2008 Report

The Health of Colorado's Forests

Special Issue:
High Elevation Forests

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Dave Leatherman

February 2009

The *2008 Report on the Health of Colorado's Forests* focuses on our high country forests and the insects and diseases that threaten them. It also takes a look at the connection between humans and these forests, which provide unparalleled recreational opportunities, food and shelter for a diverse array of animals, and raw material for homes. They also capture, purify, and release water for our use.

Recent aerial surveys confirm that our high elevation forests are being threatened by spruce beetle, sudden aspen decline, and mountain pine beetle. But change in our forests is inevitable. To truly understand what is occurring in Colorado's high elevation forests, it is important to understand how these forests die, renew, grow, and function. That is the purpose of this report.

This is the eighth in a series of forest health reports developed by the Colorado State Forest Service with guidance from stakeholders who share our concern for Colorado's forests. As you begin reading the report, you will notice that we took a different approach in telling the story about our high country forests. The report still contains the latest scientific forestry information that readers have come to expect, but it also tells a story that considers the human connection with our forests. During my travels around the state, I have been reminded about the importance of that connection. Many of us choose to live here because of the quality of life our forests provide. And it is up to each of us to take the necessary action to protect them. The action we take now will shape the forests of the future – and the benefits they provide.

I hope you enjoy reading about Colorado's high country forests, and I invite you to contact the Colorado State Forest Service office nearest you to learn more about forestry and what you can do to help restore and protect this valuable natural resource.

Thank you for your interest in Colorado's forests.

Sincerely,

Jeff Jahnke
State Forester / Director
Colorado State Forest Service

COLORADO'S High Country Forests

They are the inspiration for postcards. They define the pathways of winter playgrounds and provide food and shelter for boreal owls, paintbrush blooms, and martens. They suffer from avalanches, stem-bending wind, beetles, and killing cold. They are the shaft bones of mines rich in gold and silver memories. They yield raw material for rustic homes, exquisite paneling, and life-giving energy. They capture, purify, and release water to nurture artichokes in a Pacific valley and corn on our Eastern Plains. They buffer the earth from potential harm and sustain life, human and otherwise. These high country forests deserve our awe, respect, study, use, and sustenance. And they are the focus of the *2008 Report on the Health of Colorado's Forests.*

If the Rocky Mountains are the spine of North America, Colorado's contribution is the thoracic vertebrae. The ribs and muscle, our forests, enclose the heart of the West. Four major rivers originate atop its peaks, and one drop from one tributary at a time, they gain momentum on their journey to the sea. In draining more than a quarter of the lower 48 states, a total exceeding 750,000 square miles, they yield precious water of immense value to cities, towns, agriculture, and wildlife. It is no stretch to claim that the general natural resource health of America significantly depends on the well-being of Colorado's high-forest ecosystems.

Ecologists and foresters define our lofty forests as the mixed conifer, upper montane, and subalpine zones. For the purpose of this report, high country forests are defined as those that occur 9,000 feet and above in elevation.

Ingrid Aguayo

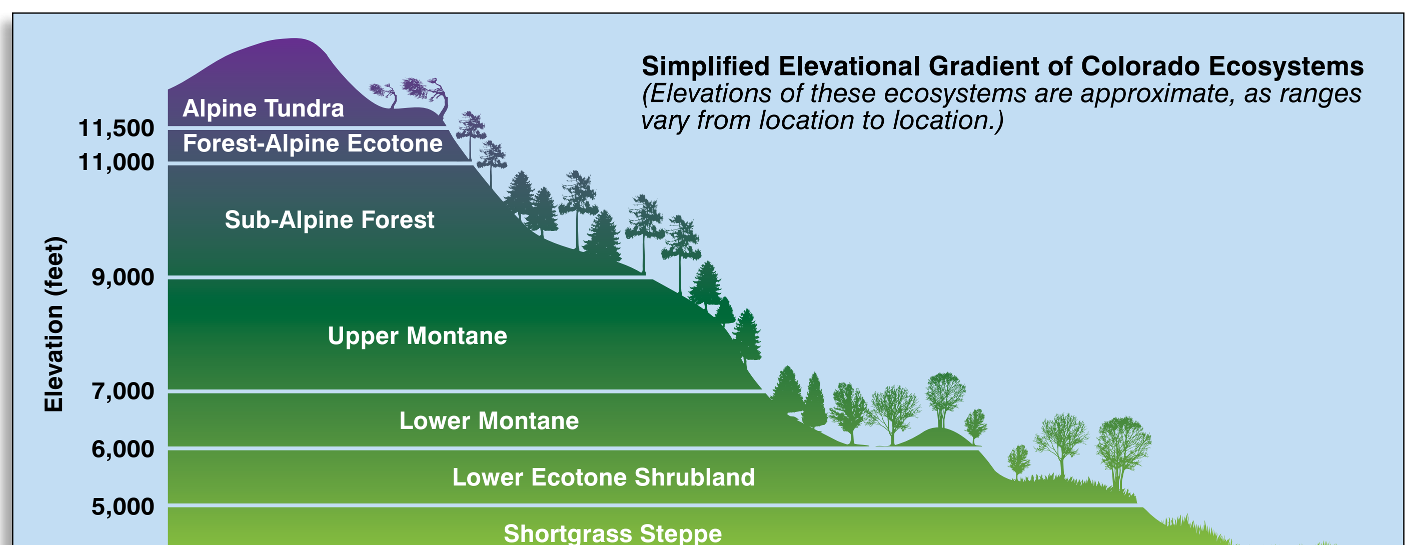
Dave Leatherman

Opposite: *Spruce and fir forest on Cameron Pass in the foreground; Nokhu Crags are in the background (photo by Ingrid Aguayo).*
Left: *Expansive spruce and fir forest near Clear Creek in Lake County.*
Above: *The phenomenon of "timberline" at about 11,000 feet in the San Juan Mountains near Silverton.*

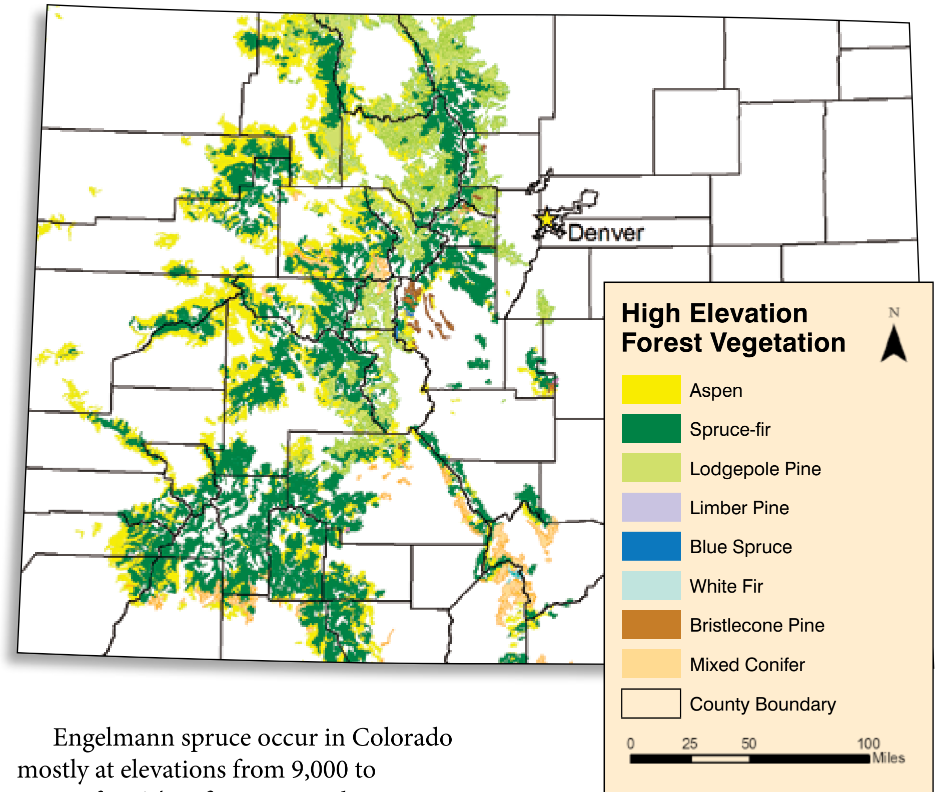
For hundreds of years, their growth and change virtually imperceptible, forests have simply existed in the minds of many as a pleasant, dark-green blanket around the flanks of beloved mountains. Not many people live there, and the ones who do are a hardy lot relying on them for subsistence. Most of us, however, know them as destinations for skiing, hiking, camping, aspen viewing, firewood gathering, hunting, and places to wow visitors. They exist at scales difficult to imagine. Who can relate to landscapes and timeframes that are more than three centuries old?

But those are the parameters of the forests we see when hiking a fourteener or cruising a paved mountain pass. Of course, change in forests, in Colorado and everywhere on earth, is inevitable. But at times like the present, when vast, old forests are reaching their time, when incremental change transforms another millimeter of new wood to bright red foliage and death, we suddenly notice. Our immediate emotional response and sense of something being out of balance is understandable. To truly understand what is occurring in our high elevation forests, we must engage our intellect and learn about how these forests die, renew, grow, and function. And during the next forest cycle, we can learn together where an active hand of intervention is appropriate and where we should just watch with eyes wide open.

The next section of this report introduces "the players" – the dominant tree species and a few of the prominent associated plants and animals of Colorado's high elevation forests. Of necessity, these pages are brief but, hopefully, will spark further inquiry.



High Country Players



Conifers dominate the vast expanse of Colorado's high elevation forests. Engelmann spruce and subalpine fir dominate the higher elevations. These two evergreens are so tightly bound that they seem one species. On closer look, they are individually mingled with the upper reaches of lodgepole pine forests. Blue spruce, bristlecone pine, limber pine, and white fir add their own assets to the portfolio. And of course, there is aspen, that diverse and essential accent to the native tree mix of Colorado's mountain tops from 9,000 to nearly 12,000 feet above sea level.

Engelmann Spruce
(Picea engelmannii)

George Engelmann, a German physician, emigrated to America in 1832 and settled in St. Louis, "Gateway To The West." He soon became interested in botany and spent his last decades exploring new plants. He is credited with first describing bristlecone pine, piñon pine, lodgepole pine, (Colorado) blue spruce, and saguaro cactus, among others. His good friend and fellow physician-turned-botanist, Charles Parry, named Engelmann spruce and Mount Engelmann (south of Berthoud Pass) for him.

George Engelmann *(courtesy of the Missouri Botanical Gardens).*

Engelmann spruce occur in Colorado mostly at elevations from 9,000 to 12,000 feet. They fit our mental image of a "typical" cool, wet Rocky Mountain forest and are shade-tolerant, preferring to begin life in the shadow of rocks or trees such as other spruces, firs, or aspen, or from the shelter of old, decaying logs. Engelmann spruce most commonly grow with subalpine fir. Mostly pure spruce stands exist, as do mixed forests with trees like aspen and other conifers. As would be expected of high mountains, a typical spruce forest endures cold winters, a short growing season of only a few months, and good moisture.

It is fair to think of spruce as slow-growing and long-lived. They can exceed 100 feet in height and live 400 years or more. In 1995, researchers found an individual Engelmann spruce along Fool Creek on the Fraser Experimental Forest in Grand County (it goes by the unglamorous name of "FCC-24") that is still alive at the age of 773!

Typical trunk diameters for mature trees in optimal growing conditions range from 16 to 22 inches. Every three to six years, Engelmann spruce produce a heavy crop of dangling cones. Spruce are monoecious, meaning both male and female flowers occur on the same tree. The cones are clustered in the top third of the crown, which is thought to be a hedge against self-pollination.

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Above: *Engelmann spruce buds and foliage.* **Opposite:** *A male pine grosbeak at home in the State Forest.*

The list of biota associated with spruce-fir forests is colorful and long. Most compilations estimate that around 145 species of amphibians, reptiles, birds, and mammals utilize subalpine forests. While none are exclusive to these habitats, the red-backed vole, pine marten, and others achieve their maximum prosperity there. Colorado columbine, the official state flower, occurs throughout, even onto, the alpine tundra. Elk calve, feed, and loaf in the darkness of these forests. Pine grosbeaks, crossbills, and Clark's nutcrackers revel in the branches above pine squirrels, yellow-bellied marmots, and least chipmunks. And the dusky penstemon, monkshood, rosy paintbrush, and a field-guide full of other flowers decorate the forest floor. This is just a fraction of the grand tapestry nature weaves on high.

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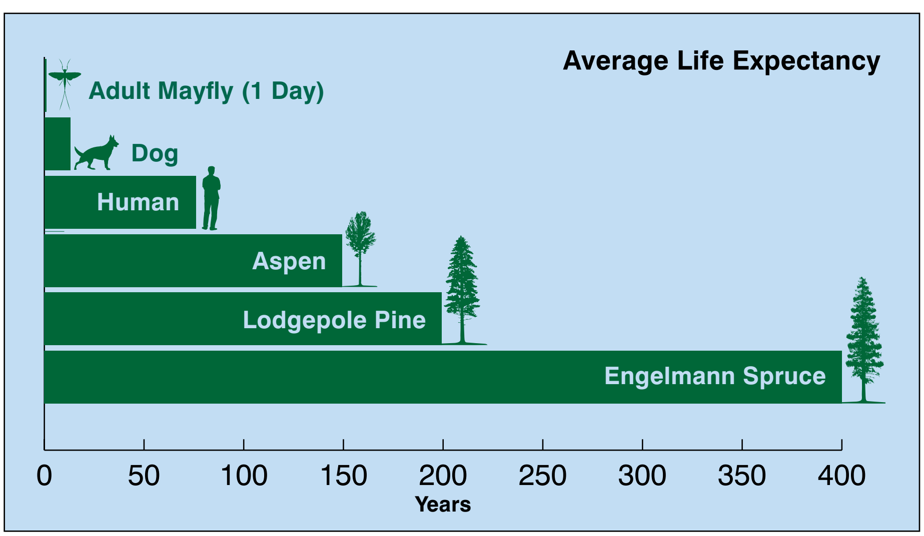
Dendrochronology, or tree-ring studies, show that in the southern Rockies, spruce beetle is the cause of death for many old spruce stands. Epidemics of these pine beetle relatives, occurring every 116 years on average since the 1700s, typically begin in large, old trees along streams or in large trees blown over by wind. If the surrounding forest is of suitable age and diameter, such beetle outbreaks often spread into them. Colorado has experienced expansive spruce beetle populations in the past, most notably on the White River National Forest in the late 1940s, and most recently following the Routt Divide blowdown near Clark in October 1997. Wind storms that level large numbers of spruce trees primarily are responsible for most of the recent and current spruce beetle epidemics. This insect is currently active in many areas of Colorado and, after the current mountain pine beetle epidemic subsides, may well be one of our next big concerns.

Another insect, the western spruce budworm, includes spruce needles in its diet. Historically, it has had a bigger impact on Colorado's Douglas-fir and white fir forests (see Colorado Insect and Disease Update on page 16).

