is lost. Lodgepole pine forms dense single-aged stands that may dominate for 100-300 years as spruce and fir establishes under the canopy. At higher elevations, these associated species tend to become increasingly limited, allowing for homogeneous stands of subalpine fir and Engelmann spruce.

Ecology

Spruce/fir forest is often humid, as it is covered with snow 6 to 9 months out of each year, with annual precipitation ranging from 30 to 60 inches per year. Shaded forest floors, along with cool temperatures, help keep snow on the ground until late spring or early summer. Extremely cold winters, cool summers with frequent frosts, and heavy snowpack reduces the growing period to only a couple of months. The inner wood is often straight, but may be spiraled in trees growing on harsh sites, most likely caused by a combination of the genetics, the difference in the angle of the sun between the northern and southern hemispheres, and the direction of the prevailing winds.

Both spruce and fir are extremely well adapted to these harsh winter conditions. Their tall, narrow, pyramidal growth form limits snow loading and wind resistance. Heavy snow on the lower branches causes contact with the soil. This allows for reproduction via layering around the parent tree. This is especially

important for trees that occur above timberline because they do not produce viable seeds. Spruce and fir also have a lower limit for peak photosynthesis than the general 46°F, which allows for increased growth in the colder environment.

Tree seeds are eaten by small mammals and birds, needles are eaten in the winter by grouse, but most of the forage comes from other understory species. Spruce/fir forest provides excellent cover for many mammals, including moose, elk, mule deer, black bear, porcupine, snowshoe hare, flying squirrel, red squirrel, chipmunks, voles, shrews, and many bird species, including mountain chickadee, red-breasted nuthatch, pine siskin, owls, grouse, and woodpeckers.

Subalpine fir is attacked by many insects including western spruce budworm, western balsam bark beetle, balsam woolly aphid, and fir engraver beetle. They are also susceptible to several wood rotting fungi including annosus root disease, red heart rot, white pocket rot, brown cubical rot, and shoestring rot. These fungi weaken trees, making them more susceptible to insect outbreaks, and result in windfall or breakage. Engelmann spruce has similar wood rotting fungi, also including dwarf mistletoe, with the most serious insect being the spruce beetle. In areas where windthrow or downed trees are abundant, they provide a good food supply for rapid beetle expansion.

Changes throughout history

Spruce and fir were used by American Indians for a variety of purposes including teas or poultices for medicinal purposes, incense or perfumes, and the bark for canoes, baskets, or roofing. American Indians also relied heavily upon the cool spruce/fir forests as hunting grounds in late summer to early fall.

Harvesting spruce and fir for solid wood products (e.g., timber, logs) is common, with single tree and group-selection silvicultural methods favoring regeneration of both species. Clear cutting often results in failed regeneration, even decades later. Shelterwood, which is a technique that involves selectively cutting mature trees to allow just enough sunlight and space for regeneration, is also highly effective, but is used less often. In Utah, Engelmann spruce has been and continues to be an important lumber source, but is rather difficult to harvest because it grows at higher elevations. The wood has been used for timber, poles, railroad ties, and mine props, historically. Spruce is currently highly valued as logs for premium log homes. In Utah, subalpine fir harvest has been limited due to lower value. The wood is primarily used for products such as lumber (e.g., 2x4s) for home construction and for prefabricated wood products. Use for poles and pilings requires large amounts of preservatives because the wood decays rapidly. Small trees are commonly used for Christmas trees. To control spruce beetles, infected trees or logging slash should be removed. Much of the standing dead spruce is also used as premium cabin logs.

Wildfires are rare in spruce/fir forests, usually occurring every 150-400 years, or perhaps longer. If fires do occur, both tree species are not fire resistant, resulting in high levels of mortality. However, the intensity and spread of wildfires in spruce/fir forests tend to be highly variable and unpredictable due to variability in factors such as soil moisture and stand density at higher elevations. Unburned patches serve as important seed sources for regenerating burned areas. Because spruce/fir forests burn so infrequently, there tends to be a large accumulation of fallen trees that only burn during wildfires that occur during prolonged periods of drought.

Subalpine Meadows

Abundance in Utah

Subalpine meadows are found near treelines in Utah, usually around 8,000-10,000 feet. Most plants in subalpine meadows require open, sunny areas. With a lack of trees, herbaceous vegetation is exposed to high solar radiation and strong, desiccating winds. Subalpine meadows often receive less than 15 inches of average annual precipitation, largely remaining snow-free during the winter due to wind scour. Meadows

range from small openings in forests to areas covering hundreds of acres. Many subalpine meadows are a continuation of alpine tundra grasslands or meadows.

Structure

Generally, wet meadows have high water tables in conjunction with fine-grained soils to retain water. Dry meadows have well-drained mineral soils where frequent droughts may occur. These extremes make it difficult for trees to establish where meadows thrive. However, well-drained soils composed of glacial till may support some tree growth. In meadows that previously supported trees that were removed by disturbance, such as fire or extreme winds, trees may re-establish after 10–20 years if conditions remain favorable. On drier sites, or sites near treeline, re-establishment may take longer. Wet meadows have more vegetation than dry sites. Wildflower colors constantly change across the landscape depending on the timing of the flowering stage of different species. Shrubs are usually present on most sites, usually very sparse, and only occasionally dominate the vegetation.



A wet subalpine meadow growing around Tony Grove Lake in the Bear River Range. (Image by M. Larese-Casanova)

Composition

Differences in microclimates due to elevation, topography, wind protection, and moisture availability create variability in species composition in each subalpine meadow. Generally, wet meadows are dominated by wildflower species, where resources do not restrict growth. Dry meadows are dominated by cool-season bunchgrasses that have a waxy leaf coat and extensive root systems to conserve water, compete with surrounding vegetation, and go dormant when conditions are unfavorable.

Shrubs such as mountain sagebrush and antelope bitterbrush tolerate relatively dry soils, and shrubby cinquefoil often abound in moderately moist soils. Other common plant species include sego lily, needle-and-thread, blue grama, Idaho fescue, indian ricegrass, black coneflower, wild geranium, silver sage, yarrow, western shooting star, wild strawberry, dwarf rabbitbrush, false hellebore, and paintbrush species. Common wildlife species of subalpine meadows include squirrels, chipmunks, masked shrew, pocket gopher, big brown bat, pronghorn, elk, marmot, mountain bluebird, common nighthawk, loggerhead shrike, golden eagles, and red-tailed hawks.

Ecology

Subalpine meadows are often considered early successional communities where trees might re-establish in the absence of disturbance. Some disturbed meadow communities have a reduced number of native perennials, and an increased amount of annuals and invasive weedy species. On sites where overgrazing has eliminated bunchgrasses, shrubs and weeds become increasingly more dominant.

Grasses and sedges are wind pollinated, whereas wildflowers are usually insect or hummingbird pollinated. Many flowers can reflect UV light, which is only visible to insects, and have guide marks (e.g., patches, streaks, or spots of contrasting colors) that are hypothesized to direct pollinators to the center of the flower. Each pollinator has a specific pollination technique: beetles have brush-like mouth; hummingbirds have a long, narrow bill and tongue; bees have pollen baskets on their legs; and butterflies, moths, and flies have a bristled proboscis for drinking nectar.

Plant adaptations to prevent herbivory include both physical and chemical defenses. Physical defenses include spines or thick cuticles. Chemical defenses are toxins produced that reduce the palatability and nutritional value of plants, and have various side effects such as nerve damage, fertility inhibition, cancer, digestive disorder, or death. Common toxic plants include death camas, locoweed, lupine, or larkspur.

Changes throughout history

Undisturbed subalpine meadows may still contain biological soil crusts composed of lichens, mosses, liverworts, and cyanobacteria, that stabilize the soil, restrict invasive weed establishment, and retain water. With heavy grazing and human disturbances, cryptobiotic crust is damaged and may take several years to recover its functions. Selective grazing, when livestock eat only the plant species that are most nutritional, has benefited the less-palatable species and allowed for invasive species such as cheatgrass, Canada thistle, or Russian thistle to outcompete native bunchgrass species.

Alpine Tundra

Abundance in Utah

Alpine tundra occurs above treeline, from as low as 10,500 feet in some areas, to the highest alpine area in Utah, Kings Peak, with an elevation of 13,498 feet. Alpine tundra occurs in the Wasatch range on Mount Timpanogos and the head of Little Cottonwood Canyon; Mount Belknap and Delano Peak of the Tushar Plateau; an occasional peak in the Great Basin range; the high peaks of the LaSal Mountains; and, most abundantly, across approximately 67 miles of high peaks and crests of the Uinta Mountains, 60 miles of which are continuous. The Uinta Mountains are by far the most extensive alpine zone in Utah, with over 300 square miles of coverage, and 87% of the plant species found here are also common to the Southern Rocky Mountains.



Alpine tundra, above treeline in the Uinta Mountains.

Structure

Alpine tundra is generally divided into six subtypes: alpine grasslands, alpine meadows, fell-fields, snowbeds, alpine wetlands, and alpine talus slopes or rock crevices. Each subtype differs in soils, slope, available precipitation, and the number of frost-free days.

Alpine grasslands (dry meadows) have dense carpets of turflike grasses, sedges, and lichens, and occur on level to gently rolling sites. They are largely snow free during the winter, with snow averaging only 4-5 inches deep, since most of the snow is blown away by extreme winds. Snow free periods range from 150-200 days, with growth seasons averaging 105 days. Soils are usually deep, well-drained, fine soils that resist erosion once established. Alpine grasslands can be dominated by elk sedge, kobresia, false elk sedge, or rock sedge.

Alpine meadows (moist meadows) are dominated by forbs and grasses, characterized by long-lasting wildflowers, and are considered the most beautiful tundra type. Average snow depth is 4-10 inches, snow free for 100-150 days, with an average growing season of 96 days. Alpine meadows are found on gentle slopes or shallow basins that are protected from the harsh winters. They are usually less rocky than grasslands, with deep soils rich in organic matter.

Fell-fields are rocky, windswept ridgetops or exposed, windward slopes. Because of high wind movement, average snow depth is less than 4 inches, with snow-free periods over 200 days, and an average growing season of 109 days. Soils are coarse, rocky, and have little organic matter. Fell-fields can be dominated by cushion plants, mat-forming species, or mountain dryad.

Snowbeds are snowbanks that linger well into the summer or snowbanks and glaciers that persist throughout the entire year. They occur on leeward slopes or the leeward side of boulders or other obstacles. Snow depths average 44-60 inches, with less than 75 snow-free days, and a growing season averaging 52 days per year. The significant snow pack restricts plant species, prevents plants from prematurely breaking dormancy, and allows for constant moisture for growth throughout the growing season. These sites can be dominated by micro-organisms (e.g., bacteria, algae, fungi), sedges, rushes, or lichens.

Common species include sibbaldia, black sedge, Drummond's rush, snow buttercup, Parry's clover, or black-headed daisy.

Alpine wetlands are meadows with saturated soils. They have many of the same species as arctic wetlands including Koenigia, golden saxifrage, and arctic saxifrage. Other plant species include Rocky Mountain sedge and marsh marigold. Snow depths average 8-16 inches, with 100-150 snow-free days, and a growing period averaging 88 days. Sites are highly variable, ranging from inundated and exposed, gravelly areas to shallow, standing water with abundant growth of water-loving plants.

Talus slopes and rocky crevices are found along the bases of cliffs, around the front of rock glaciers, and slopes with loose rock rubble. Winter snow accumulates between rocks, providing a dependent supply of moisture throughout the growing season. Talus slopes have small numbers of plants, with species such as alpine thistle, talus ragwort, spotted saxifrage, and alpine rock-jasmine. Snow pack is variable, dependent upon the boulder size and amount of protection from the wind. Talus slopes provide great protection and habitat for animals such as pika.

Composition

Alpine tundra is quite similar to arctic tundra in regard to the mean annual temperature and species composition, but arctic tundra has a greater range of temperatures, lower levels of precipitation, lower average wind speeds, and three times as many plant species as alpine tundra areas. Alpine tundra is composed of approximately 300 plant species, 40% of which are found in the arctic tundra, with 67% of these occurring throughout the entire Rocky Mountains. Only 1-2% of species are annual plants because the growth season is too short for most plants to complete a full life cycle in one year. Some common species include moss campion, dwarf clover, alpine avens, alpine timothy, spike trisetum, blue columbine, alpine forget-me-not, and koenigia.

Ecology

Alpine tundra is often considered grassland with areas of permanently frozen ground, very similar to arctic tundra. Climate has a significant effect on shaping this community. Glaciers were extremely important in carving some alpine tundra such as fell-fields or talus slopes. Alpine tundra is characterized by harsh climatic conditions, which include:

- a) High solar radiation: twice as much UV rays and 25% more solar radiation than at sea level
- b) Cold temperatures: average summer temperature approximately 50°F, average yearly temperature approximately 25°F, with temperatures ranging between -35°F to 65°F
- c) Strong winds: considered the architect of the alpine areas, winter winds average 25-30 mph, with gust up to 200 mph; summer winds average 18-20 mph
- d) High precipitation: averaging 40 inches, with only 20% during summer, and the majority during the winter as snow

Extreme climate conditions in alpine tundra has led to plant adaptations including a low growth form to take advantage of moderated microenvironments near the ground, extensive below ground root systems (90% of plant biomass) that is used to store resources for rapid spring growth, floral heliotropism where flowers orient toward the sun (increasing the temperature within the flower by up to 14°F), and are mostly perennials because the growing season is too short to complete a full life cycle in one year. The alpine tundra community averages 47 frost-free days per year, with an average growing season slightly longer because most alpine plants can still photosynthesize at temperatures down to 32°F (normally 40-50°F for most lowland plants).

With twice as much UV solar radiation as sea level, many alpine plants have higher levels of anthocyanin pigments, which are the same pigments that make apples red, in their stems and leaves to protect chlorophyll from harmful UV rays. This pigment occurs in many plants, ranging from red (acidic sap)

to blue (alkaline sap), and is more prominent outside of the growing season when the green coloring from chlorophyll is not predominant. Anthocyanins also convert light waves into heat, which becomes especially important for growth in the alpine tundra. Other natural sunblock includes hairy leaves or leaves with thick cuticles to reduce the amount of damage to chlorophyll.

The plants that grow in alpine tundra are very diverse, and are limited by the conditions present in each subtype of the community. As a whole, alpine tundra receives an average of over 40 inches of annual precipitation, but intense wind movement creates very deep snowdrifts on the leeward side of ridges, while leaving other areas bare. This movement of available moisture creates a mosaic across the landscape along environmental gradients such as topography, snow cover, temperatures, wind exposure, and moisture availability during the growing season. Temperatures at the ground surface can be up to 10°F warmer than just 2 inches above the ground, and over 17°F warmer than 4 feet above the ground. Alpine plants take advantage of the warmer and moister microenvironments close to the ground by having a very short growth form.

Only 19 mammals (mostly shrews, pika, voles, pocket gophers, yellow-bellied marmots, and weasels) and 1 bird species (white-tailed ptarmigan) are year round residents of alpine tundra. These species are able to survive by using the micro-climates created by the low-growing plants or by taking shelter in the talus slopes, and many species hibernate throughout much of the long winter. Even though there are few year-round residents, there are many other animal and insect species that use these communities during the spring and summer breeding season. Common species include bobcats, coyotes, mule deer, elk, mountain goats, least chipmunk, bighorn sheep, white-tailed jackrabbit, mountain bluebird, golden eagle, red-tailed hawk, common raven, white-crowned sparrow, and a variety of flies and butterflies.

Changes throughout history

The increase in annual temperatures in these environments are melting glaciers and perennial snowfields, trees are moving higher in elevation with lengthening frost-free intervals, and the conditions needed for alpine specialists such as pika and white-tailed ptarmigan are being reduced. As islands atop mountains, alpine tundra that is smaller in size or more remote is less likely to support populations of plants or animals that specialize in surviving in this community. For example, pika are unable to survive in sustained temperatures above 80°F, and as alpine tundra warms and pika migrate to higher elevations, their habitat shrinks. However, recent research suggests that pika might be able to survive at lower elevations as long as cool, moist microclimates are available.

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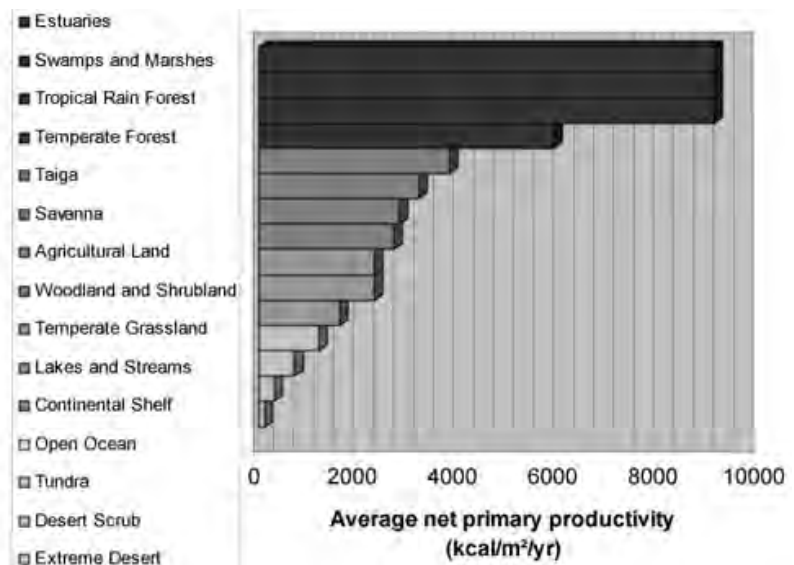
Mountain Ecology

Food Webs

While all food webs begin with the sun, life in montane environments begins with the plants, bacteria, and lichens that photosynthesize. **Photosynthesis** is the process of converting the sun's energy, water, and carbon dioxide into carbohydrates that are stored within plant tissue, and oxygen. This form of potential energy is stored for the plants' survival and growth. Some of the carbohydrates get used by the plant for its own growth and reproduction through a process called **respiration**. The produced organic material, called biomass, is then available to herbivores and omnivores that rely on it as an energy source for survival. Animals that directly consume the energy by eating the plant are the **primary consumers**, and the animals that eat the animals that ate the plants are the secondary consumers. As energy is transferred to a higher level of the food web, approximately 90% of it is lost. This occurs, in part, because portions of organisms that don't get consumed (e.g., beaks, shells, and bones) required energy to be created, but that energy is not available to the subsequent consumer. More importantly, though, is that the vast majority of energy consumed by an organism is devoted to growth and daily metabolic needs. Because of this, ecological systems need to produce a large amount of organisms at the lowest level of the food web (i.e., the producers) in order to sustain relatively few consumers at the top.

In the mountains, you may find dense, lush aspen forest or sparse, miniature plants across a talus slope. In each community, only 40% of the total plant biomass of the ecosystem is found above ground. The remaining 60% is located underground, in the form of roots or rhizomes (stems producing roots to develop into new plants) or soil microbes, and is unavailable to most herbivores. Because of this, primary production, the maximum amount of plant material produced each year, is often only measured above ground. **Net primary production**, measured as total energy production minus that used for plant respiration, and minus those plants that die, provides the food for animals (i.e., the consumers) and gives them the nutrients and energy they need to survive.

Because climatic factors and the availability of nutrients control net primary production, mountain ecosystems can be anywhere from low to high producers of total biomass. As a general rule, net primary production usually decreases with an increase in latitude and altitude due to the lower temperatures at these sites. In Utah, lower elevation forests receive less precipitation, have warmer average temperatures, and snow pack covers the ground for a shorter period than in alpine tundra zones. As a result, the growing season is longer in the lower elevation forests than it is in the alpine tundra zone. Therefore, as assumed, net primary production is relatively high in temperate forests, but predominantly low in alpine tundra.



Net primary productivity for tundra is low, but high for temperate and coniferous forest (taiga) (Image from Algebra LAB)

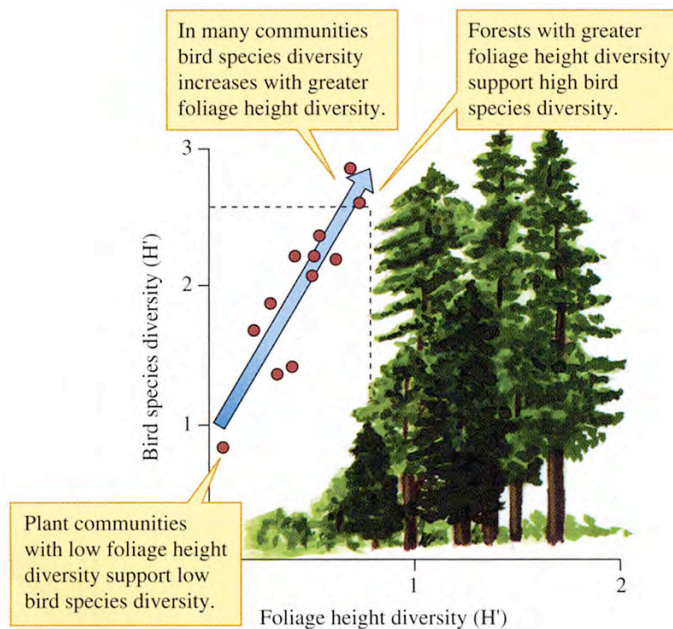
Mountain Food Webs

Mountain food webs are very interesting because of the complexity of external and internal interactions. Food webs are limited by diversity of species that interact with each other. The diversity of a mountain food web is controlled by the temperature, water availability, limited growing seasons, and the net primary productivity of each montane community. Other factors such as elevation, habitat diversity, community structure, and habitat size also play a significant role in food web interactions and the diversity of species that make up the food web. As mentioned before, the decline in species diversity at higher latitudes is well documented. Similarly, a decline in diversity at higher elevations is also usually present. However, for some taxonomic groups, diversity increases at lower montane elevations, reaches a plateau at mid montane elevations, and then decrease to the lowest diversity at the highest montane elevations. This pattern usually occurs on mountain ranges that have an arid base, such as those in Utah. The reason for such a pattern is that that diversity is usually highest where moisture and temperature do not limit plant growth. In Utah, the foothills and valleys receive relatively little moisture, and become hot and dry without artificial irrigation. As elevation increases, water availability increases, but annual temperatures begin to decrease. The highest diversity occurs at mid-elevation montane zones because water availability and growing season length reach a climax, where the highest amount of net primary productivity can occur in the state. Above a certain elevation, low temperatures limit growth and renders water unavailable for the majority of the year in the form of snow and ice.

A higher level of biodiversity generally provides more ecological, economical, scientific, and ethical benefits. For instance, more diverse ecosystems are better able to withstand environmental stresses, and they are more consistently productive each year; higher diversity provides a larger reservoir of resources to manufacture food, pharmaceutical, and cosmetic products, and it also increases the services that are provided by our natural ecosystems, including water and air filtration, erosion control, and aesthetic or recreational enjoyment. Additionally, scientists are able to better understand the role each species plays in a healthy, functional ecosystem, and diversity of an ecosystem is a good indicator of human relationship with nature.

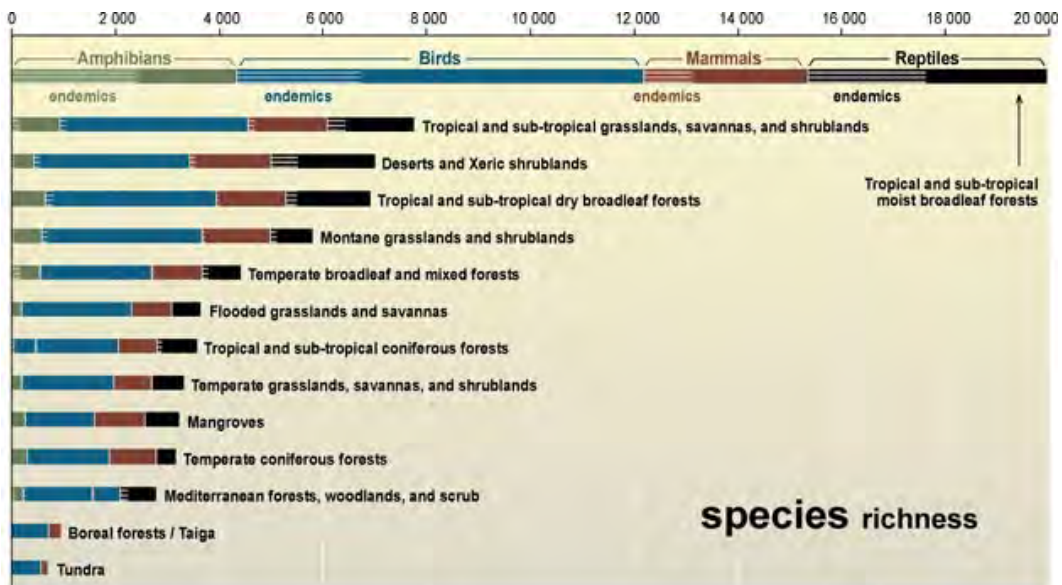
With regard to Utah's mountains, as elevation increases, plant communities and habitat patch size tends to decrease. Reduction in habitat patch size results in higher amounts of fragmentation as the distance from similar mountain top habitats increases. Scientists relate the effects of habitat fragmentation of the high mountain habitats, to theory of **island biogeography**, established by Robert H. MacArthur and Edward O. Wilson in the 1960s. These high-elevation habitats become, in a sense, islands, which support a lower level of biodiversity, lower rates of immigration, and higher rates of extinction, as the area of each habitat type become smaller and more isolated from each other. However, high elevation forest patches or mountain tops are not true islands, and many organisms can move between them (unlike on real islands surrounded by water).

