Colorado Forest Health Report

A Baseline Assessment 1992-1995

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COLORADO
FOREST HEALTH REPORT
1992-95:
A BASELINE ASSESSMENT

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Forest Health Highlights

Forest Health Monitoring has been active in Colorado since 1992. After four years of detection monitoring, we present this baseline assessment of forest conditions in the state. The following highlights represent some of the more prominent messages presented in this report.

- Forest conditions are constantly changing, but documentation is limited at state and regional scales. This report provides a baseline assessment of forest health issues.
- Given the preliminary nature of our data collection and analysis, we caution against the conclusiveness of our statement that generally Colorado forests seem to be healthy.
- Forest lands are found in all ecoregions of the state, although the Southern Rockies comprise the majority of forest area and the greatest variety of forest types.
- The most common tree surveyed was aspen, although this species appears to be declining because of historic management practices.
- The most common forest type in the state is pinyon-juniper, with spruce-fir forests covering slightly fewer acres.
- Insects and diseases regularly wax and wane on the state's forested lands. (Currently, mountain pine beetle may be building up to a serious outbreak.). Increased tree densities, advanced succession, drought conditions, or climate fluctuations may initiate more severe insect or disease disturbance events.
- Human development along the urban/wildland interface poses a threat to the health of humans and forest attributes. Proactive forest management practices could alleviate potential catastrophic events in these areas.
- Air quality appears to be having some effects on forest vegetation, especially in localized situations. Evaluation monitoring of specific problem areas is warranted, given preliminary lichen assessments. Pollution effects on tree crowns are not evident at this time.
- Exotic plant invasions are the lowest of any region in the country, but apparent declines in aspen cover may affect future diversity readings. Overall, Colorado seems to be maintaining diverse forests.

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Introduction

The forests of Colorado are a valuable resource used in many ways by the people of this state, and by a growing contingency of nonresidents. These forest lands serve many functions to both rural and urban dwellers. Some may even argue that the forests of Colorado constitute one of the state's greatest assets in providing magnificent vistas, in acting as a primary means of water storage (often in the form of generous snow cover), and as an economic foundation for a burgeoning tourist industry.

Though forests are of great value to humans, we must recognize that their condition is not stagnant and, therefore, may not retain whatever values we as individuals derive from them. Forests in Colorado are in a constant state of transition - from young to old, rural to developed, one species to another, vigorous to diseased, or even away from forest conditions altogether. These changes are both natural and human-induced. Pressure from people on forest resources may stimulate natural change agents in unpredictable ways. While many of these changes are perfectly acceptable, others may reach well beyond what society is willing to tolerate. A key element to scientists monitoring forest health is the *rate* of change. In order to make scientific assessments of rates of change, it is important to establish baseline measurements of forest attributes. These attributes, such as numbers of live and dead trees or number of species present, can then be remeasured over long periods to determine rates and possible trends.

Forest Health Monitoring (FHM) provides a framework for baseline and long-term monitoring of forest change. FHM is divided into three primary phases. The first of these, Detection Monitoring, is where data for this report originate. With a coordinated network of ground-based sample plots and airborne surveys of Colorado's forests, this first phase can detect abnormal rates of change in forest conditions before they reach epidemic proportions. Equally important, though, is FHM's ability to accurately report healthy forest conditions. In essence, if we as a society are managing our forests well, this system will be able to verify that fact. However, if unexplained changes are detected, a second phase, Evaluation Monitoring, is activated to investigate the extent and severity of changes. A third phase of FHM, Intensive Site Monitoring, involves establishing a small network of sites nationally for research on ecological processes related to change elements.

FHM PLOT NETWORK

Since 1992, the USDA Forest Service, Colorado State Forest Service, U.S. Environmental Protection Agency, and other federal agencies have been cooperating to establish permanent FHM plots across the state's forest lands. In each of the following three years, an additional 1/4 of the total forested plots was sampled. By 1995, the first cycle of FHM plots in Colorado was completed. This report is a summary of that first FHM sampling cycle. The rotation began again in 1996 with the remeasurement of the 1992 plots. Measurements taken on all plots will be updated as field crews revisit sites in the second and subsequent cycles. Updates on specific forest measurements allow researchers to assess trends in forest conditions.

What is an FHM plot? A plot is a permanent sample location, covering about 2.5 acres, which is remeasured on a regular cycle. Plot readings on tree diameters, crown conditions, and damage assessments, as well as understory vegetation inventories, solar radiation intensities, and lichen community samples provide a variety of forest health indicators. Field crews are rigorously trained in all forest measurements and regularly tested to ensure high data quality standards. As the program develops, new indicators may be added to supplement the current set of field measurements.

SURVEY COMPONENT OF DETECTION MONITORING

The survey component of FHM provides a record of broad-scale disturbance events that may not be detected by the FHM plot network. Survey information provides a context for interpreting plot data and for identifying likely factors that contribute to forest health changes.

Aerial detection is the primary survey activity. Other measures used by the Forest Health Management Group to detect broad-scale disturbance information include: 1) Ground surveys for specific insect and/or disease activity such as dwarf mistletoe and mountain pine beetle; 2) Analysis of other plot-based data from Forest Inventory and Analysis, National Forest inventories, and Forest Health Management insect and disease plot inventories, and; 3) Service trip reports and technical reports for historical data or trends.

Beginning in 1992, as field plots were established in Colorado, aerial photography of all FHM network plots was taken with the intent of capturing the vegetative status of forests adjacent to the plots. An area of approximately 25 acres surrounding the plots has been photo interpreted. Results of this effort have recently been published by the Forest Health Management Group (Johnson, Johnson, and Johnson, 1997). Tree species, mortality, and other known disturbance agent (e.g., fire, Douglas-fir beetle, and Subalpine fir decline) information from these photos will be used in combination with other survey data to develop baseline data sets in support of FHM.

SCOPE OF THE CURRENT REPORT

The purpose of this initial FHM report is to address the prominent forest health issues facing the state of Colorado. FHM is a long-term monitoring program, therefore, the data presented in this report must be viewed in that light. This report presents a first-time, or baseline, assessment. Subsequent reports should give a much clearer perspective on trends and changes over time, as the current plots and other detection surveys are remeasured.

In order to adequately address the forest health issues, it is important to establish a foundation by describing the resource encompassed within Colorado's forests. This will be done by describing the state's forest cover and land-ownership patterns at a broad scale, then ecological regions, or ecoregions, will be discussed. Ecoregions are an important first step in addressing forest issues across political and agency boundaries for the good of the resource as a whole. Finally, a brief summary of the size, status, and species of trees tallied will give an idea of forest composition statewide.

The body of this report will focus on important forest-related issues in Colorado. For example, how does air quality, both in urban centers and rural areas, affect the health of forests? Are wildfires a threat or an asset to forest health? How do forest fires affect human health? Do these answers change with proximity to population centers? Are the forests of Colorado changing? Is that good or bad? These are difficult questions, with difficult issues underlying them. This report will address these issues, though the ultimate answers to these questions will depend largely on public understanding of the trade-offs involved.

This report will conclude by summarizing FHM activities in the state thus far. The **Forest Health Highlights** section contains a review of this report's findings. For those interested in more detailed information, additional tables are presented in the appendices. Please refer to FHM contacts listed on the inside back (Appendix D) for further information.

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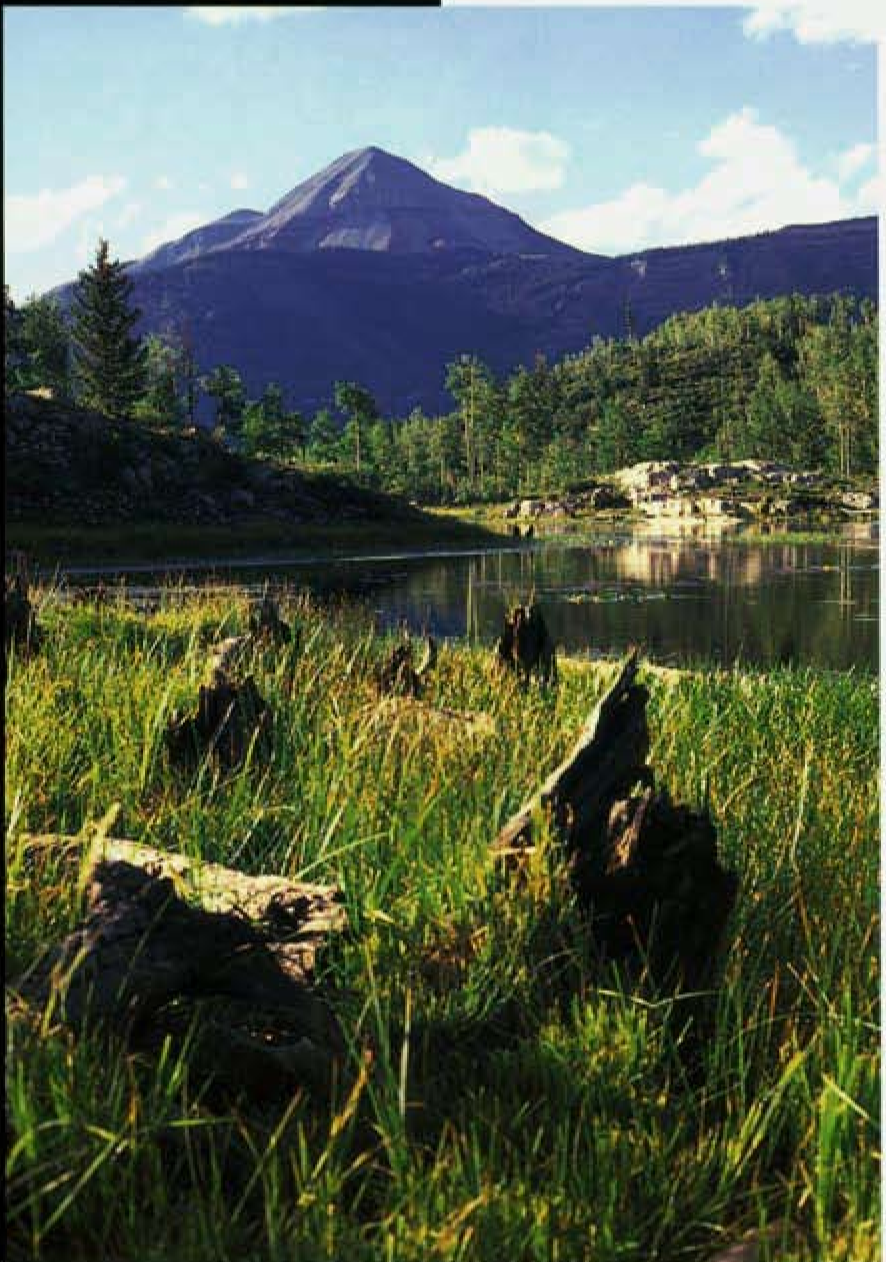
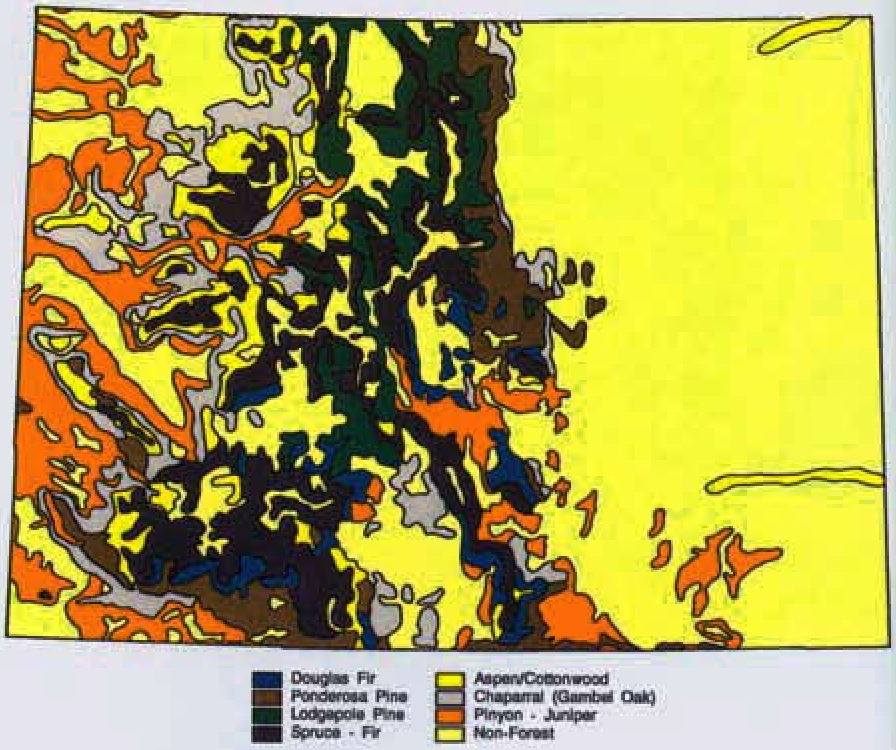
The Forest Resource



