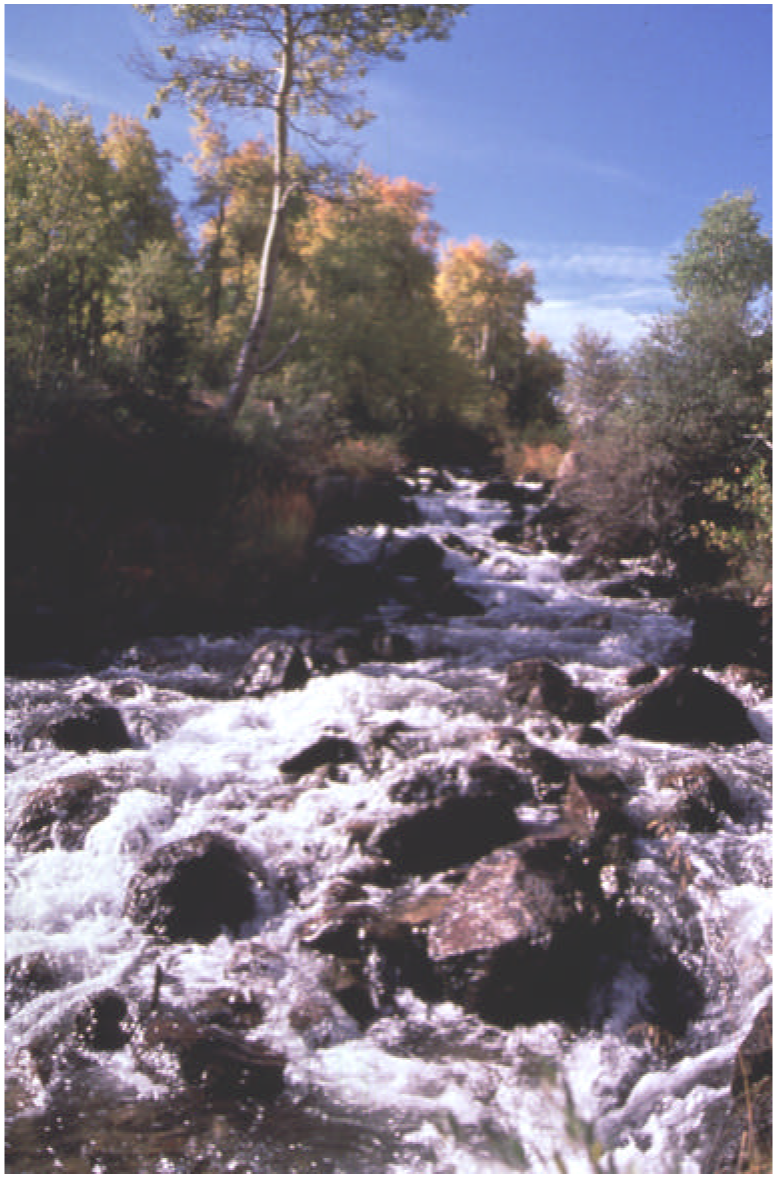
Wyoming Forest Health Report



A Baseline Assessment 1995 - 1998

Wyoming
Forest Health Report

1995-1998

A BASELINE ASSESSMENT

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Photos provided by Wyoming Travel and Tourism

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Forest Health Highlights

Forest health monitoring has been active in Wyoming since 1995. This report reflects four years of Detection Monitoring and provides a baseline assessment of forest conditions in Wyoming. The following highlights represent some of the more important facts and conclusions presented in this report.

Wyoming covers approximately 62.6 million acres in which 9.8 million acres are forested or 16 percent of the land area. Roughly 1.4 million forested acres are in state and private ownership; 8.2 million acres are federally owned; and Tribal lands account for 208,000 acres.

Approximately 42 percent of Wyoming's lands are privately owned with most located in the eastern Great Plains. The Bureau of Land Management has nearly double the land ownership of the Forest Service with percentages at 28 and 15, respectively.

There were ten forest types and four ecoregions identified. The Southern Rockies ecoregion supports seven of the eight forest types. The Semidesert ecoregion covers the largest area.

Lodgepole pine is the most common forest type in Wyoming, with spruce/fir and ponderosa pine forest types ranking slightly behind.

Limber pine, whitebark pine, cottonwood, and aspen appear to be declining due to diseases, changes in fire frequency, introduced plants, and changes in water flow.

Insects and diseases play perennial roles in the health of the state's forests. Dwarf mistletoes and Comandra blister rust are at high levels. Douglas-fir beetle populations are increasing in northwest Wyoming. Subalpine fir is undergoing extensive mortality from a complex of factors.

Exotic plants and tree diseases are changing forest communities.

Three species comprise 44 percent of Wyoming's urban street trees. This lack of diversity puts urban forest at risk from damaging agents that affect a single species.

Air quality appears to be having an effect on lichen diversity. This finding supports the development of a gradient model to evaluate changes in lichen diversity over time.

Introduction

Wyoming's forests provide many valuable resources including wood fiber, recreation, tourism, wildlife and fish habitat, and water. Approximately 4.3 million acres are available for commercial use with a wood volume estimation of 29 billion board feet (Wyoming State Forestry Division 1991). Forested lands provide grazing for many cattle and sheep operations. Wildlife and fish habitats are used for both sport and non-consumptive activities such as observation and photography. Water from forested lands provides the resources for the state's 19,437 miles of streams and 427,219 surface acres of lakes (Wyoming State Forestry Division 1991).

Forest resources are well recognized as a great benefit to humans and are often mistaken as a static resource. Forests are dynamic and therefore may not always retain the values that each individual derives from them. Due to the wide variety of attitudes and perceptions of forest management, much attention has now focused on *forest health* or *forest ecosystem health*. A *healthy* forest meets the current and future needs of people in terms of values, products, and services and is more likely to withstand disturbance by maintaining various structures, compositions, and functions.

Forest ecosystem health has gained considerable attention in recent years due to environmental concerns about air pollution, wildfires, insect and disease epidemics, acid rain, global climate change, population growth, and long-term resource management. These concerns overlap political and ownership boundaries and therefore require coordinated action.

Forest Health Monitoring (FHM) is a national, long-term program designed to determine the status, changes, and trends in *indicators of forest condition* and ecosystem health on all land ownerships. FHM is a cooperative effort between a variety of state, private, and federal institutions, including the Wyoming State Forestry Division, USDA Forest Service Rocky Mountain Research Station, USDA Forest Service Forest Health Protection, USDI Bureau of Land Management (BLM), and the USGS Biological Research Division. FHM uses data from ground plots and surveys, aerial surveys, and other sources of biotic and abiotic data to develop analytical approaches to address forest health issues that affect ecosystem sustainability.

Perhaps the most important element in monitoring changes in forest health is assessing the *rate* of change. These FHM components establish monitoring activities to determine rates of change and possible trends: (1) Detection Monitoring, (2) Evaluation Monitoring, and (3) Intensive Site Ecosystem Monitoring. A fourth related activity is Research on Monitoring Techniques. Data collected through Detection Monitoring is used in this report. Evaluation Monitoring is designed to provide more detail on the extent and severity of adverse forest conditions and determine the causal agent if not explained in Detection Monitoring. The third activity, Intensive Site Ecosystem Monitoring, is the establishment of research sites to study regionally specific ecological processes. Finally, Research on Monitoring Techniques is responsible for developing reliable forest health indicator measurements and improving analysis of FHM and other data. Each monitoring activity provides a different level of information with specific, complementary goals. Information concerning the three phases of FHM can be found in the USDA Forest Service Forest Health Monitoring Fact Sheet Series available at Forest Service offices or at http://www.na.fs.fed.us/spfo/fhm on the internet.

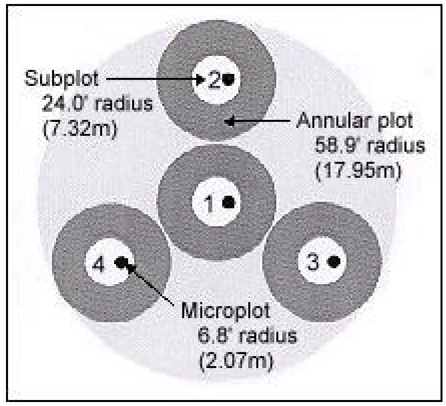
The FHM reporting format follows a three-level, hierarchical framework to meet state, regional, and national needs. Special or local reports are also submitted if certain situations arise that are appropriate for the area of consideration.

The United States is committed to reporting on the criteria and indicators of sustainable forests found in the Santiago Declaration - Montreal Process (Anonymous 1995). These internationally agreed upon indicators are reflected in Wyoming's FHM program and are as follows: biological diversity, productive capacity, ecosystem health and vitality, soil resource, water resource, and global carbon cycles (Stolte 1997).

Plot Component of Detection Monitoring

The purpose of Detection Monitoring is to collect information on the conditions of forest ecosystems, estimate baseline (current) conditions, and detect changes from those baselines over time. Detection Monitoring has a plot and survey component. Since 1990, the USDA Forest Service and state forestry organizations have been cooperating to establish permanent FHM plots across participating state's forested lands. The plot component is a network of permanent forested plots (about 4600 for the 50 states; 68 in Wyoming) on which environmental indicators are measured annually. Wyoming was added to the plot component of Detection Monitoring in 1997.

***Figure 1**. FHM plot diagram*



A forested plot is a permanent sample location covering roughly 2.5 acres and is measured on a five-year cycle (Figure 1). The field plot consists of four subplots approximately 1/24 acre in size for measuring mature trees. The center subplot is subplot one. Subplots two, three, and four are located 120 feet horizontally at azimuths of 360, 120, and 240 degrees, respectively from the center of subplot one. Each subplot contains a microplot approximately 1/300 acre in size for measuring young trees. The microplot center is offset 90 degrees and 12 feet horizontally from each subplot center (FIA National Core Field Guide 2000).