Fires, some of them intense, can occur at high elevation but at very long intervals of perhaps 200 to 400 years. It takes the right combination of forest condition, extended drought, and warm temperatures for fires to occur in these generally cool, moist forests. Fires that ignite under these conditions can be severe and may burn many thousands of acres. The possibility of climate change warming and drying spruce-fir forests,



Bob Sturtevant

Colorado Christmas Trees

In 1990, the Town of Walden, celebrated its gift of a National Christmas Tree to Washington, D.C. The 75-foot Engelmann was harvested from the Routt National Forest.

After 3½ years of meetings, fundraising activities, and ceremonies, the National Christmas Tree finally took its place in Washington, D.C. December 12 was Walden's day. It began with a reception at the U.S. Forest Service office, where then U.S. Forest Service Chief Dale Robertson held a ceremonial tree decorating event and reception.

The formal tree-lighting ceremony followed. After so many months of work, it went incredibly fast. The entire event lasted only about 30 minutes!

CSFS Archives

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Above: *Logging trucks leaving the State Forest.* **Left:** *Bull moose in a wet meadow framed by spruce and fir.* **Below Left:** *Dusky penstemon at Lizard Head Pass.* **Below:** *Rosy paintbrush flourishing in the runoff of alpine snows.*

and thereby influencing fire incidence and behavior, has the attention of scientists, citizens, and firefighters alike (see High Country Fire on page 28).

Under the exceedingly difficult growing conditions of mountaintops, at about 11,000 feet, the area referred to as timberline occurs. Nature draws this line in the sand with wind, ice, snow, and cold. Although complex, in essence this line defines where -40°F occurs. At this temperature, despite various tree adaptations to avoid it, water within cells freezes, resulting in death. Just below it are woody plants barely recognizable as trees, many of them stunted and bent in one-sided obedience to prevailing gales. This condition, called "krummholz," translates to "elfin-tree" in German. Engelmann spruce is one of the last diehard species capable of eking out life in this extreme zone.

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People have long valued Engelmann spruce for its utility. Railroads and mining elevated lumbering in Colorado's early history. The Bockman Lumber Camp on the Colorado State Forest near Cameron Pass, the largest logging camp in state history, supported 100 loggers and their families. Spruce proved its value there and elsewhere.

Its light, soft wood of uniform color makes it ideal for boards, mine props, pulp, plywood, particleboard, and wood for musical instruments. Large-diameter trunkwood makes the best exterior walls for log homes. Spruce killed during the huge spruce beetle outbreak of 1939-1951, many of them still standing gray and solid, continue to be used in this way. Indeed, the decades following this beetle outbreak, which killed an estimated 6 billion board-feet of timber, constitute the highest use of spruce in our state's history. Today, more than one-third of the Engelmann spruce suitable for use as wood products in North America grows in Colorado, some 25 billion board-feet.

If, when, and where Engelmann spruce stands are managed, uneven-aged systems may make the most sense. Stand-replacing fires, wind events, or

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spruce beetles initially established spruce stands as mostly even-aged, but over long time periods between major disturbances, a series of smaller events introduced complexity of size, age, and tree type. Management can mimic this complexity by removing individual trees, groups of trees, or small patches. The blueprint recommended here for forest activity within stands is not to be confused with forest activity that makes sense for spruce-fir forest management at the landscape level. (See High Country Fire on page 28).

The challenge for society is to decide the best mix of uses for this important tree species, on and off the stump.

Subalpine Fir
(Abies lasiocarpa)

One of the "true" firs, this sidekick to Engelmann spruce receives little attention by comparison. It is literally lost in the shadow of its cohort. The quite narrow crown of a mature tree mirrors its growth in thin air and might suggest it abhors attention. Yet it is quite essential to the team chemistry of upper-elevation forests. Like other firs, subalpine fir produces cones that are upright, beautiful, and ephemeral. This last feature is unlike our other native evergreens. After the cones form in mid-summer, they disintegrate, releasing the seed and leaving behind only a central stalk. Aptly, its species name "lasiocarpa" is Latin for "shaggy fruit." Crossbills, well-known for their attraction to spruce cones, apparently avoid subalpine fir because its seed-coat resins are thought to inhibit protein digestion. That is not a problem for red squirrels, which store away large quantities of subalpine fir cones for winter and spring use.

Subalpine fir thrives in a climate of cold winters, cool summers, and abundant moisture. In that respect, it is similar to Engelmann spruce, albeit much shorter-lived. In specific locales, subalpine fir, along with spruce, aspen, willows, and certain pines, is part of the krummholz forest and helps define the moving target that is "timberline." Water studies show that this subtle roughness at the alpine-subalpine interface, which amounts to woody outposts a few feet tall by several feet long, helps trap snow that contributes 1 percent to total streamflow.

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Above: *Engelmann spruce in "krummholz" form.* **Left:** *Subalpine fir foliage and buds.*

These leeward drifts also melt late, providing moisture for plant growth and soil recharge at a time in summer when it is otherwise lacking.

Subalpine fir is less tolerant of dry, warm conditions than spruce. Spruce-fir encroachment into aspen groves often is natural but at other times can be an enhanced outcome of fire suppression. Most ecologists agree that aspen function in Colorado needs to be restored over large portions of the high country. Judicious removal of spruce and fir in select locations would provide a positive contribution to such restoration.

Although there are fewer uses for subalpine fir than spruce, it does pulp

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Above: *A red crossbill male extracts spruce seeds from cones with its unique beak.* **Right:** *Beautiful subalpine fir cones prior to hoarding by squirrels or unceremonious disintegration.*

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Above: *A red squirrel in its cavity home.*
Left: *Healthy aspen forest.*

well, can be made into lumber, and makes a fine Christmas tree, and its aromatic resin serves as a basis for "pine-scented" products and laboratory adhesives.

Quaking Aspen
(Populus tremuloides)

The value of aspen may be in the eye of the beholder. Tourists first look at its leaves, foresters its trunk, and ecologists its roots.

The celebrated bright yellow leaves of Colorado aspens in the fall signifies a change of seasons. Beginning in August, as daylight hours wane and temperatures cool, green-leaf chlorophyll yields dominance to yellows previously hidden. By late September and into October, the modern "Gold Rush" peaks. During this period, TV anchors recommend the best drives and the ideal weekends to view the splendor. The resultant dollars generated, while difficult to calculate, are not insignificant.

Undeniably, aspen is a special tree, and Colorado has more acres of aspen than any other western state. Fossil evidence of trees in all ways identical to modern "quakies" dates back almost 15 million years. It is the most widely distributed tree species in North America. Amid southern Rocky Mountain forests dominated by deep-green conifers, aspen almost single-handedly carries the banner for deciduous or "hardwood" trees. It prospers, mostly in even-aged stands, on

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Left: *Aspen foliage.* **Below left:** *Red-naped sapsucker nest holes excavated in an aspen infected with trunk decay* Phellinus tremulae*. Note the two spore-producing structures of the fungus ("conks") at branch scars in between the two woodpecker cavities.* **Below:** *Warbling vireo nest in aspen. This species, which winters in the neotropics, is perhaps the most common songbird breeding in Colorado's mature aspen forests.*

high plateaus and mesas, and on rolling mountains of intermediate elevation. Extreme individuals, however, help define the limits of woody plant life at timberline near 12,000 feet, standing side-by-side with species perceived to be tougher, like spruce and fir.

Chlorophyll hides in the chalky bark of aspen, complementing that within its grass-colored leaves. These white trunks, with their black accents, are the trim that visually cements our adoration of the tree. They are like the mat on a professionally framed picture – not the first thing that catches the eye but essential to the overall impression. Most mature aspen grow to a girth of 3 to 18 inches and heights of 20 to 60 feet (for details of Colorado's largest aspen, see the Champion Tree chart on page 33).

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The thin, living bark of aspen makes it prone to a host of insect and disease issues. Although these and other issues make it less than ideal for urban settings, aspen certainly add biological diversity to native forests and enhance forests' utility to wildlife.

Aspen woodlands typically are much more biologically diverse than associated spruce-fir forests. Elk commonly browse branch tips and gnaw bark, leaving recognizable scrapes. Voles nibble basal trunk bark under the snow. Beavers rely heavily on this tree for dam construction material and feed on its tender leaves and shoots. Canker and decay-causing fungi flourish on aspen. Their alteration of the wood often leads to internal hollows widely exploited by woodpeckers, the holes of which are subsequently inherited by bluebirds, swallows, nuthatches, wrens, chickadees, owls, squirrels, bats, and others. The red-naped sapsucker breeds almost exclusively in aspen. Forests dominated by this tree not only are important to the hole-nesting guild, their open crowns and lush understory vegetation make them important to a wide selection of other bird species.

An important attribute of aspen is its ability to start as many as 30,000 new stems per acre from suckers that arise from existing tree roots. Fires tend to trigger this occurrence, and physiologists have surmised that two hormones are involved. The production of auxin, a sucker-suppressing material produced in the crown, is disrupted when the tree is stressed. Cytokinin, the second material, is then free to stimulate suckering.

Because of its rootstock reproduction method – reproduction from seed in nature is very rare, but it does occur (see sidebar on page 10) – it is fair to say an entire aspen grove covering many acres of a mountain hillside is not thousands of individual trees but rather one, huge living thing! For example, botanists in Utah have dubbed a particular Utah clone of aspen "Pando" (Latin for "I spread").

Dave Leatherman

While fires occur in aspen stands during periods of extreme weather conditions, under normal conditions, aspen stands serve as firebreaks. This fact is important at a time when prevention of large-scale fires involving entire watersheds is desirable. It is possible to encourage a network of vigorous aspen groves among aging spruce-fir forests by removing mature aspen in large patches of 500 to 1,000-

Paige Lewis

Aspen From Seed

While aspen usually are grown from cuttings, Randy Moench and his staff at the Colorado State Forest Service Nursery in Fort Collins have pioneered the art of growing aspen from seed. Such reproduction is rare, even in nature. Individual aspen stems usually produce only one gender of flowers, male or female. Flowering female branches, fertilized earlier in spring by pollen from male trees, are collected from the field at precise times (usually between late May and mid-June) and placed in water tubs at the nursery. When "cotton" bursts from their capsules, very tiny seeds hidden within are monitored for maturity and then extracted using forced air and mesh sieves. Once collected and properly stored, the seed is inoculated in growing tubes by means of a standard salt shaker. If more than one seedling grows in a tube, one is selected and the competitors are culled. This method is cost effective and gives the nursery flexibility in producing more than 30,000 aspen seedlings in a typical year. For a copy of the illustrated fact sheet with details, see http://csfs.colostate.edu/pdfs/aspenseed.pdf.

Bill Ciesla

Sudden aspen decline on Bull Mountain.

plus acres, mechanically stimulating roots at the edges of established groves, and removing encroaching spruce and fir.

Recently, foresters, the public, and the media have focused significant attention on a condition dubbed sudden aspen decline (SAD). Early this century, mostly after the unusual heat in 2002, older aspen stands in many areas of Colorado began dying rather quickly. The state's southwestern quadrant was particularly impacted. These stands initially displayed the classic symptoms of drought – the overstory dies and some of the aspens fail to renew via root-suckering. Ungulate grazing, fire exclusion, and perhaps drought are factors in the lack of regeneration that is evident around the edge of many established groves. Stands of vigorous young trees that regenerated through forest management activities prior to the drought remain healthy, perhaps because the root systems are able to sustain a lower volume of woody biomass.

Many organisms, mostly wood-boring insects and fungi, have been associated with SAD, but to date, they appear to be more indicators (that is, "secondary") than direct causal agents. While drought may be central to the issue, other factors also may be involved. It is possible that fire suppression and/or livestock grazing within aspen stands directly altered the understory in ways that affect how moisture reaches the roots.

At this time in history, the singular ecological importance of aspen becomes even more evident. Perhaps more than any other tree species, aspen will be responsible for restoring order and beauty to Rocky Mountain forests suffering turnover at the hands of bark beetles and other forest disturbances. To be sure, young conifers of the same species being killed, notably lodgepole pine and Engelmann spruce, will be major elements in the massive recovery project nature has planned for the next few decades. But the characteristics of aspen are uniquely suited to play a major role in recovery. It is genetically diverse and, as such, adapted to a large array of growing sites and conditions. And it likes starting life in full sun. The big question is whether the climate will provide enough moisture to satisfactorily complete the cycle. All the ingredients for restoration and renewal are in place, assuming precipitation falls in the right amounts and at the right time to propel the process.

Lodgepole Pine
(Pinus contorta)

Forests of lodgepole pine appear as upper montane or subalpine telephone poles with needles. They usually occur after hot, stand-replacing crown fires burn at intervals of several decades to a few hundred years. Their normal woody associates, if any, are aspen, Engelmann spruce, subalpine fir, or shrubs. They also may be components of mixed conifer forests.

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Lodgepole is one of several North American pines with "serotinous" cones, meaning they only expose seeds when the cone-sealing pitch is melted by heat, usually from fire or through close proximity to the ground after forest management activities. The temperature range required to release the seeds is 113° to 140°F. But not all southern Rocky Mountain stands are serotinous, and this trait is inconsistent within a given forest. Seed yield from nonserotinous and serotinous stands killed by something other than fire (such as beetles), while less spectacular than classic serotiny, does occur. Such seed-spill takes place over a longer period of time under the influence of dry air, wind, and heat reflected from the forest floor. The fullness of future Colorado forests experiencing the current mountain pine beetle epidemic is depending on it.

Young lodgepole pine forests created from the chaos of a fire in an old lodgepole forest are examples of nature's excess. Foresters refer to them as "dog-hair stands," an apt description of pine carpets sown with 100,000 or more seedlings per acre. Each stem has essentially the same birthday – the day of the fire. During the forest's formative years, mammals, insects, diseases, and shade thin the thicket to thousands or several hundred trees per acre. Depending on the degree of thinning, a very dense stand can stagnate after as few as 40 years. Less excessively stocked populations can stagnate at the relatively young age of 50 to 80 years. To influence ultimate stand productivity or longevity, tree thinning should occur in sapling stands. After that, by virtue of lodgepole's tendency for shallow root systems, thinning without subsequent wind damage is difficult. Its wind-firmness depends not only on stand density but also on soil and topography. For older lodgepole forests, practices such as clearcuts and patchcuts that mimic natural processes can maximize production and introduce diversity to lodgepole pine landscapes.

Lodgepole pine requires less moisture than spruce or fir and more than ponderosa pine or Douglas-fir. Three distinct types of lodgepole forests are recognized. Pure stands occur between 9,000 and 10,000 feet at the bequest of fire and other conditions that exclude

Dave Leatherman

Kathryn Hardgrave

Above left: *Foliage and nonserotinous cone of lodgepole pine.* **Left:** *"Dog-hair" lodgepole pine stand.* **Above:** *Mistletoe brooms in lodgepole pine.*

additional species. Above 10,000 feet, lodgepole pine can be a part of the subalpine forest, along with spruce and fir. Likewise, at the lower edge of its range, lodgepole is occasionally part of the mixed-conifer forest with ponderosa pine, Douglas-fir, limber pine, white fir, and aspen.