Before discussing the prominent forest health issues, it is important to realize the variety and quality of forested landscapes statewide. Much of our basic data describing the composition of Colorado's forest resource is derived from regular forest inventories of the state (Conner and Green, 1988; Benson and Green, 1987; Miller and Choate, 1964). These reports contain detailed information on the extent, condition, and location of forest resources. When we discuss the health of Colorado's forests, it should be clear that we are dealing

Figure 2.1: Major Forest Types of Colorado

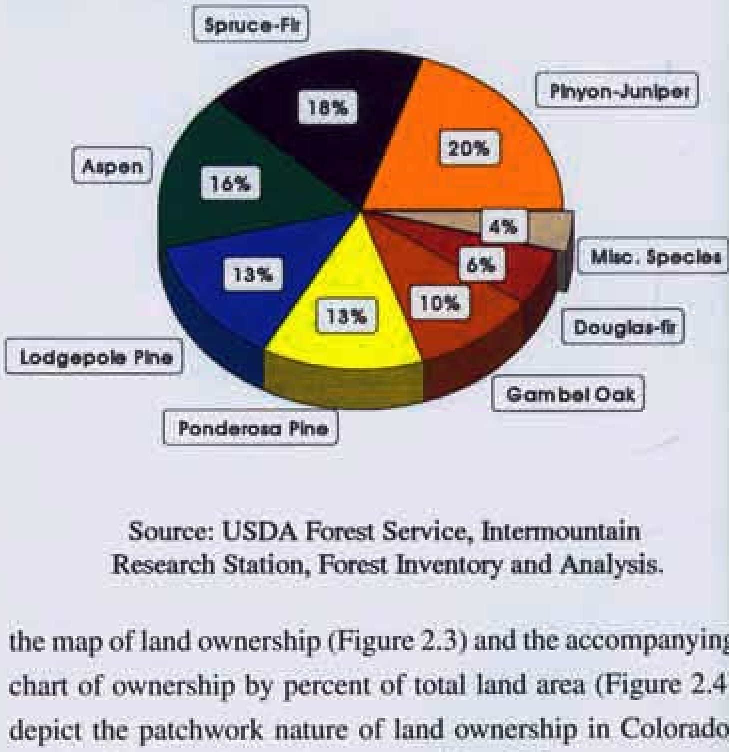


with many "forests": high elevation spruce and fir, dry-site pinyon pine and juniper, mid-elevation aspen and Douglas-fir, Front Range ponderosa pine, and riparian cottonwoods, just to name a few. The following sections will describe the forests in more detail by examining the forest types, land ownerships, and ecological divisions that often frame issue discussions. A final section will summarize tree data taken from FHM plots.

FOREST TYPES

Figure 2.1 depicts the distribution of forest types across the state of Colorado. Forest type is synonymous with forest cover, or the dominant tree species in the overstory at a given site. Forest types are influenced by a number of factors including climate, elevation, aspect, soil type, and recent disturbance. The accompanying chart (Figure 2.2) shows the percentages of forested area covered by the primary forest types found in the state. Pinyon-juniper, spruce-fir, and aspen forest types, combined, comprise more than half of that total area.

Figure 2.2: Forest Types of Colorado



Source: USDA Forest Service, Intermountain Research Station, Forest Inventory and Analysis.

LAND OWNERSHIP

FHM samples all owner categories of forested lands. Management of forested lands across the state is complicated by a variety of ownership philosophies and directives. Both the map of land ownership (Figure 2.3) and the accompanying chart of ownership by percent of total land area (Figure 2.4) depict the patchwork nature of land ownership in Colorado. Much of the nonforested eastern portion of the state accounts for the large percentage of privately owned land in Colorado. Most forested acreage lies within the National Forests, is privately owned, or is managed by the Bureau of Land Management.

Figure 2.3: *Land Ownership in Colorado*

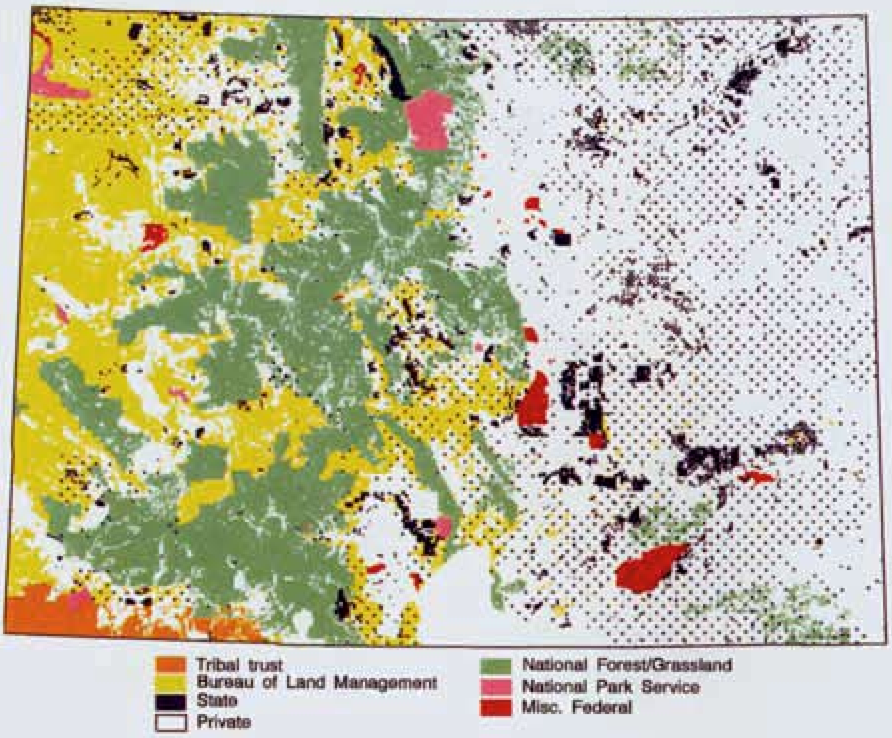
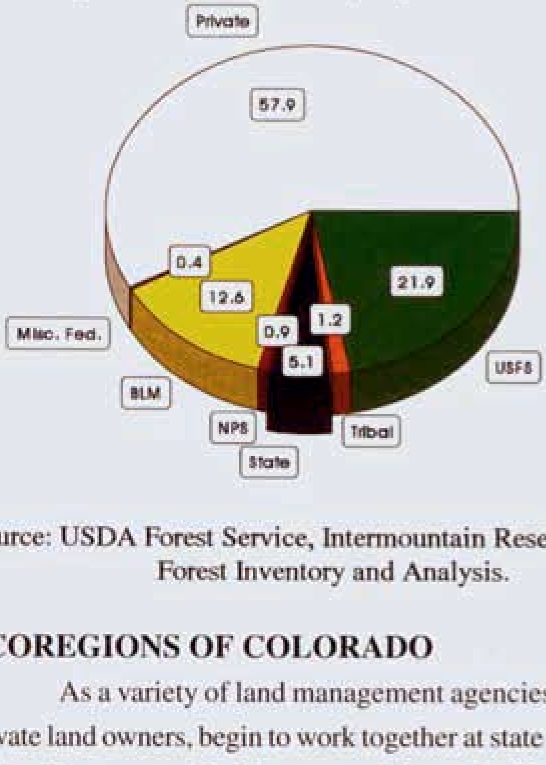


Figure 2.4: *Ownership by Percent Area*



Source: USDA Forest Service, Intermountain Research Station, Forest Inventory and Analysis.

ECOREGIONS OF COLORADO

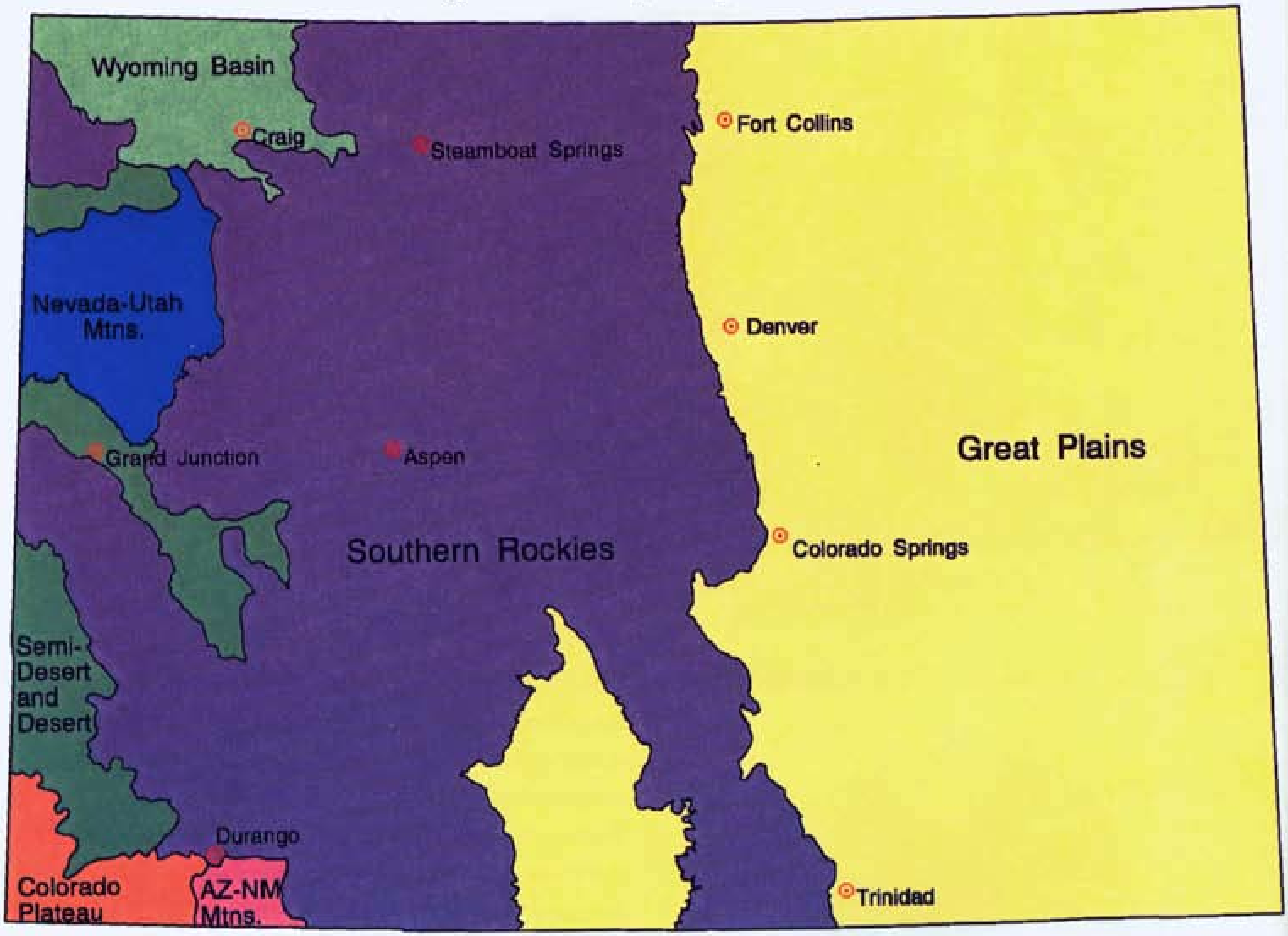
As a variety of land management agencies, along with private land owners, begin to work together at state and regional scales, it seems practical to approach forest health issues using nonpolitical land divisions. Bailey's *Description of the Ecoregions of the United States* (1995) presents a hierarchical framework for logically delineating ecological regions based on their unique combinations of physiography, soil type, potential vegetation, and climate. Note that of these components, climate (a pattern of weather) is the quickest to change over time and across ecoregions (recent climate data see Doesken and McKee, 1993). As the Forest Health Monitoring program expands, reports on forest health conditions will cover entire ecoregions, even as ecoregions cross state boundaries.