Data was collected from all plots during the 1997 field season. One-fifth of these plots are remeasured annually to assess trends. Field crews measure tree diameters, crown conditions, tree damage, lichen communities, understory vegetation, ozone bioindicators, and soils. Field crews are trained annually and tested to ensure high quality standards. As monitoring progresses, new indicators may be added to supplement the current field measurements.

Survey Component of Detection Monitoring

The survey component of FHM provides a record of broad-scale disturbance events such as large-scale insect and disease outbreaks that may not be detected by the FHM plot network. The primary survey activity is aerial detection. Broad-scale disturbances are also detected by ground surveys for specific insect and disease activities, inventories and plot-based data from other federal programs such as Forest Inventory and Analysis and the National Park Service, and service trip reports and technical reports.

Scope of Report

This baseline report is intended to be a snapshot of current conditions of forest health in Wyoming and will establish a benchmark for future reporting of changes and trends. FHM is a long-term monitoring program and data in this report reflects only a one-time assessment. Future reports will undoubtedly provide a more accurate picture of changes.

Wyoming's forest resources, land ownerships, topography, forest types, and ecoregions are described first. This format provides a basis for addressing forest health issues across political and ownership boundaries.

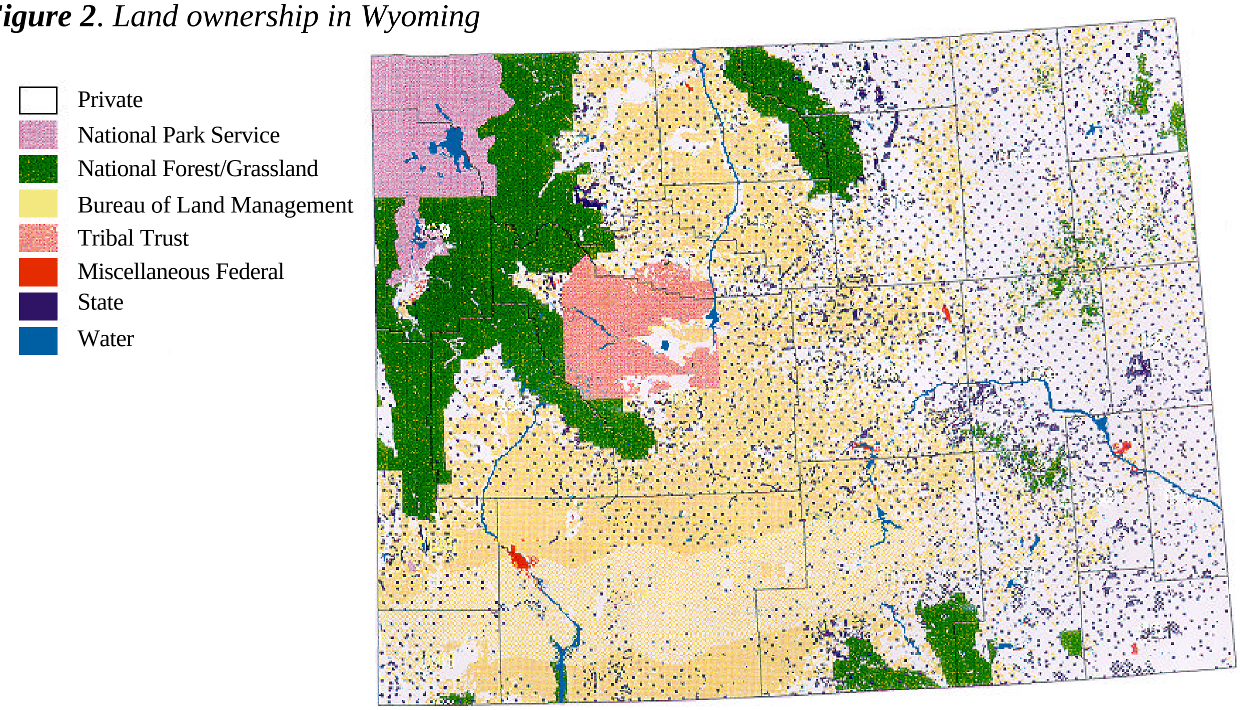
Several forest health issues in Wyoming are defined next and brief reports of their impacts on our forests are discussed. This assessment raises some interesting questions. What impacts will air quality have on Wyoming's forests? Is there adequate biodiversity in our forests to withstand outbreaks of insects and diseases and exotic plants? This report cites substantial lack of diversity in Wyoming's urban forests. Are our urban forests being adequately managed and established to account for this lack of diversity? What forest health issues will the increasing rural-urban-wildland interface areas present? While one report cannot sufficiently answer these questions, it can provide insight into conditions now that may be used for comparison with future reports to assess change.

Several of the appendices provide summaries of the size, status, and species of trees tallied as well as crown measurements and damage assessments from permanent plots. These data are available to the public upon request. A list of State and federal FHM personnel are included in the final **Appendix** and can be contacted for additional copies of this report or related FHM reports.

Wyoming's Forest Resources

This section features two types of information: (1) land ownership, forest type, and ecoregion materials are taken from sources outside the FHM program and (2) plot and tree summary data are taken directly from FHM ground plots distributed throughout the state. Describing Wyoming's forest topography, climate, and ownership will provide a better understanding of the material presented in this report. Green and Conner (1989) present a more detailed description of Wyoming's forests and ownership statistics.

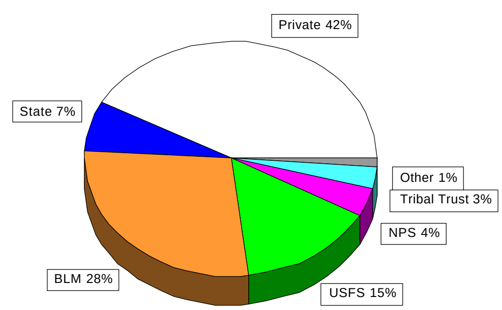
Figure 2. *Land ownership in Wyoming*



Land Ownership

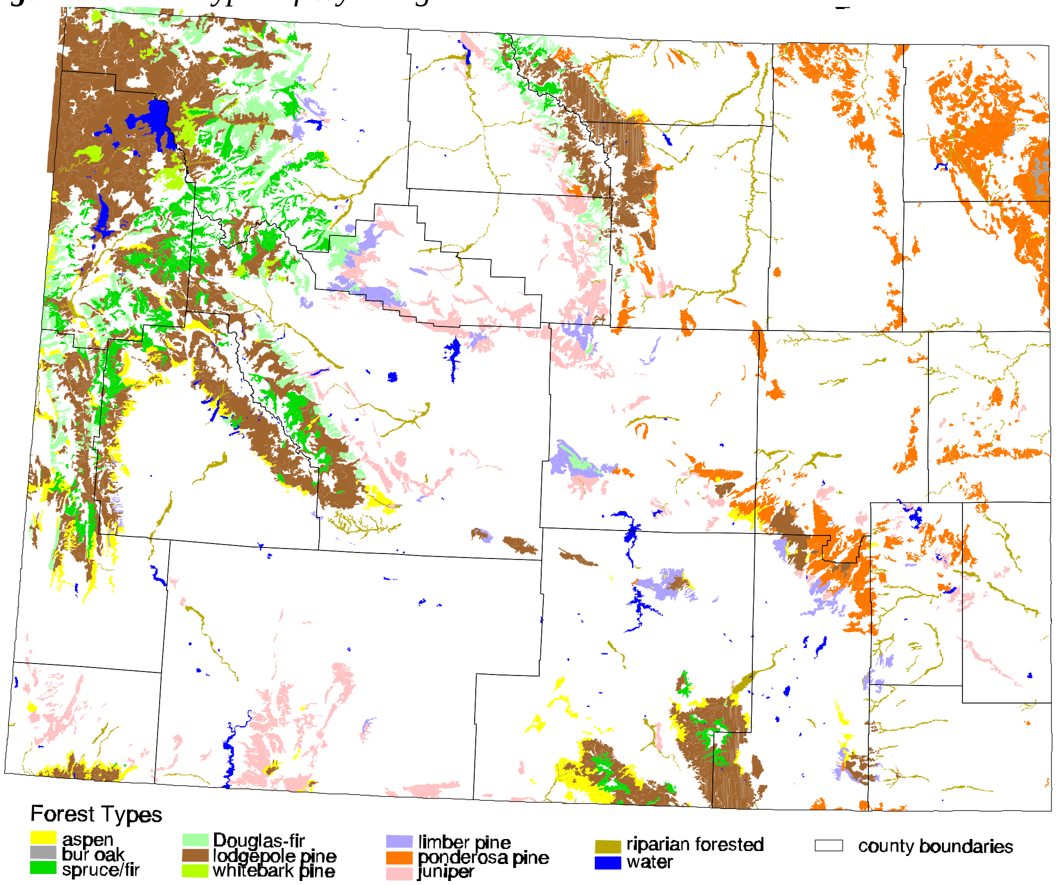
FHM samples all ownership categories of forested lands since environmental concerns overlap political and ownership boundaries. Figure 2 shows Wyoming's 23 counties and illustrates the distribution of land ownership by primary ownership categories. Figure 3 shows the percentages of land in each owner-ship. Both the map and the chart depict all lands, not just forested parcels. Three patterns emerge from the map of Wyoming land ownership. First, private lands account for 42 percent of the ownership with the majority located in the eastern Great Plains. A second pattern is the block-type ownership of most federal lands with the exception of BLM properties. Related to this, a third ownership pattern is the distinct checkerboard land division between BLM, private, and state lands along the former Union Pacific rail line land grant. Most forested lands are federally owned (Green and Conner 1989). These

Figure 3. *Ownership by percent area*



Source: USDA Forest Service, Rocky Mountain Research Station, Forest Inventory and Analysis

Figure 4. *Forest types of Wyoming*

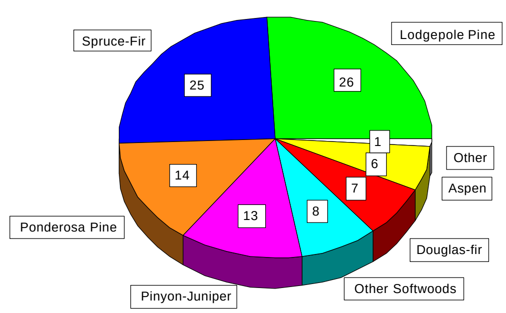


ownership patterns affect forest management and health due to a variety of political and personal land ownership objectives.