The diversity of habitat types within mountain communities can also increase the species diversity. This is evident when Douglas-fir forests, aspen forests, and alpine



Bird species diversity as a function of habitat diversity.

tundra communities in Utah are compared. Douglas-fir forests have an even-aged, closed canopy structure at maturity. The low light conditions that this structure exclude plants that need light but provide unique habitat for shade-tolerant species. Aspen forests, which are similar in elevation to Douglas-fir forests, usually have an open canopy, with a multi-age and multi-height structure. Aspen stands usually have moister soils, higher net primary production, higher understory plant diversity, and higher wildlife diversity. Subclimax communities generally have the highest diversity and abundance of wildlife because of the multi-height habitat structure that is lost when vegetation has reached its late-successional state. This concept is shown in the graph at the end of this section. Lastly, alpine tundra communities are characterized by winter conditions too severe for plants to be able to grow large structures (such as woody stems). As a result, alpine tundra communities have the lowest plant and animal diversity of the three habitat types because the diversity of vegetative-height and habitat structure is limited.



Vertebrate species richness is low in alpine tundra, but moderately high in temperate forests.

Keystone Species

Keystone species are species whose presence or absence can have a disproportionate and dramatic effect on the survival and abundance of many other species within an ecosystem. Keystone species can exist in any trophic level from plant to carnivore. Gray wolves are considered a top predator species, but they can also be considered a keystone species because they have such a significant effect on an entire ecosystem. From a different point of view, aspen reproduction and forest regeneration is often used as an indicator of ecosystem health. Aspen forests are considered to be the most biologically diverse ecosystem, second only to riparian areas, in the Intermountain West. Aspen trees are therefore a keystone species because they provide habitat for more species per unit area than any other habitat, and some species rely solely on aspen forests to survive.

Many keystone species are considered ecosystem engineers that are responsible for creating or maintaining various habitat types. Some of these species include woodpeckers, sapsuckers, beavers, gophers, and other burrowing animals. The red-naped sapsucker, for instance, serves two keystone roles in aspen and conifer forests. Similar to other woodpeckers, the red-naped sapsucker excavates new nest cavities in trees. It is therefore considered a primary cavity-nester species. After the sapsucker is finished nesting, its nest cavities can be used by secondary cavity-nesting birds that are unable to construct their own. Secondly, sapsuckers drill sap wells in multiple tree species, including spruce, aspen, and willow. Sapsuckers then return to these wells later to drink the sap and eat the insects that have become trapped

in the sap. The sap from these wells are commonly stolen and used by over 40 other species of birds, mammals, and insects. The sapsucker not only provides food for itself, but it also helps provides some nourishment for the reproduction, migration, and hibernation of multiple other species.

Similar to primary cavity nesters, burrowing animals such as ground squirrels and rabbits create underground burrow habitat for various species to use. In addition, they help to facilitate soil turnover, modify the properties of the soil, and modify the plant community, which contributes a substantial amount of production in high elevation environments like spruce-fir forests. Beavers are another good example of keystone engineers. They cut down trees and use them to construct dams. The dams alter hydrology, create wetland habitat, and influence community composition and diversity. The wetlands that are created provide habitat for various species such as ducks and shorebirds, retain eroded sediments, modify nutrient cycling dynamics, and modify the dynamics of the riparian zone.

Trophic Cascades

Trophic interactions have been debated for some time, including the debate over whether the primary control is resource availability (bottom-up forces), or predator control (top-down forces). Previously, bottom-up forces were suspected to drive community structure because the limitation of food for herbivores limited the amount of energy available to upper trophic levels. Since its origin in the 1960s, the concept of top-down forces has received a great deal of attention. A top-down **trophic cascade** has been defined as “the progression of indirect effects by predators across successively lower trophic levels.” These top-down interactions are also based on the availability of food, but only the availability of food to upper trophic level species, called top predators. The trophic levels below the top predators are primarily controlled by predation factors, and secondarily controlled by food availability. However, top-down interactions are very complex because factors such as the number of predator and prey species within the community, the magnitude of competition and prey sharing between predators, the elusiveness prey, the availability of cover, and the time lag between prey consumption and predator reproduction responses are highly variable. Understanding how these factors are effecting the trophic level interactions is critical to understanding how the community reacts under such forces.

A great example of research on top-down predator interactions was conducted in conjunction with the re-introduction of wolves into the Greater Yellowstone Ecosystem. After the gray wolf was extirpated from much of the western U.S., elk and deer populations increased to historically large levels. This resulted in intense grazing pressures, which altered the structure and composition of some plant communities, such as riparian areas and aspen forests. The majority of habitat degradation that occurred during this period is usually attributed to abnormally large elk populations. For example, aspen and willows were heavily overgrazed to the point where re-growth could not occur. This resulted in habitat alteration and altered food web interactions for the remaining wildlife species.

This cascade continued and allowed for a **mesopredator release** (i.e., increase) to occur. This phenomenon occurs when smaller predator populations, such as coyotes and foxes, increase without the competition from their top predator, the wolf. The mesopredators are then able to reduce the population of their prey species, sometimes to the point where some species cannot reproduce and recover. One example of this was the decrease in pronghorn antelope with the increased predation by coyotes. One study, comparing wolves, coyotes, and pronghorn, measured the pronghorn fawn mortality for an area with wolves present, and an area without wolves present. Fawn survival was four-times higher in areas with wolves present than in areas without them. This was not due to the density of resident coyotes in the area, which remained nearly the same, but because of an increase in transient coyotes where wolf competition was not present. This cascade effect even continues on to subsequently lower trophic level, and is the basic concept of top-down trophic cascades.

The re-establishment of the gray wolf into Yellowstone National Park in 1995 help reverse the effects of this trophic cascade. Increased competition from a top predator reduced mesopredator populations,

decreased the large herbivore populations, and created a warier prey community. Elk and deer began shifting their previous habitat preference to those with more cover and a reduced risk of predation. This kept animals moving, which spread the herbivory pressure over a wider variety of plant communities. As a result, herbivory on many high-quality riparian and forest plant communities was reduced. For example, the proportion of willow stems that were browsed decreased from approximately 90% in 1998 to less than 5% by 2001, and the proportion of aspen stems browsed decreased from around 95% in 1999 to roughly 20% by 2005. The average plant height for both these plant species also increased from roughly 1.5 feet to around 6.5 feet over each of their respective time scales. As riparian communities recovered, beaver populations increased and created a more diverse aquatic habitat. Aspen forests also began regenerating, and provided increased habitat and wildlife diversity. This reintroduction has paved the way for future management using top predators as a tool for ecological restoration in degraded ecosystems.

Forest Succession

Succession is defined as the observed change in the composition or structure of an ecological community over time. In plant communities, succession is usually the gradual growth of a plant community following a disturbance and/or the replacement of one plant community by another. Over years or decades, many plant species will continually be outcompeted and replaced by new species until they reach either a forest comprised of shade-tolerant trees, or a shifting mosaic on the landscape driven by small scale disturbances. A forest that has experienced a long time since disturbance is known as a late-seral community, which in theory, will persist. However, in Utah, fires, windstorms, episodic drought, and beetle outbreaks continually disturb the forests, preventing a steady state system from developing. Human disturbances, such as harvest, heavy grazing, construction, or climate change, also keep forests in a state of flux.

Succession is different in each ecosystem. In Utah's mountains, forest ecosystems predominantly consist of pines, spruces, firs, and aspen. Since aspen, lodgepole pine, and ponderosa pine grow well in sunny openings, where fire, avalanche, or logging has cleared the land, these species are often the first tree species to grow under such conditions. However, these tree species are not shade-tolerant. Eventually, the canopy closes as existing trees reach maturity, and new seedlings or saplings of shade-intolerant species are unable to replace the older trees. Thus, these forest types commonly convert to some mix of more shade-tolerant tree species, such as Engelmann spruce, Douglas-fir, and subalpine fir. These species slowly establish in the understory of aspen and lodgepole pine forests, and are capable of growing to the forest canopy in low light conditions. Over time, the more shade-tolerant trees outcompete the less shade-tolerant aspen and lodgepole pine.

However, even forest succession does not begin with trees. Immediately after disturbance, bare ground is first colonized by smaller plants, such as mosses, grasses, and forbs. Trees and shrubs establish at this time, too, but in the initial years following disturbance, trees and shrubs grow more slowly and may go unnoticed. Even on bare rocks, lichens can take hold and begin the process that leads to succeeding generations of plant communities. Like all plant communities, forests are dynamic, ever-changing systems that are affected by many disturbances. These disturbances can affect the process of succession, halting succession at early stages. For example, elk can browse aspen seedlings and prevent grasslands from succeeding to aspen groves; and wildfire, avalanches, wind storms, and floods can wipe out even the largest evergreen trees, inevitably starting the cycle of succession over again.

Succession vs. Disturbance

Although succession is a slow progression forward, **disturbance** can be a dramatic step backward toward **early successional communities**. Quick disturbances include events such as fire, logging,

avalanches, wildlife browsing, insect outbreaks, or floods. If little or no disturbance occurs within a community, the existing plant community may be replaced by a **late successional community** structure.

Although disturbances are a natural part of ecosystem dynamics, severe disturbances, such as uncharacteristically large wildfires or massive bark beetle outbreaks, can occur if large continuous areas are susceptible. Because fire suppression efforts since about 1900 have allowed surface fuels to increase and made forests denser, large-scale disturbances have become more likely. Bark beetle outbreaks have recently become the most notable and widespread cause of tree mortality in the Intermountain West, most likely because undisturbed landscapes have resulted in dense, uninterrupted forests with trees of low vigor. This continuity and connectivity allows for the rapid growth and dispersal of large numbers of beetles to spread across the landscape, and also provides fuel for large scale wildfires to occur. However, despite the negative effects of large disturbances, such events provide an opportunity for early successional communities to re-establish.

But, with any change in structure, a change in forest function and animal occupancy also occurs. For example, a change from aspen forests to conifer forests will result in a decrease in water yield, water quality, and overall biodiversity; an increase in erosion and timber harvest productivity; and an alteration in the wildlife and plant species that can reside in that community. If an old forest were to burn at high severity, the bare landscape would result in a loss of vegetative cover, canopy structure, and biodiversity; an increase in erosion, soil fertility, and soil temperature; but would provide habitat for the organisms that need this type of habitat to survive. The continual dynamics of all plant communities are critical in maintaining diversity, rejuvenating ecosystem fertility, and maintaining a healthy and resilient ecosystem structure and function.

Natural, Non-Human Disturbances

Natural, non-human disturbances are considered to occur under normal conditions without direct influence from humans. In forests, disturbances primarily include wildfire, wind, and insects, but other secondary disturbances can result, such as those from the force of water, wind, or snow. Disturbances tend to affect patches of forest, which result in a **mosaic** of different successional forest stages across a landscape. This is especially true for secondary disturbances, which are localized and generally occur on higher and steeper slopes. The relatively short growing season at higher elevations, due to the long duration of snow-cover upon the ground and lower annual temperatures, means that forests develop very slowly, and may take over a thousand years to recover from a severe disturbance.

Unlike natural disturbances, human-caused disturbances are not part of the normal processes affecting succession. Logging and forest thinning have occurred ever since humans have occupied Utah's mountain ranges, but the intensity of such actions have increased since the state was settled by early pioneers. Livestock grazing has also occurred since settlement, and early unmanaged grazing significantly affected the structure of rangeland and forest communities. Current management has reduced the effects of livestock grazing, but livestock selectivity of different plant species may still alter the composition of some plant communities. Fire suppression, promoted through anti-fire programs such as "Smokey the Bear", has restricted the amount of natural disturbance in many forest communities. Recently, more research has proved the value of fire in habitat management and restoration. Prescribed fire treatments, consisting of highly controlled fires that are set to burn a specific area under a specific set of weather conditions, have become more common in an effort to reverse the impact of fire suppression. However, the controlled nature of prescribed fires may not allow for habitats to burn in a natural manner, thereby differing from natural burns.

Early Successional Communities in Utah's Mountains

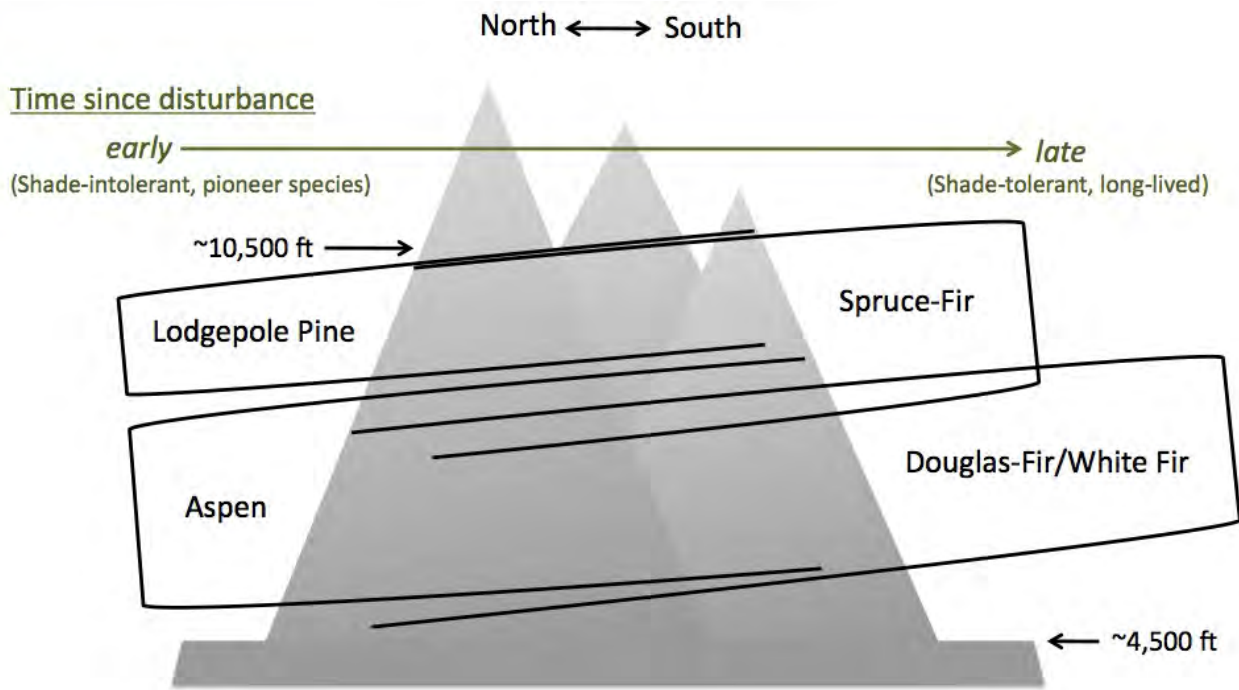
Early successional communities are the plant communities that are quick to establish after disturbance. The plant species that occupy these sites, also called **pioneer species**, are generally intolerant of shade, but tolerant of direct sunlight. Grasses and forbs are the first plants to establish after disturbance because of their rapid growth form. These species form beautiful, green meadows with colorful wildflowers. In lower montane communities, quaking aspen are predominately the first tree species to establish. Aspen forests can occur in three different forms including 1) a stable structure, which means aspen stands are properly functioning and continually replace themselves with new aspen growth and establishment, without conifer succession occurring; 2) succession to conifers, which means that shade-tolerant conifers are able to out-compete aspen saplings, and forests are eventually converted to pure conifer stands in the absence of disturbance; and 3) decadent stands that are falling apart, which means a single-age stand of aspen is not able to reproduce effectively, primarily because new shoots are being consumed by large herbivores. Although aspen forests are usually found at lower montane zones, aspen may extend into the upper montane zone. Aspen grow best on flat benches where the soil is deeper and has a higher moisture content. On steeper slopes, where soil is shallow and disturbance is more frequent, aspen are often more distorted and shrubby in appearance. Reproduction primarily occurs as vegetative suckering, with greater regeneration of disturbed sites if aspen clones previously existed on or adjacent to the disturbed site. At lower elevations throughout Utah, white fir and ponderosa pine are common pioneer species.

In the upper montane forests, especially throughout the Uinta Range and northern Wasatch Range, lodgepole pine is the first tree species to establish in early successional communities at mid- to high-elevations. Lodgepole pine reproduces via seed, which are contained in resin-sealed cones. Oftentimes lodgepole pine cones are serotinous, which means that high temperatures generated by fire are needed to open the cones and release the seed. Some areas, however, have non-serotinous individuals, which do not require heat to release their seeds and the cones will open naturally while still on the tree. While lodgepole pine usually establishes on recently burned sites, sometimes non-serotinous trees can establish on bare sites that have not recently been burned. Lodgepole pine does not have deep root systems like some other tree species, instead they produce extensive shallow root systems that help make the species more competitive on drier sites. Engelmann spruce and subalpine fir typically coexist as a distinct forest type (spruce-fir) throughout Utah because relatively infrequent large disturbance events allow them to co-occur for many centuries. Small-scale disturbances such as windthrow and small disease pockets result in the establishment of more spruce and fir, perpetuating the type. Tree establishment on non-forested or disturbed sites, by spruce or fir species, is extremely limited because seeds must compete with vigorous forbs and shrubs, and direct sunlight is detrimental to seedling establishment.

Late Successional Communities

After early successional forests have established, their canopy restricts the amount of understory growth that can occur. Shade-tolerant spruce and fir species are able to more easily establish under such conditions than the early successional tree species. These shade-tolerant species, such as Engelmann spruce, Colorado blue spruce, and subalpine fir, establish in the understory, and without disturbance, they can eventually outcompete and replace the early successional plant communities. The resulting spruce-fir forests are usually considered late successional communities. In lower montane forests, aspen, which does not often form a closed canopy, is commonly replaced by Douglas-fir or white fir in the Wasatch Range (white fir is absent from the northern Wasatch Range); and ponderosa pine more commonly replaces aspen on the lower, drier sites of the south slope of the Uinta Range. In the upper montane forests, Engelmann spruce and subalpine fir forests dominate higher elevations in the Uinta Mountains, in the Wasatch Range, and across the scattered plateau region in southern Utah.

A lack of disturbance helps to promote more structurally diverse forest communities by allowing establishment and survival of primarily shade-tolerant species. Because of the increase in understory trees (which are fuel and fuel ladders), there is less stability when faced with catastrophic disturbances such as wildfires. In situations where succession leads to dominance by a particular species (e.g., Engelmann spruce or lodgepole pine) that are susceptible hosts for bark beetles, large insect outbreaks become more likely. Dense forests of with understories of shade-tolerant species are probably more common today, especially in lower montane forests (such as ponderosa pine), than they were in the past largely due to fire suppression, livestock grazing and other human alterations to the natural system. In an effort to protect human lives and property, the suppression of fire over time has allowed the establishment of shade-tolerant trees, and led to accumulations of dead-fall material in many low elevation forest ecosystems. As a result, large and severe wildfires and extensive and severe bark beetle outbreaks appear to be occurring more often, and have the ability to dramatically alter large areas of forest ecosystems. Although these catastrophic events commonly occur at a larger scale than is typical, they still allow for habitat renewal. It will take time and proper management in the future to maintain diversity and early successional communities that are a necessary part of forest health.



A schematic diagram of forest succession, as influenced by elevation, time since disturbance, and aspect, in Utah's mountains. (Image by M. Larese-Casanova)

Plant Adaptations to Mountain Ecosystems

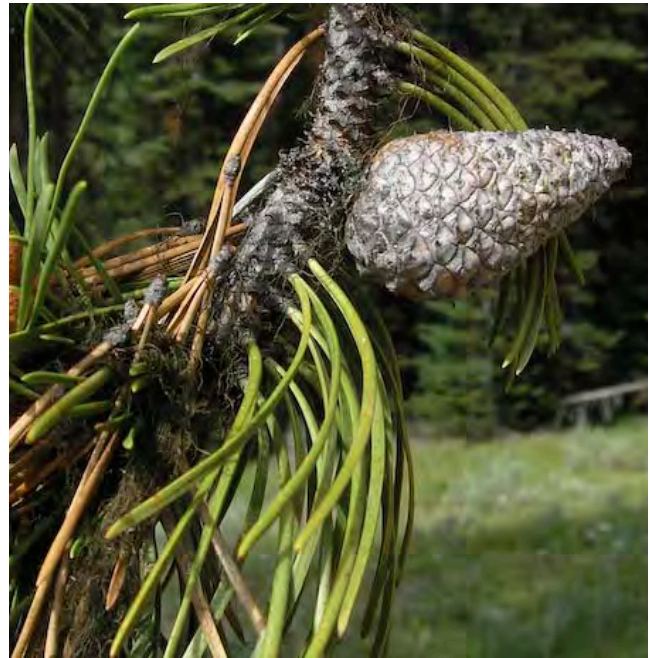
Although most mountain plants are adapted to extremes in climate, such as heavy snowpack, freezing temperatures, and limited growing season, the plants of the alpine and higher subalpine zones have the most extreme **adaptations** for surviving in such mountain climates. Plants of the alpine tundra and those near treeline, are exposed to excessive winds and freezing temperatures for the majority of the year. These high elevation, windswept cliffs and mountain habitats are shaped by the **krummholz effect**, where winds and other harsh climatic conditions sculpt the plant communities. Krummholz trees that form in these habitats are typically stunted, warped, and irregular in shape and lack a vertical leader. Spruces and firs commonly look more like shrubs than like trees. Other plant species are extremely short, often growing in

thick little clusters in order to hug the ground where it is warmer and safer from the elements. In addition, these plants must also grow during a limited growing season, where annual temperatures are below freezing. Being able to photosynthesize under cold conditions is critical to survive at high elevations.

Alpine communities in southern Utah are generally considered to be relict communities because they currently hold only fragments of the alpine biota that likely occurred here. Historically, alpine plant communities and subalpine plant communities migrated up and down the slope with changes in annual temperatures. Currently, subalpine communities are thought to be slowly rising in elevation as temperatures increase due to climate change.

Cone Serotiny

Some lodgepole pine reproduce via serotinous cones. The serotinous cones have scales that are bonded together by resin. Unlike the cones of most conifer species, lodgepole pine cones do not open as soon as they reach maturity, instead, they require temperatures of 113-140°F (45-60°C) to break the resinous bond and release their seeds. In nature, only fire provides temperatures high enough to break this resinous bond. This allows lodgepole pine seeds to remain dormant until fire provides a clear, safe site for seedling establishment to occur. In some cases, when a serotinous cone falls on open ground in direct sunlight, solar radiation may provide enough heat to open the cone. When seeds are released, densities can surpass tens of thousands of seeds per acre. Having such a high seed density, in addition to high rates of viability, germination, and growth, makes cone serotiny an exceptional adaptation to large-severity fires for this early successional tree species. However, not all lodgepole pine have serotinous cones. Those individuals with nonserotinous cones are adapted to slowly colonize new habitats, such as sagebrush woodlands or mountain meadows. Nonserotinous trees are useful in maintaining stands of lodgepole pine in the absence of fire, and may have been important for reproduction during the recent period of fire suppression.



A sealed serotinous lodgepole pine cone.
(Image by M. Larese-Casanova)

It is possible to have both nonserotinous and serotinous cones in a stand of lodgepole pine; however, stands that originated after fire usually have a high percentage of serotinous individuals, and stands that originated after other types of disturbance usually have a high percentage of nonserotinous individuals. Also, stands with an even-aged structure, where all lodgepole pines are about the same age and height, usually have a higher proportion of serotinous individuals because the stand likely regenerated from seeds released during a single disturbance event such as fire. Stands that have a mixed-age structure, with trees of different heights and ages, usually have a higher proportion of nonserotinous individuals because seeds were not released during a single event. Mixed severity fires often kill some trees on sites where understory fuels have accumulated while sparing other sites where understory fuels and densities are more limited. As a result, some mature trees may persist on sites that are frequently disturbed by fire.