Lodgepoles grow and die uniformly. If fire does not do the job, mountain pine beetle, lodgepole dwarf mistletoe, or wind usually does. Massive mortality events over hundreds of square miles that occur within a decade or less are possible, even probable, when old forests become stressed. Such events have happened throughout history, are happening now, and likely will happen again. The younger, green lodgepole pine forests created through forest management activities 20 to 30 years ago provide a stark contrast to the vast acreages of older dead trees. (See Colorado Insect and Disease Update on page 16).

Mistletoe (*Arceuthobium americanum*) is more chronic and slower-acting. As a plant parasite living on its host, it normally co-exists with the tree for decades, even its entire life, without causing either plant to die. In late summer, under water pressure, the parent plant shoots explosive, sticky mistletoe seeds, reinfecting the same tree or new trees nearby. The direct activity of mistletoe results in a slow, intense march through the forest (about 1 foot to 1.5 feet per year). Birds and mammals, gray jays, and least chipmunks also contribute to the long-distance spread of the parasite. Seeds stuck to mobile bodies at infection centers are groomed by the carriers in new locations. Mistletoe, lethal or not, has major consequences on lodgepole pine. Infected trees are slow-growing and often develop poor shape, particularly in the form of densely branched areas on limbs or trunks called "witches' brooms." In situations where young lodgepoles develop below living parent pines, seeds that rain down from overtopping mistletoe plants infect them and ensure continuance of the cycle. Natural fire, clearcutting, and isolation cuts can cleanse mistletoe from sites or at least restrict and reduce its impact and movement.

White Fir
(Abies concolor)

White fir is part of the mixed-conifer forest. In Colorado, it is restricted to the southwestern quadrant, ranging from southern Douglas County south to Raton Pass on the New Mexico border and west to the Four Corners area of Montezuma County. It occurs from 6,000 to more than 10,000 feet in elevation. Until recently, it has not been widely used for wood products in Colorado; however, new sawmill technology has resulted in increased utilization of white fir. In urban areas, however, white fir makes a good substitute for blue spruce. The two are quite similar, but the foliage of white fir is softer. White fir is cultivated in both native forests and on plantations as Christmas trees. Important natural enemies include drought, western spruce budworm, Douglas-fir tussock moth, fir engraver, annosus root rot, and fir broom rust.


Dave Leatherman


Dave Leatherman

Above: *White fir.* **Below:** *White fir foliage and buds.* **Below left:** *Galleries of the fir engraver, a bark beetle that infests drought-stressed mature white fir.*


Dave Leatherman

Blue Spruce
(Picea pungens)

"Colorado" blue spruce is Colorado's official state tree. Charles Christopher Parry, renowned botanist and explorer of the West, discovered this tree on the flanks of Pike's Peak in 1862. The Colorado Horticultural Society, a bureau of state government, began promoting tree education in schools and sponsored a contest to decide the children's favorite tree in 1892. Denver high school teacher

Bob Sturtevant

Dave Leatherman

Above: *Blue spruce cones (top) are larger than those of Engelmann spruce (bottom).* **Left and Below:** *The Town of Woodland Park, Colo., provided the 2000 National Christmas Tree, a blue spruce. The tree was harvested from the Pike National Forest.*

George L. Cannon Jr. developed criteria for a fitting choice, and blue spruce was declared the winner. Finally, on March 7, 1939, the Colorado General Assembly approved House Joint Resolution No. 7 declaring blue spruce Colorado's official state tree.

Perhaps seen more often in front lawns than in the forest, blue spruce has a rather restrictive set of requirements and thrives best along mountain streams and rivers. The bluest and greenest individuals of blue and Engelmann spruce, respectively, exceed the color extremes of the other species. But the color overlap is such that it is not a particularly good way to tell these two trees apart. The bigger cones and more layered branching habit of blue spruce, as well as the differing bark characteristics of the two species, are better identifiers, but even with the help of these visual aids, identification can be difficult.

Limber Pine
(Pinus flexilis)

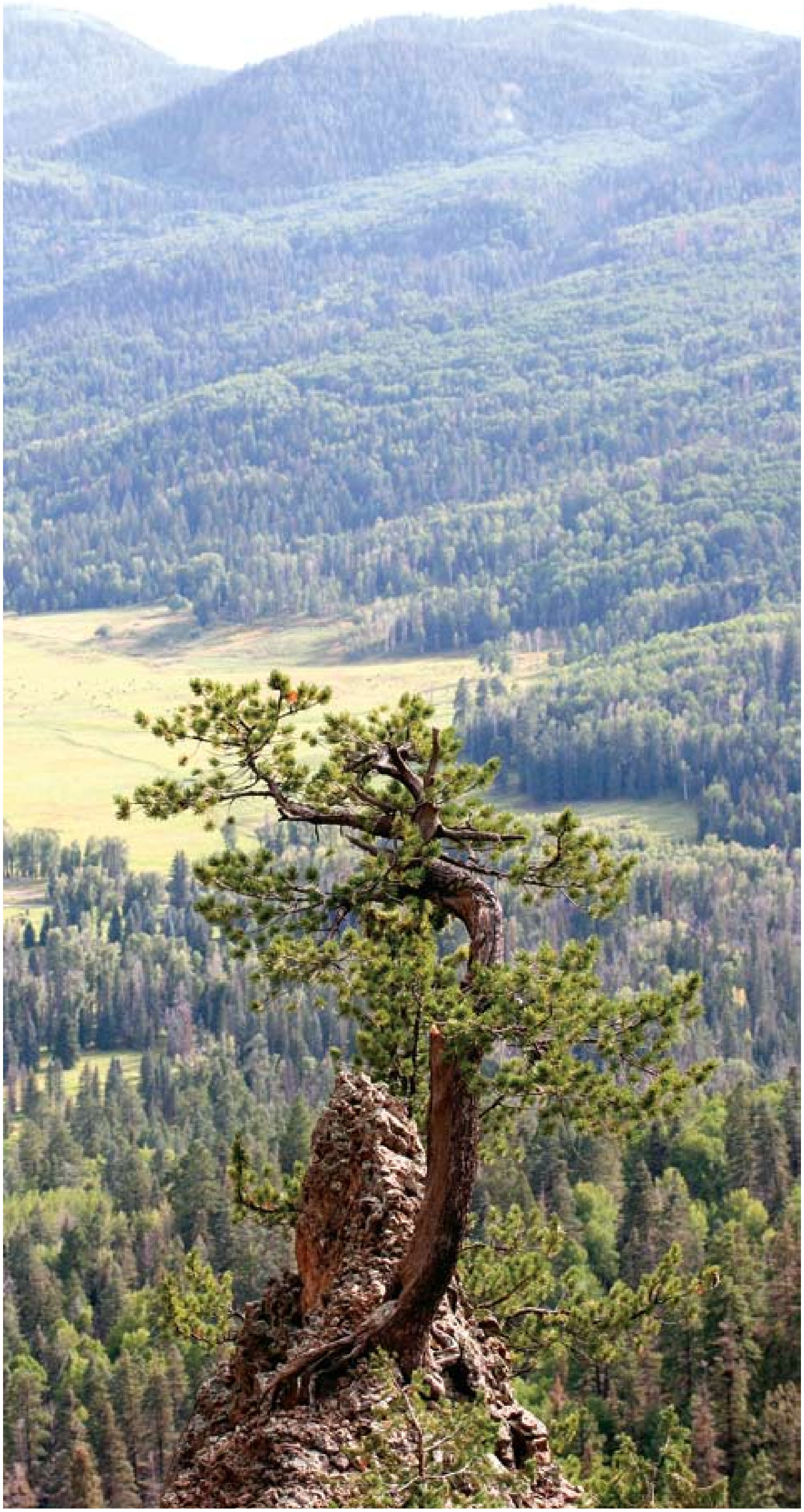
The needles on this member of the white pine group are found in bundles of five, and live branches of small diameter actually can be twisted into a knot without breaking, hence its name. A rugged survivor of poor soil on rocky ridgetops, this little-known species is ecologically important. A limber pine in northern New Mexico is 1,670 years old.

The seeds, born in large cones, likewise are large, nutlike, and nutritious. Corvids (jays and crows) like the Clark's nutcracker depend on them heavily, as do many mammals, including bears.

Though its range is fairly restricted in Colorado, limber pine is one of the three most common hosts for mountain pine beetle. Like lodgepole pine, it also is under siege at this time. Ecologists are concerned about the extent to which climate change appears to be influencing the intensity of attacks by pine beetle on this and other white pine species throughout the Interior West. Historically, environmental extremes, primarily extremely cold temperatures, at the upper range of these species have precluded heavy bark beetle mortality. But as temperatures moderate and drier conditions induce moisture stress higher up the mountain, pine beetle is less restricted and appears to be taking advantage of newly available food resources. Combined with the sinister invasion of an exotic disease, white pine blister rust, invading Colorado from two directions – down from Canada via the northern Rockies and up from New Mexico – white pines like limber could well be in trouble.

Bob Sturtevant

Dave Leatherman



Management of this situation is logistically difficult. As for pine beetles, anti-aggregant chemicals and pesticide treatments to protect individual large, cone-bearing pines have bought time but are not the ultimate solution. Detection of white pine blister rust, which affects hosts of all sizes, is most difficult because of the terrain involved. Doing anything about the issue once

Dave Leatherman

Left: *A limber pine on Wolf Creek Pass.*
Above: *Foliage and cone of limber pine.*

discovered is even more problematic. The rust involves currant plants (genus *Ribes*) within its life cycle, and removal of these alternate hosts has traditionally been part of management schemes for other rust diseases. However, a survey by Colorado State University pathologists determined that currants essentially are everywhere, throwing a stick in the spokes of meaningful action. Work currently being done by U.S. Forest Service researchers and plant pathologists has identified some tree sources that exhibit genetic resistance to the rust. Future goals include planting seedlings from these sources.

Rocky Mountain Bristlecone Pine
(Pinus aristata)

Rocky Mountain bristlecone pine, another white pine, is a minor but interesting inhabitant of the high country and is classified as a mixed conifer. The cones of Rocky Mountain bristlecone pine do, indeed, sport bristles, and the needles are spotted with dabs of white

Clark's Nutcracker

As the famous Lewis and Clark Expedition was concluding in 1806, William Clark made the most of a travel delay in Idaho and joined colleague Meriweather Lewis to search for new plants and animals. A new bird later named in his honor, the Clark's nutcracker, was among them.

These fascinating birds are intimately connected to many of our white pines, including limber. The wingless seeds, or nuts, are critical to their diet. From late summer through early winter, nutcrackers busily stock the pantry for winter and spring. This process of storing seeds in protected locations, one full throat pouch after another, is called "caching." A full load of a hundred or more seeds resembles a goiter in the throat area and might be as heavy as 20 percent of the bird's total weight. Limber pine seeds, as many as 16,300 per bird, are stashed in little piles of one to 15, mostly in obscure sites on which snow melts quickly in spring. Remarkably, the birds remember most of the hundreds of locations in which they stored seeds months earlier. They do so by means of visual clues like rocks, logs, and tree stems. The clumpy growth habit of limber and other pines utilized by nutcrackers – each clump comprised of individual stems of varied genetic make-up – is direct evidence that the bird is involved in the trees' origin. It means some cached seeds are either forgotten or simply are not retrieved and ultimately germinate. Some studies show nutcrackers cache two to three times the number they actually need. A measurable amount of reforestation following the 1988 Yellowstone fires is attributed to the efforts of highly intelligent "Johnny Appleseed" nutcrackers.

Dave Leatherman

Clark's nutcracker.

pitch that often are mistaken for insect infestations. This tree is worthy of the same concerns mentioned above for limber pine.

"Ancient" is an adjective that often is applied to bristlecone pines. Great Basin bristlecone pine, a related species only recently split from Colorado's, lays claim to the moniker "World's Oldest Living Thing." One specimen, dubbed "Prometheus," lived 4,844 years on Nevada's Wheeler Peak. The oldest Rocky Mountain bristlecone, in central Colorado, is a mere baby by comparison at approximately 2,434 years old. It began life when the Spartans were at war with the Persians in Asia Minor and Greek engineers were inventing the catapult.

Dave Leatherman

Riparian Shrubs

The term "riparian" refers to the immediate flanks of flowing waters. The journey of water, always at the whims of gravity, can be both peaceful and tumultuous. Vegetation along the banks of trickles, streams, and rivers is essential to the process and provides an important service to montane ecosystems. Willows – many only identifiable by botanists with microscopes – and birches, thinleaf alder, red-osier dogwood, shrubby cinquefoil, and mountain maple compose the starting roster. These species serve as essential intermediaries between upland forest life forms and those of fully saturated aquatic habitats. They feed and shelter wildlife species. Despite their importance, much remains to be learned about their ecosystem functions and limitations. Like other species, the effects of climate change loom large in their future.

Ingrid Aguayo

Above and left: *Bristlecone pine foliage and cones.*

Colorado Insect and Disease Update

This section highlights insect and disease issues in high elevation forests first, followed by key issues of concern in other parts of Colorado. The information provided comes from many sources. The U.S. Forest Service, with help from the Colorado State Forest Service, conducted aerial surveys of 28 million acres of the state in 2008. The CSFS entomologist and personnel in the 17 CSFS districts conduct dozens of specific evaluations each year. The public and local natural resource personnel bring attention to additional situations.