Forest Type

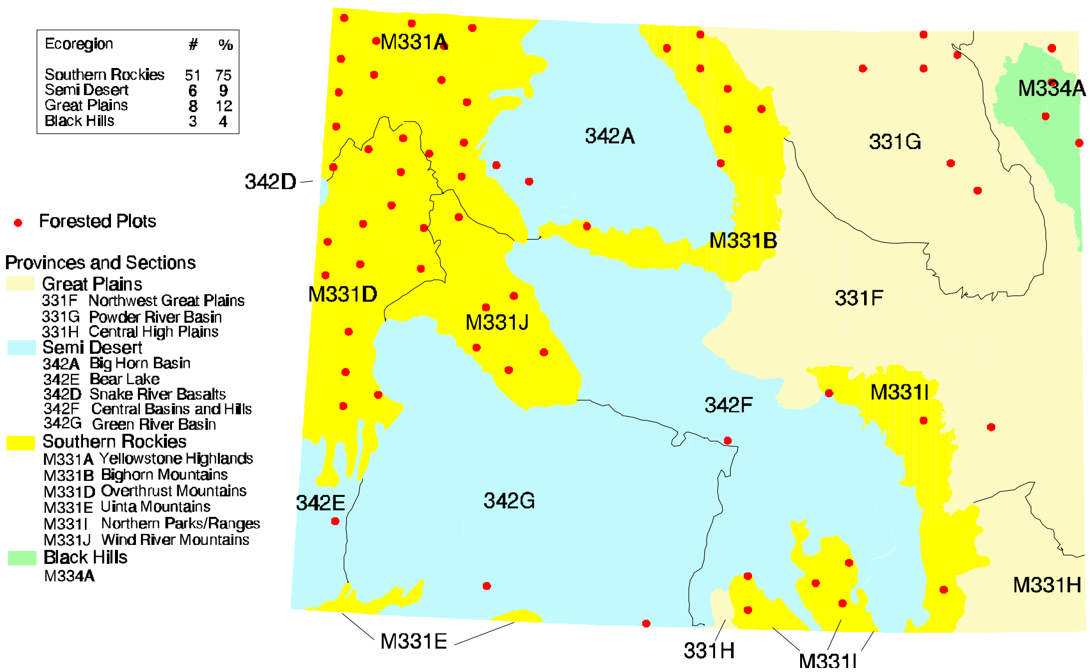
Figure 4 displays the general distribution of forest types in Wyoming using U.S. Biological Survey satellite data. Figure 5 displays the percentages of forest types. Forest type is defined as the dominant tree species present at a given location. Forest types are influenced by a number of factors including climate, soils, elevation, aspect, and natural or human disturbance. Satellite imagery and ground surveys may yield slightly different distributions of forest types based on

Figure 5. *Forest types by percent area*



Source: USDA Forest Service, Rocky Mountain Research Station, Forest Inventory and Analysis perspective and criteria used. Forest types are

Figure 6. Forested plots by ecoregion



represented at the state-scale by figure 4 but discussions of forest types based on plot data will use a more specific field-based definition. On FHM plots, crews evaluate forested stands for their species composition. Though forests often include multiple tree species, the species constituting the majority of the mature over-story is the forest type. For example, a forested stand comprised of 40 percent lodge-pole pine, 20 percent Engelmann spruce, 20 percent subalpine fir, and 20 percent aspen, is classified as a lodgepole pine forest type. Lodgepole pine is the most common forest type in Wyoming followed by spruce-fir and ponderosa pine.

Ecoregions

One mission of the FHM program is to describe forest conditions on all forested lands. The map of land ownership provides a helpful view; however, it seems practical to approach forest health issues using non-political, ecological land divisions to gain a more complete picture of forest conditions. Figure 6 depicts FHM plot locations and eco-region delineations for Wyoming. Bailey's (1995) Description of the Ecoregions of the United States is used here as a hierarchical framework for logically delineating ecological regions based on their unique combinations of physiography, soil type, potential vegetation, and climate. As FHM expands, reports on forest health conditions may cover entire ecoregions, irrespective of state boundaries. Ecoregion sections are included in this baseline report as reference to finer divisions which may be used in future FHM analysis at state, regional, and national scales.

The following descriptions focus on province-level ecoregions as described by Bailey (1995). Additional information on vegetation types was taken from Knight (1994).

Great Plains-Palouse Dry Steppe Province (Great Plains)

This province encompasses the majority of the eastern one-third of the state. Also known as the shortgrass/mixed-grass prairie or American steppe, the Great Plains province elevations range from 3,200 feet near the northeastern border to 6,000 feet at the foot of the Front Range. Rolling hills, badlands, and plains characterize the topography of this province. The lack of forested environments is due mainly to the rain shadow effect of the Rocky Mountains to the west. Evaporation exceeds precipitation during most of the growing season. Average annual precipitation is about 20 inches, mostly 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; forests are limited. Common grass and forb species include blue grama, buffalograss, needle-and-thread-grass, pricklypear cactus, and scarlet globemallow. Forested areas include scattered stands of ponderosa pine mixed with juniper and Douglas-fir along the ridges, and ponderosa pine and bur oak along the margins of the Black Hills. Riparian zones in this province are sporadically forested by linearly arranged cottonwood stands. Much of the Great Plains has been altered by agricultural and urban uses, and therefore may not reflect the native plant communities described for this province.

Intermountain Semidesert Province (Semidesert)

The Intermountain Semidesert province covers the largest portion of the state. This province includes valleys, also known as intermontane basins, which range in elevation from 6,000 to 8,000 feet. 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. Evaporation rates are high and wind is a nearly constant element.

The vegetation of the Semidesert province is composed primarily of sagebrush, greasewood, rabbitbrush, and a variety of bunch grasses. Riparian zones are lined with cottonwoods, shrub-form willows, and sedges. Forests are somewhat scarce. Limber pine and juniper are the most common trees of these high and dry basins, although lodgepole pine, Douglas-fir, and aspen may occupy relatively moist northerly aspects of Semidesert ranges.

<u>Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province</u> (Southern Rockies)

This province is composed of the major ranges of the Wyoming portion of the Rocky Mountains. More than surrounding states, the ranges of this province are widely separated by large intermontane basins. The highest peaks top 13,000 feet and the valley floors range from 5,500 to 7,000 feet. Climate is highly variable, depending on local topography. In general, valleys are warmer and drier, with annual precipitation of 15 to 25 inches per year. Higher mountain ranges are typically much cooler and annual precipitation often exceeds 40 inches. Much of the moisture comes as winter snow.

The flora of this region is also highly variable. Due to differences in elevation, aspect, soil types, rainfall, and evaporation rates, mountain vegetation resembles a large-scale mosaic of conifers, few hardwoods, and mixed shrubs and grasslands. This province represents the most forested portion of the state. Rocky Mountain forests are often described in terms of vegetation zones; with spruce, subalpine fir, and whitebark pine dominating the highest forested elevations; lodgepole pine, aspen, and Douglas-fir in the middle montane zone; and ponderosa pine, limber pine, and juniper defining the lowest forested zone. There are often exceptions to these zonal rules based on aspect and the occurrence of some less common forest types.

<u>Black Hills Coniferous Forest Province</u> (Black Hills)

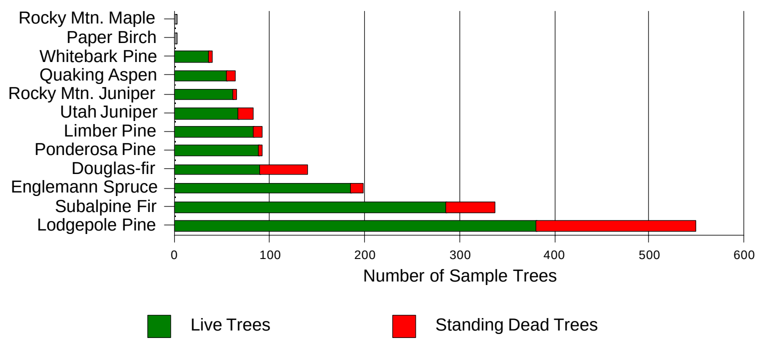
The Black Hills is a region of relatively low mountains averaging 3,000 to 7,000 feet in elevation. The province is divided by the Wyoming and South Dakota state line. Precipitation ranges from 15 to 26 inches, usually as winter and spring snow.

The dominant tree species is ponderosa pine, however, there are limited stands of white spruce and paper birch from the north; green ash, hackberry, American elm, and bur oak from the east; as well as other common western species like aspen and lodgepole pine.