Adaptation to Cold by Conifers

Since conifers dominate the higher elevations of Utah's mountains, they must have adaptations to make them more competitive in surviving the harsh conditions. Most broadleaf trees have large flat leaves, which provide more surface area for capturing sunlight for photosynthesis; however, they are also more susceptible to wind damage and increased water loss because of higher transpiration rates. The needle-shaped leaves of conifers lose less water from transpiration due to their smaller size and waxy, outer coating. Conifers are also called evergreen trees because they retain their needles throughout the winter. This allows for photosynthesis to occur during the cold temperatures of late fall and early spring (as long as temperatures are above freezing), when broadleaf leaves are not present. The tall, thin, cone-shaped structure of conifer trees is also critical in order to live in a mountain habitat. This shape helps trees to shed snow and ice that accumulate on their needles and branches throughout the winter.

Lastly, conifers exhibit **extracellular freezing** that protects cell tissues from freezing, but also causes dehydration inside the cell proportional to the temperature below freezing. In other words, conifer plants move water outside the cell wall into external, non-living tissues, so that when water freezes, living cells are protected from ice crystallization. However, by moving water out of the cell for extracellular freezing, cellular dehydration becomes a problem because of limited water availability within the living cell. Therefore, conifers must balance extracellular freezing, with the risks of intercellular freezing and cellular dehydration.

Multiple Reproductive Strategies

Due to the short growing season and cold temperatures of mountain communities, seedling germination and establishment is not always an effective reproductive method. Vegetative reproduction, therefore, becomes critical for many species in mountain communities. Engelmann spruce and subalpine fir are usually considered to reproduce mainly by seed, but under certain circumstances, asexual reproduction is their primary reproductive strategy. In high mountain communities, branches often touch the ground and are covered by soil. These branches eventually take root and sprout new trees from the tips of lateral branches, a process called **layering**. This type of reproduction is most commonly found at the edge of alpine communities, forming krummholz and prostrate flag trees. In many cases, krummholz trees that occur near treeline do not ever produce viable seeds, and rely on asexual vegetative reproduction to survive on the landscape. This leads to clonal growth of multi-aged stands, creating tree islands. Tree islands form when established windward trees provide protection from alpine harsh winds, allowing for new growth to occur on the leeward side. As trees establish and grow on the leeward side of a tree island, trees on the windward side die off from exposure to the harsh elements. As a result, tree islands slowly move across the landscape as this cycle repeats itself. A tree island is suspected to have started from a single seedling on a site with moderated conditions, and have slowly moved to sites where seedling establishment cannot occur.

Quaking aspen is another tree species that relies heavily on asexual reproduction to produce new stems. Aspen can reproduce from both seed and vegetative rhizomes. Successful seedling establishment is thought to be somewhat rare in the semiarid Intermountain West, but recent research suggests that seedling establishment occurs more often than was once expected. However, vegetative reproduction from existing individuals is considered the primary means of reproduction in most conditions. Aspen reproduce asexually from underground rhizomes, through a process called suckering, producing multi-stemmed clones that can ensure the survival of that genetic individual into the future. Even in transitional zones where succession has converted aspen forests into spruce-fir forests, persistent aspen rhizomes can sucker following a disturbance, such as fire. Most aspen stands consist of several genetically distinct clones that can sometimes be distinguished by differences in seasonal timing, such as green up in the spring or leaf

color change in the fall. Perhaps the multiple reproductive strategies and high genetic diversity of quaking aspen contribute to it being the most widespread native tree species in North America.

Animal Adaptations to Mountain Ecosystems

Adaptation Types

Mountain climates vary dramatically from season to season, and even between night and day. As a result, animals must be able to adapt to a wide variation in living conditions. Since Utah was not always characterized as having high-elevation mountain ranges, adaptation of Utah's mountain animals is likely a result of slow changes over a long period of time. Animal adaptations for surviving in a climate with warm summer daytime temperatures, cool summer nighttime temperatures, and extremely cold and snowy winter conditions, can be separated into three general categories:

Behavioral– moving to a new area when food is not available or snowpack becomes too deep.

Morphological– changing the color of an animal's fur to blend in with their environment.

Physiological– reducing an individual's metabolism when food is not available.

Behavioral Adaptations

Many behavioral adaptations exist to avoiding the extreme temperatures of mountain climates. Many wildlife species that inhabit Utah's mountains live inside underground dens and burrows to buffer the effects of harsh winds and bitter cold temperatures. For example, the 2nd lowest recorded temperature ever recorded in North America occurred at Peter Sinks in Logan Canyon in 1985 at - 69°F. Animals such as badgers, foxes, hares, rabbits, mice, and voles, dig their own underground burrows. Other species, such as bears, mountain lions, and bats, survive these harsh conditions by living in naturally formed caves and other similar structures. By living underground or in caves, animals enjoy more consistent living temperatures and are buffered from the negative impact of daily and annual air temperature extremes. Many bird species, and some small mammals, live inside tree cavities that are often created by woodpeckers and sapsuckers. Tree cavities provide shelter from harsh winds, and provide insulation to retain heat within the cavity. However, not all species can escape the elements as easily as burrowing and cavity-dwelling animals. Ungulates, such as deer, elk, and moose, must rely on shelter from trees and shrubs to survive. Vegetation may block some of the wind, and retain heat more effectively than areas without vegetation, but vegetated areas are certainly not as effective at protecting animals from the elements as underground burrows or tree cavities. Because of this, ungulates must migrate to lower elevations to survive during the extreme winter months.

Migrating Throughout the Year

Because temperature decreases at higher altitudes, and precipitation tends to increase, living in the high elevations of Utah's mountains throughout the winter months can be very difficult. Most species that remain at higher elevations during the winter undergo some form of hibernation or torpor. Other species, which do not have this sort of physiological adaptation, must **migrate** to lower elevations to escape the harsh winds, extremely cold temperatures, and deep snowpack that can make escaping predators and finding food extremely difficult. Ungulates, such as elk and deer, migrate to the lower valleys and foothill slopes during the winter. Other large mammals such as mountain goats and bighorn sheep follow a similar migratory pattern. During the spring, they migrate back to the mountain forests to give birth, then to higher alpine and subalpine sites to escape the heat for the summer, before completing a full migration cycle back to the valleys below in the fall.

Seasonal elevational migration is not restricted to large mammals. Many bird species, such as cedar waxwings, western tanagers, or mountain chickadees also make similar migrations. These species migrate by following the emergence and availability of food items throughout the seasons. As insects and plants emerge at lower elevations in the spring, the birds migrate upward from low elevations as temperature and food availability increases. By summer, they reach their high-elevation breeding habitats. As temperatures start to decrease during the autumn months, they start their migration back to lower elevations to increase their survival during the winter months. Similarly, the mountain bluebird spends its summers in mountain meadows above 5,000 feet. During the fall, this bird migrates to lower elevation valleys, and may even migrate southward during the winter.

Even aquatic species take advantage of seasonal climatic variations to complete their life cycle. Salmonid fish, which includes salmon, trout, graylings, and freshwater whitefish species, generally migrate upstream into higher elevations (where cooler, deeper water is abundant) during the spring to spawn. This allows them to take advantage of higher water flows during spring runoff events and to access isolated stretches of stream habitats for their offspring to grow. Here their offspring can access habitat with ample food during the summer while enjoying a lower risk of predation from larger predators as water levels decrease during the summer and fall.

Shifts in Foods Throughout the Year

Food abundance and availability varies greatly with the different seasons of the year. Because of these cycles, many animal species strategically alter their food preference to take advantage of seasonal variations. For example, during the spring, vegetative growth and insects are plentiful as daily air temperatures rise; but during the fall, plants are putting energy into producing seeds that provide an extremely nutritious food source for animals preparing for winter. Food shifts are apparent in the diets of a variety of small mammals that eat herbaceous vegetation throughout the spring and summer when it is plentiful and more nutritious. But come fall, they shift to eating seeds in order to gain weight and store nutrients for their upcoming winter hibernation. Similarly, ungulate species forage on herbaceous vegetation throughout most of the year, but they must switch to eating woody vegetation throughout the winter because most plants have lost their leaves. For many bird species, such as grouse, insects make up a large portion of their young's diet in the spring and summer. These insects help chicks build muscle and grow faster. This phenomenon can also occur in large omnivore species, such as bears. For example, when berries and seeds are available (i.e. summer), bears will eat these food items almost exclusively, but when these items are no longer available, bears rely more on meat from prey items or scavenged carcasses to obtain nourishment.

Storing Food for Winter

Similar to animals that eat food and store fat to hibernate through the winter; others store food in other ways to survive during these harsh months. Red squirrels are called "larder hoarders," which means that they store their winter stash of nuts and seeds in a single, central location. Because the red squirrel relies on this single stash, they valiantly defend it from impending intruders. Typically, most caching animals create several smaller caches instead of a central stash. These caches are found in the softer soils that surround an animal's nest or den site.

One of the most interesting food-storing mammals is the American pika. This little rabbit-like species lives among rocky outcrops in alpine areas. Even though its environment can be extremely harsh throughout the majority of the year, the pika remains active year-round. Pika are active during the daylight hours, largely because nighttime temperatures in the alpine zone drop dramatically. During the summer months, this species collects and stores various grasses and wildflower species in haystacks near the entrance of their underground dens. The haystacks dry in the sun, and are then carried within their burrow

to be used as a supplemental feed throughout the winter. These haystacks are not large enough to sustain an individual throughout the entire winter, so individuals remain active by collecting and foraging for lichens and other alpine plants that it can find during the warmest part of the daylight hours. Other species that store food for winter include corvids (e.g., nutcrackers and jays), beavers, and other small mammals.

Morphological Adaptations

Morphological adaptations, or particular variations in an animal's body, can be particularly beneficial to surviving in a mountain climate.

Large Feet

Deep snowpack can be challenging for wildlife species that live in the mountains during the winter. Therefore, adaptations to deal with this constraint are fairly common. One solution is to increase the surface area of an animal's feet, which will increase an animal's ability to move on top of deep snow. Snowshoe hare and Canada lynx are active throughout the winter, and have relatively large feet that allow them to walk on top of the snow. Since Canada lynx usually feed exclusively on snowshoe hare, this predator-prey relationship is the result of an important evolutionary force where natural selection selects for the more effective predators and the more elusive prey. When hare populations are scarce, lynx populations respond by declining, which causes hare populations to grow, which (due to increased food availability), causes lynx populations to expand, and so on. The increased surface area of these two species' feet are likely a result of a natural selection "arms race" to make each species more competitive and more likely to survive winters requiring snowy navigation.



The large hind feet of a snowshoe hare allow it to walk on deep snow and evade Canada lynx.

Long Legs

Conversely, elk and moose have long, slender legs. Unlike hare and lynx, these species are adapted to walking through, rather than on top of, deep snow. Long legs keep the majority of an elk or moose's body above the snow, and only require the movement of relatively slender legs through the snow. Moose are even more adapted to walk through deep snow with more flexible shoulders that allow them to lift their legs as high as their shoulders. Hoofed animals, such as elk and moose, often use their specially-adapted

hooves to maneuver through rocky terrain and protect themselves from the jagged rocks. Hooves also reduce the amount of surface area that touches the ground, which increases the speed of an animal while running from predators.

Long, Slim Bodies

Another struggle of living in the mountains during winter is finding food. Members of the Mustelid family, such as short-tailed weasels, have very long and slender bodies. This slim body structure allows short-tailed weasels to enter into the burrows of small mammalian prey species, giving them the unique ability to easily seek out hibernating prey during the winter. Without this adaptation, the restricted availability of smaller prey items above ground during the winter could significantly hinder the survival of weasels.

Pelage

Many mammals grow thicker fur coats in the winter to keep warm, and shed the extra fur during the summer to stay cooler. Snowshoe hares, voles, and shrews have a thick winter coat that is twice the length and thickness of their summer coat. Some animals also change the color of their fur to **camouflage** themselves with changes in their environment. For mountainous species, white pelage in the winter offers the distinct advantage of camouflage for both predator and prey species. Snowshoe hares have a white-tipped winter pelage to blend in with their snow-covered landscape, and a brownish-gray summer coat blend in with the vegetation and soil. Similarly, weasels, like the short-tailed weasel, undergo a full molt (i.e., shedding) every fall where each brown hair is replaced with a white hair. In the spring, the opposite molt occurs. Generally, this type of seasonal pelage change occurs above 40°N latitude. Otherwise, snow does not usually cover the landscape for a significant portion of the year, and pelage changes are not necessary. In fact, pelage changes would be severely detrimental without this white background of snow.

Physiological Adaptations

Torpor

Torpor is defined as a temporary hibernation where an animal remains in an inactive state for a relatively short period of time. Often torpor can last overnight, which is the case for many birds and small mammal species. Most of these species could not survive prolonged periods of inactivity because their body size limits the amount of stored energy that is available. This limitation requires them to become active and look for food when the physiological cues arise. Torpor involves a less drastic reduction in body temperature and metabolism than true hibernation; however, this reduction in metabolic activity is still beneficial to the animal. Once an animal has entered torpor, it often survives on body fat reserves or on stored food caches near its nest.

Contrary to popular belief, larger mammals, such as bears, experience a prolonged period of torpor rather than true hibernation. Because of their large body size, insulating fur, and extensive fat reserves, bears can survive through the winter without dramatically reducing their body temperature and metabolism – this is the distinguishing characteristic between torpor and hibernation.

Other mammals, like bats, can regulate the degree of metabolic reduction depending upon their environmental conditions. During the winter, bats can go into a deep, prolonged torpor that can last for many months. This type of metabolic reduction is actually considered true hibernation because metabolic activity is significantly reduced during times of limited food availability. However, during other times of the year, bats can go into a shorter period of torpor (e.g., a couple hours), which results in a short-lived, minimal reduction in metabolic activity. Because bats have the ability to slow their metabolism so

remarkably, some torpid bats can survive being submerged underwater for up to an hour with little harmful effects.

Hibernation

Unlike torpor, true **hibernation** is an extended period of inactivity that results in a deep drop in body temperature and metabolic rate. The decline in metabolic rate compared to the drop in body temperature is explained by Van't Hoff's Rule which states that in a hibernating animal, for every 10°C drop in body temperature, metabolism is slowed down by half. True hibernation occurs in a variety of mammals, birds, amphibians, and insects; however, the length and degree of hibernation can vary between species belonging to the same family group (e.g., Sciuridae; the squirrel and chipmunk family), or even between individuals of the same species at different elevations.

There are two types of hibernating species, facultative hibernators and obligate hibernators. **Facultative hibernators** enter hibernation in response to environmental conditions, such as prolonged periods of cold weather or a limited availability of food. For example, the western jumping mouse is cued to enter hibernation after an adequate accumulation of fat deposits following increased seed consumption. These fat deposits signal the end of the growing season, the onset of fall, and the beginning of a decrease in ambient temperatures. Facultative hibernators are usually awakened or aroused from their hibernation during periods of increased ambient temperatures.

Obligate hibernators undergo an annual sequence of fattening and hibernation as an internal physiologically-controlled cycle. Unlike facultative hibernators, obligate hibernation is independent of environmental conditions. Obligate hibernators are cued to prepare for hibernation by their physiology (e.g., the arctic ground squirrel enters hibernation between October 5 and October 22, precisely every year, regardless of the weather). They are usually awakened from hibernation by internal cues independent from their environment. Ground squirrels and marmots are some examples of obligate hibernators. Although these two groups of hibernators are controlled by different factors, they have similarities in function. Both groups can experience an alarm arousal in response to a dramatic drop in ambient temperatures. This alarm arousal will result in intense shivering to produce enough heat to tolerate the cold and survive.



A chipmunk, which is a facultative hibernator, fast asleep in its hibernaculum.

Although similar to hibernation in nature, reptiles and amphibians experience a form of hibernation called **brumation**. Rather than sleeping and living off their bodies fat reserves like mammals, reptiles are

often awake during this brumation state. Since there is little external heat to increase their body temperature, they become lethargic and use little energy to maintain basic function. During the brumation period, feeding is not necessarily important; however, reptiles must acquire a source of water to survive. Similar to facultative hibernators, the timing of brumation is controlled by environmental conditions such as daily temperatures.

Increased Metabolism

Non-hibernating animals can increase their metabolism to produce heat during extremely cold conditions. However, by increasing their metabolism, an individual's risk of starvation increases because stored energy is burned at a higher rate. This increase in metabolic rate due to cold environmental conditions is commonly referred to as seasonal metabolic acclimatization. Seasonal metabolic acclimatization is very common among various temperate zone bird species. For example, chickadees and titmice use brown adipose tissue to help keep them warm during the winter. Brown adipose tissue is a form of fat that is high in mitochondria that produce and dissipate heat. On a single winter night, a chickadee can consume all of its stored fat in order to stay warm. Therefore, this fat must be replenished every day to provide new energy stores for the following night.

Symbiotic Relationships

Symbiosis is a long-lasting association between two or more species of organisms. **Mutualism** is a type of symbiosis where both organisms benefit from their relationship. **Parasitism**, on the other hand, is a form of symbiotic relationship whereby only one organism benefits at the expense of the others. **Commensalism** is where one organism benefits and the other is not affected. Nature is full of symbiotic relationships because all animals and plants rely on other resources for survival. Some symbiotic relationships are critical for the survival of either one or all of the interacting species.

Lichens

A lichen is the product of a symbiotic association between a fungus, also called the **mycobiont**, and one or more photosynthetic partners, called the **photobionts**. Photobionts are usually green algae or cyanobacteria that possess a pigment called chlorophyll, which enables them to convert the sun's energy into sugar through the process of **photosynthesis**. In addition, cyanobacteria can build amino acids directly from fixing atmospheric nitrogen. Lichens can grow on almost any stable and reasonably well-lit surface. In order for a lichen to reproduce, fungal spores must disperse together with a photobiont individual. Lichens form a mutualistic relationship whereby the fungus provides protection to the photobiont, and the photobiont provides energy to the fungus. In all lichens, the fungus forms a thallus, which is a solid structure that incorporates the fungus and the photosynthetic partners, as well as other unique secondary



A diverse lichen community. (Image by M. Larese-Casanova)

compounds, some of which are even poisonous. These secondary compounds are assumed to protect lichens against disease, parasites, and browsing by herbivores, and are sometimes used to make various perfumes and dyes. After a symbiotic relationship is established, the fungus has the greatest influence on the final form of the lichens body's shape and structure. The mutualistic relationships of lichens are similar to mycorrhizal partnerships of fungi and plant roots.

One of the most interesting things about lichen is their ability to detect changes in air quality. The majority of the elements and chemical compounds that are used for lichen growth and development are extracted from the atmosphere. However, toxic metals and compounds are also extracted, and are readily accumulated within the lichen under processes such as particulate trapping in the thallus. A lichen's sensitivity to pollutants is high because air and water exchange occurs over the entire thallus surface; they lack root systems and therefore cannot access soil nutrients; they lack any protective tissue to maintain a constant internal water content, therefore concentrating absorbed pollutants during drier conditions. High pollutant levels can either affect the entire organism, resulting in bleaching of the thallus, change in thallus size and fertility, and increased mortality of sensitive species, or it can affect microscopic elements that support the plant, such as decreasing the number of algal cells, degrading photosynthetic pigments, altering photosynthesis and respiration rates, and elevating the concentration of heavy metals in the thallus. Some common pollutants include sulfur dioxide, nitrogen oxides, ozone, fluorine, lead, and mercury. The effects of deteriorating air quality is a critical management concern facing ecological communities with sensitive lichen species. As a result, the presence or absence of specific lichen in an area has been used to detect the atmospheric concentration of pollutants in an area.

In addition to being an indicator of air quality, lichens have many other uses. Research suggests that changes in lichen communities may also provide an indication of the general health and diversity of their ecosystem. Therefore, monitoring lichen communities may also be a good indicator of habitat diversity and health, rather than just of air quality alone.

Lichens are a very important food source in extreme environments. In arctic tundra, lichens make up a large proportion of a caribou's diet. In Utah elk, mule deer, mountain goat, American pika, northern flying squirrel, and various other small mammals consume lichens as a part of their diet. Various birds and small mammals also use lichens for nest construction material. Lastly, lichens are important in creating soil. They break down rocks using both physical pressure (e.g., breaking apart rocks by infiltrating cracks) and chemical processes (i.e., as chemicals are released by the lichens, these chemicals dissolve the rocks surface to release minerals). This is an extremely slow process, but the resilience and persistence of lichens allows for such processes to occur.

Squirrels, Conifers, and Fungi

Mycorrhizal fungi is a general term for a common symbiotic relationship between one species of fungi and a root system of a plant species. In fact, mycorrhiza literally means fungus-root. Coniferous plant species, particularly those in the Pinaceae family, depend upon mycorrhizal fungi to provide the roots with nutrients. In return, the tree shares its food, carbohydrates formed from photosynthesis, with the fungus. Eventually, the fungus creates mushrooms to release spores. Squirrels are fond of eating mushrooms, and provide the dispersal mechanism for the fungi when they consume or cache mushrooms.

The fungal hyphae penetrate into the tiny rootlets of their host plant, creating a mutualistic, mycorrhizal symbiosis with their host plant. Fungi will also sometime produce compounds to protect their host tree from pathogens and parasites. In addition, nitrogen-fixing bacteria live in proximity to plant roots, and obtain resources from the fungi. In return, the bacteria will provide the fungi and the host plant with nitrogen. Lastly, mycorrhizal fungi are known to "collect" phosphorus from the surrounding soil and transport it to the host plant in times of low phosphorus availability. Sporocarps, which are the spore-producing, fruiting structures of a fungi (e.g., mushrooms), may be present year-round and provide a good food source for a variety of small animals. Squirrel species, particularly red and northern flying squirrels,

eat these sporocarps. As sporocarps mature, they produce a strong odor that attracts foraging squirrels. In addition to providing nutrients and water to the squirrel, sporocarps contain fungal spores, nitrogen-fixing bacteria, and yeast. These items pass through the normal digestion process until they reach the cecum within the squirrel's intestines. In the cecum, the spores, bacteria, and yeast become concentrated for up to a month or more. The squirrel's waste pellets, containing the viable fungal spores, are deposited throughout the forest and germinate into new mycorrhizal colonies. Without this symbiotic system, the trees would not grow as fast or efficiently, the squirrels would struggle to find enough food, and the fungi would have no way of obtaining photosynthetic sugars for food.

Clark's Nutcrackers and Pines

The Clark's nutcracker is a member of the Corvidae family, which usually breed in coniferous mountain forests. Nutcrackers are critical to many conifer forests because they facilitate the dispersal of pine seeds into ground caches, which are either eaten later or are left to germinate and grow into new trees. Although nutcrackers disperse the seeds of most conifer species, there are at least seven tree species, including the limber pine, pinyon pine, and whitebark pine, that form a mutualistic relationship with the Clark's nutcracker in order to survive. The limber pine and pinyon pine occur in Utah, but the whitebark pine occurs just north of Utah in Idaho and Wyoming. These soft pine species do not have winged seeds, like other pine species, and therefore cannot be wind dispersed. The mutualistic relationship is complex, but is critical for the survival of the species involved.



A Clark's nutcracker, foraging for seeds atop a conifer tree.

Clark's nutcrackers usually start collecting pine seeds around late August. It will usually break off the green cones, fly to a perching site, and start pecking apart the scales to get at the seeds. Even in the late autumn, when cones have opened up to expose the seeds, green cones that are still sealed shut are preferred. Sometimes, cones are not removed from the tree; instead the seeds are extracted on site. During seed extraction, nutcrackers leave behind most of the diseased and aborted seeds in the cone. Any seeds that were extracted that were not edible are then discarded. Nutcrackers probably differentiate edible from non-edible seeds by color, and secondly by tapping the seeds to determine differences in density. Although the color of edible and aborted seeds may be the same, the edible seeds are denser than

those that are aborted. Spoiled seeds likely have a density similar to edible seeds, and the mechanism for distinguishing these seeds is unknown. The edible seeds are removed undamaged, and held in the nutcracker's sublingual pouch, a structure located in the bottom of their mouth that is capable of holding a volume of 20 ml. Approximately 125 limber pine or 95 pinyon pine seeds can be carried at a time.

Once seeds are collected, a nutcracker then flies to a caching area, where it creates multiple caches of one to five seeds that are buried about 1 inch beneath the soil surface (i.e., a depth where germination can occur). Nutcrackers have been known to fly up to 14 miles to a caching site from the foraging area, but caching sites are typically within 3 mi. Seeds are usually cached on south-facing slopes, where winter snow is melted off more quickly. Also, caching sites are sometimes communal, where many nutcrackers cache their seeds in the same area. This behavior may be a result of cooperation between related individuals, the limited availability of winter caching sites, or because communal caching sites are not used for breeding so there is no need to defend them. In one study, between 22,000 and 33,000 seeds were cached each year by a single nutcracker. This would provide 2 to 3 times the necessary energy requirements for a nutcracker through the winter. Because the Clark's nutcracker has such a good spatial memory, a large majority of their seeds, generally 55% to 90% are later retrieved and consumed. The remaining seeds will either be stolen by other animals, or will germinate and establish new trees. Interestingly, because caches are usually made up of more than one seed, undisturbed caches can result in the germination of multiple seeds. This results in multi-trunk trees, with each trunk having its own distinct genetic origin. Therefore, Clark's nutcrackers also provide a unique community structure in addition to seed dispersal.