The ecoregions of the United States are classified, in descending order, by domains, divisions, provinces, and sections. In this report, we will focus on the ecoregions of Colorado at the province level. There are seven distinct provinces found in the state (Figure 2.5). All of the provinces of Colorado have some forested conditions and, therefore, have been sampled by the FHM plot system. Figure 2.6 shows the distribution of forested sample points across the state by ecoregions. Descriptions of the seven ecological provinces of Colorado, following Bailey (1995), are presented here.

Great Plains-Palouse Dry Steppe Province (Great Plains)

This province comprises the eastern one-third of the state, plus the San Luis Valley. Also known as the shortgrass prairie, the Great Plains Province is the least forested of all the Colorado provinces. The topography of this province is

Figure 2.5: *Ecoregions of Colorado*



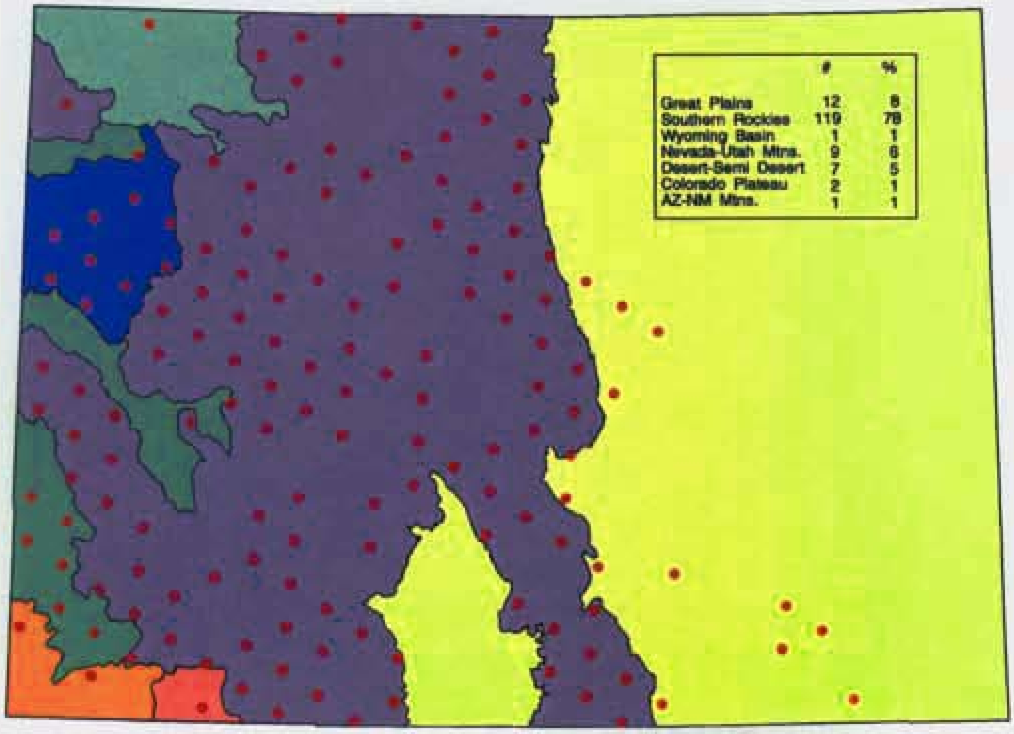
characterized by rolling hills and flatlands ranging in elevation from 5,500 feet along the Front Range to 4,000 feet near the Nebraska border. The lack of forested environments is due mainly to the rainshadow effect of the Rocky Mountains to the west. For most of the summer growing season, there is more evaporation than there is precipitation. Average annual precipitation is about 20 inches, with most of that coming in the form of winter snow and sporadic spring and summer thunderstorms.

The vegetation of the Great Plains Province is composed primarily of grasses and forbs, which are often widely spaced. The forested component of this province is small. Forested areas include scattered stands of ponderosa pine mixed with juniper along the Front Range, pinyon-juniper woodlands in the southeastern portion of the state, and cottonwood-lined riparian zones paralleling the major rivers of the province. Of course, much of the Great Plains has been converted to agricultural or urban uses and, therefore, will not reflect the native plant communities described for this province.

Southern Rocky Mountain Steppe – Open Woodland – Coniferous Forest – Alpine Meadow Province (Southern Rockies)

This province is composed of the major mountain ranges of the Colorado portion of the Rocky Mountains. In area, the Southern Rockies is a little more than 1/3 of the entire state's land. From the Front Range on the east side to the West Slope and Uinta Ranges on the west side, this province is characterized by high mountains and plateaus regularly dissected by north-south running valleys, or "parks." In terms

Figure 2.6: *Forested Plots by Ecoregion*



of elevation, the highest peaks are higher than 14,000 feet, and the valley floors range from 6,000 to 7,000 feet. Climate in this province is best described as highly variable depending on local elevation and aspect. In general, valleys are warmer and drier, with annual precipitation of 15-25 inches per year. Higher mountain ranges are much cooler, and precipitation is 40 inches or more annually. Much of the annual moisture comes in the form of winter snow; however, a northerly flow of summer storms is a prominent feature of the southern Rocky Mountains. As summer hikers can attest, afternoon thunderstorms become almost predictable during July and August.

The flora of this region is also highly variable. Because of differences in elevation, aspect, and subsequently soil types, rainfall, and evaporation rates, mountain vegetation resembles a large-scale mosaic of conifers, hardwoods, and shrub/grasslands. This province represents the most forested portion of the state and also the greatest diversity among forest types. Rocky Mountain forests are often depicted in terms of discrete elevation/forest type zones, with spruce and fir dominating the highest forested elevations; lodgepole pine, aspen, and Douglas-fir in the middle mountain zone; and ponderosa pine, pinyon, and juniper defining the lowest forested zone. Although this holds true generally, there are often exceptions to these zonal rules based largely on aspect and the occurrence of some less common forest types. A disjunct portion of this province is the eastern end of the Uinta Mountains. In the state of Colorado, the Uinta Mountains are covered almost entirely by pinyon-juniper forests.

Many think of the "Colorado Rockies" as being the most forested area of the state. Indeed, more than 2/3 of FHM's forested plots in the state are located in this region. While this popular perception is generally viewed in a positive sense by forest users, it also serves to increase the amount and kind of human pressure exerted on these landscapes.

Intermountain Semidesert Province (Wyoming Basin)

The Intermountain Semidesert Province covers an area beginning near the town of Craig and extending north and northwest to the Wyoming border. This area includes formations of low hills (8,000-9,000 ft.) and high-elevation valleys (6,000-8,000 ft.) in what is commonly known to geographers as the Wyoming Basin. Unlike the Rocky Mountain Province, there is little variation in temperature or precipitation across the Semidesert Province. Annual precipitation is about 15 inches per year and is fairly evenly distributed through the seasons.

The vegetation of the Semidesert Province is composed

Table 2.1: Percent Forest Type by Ecoregion

	Great Plains	Southern Rockies	Wyoming Basin	Nev.-Utah Mtns.	Desert-Semides.	Colorado Plateau	AZ-NM Mtns.	Total Percent
Pinyon-Juniper	20	40	3.3	10	16.7	6.7	3.3	100
Spruce-Fir	0	96.6	0	3.4	0	0	0	100
Aspen	0	96.3	0	3.7	0	0	0	100
Lodgepole pine	0	100	0	0	0	0	0	100
Ponderosa pine	10.5	84.3	0	0	5.2	0	0	100
Gamble	16.7	55.5	0	22.2	5.6	0	0	100
Douglas fir	0	90	0	10	0	0	0	100
Misc. forest types	0	100	0	0	0	0	0	100

primarily of sagebrush, rabbitbrush, and bunch grasses. Riparian zones are lined with shrub-form willows and sedges. The forested component of this province is rather sparse, being mostly pinyon-juniper highlands, with some oak woodlands on the south and east margins of the area.

Nevada-Utah Mountains Semidesert – Coniferous Forest – Alpine Meadows Province (Nevada-Utah Mountains)

This province is formed by a series of high-elevation mountains surrounded by sagebrush and bunch grass-dominated valley floors. In Colorado, the Nevada-Utah Mountains Province is made up entirely of the high Tavaputs Plateau. This plateau is split politically by the Utah-Colorado border. The Tavaputs is actually a tilted block that rises gradually from north to south, terminating in striking erosional cliffs just north of Grand Junction. Elevations range from 4,000 to 10,000 feet. The series of cliffs, most prominently the Roan and Book Cliffs, are dissected by a few smaller north-south running streams in the area. Yearly precipitation ranges between 8 and 25 inches depending on elevation. Valleys tend to be hot and dry in the summer and cold and moist during the winter. In contrast, the higher elevations are relatively wet and warm in the summer and cold and wet during the winter.

The forested component of the Nevada-Utah Mountains consists of pinyon-juniper just above the valley floors, followed by a succession of Gambel oak, mountain mahogany, ponderosa pine, aspen, Douglas-fir, and even spruce-fir on some high peaks. Due to extreme erosional situations, large portions of these high plateaus are devoid of forested vegetation and made up primarily of exposed soils and geologic strata.

Intermountain Semidesert and Desert Province (Semidesert and Desert)

In its western reaches, this province represents most of the lower elevation Great Basin and the northern canyonlands country of Utah. While the Semidesert and Desert Province is characterized by sagebrush-covered valleys, highly dissected canyons, and occasional isolated mountain ranges, in Colorado there are no mountains to speak of. The northern portion of the province is composed of a large valley containing the cities of Grand Junction, Delta, and Montrose. The southern section is dominated by the canyons and tributary canyons of the lower San Miguel and Dolores rivers, with large sagebrush and woodland plateaus between them. A small section of the Uinta Basin, also part of this province, crosses into the state further north along the Utah border. Elevational ranges are between 4,500 and 7,000 feet. Rainfall is between 10 and 15 inches per year, with most of that coming in the fall and spring. Summers are hot and dry, while winters are cold and dry.

Vegetation of the Semidesert and Desert Province is composed of lowland sagebrush valleys and upland pinyon-juniper forests. Both the Uinta Basin and the Gunnison Valley are, for the most part, nonforested, although they are fringed by pinyon-juniper and oak communities. The Canyonlands of Colorado contain vast pinyon-juniper woodlands and, in some spots, ponderosa pine cover.

Colorado Plateau Semidesert Province (Colorado Plateau)

The Colorado Plateau consists of tablelands broken by occasional steep canyons. The primary difference between this province and the Semidesert and Desert Province is the timing of annual rainfall. On the Colorado Plateau there is a marked summer thunderstorm season, whereas in the Semidesert and Desert Province there are rarely summer rains. Total precipitation averages 10 inches annually with local increases on higher ridges. Elevations range from 5,000 to 7,000 feet, although a handful of peaks reach 9,000 feet.

Forest cover is very similar to the Semidesert and Desert Province. Continuous stands of pinyon and juniper are common, while the lower valley floors contain xeric grass and shrub species. Agricultural fields fragment the woodlands in some areas.

Arizona-New Mexico Mountains Semidesert – Open Woodland – Coniferous Forest Alpine Meadow Province (Arizona-New Mexico Mountains)

This ecoregion covers the smallest area within the state. The Arizona-New Mexico Mountains consist chiefly of high-elevation foothills, mountains, and plateaus. The principal topography of this small province is the highly dissected Mesa Mountains, which climb to just under 8,000 feet. In Colorado, there is little difference in elevational range, climate, or vegetation between the Arizona-New Mexico Mountains and the Colorado Plateau Province. The single distinguishing feature is the lower density of pinyon-juniper forests in this region as compared to the Colorado Plateau. This is most likely due to the slightly lower elevations and, therefore, less precipitation.