Table 1. *Percent forest type by ecoregion*

	Great Plains	Southern Rockies	Semidesert	Black Hills
Juniper	20	40	40	--
Spruce-fir	--	100	--	--
Aspen	--	100	--	--
Lodgepole pine	--	94	6	--
Ponderosa pine	50	20	--	30
Oak	100	--	--	--
Douglas-fir	--	80	20	--
Limber pine	--	80	20	--

Figure 7. *Mature trees sampled in Wyoming*



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

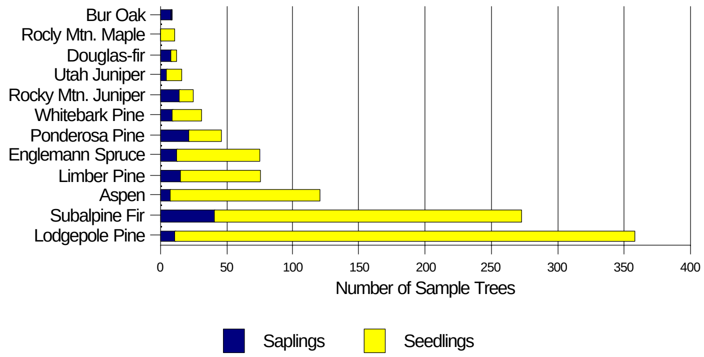
Fauna include elk, mule deer, white tail deer, bison, and pronghorn antelope. Lower elevations are dotted with open parklands of sagebrush and grass.

Plot and Tree Summary

Plots are selected systematically across all lands in Wyoming. The majority of potential plot locations in the state are non-forested (Appendix A). Appendix B provides break-downs of percent of forested plots sampled based on these standard FHM stand-level categories: forest type group, stand origin, stand size, stand age, seedlings per acre, snags per acre, and basal area per acre. FHM sampled 68 field locations in Wyoming that were either fully or partially forested. A small percentage of plots straddled more than one forest type; hence, there are more forest types recorded (70) than there are total plots. Table 1 presents a summary of major FHM plot forest types by ecoregion. Seventy-five per-cent of plots fell in the Southern Rockies ecoregion, and no spruce-fir or aspen plots were sampled outside this province. No forest types occur in all ecoregions of Wyoming.

Figure 7 describes the number of overstory trees tallied by species, and whether trees were alive or dead. There is a rough correlation between those species most commonly tallied and the prominent forest types in the state (figure 5). For example, lodgepole pine is the most common forest type displayed in figure 5 and this species was also the most commonly sampled tree as illustrated in figure 7. This correlation falls short with other species because they may be commonly tallied within other forest types. There are more spruce and subalpine fir tallied statewide than the forest type mapping (satellite imagery) suggests. Many dead lodgepole pine were sampled from burned trees still standing from the 1988 Yellowstone National Park fires and this accounts for the high ratio of dead-to-live lodgepole pines.

Figure 8. *Regeneration sampled in Wyoming*



*Saplings have diameters between 1.0 inches and 5.0 inches at breast height or root collar. Seedlings are less than 1.0 inches breast height or root collar and exceed 1.0 foot in height.

Figure 8 tallies understory species specifically showing the number of understory seedlings and saplings sampled by species. As with the most common tallied tree, the most seedlings tallied were lodgepole pine. These numbers relate to the huge amount of regeneration of lodgepole pine after the 1988 Yellowstone National Park fires. Subalpine fir and aspen also produced abundant regeneration numbers. The majority of these seedlings either do not survive to reach full tree size or mature in very dense stands, rarely growing beyond five to seven inches in diameter. Initial densities of these species will be substantially reduced due to limited light and water. Bur oak, Douglas-fir, and Rocky mountain juniper are the only species sampled showing saplings outnumbering seedlings. The ratio of seedlings to saplings in ponderosa pine is quite different. The regeneration of ponderosa pine is more evenly split between seedlings and saplings, suggesting greater survival from seedling to maturity.

Appendix C is a complete list of analytical variables measured on FHM plots. Variables measured include tree diameter, height, damages, seedling counts, soil texture, ozone bioindicators, and lichen species present.

Appendix D provides a complete tally of all tree damage measured on FHM plots by damage type. There is also a column showing the percentage of trees, by species, with no significant damage.

Appendix E addresses crown condition. Visual crown assessments are made to determine changes in crown conditions resulting from a variety of causal agents. Estimates of crown dieback, foliage transparency, and crown density were taken on field plots for all live trees greater than five inches diameter-at-breast-height to document crown health. Results show little impact on crown conditions statewide. However, long-term tracking of plots will provide a better understanding of how crown health reacts to changing conditions in the atmosphere and on the ground.

Appendix F lists the common and Latin species names of plants, animals, insects and diseases described in this report.

Considering land ownerships, forest types, ecoregions, and the initial plot and tree summary data, the variety and complexity of Wyoming's forests are evident. The forest resource, as presented thus far, is really a static view of the forested landscape of the state. However, we know that conditions change, sometimes rapidly, often gradually, based on many factors. Forest health issues described in the body of this report examine agents of change, whether human or natural, in the various forests of Wyoming.

Forest Health Issues

The forest health issues discussed throughout this report validate the dynamic nature of Wyoming's forests. Data came from many sources including aerial and ground surveys by state and federal scientists, and studies conducted by university and federal researchers. This section addresses forest health issues that are currently of primary concern in Wyoming. Forest cover changes in Wyoming are initially explained by three topics: (1) White pine blister rust incidence and severity, (2) riparian forest health, and (3) aspen decline. Next is a discussion of the primary insects and diseases that are significant in Wyoming's forests. Air quality information is the next topic, where emphasis is placed on tree crown evaluations, lichen sampling, and ozone bioindicators. Biodiversity, Wyoming's urban forests, and the expanding rural-urban-wildland interface are discussed last.

Forest Cover Change

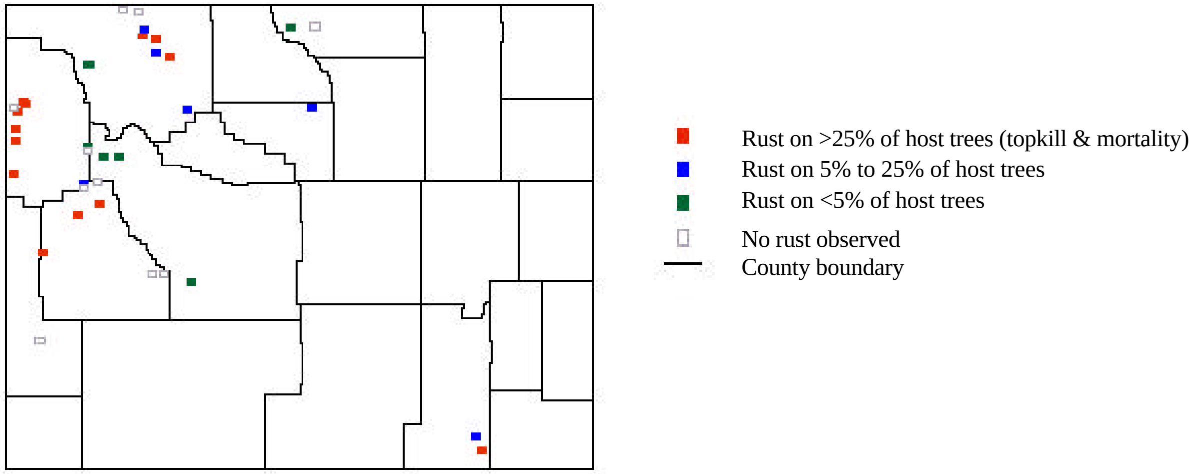
FHM is designed to assess forest cover change by documenting species composition, forest structure, and disturbance agents. This is done by tracking the species makeup as well as size, age, and relative dominance of all trees on a particular site. FHM describes the condition of individual trees by assessing growth, mortality, regeneration, damage, and estimates of crown conditions.

Forest cover change is commonly attributed to wildfire suppression, termination of traditional Native American burning practices, forest succession, flood control, and livestock grazing. Related disturbance cycles and introduction of exotic species, such as white pine blister rust and tamarisk, work in tandem with human disruptions to affect large-scale species change. Shifts in forest cover take place over a period of decades, or even centuries, and may not be readily observed by casual forest visitors. None-theless, cover changes have far-reaching effects on a forest's susceptibility to fire, insects, disease, soil erosion, and water evaporation and retention. Forest cover changes in Wyoming include loss of five-needled limber and whitebark pines, conversion of riparian forests by invasive species, and a decline in aspen.

White pine blister rust

White pine blister rust is an exotic disease introduced to western North America at Vancouver Island, Canada in 1910. The host species for this disease are all five-needled pines. Whitebark and limber pines are the species affected in Wyoming. The disease can kill both young and mature trees although younger trees are usually killed quicker. White pine blister rust coupled with mountain pine beetle recently produced extensive mortality in forests in northern Idaho and western Montana (Kendall and Arno 1990, Keane et al. 1994). High mortality from white

Figure 9. *White pine blister rust: incidence and severity*



pine blister rust has not yet developed in Wyoming.

Whitebark and limber pines are of little economic value but have considerable importance ecologically. Whitebark pine seed is an important food source for Clark's nutcracker, grizzly bears, and red squirrels in the Greater Yellowstone Area (Kendall and Arno 1990). These animals also serve as primary agents of regeneration by dispersing seeds through their consumption and excretion, often miles from the seed source. Whitebark and limber pines have differing water relations than associated species such as subalpine fir and Engelmann spruce. These differences affect the amount of water produced from a watershed (Moore and McCaughey 1997). Both whitebark and limber pine grow in high elevation areas that are common in wilderness, parks, and other areas sought for public recreation. Whitebark pine has a striking aesthetic appearance and its loss could affect recreational experiences (McCool and Freidmund 2000).

Figure 9 displays survey results assessing the amount and distribution of white pine blister rust. The disease is present at most white pine locations in western Wyoming, although this incidence is not enough to be detected by FHM plots currently. Smith and Hoffman (1998) found the disease had only moved 30 miles south over a 30-year period in western Wyoming but the intensity and severity of infections had increased. The cooler and drier climates in Wyoming compared to the west coast and the northern Rockies seem to result in a slower rate of spread. Knowledge of spread rates and implications for managing these pines in eastern Wyoming is unclear and needs further investigation. Research on whitebark pine has shown some natural resistance where rust pressure has been high (Hoff et al. 2000). This provides some hope for maintaining this species and its role in high elevation ecosystems.