Dave Leatherman

Top: *Mountain pine beetle-killed lodgepole pine trees at Michigan Reservoir (photo by Ingrid Aguayo).* **Right:** *Mountain pine beetle-killed trees on Rabbit Ears Pass.*

Mountain Pine Beetle

(Dendroctonus ponderosae)

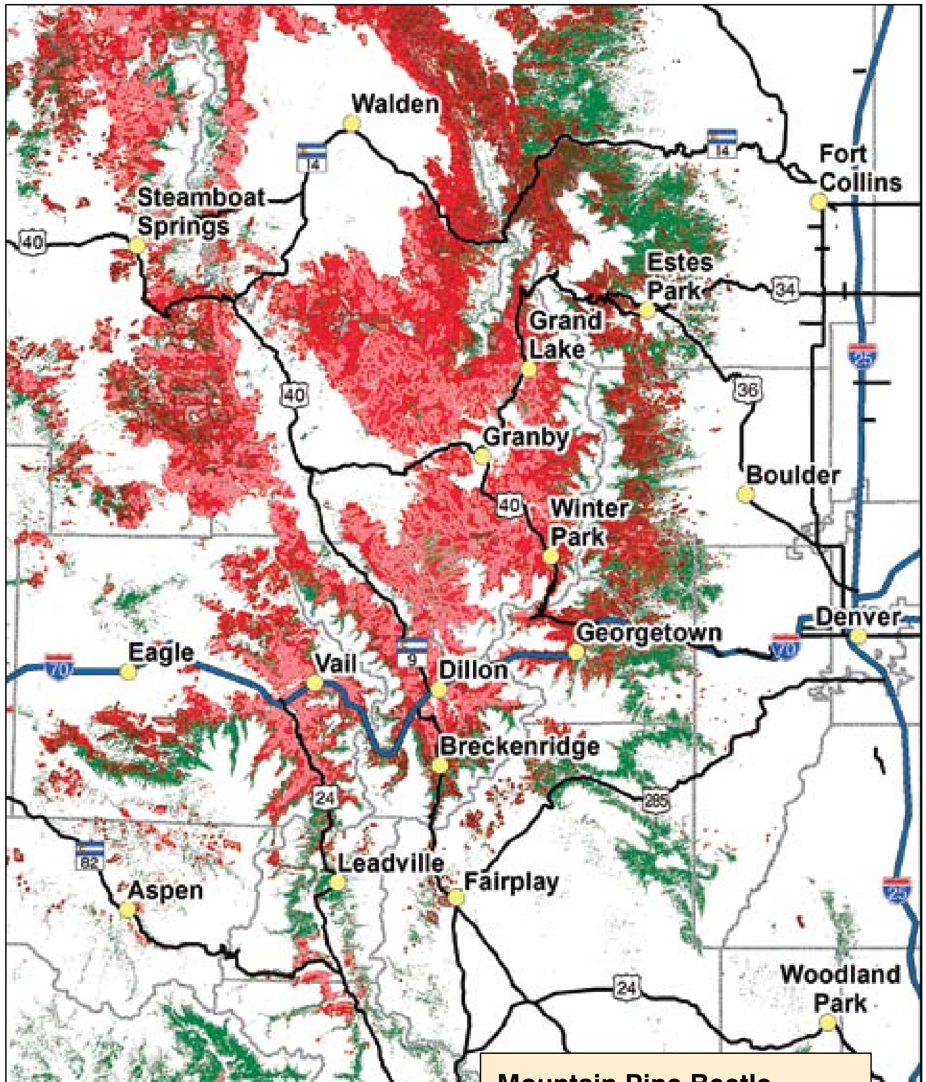
A cyclic insect that favors old, dense forests, mountain pine beetle continues to dominate the forest news in Colorado and much of western North America. Nearly all of Colorado's aging 1.5 million acres of pure lodgepole pine forests match the beetles' requirements. The result is an epidemic of massive proportions. Since 1996, when the epidemic was first noted, an estimated cumulative total of 1.9 million acres of forest have been infested by mountain pine beetle. This acreage consists mainly of lodgepole pine in pure lodgepole and mixed conifer stands, which include limber and bristlecone pine. In 2008, aerial surveyors noted a significant increase in the number of infested ponderosa pine trees. The analysis of the aerial survey data revealed that an estimated total of 1.16 million acres of pine trees were infested, and 400,000 of these acres were only recently infested.

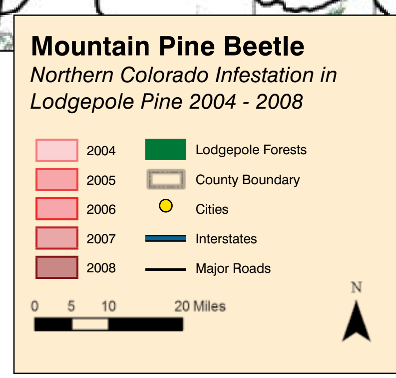
But not all lodgepoles are dead, nor will they be. The majority of trees less than 30 or 40 years old should survive the epidemic. Young, green, regenerating forests can be found where forest management activities were conducted in the last several decades, providing a stark contrast to surrounding unmanaged forests.

Surveys by Colorado State University researchers and others, while not exhaustive, confirm the survival of some large trees in local areas within and outside the general infestation, and highly variable populations of small lodgepoles in the understory of beetle-affected stands.

Innovative new initiatives to utilize beetle-killed wood for biofuel have begun in Kremmling and Walden. Facilities in Gilpin County and the National Renewable Energy Laboratory in Golden have made biofuels part of their operations.

The structural integrity of wood stained blue by beetle-introduced fungi is equal to that of other lodgepole pine lumber products. In addition to lumber, blue-stained wood can be used for specialty products such as paneling, furniture, and craft items. One furniture manufacturer sold their entire line of blue-stained products at a recent northern Colorado exposition. New cooperatives to reduce the costs of consolidating, sorting, and transporting this material also are being explored.



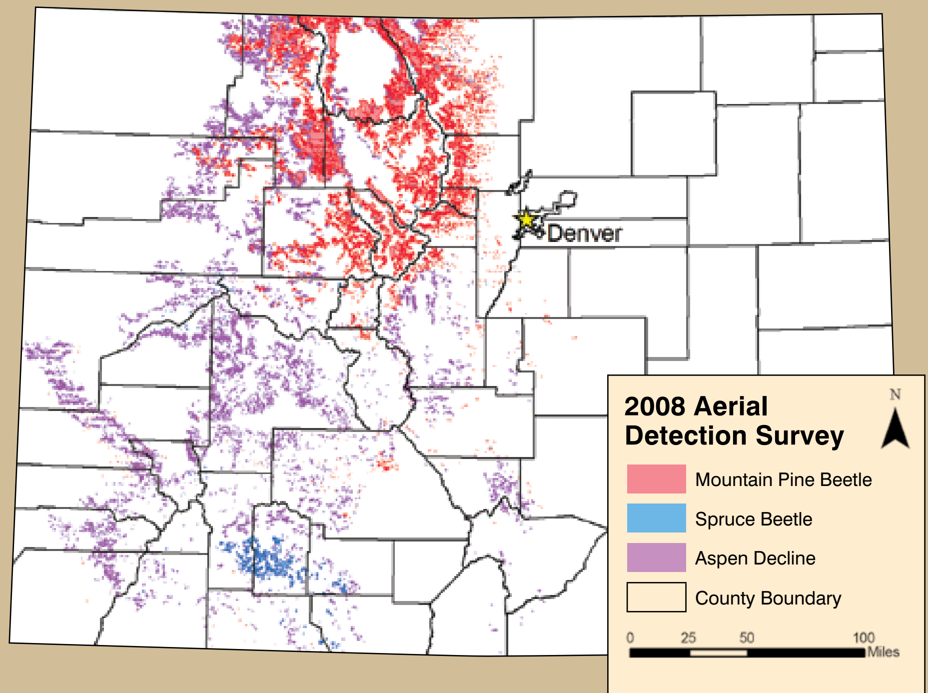


Subalpine fir decline is caused by multiple organisms – the **balsam bark beetle** *(Dryocoetes confusus)* and two root disease fungi (Heterobasidium annosum and Armillaria spp.). Combined with dry, warm climate conditions, these organisms are killing large numbers of subalpine fir. The result is a "bathtub ring" of red fir defining the lower reaches of this tree that thrives in cool, wet conditions.

Where Do Those Aerial Survey Numbers Come From?

The alarm goes off at about 6 a.m., and it's time to check the weather, get dressed, grab your briefcase, and head to the airport for a morning of surveying. So begins the day of an aerial sketch-mapper. A normal session involves four to five hours of flying shotgun in a small fixed-wing aircraft with an experienced pilot over mountain terrain, 1,000 to 1,500 feet above the tree tops at about 100 miles per hour, straining to accurately map the location, number, and identity of obviously sick trees.

Surveyors cover more than 100,000 acres in just one flight. If the computer is working properly, the display screen in your lap accurately pinpoints your exact location, give or take a few seconds. With training and experience, you discern fir from pine from spruce from aspen, and bark beetles from budworms from tent caterpillars from root disease pockets. You tip off the pilot to another plane or turkey vulture at 3 o'clock low. You rapidly distinguish this year's mortality from older damage, estimate the acres or numbers of trees involved, all while ignoring the onset of nausea and pressure in your head.



Bill Ciesla

Aerial survey briefing before the flight.

This is the hardest work in terms of sustained intensity and required skill you have ever done. Your mind flashes to the co-worker stuck in the office who whined about how lucky you are to be a surveyor. But by 1 p.m. or so, as the August air warms and thermal bumps increase, the pilot utters those magic words, "Back to the barn." The back-and-forth and contouring are over for the day. During the level trip home, you crank up the air, notice a magnificent rock face, and peer straight down on a big herd of elk crossing an inaccessible alpine meadow. Surveying's not so bad.

When performed by the dedicated individuals selected for this potentially dangerous work, aerial surveys provide valuable trend information and early warning about emerging insect and disease infestations to foresters on the ground.

This activity, now referred to as the Aerial Survey Partnership, is led, coordinated, and funded by United States Forest Service Forest Health Protection personnel. The Colorado State Forest Service has assisted with this effort since the 1970s and became significantly involved in 1997. In 2008, three agencies, four aircraft, and 11 surveyors covered a total of 43.7 million acres in Colorado and the rest of the Rocky Mountain Region (Region 2) of the United States Forest Service.

Bill Ciesla

Sudden aspen decline is a somewhat new condition used to describe established aspen groves that experience crown dieback over a relatively short period of a few years and do not appear to be regenerating. Many secondary organisms are associated with the dead and dying trees, but drought is suspected as the most important factor, combined with the accumulated effects of a century of fire exclusion, past grazing practices, and extensive elk browsing. Heavy snowpacks in some impacted areas during the winter of 2007-2008 seem to have slowed or stopped further increases in some areas, but the much-needed moisture was not uniform statewide. In 2008, the survey focused on aspen mortality and severity of damage, and 542,000 acres were noted. The phenomenon is scattered throughout the mountainous range of this tree but is most evident in the southwestern national forests west of Durango.

Spruce Beetle *(Dendroctonus rufipennis)*

The spruce beetle continues and is expanding in many Engelmann spruce areas statewide, especially in southern Colorado. In the wake of the 1997 wind event north and west of Steamboat Springs, which started in large-diameter downed timber and spread to nearby standing spruce, forests are mostly devoid of large spruce throughout Routt and Jackson counties. Spruce beetle infestations are increasing in the southwest mountains of Colorado. A wind event in June 2007 affected almost 1,000 acres in the Wet Mountains of the San Isabel National Forest. A 2008 survey identified broods of spruce beetle that may prove problematic in the near future.

Bill Ciesla

Top: *Sudden aspen decline on the upper Poudre River.* **Left:** *Aerial photo of spruce beetle-killed trees.*

Western Spruce Budworm
(Choristoneura occidentalis)

Western spruce budworm defoliates Douglas-fir, spruces, and true firs. The larvae of this moth chew new foliage in early summer. Heavy feeding for two to three years can kill host tops and entire trees. Colorado experienced a major cycle in the 1970s and early 1980s and is due for another. Increased populations noted along the Front Range in the Rampart Range near Colorado Springs, north of Durango, and around the Telluride area indicate the expected upsurge may be underway. Historically, Douglas-fir has been hardest hit, and this conifer tends to occur at lower elevations than the other hosts. As such, budworm occurs where tree values and human interest are highest due to mountain developments. Few management practices involving silviculture are feasible due to current markets, landownership patterns, and the lack of proven efficacy. Aerial application of bacterial insecticides on private lands was the primary activity directed at this insect in the past.

Ingrid Aguayo

Dave Leatherman

Western spruce budworm damage.

Western Tent Caterpillar
(Malacosoma californicum)

With a long history in Colorado, this defoliator of aspen and other deciduous trees and shrubs, long absent from traditional areas, is experiencing an upsurge and currently is active in the San Juan Mountains north of Durango and portions of the Wet Mountains.

Dave Leatherman

Minor bark beetles fail to kill large numbers of trees that grab front page headlines, but they do cause concern locally. Secondary species *(nonaggressive species that usually require some other organism or environmental factor to predispose trees to attack)* in the genera *Ips*, *Pityophthorus*, *Pityogenes*, and others attack pines and other conifers. When mountain pine beetle or spruce beetle successfully attack pine and spruce trunks, respectively, ips beetles and other smaller species called “twig beetles” commonly colonize branches and twigs. Because vast bark beetle events are active at present, the corresponding populations of the smaller beetles also are vast. This has allowed, or perhaps forced, large populations of these smaller beetles to kill small trees outright. This activity is predicted to cease within a year or two after activity by the larger species winds down. In the interim, their abnormal levels may necessitate preventive spraying of high-value, live, small trees so they are available to form the core of the next forest.

Exotic organisms, those not native to new areas where they currently are present, continue to be a concern. The term “exotic” can apply to a Colorado mountain species introduced to a town on Colorado’s Eastern Plains, an Arizona species blown by the wind to Colorado, or a foreign organism hiding in a pallet brought to a loading dock in Denver. The following are key examples of exotic organisms relevant to Colorado:

Dave Leatherman

Top: *Tent caterpillar and spruce budworm damage on Cuchara Pass.* **Lower left:** *Tent caterpillar “tent” on bitterbrush.* **Above**: *Tent caterpillar.*

Gypsy moth
(Lymantria dispar)

A Eurasian defoliator of many trees, mostly deciduous species, the gypsy moth established itself in the Northeast back in the 1860s. In the egg and pupal stages, it hitchhikes on vehicles and outdoor objects. Since CSFS and others began surveys back in 1986, it has been detected dozens of times. A few of these incidences proved to be established infestations and were eradicated. In 2008, 1,600 detection traps utilizing pheromones were placed throughout Colorado, and one moth was detected.

Ingrid Aguayo

Gypsy moth detection trap.

The Walnut Bark Beetle
(Pityophthorus juglandis)

and two canker fungi (*Geosmithia sp.* and *Fusarium solani*) are the known organisms involved in a new problem referred to as **thousand cankers disease of black walnut**. The beetle is thought to be native to Arizona walnut in the Southwest and new to black walnut and Colorado. Its involvement with the *Geosmithia* fungus also is new. How these organisms got here is unknown. Ned Tisserat and Whitney Cranshaw, researchers in the Department of Bioagricultural Sciences and Pest Management at Colorado State University, have been the primary investigators of this issue, which threatens all ornamental black walnuts growing in Colorado's urban areas and, even more importantly, the native population of black walnuts in the eastern half of the United States. To date, most of the black walnuts, including the state champion in Denver, are dead or in harm's way. Currently, no preventive or curative measures exist, although progress has been made.

Emerald Ash Borer
(Agrilus planipennis)

Another exotic looming in our future, and a pest of major consequence, it was introduced into Detroit from Asia in the 1990s via packing materials, and it already has killed millions of ash trees in Michigan and bordering areas. Its primary means of spread is via firewood or other wood products with the bark attached. The closest known infestation is eastern Missouri, a day's drive from Colorado. Extensive education about this insect is underway, and some cities have formed contingency plans. The fact that Colorado's urban ash trees are planted and therefore isolated in our cities and towns gives us a fighting chance to contain and eradicate this exotic if detection is swift following introduction. CSFS, along with the Colorado Department of Agriculture and USDA-Animal Plant Health Inspection Service, has actively conducted surveys for the past four years, including 140 trap sites in 2008. These surveys are essential to early detection that leads to swift eradication. Colorado's native ash (*Fraxinus anomala*) growing in arid areas of the western part of the state is being studied to determine if it is a potential host of emerald ash borer.

Our measured confidence in matters involving early detection and aggressive suppression of exotics comes from demonstrated successes over the last four decades with **Dutch elm disease** and **gypsy moth** (mentioned above).