PLOT AND TREE SUMMARY

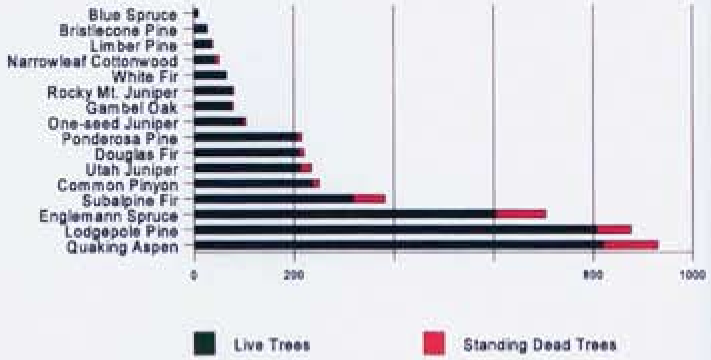
FHM sampled 151 field locations that were either fully or partially forested. From the total of all plots, a small percentage straddled more than one forest type. Hence, there are more forest types recorded (158) than there are total plots. With this in mind, Table 2.1 presents a summary of major forest types by ecoregion. Three trends emerge from this table. First, the highest percentages of forest types sampled, by far, fall in the Southern Rockies ecoregion. This seems logical, given that 78 percent of all plots fell in this area. Secondly, several forest types occur almost exclusively within the Southern Rockies Province: spruce-fir, aspen, lodgepole pine, Douglas-fir, and miscellaneous forest types. Thirdly, two prominent woodland forest types, pinyon-juniper and Gambel oak, occur widely within several ecoregions. This may be attributed to their adaptability to different environments and to the wide elevational variations within some ecoregions. Interestingly, the greatest portion of pinyon-juniper forest types were also found in the Southern Rockies.

Finally, the two graphs, Figure 2.7 and Figure 2.8 (page 22), describe the variety and amount of species tallied in the forested overstory and understory. Note that there is a rough correlation between those species that were most commonly tallied and the prominent forest types in the state. Some species are grouped in forest types by common association. For example, the pinyon-juniper forest type comprises common pinyon *(Pinus edulis)*, one-seed juniper *(Juniperus monosperma)*, Utah juniper *(J. osteosperma)*, and Rocky Mountain juniper *(J. scopulorum)*. The combined tally of all these species results in a ranking similar to the pinyon-juniper type among all forest types. To the contrary, both aspen *(Populus tremuloides)* and lodgepole pine *(Pinus contorta)* are less common as forest types, but more common in total number of trees tallied. This may be because where these species occur, they grow in denser stands than other more common forest types, or they are more commonly found as associates of many other forest types where they do not constitute the majority of the trees in those stands. The higher ratio of dead-to-live trees among aspen corresponds with the slightly higher frequency of damage to live trees among aspen as compared to other species (Appendix B). Damages are also relatively common on pinyons and junipers, but they show markedly lower ratios of dead-to-live in Figure 2.7. Woodland species, such as junipers, commonly display damages or dead portions of the tree for several decades while the rest of the tree is healthy.

In terms of regeneration (Figure 2.8), the large number of Gambel oak sampled is due probably to the way seedlings and saplings are defined, rather than to the actual "regeneration" on the site. Gambel oak often occurs over wide areas as a stunted tree of between 1 and 2 inches diameter at the base. These short trees often do not conform to size standards of other species; however, they may be "mature" in that they are several decades old. In addition, the ratios between saplings and seedlings of different species vary widely. This may be attributed largely to their different reproductive strategies. For instance, quaking aspen sends up hundreds of "seedlings" (technically suckers) after an area is disturbed. However, in subsequent years, this initial density of regeneration will be reduced substantially due to mortality caused by limited light and water resources.

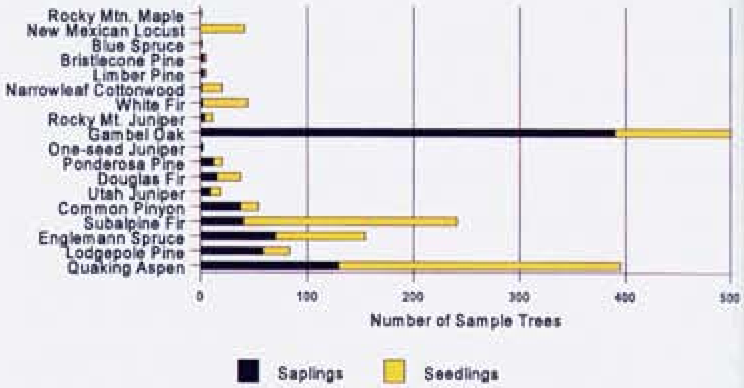
As we conclude this portion of the report, the variety, and complexity of Colorado's forest resource should be evident. The following section will describe specific forest health issues and how they affect the various "forests" of the state.

Figure 2.7: *Mature Trees Sampled in Colorado*



* Mature Trees are those greater than 5.0 inches diameter at breast height or root collar.

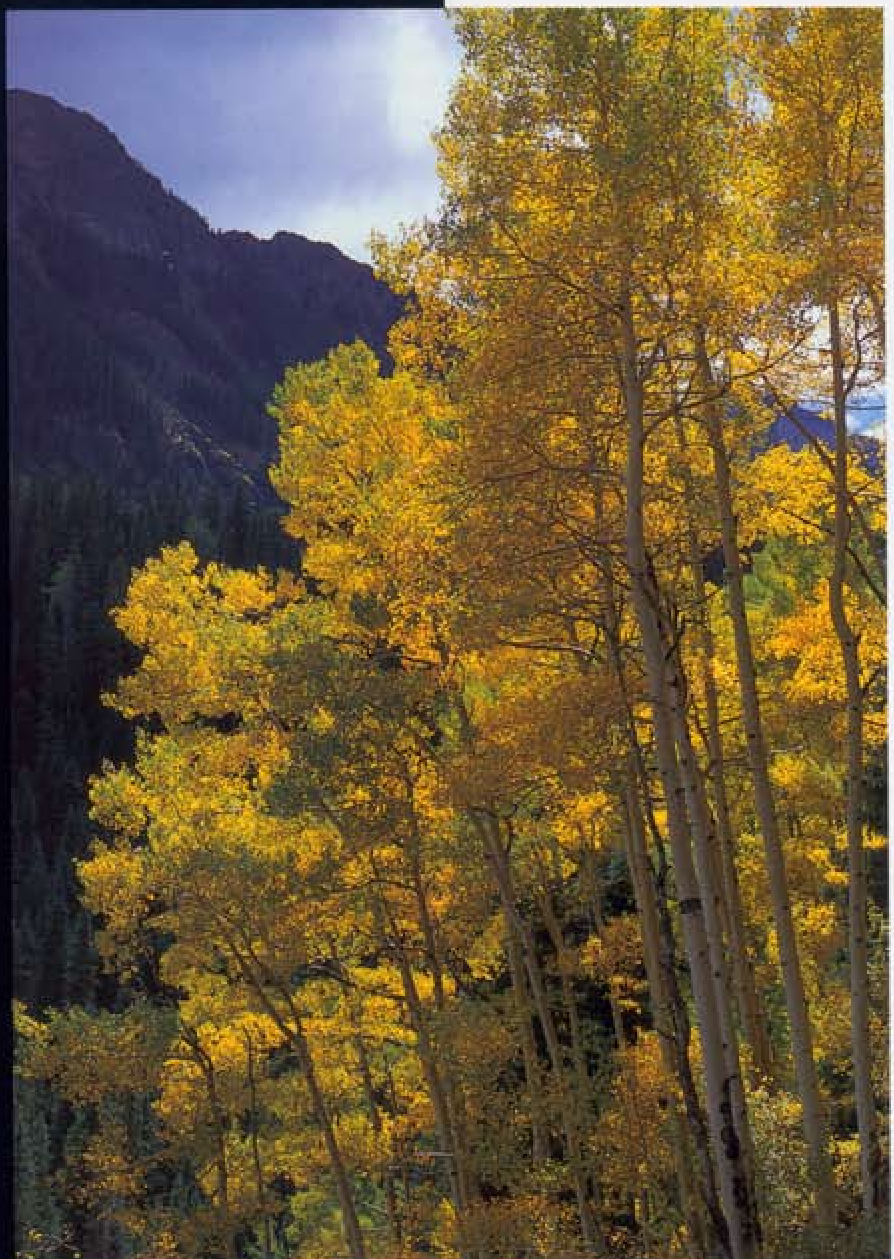
Figure 2.8: *Regeneration Sampled in Colorado*



* Actual number of Gambel Oak seedlings is 1250. The number was reduced to improve the overall graphic.

* Saplings are trees with diameters between 1.0 inches and 5.0 inches at breast height or root collar. Seedlings are trees less than 1.0 inches breast height or root collar and greater than 1 foot in total height.

Forest Health Issues



Forest scientists and the general public are concerned with forest health. This program is designed to address forest health-related issues. Many issues of controversy today may only be fully understood through the collection and analysis of long-term data sets, such as those being provided by FHM. This initial FHM report will address the issues of primary concern in the state today. However, it is expected that the pertinent forest health issues will change in the future. This program will continue to monitor established issues as they develop, or new

issues as they arise.

The following sections will examine the current forest issues in Colorado. Though regular reports on insect and disease fluctuations have been published for years, this report will develop this broad area as a single forest health issue. Greater detail on insect and disease issues may be gleaned from annual reports (Forest Health Management Group, 1996). A second issue is broadly defined in the title "Forest Cover Change." This report will view change over recent decades in aspen and ponderosa pine using the current FHM data sets. A third issue is the rapid change, and potential hazards, that are developing in forests along the urban and wildland interface. A fourth issue that affects forests is air quality. In this section a closer examination of FHM tree crown and lichen biomonitoring data will be conducted. A final issue is forest diversity. Often scientists use different measures of diversity as a reflection on overall forest health. This report will look at three specific types of diversity: overstory species diversity, understory species diversity, and lichen diversity.

INSECTS AND DISEASE

Colorado experiences frequent advances and declines of prominent insect and disease infestations. Recently, foresters have monitored and treated large-scale mountain pine beetle (late 1960's-mid 1980's) and spruce budworm (1975-1985) outbreaks throughout Colorado. These large outbreaks increase forest susceptibility to fire and reduce the marketability of commercial timber. Some infestations, however, may positively regulate forest conditions by naturally thinning dense stands and facilitating species diversity.

Long-term monitoring of damage occurrences can be documented through the FHM plot network. Additionally, aerial monitoring and mapping of insect and disease occurrences will supplement the plot information. Using this two-pronged monitoring effort across the state will assure that any insect, disease, or mortality events greater than 5,000 acres in size will be detected in Colorado.

During the period from 1992-1995 the major damage agents of concern were: (1) mountain pine beetle; (2) Douglas-fir tussock moth; (3) western spruce budworm; (4) pine sawflies; (5) dwarf mistletoes; (6) Armillaria root disease; (7) pinyon decline and; (8) subalpine fir mortality. Detailed information concerning these damage agents can be found in the annual report *Forest Insect and Disease Conditions in the Rocky Mountain Region, 1995* (Forest Health Management Group, 1996). A summary of current conditions is provided here for the prominent damage agents.

Mountain pine beetle, *Dendroctonus ponderosae*

From the Colorado-Wyoming border south through the Rocky Mountains, mortality appears to be on the rise.

In lodgepole pine, epidemics of mountain pine beetle (MPB) are correlated with large-diameter trees. Old growth stands with trees greater than 10 inches in diameter at breast height (dbh) in the lower elevation zone for lodgepole pine are highly susceptible to MPB activity.

In ponderosa pine, mountain pine beetle activity occurs in mature forests and in young, over-stocked stands. Trees from

5 inches dbh up to those of the largest size may be attacked by the MPB. Secondary growth stands with a basal area around 120, old growth stands with high risk rating, and stands on poor sites are susceptible to MPB epidemics.

Douglas-fir tussock moth, *Orgyia pseudotsugata*

Heavy defoliation affected about 6,000 acres on the South Platte River drainage of the Pike National Forest. This epidemic is the first of significant size in recent Colorado history. The infestation is declining and no other areas of concern have been detected.