Whitebark pine has also been experiencing decline due to advanced succession of shade-tolerant species (Keane and Arno 1993). Whitebark pine has a unique set of ecological functions and reproductive strategies, but the lack of fire in this region, sometimes working in concert with white pine blister rust, is the predominant reason for the decline of this species.

Riparian forest health

Riparian forests are important ecologically and play significant roles in human conditions. Rivers, intermittent streams, ponds, and associated vegetation are critical to the survival of most animals due to Wyoming's arid climate. Most animals rely on riparian areas for water, food, and cover. The woody vegetation provides nesting habitat for cavity-nesting birds and bald eagles and foraging habitat for deer, moose, raccoons, birds, and many smaller mammals. Because of the greater moisture in riparian areas, riparian forests support a greater diversity of life than the surrounding uplands. Riparian areas also influence where cities are built and where humans choose to recreate. The condition of the riparian vegetation along watercourses influences the water clarity, water volume, temperature, speed, and depth of the water course. These qualities in turn influence drinking water quality, fish habitat, and flood severity.

By examining data from various state and federal sources on river systems throughout Wyoming, a general picture of riparian forest health can be formed. A big concern in the Bighorn basin is the proliferation of tamarisk and Russian olive along waterways (Walford 1996). These exotics are replacing native willows and cottonwoods along most of the watercourses in the basin. As a result, these habitats do not support the same diversity of wildlife as native vegetation. Other riparian areas show large gradual changes in tree age classes due to changes in water flow where very few cottonwoods younger than 50 years can be found (Jones and Walford 1995). If regeneration continues to be a problem, these areas will slowly become nonforested and plant and animal communities associated with these forests will change.

Working with other agencies and organizations, FHM may illuminate and clarify the condition of riparian forests. However, riparian forests are under-sampled by the current FHM grid largely because of their linear nature. Improved sampling methods are being evaluated to improve our understanding of riparian forest dynamics. By gathering data on tree size, tree condition, presence of exotic species, lichen diversity and other indicators, FHM can help alert land managers to the changing conditions of riparian forests.

<u>Aspen decline</u>

Aspen cover throughout the Interior West appears to be declining (Brown 1995, Bartos and Campbell 1998, Rogers et al. 1998, Rogers 2001). Aspen, the predominant hard-wood of this region, supports a unique range of understory plants and lichens which would likely decline with the change in overstory. Aspen also reproduces abundantly and rapidly after fire. Aspen regenerate primarily by suckering from underground rootstock. An exception to regeneration by suckering has been documented in Yellowstone National Park where *seeding* was prompted by large-scale burns during the summer of 1988 (Romme et al. 1997). Although 1988 was an exceptional fire year, over the past 150 years a reduction in widespread burning has led to a significant drop in aspen regeneration in Wyoming and regionally. Moreover, when no disturbance takes place, older aspen (80 to150 years) are eventually replaced by competing conifers. A preliminary look at FHM data regionally, including Wyoming plots, shows that the average age of aspen forest types is 68 years, while the average age of non-aspen forest type stands (with aspen present) is 89 years. Finally, older aspen stands are more susceptible to cankers, conks, and decays in the bole. Over half of all aspen trees recorded on FHM plots were damaged (Appendix D) further speeding the decline of aging stands.

Long-term FHM data sets will provide a reliable source for monitoring tree cover changes over time. FHM will evaluate these species fluctuations as forest plots are remeasured and aerial survey data is gathered.

Insects and Diseases

Forest insects and diseases are a natural part of forests and are partially responsible for forest renewal. Most insects and diseases are native, evolved with their hosts, and are considered essential components of a healthy forest. They play roles as decomposers and nutrient recyclers, serving to continuously rejuvenate forest soils. Insect and disease activity is often interpreted as harmful when they alter human expectations of the forest. This happens when insect and disease activity reaches noticeable levels in areas of high economic or aesthetic value. Determining when insect and disease incidences are beyond a normal or healthy range can be difficult. However, long-term monitoring will help calibrate these disturbance events over time.

Insect and disease activity in Wyoming is detected through aerial and ground surveys. Aerial detection maps are produced annually by state and federal surveyors and are used as a management tool by landowners. The following insects and diseases have been contributing to large-scale tree decline and mortality over the last three to seven years.

Dwarf mistletoes

Dwarf mistletoe is a parasitic seed plant and is common in Wyoming's pine stands, particularly lodgepole pine. Different species of dwarf mistletoe infect ponderosa pine, lodgepole pine, and Douglas-fir. Lodgepole pine dwarf mistletoe occurs in 30 to 64 percent of the stands in the three national forests east of the Continental Divide (Johnson et al. 1978; Johnson et al. 1979). West of the Continental Divide, dwarf mistletoe infected 67 percent of lodgepole pine and 17 percent of Douglas-fir (Hoffman and Hobbs 1979).

Dwarf mistletoes can cause growth loss and reduced vigor in trees rendering them more susceptible to other mortality agents. Mortality in stands with dwarf mistletoe can increase the amount of down woody debris, contributing to wildfire hazard. Dwarf mistletoes are also beneficial to many wildlife species. The brooms and down wood provide shelter and food for many bird, mammal, insect, and arachnid species (Hawksworth and Wiens 1996).

Comandra Blister Rust

Comandra blister rust is one of the most destructive diseases of lodgepole pine in Wyoming. Comandra blister rust is a native rust fungus that requires two different hosts to complete its life cycle: bastard toadflax and hard pines such as lodgepole and ponderosa (McMillin et al. 2000). This rust fungus frequently occurs in dwarf mistletoe infected stands although it is unknown if either disease makes trees more susceptible to infection by the other. Comandra blister rust produces girdling cankers on stems of pine trees and results in top killed stems. Large amounts of deadfall from infected trees increase fuel loading and potential for wildfire in these stands.

Recent ground surveys conducted on the Bighorn, Medicine Bow, and Shoshone National Forests indicate that half of the basal area of lodgepole pine is infected. In addition, 85 percent of these trees had dead tops, so this disease often causes a "thinning from above." The rust may delay or even prevent tree maturation.

Douglas-fir Beetle

Douglas-fir beetle infests and kills Douglas-fir throughout its range in Wyoming. Typically, the beetle reproduces in scattered trees that are highly stressed from drought, fire, root rot, defoliation from western spruce budworm, or windfall. If enough suitable host material is present, beetles can build up in these trees and move to infest nearby green trees. For example, the 1988 Yellowstone National Park fires burned onto neighboring national forest lands killing and scorching a large number of trees. Douglas-fir beetle populations expanded in these scorched trees and began attacking neighboring green trees. Since these fires, populations of the beetle in this area have been extremely high, with high levels of tree mortality occurring nearly every year. Beetle-caused mortality decreased in 1997 in the Sunlight Basin area, but has since increased in this area and along the North Fork of the Shoshone River. Between 1998 and 1999, tree mortality increased from 1,680 trees killed by Douglas-fir beetle on 2,383 acres to 14,450 trees killed on 5,791 acres (Johnson and McMillin 2000). Periodic infestations of Douglas-fir beetle have been documented in the Bighorn Mountains.

Mountain pine beetle

Mountain pine beetle is a native bark beetle that attacks and kills lodgepole, ponderosa, whitebark, and limber pines in Wyoming. Currently, mountain pine beetle populations are increasing along the eastern slope of the Bighorn Mountains and along the Snake River in the Bridger-Teton National Forest.

Subalpine fir decline

Currently there is widespread subalpine fir decline occurring throughout the Rocky Mountains of Wyoming. Large areas of sub-alpine fir mortality have been observed on the Bighorn, Shoshone, Bridger-Teton, and Medicine Bow National Forests during recent aerial surveys. The exact causes have not been defined, but western balsam bark beetle, fir engraver beetle, and Armillaria and Annosus root diseases are known to play a role in this phenomenon. Western balsam bark beetle is known to cause tree mortality in other western states. Armillaria root rots generally weaken hosts, increasing their susceptibility to insects, windthrow, and other diseases. Many of the stands affected by this decline are very dense. Because western balsam bark beetle, Armillaria, and Annosus are not often aggressive killers, they may be acting as natural thinning agents in over-crowded stands.

Air Quality

The Forest Health Monitoring program originated largely from a reaction to the mid-1980's concern about the effects of industrial pollution, or "acid rain," on the forests of eastern North America and Europe (Burkman and Hertel 1992). Tree crown evaluations, damage detection, lichen sampling, and ozone biomonitoring may be applied to air quality analysis. Lichen sampling and ozone bio-monitoring link pollutants to forest health although symptoms of air quality change may show up in both crown and damage data.

Ozone biomonitoring involves locating ozone sensitive plant species and assessing their damage specifically from atmospheric ozone. Atmospheric ozone is a chemical pollutant hazardous to the earth's biosphere. This “manufactured" ozone results primarily from excessive automotive exhaust, mostly near large urban areas. Stratospheric ozone is natural, protecting the earth from the sun’s ultraviolet rays. Ozone damage to forests has been documented in southern California for decades (Miller and Millican 1971). In Wyoming, FHM field crews have located potentially sensitive plants near most plots to assess long-term change. Thus far, no damage from atmospheric ozone has been detected in the state.

Numerous studies have documented the relationship between air quality and lichen communities in forested areas (McCune 1997). Lichens utilize nutrients in the air to sustain themselves and to regenerate. Poor air quality leads to a loss of some sensitive species and an increase in species tolerant of certain chemical pollutants. Field crews sample the diversity of species at each forested location. Statewide monitoring of lichen species and their abundance on plots permits early detection of pollution effects. Preliminary analysis of Wyoming lichen data has recently been completed (Neitlich et al. 1999). Initial results are tentative since a gradient model for the state has not been developed, and no trend information is available to evaluate changes over time. Nevertheless, data does indicate a depression

of lichen species diversity in the southern portion of the state and a preliminary gradient analysis shows a greater relative abundance of pollution-tolerant species. This information is consistent with FHM information reported for areas around Steamboat Springs and Denver, Colorado (McCune 1997).