Ingrid Aguayo

Ingrid Aguayo

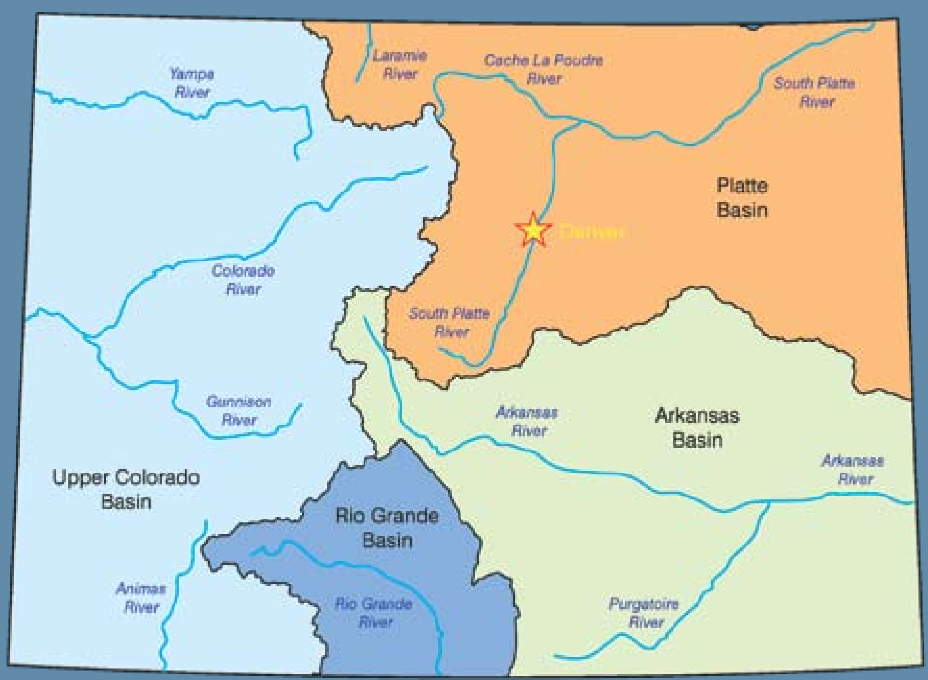
Above: *Dieback in black walnut.* **Top:** *An entomologist's finger points out walnut bark beetle larva.*

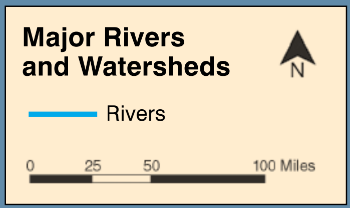
High Country Watersheds

Water is an essential requirement of life. Our earth has a fixed amount, existing as either salt water (97 percent of the total) or fresh water. The pathways of water are explained by the hydrologic cycle. Human uses of water have made nature's already complex aquatic system even more so. Plants, including trees, are key to the proper functioning of water movement within the environment. The U.S. Geological Survey identified 16 elements within the hydrologic cycle; forests are directly involved in most of them and are indirectly influenced by the remainder.

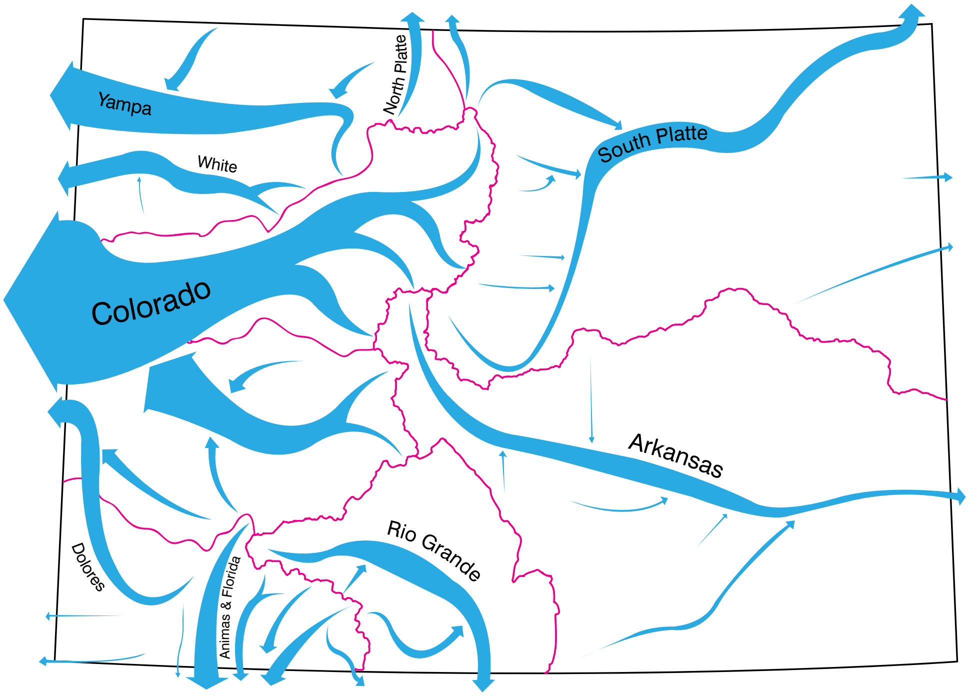
Forests receive precipitation; they utilize it for their sustenance and growth, and influence its storage and/or passage to other parts of the environment.

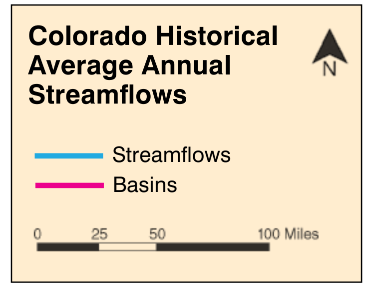
Three percent of the planet's water is fresh, so it is imperative that this resource be protected with vigilance. Looking further, 69 percent of fresh water is tied up in icecaps and glaciers, and another 30 percent occurs as groundwater. In other words, 1 percent of all water exists as surface water (such as lakes, swamps, and rivers). Two percent of the total surface water is contained in rivers. Virtually all of Colorado's drinking water comes from snowmelt carried at some point by a river. A quick glance at a map shows how important rivers have been to all areas of human civilization. The cities of Denver, Pueblo, Greeley, Fort Collins, Sterling, La Junta, Grand Junction, Durango, Gunnison, Craig, Fort Morgan, Glenwood Springs, Alamosa, Cañon City, Salida, Trinidad, Lamar, Loveland, Montrose, and many others owe their establishment and continued prosperity, in part, to rivers. Forest watersheds





Above: *Colorado's major rivers and watershed basins.* **Top:** *Molas Lake (photo by Ingrid Aguayo).*

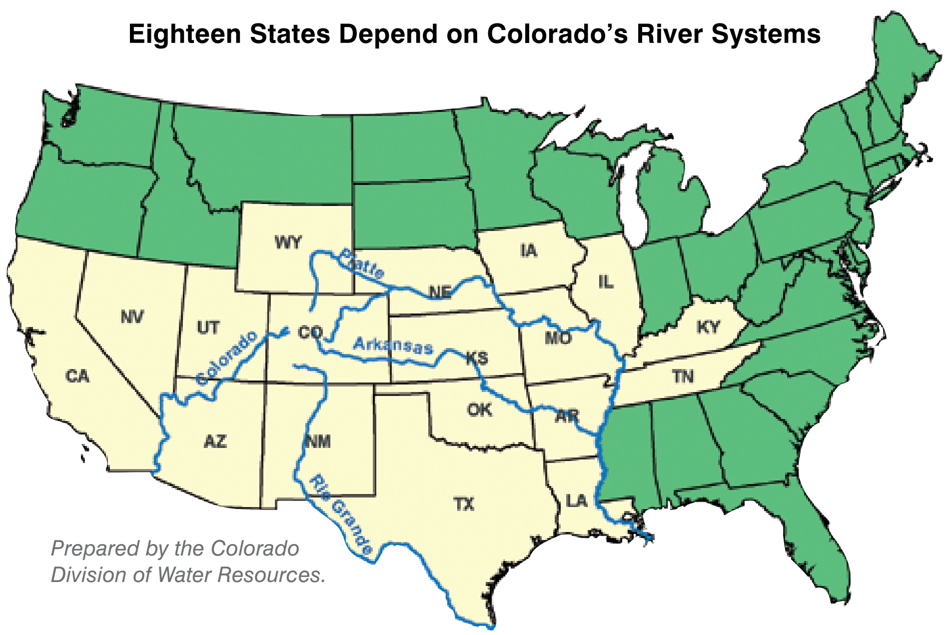




Acre Feet (af.)
Water leaving Colorado West – 8,807,450 af.
Water leaving East – 1,373,000 af.
Total leaving Colorado – 10,240,500 af.

(Prepared by the Colorado Division of Water Resources. Historical averages obtained from the USGS Water-Data Report CO-02.)

Eighteen States Depend on Colorado's River Systems



Prepared by the Colorado Division of Water Resources.

contribute to water quality and quantity, and their importance to Colorado and other states is, indeed, significant.

As mentioned in the introduction of this report, four major river systems – the Platte, Colorado, Arkansas, and Rio Grande – originate within the mountains of Colorado, and they drain fully one-third of the landmass of the lower 48 states. About 80 percent of Colorado's precipitation falls on the Western Slope, and about 80 percent of the state's population lives on the Eastern Slope between Fort Collins and Pueblo. Mountain snows supply 75 percent of the water to these river systems. About 40 percent of the water comes from the highest 20 percent of the land, most of which lies in national forests. National forests yield large portions of the total water in these river systems: North/South Platte, 44 percent; Upper Colorado, 74 percent; Upper Arkansas, 51 percent; and Rio Grande, 67 percent.

Via natural channels and a vast network of artificial conveyances such as tunnels, ditches, aqueducts, pipelines, and canals, 63 percent of Colorado's 4.3 million residents obtain at least part of their water from areas west of the Continental Divide. The potential for forest influence, both positive and negative, on transporting water such immense distances is great.

A typical example of Centennial State water travel, the Northern Colorado Water Conservancy District pumps a portion of the Colorado River in Grand County west of the Continental Divide to Shadow Mountain Reservoir north of Granby, channels it to Grand Lake, then into the west portal of the Alva B. Adams Tunnel, which carries it eastward under Rocky Mountain National Park for 13.1 miles to the Ram's Horn Tunnel to Mary's Lake in Estes Park, then through the Prospect Mountain Tunnel to Lake Estes into the Olympus and Pole Hill Tunnels to Flatiron Reservoir, and finally into the Handy Ditch and Horsetooth Supply Canal to Horsetooth Reservoir west of Fort Collins. And this is a simplified version. The Adam's Tunnel, named for a U.S. senator whose father was one of Colorado's governors, is arguably the most amazing feature of this pathway. Built over a period of seven years

Ingrid Aguayo

A view of the Poudre River.

beginning in 1940, it cost approximately $1 million a mile. On average, it delivers more than 200,000 acre-feet of water annually to cities, towns, and agricultural communities, and makes 690 million kilowatt-hours of power available to customers in northern Colorado, eastern Wyoming, and western Nebraska.

The following phenomena occur in relation to forests and water:

Tree crowns, collectively referred to as the forest canopy, intercept precipitation that falls from clouds. The destiny of fallen moisture in forests depends on many factors but foremost are the physical state of the water (liquid or solid), the density of tree crowns on which it falls, and the composition of the forest floor. Much of the moisture in snow that is intercepted and retained in the tops of dense forests, particularly coniferous ones, tends to evaporate back into the atmosphere. Rough forest floors topped by canopies that cast significant shade tend to allow slow infiltration of water into soil profiles without substantial evaporation or run-off. Once moisture travels to the root zone, the root tips actively absorb and utilize what they need; the rest is lost back to the atmosphere via evapotranspiration from the leaves. Moisture in excess of plant needs remains within the soil or moves gravitationally by surface movement or groundwater to lower areas. The rate and timing of exit influences water quality and quantity.

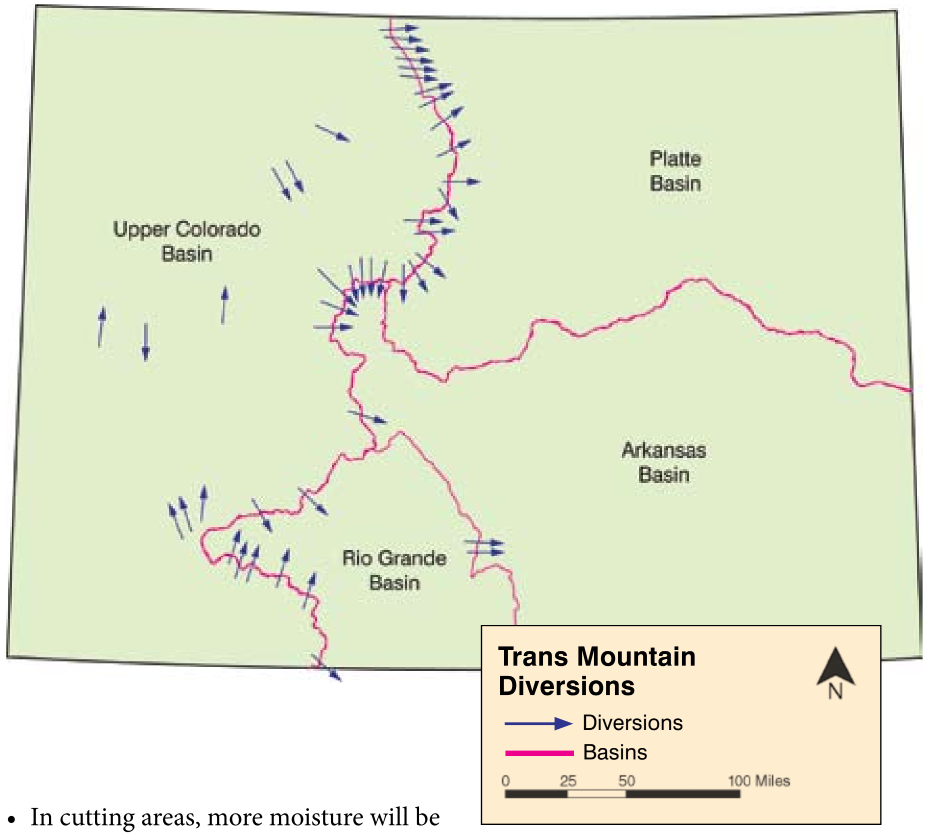
In summary, by buffering precipitation between its atmospheric origin and its various pathways on land, forests provide:

- soil protection;
- erosion prevention and the costs of associated clean-up in running water pathways, storage facilities, and treatment plants;
- soil moisture recharge and storage;
- water stabilization, purification; and
- plant maintenance and growth, which indirectly does the same for plant-eating animals (that is, total biodiversity).

Colorado is fortunate to benefit from a century of forest watershed research conducted within our state. U.S. Forest Service scientists did, and continue to do, the majority of this research, beginning at Wagon Wheel Gap (Mineral County between South Fork and Creede) back in 1909. The vast majority of watershed information comes from ongoing U.S. Forest Service research at the Fraser Experimental Forest (Grand County) in the Fool Creek and Deadhorse Creek drainages.