The mutualistic relationship between Clark's nutcrackers and conifers is crucial to the survival of both species. The nutcracker is able to compete with other bird species and provide itself with enough energy to survive the harsh winter; in return, the nutcracker provides the mechanism for dispersal of multiple pine tree species. Disruptions to this mutualistic relationship increase the risk of extinction for both the plant and animal. In subalpine whitebark pine forests, invasions from fungal pathogens and mountain pine beetles threaten to destroy this relationship. A specific fungal pathogen, *Cronartium ribicola*, causes white pine blister rust. Tree mortality from this pathogen has exceeded 90% in some areas. In turn, this reduction in trees will drastically decrease the production and availability of seeds for the nutcracker. When food availability decreases, nutcrackers generally migrate to areas with higher seed production, and this mutualistic relationship may be threatened. However, there were always a few nutcrackers in areas with at least some remaining whitebark pines, but whether or not these few can facilitate the recovery of the forests is unknown. Similarly, mountain pine beetle infestations may also threaten pine-nutcracker mutualism.

Pollination by Hummingbirds and Insects

Pollination is important in any ecosystem because it is critical in the regeneration of many plant species. Pollination is the act of taking pollen from the male flower part, the stamen, and using it to fertilize the female part, the pistil. Some plant species can use wind and gravity for pollination, but many plant species, such as wildflowers, require fertilization by animals. Although most people think of insects and bees when they think of pollination, many of Utah's mountain wildflower species are specially adapted to attract certain animals to facilitate pollination. Hummingbirds drink the nectar from many plant species in order to obtain energy. In the process, the hummingbird's long beak accumulates sticky pollen, some of which will be transferred to the next flower it visits in search of nectar. If the flowers are the same species, pollination will likely occur. As a result, a mutualistic relationship is formed. The hummingbird gets energy, and in return, it provides the flower with pollination services. Without such services, there are some wildflower species, such as some columbine and larkspur species, that would cease to exist because they rely almost exclusively on hummingbirds for pollination. The broad-tailed hummingbird, rufous hummingbird, and calliope hummingbird can be found in Utah's mountains during some months of the year.

Climate Change

Climate change has the potential to alter habitat and ecosystem function on large scales. In mountain habitats, many species of plants and wildlife will need to migrate higher in elevation to escape warmer temperatures. Even so, these species can only go so high before their habitat is gone. Higher elevation species, which are adapted to the harsh, cold conditions, will not be able to properly function. Hibernation patterns of various wildlife species may shorten or cause animals to awaken from hibernation prematurely. As mountain ecosystems change, species from lower elevations may begin to migrate upward, inevitably outcompeting mountain species, altering the natural ecosystem functions. In addition, humans rely heavily on the ecosystem goods and services that originate in mountain ecosystems to survive; these goods and services include water resources (including high quality water), timber products, recreational activities, food resources, and many others. Many of the benefits from these resources are decreased or lost entirely.

Disturbance Regimes

As average temperatures have been increasing in the west, the number of wildfires and length of the wildfire season have been increasing. Snow melts sooner, and forests are drier for a longer period of time, making them ripe for severe wildfires. Larger and more frequent wildfires remove vegetation and lead to increases in erosion. Erosion alters the landscape and negatively affects aquatic systems through siltation.

Some insects are expanding their range into warmer areas. Species such as mountain pine beetles are flourishing with warmer temperatures. They are able to extend over a larger range, sometimes complete a life cycle in 1 year rather than 2 years, and they continue to decimate forests throughout the western United States and Canada. Bark beetles have become more prominent at higher elevations and latitudes as a result of fewer cold winters to limit population growth, causing significant disturbance.

Effects on Species' Annual Cycles

Although all ecosystems are affected by climate change, mountains seem to be disproportionately affected and are having larger changes in temperature compared to lower elevation ecosystems. Warmer spring temperatures have resulted in earlier migrations of bird species (e.g., American robin) to their mountain breeding habitats. Although data show that the average date for robin migration has not changed, the date of first-migrant arrival has. First migrants arrive an average of 14 days earlier than 19 years ago; however, there is a chance that large amounts of snow will still be on the ground at this time. In alpine species, such as the yellow-bellied marmot, spring warming has also resulted in an earlier emergence from hibernation each year. It is typical for marmots to emerge from hibernation, dig through a few feet of snow, and decide whether to re-enter hibernation or not. Despite the presence of several feet of snow on the ground, the date of first marmot emergence from hibernation has been 38 days earlier over a period of the last 23 years.

Emerging or migrating during periods of heavy snow cover might make food more difficult to find, and threaten survival. On average, robins must survive under harsh mountain conditions for an extra 18 days with snow covering the ground. Similarly, marmots that awake from hibernation early will burn off excess fat reserves before plants (i.e., food) have emerged, which may lead to starvation or a reduction in litter sizes during reproduction.

Some mountain plants are following a similar pattern, flowering 8 days earlier than they did a century ago. The occurrence of lower winter snowfall and warmer springs has cued earlier growth and flowering. While a longer growing season might seem to be an advantage, it puts the plants at a greater risk of death from hard frosts that are likely to still occur earlier in the spring.

Change in Species Distribution

Some species cannot adequately respond to changes in climate. Alpine species are extremely susceptible to these changes because their habitat will be the first to disappear under warmer conditions. The American pika is one species that has received considerable attention recently. In one study, 28% of previous known sites where pika historically occurred no longer have pika living there. These sites were located at lower elevations, and warmer temperatures are thought to have forced the pika to leave these sites and move to higher elevations. Since pika usually live on isolated mountain peaks, surrounded by lower elevation valleys, they are not able to migrate to higher latitudes to escape the warming trend. As summer temperatures become warmer, and pika have reached the top of their mountain habitat, they will no longer be able to survive.

Similarly, bighorn sheep inhabit isolated mountain ranges throughout western deserts. As temperatures have increased recently, lower-elevation mountain ranges have lost bighorn sheep entirely. Similar to the pika, bighorn sheep are unable to migrate to new mountain ranges in more northern latitudes.

The effect of climate change also extends into aquatic ecosystems. Some species of cold water trout are adversely affected by warming trends. Although bull trout are not native to Utah, they are found throughout most western states to our north. They live in high mountain lakes and streams, require colder water than most species, and need clean water to breed. Although climate change is not necessarily the primary factor responsible for their decline, if human-based mortality were eliminated, increases in summer water temperatures could likely threaten the existence of bull trout and other cold-water species.

Conversely, some species can and do move northward to escape rising temperatures. In a study of more than 1,700 species, over 80% of them have exhibited shifts northward in their range, changes in annual cycles (i.e., phenology), or behavioral changes in response to current warming trends. Historic wolverine extirpations in Utah have likely been affected by changes in climate. Research suggests that the distribution of wolverines is correlated to areas with persistent snowpack. With warming temperatures, persistent snowpack and glaciers are suspected to eventually melt completely in the lower 48 states, and wolverines may be forced to higher latitudes.

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Management

Public Lands in Utah's Mountains

The western United States has the largest amount of public land in the country. In Utah specifically, nearly three-fourths of the state is publicly-owned and managed by either the federal or state government. The federal government alone controls over 36 million acres, or 67% of the state; however, 4.6% of this federal land is owned by the military and is closed to the public. Nonetheless, with around 63% of Utah's lands owned by the federal government for public use, and 7.2% owned by the state, approximately 70% of the state is open for public use. The remaining portion of the state's lands either belongs to American Indian tribes or is privately owned. Approximately 4.2% of Utah is owned by American Indian tribes, with the rights to manage their lands as a sovereign nation. The remaining 21.5% of Utah is owned by private parties; however, there are federal, state, and local laws and permits that govern how private individuals can use and manage their lands.

Nearly one third of Utah is covered by forests, occurring throughout the state, mostly above 5,000 feet in elevation. Utah's forested lands are 80.6% publicly owned, with a large majority (i.e., 75%) managed by the United States Forest Service. Only 4.9% of Utah's forests are state-owned, with around 60% of these lands concentrated in the southeastern region of the state. The remaining 19.4% of Utah's forests are privately owned, making up around only 1.1% of the state's total land area. Furthermore, over half of all private commercial forests are concentrated in just four counties (i.e., Summit, Carbon, Wasatch, and Morgan). Utah's forested lands are commonly split into two groups, timberlands, which support more commercially valuable tree species, and woodlands, which support less commercially valuable species. Timberlands represent only about 21% of all Utah's forests, and include forest types such as ponderosa pine, Douglas-fir, aspen, lodgepole pine, and spruce-fir. Noncommercial woodlands make up the remainder of the states forests and include oak-maple and pinyon-juniper communities. Utah's private timberland forests are comprised of 62% aspen, 19% Douglas-fir, 10% ponderosa pine, 7% spruce-fir, and 2% lodgepole pine forest types. The proportion of timber harvest coming from private lands increased from 6% in 1966 to 17% in 1992; however, recreation is still the dominant land use of Utah's forests regardless of ownership. Other forest land uses, in addition to recreation and timber harvest, include livestock grazing, hunting, camping, and firewood harvesting.

U.S. Forest Service Management and Policies

Most of Utah's mountain ranges are predominately **National Forests**. The USDA Forest Service, also known as the **United States Forest Service** (USFS), has the largest managerial responsibility of Utah's mountains, managing approximately 75% of Utah's forests. There are seven National Forests in Utah-Sawtooth, Uinta, Wasatch-Cache, Ashley, Fishlake, Dixie, and Manti-La Sal. The mission of the USFS is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

All USFS activities are regulated under the **National Environmental Policy Act** (NEPA) and by the **Environmental Protection Agency** (EPA). NEPA ensures that federal agencies give proper consideration to potential negative environmental impacts of any major federal action using federal money or any action conducted on federal lands. Depending on the size and anticipated impacts, an activity may require one of three levels of investigation and preparation; 1) a Categorical Exclusion (CE), 2) an Environmental Assessment (EA) with a Finding of No Significant Impact (FONSI), or 3) an Environmental Impact Statement (EIS). A CE is an action that has been described and approved by the Environmental Protection Agency

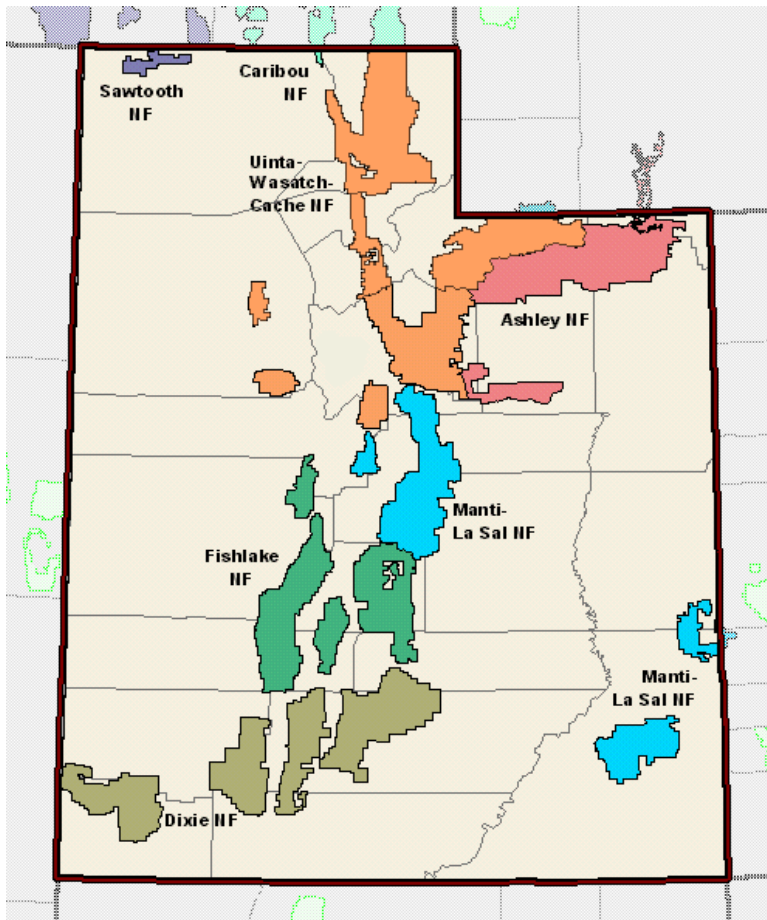
(EPA) to have no significant impacts if it meets certain criteria. An EA or EIS must be completed for any action that has not been specifically described and approved by the EPA. An EA is prepared when the action is not suspected to have a significant impact, which would then result in a FONSI. If during EA preparation a significant impact is found, and EIS is prepared. An EIS is a detailed evaluation of any action that is likely to have a significant impact, so that the EPA can determine whether the impacts would be severe enough to deny approval. Both the EA and EIS provide an analysis of all possible alternative solutions of an action in order to minimize the impacts on the environment.

In addition to NEPA documents that protect the general environment, the EPA has additional regulations regarding federally-listed species under the Endangered Species Act (ESA). A Biological Assessment (BA) or Biological Evaluation (BE) must be prepared if federally-listed species or their critical habitat is likely to be affected by any action. A BA is prepared if major construction activities are expected to negatively affect listed species or their critical habitat. A BE is prepared for all other types of non-construction impacts on a listed species or critical habitat. Information included in these assessments must include whether or not a listed species is present on the project site, what the effects on that species or its habitat are likely to be, and whether these effects can be minimized or avoided.

In addition to NEPA and the EPA, the **Wilderness Act of 1964** resulted in the creation of several wilderness areas interspersed within Utah's National Forests. The Wilderness Act of 1964, which was signed by President Lyndon B. Johnson, had the purpose of "establishing a National Wilderness Preservation System for the permanent good of the whole people, and for other purposes." It defined a wilderness as "an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this chapter an area of underdeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least 5,000 acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value." The National Wilderness Preservation System created hundreds of wilderness zones within federally protected lands, restricting motorized entry, road construction, logging, mining, and other human alterations of the landscape, in order to preserve the natural characteristics of these landscapes.

Utah's National Forests and Wilderness Areas

The seven National Forests in Utah, consisting of the Sawtooth, Uinta, Wasatch-Cache, Ashley, Fishlake, Dixie, and Manti-La Sal, cover a total area of approximately 10,500,000 acres, or 20% of the entire state. The Ashley National Forest is located in northeastern Utah and continues into Wyoming. It covers a total of 1,384,132 acres of land, with the majority of this National Forest (1,287,909 acres) found within Utah. This forest covers portions of the north- and south-slope of the Uinta Mountains, the Wyoming Basin, and Tavaputs Plateau. About 276,000 acres are part of the High Uintas Wilderness Area, and is home to Utah's tallest mountain, King's Peak. Elevations in the Ashley National Forest range from 6,000 feet to over 13,500 feet above sea level. This National Forest has two scenic byways and two scenic backways that offer spectacular views for scenic road-trip. Ashley National Forest also includes Flaming Gorge National Recreation Area, that encompasses Flaming Gorge Reservoir and portions of the Green River below Flaming Gorge Dam that are home to some of the best Mackinaw (Lake Trout) and Kokanee Salmon fishing in the state. Ashley National Forest was created by President Theodore Roosevelt in 1908.



Utah's National Forests encompass most of the Wasatch and Uinta Mountains. (Image from U.S. Forest Service)

Wasatch-Cache National Forest runs along one of the western United States' fastest growing metropolitan areas, the Wasatch Front, and covers 1,200,000 acres of the Wasatch Range and North Slope of the Uintas. Positioned adjacent to this National Forest, the Uinta National Forest contains another 950,000 acres to the southeast. These two National Forests are commonly combined, resulting in the Uinta-Wasatch-Cache National Forest that encompasses the Wasatch Mountains, the north-western half of the Uinta Mountains, and the Oquirrh and Stansbury Mountains to the west of the Salt Lake Valley. The Uinta-Wasatch-Cache National Forest encompasses nearly 2.1 acres of Utah's most diverse landscapes, rugged peaks, and majestic terrain. This National Forest includes a total of nine wilderness areas, including the remaining 180,500 acres of the High Uintas Wilderness area. Other wilderness areas include the Mount Naomi, Mount Nebo, Wellsville Mountain, Mount Olympus, Mount Timpanogos, Twin Peaks, Lone Peak, and Deseret Peak Wildernesses. It has a total of 8 scenic byways to provide scenic travel routes: the Bear Lake, Big Cottonwood Canyon, Little Cottonwood Canyon, Logan Canyon, Mirror Lake Highway, Nebo Loop, Ogden River, and Provo Canyon Scenic Byways. Because of its location and diverse recreational opportunities, the Uinta-Wasatch-Cache National Forest is among the most frequently visited National Forests in the nation. Recreational activities range from skiing in world-renowned powder, cruising along the scenic highways, or backpacking into remote lakes to enjoy an afternoon of fishing.

The Manti-La Sal National Forest encompasses 1,400,000 acres that includes not only portions of the Wasatch Plateau and Sanpitch Mountains in central Utah, but also the La Sal and Abajo Mountain ranges in southeast Utah. Elevations range from 5,000 to 10,000 feet above sea level along the Wasatch Plateau, and up to 12,000 feet in the La Sal Range. The Manti-La Sal National Forest was the result of two forest reserves created by Present Theodore Roosevelt in the early 1900s; the Manti Forest Reserve created in

1903, and the La Sal Forest Reserve created during 1906 and 1907. In 1949, these forests merged to form the Manti-La Sal National Forest. This National Forest contains over 5,000 known archeological sites that date from 10,000 years ago to the mid-1900s; it includes the Dark Canyon Wilderness that covers 47,000 acres, and is the only designated wilderness in southeastern Utah's canyon country. It is the source of 85% of the coal mined in Utah, and it provides habitat that supports some of the densest black bear and elk populations in the state. A fossilized mammoth skeleton was discovered on the Manti-La Sal National Forest near the summit of Huntington Canyon. Scientists believe that the male mammoth retreated to a cooler mountain climate at the end of the Ice Age to avoid warmer temperatures, and died here from old age and arthritis.

Fishlake National Forest of central Utah gets its name from Fish Lake, the largest natural mountain lake in the state. This National Forest, covering about 1.5 million acres, is characterized by majestic stands of aspen encircling lush montane meadows. Fishlake National Forest encompasses the Fish Lake Recreational Area, which provides some of the best fishing in the state, and is also home to Bullion Canyon, which was the site of historic mining operations in the late 1800s. Today, ruins of these mining operations still exist and are regularly toured by visitors. Hunting, fishing, and OHV use is among the most popular recreational uses of this forest. Interestingly, the Fishlake National Forest straddles the boundary between the Basin and Range and the Colorado Plateau. About 20% of the water from this forest drains into the Colorado River; the remaining 80% drains into the Great Basin.

Dixie National Forest is located in southern Utah, and was named after the area of Utah referred to as Dixie, a name given to the St. George area by early Mormon Settlers in the 1850s. Dixie National Forest covers nearly 2 million acres, and ranges in elevation from 2,800 feet to over 11,300 feet at Blue Bell Knoll on Boulder Mountain. Temperature extremes in this forest are also quite impressive, ranging in excess of 100°F at lower elevations near St. George to lows exceeding -30°F at plateau tops. Vegetation in this National Forest includes desert plant communities at low elevations, pinyon-juniper woodlands at mid-elevations, and aspen-conifer forests at high elevations. There are four wilderness areas on Dixie National Forest that cover over 85,000 acres, including the Ashdown Gorge, Box-Death Hollow, Cottonwood Forest, and Pine Valley Mountain Wildernesses. American Indians inhabited Dixie National Forest thousands of years ago.

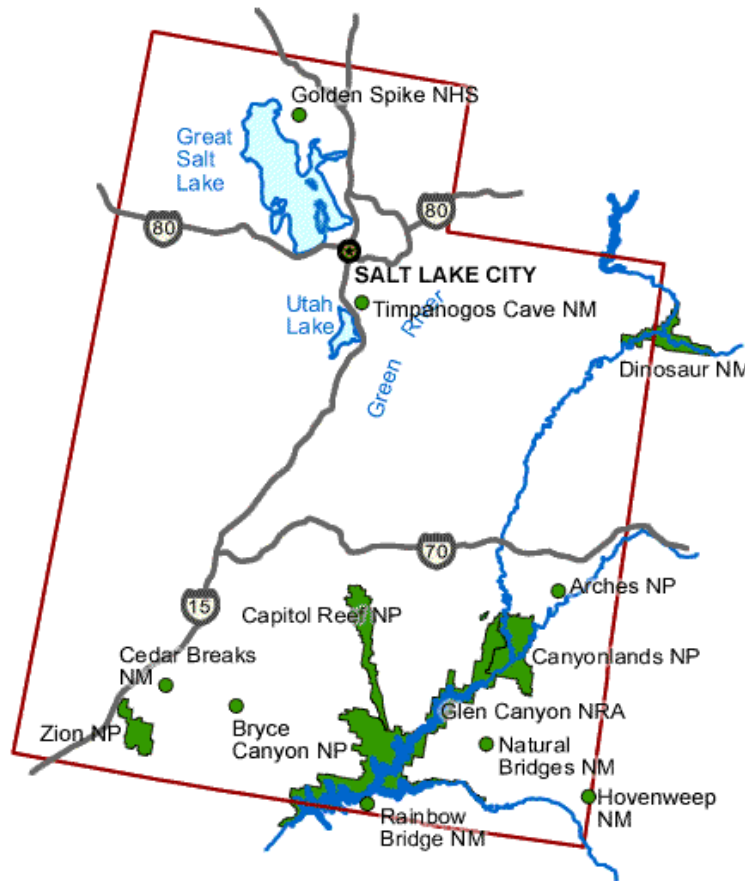
Sawtooth National Forest is not usually considered one of Utah's National Forests because most of the forest is actually found in Idaho. Sawtooth National Forest was created in 1905 by President Theodore Roosevelt, and contained approximately 1,947,500 acres. Today, there are about 2,100,000 acres in the Sawtooth National Forest. It is home to the Sawtooth National Recreation Area and the 217,000 acre Sawtooth Wilderness. Utah's Raft River Mountains are now considered part of the Southern Sawtooth National Forest. This Utah portion of about 92,000 acres was once called the Minidoka National Forest before it was combined with the Sawtooth in 1953.

National and State Parks in the Utah Mountains

Thanks to Utah's vast array of scenic landscapes and wildlands, Utah is home to many National and State Parks. A large number of these parks are found within the mountainous regions of the state. National Parks and National Monuments are managed by the **National Park Service (NPS)**, which is a federal agency that was founded in 1916 with this purpose, "to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." There are two National Parks in Utah that are located in the high elevation montane zone, Bryce Canyon National Park and Cedar Breaks National Monument.

Bryce Canyon National Park is small, covering only 56.2 square miles, and is located in the high Paunsaugunt Plateaus at the southern tip of the Wasatch Mountains. It reaches elevations from 8,000 to 9,100 feet above sea level along its rim. It was named after the Mormon Pioneer Ebenezer Bryce, and

became a National Park in 1928. Bryce Canyon National Park’s uniqueness comes from its colorful rock formations, which form bizarre shapes as rainwater and the freezing and thawing of ice, a process called frost-wedging, wears away the weak sandstone. This process created huge horseshoe-shaped amphitheaters with spire-like “hoodoos” and slot canyon formations. The park covers a 2000 feet range in elevations, with three distinct climatic zones: spruce/fir forest, ponderosa pine forests, and pinyon/juniper forest. The diversity of habitat provides for a high diversity of wildlife and plants, with over 100 species of birds, dozens of species of mammals, and more than a thousand plant species. This park is home to three federally-listed wildlife species; the Utah prairie dog, California condor, and the southwestern willow flycatcher. Lastly, Bryce Canyon is a perfect place to learn about and enjoy the night sky. Because it is so far from the light pollution of civilization, and the air quality is so good, the night sky at Bryce Canyon has a 7.5 magnitude night sky, which is dark enough to see 7,500 stars on a moonless night. This makes Bryce Canyon one of the darkest places in North America.