Other sources of information may be available for localized areas in Wyoming. St. Clair (1993) sampled lichens in the Bridger Wilderness for species abundance and chemical properties. Results showed floristic diversity with no visual signs of pollution sensitive species. The chemical analysis indicated elevated levels of lead, zinc, and manganese. These levels were above concentrations for most of the Rocky Mountain region although quite low compared to more heavily polluted areas.

The real value of all of these baseline measurements, both local and statewide, will be a long-term effort to consistently assess the effects of atmospheric pollutants on forest communities. Today's data will give us a benchmark to assess future changes.

Biodiversity

Biodiversity is a measure of the variety of living organisms in a particular area and serves as an important indicator of ecosystem function. Recent reports suggest there is a decrease both regionally and nationally in diversity (Langner and Flather 1994). FHM is designed to monitor change in biotic diversity over time as an indicator of ecosystem health. Sustained healthy habitats for plants and animals are an important measure of all living communities, including forests. Forests that are structurally and floristically diverse appear more resilient to natural and human-related disturbances, such as fires, windstorms, insect and disease infestations, and logging related impacts (Stapanian et al. 1997).

Diversity is commonly measured at genetic, species, and community levels. FHM is most concerned with community diversity, though the underlying importance of species and genetic diversity is recognized. There is considerable diversity in Wyoming but the effects of human activity and changes over time on diversity are not well understood. A brief look at forest fragmentation and exotics will offer some explanation.

Forest fragmentation is a measure of forest health affecting community diversity. Fragmented forests display a greater number of landscape "patches." Increased forest fragmentation results in shrinking patch sizes, which negatively affects interior-dwelling wildlife species. Increased fragmentation also results in an increase in forest-edge habitat favoring some species, such as deer and elk. A recent study done in southeastern Wyoming suggests that road building may have a greater overall impact on forest fragmentation than clearcut logging (Reed et al. 1996).

Introduction of exotic species into Interior West ecosystems also seems to be affecting biodiversity over time. Whether introductions are accidental or intentional, exotic species of plants, animals, and diseases are spreading rapidly through many forests in Wyoming. There are many exotic plants invading forested and adjacent non-forested zones. Human travel and livestock grazing are two key factors contributing to exotic plant invasions. The dominance of leafy spurge over much of the rangeland in the state is slowly succumbing to the work of several introduced biological control agents. But just as it has taken decades for leafy spurge to become so dominant, so it is taking decades to reclaim the rangeland with native grasses.

FHM will assess human impacts on biodiversity by utilizing systematic plot measurements in combination with pertinent studies conducted by others. As part of our current protocol, field crews note recent natural and human disturbances in sample areas. Documentation of plot disturbances can be classified and compared to the number and type of plant species found on plots as an indicator of human effects on species diversity (Stapanian et al. 1997). FHM will use soil sampling and erosion data, in part, to document how recent disturbance has affected basic soil properties. Significant soil alteration can affect the types and richness of communities that can be supported.

Urban Forests

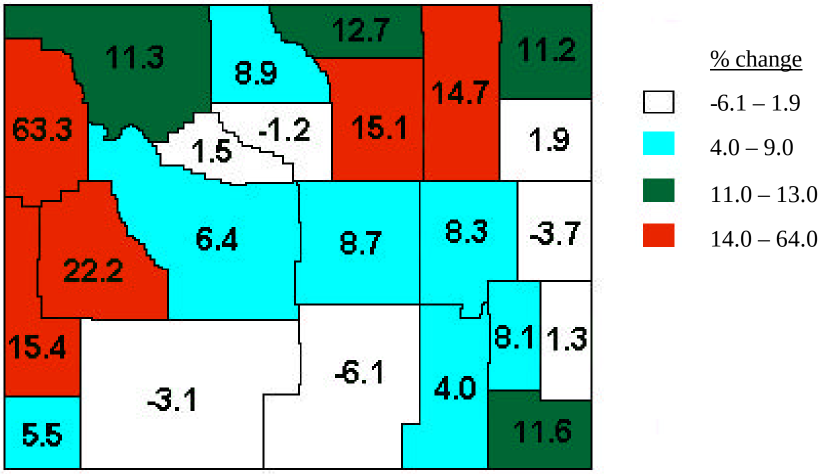
Urban forests have a profound effect on our quality of life. Trees in cities moderate wind, heat, cold, and other weather effects and beautify the areas we see everyday. Wyoming's urban forests are particularly important because they represent the only forests in some areas. Because each urban tree provides a variety of benefits, these trees are very valuable. The 108,000 public trees recently inventoried in 37 communities in Wyoming have an estimated value of $115,313,827 (Wyoming State Forestry Division 1991-1996). Monitoring the health of urban forests provides a measure of the health of the environment most Americans inhabit. Monitoring enables managers to prevent catastrophic tree problems.

Thousands of community trees, now reaching maturity, were planted during the development of Wyoming's cities and towns (Wyoming State Forestry Division 1991). Wyoming's high elevation, arid climate, and persistent wind present formidable challenges in urban forestry establishment and maintenance. Wyoming's urban forests lack the diversity to resist weather and pest impacts. Nearly one in five street trees are cottonwoods while just three species (cottonwood, blue spruce, and green ash) comprise 44 percent of street trees in Wyoming (Wyoming State Forestry Division 1991-1996). Any natural disaster or insect or disease problem targeting any of these three species would have a devastating impact on most Wyoming towns. Long-term monitoring of urban forest species, age diversity, and the presence of insects and pathogens can yield early indications of potential problems. Although urban forests are not sampled in the current FHM program, sampling methods to address urban areas are currently being evaluated.

Rural-Urban-Wildland Interface

The rural-urban-wildland interface represents rural and urban areas where

__Figure 10__. Percent change in population for Wyoming counties: 1990 to 2000



Source: Wyoming Department of Administration and Information, Division of Economic Analysis

structures or other human developments meet or intermingle with undeveloped wildland or vegetative fuels. In recent decades, Wyoming has seen an increase in development in and near forested lands. Data from the 1990 Census and subsequent updates conducted by the U.S. Census Bureau indicate the state population is increasing. As figure 10 illustrates, most counties showing population increases are those containing or adjoining National Forests and National Parks. This is particularly evident in western Wyoming where the three fastest growing counties are located. The Bridger-Teton and Shoshone National Forests as well as the Grand Teton and Yellowstone National Parks are located in this area.

People are relocating for a variety of reasons including employment opportunities, building larger homes, and the availability of open space and recreation. Growth in the rural-urban-wildland interface affects the diversity, beauty, and health of the surrounding landscape and will undoubtedly provide considerable challenges in the future.

Summary

Forest Health Monitoring began in Wyoming in 1995. Every five years, a complete remeasurement cycle will be completed. This report provides the first snapshot of forest conditions as measured by the same set of indicators in all types of forests statewide. Long-term data collection will provide a series of these snapshots. A comparison of these snapshots will provide an indication of forest condition trends. As data gathering continues, much will be learned about how these forests function and how they change.

Current monitoring reveals several changes occurring in Wyoming's forests. Limber pine, whitebark pine, cottonwood, aspen, and subalpine fir appear to be declining due to one or more of the following reasons: changes in fire frequency, changes in water use, exotic diseases, and competition from exotic plants. Road building may be impacting the biological diversity of many forests. Lack of tree-species diversity in Wyoming's urban forests puts them at risk

from a single insect or disease.

This report utilizes many sources of information in an attempt to present an overview of Wyoming forest health. Sources include FHM plot data, aerial and ground surveys by State and federal foresters, and studies conducted by university and federal researchers. A state synopsis of current issues is available on the internet in the Forest Health Highlights at the US Forest Service's National Forest Health Monitoring home page: http://www.na.fs.fed.us/spfo/fhm. For more information, access to data, or for answers to specific questions, see Appendix G for a complete list of contacts.

References

Anonymous. 1995. Sustaining the World's forests: The Santiago Agreement. J. of Forestry 93:18-21.

Bailey, R.G. 1995. Descriptions of the ecoregions of the United States. (2nd ed. rev. and expanded). USDA Forest Service, Washington, DC. Misc. Publ. No. 1391.

Bartos, D. and R. Campbell. 1998. Decline of quaking aspen in the Interior West - examples from Utah. Rangelands 20(1):17-24.

Brown, M. 1995. Aspen decline in the inland Northwest: a review of some relevant literature. Unpublished report. Copies filed at: USDA Forest Service, Pacific Northwest Research Station and the Smithsonian Institution.

Burkman, W. and G. Hertel. 1992. Forest Health Monitoring: a national program to detect, evaluate, and understand change. J. of Forestry 90(9):26-27.

Forest Inventory and Analysis National Core Field Guide. February 2000. Volume 1: Field Data Collection Procedures For Phase 2 Plots – Version 1.4. USDA Forest Service. 172 p.

Green, A.W. and R.C. Conner. 1989. Forests in Wyoming. Resource Bulletin INT-61. USDA Forest Service, Intermountain Research Station, Ogden, Utah. 91 p.

Hawksworth, F.G. and D. Wiens. 1996. Dwarf Mistletoes: Biology, pathology, and systematics. USDA Forest Service. Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. Agriculture Handbook 709. 410 p.

Hoff, R. J., R. E. Keane, D. E. Ferguson, and G. I. McDonald. 2000 in preparation. Strategies for managing whitebark pine in the presence of white pine blister rust. "Restoring Whitebark Pine Ecosystems Proceedings September 9-12, 1998. Island Press.

Hoffman, J.T. and L.G. Hobbs. 1979. Dwarf Mistletoe Loss Assessment Survey in Region 4, 1978. USDA Forest Service. State and Private Forestry, Ogden, Utah. R-4-79-4.