Western spruce budworm, *Choristoneura occidentalis*

Widespread defoliation of Douglas-fir, true fir, and spruce occurred throughout southern Colorado forests from Lake City east to South Fork and north to Salida. Defoliation pre-disposes trees to attack by secondary insects, Douglas-fir beetle, and diseases.

Pine sawflies, *Neodiprion* spp.

Ponderosa pine in native stand and conservation plantings throughout the eastern plains were defoliated. The Black Forest between Calhan and Fondis was the hardest hit area in 1994.

Dwarf mistletoes, *Arceuthobium spp.*

The several species of Dwarf mistletoe are primarily host-specific parasites of most western conifers in the family Pinaceae. Dwarf mistletoe damage causes reduced increment growth, lower timber quality, reduced seed production, increased mortality, and indirect losses. Indirect losses include increased susceptibility to insect attack, root diseases, and storm damage. When dwarf mistletoe impacts are evaluated, losses combine to equal at least 10 million cubic feet annually for Region 2 of the USDA Forest Service (Colorado, Nebraska, Kansas, South Dakota, and eastern Wyoming).

Arceuthobium americanum infects 50 percent of Colorado's lodgepole pine resource.

Arceuthobium vaginatum subsp. *cryptopodum* in ponderosa pine is common throughout the Front Range and southwestern Colorado. It is estimated that losses amount to 855,000 cubic feet annually.

Arceuthobium douglasii in Douglas-fir occurs mostly in the southern two-thirds of Colorado.

Armillaria root disease, *Armillaria* spp.

Armillaria spp. is the most common forest root disease in Colorado. The disease was identified as a factor affecting management of forests throughout southwestern Colorado.

Pinyon pine decline

This decline appears to be a complex of organisms that impacts pinyon in the Salida and Mancos areas of Colorado.

Subalpine fir mortality

Fire exclusion has resulted in conditions that favor subalpine fir. When these stands reach a mature state, they are highly susceptible to a root disease/*Dryocoetes* beetle complex. Mortality was common throughout the cover type from the Colorado-Wyoming border south throughout the Rocky Mountains.

FOREST COVER CHANGE

To the casual outdoor enthusiast, tree-covered mountains epitomize the wealth and stability of Colorado's forests. Others will undoubtedly note subtleties of the varying tree species. Obvious signs include the brightness of aspen among evergreen in the fall or the long-needled ponderosa pine with its sweet scented bark standing majestically among the foothills. Though the forests of Colorado, and the tree species that these forests comprise appear stable, in reality they constitute very dynamic environments. While most changes in the forest cover constitute healthy ecosystem fluctuations, others appear to signal long-term departures from historic patterns.

Forest Health Monitoring plots measure change in species composition, as well as forest structure. To study forest change, it is critical to document species composition and individual tree and stand life stages. This is done by tracking not only the species makeup, but also the size, age, and relative dominance of all the trees on a particular site. Currently, scientists are interested in long-term changes in the forest cover of sites previously dominated by aspen and ponderosa pine.

Aspen

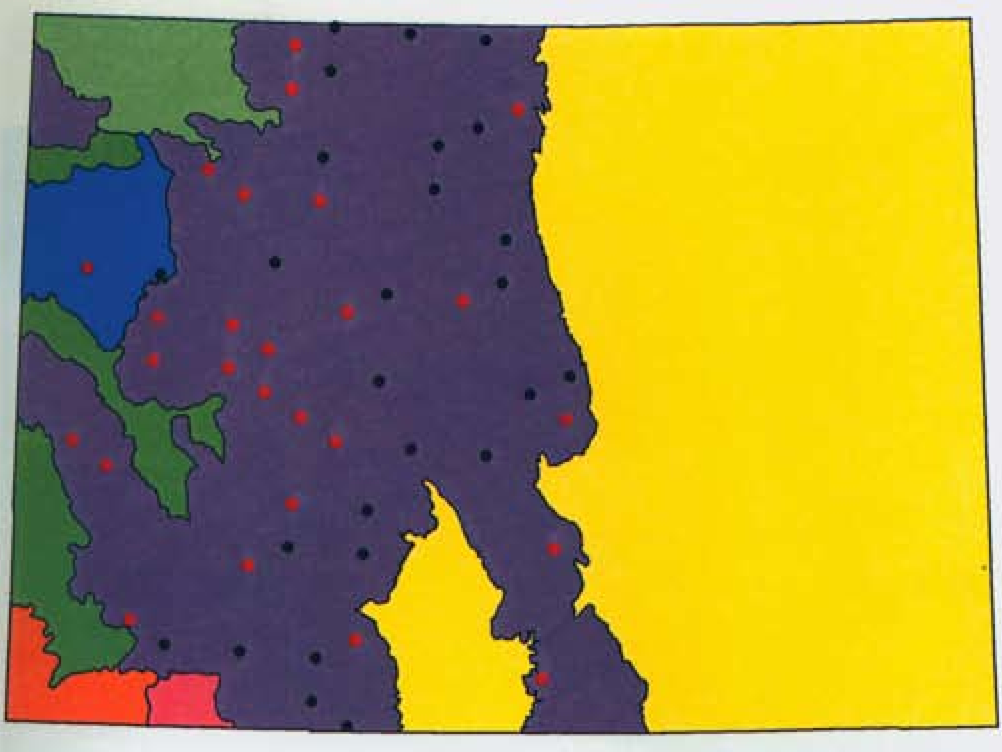
Aspen cover throughout the Interior West appears to be on the decline (Bartos and Mitchell, 1997; Brown, 1995). In addition to the decline in tree species diversity in the state, loss of aspen forests may have far-reaching impacts on forest biodiversity. For instance, aspen cover supports a unique range of understory plants and lichens, which would likely decline with the trees.

The chief cause of this apparent decline, scientists speculate, is the lack of natural and human-caused forest fires. Aspen is one of a few tree species that readily regenerates after a fire burns through a forest. Because aspen regenerate primarily by suckering from underground root stock, they maintain a certain advantage over other species whose reproductive parts (i.e. cones and seeds) are often consumed in the fire or take longer to establish when they are not burned. Since the turn of the century, there has been a virtual elimination of Native American-set fires and a successful campaign of wildfire suppression implemented by various land management

agencies. It appears that a sharp reduction in regular burn events has led to a significant drop in aspen regeneration. But this is only a part of the picture. In the absence of fire, older aspen stands (80-150 years of age) tend to eventually be replaced by competing conifers. So, while few stands are regenerating due to the lack of fire, older stands of aspen are being replaced by shade-tolerant conifers. This basic formula, in combination with other factors, such as grazing and browsing pressures on seedlings, appears to be causing a large-scale decline of aspen. These shifts in forest cover take place over the period of several decades, or even centuries, so they may not be readily observed by the casual forest visitor. Nonetheless, these changes have far-reaching affects on a forest's susceptibility to fire, insects, or disease.

The phenomenon of aspen decline appears to be most critical in the Southern Rockies ecoregion. Our data show that about one-third of all sample plots had either live or dead aspen present. Plots with aspen present are located almost exclusively in the Southern Rockies Province (Figure 3.1). For analytical purposes, these plots may be logically divided into those of which aspen are the majority of trees sampled, otherwise known as an aspen *forest type*, and the remaining plots of which other

Figure 3.1: Aspen Plots in Colorado



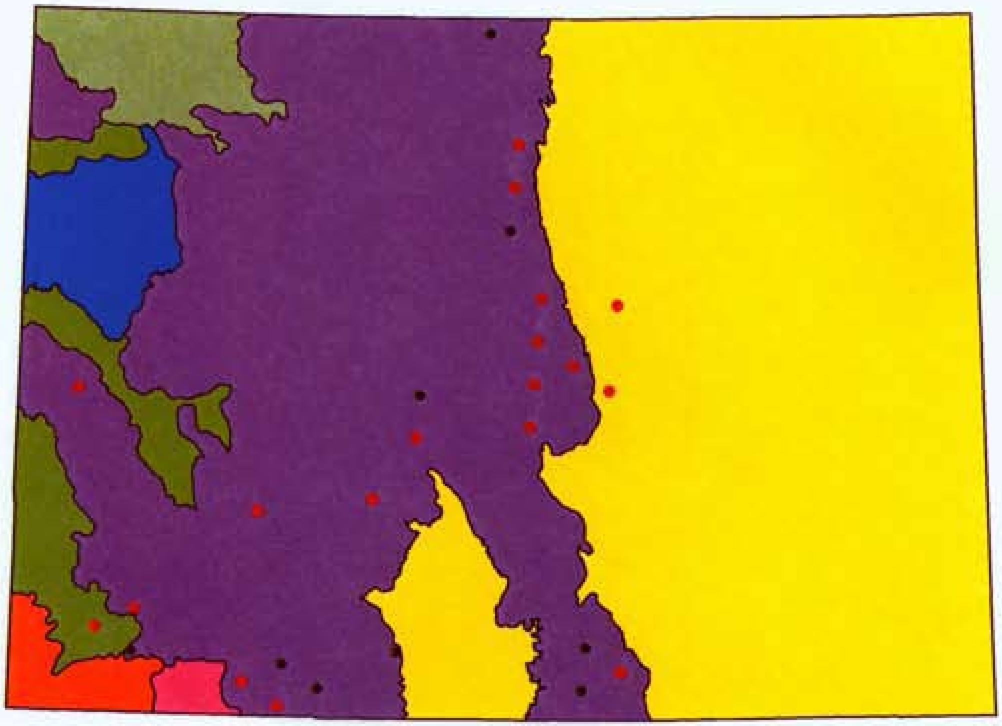
species represent the majority of cover, but aspen is still present. The data reveal that a little over 50 percent of the forested plots with aspen present are now dominated by more shade-tolerant species. At one time, aspen may have been the dominant species found in some or all of the plots with aspen currently present, but the lack of large-scale disturbance has favored some conifer species. If the relationship between aspen-dominant and aspen-present plots depicted in Figure 3.1 signals a decline in aspen cover, then this phenomenon seems particularly acute in the eastern half of the Southern Rockies. This portion of the aspen range represents a geographic limit of the species regionally. If indeed there is a threat to the health of aspen forests, it seems likely that a decline would manifest itself first near the margins of the species' natural range, where climate and soil may already be limiting factors.

One may infer that plots taken in aspen forest types (those sites where aspen is the dominant species) represent the stable portion of the aspen community statewide. However, further examination of the stand structure and the amount of regeneration reveals that 31 percent of the plots in aspen forest types can be viewed as unstable and possibly in transition toward other forest types. Plots were considered unstable (converting from aspen dominated cover) if they (1) had other species present, (2) had little or no regeneration in aspen, (3) had some regeneration of other species, or (4) had little or no lower canopy in aspen.

Further evidence of the instability of the aspen community may be seen in their physical damages. FHM fieldcrews record any damages on trees that could significantly affect the long-term growth or survival of the tree. Aspen trees had more damages recorded than all other species, except the pinyon and juniper group. While pinyon and juniper often live with damages for decades, aspen trees tend to be severely affected within a few years. Aspen led all species in the two most serious forms of damage, cankers and decay. Twenty-four percent of all aspen trees were tallied with these damages. A more detailed listing of damage totals among all species can be found in Appendices A and B.

Data presented here appear to confirm an aspen decline, but do not suggest a level of that decline. Future remeasurements of these same plots will give us an idea of the extent and rate of decline or possibly the reversal of this apparent trend given some large-scale disturbance initiated by land managers or nature.

Figure 3.2: *Ponderosa Pine Plots in Colorado*



Ponderosa Pine

Similar to aspen decline, there appears to be a regional trend among conifers towards shade-tolerant species and away from those species that prosper from frequent forest fires. Ponderosa pine prospers from frequent -low to moderate intensity- fires because of its particular physiology. Thick bark and few near-ground branches increase this species resistance to moderate intensity flames while competing species are often consumed by fire. The older and larger ponderosa pine trees grow, the better their chances of surviving even more intense fire events. However, given a long enough fire-free period, other species that are shade-tolerant will eventually overtop the ponderosa pine forest. In addition, a dense undergrowth of younger shade-tolerant species, such as Douglas-fir, subalpine fir, and Engelmann spruce, may act as "fire ladders" in transporting ground-level flames to crown fires in old growth ponderosa pine. Without periodic fires to reduce less fire-resistant species (which happen to be more shade-tolerant), the overall cover of these forests may change dramatically from one that is pine-dominated to one that is dominated by other conifers.