Utah’s National Parks and Monuments. (Image from National Park Service)

Cedar Breaks National Monument is also located at the southern tip of the Wasatch Plateau, just west of Bryce Canyon National Park. Rather than becoming a National Park, which requires Congressional approval, Cedar Breaks was declared a National Monument in 1933 by an Executive Order of President Franklin D. Roosevelt. Resting on top of the Colorado Plateau, Cedar Breaks reaches over 10,000 feet in elevation. Similar to Bryce Canyon, Cedar Breaks was also formed by frost-wedging and rainwater erosion, which carved a giant natural amphitheater that spans several miles and extends more than 2,000 feet deep. Chemical erosion also occurs as water combines with carbon dioxide in the atmosphere to form a weak carbonic acid that reacts with the sandstone. Like many areas in Utah, American Indians, such as the Southern Paiutes, used this area for thousands of years before Europeans arrived.

In addition to the Utah's National Parks, there are also a large number of **Utah State Parks** that are located in Utah's mountains or mountain valleys. These State Parks include East Canyon, Rockport, Wasatch Mountain, Jordanelle, Deer Creek, Scofield, Palisade, Piute, and Otter Creek State Parks. All of Utah's 43 State Parks are managed by Utah State Parks and Recreation. Their mission is to preserve and provide natural, cultural, and recreational resources for enjoyment, education, and inspiration for this and future generations. Utah State Parks and Recreation is named among the top three state park systems in the nation for excellence in public and private partnerships, long-range planning, resource management, preservation, and technological integration.



Utah's vast diversity of State Parks. (Image from Utah State Parks)

Many of Utah's montane State Parks are built around bodies of water that provide recreation in addition to drinking and irrigation water. East Canyon State Park is located in Morgan County in Northern Utah in a 5,700 feet elevation mountain valley. Although this park is largely surrounded by private lands, it includes 680 acres of prime boating and fishing access near the Wasatch-Cache National Forest, and was first opened to the public in 1962. East Canyon State Park and its surrounding areas have a rich pioneer history. The Donner Party was the first wagon train to travel through this valley in 1846 on their way to California. The canyon's high brush and rocky obstacles slowed the party down, and added to the high mortality and late arrival of this party in California. Just one year later, Mormon pioneers used this same trail to get to the Salt Lake Valley. East Canyon State Park's visitation increases every year as the population along the Watach Front grows.

Rockport State Park, located near Wanship, Utah, in Summit County, is another reservoir-focused state park located at 6,000 feet in elevation in one of Northern Utah's mountain valleys. Similar to East Canyon,

Rockport State Park is largely surrounded by private property, but the park itself covers 770 acres and over 1,000 surface-water acres that can be used by the public for fishing, camping, and boating activities. The Rockport area was first colonized in 1860, and was named for the rock fort that was constructed to protect the 200 settlers that lived here from Indian attacks. In 1957, the U.S. Bureau of Reclamation bought the land to build the Wanship Dam, in order to store runoff water from the Weber River. Rockport State Park was open to the public in 1966.

Jordanelle State Park is located at an elevation of 6,166 feet in the mountains just north of Heber City, Utah. Similar to other reservoir-focused parks, Jordanelle offers fishing, boating, camping, swimming, and hiking opportunities. This park offers two recreational areas, Hailstone and Rock Cliff. Hailstone is a large developed campground on the west side of Jordanelle Reservoir. Rock Cliff is located on the southeast side of the reservoir, and includes a nature center, a boardwalk and trail system through the wetlands and river habitat nearby, and camping sites. The construction of Jordanelle Dam began in 1987, was completed in 1993, and this reservoir became one of Utah's most recent State Parks, opening to the public in 1995.

Deer Creek State Park is found at 5,400 feet in elevation downstream from Jordanelle Reservoir at the eastern edge of the Uinta-Wasatch-Cache National Forest near Heber City. Deer Creek State Park offers fishing, boating, camping, and other water-based recreational opportunities similar to other reservoir-based State Parks. Deer Creek Reservoir was built by the U.S. Bureau of Reclamation between 1938 and 1955. However, until 1971 when the Utah State Parks and Recreation signed an agreement to manage Deer Creek, this reservoir was not open to the public for recreational activities. It was used solely for supplemental water storage. Today, this reservoir offers 18 miles of shoreline and up to 2,900 water-surface acres to enjoy.

Wasatch Mountain State Park, located at an elevation of 5,900 feet, is the only mountain park in Northern Utah that isn't centered around a reservoir. Recreational opportunities include camping, picnicking, golfing, hiking, biking, camping, horseback riding, snowmobiling, cross-country skiing, and snowshoeing in the Wasatch Mountains. This 22,000-acre park was set aside by the state in 1961, and was made a State Park in 1968. Wasatch Mountain State Park was a proud host of the 2002 Winter Olympic Games at Soldier Hollow, which remained open to the public afterward for skiing, tubing, inline skating, and biathlons. This park also offers two historic sites, the Historic Tate Barn and the Huber Grove. Tate Barn is an important architectural landmark and symbol for the Heber Valley, and the Huber Grove was a historic farmhouse and creamery.

Scofield State Park is located high in the mountains of the Manti-La Sal National Forest, in Pleasant Valley near the town of Scofield. Recreational opportunities include camping, fishing, boating, snowmobiling, cross-country skiing, and hiking. Settlers came to this valley in the 1870s because of the large amount of grazing lands. The town of Scofield was named after General Charles W. Scofield, who was a timber contractor that became the President of Utah's first coal mining company. Mining peaked in the 1920s when the town had over 6,000 residents. Today, Scofield has less than 100 residents; yet, the popularity of Scofield Reservoir brings over 70,000 visitors each year to the nearby State Park. This park is located at an elevation of 7,600 feet, and was first opened to the public in 1965.

Palisade State Park is located in Central Utah's Sanpete Valley, south of Manti near a town called Sterling. At an elevation of 5,800 feet, it provides a variety of recreational activities including camping, fishing, boating, golfing, OHV trail accessibility, and hiking. In the 1860s, an early settler named Daniel B. Funk had an idea of a summer and weekend resort area. At the time, the valley was owned by a small group of Sanpitch Indians. Mr. Funk bargained with the chief and obtained a land patent from the government. He and his family then built a dam, which would hold diverted water from Six-Mile Creek. The lake quickly became a well-known resort, now called Palisade. Palisade became a public State Park in 1962.

Piute State Park rests on the cliffs of the Sevier Plateau, and surrounds the Piute Reservoir. This primitive park is a quiet getaway and a well-kept secret that offers enjoyable fishing, boating, and camping experiences. Robert D. Young built the Piute Reservoir on the main fork of the Sevier River in 1908. Both

the reservoir and the county where it is located were named after the Paiute Indians that occupied this area. Later, the Utah legislature changed the original spelling of this state park from Paiute to Piute. This State Park opened in 1963.

Otter Creek State Park is located just south of Piute State Park. Construction of Otter Creek Reservoir began in 1897, and similar to Piute Reservoir, construction was supervised by Robert D. Young, who had no prior experience with dam construction. The reservoir was built to provide irrigation water for local farming communities. In 1965, Otter Creek was opened as a State Park. This park is another quiet getaway that is a great destination for fishing, ATV riding, boating, and birding. It is located at 5,900 feet at the edge of the Dixie National Forest, and has around 60,000 yearly visitors.

Private Land

Although private land ownership only comprises about 20% of the state, private ownership is common through the valleys of the northern Wasatch Mountains. Numerous small towns are scattered throughout the entire range, and the farmlands that surround these towns are also privately owned. Some better known examples include Richfield, Manti, Heber City, Park City, and Logan, but smaller towns such as Hoytsville, Sterling, Paradise, Aurora, or Oakley are abundant. Many of these small towns are surrounded by privately owned farmland and rangeland that some residents still rely on today to make a living. These mountain valley towns typically experience colder temperatures and higher precipitation totals than cities found along the Wasatch Front (i.e., Salt Lake, Provo, and Ogden). These mountain towns generally have easier access to fresh water supplies, and are closer to recreational opportunities in the mountains, including camping, fishing, hiking, and skiing. On the other hand, the mountain towns also have shorter growing seasons for agricultural crops, and provide less suitable wintering land for livestock because they are located at higher elevations with greater snowpack. Large areas of private mountain lands are fairly common in Northern Utah. Most are large private ranches that border National Forests, and are managed for cattle grazing and high-dollar big-game hunts.

Grazing

Historic Perspective

Historically, raising livestock was the economic backbone of many rural towns. After the Mormon pioneers first settled in Utah in 1847, nearly everyone in each small town had a small farm, or just a few cattle and sheep. The animals fed on community grazing lands near the town or on their own farm. Utah's diverse landscape provided a year-round grazing system that changed with the season. In the summer, livestock grazed lush mountainous areas; in the spring and fall, livestock were moved to the sagebrush foothills and valley grasslands; and in the winter, livestock were moved to the desert areas where snowpack was minimal.

One over-enthusiastically but visionary account written by Parley P. Pratt, a Mormon apostle and settlement explorer for the Mormon Church between 1847-1852, stated, "The supply of pasture for grazing animals is without limit in every direction. Millions of people could live in these countries and raise cattle and sheep to any amount." Although Utah still supports a fair amount of livestock grazing, there was a definite limit to the amount of grazing that the landscape could handle. Many other early settlers had the same opinion, and the unmanaged grazing that occurred over the next half a century, resulted in the large amount of overgrazing.

Although livestock ranching grew slowly in the beginning, by 1885 there were approximately 1 million sheep and 200,000 cattle in Utah. Sheep skyrocketed to 3.8 million around 1900, but then fell to 2.5 million shortly afterward due to drought and slow markets. Cattle, on the other hand, continued to grow fairly steadily over the next century, with the only decline occurring during World War II.

In order to maximize income while faced with increased competition and lower market values, many community lands were heavily overgrazed. Even by 1860, places in Sanpete County were considered destitute of grass, which were eventually replaced by invasive weeds. By 1910, these Sanpete towns were experiencing regular flooding and heavy erosion as a result of deteriorated vegetation conditions causing increased runoff. By the 1920s some areas were so heavily grazed that there wasn't enough forage remaining to support any livestock. And, by 1930, deteriorated rangelands and floods occurred throughout the Wasatch Front.



Sheep grazing ponderosa pine forests in 1899. (Image from Northern Arizona University)

The period from 1880-1900 was considered the period of spoliation of western rangelands due to heavy livestock grazing, extensive timber harvesting, and other human practices that occurred without proper management. In 1881, the **Department of Agriculture's Division of Forestry** was first established, but their job was mainly to gather information about the condition of the nation's forests. The first forest reserves were established under the **Federal Reserve Act in 1891** through the General Land Office. In 1901, the Division of Forestry was renamed the Bureau of Forestry and was led by Chief Forester Gifford Pinchot. In 1905, the Transfer Act was passed that established the **United States Forest Service (USFS)** under the Department of Agriculture that exists today. In addition, the Transfer Act switched the control of all forest reserves from the General Land Office to the USFS. In 1907, all Forest Reserves were renamed as National Forests. In the beginning, the USFS was created to protect and renewably manage timber, grazing, minerals, water, and recreational activities. Forest managers were faced with developing policies and practices to manage wildfire, logging, road building, wilderness designations, wildlife and watershed protection, grazing, and ownership disputes with states and counties. Many of the same challenges and controversies still exist today.

In 1902, Albert F. Potter, who was the inspector of grazing for the Interior Department's General Land Office, completed a survey of potential Forest Reserves in Utah. Most of Utah's forest reserves were created shortly afterward. Originally, many smaller forest reserves were created, and then later combined to make up the larger National Forests that exist today. For example, the Uintah Forest Reserve was the first Utah Forest Reserve created in 1897; shortly thereafter in 1906, more land was added and the name was changed to Uinta.

Approximately 70% of all western states, including Utah, are grazed by livestock. Overgrazing is said to have three ecological costs, 1) alteration of species composition of communities, including a decrease in plant and wildlife density, biomass, and species richness, 2) disruption of ecosystem functioning, including

interferences in nutrient cycles and ecological succession, and 3) alteration of ecosystem structure, including changes to vegetation coverage, which can contribute to increased soil erosion and decreased water retention and availability. Historic overgrazing has resulted in major costs in all three areas.

In 1945, a study conducted on Utah's mountain canyon habitats showed that there was an absence or near absence of 10 grass species on grazed sites. In another study conducted on Cedar Mountain in southern Utah in the 1980s, exclusive heavy sheep grazing since the 1890s resulted in only 18 plant species; in contrast, an adjacent reference enclosure that was limited to minor cattle or horse grazing since the 1920s, had 33 plant species. The desirability of plant species for grazing was also reduced. This shows that heavy grazing by sheep, versus light grazing by cattle and horses, resulted in a lower quality plant community from the 1920s to the 1980s. Additionally, riparian habitats are often significantly deteriorated and prone to accelerated erosion. Unlike wildlife, such as bison, that roam freely across the landscape, livestock spend a disproportionate amount of time near riparian water sources. Historically, unmanaged grazing led to the deterioration of many riparian zones throughout the state which caused extensive erosion and flooding issues.

In the 1920-1940s, there were approximately 2,500,000 sheep and 500,000 cattle in the state of Utah. The percentage of the feed coming from federal lands that was needed to support livestock in 1940 was nearly 60%, and the number of animal unit months (AUMs) of grazing permitted on Forest Service land was 1,000,000 AUMs. An AUM is the amount of forage required to sustain one cow and her calf, one horse, or five sheep goats for a month. Today, these figures are notably different. In a society that relies more on cattle products than sheep products, sheep populations in Utah dropped to approximately 250,000 in 2000, while cattle herds increased to over 900,000. The amount of feed that came from federal lands dropped to less than 25%, and the amount of cattle feed coming from federal lands alone dropped from around 42% in 1940 to 15% in 2000, even though cattle numbers increased. The number of AUMs allotted to Forest Service land has been reduced to 600,000 AUMs. However, the largest reduction in AUM's occurred on BLM land during this same period, from 2,750,000 AUMs to 750,000 AUMs. Historically, federal lands provided the forage for livestock. Currently, more and more private farmland and ranches are used to provide feed for livestock as restrictions have limited the amount of grazing on federal lands to protect the habitat.

Current Management

Grazing in Utah's mountains has been controlled by the USFS for over 100 years, and has a long history of partnerships with livestock producers that rely on National Forest lands. Permit holders are given operating instructions each year to help ensure the health of the allotments that their livestock are grazing. Grazing allotments are further split into pastures, which allow herders to effectively move livestock around on the landscape so specific areas are not overgrazed. Grazing instructions include details such as the number of each type of livestock allowed (AUMs), the duration animals can graze a specific pasture, and the beginning and ending date for their grazing season on their National Forest allotment. In order to limit the effects of grazing on riparian habitats, Riparian Habitat Conservation Areas are established along all rivers and streams to limit grazing utilization and preserve a certain vegetation height to control erosion and flooding.

Grazing was one of the earliest resource debates in America, but the first chief forester, Gifford Pinchot, recommended that grazing be controlled rather than prohibited. Today, there are grazing allotments on nearly half of all Forest Service Lands in the country, 99% of which are in the western half of the United States. A combined total of about 9.9 million AUMs are allotted each year for sheep, cattle, horse, and goat grazing. However, in 1995, nearly half of all grazing allotments were scheduled to expire and needed a NEPA analysis before renewal. In order to avoid a disruption of livestock grazing on federal lands, Congress passed the Rescissions Act, which set up a schedule to review all 6,886 grazing allotments before 2010, while still allowing grazing to continue until allotments were reviewed.

In order to properly manage our National Forests, the ecological conditions of all rangelands are monitored closely and must meet specific standards. There are two types of monitoring that occur, implementation monitoring and effectiveness monitoring. Implementation monitoring is the annual measurement of vegetative growth and % consumption by livestock to assure that the requirements of the permit are met. Effectiveness monitoring is a longer-term monitoring, occurring every 5-6 years, to determine if vegetation descriptions of a site match the objectives of the forest management plan. Effective monitoring and management requires a variety of stakeholders, including land managers, land owners or permittees, universities, other agencies, and the public. They all work together to provide local insight and scientific information about the landscape.

Today, there are still some people that rely on livestock to make a living, but more and more people in rural Utah have converted to other industries. This leaves the livestock and agricultural production to fewer larger ranches. However, many small town livestock producers continue to farm their small family farms during their spare time, after their day job ends. Two-thirds of Utah's livestock owners raise less than 50 cattle, but produce only 15% of the entire state's cattle. About 52% of Utah's cattle are raised by large ranches (26% with 200-500 head, and 26% with over 500 head) that comprise only 9% of the total livestock producers in the state. Even though fewer people in Utah make a living from the livestock industry, there is a large portion of the population with deep roots in the heritage of livestock enterprises throughout the state, and they will offer continued support as a result.

In order to better manage grazing on private lands, various programs and initiatives have provided the public with technical assistance, best land management practices for their grazing lands, and various coalitions of producers, agency personnel, and university faculty members help private landowners improve their private grazing lands. Two examples are the USDA Natural Resource Conservation Service (NRCS) Conservation of Private Grazing Land program and the Utah Grazing Lands Conservation Initiative. Both programs provide landowners with resources to measure the health of their rangeland; information about how to protect the habitat, air, soil, water, and other resources; information about how to be more energy-efficient in production; benefits of increasing their involvement in efficient management programs and practices; and ways to provide habitat for wildlife as well.

Ongoing Issues

In Utah, livestock grazing is the largest sector of the state's agricultural economy. Therefore, it is worth sustaining and improving. Recent efforts have proven that severely degraded habitats can still successfully be restored for native plants and animals. For example, in one study in Utah, there was a 350% increase in use and diversity by songbirds, raptors, and small mammals after 8 years of rest from grazing. Although management has reduced the negative effects of grazing, successful restoration of historically degraded habitats represents only a small fraction of the work that needs to be done. Currently, the vast majority of damaged rangelands are located on arid and semiarid sites, where the chance for restoration is poor. Rehabilitating arid lands is somewhat like trying to grow a garden without water. Because of the limited chance of rapid success, restoring these habitats is especially challenging. Even under current management, and despite the best efforts of the USFS, some areas are still threatened by overgrazing. The impacts to riparian areas are especially prominent, resulting in erosion, flooding, and degradation of fish habitat. In other communities, the intensity of impacts from overgrazing ultimately depends on the duration and intensity of grazing that has occurred. Some of these impacts include a reduction in grass and forb understory diversity and quality, a reduction or elimination of aspen recruitment, and even interruption to forest succession.

One of the challenges of proper grazing management is continual pressure from grazing interests to increase grazing permits. Although the abundance of food may exist to sustain increased livestock grazing, the negative effects from such actions would likely be further losses in diversity and stability. In addition, increased disturbance may also magnify the challenges of invasive species management. The spread of

invasive species increases the challenge of restoring diversity and functionality to native habitats. Most of the time, non-native species are the culprit of invasion, but sometimes disturbances can also facilitate the dispersal of native species on sites where they normally wouldn't establish. Grazing seems to increase the spread of these invasive plants by providing disturbances that reduce the competition from native vegetation.

Another current issue facing Utah's livestock industry is the future spread of wolves into Utah's mountains from Idaho and Wyoming to the north. Interestingly, a state law passed in 2010 required the Utah Division of Wildlife Resources to avoid the establishment of a viable wolf pack in areas where wolves are no longer listed as endangered. This law suspended the portion of the Wolf Management Plan that would allow two packs to establish in the state, but the remainder of the plan is still legal where wolves are not listed. In August of 2010, a U.S. Court overruled a delisting of wolves in the part of the western United States, which voided the effects of the new state law, and restored the wolf to federal protection in all of Utah. However, as of April 2011, U.S. Congress intervened and permanently removed wolves from the Endangered Species List in parts of the western United States.

When wolves were delisted from some western states in 2011, they were only delisted in a very small portion of northern Utah, mostly in the Cache National Forest area. Although there are no confirmed packs of wolves in Utah, a few single wolves have been known to enter the northern portion of the state. Under the current wolf management plan in Utah, northern Utah livestock owners are only authorized to kill a wolf when it is seen harassing, chasing, harming, or in the act of killing livestock, or within 72 hours of a livestock kill after the wolf has been confirmed by a state or federal wildlife agency to have killed that animal. However, livestock owners across the rest of the state have no authority to kill wolves under any circumstances, and livestock owners will not be reimbursed for killed livestock. Under the 2010 state law, the UDWR is also required to request that the U.S. Fish and Wildlife Service remove any wolves discovered in areas that are still listed under the ESA. Right now, threats to livestock from wolves are extremely limited in Utah; however, by looking at the challenges that must be faced in the future, wolves may cause bigger issues for Utah's livestock owners and those that manage Utah's wildlife. A compromise between killing and protecting wolves must be reached if managers are going to address future challenges concerning wolves, livestock, and other wildlife species.

Timber Harvesting & Forest Products

Historic Perspective

Utah's forests were heavily utilized by American Indians for thousands of years. American Indians used the trees in Utah's forests for survival, and had a deep respect for their uses and future existence. Trees were largely used for medicine, food, tools, shelter, and ceremonial aids. The needles of conifer trees were commonly used for tea, the inner bark was consumed for food or medicine, the wood was used for home and tool construction, and multiple parts were used for the purification or cleansing of both physical and spiritual self. Each specific tree species had their individual uses. Pinyon pine provided edible seeds, many medical uses (e.g., pitch used for cuts, infectious diseases, and skin problems), pollen used in ceremonies, and other practical uses (e.g., pitch used to make dyes and paints, glue arrows, and waterproof baskets; wood used to build houses since it is rot resistant).

Juniper was used for variety of medicinal properties (e.g., kidney and heart troubles, headaches, and various diseases), its bark was used as a torch or tinder to start fires, the wood was used for house construction, corrals, bows, and bowls, and the needles and boughs were used ceremonially for protection.

All parts of Douglas-fir had medicinal uses (e.g., pitch for cuts, skin problems, coughs, and a laxative; bark used as antiseptic; needles used to treat paralysis; and infusion of young shoots used for colds, athlete's foot, and fevers). Its wood was used for snowshoe frames, bows, spears, tepee poles, and canoes;

boughs made good camping beds; pitch used as glue and patching material for canoes; and many tribes had ceremonial uses for various parts of the Douglas-fir.

Ponderosa pine was also used medicinally (e.g., pitch for sores and aches), inner bark used for food, and many practical uses (e.g., pitch used as hair tonic, glue, and waterproofing agent; bark used for temporary shelters; needles used in making baskets and for insulation; roots were used to make blue dyes and in basketry; and the wood was valuable for building construction, canoes, corrals, and snowshoes). The Utes used the pitch from ponderosa pine to glue rawhide to their horse's hooves to protect them from rocky terrain. Limber pine and bristlecone pine were not heavily used because they live at higher elevations; however, they were used in cough and fever medicines, ceremonial rituals, and seeds were ground and consumed.

Lodgepole pine was used in medicine (e.g., pitch used for colds, coughs, sore throats, stomach aches, and ulcers; needles were boiled into an extract for paralysis, body sores, and weakness; and the bark was used as a blood purifier, laxative, and general tonic helpful for tuberculosis, coughs, and stomach problems), and was also used in many practical ways (e.g., wood for tepee poles, bowls, fire tongs, tools, and small totem poles).

Subalpine fir was known as the medicine tree by a number of tribes because of its impressive list of ailments it was used for, including colds, fevers, skin diseases, rashes, venereal diseases, headaches, tubercular coughs, general weakness, antiseptic for wounds, and allergies caused by water hemlock. Its inner bark and seeds were sometimes eaten, needles could be used for incense, and the wood was used to make chairs.

Engelmann spruce was not as commonly used for medicine as the subalpine fir; however, the pitch was used for eczema, sores, and slivers, and the bark was infused for respiratory ailments. Practical uses included using the wood for framing timbers, and some percussion instruments, as well as using the bark for baskets, roofs, utensils, and canoe covers.

Aspen tree bark was used in medicine (e.g., diseases, dress wounds, and to quiet crying babies), and the wood was used for lodges, tepee frames, dugout canoes, and traps for bears.

Unlike the American Indians, the first European settlers in Utah viewed trees mostly as a source of timber products to be used for construction of homes, mines, fences, furniture, and other uses, such as fuel to heat homes during the winter. Early logging, where the emphasis was on subsistence, worked well and were sustainable; however, after larger communities established, and individuals began utilizing the timber for profit, uncontrolled harvest of timber, together with overgrazing, left large portions of Utah's northern mountain slopes stripped of forests and other vegetation by 1880. By this time, forest deterioration had become a critical issue in Utah. In an effort to stop further degradation, the federal government passed the Forest Reserve Act of 1891 and the Organic Act of 1897 that authorized the President to set aside forest reserves to ensure the future protection of forests and watersheds.