Johnson, D.W., F.G. Hawksworth, and D.B. Drummond. 1978. 1977 Dwarf Mistletoe Loss Assessment Survey: Medicine Bow National Forest, Wyoming. USDA Forest Service. Forest Insect and Disease Management. Methods Application Group. Report 78-1. 6 p.

Johnson, D.W., F.G. Hawksworth, and D.B. Drummond. 1979. 1978 Dwarf Mistletoe Loss Assessment Survey: Bighorn and Shoshone National Forests, Wyoming. USDA Forest Service. Forest Insect and Disease Management. Methods Application Group. Report 79-3. 8 p.

Johnson, E. and J. McMillin. 2000. Forest Health Monitoring Aerial Survey. Rocky Mountain Region. 3410 RCSC-00-03.

Jones, G. P. and G. M. Walford. 1995. Major Riparian Vegetation Types of Eastern Wyoming - A report submitted to the Wyoming Department of Environmental Quality, Water Quality Division by Wyoming Natural Diversity Database (The Nature Conservancy) 1604 Grand Avenue, Laramie, Wyoming 82070. Grant #9-01136.

Keane, R.E., P. Morgan, and J.P. Menakis. 1994. Landscape assessment of the decline of whitebark pine (Pinus albicaulis) in the Bob Marshall Wilderness Complex, Montana, USA. Northwest Science 68 (3):213-229.

Keane, R. and S. Arno. 1993. Rapid decline of whitebark pine in western Montana: evidence from 20-year remeasurements. Western Journal of Applied Forestry, Vol. 8, No. 2, p. 24-37.

Kendall, K. and S. Arno. 1990. Whitebark pine: an important but endangered wildlife resource. *In*: Proceedings of the symposium: Whitebark pine ecosystems: ecology and management of a high mountain resource. March 29-31, 1989, Bozeman, Montana, USA. USDA Forest Service, Intermountain Research Station, Ogden, Utah, Gen. Tech. Rep. INT-270, p. 264-274.

Knight, D. 1994. Mountains and Plains: the ecology of Wyoming landscapes. Yale University Press, New Haven and London. 338 p.

Langner, L. and C. Flather. 1994. Biological diversity: status and trends in the United States. Gen. Tech. Report RM-244. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 24 p.

McCool, S.F. and Freidmund, W. 2000. The diminished landscape: aesthetic and recreational consequences: Restoring Whitebark Pine Ecosystems Proceedings, September 9-12, 1998. Island Press.

McCune, B. 1997. FHM Lichen Community Results from Colorado: a Preliminary Summary. Oregon State University. Corvallis, OR. 43 p.

McMillin, J., J. Harris, and K. Allen. 2000. Insect and Disease Survey of the Bighorn National Forest. Biological Evaluation R2-00-04. 27 p.

Miller, P. and Millican, A. 1971. Extent of oxidant air pollution damage to some pines and other conifers in California. Plant Disease Reporter 55(6):555.

Moore, C.A. and W. W. McCaughey. 1997. Snow accumulation under various forest stand densities at Tenderfoot Creek Experimental Forest, Montana, USA. 66th Western Snow Conference, May 5-8, 1997, Banff, Alberta, Canada.

Neitlich, P., Hasselback, L., Szewczak, S., and Rogers, P. 1999. FHM lichen community results from Wyoming, 1997: a preliminary summary. A report to the USDA Forest Service, Rocky Mountain Research Station, Forest Health Monitoring Program. White Mountain Research Station, Bishop, CA. 27 p.

Reed, R., J. Johnson-Barnard, and W. Baker. 1996. Contribution of Roads to Forest Fragmentation in the Rocky Mountains. Conservation Biology 10(4):1098-1106.

Rogers, P., M. Schomaker, W. McLain, and S. Johnson. 1998. Colorado Forest Health Report 1992-95: a baseline assessment. USDA Forest Service, Rocky Mountain Research Station and Rocky Mountain Region; and Colorado State Forest Service. 44 p.

Rogers, P. 2001. Using forest health monitoring to assess aspen forest cover change in the Southern Rockies ecoregion. Forest ecology and management (in press).

Romme, W., M. Turner, R. Gardner, W. Hargrove, G. Tuskan, D. Despain, and R. Renkin. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides* Michx.) following the 1988 Yellowstone fires. Natural Areas Journal 17:17-25.

St. Clair, L.L. and Newberry, C.C. 1993. Lichen Biomonitoring Program and Air Quality Baseline in Selected Sites of the Bridger Wilderness Area, Bridger-Teton National Forest. Final Report. Bridger-Teton N.F. 52 p.

Smith, J. and J. Hoffman. 1998. Status of white pine blister rust in intermountain region white pines. Intermountain Region, State and Private Forestry Report No. 98-02. 24 p.

Stapanian, M., D. Cassell, and S. Cline. 1997. Regional patterns of local diversity of trees: associations with anthropogenic disturbance. Forest Ecology and Management 93(1-2):33-44.

Stolte, K. 1997. National Technical Report on Forest Health. USDA Forest Service, Asheville, North Carolina. Administrative Report.

Walford, G.M. 1996. Statewide Classification of Riparian and Wetland Dominance Types and Plant Communities - Bighorn Basin Segment. A report submitted to the Wyoming Department of Environmental Quality, Water Quality Division by Wyoming Natural Diversity Database (The Nature Conservancy) 1604 Grand Avenue, Laramie, Wyoming 82070. Cooperative Agreement #WET04, Grant #CD998066-01-0.

Wyoming State Forestry Division, Statewide Urban Forest Inventories 1991-1996, Cheyenne, WY.

Wyoming State Forestry Division. 1991. Wyoming State Forest Resource Program 1999-2000, Executive Summary. Cheyenne, WY.

Appendix A

Plot Distribution in the Interior West by State and Land Use

(totals are in fractions of plots)

Land Use Category	Region totals	Wyoming totals	Colorado totals	Idaho totals
Timberland	271.66	**53.89**	93.79	123.98
Woodland	58.38	**8.25**	41.85	8.28
Inaccessible Forest	23.00	**6.25**	11.75	5.00
Non-Forest	778.96	**324.61**	266.61	187.74
Totals	1132.00	**393.00**	414.00	325.00

Appendix B

Distribution of forest land (% forested plots) in Wyoming by stand-level categories, 1997

Stand-level category	% of plots
Forest Type Group	
Douglas-fir	6.84
Ponderosa Pine	13.97
Lodgepole Pine	25.69
Spruce/Fir	25.53
5-Needle Pines	8.05
Aspen	5.85
Miscellaneous Hardwood	0.80
Juniper	13.27
Stand Origin	
Natural	100.00
Planted	0.00
Stand Size	
Sawtimber	59.65
Poletimber	27.87
Seedling/Sapling	12.47
Non-Stocked	0.00
Stand Age	
0 - 50	15.31
51 - 100	39.38
101 - 150	30.00
151 - 200	11.60
201 - 250	3.71

Stand-level category	% of plots
Seedlings/Acre	
0 - 999	71.89
1000 - 1999	13.60
2000 - 2999	3.22
3000 - 3999	2.42
4000 - 4999	3.22
5000 - 5999	2.42
6000+	3.22
Snags/Acre	
0	38.73
1 - 24	28.16
25 - 49	19.16
50 - 74	1.82
75 - 99	4.83
100+	7.29
Basal Area/Acre	
0 - 39	38.91
40 - 79	16.74
80 - 119	11.18
120 - 159	17.33
160+	15.84

Appendix C

List of analytical variables from FHM plots

Variable name	Data type*	Variable name	Data type*
MENSURATION, CROWNS, DAMAGE			
Plot level			
County number	code	Current plot status	code
Elevation	num.	FHM region	code
Hexagon (location number)	num.	Measurement type	code
Overlap	code	Old plot status	code
Panel	code	Quality assurance status	code
Plot mensuration year	num.	Plot number	num.
Plot status	code	Plot type	code
Project	code	State	code
Condition level			
Condition class	num.	Condition class change	code
Density check	code	Disturbance year 1	num.
Disturbance year 2	num.	Disturbance year 3	num.
Forest type	code	Land Use class	code
Past disturbance 1	code	Past disturbance 2	code
Past disturbance 3	code	Previous stand age	num.
Stand age	num.	Stand origin	code
Stand size	code		
Tree level (trees, saplings, site trees)			
Basal area factor (site tree)	num.	Cause of death	code
Competing basal area	num.	Crown density	num.
Crown diameter (mean)	num.	Crown dieback	num.
Crown light exposure	code	Crown position	code
Crown vigor (saplings)	code	Current tree history	code
DBH(diameter breast height)	num	DRC (diameter root collar)	num.
Damage 1 - 3	code	Description (tree notes)	alpha.
Foliage transparency	num.	Ground year	num.
Live crown ratio	num.	Location (damage) 1-3	code
Mortality year	num	Nonforest year	num.
Old DBH	num.	Old DRC (woodland)	num.
Old stem count (woodland)	num.	Old tree history	code
Severity (damage)	code	Species	code
Stem count (woodland)	num	Tree age at DBH	num.
Tree height	num.		
Understory cover and seedlings			
Crown light exposure	code	Crown position	code
Crown vigor	code	Percent Ferns	num.
Percent Herbs	num.	Percent Moss	num.
Percent seedlings	num.	Percent Shrubs	num.
Seedling count	num.	Species	code

*Data types: num. = numeric value code = numeric code alpha. = letters or words

Appendix C (continued)