Basically, from this research we know:

- Since 1860, water yield from our aging forests has decreased about 20 percent.
- At 5,000 feet elevation, about 22 percent of the year's moisture falls in summer and 12 percent in winter.
- At 10,000 feet elevation, about 7 percent of the year's moisture falls in summer and 19 percent in winter.
- Removing trees increases water yield from forests.
- Most of the increased water yield from tree-cover removal comes from reduced evaporative losses (snow trapped in crowns), not increased deposition/infiltration, and begins in earnest the second year after the reduction in tree cover.
- Increased water yield from tree removal, while not dramatic, lasts up to 50 years or more before increased new growth reclaims excess water.
- Maximum stream flow from high elevation forests occurs in May.
- Our forests, even those at high elevation, need more water than is available in late summer.
- Following cutting, potential gains from deposition are offset by increased evapotranspiration from uncut trees and understory plants.
- Disturbances like fire, beetles, or cutting that result in the removal of similar amounts of vegetation have similar effects on water yield but not on the quality and timing of water released.
- The spruce beetle epidemic on the White River National Forest in the late 1940s reduced 30 percent of the spruce cover resulting in a 2-inch per unit area increase in stream flow.
- Fire is essential to proper functioning, including watershed function, of most Rocky Mountain forest types.
- Fires that involve entire landscapes are increasingly unacceptable within forest watersheds near human populations, and the lower the elevation, the more dire the consequences of these huge events.



Forty-four ditches, canals and tunnels divert water to, from, and within Colorado's major watersheds. Of the Platte, Arkansas, Upper Colorado, and Rio Grande, the Platte and the Arkansas only receive water from diversions. No diversions send water from the Platte or Arkansas back to the Western Slope.

- In cutting areas, more moisture will be available for the establishment of new trees if organic debris that is taller than expected snowpack is left on site, as opposed to leaving the site "slick."
- A good scheme for increasing water yield from subalpine forests (spruce-fir) by 25 percent to 75 percent is to reduce the normal forest density by at least one-third; this is accomplished by cutting individual stems and small groups of trees or by creating small forest openings (diameter of openings should be 5 to 8 times that of tree heights), with renewal of the cuts about every 30 to 50 years.
- A good scheme for increasing water yield from lodgepole pine forests would be similar to the subalpine scheme, except that the cutting interval would be about 30 years and should involve early thinning of the newly established forest in the interim.
- Modification of riparian vegetation holds the most potential for increased water yield from montane forests, but the associated degradation of other resource values such as wildlife habitat/biodiversity and erosion control precludes this as a viable option.

As with most things in natural systems, delicate balances are involved. There are no absolutes and serving societal demands while mitigating related human-induced impacts are complex and expensive. Abundant clean water is a necessity, but simply opening the forest spigot by allowing unchecked natural disturbances or unregulated cutting is not practical or desirable. Perhaps no aspect of forestry requires the combined knowledge and inputs of biological science, geology, hydrology, meteorology, social studies, and law more than the practice of wise watershed management. And perhaps none is more critical. (See High Country Fire on page 28).

High Country
Carbon Sequestration/Climate Change

By any measure, carbon, the sixth of 117 elements known at present to comprise matter on earth, is remarkable. Indeed, its number and arrangement of nucleus-encircling electrons and associated imbalance of electrical charges allow it to combine with other elements in unique ways. Carbon, more than any other element, is the substance of life. Joined with hydrogen, nitrogen, and oxygen, it makes up 96 percent of living matter, and compounds that contain carbon are referred to as organic.

During respiration, humans breathe in oxygen and give off carbon dioxide. Plants, including trees, do the opposite. Utilizing photosynthesis, they take in carbon dioxide, tap sunlight, and process them through chlorophyll. Photosynthesis produces sugars and oxygen. Plants utilize the sugars for growth, maintenance, and defense. The oxygen goes back into the atmosphere.

The atmosphere surrounding earth needs both oxygen and carbon dioxide. However, science indicates that too much carbon dioxide, along with other "greenhouse gases" such as nitrous oxide, water vapor, and methane, trap reflected heat from sunlight near the earth's surface. There also are sunspots and oscillations in ocean currents, all interrelated. Determining cause and effect is difficult. Although these processes are complex and our understanding incomplete, it seems clear, in balance, that excessive carbon dioxide in the atmosphere is detrimental to sustaining life on earth as we know it.

That is where forests come in. Growing forests tend to store more carbon than they give off. They are "sinks." Slow-growing, dying, and decaying forests give off more carbon dioxide than they absorb. These dying trees are "sources."

From this point on, generalities about carbon sequestration are difficult to formulate because there is much that we don't know, and interactions always are the theme. Just as a spruce harbors a boreal owl that dines on a vole that relies on lichens living on nitrogen and other nutrients leached

from snowmelt, equally entwined are the physical forces driving life. The physics of weather and air meet the chemistry of cells and soil, determining when, where, and if a bud opens.

Humans have increased the amount of carbon dioxide in the atmosphere by an estimated 35 percent over the last two centuries. The burning of fossil fuels and use of cement by human civilization accounts for 75 percent of the increase. Land conversion and land use contributes the rest. Of the carbon dioxide produced by burning petroleum products, various studies estimate that growing forests and wood products that store carbon long-term offset 13 percent to 20 percent of the total.

In a broad sense, trees are sinks in the daytime and summer, and they are sources at night and in winter. Trees store carbon, acquired via photosynthesis and absorption, by allocating it to three areas: foliage, wood, and roots.
Likewise, live trees yield carbon during respiration, and dead trees yield carbon when fungi, bacteria, and other organisms break them down. Soil is another important stockroom for forest carbon, both in organic and inorganic forms. It is the balance between the taking and giving of carbon that is the crux of the sequestration issue.

Teams of scientists toil daily to clarify how it all works. They are working in living laboratories constantly being remodeled by the momentum of succession. The variables in their experiments are extremely variable. Given all the known and unknown interactions, predicting outcomes in a broad sense and discerning actual answers will be difficult.

In a scenario of warmer temperatures, we can predict, among others, the following changes:

- increased frequency and size of wildfires;
- south to north range extensions of both plant and animal species (likewise, movement from low to high elevation);
- shortened life cycles of native insects (possibly more generations per year);
- longer plant-growing seasons;

Ingrid Aguayo

Opposite: *The San Juan Mountains near Telluride, Colo. (photo by Katherine Timm).*
Above: *A high country stream near Vail.*

- altered temperature extremes (both if and when they occur during the year);
- altered predator-parasite/host relationships (a shuffling of checks and balances);
- the introduction of exotic species into ecosystems comprised of natives; and
- moisture shortages resulting in stress to natural systems.

To put things in a practical perspective, a recently released study by Stratus Consulting of Boulder predicts that, by 2030, the likely result of predicted increases in carbon dioxide levels on climate will elevate the snowpack up the slope at least 650 feet and shorten the ski season at one major ski area, Aspen, by four to five days. Many ski areas only realize profits at the end of the season, and the loss of nearly a week may be critical to their success. In some cases, they might need to purchase more water rights to allow more snowmaking, construct more high elevation and north-facing runs, and construct gondolas and high-speed lifts that can more quickly transport skiers to areas of the mountain with snow. (See Winter Sports and High Elevation Forests on page 31.)

Clearly, forests can be part of the solution to fixing current and future carbon imbalances. Enough information exists to suggest the following course of action:

- Do what we can to promote the active growth of forests designated to meet societal needs.
- When forests die of old age and/or disturbances such as fire, insects, diseases, and weather events, convert a responsible percentage of the dead tree biomass, without disrupting on-site nutrient cycling, into long-lasting wood products and biofuels that displace fossil fuels.
- Carefully monitor natural regeneration and growth of the next forest and augment it through planting, thinning, and other means where feasible and justified.

High Country Fire

High elevation forests are cool and wet. And every so often, sometimes with a century or more elapsing between events, they burn. There is a misperception that wildfire is not a major part of high elevation forests.

Spruce and fir forests in Colorado burn roughly every 200 to 400 years, as measured by careful tree-ring analysis and soil-core studies. The "mean fire return interval" (MFRI) is so infrequent in these areas that fire's potential and influence are easy to miss. But the natural functioning of the subalpine zone depends on fire.

Many factors contribute to the infrequent but intense fires that occur in high elevation forests. About two-thirds of the annual precipitation that falls in Colorado subalpine is snow.

The temperature range at high elevation can dip to below 50°F at the bottom end, but it also can climb to above 90°F at the top end. Most precipitation falls during the winter, with peak melt in May. By the end of June, most of the snow is gone, and by late summer, the high forests usually experience a moisture deficit. While unusual, drought and atypical conditions that last for years or even decades do occur. Most fires in spruce-fir happen in late summer and fall. When they do, the fine needles of the trees that have accumulated on the forest floor, combined with the slow decomposition rates typical of cool sites, provide abundant fuel and ignition potential. Most spruce-fir forests are scattered with large stumps and other woody debris, casualties from past wind or spruce beetle episodes. Then, there is the tree architecture. The flexible branches of spruce and fir that are designed to shed and bend to the ground, but not break under the weight of water-laden snow, also provide the perfect ladder for fire. A lightning or human-caused fire that starts in leaf litter easily can reach the crowns of dominant overstory stems. Fires that heavily consume branches and foliage kill trees and are "stand-replacing."

If large areas of big trees and the smaller stems beneath are killed by fire, spruce-fir forests will not return for long time periods. Spruce and fir have thin bark and, unlike some of their lower-elevation counterparts, are not fire-adapted. For example, as fire adaptations, ponderosa pine has evolved with thick bark, and aspen has the ability to sucker from parent rootstock. Spruce and fir seeds are wind-dispersed; if a stand-replacing fire is large, seed from nearby unburned areas cannot easily reach the burn, and the lack of shade makes it difficult for seedlings to sprout and grow. In one study, it took 25,600 seeds to produce 800 five-year-old seedlings on the shaded north side of a slope with exposed mineral soil, good sites for spruce seed to grow. Imagine the odds of enough seed reaching the middle of a big burn and sprouting successfully.

Most foresters and ecologists are uncertain whether fire at high elevation is still operating within its range of natural variability (RONV). Still, concern is warranted. Livestock grazing, fire suppression, increased potential for human-caused ignitions, forests composed of mostly old, dense stands of trees, greatly expanded infrastructure values located within the zone, and climate change can contribute to alteration of these systems.

Perhaps most important are the watershed implications of landscape-scale fire in upper montane and subalpine forests. We no longer can afford the societal costs of stand-replacing fires across certain expanses of the high country. The direct impacts of fire to power and water transmission amenities, homes, and skiing and other recreation facilities are immense. But of equally negative potential are the subsequent results from falling trees, flooding, and sediment that clogs water storage reservoirs. The spatial scales and attendant extreme environmental conditions involved make tackling this issue a daunting task. Big fires are unavoidable, but we may be able to influence where fires occur through

Paul Mintier

Left: *In 2007, fire broke out at the YMCA Snow Mountain Ranch near Winter Park.*

active management and human behavior based on the unique characteristics of the trees and land. Following are examples of management activities:

- Allow spruce-fir fires to burn that do not directly threaten human infrastructure or damage important watersheds, and that likely will only operate on the scale of stands as opposed to landscapes. This allows fire to perform its valuable ecosystem functions, benefitting the forest and the other life forms that rely on it in the long term.
- Cut large enough blocks of spruce-fir forests to take advantage of their natural slow return, making such areas function as fuelbreaks within subalpine landscapes – areas selected should be strategically chosen, harvested in ways that capture carbon in the resources removed, respect aesthetics, and involve recognized best management practices to avoid sediment.
- Protect power transmission lines, water conveyances, and structures with standard vegetation management techniques designed to reduce fire hazard.

Deborah Carr

Above: *2007 fire at the YMCA Snow Mountain Ranch near Winter Park.* **Top:** *Judicious forest management activities can influence the spread of wildfire, address insect and disease outbreaks, and create healthier, uneven-aged forest stands. Note the regeneration in light green areas (photo by Ingrid Aguayo).*

Aspen, lodgepole pine, white pines, and mixed conifer forests also are particularly dependant on periodic exposure to fire. Fire suppression, and perhaps climate change, has allowed these forest types to expand both down and up the mountains into subalpine and lower montane forests alike.

Aspen is a bit of an anomaly – depending on the day, season, or year, it is both fire-proof and fire-needy. Aspen

Jen Chase

Flames from the Big Fish Fire threatened historic cabins near Steamboat Springs.

forests generally do not burn easily, and moist, pure aspen forests function as firebreaks. Under certain chronic or acute conditions, like spruce-fir forests, they do burn. An early-succession species, aspen requires fire, among other disturbances, to create openings and set back the competition, namely conifers. The ability for new stems to sucker from the roots of established stems, even those dead from the soil surface to their highest twigs, is its ticket to survival and success.

This report already has discussed lodgepole pine and its relationship with fire. Historical information that would provide us with some guidance is scarce, but many ecologists think that the dead trees, if not harvested, will fall within a decade or two. A subject of major current interest is the issue of increased fire hazard in lodgepole pine forests recently affected by pine beetles. Beetle-killed trees may contribute to fire and fire-related issues by falling across power lines; blocking access roads used by firefighting personnel; adding volumes of dead, woody fuels; or as a result of additional ignitions caused by equipment or people engaged in clean-up activities.

Fire hazard is high while dead needles remain on the trees. After the needles have dropped, but while the trees remain standing, fire hazard may be relatively low. Hazard once again increases when the trees fall to the ground and forests are regenerating. Fires that occur at this time can be intense due to large amounts of dead and downed trees and new growth. If this occurs before lodgepole pine saplings begin to express serotiny, the lack of a seed source could delay regeneration for lengthy periods of time.

Climate change casts a particularly long shadow on the discussion of fire at high elevations. Its influence in this area is multifaceted, and there are many unknowns. But our highest-elevation forests appear to be operating within their RONV for fire, although it may be advisable to break up lodgepole pine forests into less-homogenous units. The respective RONVs for fire in the upper montane forests are not well known. The lower montane forests appear to be outside their RONV, and fuel–reduction treatments appear to be warranted.

If the effects of climate change continue to accumulate according to prevailing predictions, the following can be expected:

- more fire escapes;
- faster spread of fires;
- an earlier fire season (due to earlier snow melt, and earlier and deeper depletion of available moisture);
- a longer fire season (this has increased by an estimated 76 days since 1986);
- larger fires (more acres per fire);
- more successful ignitions (because of drier soil and vegetation over bigger areas);
- longer-burning fires (an average increase of 7.5 days to 37.1 days since 1986); and,
- an increase in the size of the area vulnerable to fire.

To summarize, fire is a natural force within western forest landscapes. The challenges begin when we overlay once-wild lands with human value systems and influences.

Following are the most pressing challenges within the scope of this report:

- Identify how and where it is appropriate to shape forests to meet future needs.
- Modify structures and forests in their immediate vicinity to reduce fire risk and hazard and improve defensibility.
- Address the fire risk and hazard associated with falling beetle-killed trees.
- Manage selected areas of spruce and fir forests to prevent large fires and the resulting damage to watersheds.
- Monitor beetle-killed forests in their recovery from the recent epidemic to learn from, and respond adaptively to, the process.
- Do what we can individually and as a society to slow, and perhaps reverse, human contributions to climate change and associated fire implications.

Winter Sports and High Elevation Forests

Mention Colorado to an out-of-state friend or relative, and generally speaking, they will inquire about the skiing or relate their favorite Colorado skiing or snowboarding experience. For many outside of our state, Colorado equals high country winter recreational experiences.