Figure 3.2 depicts the distribution of measured ponderosa pine plots among the ecoregions of Colorado. Generally speaking, this species is found at low to moderate elevations around the fringe of the Southern Rockies Province.

A closer look at the plots displayed, using similar techniques described for aspen evaluation, show that about 2/3 of the total plots with pine present are actually in pine forest types. This would suggest that the decline phenomenon is less evident in pine than aspen. However, some caution should be used in reaching this conclusion, since reproductive strategies are significantly different between the species. Whereas aspen reproduces by means of any established root system, often sprouting from many trees, pines rely on the dispersal of individual seeds. The net result of these vastly different reproductive modes is that it is much more likely that individual pine trees will prosper among other species, while aspen establish with other aspen. When a lone aspen is tallied, that species is probably in decline locally, whereas a lone pine may lead to a variety of interpretations and remain in lone existence for a long period. So, conclusions regarding the advance or decline of stands without a majority of pine trees should not be drawn without further evidence.

We can look at the relative stability of those plots where

ponderosa pine does constitute a forest type to further judge the state of this species. Using identical criteria to those used for aspen, exactly 50 percent of the ponderosa pine forest type plots were found to meet the "unstable" criteria. However, many of the plots that had no pine reproduction were competing directly with dwarf stands of Gambel oak. Since this species does not represent competition for shade in the same sense that other conifers compete, it is difficult to interpret these data. Some of the remaining pine plots were associated with pinyon and juniper stands. In general, relationships with woodland species in terms of long-term successional changes are poorly understood. However, it seems likely that the proliferation of woodland understory is due to a general lack of fire throughout the region.

An examination of damage data for ponderosa pine reveals that slightly more than three-quarters of this species had no damage at all (Appendix A). The most common damage found on these pines was decay (Appendix B). Just over 10 percent of all ponderosa pines were tallied with this damage. The second most common damage was loss of apical dominance (5.7 percent). Usually this means that the top of the tree was broken off. These two damages, in combination with the lower overall rate of damage, suggest that no real trend is evident concerning serious damages among this species.

In summation, ponderosa pine may be undergoing significant changes in its cover, but conclusive data are not evident to support that theory currently. As FHM plots are remeasured over several cycles, broad-scale changes in forest cover will become more apparent.

URBAN AND WILDLAND INTERFACE

Rapid expansion of Colorado's population in recent decades, in combination with the desirability of living in or near forested environments, may lead to many potential problems for humans, wildlife, and forests. Healthy forests are critical to maintaining a balance along the urban and wildland interface. If forests deteriorate, humans will be affected directly by the loss of the aesthetic properties for which they moved to the area. Moreover, unhealthy forests, in the form of excessive dead or dying trees, provide significant fire hazard and, therefore, a direct threat to life and property. Currently, the threat of wildfire overrunning forested estates is very real. Other byproducts of reduced forest health near urban areas, such as loss of wildlife habitat, increased number of hazard trees, or introduced exotic species, may cause further problems for landowners and forest users. This section will examine forest-related issues along the Front Range from Fort Collins south to Trinidad.

The two primary ecoregions affected by urban/wildland forest issues are the Great Plains and Southern Rockies, although smaller urban centers in the state confront these same issues to a lesser degree. Humans have influenced forest conditions along the Colorado Front Range dramatically in the past, especially the settlement and mining booms of the late 19th century (Veblen and Lorenz, 1986). The long-term effects of past human disturbances, such as clear-cutting and fire ignition around mine sites of the previous century and intensive fire suppression efforts in this century, are widely visible in the forested landscape today.

While natural disturbance events like fires and insect outbreaks are common and even healthy for many forests (Rogers, 1996), they present more difficult situations in populated areas. Through long-term monitoring of forest conditions and population growth patterns, early indication of potential forest-related crises can be detected. For example, wildfire risk along the interface can be assessed by closely monitoring forest structure, incidents of insects or disease, and climatic fluctuations. Potential "hot spots" can be identified where natural disturbances may impact human settlements. Criteria for identifying potential hazard areas include population and housing density, tree size and density, abundance of dead or dying trees, tree species, and potential for disturbance initiation, such as frequency of lightning strikes or presence of forest pathogens. Density, size, and species of trees present are very important in determining a forest's likelihood of insect infestation, which further influences fire susceptibility. Moreover, the probability of human-started fire is greater in heavily populated areas, simply because more people are present in these forests to ignite them. This fact, in conjunction with specific weather conditions, further increases the chances of large-scale forest fires. In addition to being prone to wildfires, numerous insect- or disease-killed trees may be toppled either individually or catastrophically by high winds.

To combat potential impacts from natural or human-related disturbances, more intensive management practices, such as forest thinning or creating non-forested buffers, may be necessary to alleviate serious loss of life and property where human development is adjacent to forested wildlands. For instance, selective cutting of "hazard trees" near human structures is good preventative medicine against future injury or property damage.

Of course, forest health along the urban/wildland interface is more than just a problem for people. Many state residents are already well aware of wildlife conflicts when people move into forested areas or remove forest cover. When habitat is diminished either by human development, forest fragmentation, or forest decline, wildlife must roam further in order to subsist. Examples of this problem include mountain lions preying on domestic animals and deer browsing on residential shrubbery.

Other problems affecting this human/forest interface that can be discerned by analyzing Forest Health Monitoring data sets are the invasion of exotic plant species and the maintenance of healthy watersheds for urban use. Just as the overstory of a forest is in continual flux, understory plant composition changes due to environmental factors, too. Sometimes the introduction of exotic plants (those that are not native to the area) can drastically change or effect current plant cover, thereby having long-term effects on forest health. Similarly, changes in watershed plant cover or health can dramatically change the amount of water available to downstream users. A forested area in which the tree cover is significantly reduced, for example, following establishment of a housing development, will retain much less water or snowpack for summer use.

Finally, urban expansion tends to markedly affect air quality. Since FHM was designed, in part, to measure the effects of air quality on forests, this issue will be addressed separately.

AIR QUALITY AND FOREST HEALTH

Air pollution is monitored by numerous agencies. Currently, effects of various pollutants on forest environments in Colorado are unclear. However, we do know that in areas of consistently poor air quality, certain plants are impacted. Many plants, such as the shrub ninebark (*Physcocarpus malvaceus*) or ponderosa pine trees, are adversely affected in the form of foliage damage or dieback (Mavity, Stratton, and Barrang, 1995; James and Staley, 1980). Other plants, most notably certain lichen species, display less tolerance and, therefore, may be completely eliminated from affected forested environments as a result of poor air quality.

By utilizing data from Colorado Department of Health monitoring sites, in conjunction with state and federal agency stations in nonpopulated areas, we are able to gain an overall picture of air quality conditions throughout the state (Colorado Department of Public Health, 1994; Malm and Gebhart, 1996). Specific areas of concern presently are ozone damage along the Front Range and sulfate and nitrate deposition in the Yampa Valley and on the Colorado Plateau. More generally, acid deposition is greater with increased precipitation. Since high elevation forests generally receive more rain, scientists have begun to focus monitoring efforts in some Colorado wilderness areas (Malm and Gebhart, 1996; Fox, Bernabo, and Hood, 1987). While concentrations of pollutants in these areas, and elsewhere, are currently low, continued monitoring of air quality inside and outside of wilderness areas will provide a crucial link to FHM observations. Further evaluation of the effects of atmospheric pollutants on forest health will also be critical.

One method of observing the effects of air quality on forest health is to measure foliage condition on the FHM plots.

Tree Crown Assessments

Visual crown assessments are made to determine changes in crown conditions resulting from a variety of causal agents. Atmospheric pollutants, for example ozone, have been shown to cause direct damage to trees and other plants in the form of foliage damage and dieback (Miller and Millecan, 1971). Estimates of crown dieback, transparency, and density were taken on field plots for all live trees greater than 5 inches d.b.h. in order to document crown health. Results of the baseline measure of crown conditions show little impact of pollutants on tree health statewide. However, long-term tracking of plots near identified source areas of pollution, such as the Front Range and the Yampa Valley, will be important to future analysis. More detailed discussion of each crown variable is

Figure 3.3: *Crown Dieback*

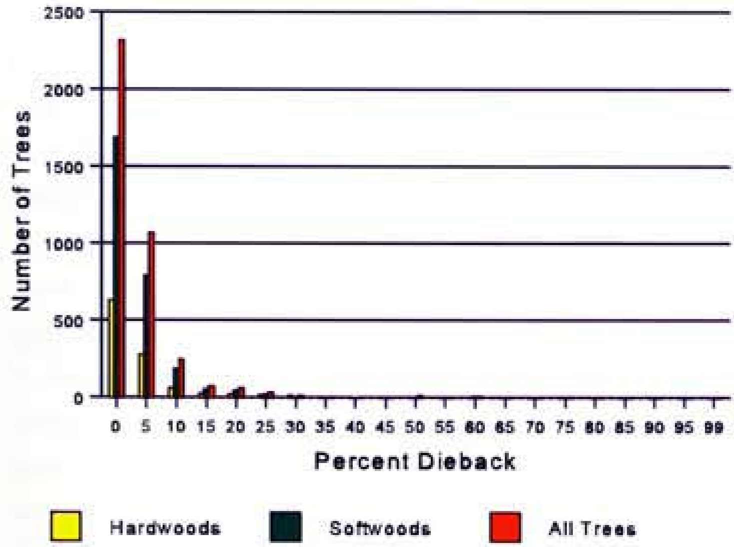
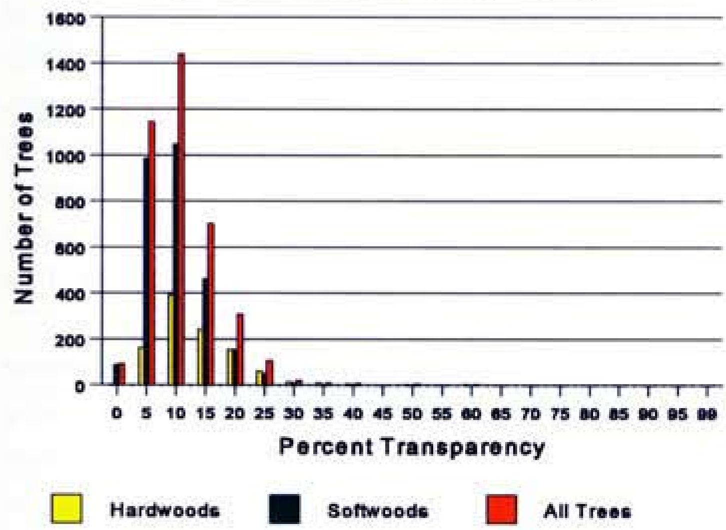


Figure 3.4: *Foliage Transparency*



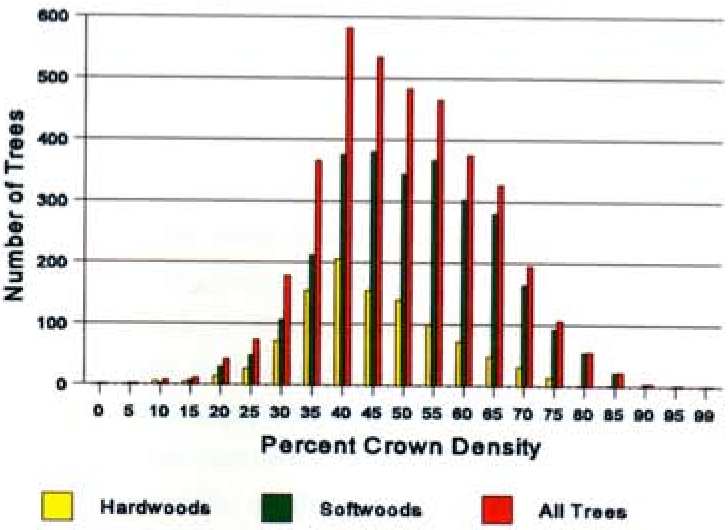
presented below.