The Uinta Forest Reserve was the first to be established in Utah in 1897, and encompassed a large majority of the current Uinta and Ashley National Forests. However, by the time the Uinta Forest Reserve was created, nearly all accessible timber in the region was gone. Albert F. Potter, who was hired as a grazing expert for the USFS, completed a survey in 1902 of other potential forest reserves in Utah. Several smaller forest reserves were established in Utah as a result of Potter's survey, and they were later combined into



Albert F. Potter, former Associate Chief of the U.S. Forest Service. (Image from Utah State Historical Society)

the six current national forests in the state. From the establishment of these reserves until the 1950s, commercial logging slowed dramatically because of a decline in available timber reserves; however, overgrazing still occurred throughout the state. Albert F. Potter went on to become the Chief of Grazing from 1906-1916, as well as the Assistant Chief Forester in 1907-1920, and also acting Chief Forester from 1910-1911 and again from 1917-1918.

From the time the Uinta Forest Reserve was first set aside, until World War I, a large majority of logging was for building railroads and mines. Logging increased dramatically during World War I to meet the demands for wood. Later in 1933 during the Great Depression, the **Civilian Conservation Corps** (CCC) was established by Franklin D. Roosevelt to not only provide financial relief through creating work, but also to help implement conservation strategies across the country. As a result of the program, 116 CCC camps were set up throughout Utah over 9 years, and each camp was supervised by a land management agency (e.g., USFS, BLM, Bureau of Reclamation, Soil Conservation Service, NPS, the state of Utah, U.S. Biological Survey, Bureau of Indian Affairs, and the U.S. Army). CCC corpsmen built trails, campgrounds, fences, bridges, cabins, primitive roads, and dams for flood and erosion control. They removed noxious weeds, instituted insect and rodent control programs, and replanted and reseeded lands that were affected by logging and overgrazing. The CCC was fundamental in re-foresting much of the Wasatch and Uinta Mountain ranges that had been deforested near the Wasatch Front. One camp, which was located at the mouth of Big Cottonwood Canyon, housed approximately 200 workers and was crucial in the restoration of the Cottonwood Canyons.

In the 1940s, destructive logging practices that were adopted to meet war-time timber needs were greatly diminished. In 1944, the Sustainable-Yield Management Act was passed, which allowed the Forest Service and lumber companies to establish long-term agreements that promised a constant supply of timber. In addition, a change to the federal income tax allowed loggers to record income from lumber as a capital gain, which would increase their profits and require less timber for the same financial gain. Around World War II, about 6 million board feet of lumber were being removed each year from the Uinta National Forest; however, because of excessive timber harvest cuts made after WWII, by 1949 there was only 3.85 million board feet removed each year from the Uinta National Forest. Similar decreases occurred throughout the state.

During the 1950s and 1960s, the USFS began to implement multiple-use management strategies. This meant considering a variety of activities on public lands that included recreation, grazing, timber management, watersheds, wildlife protection and management, and mineral extraction. In addition, legislation and court rulings during the 1970s required extensive public discussion in the decision making process, therefore reducing the Forest Services' independence in making management decisions. By the 1980s, pressure from timber and grazing interests to increase permits, mixed with public perceptions on such activities, has resulted in constant pressure and controversy in managing the nation's National Forests. In addition, until the 1980s, timber was harvested under an even-aged management strategy where all mature timber was cut, leaving only younger trees. In the 1990s, management shifted to an uneven-aged management strategy where a certain proportion of trees in each age group were harvested, rather than only mature trees.

Current Management

Sustainable forest management has become progressively more important in Utah over the past century in order to provide economic and recreational benefits to current and future generations. Starting with Gifford Pinchot and then Albert F. Potter, forest management has adapted to what it is today. Although overgrazing still occurs in some areas of the state, most public lands in Utah are recovering from poor management in the past, and are managed in a more sustainable manner. A document published by the USFS in 2005 shows various picture comparisons of forests throughout Utah; it compares pictures taken by Albert F. Potter during his survey of Utah's forest reserves in 1902 to pictures taken 100 years later of

the same landscapes. Most pictures show an increased growth of grasses, forbs, and shrubs with a decrease in grazing over the past few decades; also trees are often more abundant on the landscape and look healthier (Found at http://www.fs.fed.us/r4/publications/range/full_version.pdf).

Although forest management most often occurs on National Forests, private timber land management throughout the state is also very important. In fact, contributions from public lands to the state's timber harvest have decreased in recent years, while contributions from private lands have increased. The proportion of harvest from private property increased from 6% in 1966 to 17% in 1992. As a result, private timber management is more important today than it has been in the past, and more effort is being placed on helping private landowners manage their property sustainably.

Sustainable forest management also benefits other natural resources. For example, forest management is crucial in order to manage for improved water quality. Much of Utah's water supply originates in high elevation forest watersheds. These forests play a vital role in purifying and maintaining clean water in the state's streams, lakes, and groundwater. The area of land directly adjacent to any body of water is called the streamside management zone (SMZ). Management in this zone should be planned and implemented in a manner that protects water quality, aquatic wildlife, and wildlife habitat. Trees and other vegetation in the SMZ serve as a natural filter to reduce sediments in streams, reduce erosion, shade the water to keep it cool, provide food and habitat for wildlife, and buffer the stream from other types of impacts that may occur nearby (e.g., road construction, prescribed burning, or timber harvest). The SMZ is usually a 35-100 foot buffer zone around water bodies, depending upon the water-body size and the slope of the land, and also includes any wetland areas that may be present. Larger sized water bodies and steeper slopes have a larger buffer zone. A SMZ is critical for all types of forest management, including timber harvest, recreation, and livestock grazing.

Harvesting timber from a forest has the potential to increase erosion and sediment in water bodies. In order to reduce erosion on harvested land, managers often only harvest a portion of the trees. This leaves a large portion of the existing vegetation on-site to stabilize the soil. Harvesting timber to reduce erosion can happen in one of two ways, an even-aged harvest strategy or a multi-aged harvesting strategy. An even-aged harvest is when all the mature trees are harvested to provide good economic benefits, while leaving smaller trees behind to stabilize the soil and allow for future harvests. A multi-aged harvest is when a portion of both mature and young trees are harvested. This allows for an economic profit from the mature trees, while leaving some mature trees on site to provide shelter and stability, as well as removing some younger trees that are deformed or less desirable. Often the multi-aged harvest is the best long-term harvesting strategy because it protects the forest structure, provides both short and long-term profits, and decreases forest density in an attempt to reduce threats from insects and wildfire.

Before the use of mechanical equipment to harvest timber, real horsepower was used to accomplish the task. Although times have changed, historic ways of doing something should not be forgotten. At Sundance Resort in Provo Canyon, harvesting timber is a management strategy that is used to decrease the threat of bark beetle outbreaks and wildfires by thinning dense forest stands. However, instead of using modern mechanical logging equipment to do the job, two teams of Belgian draft horses are used to reduce the impact of timber harvesting on the landscape. Unlike mechanical logging, horse logging allows for increased accessibility, reduced impact on the remaining vegetation, and only requires small trails instead of wide roads. Although horse logging techniques do not bring as high of a profit and are more time consuming, they preserve the aesthetic beauty of the landscape, reduce the amount of disturbance and erosion, and are less damaging to the habitat. As a result, logging with horses is more beneficial to landowners with smaller stands of timber, and for those who want to reduce the amount of noise and disturbance on their land from logging practices.

Ongoing Issues

In recent years, there has been an increase in public input on public forest management. Some of the biggest problems created by timber management occur when poor timber harvest practices result in an eyesore on the landscape. In order to avoid public conflicts about timber harvesting, managers must harvest timber in a way that reduces the aesthetic and ecological impacts on the landscape. When harvesting timber, harvested areas should blend into the landscape whenever possible to preserve the aesthetic value of the habitat. Large trees may be left across the landscape, areas where the soil has been exposed (e.g., trails, roads, landings) may be re-seeded to prevent future erosion problems, and excessive logging debris or slash can be removed to limit the risk of fire and insect outbreaks.

Private timber management has many similar issues as public timber management, but one of the most common challenges of private management is access to best management practices for sustainable timber harvesting. Some of the most common landowner complaints in Utah are getting paid less than current market value, a lack of payment for timber that is damaged, poor treatment of logging debris that causes fire and insect problems, poorly designed roads or trails that lead to excessive erosion and impacts to water quality, or logging companies only removing high-value timber and leaving behind poor trees that have no future value. Many times, these issues have been resolved by hiring a forest consultant, creating a forest management plan, and using educational services that are available in the state (e.g., Utah State University Forestry Extension).

On the other hand, some private landowners believe that taking a passive approach to forest management is the best strategy. However, there are many consequences of passive management that will often produce results that are unacceptable to the owner. Particularly dense forests are susceptible to outbreaks of dwarf mistletoe, spruce beetles, and other bark beetles, and extensive fuel loads that may facilitate destructive wildfires.

It is also necessary for the public to understand the principles of sustainable forest management. With an increase in public input on managing natural resources, it is important for the public to understand that lands require occasional harvest or wildfire to restore and regenerate natural forest structure and function. In addition, sustainable timber harvests reduce our dependency on foreign wood supplies, reduce the risk of insect outbreaks and wildfires, provide income, and can result in more diverse and aesthetically pleasing forests in the long-term. With so many viewpoints how our National Forests should be managed, agreeing on the best sustainable management practices is often difficult to accomplish.

Wildfire Management

Historic Perspective

Prior to European settlement, wildfires were more common throughout the mountains of Utah. Wildfires were a result of natural disturbance, and were also intentionally set by American Indians. It is thought that American Indians profoundly influenced the mosaic of vegetation for over 12,000 years partly by using fire as a management tool. As a result of intentional and naturally-occurring fire, Utah's landscape was in a continual state of flux. Fire served as a natural disturbance that would restart the cycle of forest succession. In addition, varying fire intervals and intensity created a mosaic of plant communities with varied age and species across the landscape.

Fire suppression over the past century has increased the amount of time between fires in every mountain community in Utah. As a result, the original structure and composition of many forests and woodlands have changed considerably, and the future existence of some species has also been threatened. The **mean fire return interval** (MFRI) is the average length of time between each fire disturbance, and is often combined with the intensity of the average wildfire to understand fire ecology in forests. Ponderosa pine forests in Utah have a historic MFRI ranging from 4 years to 79 years, depending on site conditions,

and fires burned an average of about 100 to 1000 acres. Historic fires were generally characterized as frequent, low to moderate severity ground fires; fires that reached into the forest canopy were generally rare. However, on moister sites, fire did not occur as frequently and accumulations of understory fuels resulted in more mixed-severity and stand-replacing fires. In general, though, frequent fires were the driving force that shaped forest structure in ponderosa pine forests, along with other contributing factors such as insects and disease.

Mixed conifer forests in Utah, which contained a mixture of ponderosa pine, Douglas-fir, white fir, aspen, blue spruce, Engelmann spruce, and subalpine fir, had a historic MFRI ranging from 2 to 129 years, depending on location and species composition. Forests at lower elevations had the most frequent fire interval; as elevation increased, the length of the fire interval also increased. Most fires in mixed conifer forests were considered to be low to moderate intensity surface fires; however, in areas with high tree density, high mortality from disease or insects, or longer MFRI, some high intensity fires did occur. At the highest elevation, mixed Engelmann spruce and subalpine fir forests generally had a long historic MFRI of between 40-400 years, which was mostly caused by wetter and cooler conditions at high elevations. Spruce beetles may have played a more of a significant role in spruce-fir forests than other forest types because deadfall accumulations with the longer MFRI.

Aspen is the most widespread forest type in Utah, and is a component of most mountain ecosystems in the state. Aspen forests had an estimated historic MFRI of 7-10 years, but some areas may have had MFRI of up to 60 years. Aspen stands are twice as hard to burn as other forest types in Utah because of the high moisture content of the understory vegetation. As a result, fires were generally low to moderate in intensity and burned mostly the understory.

Historically, pinyon-juniper woodlands were less abundant and less dense than they are today. The historic MFRI of pinyon-juniper woodlands ranged from about 30 years to over 200 years, and fires were generally mixed severity or high severity in nature, often resulting in stand replacement. Historically, fire created a mosaic and a natural cycle between pinyon-juniper woodlands and sagebrush communities. Higher MFRI sites were generally dominated by woodland species, and sites with more frequent MFRI were dominated by sagebrush.

After European settlement in Utah, the natural fire regime changed dramatically throughout the state. Although climate change has had a major influence, human-based factors have altered the natural fire regime more significantly over the past 150 years. Fire frequency slowly declined prior to settlement due to a period of global cooling; however, fire activity significantly increased to its highest point during the settlement period between 1856 and 1909. This increase was caused by the dramatic increase in human populations and activity, such as increased surface fuel supplies from forestry practices, which inevitably led to more ignition sources for more frequent fires. Between 1910 and 1990, despite the gradual increase in global temperature, there was a significant decline in wildfires throughout Utah due to intense livestock grazing, habitat fragmentation as a result of development, agricultural expansion and conversion of native communities, and effective fire suppression strategies. As a result, shade-intolerant species that relied on fire for regeneration, such as aspen and lodgepole pine, were often replaced by long-lived, shade-tolerant species, such as spruce and fir. In general, this resulted in a decline in the overall diversity within and between communities because the late-successional plant species benefited most.

Current Management

Utah's forest communities are dependent upon fire to maintain long-term health throughout the state; however, extensive fire suppression throughout the 20th century have altered many ecosystems pre-European conditions. Increased fuel loads and altered community structures have increased the intensity of and damage from wildfires. In every forest type throughout the state, the lack of fire over the past century has led to an increase in the size of fires. For the 8,335 fires that occurred in the state from 1986 to 1996, the average fire burned 125 acres (well within the historic limit of 100 to 1,000 acres); however,

some large fires burned up to 71,000 acres. Massive, high intensity fires can often damage a forest community more than they help because the intense heat can destroy the seeds and root systems of plant species. As a result, some burned sites require re-seeding of native species to regenerate effectively.

Wildfire management in Utah is regulated by cooperative efforts of local, state, and federal agencies. A statewide Cooperative Fire Management Agreement was finalized in 2002, which required the U.S. Forest Service, U.S. Fish and Wildlife Service, US Bureau of Indian Affairs, Bureau of Land Management, National Park Service, and Utah Department of Natural Resources (Division of Forestry, Fire, and State Lands) to agree and commit to fire protection assistance and cooperation in the state of Utah. Under this agreement, agencies are required to produce an annual Fire Management Operating Plan that addresses fire protection areas, responsibility of each agency, operation procedures for fighting fires, fire prevention guidelines and procedures, hazardous fuels management, prescribed fires, and a cost-share agreement.

Because wildfires are unpredictable and often uncontrollable, management is focused on the prevention, hazard mitigation, and suppression of wildfires whenever possible, in order to protect lives, property, and natural resource values. Removing hazardous fuel accumulations is one of the most recent efforts to meet this goal. Because of extensive fire suppression efforts in the past, Utah's forests and scrublands accumulated a significant amount of dead material in the understory. Once fires were started, there was too much dry fuel to control them. Prescribed burning has grown in popularity over the past couple decades; however, it requires intense planning to coordinate a burn under the right conditions to maintain control over the fire. Prescribed burn managers must factor in the condition of the site (e.g., soil moisture, slope), the type of vegetation, the amount of fuels present, and multiple weather factors (e.g., wind, humidity, temperature), as well as other site specific factors. Prescribed burns are a way to reduce the current fuel load, while preventing further buildup of future fuels, in an effort to reduce the chance of future catastrophic fires. Managers often try to also mimic the natural fire regime of the site to restore it to its natural structure and function. Prescribed fires are usually conducted in the spring or late fall in Utah when moisture is available to slow the progression and reduce the intensity of the fire.

With an increase in residential development throughout the state, efforts are commonly directed toward protecting human life and property. Extensive educational programs exist to inform the public about limiting the risk of wildfires, as well as how to protect themselves and their property in the event of a wildfire. The statewide fire prevention program, the "Living with Fire" campaign, educates residents living along the urban-wildland interface about hazardous fuel management. The state has identified over 600 communities along the urban-wildland interface that are at risk of wildfire, and helps communities remove hazardous plants and other fire risks, create fire breaks by using fire resistant plants, and create an escape plan in case of a wildfire emergency. A Wildland Fire Suppression Fund was created in Utah to provide money to Utah counties if they exceeded their normal fire budget. In order for counties to be eligible to use this fund, they must pay a premium that is based on the county's amount of private land and specific wildfire risk. The fund is financed through the contributions of participating counties and then contributions are matched by the state.

Ongoing Issues

The greatest wildfire management challenges in Utah, including increased fuel loads and bark beetle outbreaks, largely exist as a result of historic fire suppression. Increased fuel loads lead to larger and more dangerous fires that not only threaten the lives of humans, but also the forest community itself. Some forests throughout Utah require a significant amount of current and ongoing management to reverse the effects of past management practices. Aspen forests have been affected drastically by fire suppression and overgrazing, which have caused a reduction in regeneration. Approximately 51% of Utah's aspen forests have disappeared since European settlement. Current management uses prescribed burns, grazing enclosures, and timber harvest techniques to stimulate the regeneration of aspen stands where they are in decline. Lodgepole pine forests are another early succession forest, similar to aspen, that rely heavily on

fire for regeneration to occur. Recruitment of new lodgepole stands is diminishing because fire is required to open serotinous pine cones and release seeds.

Various species of bark beetle have experienced large outbreaks in the past decades as a result of drought that weakens trees, and because of higher tree densities due to the lack of fire. Without fire to burn through infested stands, and with the increase in global temperatures over the past few decades, the abundance and range of most bark beetle species has expanded. Efforts to reduce beetle outbreaks are usually limited to forest thinning in dense stands, removing dead tree snags, and also some pesticide treatments around recreational areas. Tree mortality from bark beetle infestations is part of the natural cycle of forest succession in some areas; however, historic human influence and warmer climates have increased the intensity and number of outbreaks in recent years.

Forest management becomes even more challenging with the increase in residential development on the foothills along the Wasatch Front and throughout Utah's mountain valleys and forests. The increased construction of vacation homes is a particular challenge because they are often located in the middle of forested areas. The U.S. Forest Service's annual fire suppression cost in 2006 had exceeded \$1 billion for 3 of the past 6 years. Their increasing cost to fight fires is largely due to protecting residential communities that are located along the urban-wildland interface. It is estimated that 50 to 95% of all wildfire costs are directly related to protecting private property. It is essential, therefore, that private landowners understand the risks and responsibilities of living in and adjacent to Utah's forest ecosystems.

Mineral and Coal Mining

Historic Perspective

Utah's diverse and complicated geologic history has created a vast assemblage of mineral deposits throughout Utah's mountains. As a result, there is a long history of precious metal mining in Utah, especially for silver and copper. Many discoveries of large mineral deposits were found in Utah's mountains throughout the second half of the 1800s. Several successful mining operations for gold, silver, copper, lead, zinc, uranium, and coal have been established throughout Utah. By 1917, over \$800,000,000 in income had been generated by Utah's mining districts. Discoveries of copper, gold, and silver ore were first found in Bingham Canyon of the Oquirrh Mountains, resulting in the first mining claim filed in Utah on September 7, 1863. Mining of copper in Bingham Canyon expanded so rapidly that most other operations in Utah disappeared. In fact, it produced one-third of the copper used by the Allies in World War II, and approximately 8 million tons of metal by 1963. The Bingham Canyon mine was set to expand, but the company was sold to BP Minerals America in 1987 as a result of a market drop shortly afterward. In 1989, it was sold again to RTZ Corporations and renamed the Kennecott Corporation.

Extraction of minerals at the Bingham Canyon mine was costly at first because of a lack of smelters and difficulty transporting the ore. However, smelter construction at the mine started in the 1870s. In the mid-1890s, various entrepreneurs of mining and gas commodities invested in Utah's mining operations, which led to the construction of more smelters in the Salt Lake Valley. The additional smelters significantly decreased cost and increase production. With an increase in production, a need for more laborers sparked significant population growth in the early 1900s. Large numbers of immigrants from different ethnic backgrounds came from all over the world in hopes of making a successful living. Northern Europeans arrived first, followed by other Europeans, Japanese, and Mexicans. Many Chinese immigrants out of work when the Transcontinental Railroad finished in 1869, adapted their skills to mining. In addition to copper, other precious metal such as gold and silver have also been extracted from the Bingham Canyon mine in the process, providing even more economic income. The Bingham Canyon mine, which is currently owned and operated by Kennecott Utah Copper Company, became one of the leading copper producers in the United States, and is the largest open pit copper mine in the world.



The Bingham Canyon Mine in 1910. (Image from *miningartifacts.org*)

Uranium has been another valuable commodity in Utah throughout the decades. In the earliest days, uranium ore was used by American Indians to make paints. Settlers first started mining for uranium in the 1870s, and ore was shipped to Europe to be used in the manufacturing of glass and ceramic pottery, photography and steel plating additives, and for making dyes. Radium and vanadium, which are found in association with uranium, became extremely popular during WWI as a hardening agent for steel production and an illuminating agent for gun-sights and airplane-dials. Uranium production decreased thereafter until the Cold War, and then increased again during the 21st Century as prices skyrocketed.

The environmental costs of mining have often included drastic negative impacts on Utah's landscape. With such a rapid expansion of mining operations, woodlands were quickly deforested to provide timber for mine shaft construction and firewood for charcoal in the smelting process. Mining destroys the native landscape that once occurred, often resulting in highly eroded areas, and heavy sedimentation in streams.

The greatest impacts from mining often come not from the construction and operation, but from the leftover mine tailings. As precipitation falls on piles of mine tailings, they introduce relatively high levels of heavy metal toxins into the surface soil and surrounding water bodies. Plants take up and accumulate metals such as lead, zinc, cadmium, and arsenic in their tissues. Wildlife then eat the contaminated plants and accumulate higher levels of toxins. An animal one trophic level higher in a food web will accumulate 10 times more toxins because only 10% of the biomass of one trophic level is transferred to the next (i.e., ten times the amount of biomass from one level is required to sustain the next level above). If humans then eat contaminated plants or animals, they, in turn, can accumulate dangerously high levels of toxins. This accumulation of toxins in higher trophic levels in a food chain is known as a bioaccumulation.

Water sources can also become contaminated by heavy metals from mine tailings. Some mine tailings flow downstream through rivers into the Great Salt Lake, where toxins are accumulated within the terminal lake. Heavy metals are then taken up by the algae, which is then eaten by brine shrimp, which is then eaten by shorebirds and waterfowl. Without the control and containment of mine tailings, the accumulation of heavy metals and other toxins would be devastating. Historically, mine tailings were not contained to mitigate these impacts. Even today, abandoned mining areas throughout the state are characterized by high levels of metal toxins. However, current mining operations have reduced the impact of toxins. For example, Kennecott currently has a mine-tailing impoundment that is designed to remove toxins before they reach the Great Salt Lake.

Coal has been a valuable fuel resource in Utah since the 1850s, when Mormon pioneers first settled in the state. Using coal for fuel allowed timber resources to be reserved as a building material. In 1854, territorial legislation even offered a cash prize for the first usable coal deposits found within 40 miles of Salt Lake City, however this prize was never collected. Large coal deposits were discovered between the 1850s

and the 1870s in the southwestern corner of the state in Washington County, in central Sanpete County, and at Coalville in Summit County. The Mormon pioneers built a railroad to the closest deposit in Coalville to transport coal to Salt Lake City. The railroad was quickly acquired in 1869 by the Union Pacific Railroad, which had solidified a monopoly on Utah's coal supply and all railroad transportation to the mines throughout Utah.

In years following, impressive industrial growth proceeded in the face of some major challenges. The first challenge was labor shortages, and the need for laborers sparked an influx of immigrants from many different countries. Labor agents lured in laborers from Italy, China, Finland, Greece, the Balkans, Japan, and Mexico. These immigrants created a diverse ethnic community within Utah at the time period. However, false promises, short pay, high prices for commodities and living expenses, safety concerns, and a lack of recognition of labor unions were some of the major complaints that led to repeated strikes. The demands for safer working conditions were especially recurrent after the horrific Scofield Mine Disaster in 1900, which killed 200 men and boys. The end to major abuses of safety protocol was finally achieved after a national strike in 1933.

Although coal extraction was extremely important in the early days, the conversion of locomotive engines to natural gas and the increase in diesel-powered transportation decreased the demand for coal in the 1900s. A nationwide mining depression began in the 1920s, after a spike in demand during World War I. This first depression lasted two decades before World War II again required Utah's coal production level to peak. Afterward, another coal depression occurred during the 1950s and 1960s. This depression ended when the Arab oil embargo restricted access to petroleum fuels, which stimulated the use of coal to generate electricity. Coal production reached an all-time high in the early 1980s, but is currently in decline as natural gas and alternative energy production becomes cleaner and more sustainable.