Colorado is an iconic destination for those who wish to experience the best snow, the best trails, and the best accommodations. Increasingly, these mountain resorts also are finding ways to lure outdoor-lovers for year-round activities.

Of ecological necessity, these pleasure destinations are found in Colorado's high country forests where more snow falls and stays on the ground than in lower elevations. Creative and technically challenging runs are carved from spruce-fir, lodgepole, and aspen forests to test those eager for the exhilaration.

And there is no shortage of those thrill-seekers – Colorado Ski Country USA reports skier visits for the 2007-2008 season totaled 12,515,439.

According to a study commissioned by the Colorado Tourism Office, 65 percent of those who visit Colorado strongly agree that skiing is important to them in a travel experience. The state now ranks ninth in the country for outdoor trips, with a 3.8–percent market share in 2007. Total direct travel spending in Colorado in 2007 (preliminary) was more than $15 billion and supported 143,100 jobs with earnings of more than $4 billion.

In relation to the size of the total economy, travel is more important in the Mountain Resort Region of the state, where nearly 12 percent of total earnings is travel-generated. Preliminary data for 2007 shows total direct visitor destination spending in the Mountain Resort Region in excess of $3 billion; state and local tax receipts related to spending is projected to be approximately $183 million.

In addition, the Colorado Economic and Demographic Information System (CEDIS) projects that by 2010, population increases in Eagle, Gilpin, Grand, Gunnison, Hinsdale, Lake, La Plata, Ouray, Pitkin, Routt, Saguache, San Miguel, and Summit counties will average 2.23 percent, compared to 1.9 percent growth rate expected statewide. CEDIS also projects that the average of tourism-related jobs as a percentage of overall jobs will be more than 35 percent for those same counties by 2010.

Obviously, tourism is vitally important to Colorado in terms of dollars spent, jobs created, and taxes collected. As noted elsewhere in this report (see High Country Carbon Sequestration/Climate Change on page 26), "a recently released study … predicts that, by 2030, the likely result of predicted increases in carbon dioxide levels on climate will elevate the snowpack 650 feet up the slope and shorten the ski season at one major ski area, Aspen, by four to five days. Many ski areas only realize profits at the end of the season, and the loss of nearly a week may be critical to their success."

Changes in our high country forest landscapes will affect not only the quality of our outdoor experiences, the aesthetics we enjoy, and the ephemeral qualities that sooth our senses – they also may affect our "bottom line."

Top: *Skiing at Monarch.* **Above:** *Aspen, Colo., at night (photos courtesy of Monarch/CSC USA).*

A High Country Case Study:
Lake County Landowner Keeps the Forest Green and Growing

The view of the open meadow surrounded by pine trees and snow-capped mountain peaks on the King family property in Lake County epitomizes the image of Colorado that so often graces the cover of magazines.

Located five miles southwest of the City of Leadville near Half Moon Creek, the 113-acre property has been in the King family for more than 100 years. The 1870 U.S. Census for Lake County lists Jon and Delilah King as the owners. He was a farmer from Pennsylvania, and she was from Ohio.

The original owners might be happy to know that the portion of the property inherited by the current owner still is undeveloped and remains much as it was more than 100 years ago. Implementation of a forest management plan developed by the Colorado State Forest Service in 2004 will help keep the forested land healthy for the next generation to enjoy.

The average age of the trees in the lodgepole pine forest on the King property is 125 years. Currently infested with dwarf mistletoe, the trees are susceptible to bark beetles. The mountain pine beetles (MPB) that have affected more than 1.5 million acres of mature lodgepole pines in Colorado are working their way to the south of a stand in Box Creek on the King property, so efforts are underway to promote regeneration and establish a younger, healthier stand.

This management objective of creating a healthier, more diverse forest is being accomplished by clearcutting the 16-acre stand. Lodgepole pine is referred to as a pioneer species that regenerates after a catastrophic event such as a large wildfire. After a wildfire, open areas are created with lots of available sunlight for new lodgepole pine seedlings. Clearcutting in lodgepole pine mimics wildfire and is a proven practice to regenerate lodgepole pine stands.

Below: *Posts and poles generated from the timber harvest on the King property in Lake County were used to build fence on the Clear Creek Ranch in nearby Chaffee County.* **Above:** *Management activity on the property resulted in healthier forest conditions (photos by Damon Lange).*

Building on lessons learned from the epicenter of the MPB epidemic in Grand County, Damon Lange, Salida District Forester, Colorado State Forest Service, worked with the King family to determine the best course of action given current levels of infestation in the area.

Rather than wait until the epidemic established itself locally, the King family decided to harvest the stand, so they worked with Lange, who inventoried and advertised a timber sale that was purchased by a local contractor in nearby Buena Vista. Had the King family waited until the infestation had progressed, the health of the trees on the remainder of their forested land would have been compromised, and they might have had to pay a logger to remove infested, dead wood.

Green Ridge Fuels Reduction: *Good Neighbor Project Helps Protect Recreation Area*

Hans Rinke

Above: *Infested and dead trees were removed on federal land, complementing defensible space work on private land.*

Hazardous fuels on 136 acres of the Arapaho National Forest adjoining the Arapaho National Recreation Area presented a threat to recreationists, as well as nearby Soda Creek and the Town of Grand Lake, located eight miles south.

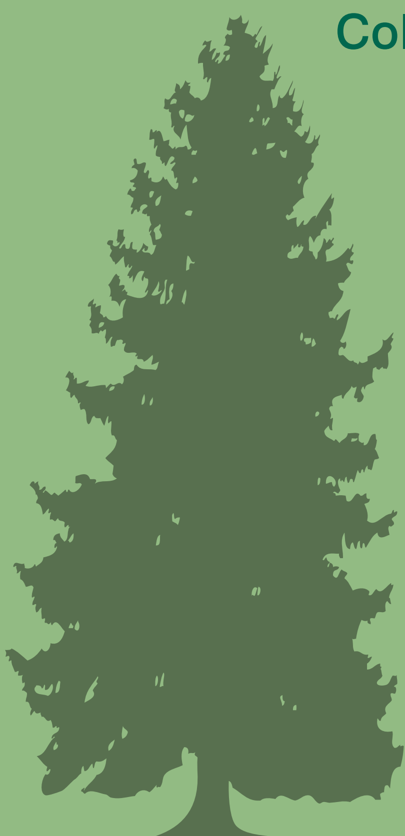
Situated in the heart of mountain pine beetle country, 90 percent of the mature lodgepole pine in the area was infested or killed, which increased the hazard of a high-severity wildfire occurring near homes and watersheds in the area.

To reduce the hazard and create defensible space, infested and dead trees were removed on 136 acres of federal land, complementing work already completed on the adjacent private property.

Access to the treatment area was limited to private land and roads because the U.S. Forest Service land was classified as roadless. As a result, the project was implemented using the Good Neighbor Authority, which encourages boundaryless forest management in areas where federal land adjoins state and private land.

The project was implemented through a Cooperative Agreement between the Sulphur Ranger District of the Arapaho and Roosevelt National Forests and the Colorado State Forest Service. In 2006, the CSFS solicited bids and awarded an independent services contract to an area contractor. The CSFS also administered the contract.

Work on the Green Ridge fuels reduction project was completed in 2008 under the auspices of the Arapaho National Recreation Area Forest Health Project Environmental Impact Statement.



Colorado High Country Tree Species Champions

Name	Dia.	Circ.	Ht.	Crown Spread	Pts.	Location
Blue Spruce	41"	128.74"	153'	26'	288.24	San Juan NF
Engelmann Spruce	46.6	146	135	44	292.32	White River NF
Subalpine Fir	45.3	142.24	106	27	254.99	White River NF
White Fir	49.0	153.86	138	34.5	300.49	Mineral County
White Fir	50.6	158.88	138	22.25	302.45	San Juan NF
Bristlecone Pine	56.4	177.1	63	41	250.35	Huerfano County
Bristlecone Pine	56.7	178	63	41	251.25	San Isabel NF
Limber Pine	69	216.66	62	67	295.41	Huerfano County
Lodgepole Pine**	26.4	82.9	99	27	188.65	White River NF
Lodgepole Pine**	30.4	95.46	83	35	187.21	Summit County
Aspen	32.2	101.1	109	33.5	218.48	Rio Grande NF

* Two or more trees listed for the same species indicates a tie for first place according to CTC rules.
** At press time, it is unknown whether this tree has survived the current mountain pine beetle epidemic.

See the Colorado Tree Coalition's (CTC) website for more information on Colorado's Champion Trees and how potential champions are measured and nominated (http://www.coloradotree.org/champions).

High Country Environmental Education

Project Learning Tree (PLT) is an award-winning environmental education program that began in 1976. A function of the American Forest Foundation, training in this multidisciplinary approach to teaching kids *how*, not *what*, to think, has been delivered to more than 500,000 educators worldwide. These teachers have exposed more than 26 million kids, preschool through high school, to the valuable lessons of PLT.

In 2008, experienced facilitators from Cortez, Durango, Ridgeway, and Dolores trained the elementary and middle school teachers from Telluride – all 41 of them – in PLT. Supplementing exceptional local environmental education efforts like the Pinhead Institute and those of the Bear Creek Open Space staff, this unprecedented commitment to environmental education by a Colorado school district was recognized with PLT program awards. In addition, the CSFS Montrose District planted a Colorado blue spruce at each school represented. Durango and Aurora plan to follow suit in 2009.

Shawna Crocker

Educators receive hands-on environmental education training through Project Learning Tree.

Summary of 2008 Forestry Legislation

Bill #	Bill Name	Bill Summary
HB 1110	*Income Tax Deduction*	*Five-year program that allows a landowner to deduct the actual costs of wildfire mitigation up to $2,500.*
HB 1269	*Sales and Tax Exemptions for Beetle-Killed Trees*	*Exempts beetle-infested logs and products made from such logs from state sales and use taxes.*
HB 1318	*Mitigating the Effects of the Pine Beetle Infestation*	*Establishes a beetle mitigation fund that allows the public to make voluntary donations that can be used to treat beetle-infested state-owned lands.*
SB 71	*Extend the Forest Restoration Pilot Program*	*Extends for five years the Community Forest Restoration Grant Program that was established in 2007 through the passage of HB 1130. Grants are available to communities for fuels mitigation and restoration.*
SB 221	*Watershed Bonding for Forest Health*	*With proper authority and agreement, bonds can be issued for forest health and watershed protection projects.*
SB 232	*CSU Agency Line Item Authorization*	*Authorizes the General Assembly to appropriate funds directly to the Colorado State Forest Service, Agricultural Experiment Station, and CSU Extension.*
SB 39	*Training Directors of Fire Protection Districts in the WUI*	*Directs the Division of Fire Safety to develop a pilot education program for Board members of Fire Protection Districts in the wildland-urban interface.*
HJR 1033	*Colorado Forest Health*	*Promotes active management in national forests impacted by bark beetles.*
SJR 10	*Concerning Stewardship Contracting*	*Requests that the U.S. Forest Service, Bureau of Land Management, and CSFS work together to identify and implement up to three long-term stewardship contracts.*
SJR 25	*WUI Interim Committee*	*Creates an eight-member interim committee to hold hearings on issues related to the WUI, fuels mitigation, firefighting, tree mortality from bark beetles, and incentives for forestry-related industry.*

2008 Legislative Update

The state of Colorado values healthy, resilient forest landscapes and is willing to invest state funds in the stewardship of these resources. In 2008, the Colorado General Assembly passed seven bills and three joint resolutions addressing forest health, fuels mitigation, and public safety. This unprecedented level of legislative activity is evidence of the importance and value of Colorado's forests.

When this report was written, several forestry-related bills were being drafted for consideration by the 2009 Colorado General Assembly. The bills are aimed at creating legislation that promotes healthier, more diverse forests that are resilient to or minimize the impacts of insect and disease epidemics for the benefit of present and future generations.

The Future

The easy answer to questions about the future of Colorado's high elevation forests is "succession."

The current mountain pine beetle epidemic will either finish in lodgepole pine or switch to ponderosa pine before eventually winding down. The result will be the inevitable turnover of older, mature pine forests and the beginnings of the next forest. Facing this event will require managing the risk of increased hazard to people and infrastructure from falling dead trees and elevated fire danger. Utilizing the wood and capturing carbon, either by converting blue-stained trunks to products with long lives or by turning ghost forests into biofuel that replaces fossil fuel, can help address the situation. And in some places, it may be necessary to intervene in the structure of the next forests by thinning naturally established, high-value lodgepole forests early in their lives.

Preventing and dealing with landscape-scale fires that threaten watersheds within the lower mountains is imperative. Fires like Buffalo Creek, Hayman, and other recent fires provide evidence about the consequences of failing to protect water resources and the investments that have been made to move and store water supplies. And it is paramount to learn more about how fire functions in the upper montane and subalpine forests, particularly with respect to major watersheds.

Just when the pine beetle finally runs its course, several other major insect events are ripe for return. Western spruce budworm, spruce beetle, western tent caterpillar, and others will be prominent in the coming decades. They will impact mixed conifers, spruce, and aspen, respectively. Additionally, exotic organisms will enter the system and will need to be detected and eradicated as quickly as possible.

Dave Leatherman

Sudden aspen decline may simply be an expression of drought, or it may be something new and more complex. The question is whether there will be adequate moisture during the next few critical years for aspen, alongside young evergreens, to fill holes in the pine forest opened up by bark beetles.

Perhaps the most pressing unknown is climate change. Its effects on biological cycles and phenomena like fire are likely to be negative. Perhaps the most promising contribution to the solution is to encourage forest growth and adopt lifestyles that, in balance, sequester carbon.

Dave Leatherman

Forestry has always been "green," but perhaps it can be a shade greener by finding new uses for wood. The technologies and economics of biofuels, including those involving wood, are rapidly improving.

Forests are essential for our continued well-being. They provide us with wood products, wildlife and fish habitat, scenic beauty, and recreational opportunities – and they contribute to clean air and water.

To protect the benefits that Colorado's forests provide well into the future, the Colorado State Forest Service is working with numerous partners and stakeholders to develop a statewide strategic forest resource assessment. The assessment will provide an analysis of present forest conditions and future forest trends and threats across all ownerships in Colorado. The assessment also will identify gaps in data that need to be addressed in the future so that, collectively, we can make informed decisions about the stewardship of our forests. Specifically, the assessment will focus on how to conserve working forest lands, protect forests from harm, and enhance public benefits from trees and forests.

After the assessment is completed, the CSFS will again work with partners and interested stakeholders to develop a strategy that addresses the most critical needs in the three focus areas noted above. The strategy will provide a long-term, comprehensive, coordinated approach that concentrates and leverages future resources to achieve the greatest benefit while addressing the most critical forest health needs.

Colorado has 22 million acres of forests. They make our state the grand place it is, aesthetically and in the marketplace. Clearly, challenges abound. But Colorado's forests will persist and survive, and hopefully, those who are fortunate enough to call Colorado home will continue to observe and learn from them.

Dave Leatherman

Dave Leatherman

A view from Wolf Creek Pass.