Dieback is a measure of percent of the tree crown that has died from the top down and the branch tips inward, toward the center of the crown. Figure 3.3 shows that most of the trees sampled in Colorado have very little dieback. In fact, only 1.04 percent of all dieback ratings taken in the state are greater than 25 percent. Hardwood and softwood ratings are nearly identical in terms of dieback. Future readings of dieback can be compared to current values to look for shifts in dieback among all trees, or by individual species.

Figure 3.4 depicts the current state of foliage transparency on FHM plots. Transparency is the percent of light that passes through the foliated portion of the crown, excluding tree branches and main stems. A tree with a rating of "0" or "5" percent transparency allows either no light or very little light to pass through the leaves to the forest floor. In general, when trees are unhealthy, their crowns begin to thin out and allow more light to pass through. The bar graph of foliage transparency, similar to crown dieback, is highly weighted to the lower percent values. This indicates, once again, that very few tally trees in Colorado are thinning due to poor health. In terms of all trees, only 1.02 percent have transparency ratings of more than 25 percent. Hardwoods have a higher percent of ratings above 25 percent (2.98 percent) than softwoods (.57 percent).

Crown density is determined by estimating the percent crown area that blocks light from passing through. This rating does include woody parts of the tree, so this is not a complement of foliage transparency. As seen in Figure 3.5, crown densities for hardwoods are slightly lower, overall, than those of softwoods. This is probably more a product of the general tree morphology than it is a matter of their condition. Of particular concern in future readings will be movements away from the middle of this graph by any species groups. Currently, 96 percent of all trees are from 25-75 percent density ratings. More hardwoods are below 25 percent density ratings than softwoods, while more softwoods have ratings over 75 percent. Low density crowns may signal declines in growth from a variety of causal agents, both atmospheric and nonatmospheric sources. Very dense trees may be unhealthy too. For example, many conifer species "broom up" as a result of mistletoe infection.

Figure 3.5: *Crown Density*



Lichen Biomonitoring

Another way to monitor air quality is through the collection of forest lichens. Lichens are extremely sensitive to changes in air quality because they subsist predominantly on atmospheric nutrients. FHM samples lichens found on trees only. Though much of the lichen flora of the state grows on rock and soil, sampling methods were devised to sample the larger specimens, known as macrolichens, that occur on trees, so that species could be easily distinguished by nonspecialists in the field (Table 3.1). Generally speaking, when air quality decreases, lichen diversity decreases as well (McCune, 1988). By taking lichen samples from all FHM network plots, we gain a better understanding of how air quality is affecting plant life and diversity on the ground. To index the ability of lichens to sustain themselves given varying degrees of air quality, lichen researchers are developing an air quality gradient based on the species and diversity of lichens found on an independent set of plots located at specific intervals from known area and point sources of pollution (McCune, 1997). A similar gradient may be constructed to reflect climatic influences on lichen communities. With information calibrated to climate and air quality, researchers plan to construct a model to rate lichen

community health for all FHM plots.

Preliminary analysis of lichen communities near two known pollution sources has recently been conducted using FHM data (McCune, 1997). Both pollution-tolerant and pollution-sensitive species were found on plots where air quality is good. However, in plots near Denver and those in the lower elevations of the Yampa valley, marked decreases were found in overall abundance and variety of lichens. Interestingly, some pollution-tolerant species actually increase in abundance in polluted areas (e.g., species in the genera *Xanthoria* and *Physcia*). These species seem to thrive on certain nutrients, such as nitrates, common to pollution sources. Table 3.1 lists the common macrolichen genera found in Colorado, their characteristics, and sensitivity to pollutants.

An average of 10 species per plot was found in the state. Some plots in the Denver metropolitan area had as few as two species present, while remote area plots had as high as 19 species. On the Front Range, preliminary analysis suggests that the lichen community has been altered significantly. The pattern of fewer pollution-intolerant species is very evident in Denver and slightly less pronounced in the Boulder area. Lichen communities in the mountains just west of the metropolitan area were relatively species-rich and included pollution-intolerant species (e.g., *Bryoria, Hypogymnia,* and *Usnea*). In the Yampa Valley, coal-fired utility plants near Craig appear to

Table 3.1: Characteristics of some common macrolichen genera growing on trees in Colorado (McCune, 1997).

Genus	Appearance	Indicator value and functional roles
Bryoria	Brown, hairlike	Pollution-sensitive; forage lichen; many uses by animals
Candelaria	Yellow, very small, foliose	Pollution and dust tolerant, mainly on hardwoods
Collema and *Leptogium*	Grey or black, gelatinous, foliose	Pollution sensitive, nitrogen fixers
Flavoparmelia and *Flavopunctelia*	Greenish, broad-lobed, foliose	Moderate pollution tolerance
Hypogymnia	Grey or brown,	Mainly on conifers, some species foliose, hollow lobes pollution tolerant
Imshaugia	Small, white, foliose, brown apothecia	Mostly restricted to conifers
Melanelia	Brown to olive, foliose, medium size	Nearly ubiquitous; some species pollution tolerant; on both hardwoods and conifers
Parmelia	Grey, foliose, medium size, black below	Widespread, pollution tolerant, on both hardwoods and conifers
Phaeophyscia	Small, cryptic, grey or brownish, foliose	Usually on hardwoods; most species pollution tolerant
Physcia	Small, white, foliose	Some species nitrogen-loving; some species almost restricted to hardwoods
Physciella	Small, cryptic, grey, foliose	Usually on hardwoods; pollution tolerant
Physconia	Small, frosty-coated, foliose, often forming neat rosettes; brown, grey, or white	Usually on hardwoods; pollution tolerant, nitrogen-loving
Usnea	Greenish, fruticose, tufted or hanging; branches have a central cord	Abundant in the mountains, somewhat pollution-sensitive but persisting in polluted areas as dwarf, compact forms
Xanthoria	Orange or yellow, foliose	Widespread but more abundant in areas of elevated nitrogen, somewhat pollution tolerant

be similarly affecting lichen flora. Emissions of sulfur dioxide and nitrogen oxide appear to have reduced the diversity of lichens at lower elevations. Pollution-tolerant species were found in abundance near Steamboat Springs and Hayden, while intolerant lichens were less common than other areas of the state. Near Rabbit Ears Pass, just east of Steamboat Springs, lichen communities seemed to be quite healthy. Though the sampling networks in the Yampa Valley and along the Front Range should be intensified before conclusive findings are made, preliminary results show patterns of localized damage to the lichen flora.

BIODIVERSITY

Biodiversity, in the broadest sense, may be divided into genetic diversity, community diversity, and species diversity. This section will focus primarily on the species diversity aspect of biodiversity. More specifically, FHM concentrates on tree species and structural diversity as measures of biodiversity and, therefore, forest health. For instance, a tree plantation may appear to be very healthy, but there is little diversity in both the understory and overstory simply because it is not profitable, at least in the short term, to maintain a diverse forest if there is only one marketable plant. This is very similar to large-scale agricultural practices. In fact, in these situations, managers will often use mechanical or chemical means to suppress the development of competing species. In a diverse forest ecosystem, the wide variety of plant species in a complex structure is seen as a benefit to the overall forest. Structural diversity may also be an excellent indicator of wildlife habitat. On FHM plots, we have detailed the size, composition, and density of both understory and overstory plant species, which may give some indication of biodiversity.

Biodiversity can be measured at a number of distinct scales. For the state of Colorado, we plan to monitor changes in diversity over time at regional and statewide scales. However, if diversity on a single plot or subregional grouping of plots changes significantly, further investigation will be conducted to monitor rapid changes at any scale.

Overstory diversity

Colorado does not have a wide diversity of tree species when compared to other regions of the country. However, biodiversity is most useful when compared within ecological regions and preferably over time. Statewide there were a total of 18 individual tree species sampled (see Figures 2.7 and 2.8). On any individual plot, six was the maximum tallied and one was the minimum. The average number of species tallied per plot was 2.5.

Exotic Understory Species

Preliminary analysis of understory data collected on approximately 1/4 of the total FHM plots in the state has focused on exotic species. Analysts only viewed 1/4 of the total FHM plots in the state because these were the only plots with consistent understory vegetation sampling in this first four-year period. By comparing lists of plants tallied on each monitoring plot with lists of exotic plant species for the state, we gain further understanding of the dynamics of plant invasion. Introduction of foreign species tends to reduce biodiversity through competition. Often exotic plants are very adaptive to new environments and reproduce rapidly. For example, in some pinyon and juniper forests, exotic species, such as cheat grass, can dominate sites within a few years of introduction, crowding out native flora. Table 3.2 lists the exotic species found on FHM plots. All these plants originated on the Eurasian continent. The most common exotic plant was the common dandelion, which was found on 36.4 percent of all plots. Although exotic species are widespread in Colorado, they still make up a relatively small percent of total herbaceous cover on forested plots. In fact, Colorado had the lowest percentage of exotic species (4.5 percent) and the lowest total cover in exotics (1.5 percent) of all regions in the country (Stapanian and others, 1997). In contrast, California had the highest percent of exotic species (13.2 percent) and coverage of exotics (25 percent).

The state of Colorado probably benefits from its insular location, as both East and West Coast states seemed to have greater proportions of exotic species.

Lichen Diversity

In addition to their use as a relatively inexpensive means of monitoring air quality, lichens may be used as an indicator of vegetative and structural diversity in forests. Generally, more lichens are present when there is a greater variety of tree species and sizes. Lichens often make up a large portion of the diversity of plant species in forests. This variety contributes to nutrient cycling, as well as being an integral component of wildlife sustenance. In terms of FHM, though, the most important value of lichen monitoring is as a relatively inexpensive indicator of air quality.

The lichen flora of Colorado is composed of fewer species than other regions of the country, although sufficient numbers were present to make lichen community sampling valuable. Overall, 90 species were identified, with an average of 10 species per plot (Appendix C). The lichen community statewide appears to be healthy and diverse, although some sites seem to be declining due to local pollution sources. Additionally, losses in the aspen forest type regionally may contribute to a parallel decline in related lichen and understory plant communities.

Forest health issues may change, or new issues may emerge in the coming decades. Additionally, there are some issues, such as forested riparian zones, that need further attention but are difficult to address given our current sampling design. This section did address several forest issues of importance in the state in a baseline fashion. It was not the intention of this section to draw conclusions, but merely to describe forest issues in terms of their current status. Subsequent reports will follow-up on these issues to monitor change, and possibly trends. The following section presents a summary of this report.