Current Management

Today, precious metal mining continues in most counties of Utah. In 2006, there were 1,480 active mining claims, which covered over 367,000 acres throughout the state, and 10 active hardrock mining operations that employed over 1,400 people. All mining operations are regulated closely by the **Utah Division of Oil, Gas, and Mining**, and it is their mission to ensure a fair economic return to the public, protect the natural environment, provide human safety, prevent waste, reclaim lands that have been affected by mining, and preserve the economic and physical well-being of the state. The Division was established in 1955 to prevent the waste of oil and gas, as well as encourage conservation and protect the rights of the oil and gas owners. In 1975, the Division was assigned the task of reclaiming previously mined lands under the Mined Lands Reclamation Act. The Utah Board of Oil, Gas, and Mining is the policy making body of this Division, and is made up seven members that are appointed by the governor, with no more than four individuals from the same party, and members are chosen based on these backgrounds that relate to the division: two mining, two gas and oil, one ecological or environmental, one geological, and one private landowner that owns mining or oil lands. In general, this Division coordinates four programs: the Abandoned Mine Reclamation Program, Coal Program, Minerals Program, and Oil and Gas Program.

One-quarter of all the world's coal reserves are found within the United States, making coal one of the most valuable energy sources in the nation. In addition, about 50% of the nation's electricity is produced from coal; however, large amounts of greenhouse gases and other pollutants are released into the atmosphere when burning coal. Research is continually looking for new ways to contain these pollutants. In Utah specifically, coal extraction is still a viable industry. This is partly because approximately 80% of Utah's electricity comes from burning coal, which is 30% higher than the national average. In recent history, about 41 coal mines were in operation in Utah. Most are located on the Wasatch High Plateaus of south-central Utah, but there are a couple of coal mines in Summit County. To date, only about 24 of these mines are still currently operational or have an active permit, all of which are in south-central Utah.

The Utah Mined Land Reclamation Act was first enacted in 1975. At that point, only large mining operations needed to be bonded to ensure reclamation. Since then, amendments have been made to increase the effectiveness of the Act. In 2003, an amendment was made that required all mining operations, no matter the size, to have reclamation sureties, which would secure the cost of reclaiming the mine after extraction occurred. This Act ensures the support of a viable mining industry that benefits the state both economically and physically, the protection of the environment and public health and safety, and the management of reclaiming lands affected by the mining industry. With well over a thousand current mineral mining permits throughout the state, reclamation of these lands after mining ends is critical to the preservation of Utah's future.

Ongoing Issues

Even under current regulations, management guidelines, and environmental safety, Utah's mountain environment is susceptible to the negative effects of mining. In 2005, the EPA estimated that over 97.7 million pounds of toxins were released as a result of metal or hardrock mining in Utah, ranking Utah 3rd among the 17 states that reported mining chemical releases in 2005. The mines that reported the most pollutants included Kennecott Utah Copper Mine Concentrators & Power Plant, the Brush Resources Inc. Mill, and the Kennecott Barney's Canyon Mining Company. Furthermore, mine expansion can lead to increases in pollution. Rio Tinto, the global mining company based in the UK that owns Kennecott Utah Copper, has conducted a feasibility study related to expanding Utah's Kennecott Copper Mine. Negative effects on air quality are the most significant impacts, and the EPA may not approve the project; however, the Utah Air Quality Board says that expansion will not cause air quality pollutants to exceed the limit set by the EPA. This debate is not settled yet, and an expansion approval is yet to be decided.

Mine tailings require extensive remediation and mitigation to reduce their threat to the environment and public health. In an effort to reduce mine-tailing pollutants, mine-tailing impoundments are built, and companies mitigate habitat that was lost to mining development. At Kennecott, a proposed expansion of the mine means higher production, and requires Kennecott to build a larger mine-tailing impoundment area. The proposed site would include the destruction of valuable wetlands along the Great Salt Lake. At Kennecott, an Inland Sea Shorebird Reserve was created to reduce the impact of increasing the size of their mine tailing impoundment. This 2,500-acre reserve met EPA regulations; it maintains EPA water quality standards for freshwater life; it is used by 200 species of shorebirds, wading birds, and other waterfowl; and it has an estimated usage of around 120,000 individual birds annually. Another example exists in Park City, which was historically a silver mining town. In order to remove cadmium and zinc mine tailings from the water associated with a silver mining containment pond, a biochemical reactor (i.e., a constructed wetland) was implemented. During the first year of operation, 99% of dissolved cadmium and 98% of dissolved zinc were treated. This biochemical reactor has provided tangible results of improved water quality, low maintenance, and no energy or chemical input requirements.

Reclamation is another important issue, especially since there are an estimated 20,000 abandoned mines throughout Utah. Some present little hazard, but others are extremely dangerous to the environment and human health. Of the 79 mines identified by the EPA to be the most polluted sites in the country, also known as Superfund Sites, 6 are located in Utah (e.g., Davenport and Flagstaff Smelters, Eureka Mills, International Smelting and Refining, Jacobs Smelter, Midvale Slag, and Monicello Mill Tailings). Reclaiming Superfund Sites, as well as other abandoned mines, require large amounts of time and money. The state receives about \$1.5 million from the federal Surface Mining Reclamation and Control Act, and approximately \$30,000 from the state annually for cleanup. In an effort to prevent the likelihood of future mine-related injuries to the public, all abandoned mines were required to be sealed by 2015.

Lastly, protecting workers and public health is a continual problem facing mining in Utah. Mine collapses and cave-ins may be less frequent than they were historically; however, the deaths that occur from such an event are still as real. In 2007, a collapse at Crandall Canyon Mine killed six miners and three

rescue workers. A 3.9 magnitude earthquake occurred during the collapse; however, the collapse was suspected to have caused the quake rather than the other way around. In addition, some health problems are likely a result of mining operations. For example, gastric cancer is said to be about four times above the state average in Carbon and Emery counties, which are located in the main coal mining region of Utah. Coal miners in these regions have the highest risk of gastric cancer, averaging three times that of non-coal miners living in areas with coal mining, and eight times the national average among males living in areas without coal mining. A female's chance of having gastric cancer was not significantly different; however, a male's chance was. All homes of patients with gastric cancer in Carbon and Emery counties were heated by coal, and in some homes, coal was also used in cooking. It is therefore concluded that coal mining in this region of Utah, in addition to using coal in the home, are likely to have led to the high levels of gastric cancer in this region. Respiratory illnesses, such as asthma and lung disease, caused by inhaling dust particles in the air, are also major health risks of mining.

Recreation

Historic Perspective

Recreational use of Utah's mountains is very common today; nevertheless, this was not always the case. Historically, recreation in Utah and throughout most of the United States was relatively low. However, many things that we consider recreational activities today are often things that were essential to survival in the past. For example, hunting and fishing was a way to provide food for a family rather than a sport for trophies; hiking, horseback riding, and camping were all ways to travel across the country rather than being just a weekend adventure; and motorized vehicles were used for work rather than leisure rides through the mountains.

People in the past had far less leisure time, mobility, and wealth than they do today. With the increase in manufacturing, business, and technological advances, work is done more efficiently in all aspects of life. As a result, small farms that once had to support families have recently been sold to larger companies that produce a higher yield at a lower cost. In other words, the general public is more employed in business, marketing, and manufacturing rather than agriculture, and people rely more on money to buy food and supplies rather than learning to produce their own and living off the land. As a result of increased efficiency and a change in lifestyle, leisure time has become significantly more abundant.

With the increase in recreation due to more available leisure time over the past few decades, the numbers of people engaged in outdoor recreational activities today is increasing. During the 2000s, nature-based recreation (e.g., wildlife photography, hunting, fishing, and kayaking) had a 3.1% increase in people. In addition, the number of times each American spends participating in any type of outdoor recreational activity increased by 25%. The number of times people spend participating in nature-based recreation increased by 32%. However, the most common types of recreational activities are changing. Hunting, fishing, and camping were once the most common activities that came to mind when asked about outdoor recreation, but times are changing. By 2000, bird watching was the fastest-growing nature-based recreational activity in the country. By 2007, the number-one, fastest-growing, nature-based activity changed to viewing or photographing flowers and trees (viewing or photographing natural scenery came in as second).

From this survey, it seems that more and more people are engaging in outdoor recreational activities that do not generate funds for natural resource management agencies. Instead, the more popular forms of recreation provide money to the businesses that sell equipment to engage in the activities. The Utah Division of Wildlife Resources is funded almost entirely through hunting and fishing licenses, and, as hunting and fishing become less popular, funding for the Division declines. Outdoor recreation increases while the funds required for management declines. If natural resource agencies could raise funds through

people's engagement in all types of recreational activities, rather than just hunting and fishing, funding to preserve and manage Utah's wildlife and their habitats might not be as much of an issue in the future.

Current Management

The majority of recreation that occurs in Utah's mountains is managed by the Utah Division of Wildlife Resources (UDWR), Utah State Parks, National Parks Service (NPS), United States Forest Service (USFS), and the Bureau of Land Management (BLM). These agencies all work to optimize recreational opportunities to the public, while at the same time balancing the conservation of the state's natural resources today and into the future. The UDWR is mainly responsible for managing all recreation that pertains to wildlife in the state. They are required to protect and enhance wildlife populations and their habitat, provide hunting, fishing, and wildlife viewing opportunities to the public, and educate the public about ways to get involved, preserve, and enjoy the state's wildlife. The Utah State Parks is in charge of managing the state's 43 state parks, as well as the OHV, boating, and trails programs in order to provide access to waterways and trails, and promote education, safety, and protection of the state's natural resources.

In Utah, the NPS is in charge of managing 13 national parks and monuments, 4 national natural landmarks, 13 national historic landmarks, 642 historic places, and 6,428 archeological sites. In addition, the NPS also helps local organizations and interest groups revitalize their community, preserve local history, and provide educational and recreational opportunities to the public. The USFS mission is to achieve high-quality land management under a sustainable multi-use management strategy that will meet the needs of a diverse range of people and resources, including recreation, timber harvest, wildlife and their habitat, and educational programs. Although the BLM manages more land than any other federal agency, it does not have a significant portion of mountain land in Utah.

Ongoing Issues

Although recreation is often thought of as a sustainable way to experience nature, it can also bring about many management issues. All types of recreation result in a certain amount of disturbance to nature. Likely the most common type of disturbance from recreation is the displacement of wildlife. One study concluded that recreation on Antelope Island in Utah caused 7% of the habitat to be unusable to wildlife. The study also showed that recreationists that remained on designated trails had less effect on the wildlife than those who did not stay on the trails. In addition, only about 50% of people thought that their activities had any negative effects on wildlife, but all groups generally believed that their own recreational activities were less disruptive to wildlife than all other types of recreation. Every type of outdoor recreational activity will come in contact with multiple species of wildlife; however, some species are more sensitive to human disturbance than others. Understanding how recreational activities affect different wildlife species, and then educating the public about how to minimize their impacts, are both important to managing recreation.

One of the most common types of recreation-related impacts to big game in Utah is disturbance while on their wintering grounds. Because of heavy snowpack in Utah's mountains, ungulate species are forced to move to lower elevations to find food. Mule deer are especially susceptible to disturbance from recreation during the late winter and early spring because they are weak from scarce food supplies. Shed-antlers, which are ungulate antlers that have fallen off to allow for new antlers to grow, are commonly collected in early spring. Many avid antler hunters roam Utah's foothills and ridgelines in search of trophy antler sheds. However, routine contact can cause wintering deer and elk to expend energy that they cannot afford. In order to reduce the mortality from starvation as a result of such recreational activities, antler-hunters are required to take an online course that will educate them on the possible effects they can have on wintering wildlife, as well as provide tips to reduce their impact.

Threatened or endangered species may also be adversely affected by recreation. Outdoor recreation is the second leading cause of decline for federally threatened and endangered species on public lands, and the fourth leading cause overall. The northern goshawk, a sensitive species in Utah, is especially sensitive to disturbance during the reproduction period. Similar to most raptor species, if human disturbance near the nest is not minimized, females may abandon their nest entirely and the reduction in reproductive success could lead to a dramatic drop in the population over time. Another sensitive species, the wolverine, is even more susceptible to human disturbance. Stress and displacement due to human disturbances is probably one of the most significant reasons that wolverines have not occurred in Utah for a long time, and are just recently observed in the state. The desert tortoise, found in southwestern Utah, is a sensitive species that is close to being placed on the Federally Threatened and Endangered Species List. Recreation and other human disturbances are the main reasons for their decline. ATVs and other recreational vehicles commonly run tortoises over as they try to cross roads and trails.

With the increase in vehicle travel in Utah's mountains over the past few decades, there is an increase in disturbances to native plant and animal communities. Repeated traffic can disturb the soil, plants, and wildlife to the point where recovery can take years or even decades. Compaction of the soil will limit water infiltration, plant growth, and soil function. This will cause a decrease in soil stability, and will increase the amount of erosion during high water events or spring runoff. Vehicles can also aid in the destruction of critical habitats, such as riparian zones or habitats with endangered plant species. In addition, the noise and presence of vehicles can disturb a variety of wildlife species, and cause both short-term and long-term effects. Short-term effects include various changes in behavior, including ceasing to forage, fleeing, or altered reproductive behaviors. Long-term accumulated effects include an increase in energy expenditures, decreased foraging time, increased stress levels, and a reduction in reproductive success. In addition, excessive human disturbance may exclude some wildlife species from their habitat.

Recreational activities are also a major facilitator for the introduction and spread of invasive species. Livestock feed, especially for horses used for riding on National Forest lands, have introduced a variety of weed species to Utah's mountains. Invasive weeds and seeds can also be transported easily on recreational vehicles or even hiking boots from one site to another, and is commonly the cause of road-side weed problems. As a result of the spread and introduction of invasive species from recreational activities, extensive educational and restoration projects are occurring throughout the state. Weed-free feed programs are enforced to limit the chance of spreading weed seed on public lands. Programs that aid in the removal of some invasive species also occur, such as for dyer's woad and cheatgrass.

Wildlife Management

Historic Perspective

The first record of wildlife in Utah was recorded in 1776 by Father Escalante and his party that visited the territory during this time. His diary stated that there were no deer, and wildlife in general was quite scarce. The presence of beaver brought trappers to Utah from 1825 to 1834. At this time, wildlife was still fairly scarce, however, elk, buffalo, antelope, and deer were found in portions of northern Utah. Recorded efforts in wildlife management in Utah first started during the second half of the 19th century, after the Mormon pioneers settled here. Much of this early wildlife management was enacted to help ensure the subsistence of early pioneers. Game animals were relatively scarce during this time period, and harsh winters sometimes led to subsistence on roots and thistles rather than meat. After two winters of almost starving, Brigham Young decided to transplant California Quail to Utah in 1848 to provide another game source for the settlers. At this time, fish also became an important food source because flax seed was brought to Utah and the plants could be woven into fishing nets. As a result, fish and game birds were the first wildlife to need protection in Utah.

The first wildlife management Act passed in Utah protected the fishes of the state; it was passed in 1853, and amendments were made in 1862 that further restricting the take of fish species. In 1874, another Act for the Protection of Fowl and Fish was passed. Not only did it further protect fish, but it also protected game birds and song birds. During this year, the first County Fish and Game Commissioner was appointed to ensure that wildlife laws were obeyed. A law of the Territory of Utah in 1876 established seasons for taking game birds and big game animals. At that time, open season on big game ran from July through December. In 1888, the laws of the territory required all county courts to appoint a fish and game commissioner, whose duty was to see that all laws of the territory for the protection of fish and game were faithfully enforced. In 1890, this law was further defined. In 1896, an Act was approved that allowed for the first State Fish and Game Warden, who was appointed by the Governor with the approval of the Senate. John Sharp became the first state warden; his title later became Head Fish and Game Commissioner, and he stayed in office from 1897 to 1906. He was given control and supervision of all state waters, and all property of the state that dealt with fish or game. He recommended the first fish hatchery at Liberty Park, which opened in 1899. Although the fish populations improved greatly under Mr. Sharp's time as Head Fish and Game Commissioner, the game did not.

By the early 1900s, native elk herds had nearly disappeared from the entire state, and protection alone could not restore their numbers. From 1912 to 1915, 155 elk from Jackson Hole and northern Yellowstone herds were released in six locations throughout the state. Sportsmen, ranchers, and other interested people paid the cost to introduce them. The imported elk multiplied rapidly, so fruitfully that conflicts with private property owners soon arose. By 1921, legislation authorized game commissioners to kill elk that damaged farms or other property. By 1925, overpopulation had occurred; this created competition with domestic livestock, and therefore killing a few elk would not solve the problem. In 1927, the State Game Refuge Committee and Board of Elk Control to supervise establishing, adjusting, opening, and closing elk refuges; they designated seasons and localities where elk hunting could occur; determined sex and number of animals that could be killed; and regulated the sale of permits to sportsmen by public drawing. Elk herds were effectively managed for 6 years. In 1933, this committee was given power over all big game and designated the State Game Refuge Committee and Board of Big Game Control.

In 1958, the state was divided into four regions for administrative purposes, and region offices were established in Ogden (Northern Region), Provo (Central Region), Price (Eastern Region), and Cedar City (Southern Region). A fifth region was established in 1962, which split the Eastern Region into the Northeastern Region and the Southeastern Region. In 1967, the Utah Department of Natural Resources was created in order to coordinate and consolidate state natural resource agencies into the same department. At this time, the Division of Fish and Game was created along with six other divisions. This consolidation into a single department was suspected to establish lines of administrative responsibility, increase administrative efficiency, and decrease the cost of state government. Under this reorganization, the Board of Big Game Control was retained as the Board of Fish and Game.

Licenses were first implemented in Utah to fund the Committee of Fish & Game, which would remove the responsibility of funding from the state legislature. The first license required in Utah was issued in 1894, costing \$5.00 to seine fish in Utah Lake. In 1903, the first basic hunting license occurred when non-residents were charged \$10.00 for a gun permit. In 1905, non-resident fishing and hunting licenses were introduced and cost \$25.00. After recommendations from Mr. Sharp, legislation also passed a law at this time that allowed any resident male over the age of 14 to pay \$1.00 to receive a resident hunting and fishing license. In 1907, non-resident licenses were reduced to \$10.00. By 1919, a general license cost \$2.00 (resident or non-resident), and for the first time, women were required to have a license. Licenses for women and boys (between the ages of 12 and 16), were only \$1.00. In 1923, a non-resident and resident price distinction began again, and it was specified that no one under the age of 16 could hunt for deer. In 1947, the distinction between male and female licenses was discontinued. In 1967, when the Division of Fish & Game was created under the Department of Natural Resources, a resident fishing license

was \$5.00, a deer license was \$5.00, and a small game license was \$4.50; a non-resident fishing license was \$15.00, a small game fishing license \$20, and a deer license was \$50.00.

When the early settlers arrived, wildlife not only offered food for survival, but some wildlife species were seen only as pests. Often, hunting parties were formed to eliminate pest species specifically. One such hunting party reported the killing of 2 bears, 2 wolverines, 2 bobcats, 783 coyotes and wolves, 400 foxes, 31 mink, 9 eagles, 530 magpies, hawks, and owls, and 1,626 ravens. Specifically, great effort was expended to extirpate large predators from Utah, similarly to other areas throughout the United States. This was largely implemented by both government officials and private livestock owners in order to reduce the loss of livestock on mountain grazing lands, and to protect wildlife species that were hunted for food. For example, the Territorial Government of Utah offered bounties on wolves and foxes as early as 1852. Similar bounties on coyotes exist even today, because the extinction of wolves eliminated the coyote's competition. Claude T. Barnes, in his book titled "The Natural History of a Mountain Year: Four Seasons in the Wasatch Mountains," states that wolves had not been seen in the Wasatch Mountains since 1919. Historically, the last verified wolf in Utah was killed in San Juan County in 1930. Similarly, the last wolf in Yellowstone was killed by a Park Ranger in 1930. During the early 1930s, this pattern continued and wolves were eradicated from the western United States.

During this time, grizzly bears were also seen as a nuisance to livestock. They were known to kill both cattle and sheep that grazed in the mountains during the summer. As a result, the last grizzly bear in Utah, which was named "Old Ephraim", was killed on August 21, 1923, in Cache National Forest east of Logan, Utah. Old Ephraim was shot by Frank Clark, who was part owner in a local sheep company. After seeing over 150 dead sheep in one summer on the forest, Frank Clark killed 43 bears in his lifetime before facing Old Ephraim. The story of Old Ephraim and Frank Clark is legendary to people of Utah. Frank Clark first spotted Old Ephraim in 1913, but the bear was too smart and evaded his traps for 10 years. He was finally caught in a 21-pound leg trap on the night of August 21, 1923, and Mr. Clark went out with his gun to see what was going on. It took all seven bullets from his rifle to finally bring down the bear, but not before Frank was chased by the bear as it dragged and carried the chain and trap with him. Frank regretted killing that bear, and was sorry than man and beast could not live together; afterward, he reportedly never killed another bear in his life. As a result of the human conflicts with predators, several large predator species became rare across the western half of the United States. In Utah, the grizzly bear and gray wolf became extirpated because of their conflicts with humans; other predators, such as wolverines, lynx, and bobcats were reduced and are still extremely rare throughout the entire state.

The **Endangered Species Act** (ESA) was first established in 1973 to protect critically imperiled species from extinction. Currently, there are over 1,200 threatened or endangered species in the United States that are listed under the ESA. In addition to protecting the species itself, this Act also protects the ecosystems on which threatened or endangered species depend upon for survival. The U.S. Fish and Wildlife Service (USFWS) manage inland threatened and endangered species, in conjunction with the NOAA's National Marine Fisheries Service, which manages more of the marine species and anadromous fish species (i.e., fish that live in the ocean, but migrate up inland freshwater rivers to breed). These agencies are responsible for listing and delisting species, designating critical habitat, and formulating recovery plans. When endangered or threatened species are listed, funding for management is provided to state agencies from the federal government; but all management actions are monitored and approved by the USFWS. This puts a lot of restrictions on how the state wildlife agencies can manage listed wildlife species and their habitat. Species are only removed from the ESA list once the species reaches the recovery goal set when listing occurred. As a result, current vulnerable species are often managed now to avoid being listed in the future. Current listed mammals that occur in Utah's mountains include the gray wolf (Federally Endangered, Extirpated in Utah), Canada lynx (Federally Threatened), black-footed ferret (Federally Endangered, Experimental Non-essential Population in Utah), and the grizzly bear (Federally Threatened, Extirpated in Utah).

With the exception of threatened and endangered species listed under the ESA, the **Utah Division of Wildlife Resources**, a division of the Utah Department of Natural Resources, manages Utah's wildlife under a public trust. The UDWR is a trustee and guardian of Utah's wildlife, which belongs to the public. Their goal is to expand wildlife populations and conserve sensitive species by protecting and improving wildlife habitat. The majority of funding for Utah's wildlife management comes from a restricted fund, where 100% of the money made from hunting and fishing licenses goes to managing the states game species. Other sources include federal funds (i.e., excise tax on hunting and fishing equipment and federal funding for sensitive and endangered species), dedicated credits (e.g., profits from Hardware Ranch, other state operations, and some contributions), and general funds (i.e., tax dollars) that help to pay for nongame species management. In 2010, total revenue was broken down as follows: 44.62% restricted funds, 30.97% federal funds, 15.56% dedicated credits, and 8.86% general funds.

Although most people think that the UDWR manages the wildlife how they see fit, this is not so. Similar to the historic Board of Fish and Game, most of Utah's wildlife regulations are set by the Utah Wildlife Board. The wildlife board is made up of seven citizens from every region in the state, and each member is appointed by the governor to serve a 6-year term. This group is advised by the UDWR, as well as through public input at Regional Advisory Council (RAC) meetings; however, the Utah Wildlife Board has the final say about how to manage Utah's hunting, fishing, and wildlife in general. After the board sets the regulations, the UDWR has the job of implementing the regulations. Species in Utah that are managed under the ESA are not managed by the UDWR until the species has fully recovered under the guidelines set by the USFWS, and a UDWR management plan for that species, which will ensure the future survival of that species, has been approved by the USFWS. Rejection of state management plans has often been the deciding factor limiting the removal of some endangered species from the ESA (e.g., gray wolf in Wyoming).

Current Management

All game animals in Utah are managed by the Utah Division of Wildlife Resources. Game animals are animals that can be hunted under certain regulation and with specific permits. Each species is supposed to have an individual management plan developed by the Utah Division of Wildlife Resources; some management plans have additional input from special advisory groups created to assist in the development of management guidelines for that particular species. Management plans must have a full review of the species' natural history, habitat preferences, and the current population size; a description of management issues that threaten the species, such as disease, drought, and predation; goals and strategies for achieving a target population size, which is set based on habitat quality, quantity, theoretical carrying capacity; and lastly any other current conditions that are critical to the survival and management of the species. A problem with management plans is that they cannot accurately assess the effects of future conditions, such as expanding predator populations (e.g., gray wolves from Wyoming and Idaho). Therefore, management plans are supposed to be updated regularly (e.g., every 5 years) to incorporate the best available data. Currently, Utah has a specific management plan for bighorn sheep, moose, wolves, mule deer, elk, river otters, sage grouse, pronghorn, beaver, chukar partridge, mountain goat, bison, black bear, bobcat, sharp-tailed grouse, and cougars. Some species, which do not have a management plan now, will likely have a management plan created in the future.