References and Further Reading

Alexander, Robert R. 1984. Natural regeneration of Engelmann spruce after clearcutting– the central Rocky Mountains in relation to environmental factors. USDA Forest Service, Res. Pap. RM-254, 19p.

Alexander, R. R. 1967. Windfall after clearcutting on Fool Creek – Fraser Experimental Forest, Colorado. USDA Forest Service Res. Note RM-92, 11p.

Anon. 2008. Colorado-Big Thompson Project, Colorado. U.S. Bur. of Reclamation, http://www.usbr.gov/dataweb/html/cbt.html.

Anon. 2008. Rocky Mountain Tree-Ring Research OLDLIST. http://www.rmtrr.org/oldlist_references.htm

Baker, W.L., and T.T. Veblen. 1990. Spruce beetles and fires in the nineteenth-century subalpine forest of western Colorado. Arctic and Alpine Res. 22:65-80.

Bartos, Dale. 2007. Chapter 3 –Aspen. In, Fire ecology and management of the major ecosystems of southern Utah. USDA Forest Service Gen. Tech. Rpt. 202, Fort Collins, CO. p39-55.

Battaglia, Michael A.; Shepperd, Wayne D. 2007. Chapter 2 - Ponderosa pine, mixed conifer, and spruce-fir forests. In, Fire ecology and management of the major ecosystems of southern Utah. USDA Forest Service Gen. Tech. Rpt. 202, Fort Collins, CO. p7-37.

Bentz, B.J.; Logan, J.A.; and Amman, G.D. 1991. Temperature dependent development of mountain pine beetle and simulation of its phenology. Can. Ent.123:1083-1094.

Brown, P.M.; Shepperd, W.D.; Brown, C.C.; Mata, S.A.; McClain, D.L. 1995. Olest known Engelmann spruce. USDA Forest Service Res. Note RM-534. 6pp.

Brunstein, F.C. and Yamaguchi, D.K. 1992. The oldest known Rocky Mountain bristlecone pines. Arctic and Alpine Res. 24:253-256.

Clements, F. E. 1910. The life history of lodgepole pine burns. USDA Forest Service Bull. 79, 56p.

Crouch, G. L. 1986. Effects of thinning pole-sized lodgepole pine on understory vegetation and large herbivore activity in central Colorado. USDA Forest Service Res. Pap. RM-268, 10pp.

Dale, Virginia H.; Joyce, Linda A.; McNulty, Steve; Neilson, Ronald P. 2000. The interplay between climate change, forests, and disturbances. Elsevier, The Science of the Total Environment 262 (2000) 201-204, www.elsevier.com/locate/scitotenv

Gibson, Ken; Skov, Kjerstin; Kegley, Sandy; Jorgensen, Carl; Smith, Sheri; Witcosky, Jeff. 2008. Mountain pine beetle impacts in high elevation five-needle pines: current trends and challenges. USDA Forest Service, Forest Health Protection R1-08-020, Missoula, MT., 32pp.

Goward, S.N.; Masek, J.G.; Cohen, W.; Moisen, G.; Collatz, Healey, S.; Houghton, R.A.; Huang, R. Kennedy; Law, B.; Powell, S.; Turner, D; and Wulder M.A. 2008. Forest disturbance and North American carbon flux. EOS, Transactions, Am. Geophysical Union, 89(11):105-116.

Hawksworth, Frank G., Hinds, Thomas E, Johnson, David, Landis, Thomas D. 1977. Silvicultural control of dwarf mistletoe in young lodgepole pine stands. Tech. Rep. R2-10, Lakewood, CO. USDA Forest Service RM Region Forest I&D Mgmt., 10p.

Hawksworth, Frank G.; Nicholls, Thomas H; Merrill, Laura M. 1987. Long-distance dispersal of lodgepole pine dwarf mistletoe. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service Gen. Tech. Rpt. RM-149, p220-226.

Hood, Sharon, and Miller, Melanie, Eds. 2007. Fire ecology and management of the major ecosystems of southern Utah. USDA Forest Service Gen. Tech. Rpt. 202, Fort Collins, CO. 110p.

Hyvonen, Riitta; Agren, Goran I.; Linder, Sune; Persson, Tryggve; Cotrufo, M. Francesca; Ekblad, Alf; Freeman, Michael; Grelle, Achim; Janssens, Ivan A.; Jarvis, Paul G.; Kellomaki, Seppo; Lindroth, Anders; Loustau, Denis; Lundmark, Tomas; Norby, Richard J.; Oren, Ram; Pilegaard, Kim; Ryan, Michael G.; Sigurdsson, Bjarni D.; Stromgren, Monika; Oijen, Marcel van; and Wallin, Goran. 2007. Tansley Review: the likely impact of elevated CO2, nitrogen deposition, increased temperature and management on carbon sequestration in temperate and boreal forest ecosystems: a literature review. New Phytologist 173: 463-480.

Jaffe, Mark. 2008. Ski resorts face chilling vision: less snow, time. Denver Post. http://origin.denverpost.com/breakingnews/ci_11240672

Kaufmann, M.R.; Aplet, G.H.; Babler, M.; Baker, W.L.; Bentz, B.; Harrington, M.; Hawkes, B.C.; Huckaby, L.S.; Jenkins, M.J.; Kashian, D.M.; Keane, R.E.; Kulakowski, D.; McHugh, C.; Negron, J.; Popp, J.; Romme, WlH.; Schoennagle, T.; Shepperd, W.; Smith, F.W.; Sutherland, E.K.; Tinker, D.; and Veblen, T.T. 2008. The status of our scientific understanding of lodgepole pine and mountain pine beetles – a focus on forest ecology and fire behavior. The Nature Conservancy, Arlington, VA. GFI technical report 2008-2.

Kaufmann, M. R.; Troendle, Charles A.; Ryan, Michael G.; Mowrer, Todd. 1987. Trees, the link between silviculture and hydrology. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p54-60.

Kaufmann, M. R. 1985b. Annual transpiration in subalpine forests: large differences among four tree species. For. Ecol. Mgmt. 13:235-246.

Kaufman, M. R. 1986. Physiographic, stand, and environmental effects on individual tree growth and growth efficiency in subalpine forests. Tree Phys. 2:47-59.

Knight, Dennis H. 1987. Ecosystem studies in the subalpine coniferouos forests of Wyoming. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p235-242.

Kulakowski, D., Veblen, T.T. 2003. Effects of fire and spruce beetle outbreak legacies on the disturbance regime of a subalpine forest in Colorado. J. Biogeography 30:1445-1456.

Le Master, Dennis C.; Shao, Guofan; and Donnay, Jacob. 2007. Protecting Front Range forest watersheds from high-severity wildfires: an assessment by The Pinchot Institute For Conservation funded by the Front Range Fuels Treatment Partnership. CSFS, CSU, Fort Collins, CO, 47p.

Litton, Crieghton M.; Raich, James W.; Ryan, Michael G. 2007. Carbon allocation in forest ecosystems. Review in Global Change Biol. 13, p2089-2109, doi: 10/1111/j.1365-2486.2007.01420.x

Logan, J.A., and Powell, J.A. 2001. Ghost forests, global warming and the mountain pine beetle. Am. Ent. 47:160-173.

Lynch, D. L., and Mackes, K. H. 2001. Wood use in CO at the turn of the twenty-first century. USDA Forest Service Res. Pap. 32, Fort Collins, CO.

MacDonald, L.H., and Stednick, J.D. 2003. Forests and water: a state-of-the-art review for Colorado. Completion Rpt. 196. CO Water Resources Res. Inst., Fort Collins, CO, 65pp.

Mata, S.A.; Schmid, J.M.; and Olsen, W.K. 2003. Growth of lodgepole pine stands and its relation to mountain pine beetle susceptibility. USDA Forest Service Rocky Mountain Research Station Res. Pap. 42, Fort Collins, CO., 19pp.

McCullough, D.G.; Werner, R.A.; and Neumann, D. 1998. Fire and insects in northern and boreal forest ecosystems of North America. Ann. Rev. Ent. 43:107-127.

Meiman, James R. 1987. Influence of forest on snowpack accumulation. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p61-67.

Perry, D.A., and Lotan, J.E. 1979. Opening temperatures in serotinous cones of lodgepole pine. USDA Forest Service Res. Note INT-228.

Raphael, Martin G. 1987. Nonegame wildlife research in subalpine forests of the central Rocky Mountains. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p113-122.

Romme, W.H.; Clement, J. Jicke; Kulakowski, D.; McDonald, L.H.; Schoennagle, T.L.; and Veblen, T.T. 2006. Recent forest insect outbreaks and fire risk in Colorado forests: a brief synthesis of relevant research. CSU, CO For. Restoration Inst., Fort Collins, CO. 24p.

Schmid, J. M. 1987. Partial cutting in mountain pine beetle-susceptible pine stands: will it work and for how long? In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p243-245.

Schmid, J.M.; and Frye, R.H. 1977. Spruce beetle in the Rockies. USDA Forest Service, Gen. Tech. Rpt. 49, Rocky Mountain Res. Sta., Fort Collins, CO. 38pp.

Schmid, J.M.; Mata, S.A.; Martinez, M.H.; and Troendle, C.A. 1991. Net precipitation within small group infestations of the mountain pine beetle. USDA Forest Service Res. Note RM-508. RMRS, Fort Collins, CO.

Schmid, J.M. and Mata, S.A. 1996. Natural variability of specific forest insect populations and their associated effects in Colorado. USDA Forest Service Gen Tech. Rpt. 275, Rocky Mountain Research Station, Fort Collins, CO.

Schmid, J.M. and Mata. S.A. 2005. Mountain pine beetle-caused tree mortality in partially cut plots surrounded by unmanaged stands. USDA Forest Service Res. Paper 54. Rocky Mountain Research Station, Fort Collins, CO.

Shepperd, Wayne D. 1987. Silviculture research in Rocky Mountain aspen. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p25-29.

Stednick, J. D. 1987. The potential of subalpine forest management practices on sediment production in management of subalpine forests. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p95-100.

Stottlemyer, Robert, and Troendle, Charles A. 1987. Trends in steamwater chemistry and input-output balances, Fraser Expt. Forest, CO. USDA Forest Service, Res. Paper RM-275, Fort Collins, CO, 9p.

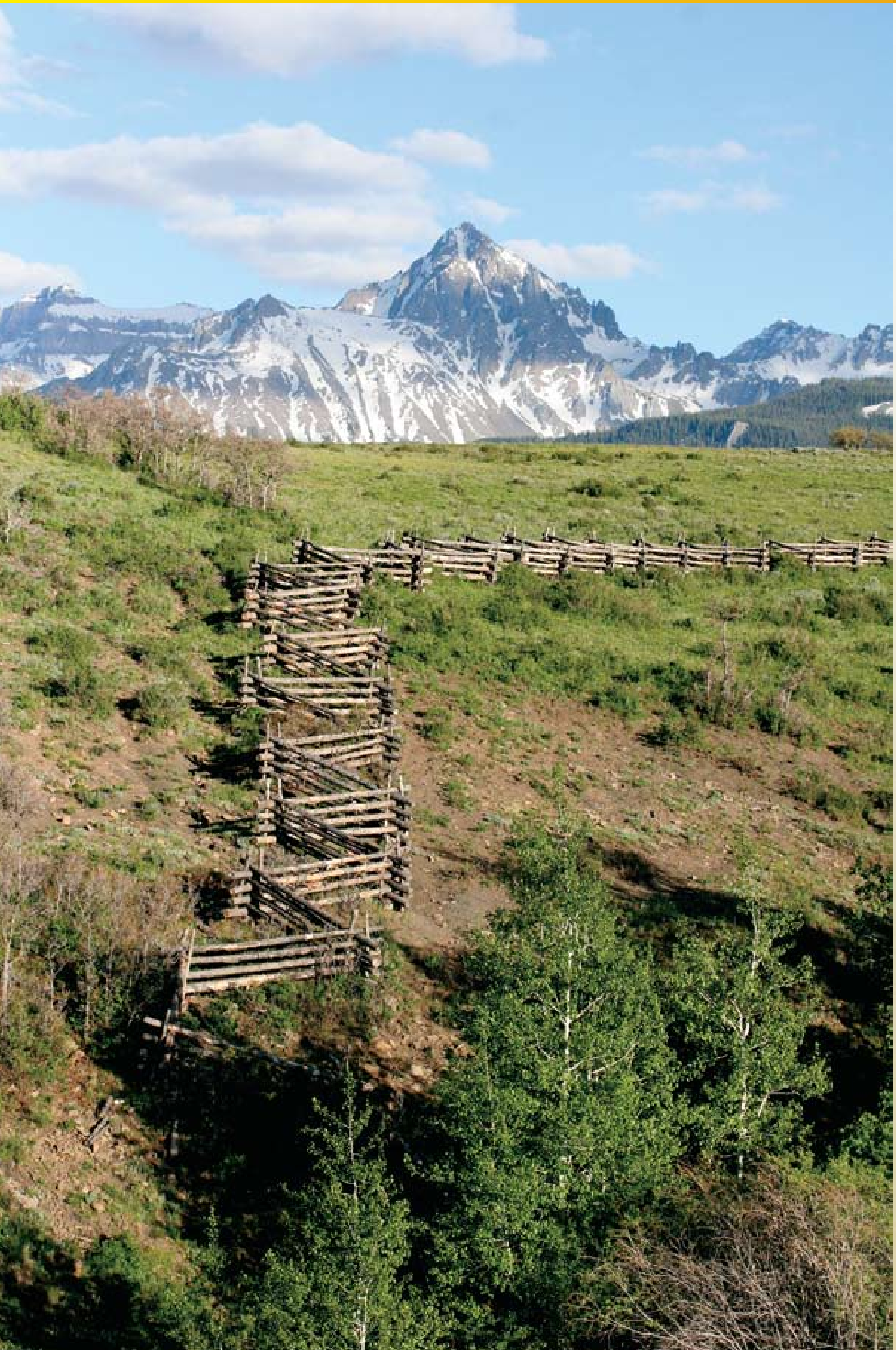
Stottlemyer, Robert. 1987. Natural and anthropic factors as determinants of long-term streamwater chemistry. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p86-94.

Troendle, Charles A.; Kaufmann, Merrill R.; Hamre, R. H.; and Winokur, Robert P., Technical Coordinators. 1987. Management of subalpine forests: building on 50 years of subalpine research (Proceedings of a technical conference, Silver Creek, CO, July 6-9, 1987). USDA Forest Service, Gen. Tech. Rpt. RM-149, 253p.

Troendle, C. A., and Kaufmann, M. R. 1987. Influence of forests on the hydrology of the subalpine forest. In, Management of subalpine forests: building on 50 years of research. USDA Forest Service, Gen. Tech. Rpt. RM-149, Fort Collins, CO, p68-78.

Troendle, C.A. and Olsen, W.K. 1994. Potential effects of timber harvest and water management on streamflow dynamics and sediment transport. In, Sustainable ecological systems: implementing an ecological approach to land management. USDA Forest Service Gen. Tech. Rpt. RM-247, Fort Collins, CO. p34-41.

Veblen, T. T. 1991. The response of subalpine forests to spruce beetle outbreak in Colorado. Ecol. 72:213-231.



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