Table 3.2: Exotic Plants Tallied

Common Name	Latin Name	Number of FHM Plots
Madwort	Alyssum alyssiodes	1
Barberry	Berberis vulgaris	1
Smooth Brome	Bromus inermis	2
Cheatgrass	Bromus tectorum	3
Centaurea	Centaurea montana	1
Pigweed	Chenopodium album	1
Canada Thistle	Cirsium arvense	1
Houndstongue	Cynoglossum officinale	2
Timothy	Phleum pretense	1
Common Dandelion	Taraxacum officinale	8
Medowrue	Thalictrum aquilegifolium	1
Water Speedwell	Veronica anagallis-aquatica	1

Source: Stapanian and others, 1997

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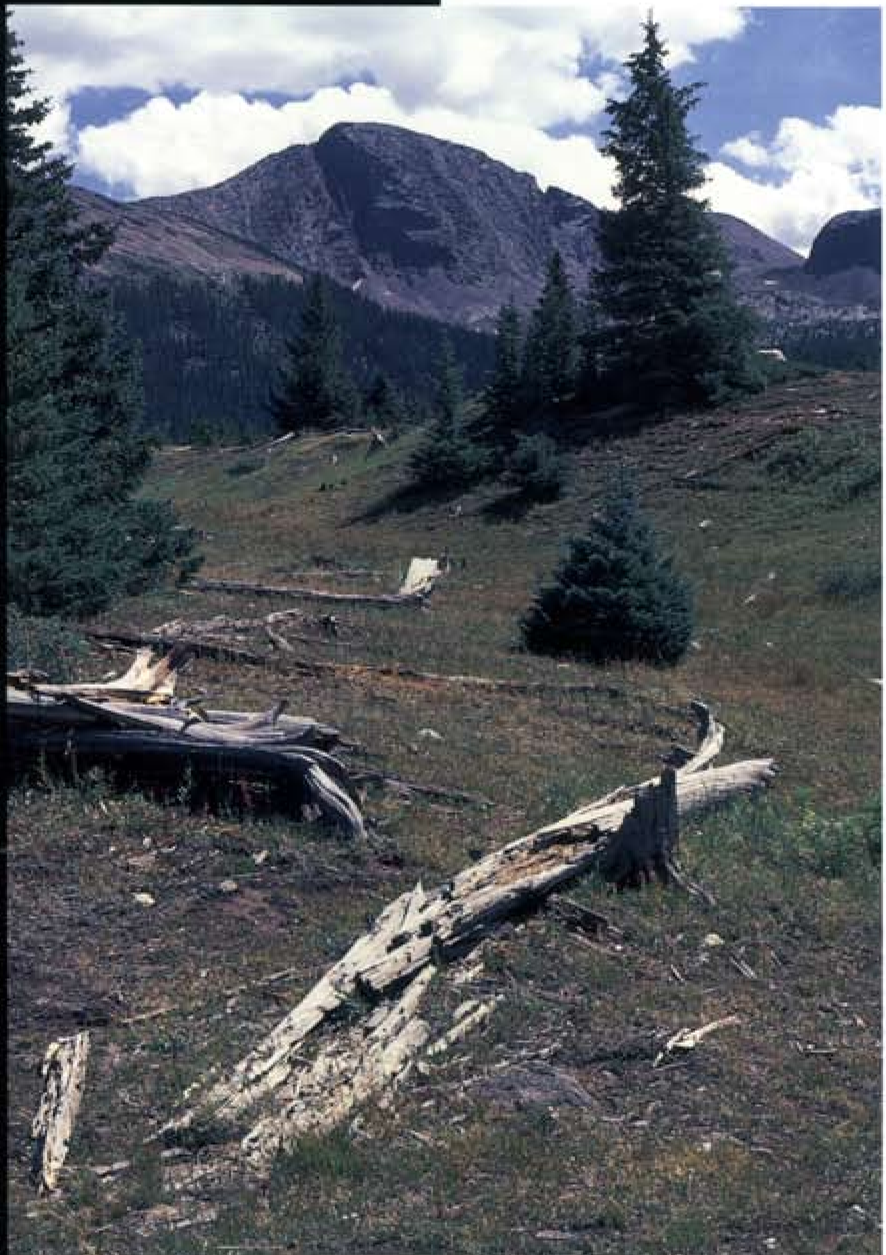
Summary



Forest Health Monitoring has been active in Colorado since 1992. After four years of detection monitoring, we have presented this baseline assessment of forest conditions in the state. In 1996, the first remeasurement of field plots took place. With the addition of remeasurement data, future FHM reports in Colorado will emphasize not only conditions, but forest health trends, as well. As we go through this process, we expect to learn a great deal about how these forests function, how their status changes, and how those changes affect

the issues.

In describing the forested lands themselves, an overarching theme here has been that Colorado is composed of many different forest covers. This patchwork of tree types and forest conditions react to natural and human-caused disturbances in numerous ways. Ecological regions are a promising method for logically viewing forest changes within the framework of multiple ownership boundaries and climatic variations. Although most forested land in the state is in the Southern Rockies, every ecoregion contains some tree cover, and consequently, FHM aerial and ground surveys will report on their status.

The crux of this baseline assessment has been to define and address the forest health issues around the state. The sum of the status of these issues gives us an overall assessment of forest health. While some issues are discretely defined in terms of ecoregions, others are geographically widespread. We have pointed out the ecoregions affected, where appropriate, so that the ecological scope of given issues can be accurately assessed. In our efforts to evaluate the issues, we have explored multiple measures of forest conditions. Some of the sources employed include FHM plot data, off-plot aerial and ground surveys, off-plot lichen surveys, state and federal air quality data, and state climatological data. Recognize that these sources have given us a first approximation of factors affecting forest health.

Indeed forest health is a complex undertaking – a puzzle with many pieces. While FHM has only begun to assemble this puzzle, some images are starting to take shape. The **Forest Health Highlights** section represents the more prominent images presented in this report.

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APPENDIX A: Number of Damages by Species

NUMBER OF DAMAGES PER TREE*

	None	One	Two	Three	Total Trees Tallied
Douglas-fir	112	18	2	0	132
Ponderosa Pine	119	31	4	0	154
Lodgepole Pine	460	85	11	3	559
Subalpine Fir	208	25	5	1	239
White Fir	34	8	1	0	43
Engelmann Spruce	421	44	6	2	473
Other Softwood	37	8	6	0	51
Pinyon and Juniper	311	157	72	12	552
Aspen	334	134	29	5	502
Cottonwood	30	11	1	0	42
Oak Woodland	40	18	5	0	63
Total	2106	539	142	23	2810

* 1992 damage data was not compatible with this data set. 1025 trees tallied in 1992 are not included in this table.

APPENDIX B: Types of Damages by Species

TABLE OF DAMAGE BY SPECIES*

	Damage	Times Recorded
Douglas-fir	Canker	1
	Decay	3
	Open wounds	3
	Resinosis/Gummosis	2
	Loss of apical dominance	3
	Broken branches	5
	Excessive branching	2
	Damaged shoots	3
Ponderosa Pine	Decay	17
	Open wounds	5
	Loss of apical dominance	9
	Broken branches	3
	Damaged shoots	4
	Other	1
Lodgepole Pine	Canker	7
	Decay	18
	Open wounds	36
	Resinosis/Gummosis	2
	Brooms on the bole	1
	Loss of apical dominance	9
	Broken branches	9
	Excessive branching	24
	Damaged shoots	8
	Discolored foliage	2

	Damage	Times Recorded
Subalpine Fir	Canker	5
	Decay	8
	Open wounds	10
	Loss of apical dominance	9
	Broken branches	3
	Excessive branching	1
	Damaged shoots	2
White Fir	Canker	2
	Open wounds	1
	Loss of apical dominance	6
	Broken branches	1
Engelmann Spruce	Decay	6
	Open wounds	11
	Resinosis/Gummosis	5
	Broken bole	2
	Broken roots	2
	Loss of apical dominance	16
	Broken branches	10
	Excessive branching	6
	Damaged shoots	2
	Discolored foliage	1

	Damage	Times Recorded
Other Softwood	Decay	5
	Open wounds	9
	Loss of apical dominance	2
	Broken branches	1
	Excessive branching	2
Pinyon and Juniper	Decay	127
	Open wounds	69
	Resinosis/Gummosis	4
	Broken roots	2
	Loss of apical dominance	14
	Broken branches	113
	Excessive branching	1
	Discolored foliage	1
	Other	3

	Damage	Times Recorded
Aspen	Canker	60
	Decay	68
	Open wounds	44
	Resinosis/Gummosis	4
	Loss of apical dominance	10
	Broken branches	8
	Damaged shoots	2
Cottonwood	Decay	2
	Open wounds	1
	Loss of apical dominance	3
	Broken branches	7
Oak Woodland	Decay	7
	Open wounds	2
	Loss of apical dominance	7
	Broken branches	12

* 1992 damage data was not compatible with this data set. 1025 trees tallied in 1992 are not included in this table.

Appendix C: Lichen Species Sampled (Epiphytic Macrolichens Only)

SPECIES LIST FOR COMBINED SAMPLE UNITS (FHM plots, sample plots, quality check plots, and air quality gradient plots)

* = tentative; needs confirmation

Code	Abbrev.	Latin	Number of plots
600	Bry	Bryoria	5
606	Brycha	Bryoria chalybeiformis	2
607	Bryfre	Bryoria fremontii	1
610	Bryfus	Bryoria fuscescens	35
8301	Cndcon	Candelaria concolor	27
1007	Cetcor	Cetraria coralligera	1
1008	Cetfen	Cetraria fendleri	4
1015	Cetpin	Cetraria pinastri	21
1200	Cla	Cladonia	6
1203	Clabac	Cladonia bacillaris	1
1210	Clachl	Cladonia chlorophaea	3
1211	Clacon	Cladonia coniocraea	1
1215	Cladef	Cladonia deformis	1
1217	Clafim	Cladonia fimbriata	3
1228	Claoch	Cladonia ochrochlora	1
1412	Colnig	Collema nigrescens	1
2401	Evediv	Evernia divaricata	3
2404	Evepru	Evernia prunastri	1
2601	Flacap	Flavoparmelia caperata	1
2702	Fpufla	Flavopunctelia flaventior	3
2704	Fpusor	Flavopunctelia soredica	33
3100	Hyp	Hypogymnia	1
3102	Hypaus	Hypogymnia austerodes	15
3301	Imsale	Imshaugia aleurites	1
3302	Imspla	Imshaugia placorodia	10
3616	Lepfur	Leptogium furfuraceum	1
3702	Letvul	Letharia vulpina	2
4000	Mel	Melanelia	3
4002	Melele	Melanelia elegantula	48
4020	Meldis	Melanelia disjuncta	1
4003	Melexa	Melanelia exasperata	1
4004	Melexl	Melanelia exasperatula	54
4015	Melsub	Melanelia subaurifera	1
4017	Melsol	Melanelia subolivacea	93
4021	Meltom	Melanelia tominii	1
4800	Par	Parmelia	1
4806	Parsul	Parmelia sulcata	25
5201	Popamb	Parmeliopsis ambigua	31
5202	Pophyp	Parmeliopsis hyperopta	11
5600	Pha	Phaeophyscia	3
5602	Phacer	Phaeophyscia cernohorskyi	3
5603	Phacil	Phaeophyscia ciliata	10
5605	Phahir	Phaeophyscia hirsuta	15
5606	Phahrt	Phaeophyscia hirtella	4

Code	Abbrev.	Latin	Number of plots	Code	Abbrev.	Latin	Number of plots
5611	Phanig	Phaeophyscia nigricans	11	6711	Punsub	·Punctelia subrudecta	6
5612	Phaorb	Phaeophyscia orbicularis	9	6900	Ram	Ramalina	1
5700	Phy	Physcia	5	6930	Ramsin	Ramalina sinensis	4
5701	Phyads	Physcia adscendens	58	8501	Rhichr	Rhizoplaca chrysoleuca	3
5702	Phyaip	Physcia aipolia	18	8502	Rhimel	Rhizoplaca melanophthalma	1
5705	Phybiz	Physcia biziana	46	8000	Usn	Usnea	27
5706	Phycae	Physcia caesia	10	8013	Usncav	Usnea cavernosa	1
5707	Phycal	Physcia callosa	1	8029	Usnfil	*Usnea filipendula	1
5710	Phydim	Physcia dimidiata	15	8041	Usnhir	Usnea hirta	47
5711	Phydub	Physcia dubia	1	8044	Usnlap	Usnea lapponica	46
5715	Phymex	*Physcia mexicana	1	8072	Usnsub	Usnea subfloridana	4
5723	Physte	Physcia stellaris	31	8200	Xan	Xanthoria	2
5724	Phyten	Physcia tenella	13	8201	Xancan	Xanthoria candelaria	1
5725	Phytri	*Physcia tribacia	1	8203	Xanfal	Xanthoria fallax	47
5801	Pclchl	Physciella chloantha	10	8210	Xanful	Xanthoria fulva	1
5802	Pclmel	Physciella melanchra	4	8207	Xanpol	Xanthoria polycarpa	72
5803	Pclnep	Physciella nepalensis	4	9000	Xpm	Xanthoparmelia	5
5909	Phoele	Physconia elegantula	1	9003	Xpmcol	Xanthoparmelia coloradoensis	4
5903	Phoent	Physconia enteroxantha	3	9001	Xpmcum	Xanthoparmelia cumberlandia	5
5906	Phoper	Physconia perisidiosa	5	9002	Xpmlav	Xanthoparmelia lavicola	1
6303	Pevint	Pseudevernia intensa	7	9004	Xpmpli	Xanthoparmelia plittii	4

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