Species that cannot legally be hunted or trapped are considered non-game animals, and include songbirds, reptiles, and amphibians. Since the majority of funding is generated through license sales, and these restricted funds can only be used for the management of game species, funding for the protection of non-game species is less common and harder to acquire. In 2010, of the 2.3 million dollars put into the Wildlife Habitat Account set up to improve or enhance wildlife habitat, game-species habitat improvement used 97% of habitat funding, while only 3% of funds were directed to non-game species habitat improvements. In order for increased funds to protect non-game species, programs need to be established to raise funds for non-game wildlife conservation. Past attempts to offer a non-consumptive fee for other

outdoor uses (e.g., bird watching, hiking, biking, camping, etc.), where the funds generated would go toward non-game habitat and wildlife protection, have inevitably failed. Therefore, game management is still the primary type of management that occurs today by the UDWR because funds are more readily available.

Large Predator Management

As stated earlier, large predators that are listed as Threatened or Endangered under the Endangered Species Act are managed by the U.S. Fish and Wildlife Service until populations have recovered to the point they are deemed viable. Those species are then removed from listing after a state management plan is submitted to the USFWS, and later approved. Approval is required before species are removed from the ESA listing, and before state wildlife agencies have the authority to manage the species according to the plan. In Utah, wolves are largest predator on the endangered species list that has recently occurred in the state. There has been significant controversy concerning wolves over the last decade; state agencies and livestock owners think that the gray wolf could be managed more effectively if it were delisted, but many private interest groups believe that delisting the wolf will only lead to excessive killing and population declines.

The USFWS approved state wolf management plans for both Montana and Idaho, and the gray wolf was being managed by their state wildlife agencies in 2009. However, in 2010, a federal court judge ruled that delisting could not occur in only a segment of the whole population (in Montana and Idaho, but not Wyoming), and returned the wolves to the endangered species list. In April, 2011, for the first time in history, Congress intervened and removed the gray wolf from the endangered species list in both Idaho and Montana again. Wyoming's wolf management plan continues to be rejected, and wolves are still on the endangered species list in that state. In Utah, a wolf management plan was completed and approved by the Utah Wildlife Board in 2005. In 2007, a copy was submitted to the USFWS for federal approval, but no approval or comment has ever been made. When wolves were delisted in Montana and Idaho in 2009, they were also delisted in a small northern portion of Utah. After the 2010 court ruling, which again put wolves back on the Endangered Species List in all of Utah, wolves were not delisted again with the Congressional intervention in 2011.

There are other large predators within Utah that do not require federal approval for state management, and each is managed by the UDWR under their respective management plans approved by the Wildlife Board. Additional large predator management plans have been drafted and approved for the black bear, cougar, and bobcats. Black bears and cougars have been protected in Utah since 1967. The second version of Utah's Cougar Management Plan was approved in 2009 and lasts until 2021. The state's cougar management plan's goal is to maintain a healthy cougar population within existing occupied habitat while considering human safety, economic concerns, and other wildlife species. The Utah Black Bear Management Plan was approved in 2000 and was supposed to last until 2010. Its goal was to maintain a healthy bear population in existing occupied habitat and expand distribution while considering human safety, economic concerns, and other wildlife species. The second version of the Black Bear Management Plan is in the Draft stage, and has not yet been approved by the Wildlife Board. It is supposed to run from 2011-2023, and has the same management goal as the first version. Utah's Bobcat Management Plan's goal is to maintain a healthy bobcat population within existing suitable habitat and provide quality recreation opportunities for bobcat harvest while considering the social aspects of bobcat harvest. It was approved in 2007, and runs until 2016.

These management plans were likely shaped around other wildlife policies such as the predator management policy created in 1996, and updated in 2006. It authorized the Division to increase predator harvests on management units where big game populations were depressed and cannot meet management goals, where big game had recently been released to establish a new population, where an individual predator is consistently preying on a sensitive prey population, or on waterfowl management areas where

predator populations are significantly affecting the population. This policy not only affects larger predators, it also includes all smaller predators. Although coyotes and raccoons are not necessarily protected by the Division of Wildlife because they are considered pests, the division may make management decisions that involve decreases in these populations to benefit other wildlife as stated in this policy.

With any management consideration that involves predators and predator control, managers must understand what factors or predators are affecting the mortality of other wildlife species. Because bobcats are relatively uncommon in Utah, their affect on prey species are suspected to be minimal. More common predators do not fit into this category. Studies on the proportion of deer fawn mortality in that was attributed to black bears, ranged from 3%-5% for New Mexico, Idaho, Colorado, and Montana. In one study in the LaSal Mountains in Utah, 13% of fawn mortality was attributed to black bears. On the other hand, in the Book Cliffs of Utah, no fawn mortality was attributed to black bears. In another example, one study in Idaho found that 73% of elk calf mortality was caused by black bears. It is concluded that bears likely seek out elk calves more often than deer fawns; however, the elk study was done in 1976, before the reintroduction of wolves. Changes in predator competition over time will likely alter how predators utilize available prey species. In general, black bear likely have a very limited effect on mule deer fawn survival and a larger effect on elk calf survival.

A cougar's diet, in contrast, is considered to be comprised of over 80% mule deer. In addition, adult survival is generally more affected by cougars than fawn survival. With Utah's decreasing deer herd population, many people like to blame predation for the loss. However, in a Utah study that started in 2009 and is ongoing, statewide adult doe mortality was only 12%. Although cougars can affect adult survival, current estimates show that adult survival is not likely the limiting factor affecting Utah's deer herds and therefore that cougars are not likely the problem.

Unlike cougars, coyotes impact fawn survival more significantly than adult survival in mule deer. In the 1980s, research suggested that coyotes accounted for between 36% and 44% of fawn mortality. Today, the statewide fawn mortality is estimated to be 45%. Since coyotes are the dominant predator affecting fawn survival, and fawn survival is suspected to be the limiting factor for Utah's deer herds, reducing coyotes would likely be an appropriate management action to increase deer populations. Coyote population management is becoming a problem, though. In just 3 years, the number of coyotes killed has been reduced by over 3,000 per year (well over 20%). In addition, studies have shown that in order for killing coyotes to be effective, it must occur in the spring to interrupt pair-bonds during courting and mating. Therefore, management of coyotes may become more prominent in the future as a way to increase the effectiveness of managing mule deer in Utah.

One way to deal with coyotes is to reintroduce wolves into Utah. Wolves are considered a top predator that feeds mostly on elk rather than deer. If wolves were to return, they would increase the amount of competition with coyotes. This would reduce the coyote population and increase deer survival. However, if wolves could not be effectively managed because they were still protected under the ESA, then elk populations would begin to crash like they have in Montana, Idaho, and Wyoming. As you can see, politics places a heavy burden on effective wildlife management.

Rare Species Conservation

A few species in Utah are considered rare species that need conservational management to survive. When habitats become small or fragmented, artificial dispersal is often required to maintain a gene pool, and a type of island syndrome can occur. The **Island Syndrome** is a general pattern of traits that occur in wildlife populations that occur on islands, and include increased densities, more stable densities, reduced reproductive output, higher survival rates, and systematic differences in behavior and body mass. High densities occur as a result of no dispersal to areas with higher mortality than the island itself. This can result in the destruction of food supplies and a lower reproductive rate. However, if a species is confined to

a small island, with a limited gene pool and no dispersal between other sub-populations, genetic diversity can decline over time due to natural selection or inbreeding depression.

The California bighorn sheep was introduced to Antelope Island in the middle of the Great Salt Lake to conserve the genetic diversity of the species. In 1997, 23 bighorn sheep (19 ewes and 4 rams) were introduced to the island from British Columbia. In 2000, a supplemental 4 rams and 2 ewes were transplanted from Nevada. By supplementing the herd from a different population, it increased the genetic diversity and decreased the amount of inbreeding that would occur. By the fall of 2000, there were 90 bighorn sheep on the island. The gene pool of these 29 bighorn would be the origin of all California bighorn sheep transplants that will occur in the state. By 2008, California bighorn sheep have been transplanted to the Stansbury Mountains and Newfoundland Mountain ranges in the west desert area. At that time, there were an estimated 190 bighorn on Antelope Island, 135 bighorn in the Newfoundland Range, and 70 bighorn in the Stansbury Range. However, only Antelope Island and the Newfoundland Range had higher total populations than the number of animals transplanted. The Stansbury Range, a more recent transplanted range, had only 70 animals, even though 92 animals were transplanted. The loss of animals experienced on the Stansbury Range also likely happened in the Newfoundland Range, and is likely due to the initial loss from introducing predator-naïve individuals into a new environment with predators. This is a major concern with Antelope Island bighorn sheep herds. Since no large predators occur on the island, the bighorn that are born on the island do not grow up with the danger of predators. Therefore, when they are introduced to an area with predators, they are not prepared to avoid or escape them. Initially, a high proportion of the transplants are eaten before the remaining animals learn to avoid predators. In addition, younger individuals learn faster to evade predators than older individuals. Because of these reasons, many initial transplants were unsuccessful. As managers learned to reduce the number of predators, increase the number of animals transplanted at a given time, and use younger animals for transplants, the success of introductions increased. The effects of the island syndrome on Antelope Island's Bighorn Sheep is somewhat limited right now due to continual transplantation off of the island; however, if transplants were to stop and animals were allowed to reach higher densities, the island syndrome may begin to occur here.

Ongoing Issues

Wolves are a very controversial wildlife management topic in the western United States. Wolves have recovered rather well, and have been on and off the Endangered Species list multiple times as a result of political battles. In Utah, the topic of wolves is just as controversial because Utah's diverse perspectives. Many ranchers and hunters are against wolves because they do not want to see excessive killing and drastic decreases in livestock and big game wildlife species. These views have likely stemmed from historic views on predators, as well as more recent experiences with livestock and wildlife in Montana, Idaho, and Wyoming. On the other hand, there are many ecologists and wildlife enthusiasts that strongly support the inclusion of gray wolves in Utah's mountain ecosystems. They believe that wolves would balance out big game populations and decrease the number of current predators, such as coyotes. Although some of the general public supports the natural immigration of wolves into Utah, a large majority of this group are actually undecided on the matter. Therefore, initial management of wolves in the state could have a strong effect on future opinions within this large undecided group of people. This puts a lot of pressure on the agencies that manage wolves.

Wolf management is currently administrated by the U.S. Fish and Wildlife Service (USFWS), following the guidelines for listed species under the Endangered Species Act (ESA). In the future and after wolves are removed from the ESA, the Utah Division of Wildlife Resources (UDWR) will be responsible for managing wolves in the state using the UDWR Wolf Management Plan. They will also be responsible for managing populations in a way that satisfies each interest group through the difficult challenge of balancing each group's perspectives. Although wolves are not currently established in the state, there have been multiple cases where lone gray wolves were found in areas of northern Utah. The wolves are considered lone

wolves because they have been pushed out of an existing pack, and dispersed to new locations in search of a mate to form their own pack. Currently, there are no records of an existing wolf pack in Utah; however, if wolf populations continue to increase and expand, it is inevitable that a pack will establish within the state. Without the ability to manage wolves in Utah, the UDWR will likely face many of the same challenges that other western states have already faced, including livestock mortality and compensation, drastic decreases in big game populations (especially elk), human safety conflicts, and funding issues. Compromise is the best solution to this problem, but with so many views that surround the issue, compromise is difficult because it results in some loss for every stakeholders.

Invasive species are any plant or animal species that are not native to a particular ecosystem and have detrimental impact on the natural function and quality of that habitat. In recent years, the influx of invasive species has been discouraging for wildlife and habitat managers because they are so difficult and costly to control. Some examples that specifically affect mountainous habitats include dyer's woad, cheatgrass, bulbous bluegrass, Russian thistle, and Eurasian watermilfoil. The majority of invasive plant species become abundant only when landscapes become degraded or overgrazed. The presence of invasive species is often a good indicator of the health of a particular community, and can usually provide some insight into previous management on that landscape. Invasive species compete with the native species and limit the amount of native habitat for a variety of wildlife.

Cheatgrass is one of the most well-known invasive species in Utah. It is an exotic species from the Mediterranean area that first arrived in the United States in the late 1800s in contaminated grain seed. By 1920, it was well established and has been increasing throughout Utah and the Intermountain Region ever since. The biggest problem with cheatgrass is that it grows very fast in the spring, forms a mat of continuous growth that outcompeting native bunch grasses, and then dries out earlier in the summer after it sets seed, therefore producing a continual, large abundance of highly flammable material. This has led to an increasing number of fires throughout the state. Mountain valleys that have been heavily grazed are often invaded by cheatgrass, along with other invasive species such as bulbous bluegrass and Russian thistle that are additional indicators of unhealthy rangeland conditions. Considering Utah's grazing history, it is easy to understand why cheatgrass and so many other rangeland invasive species have done so well here.

Dyer's woad, a member of the cabbage family, has bright yellow flowers in the spring. In Europe, this species has been cultivated for producing indigo blue dyes and for other medicinal purposes for over 2000 years. It first arrived in Utah by 1932 as a seed contaminant, similar to other invasive species. It usually invades disturbed sites, outcompeting native grasses, and then spreading by prolific seed production. In some counties, efforts to remove this species have resulted in bounty programs: for each 40 lb bag of dyer's woad, you can receive \$10. These efforts have failed to stop the expansion of dyer's woad, but it has slowed it down.

The biggest factor affecting wildlife management today and into the future is funding. As the demand for hunting and fishing licenses decline with changes in Utah's lifestyles, the UDWR also sees a decline in their budgets. Their income from hunting and fishing licenses makes up the majority of fund that go to managing species that can be hunted or fished, and state and federal tax money makes up the majority of funds for other types of wildlife funds throughout the state. In addition to the reduction in license sales, federal and state budget cuts to supplement management funds also declines during difficult economic times. Non-game wildlife management already receives little funding, and without outside funding, programs cease to exist. However, some non-game wildlife funding is received through donations from taxpayers when they file state taxes.

At the December 2009 Wildlife Board Meeting, the minutes stated that the UDWR received an 18% budget cut (about \$1.4 million) from the previous 2008-2009 fiscal year. Corrections to those minutes in January 2010 stated that an additional 3% state budget cut would occur for the 2009-2010, and the governor suggested that the division prepare for an additional 5% budget cut for the 2010-2011 fiscal year. However, the trend of budget cuts for all kinds of wildlife management in Utah is expected to continue into

future years. In the 2012 fiscal year state budget summary, the UDWR's total funds actually increased by nearly 6 million from 2010 to 2011. However, the funds from the state and dedicated credits (e.g., Hardware Ranch) decreased. There was some increase in federal funding, and a large majority of increased funds came from other funding sources. The entire Department of Natural Resources had similar trends in budget cuts and increases. It looks like state funds are decreasing, and federal funds are increasing. However, federal money is more restricted on how it can be used. Future funding will probably rely more and more on other forms of funding and donations to make up for budget cuts and continue managing the states wildlife; however, if the number of people willing to pay to enjoy wildlife in Utah continues to decrease, wildlife management and quality in the state might also dwindle.

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Stewardship

What is Environmental Stewardship?

The literal definition of a **steward** is “one who manages property or affairs for someone else.” How does this definition apply to environmental stewardship? When considering the effects of land use, it is important to include all components together as a whole: the land and the resources and people that occupy the land. Aldo Leopold believed that human benefit, economic benefit in particular, was the primary driving force behind land use. This can be summed up in the following quote:

“We end, I think, at what might be called the standard paradox of the twentieth century; our tools are better than we are, and grow faster than we do. They suffice to crack the atom, to command the tides. But they do not suffice for the oldest task in history; to live on a piece of land without spoiling it... [Q]uit thinking about decent land use as solely an economic problem. Examine each question in terms of what is ethically and aesthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong otherwise.”

One should accept the intrinsic value of all resources on the land:

“A **land ethic** of course cannot prevent the alteration, management, and use of these 'resources,' but it does affirm their right to continued existence, and, at least in spots, their continued existence in a natural state. In short, a land ethic changes the role of [humans] from conqueror of the land-community to a plain member and citizen of it.”

Considering Our Own Resource Use

There are countless ways for us to think about, and be more efficient in, our use of natural resources. Living in a desert climate, our most important resource is water. You'd be surprised by how many aspects of our lives use and depend on water or affect water resources in some way.

Living in Utah, we all know that scarce water and high evaporation are great reasons to conserve water in our landscapes. That doesn't mean a yard full of rocks and cow skulls, though! We can have yards with beautiful native and ornamental plantings and still conserve water, as long as we are putting some thought into it. There are several organizations, such as slowtheflow.org or the Center for Water-Efficient Landscaping, that can help you select beautiful, well-adapted plants and design a landscape that will not only look great, but also fit into Utah's desert climate.

There are many things that we take for granted that can affect the natural world. Our travel or transportation patterns can have a great impact on natural systems, from harmful vehicle exhaust to contaminant buildup next to roads. Exploring the ideas of carpooling or using mass transit will not only help to reduce air pollution, but could also save us money, gas, and possibly time. Do you like to travel to exotic locations when you vacation, or do you stay close to home? Even how we travel by vehicle or on foot while we are in deserts has a dramatic effect on mountain ecosystems. Staying on dirt roads and established trails minimizes our impact on fragile desert soils.

There is a lot to think about when we begin to consider how we use natural resources. The important thing is to address this issue at your own pace and start out with solutions that are easy to implement.

Being an Active Citizen

It was Edward Abbey who said “sentiment without action is the ruin of the soul.” There are many important ways in which we can *do something*. Stewardship can be promoted by educating not only others, but also ourselves. It is great to be an educator, but we can all start with our personal lives. We cannot begin to promote stewardship to others unless we have a better understanding of our own resource use. We should always ask ourselves where our resources come from, how much we are using, and if there is a way to conserve resources more wisely. Once we have made the change within ourselves we can then begin to empower others to do the same.

Showing your support for sustainable natural resource management can include everything from planting a waterwise landscape with habitat for songbirds to participating in a larger volunteer project to restore bird habitat. There are also several agencies and organizations, such as the Utah Division of Wildlife Resources and Utah State University Water Quality Extension, have developed citizen monitoring programs. These programs are excellent venues for applying knowledge and working with (and learning from) resource professionals. Monitoring can also include something as simple as recording seasonal observations of songbirds in your backyard and entering observations into eBird.

Volunteering is one of the most effective ways to promote stewardship. Our commitment of time to a person, project, or organization serves as an example of our unending desire to help others understand, appreciate, or manage Utah’s natural world.

“Never doubt that a small group of committed people can change the world. Indeed, it is the only thing that ever has.” -Margaret Mead

Promoting Stewardship in Our Professional Lives

Many of us work or volunteer as educators or land managers, so it is important to discuss some ideas to consider in our professional lives if we’re going to be effective stewards. Balancing use and resource protection is critical for ensuring a sustainable operation, for protecting wildlife and habitats, and for ensuring a high-quality experience for our audience.

Essentially, this means we need to plan for what, how, and how much in regard to resource use. How these decisions are made will influence the impacts on the environment and the type of experience that we might provide to our audience, from school children to park visitors. As individuals, we can influence planning decisions by becoming involved on committees, planning boards, and as voters.

Site Planning

In terms of planning for or managing a site for visitors, our first priority is protecting our sites from degradation. Recognizing impacts to the natural areas we manage, such as changes in plant communities, erosion, and declines in wildlife sightings, is critical for planning how to reduce those impacts. This step is just as critical to a neighborhood park as it is of a preserve that is thousands of acres in size. If we notice negative impacts, let someone in charge know about it.

What about when visitors leave our sites? Educating visitors to the potential impacts of offsite practices, such as nutrient loading from residential areas or the negative impacts of non-native plants and animals on natural communities, can help them recognize potentially damaging behaviors. An informed public is also better equipped to participate in decisions regarding land use strategies and ensuring development in Utah incorporates conserving natural areas as a high priority.

Remember that on a regional basis, we are all in this together. For that reason, we should promote other responsible nature-based opportunities - by doing so, we promote and reward good land stewardship and responsible behaviors to the benefit of nature.

Limiting Inappropriate Behavior

Informing persons about appropriate behavior can be a delicate topic. There may be times, such as the beginning of a tour, when we need to inform people about behaviors we expect them to observe (“Kids, we need to stay on the trail”). Likewise, there may be times when we need to explain to someone that his or her actions are not appropriate (“Ma’am, picking wildflowers within the park is prohibited”). To reach our audience with messages regarding ethical behavior, we need to be tactful and respectful. It is our responsibility as naturalists to inform people of the potential consequences of inappropriate behaviors, and to provide explanations that place these behaviors in perspective. In other words, an explanation can go a long way to helping people understand and support appropriate behaviors.

More often than not, people don’t recognize their actions as harmful. For example, prohibiting the picking of a single flower in a park when those same flowers can be seen growing along any roadside ditch seems a bit absurd to most people. However, this seems less absurd when one considers the potential cumulative impact of dozens or hundreds of visitors picking flowers along the trail each day. So, we should try to deliver our message in a straightforward and friendly manner and we will probably find that most people appreciate the information, rather than resent it.



Considering All Points of View

Living in a sustainable society that conserves biodiversity and wild places, that maintains important ecological functions and services, and that leaves a legacy of responsible environmental stewardship for future generations to enjoy is an admirable ethical goal. How we accomplish this goal, however, is not easily resolved when decisions are being made that affect individuals and communities. Often these issues are described and argued in terms of “rights.”

There are many perspectives on the issues of rights. Discussing these perspectives is often contentious because of their respective consequences. Consequently, discussions regarding issues that affect the rights of plants and animals, individuals, society, and of future generations are neither straightforward nor easily resolved, but need to be considered. Regardless of the position taken, an ethical approach will consider and attempt to balance the element of fairness for all stakeholders, including future generations.

The policies and philosophies we support at local, state, and national levels ultimately influence the outcome of these issues and their collective effects on the environment at scales that range from local parks, to regional strategies for maintaining wildlife corridors, to the debate on global warming. Ultimately, these decisions will weigh heavily not only on the type of world we live in, but in the world that future generations inherit and the manner in which that world will nourish those generations, both in terms of food and soul.

Stewardship in Our Personal Lives

Sharing our knowledge with others can take one of many forms. Not all of us are trained or employed as educators. Our knowledge can be shared with colleagues via discussions, reports, or management plans. We can also share our knowledge with others while volunteering on a restoration project. We can even share our knowledge with friends and family while on a leisurely hike through the woods. Sharing knowledge and passion doesn't have to be planned and doesn't have to be a "lesson."

Every educator is a role model to his or her students. Many students, especially children, learn by example. Because children are incredibly perceptive, we must be sure we truly believe in what we are teaching prior to teaching it to students. In leading by example, educators have the great opportunity, and responsibility, of making the connection between ideal and reality.

By serving as a role model and sharing our knowledge with others, we will promote environmental literacy and, ultimately, greater stewardship of Utah's natural world. One thing is for certain: by participating in the Utah Master Naturalist Program, we haven't learned all we need to know. Truly being a "master naturalist" requires a lifetime of exploring and learning! While our knowledge will always increase with effort, we will never know everything. We are people whom others will know have not only gained a wealth of knowledge related to Utah's natural world, but have also made a commitment to taking steps in our lives toward being effective stewards.

There is no standard way that someone should "be a steward." There is a lot to think about, and it all takes time to sink in. But, it gets easier! As we think more and more about the impacts that we have, and can have, on Utah's natural world, it will eventually become part of the decisions we make in our everyday life. Most importantly, we should **have fun!** Being a Utah Master Naturalist should not feel like it is a chore. Promoting stewardship should be something that we *want* to do, something that we find a way to do even if in some small but personal way. This idea of promoting environmental stewardship through literacy is best summed up in another quote from Aldo Leopold:

"When we see the land as a community to which we belong, we may begin to use it with love and respect."

Most people can say they love themselves, their family, their friends, and perhaps their community. Remember that environmental stewardship requires expanding the idea of one's community beyond the human component to include the soils, waters, plants, and animals. Before doing this, we must first understand the land where we live. We must become environmentally literate citizens, and education is the essential key to achieving this.

Thank you for participating in the Utah Master Naturalist Program! Congratulations on completing the course and may you continue to enjoy exploring, learning about, and conserving Utah's amazing natural world!