Variable name	Data type*	Variable name	Data type*
SOILS (soil sampling, erosion)			
A texture	code	A thickness (N,S,E,W)	num.
Depth to subsoil	num.	Litter decomposition	alpha.
Litter depth 1-3	num.	O thickness (N,S,E,W)	num.
Percent bare (mineral) soil	num.	Percent litter cover	num.
Percent plant cover	num.	Slope length	num.
Underlying texture	code		
OZONE BIOINDICATORS			
Amount of injury	code	Bio site availability	code
Bio site disturbance	code	Bio site status	code
First species	code	Number of plants 1-3	num.
Plot moisture	code	Plot size	code
Second species	code	Severity of injury	code
Soil depth	code	Soil drainage	code
Third species	code		
LICHEN COMMUNITIES			
Species	alpha.	Abundance	code

*Data types: num. = numeric value code = numeric code alpha. = letters or words

Appendix D

Distribution of damage types by species for trees (5" dbh and larger) on Wyoming plots

	trees with no damage (%)	# damages recorded*	cankers	conks and decays	open wounds	resinosis	broken bole	brooms on bole	broken roots	loss of apic. dominance	broken branches	excess. branching	damaged shoots	discolored foliage	other
Softwoods															
Douglas-fir	76 (85)	15	5	1	1	0	0	0	0	8	0	0	0	0	0
Ponderosa Pine	74 (84)	19	0	2	11	0	0	0	0	4	1	1	0	0	0
Lodgepole Pine	246 (65)	188	11	41	62	1	0	0	0	58	4	11	0	0	0
Subalpine Fir	227 (78)	73	17	12	12	0	2	1	0	20	8	0	0	1	0
Engelmann Spruce	162 (87)	25	3	4	7	0	0	0	0	7	4	0	0	0	0
Other Softwoods	85 (71)	46	0	13	9	0	0	0	0	15	5	0	1	2	1
Softwood Woodland	90 (70)	65	0	20	8	0	0	0	0	6	24	1	1	5	0
Subtotal, Softwoods	960 (75)	431	36	93	110	1	2	1	0	118	46	13	2	8	1
Hardwoods															
Aspen	24 (44)	37	12	20	2	0	0	0	0	1	2	0	0	0	0
Cottonwood	0 (0)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Hardwoods	0 (0)	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Hardwood Woodland	1 (100)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Subtotal, Hardwoods	25 (44)	38	12	20	2	0	0	0	0	1	3	0	0	0	0
Totals	985 (74)	469	48	113	112	1	2	1	0	119	49	13	2	8	1

* # of damages recorded may include multiple damages, up to 3, for individual trees

Appendix E

Visual Crown Ratings

Visual crown assessments are made to determine changes in crown conditions resulting from a variety of causal agents. 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 measures show that crowns have not been severely impacted statewide (facing page). However, long-term tracking of plots will give us a better reading of how crown health reacts to changing conditions in the atmosphere and on the ground. More detailed discussion of each crown variable is presented below.

CROWN DIEBACK

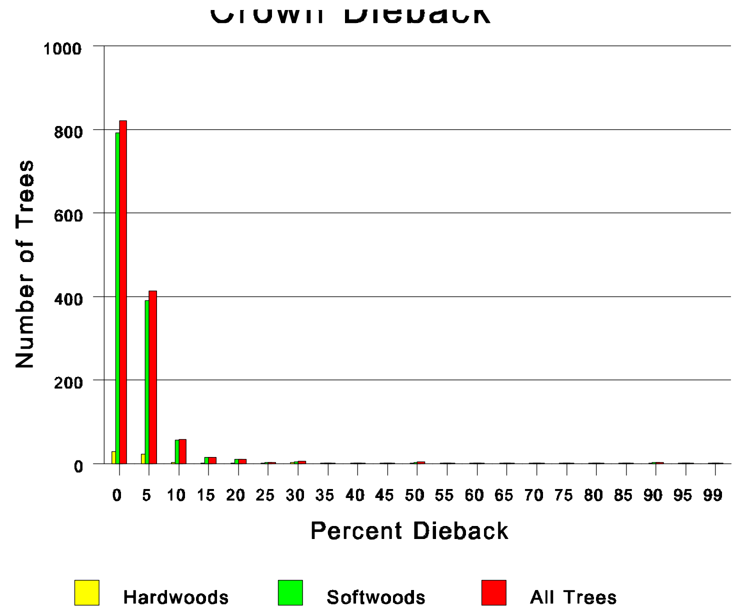
Dieback is a measure of percent of the tree crown that has died from the branch tips inward, toward the center of the crown. Crown dieback can be caused by insects, disease, and weather related injuries. The graph shows that most of the trees sampled in Wyoming have very little dieback. Hardwood and 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.

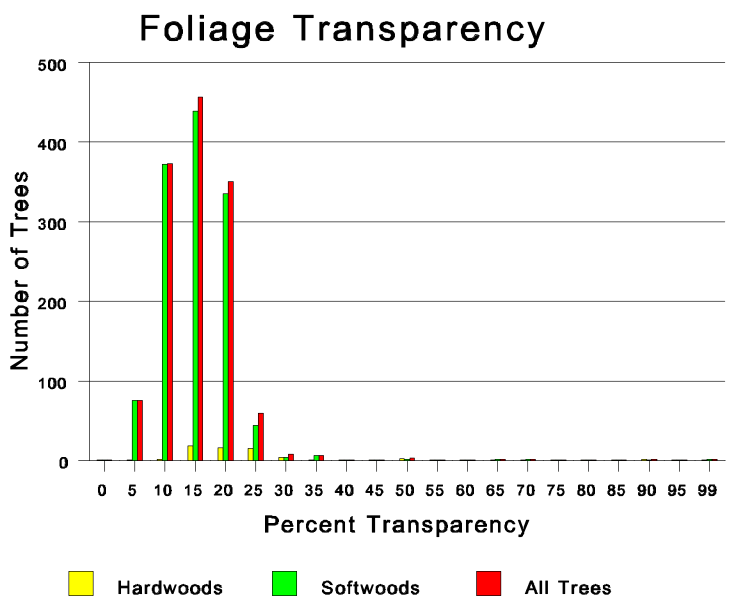
FOLIAGE TRANSPARENCY

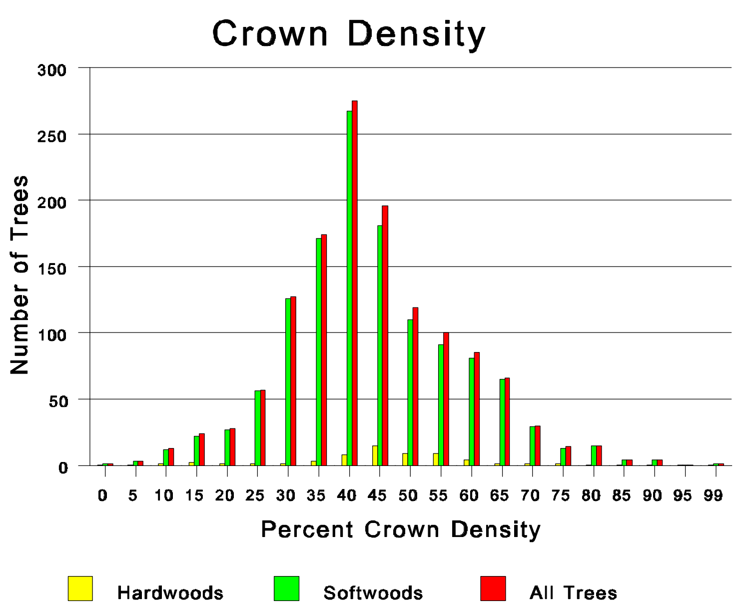
Transparency is the percent of light that passes through the foliated portion of the crown, excluding tree branches and main stems. A tree with a rating of "0" or "5" percent transparency allows either no light, or very little light, to pass through the leaves to the forest floor. In general, when trees are unhealthy their crowns begin to thin out, therefore allowing 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 that very few tally trees in Wyoming are thinning due to declining vigor.

CROWN DENSITY

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 an exact complement of foliage transparency. Of particular concern in future readings will be movements away from the middle of this graph by any species or group. Currently, most trees are rated between 25-75 percent density. Low density crowns may signal declines in growth from a variety of causal agents, both atmospheric and nonatmospheric. Very dense trees may be unhealthy too. For example, many conifer species "broom up" initially as a result of mistletoe infection.


Number of Trees
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 99
Percent Dieback
Hardwoods
Softwoods
All Trees


Foliage Transparency
Number of Trees
500
400
300
200
100
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 99
Percent Transparency
Hardwoods
Softwoods
All Trees


Crown Density
Number of Trees
300
250
200
150
100
50
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 99
Percent Crown Density
Hardwoods
Softwoods
All Trees

Appendix F: Common and Latin Species Names

Common Name	Latin Name
Plants	
American elm	*Ulmus americana*
aspen	*Populus tremuloides*
bastard toadflax	*Comandra umbellata*
blue grama	*Bouteloua gracilis*
buffalograss	*Buchloe dactyloides*
bur oak	*Quercus macrocarpa*
cottonwood	*Populus deltoides*
Douglas-fir	*Pseudotsuga menziesii*
Engelmann spruce	*Picea engelmannii*
greasewood	*Sarcobatus vermiculatus*
green ash	*Fraxinus pennsylvanica*
hackberry	*Celtis occidentalis*
leafy spurge	*Euphorbia esula*
limber pine	*Pinus flexilis*
lodgepole pine	*Pinus contorta*
narrowleaf cottonwood	*Populus angustifolia*
needle-and-thread-grass	*Stipa comata*
paper birch	*Betula papyrifera*
ponderosa pine	*Pinus ponderosa*
pricklypear cactus	*Opuntia polyacantha*
rabbitbrush	*Chrysothamnus spp.*
Rocky Mountain juniper	*Juniperus scopulorum*
Rocky Mountain maple	*Acer glabrum*
sagebrush	*Artemisia spp.*
scarlet globemallow	*Sphaeralcea coccinea*
sedge	*Carex spp.*
subalpine fir	*Abies lasiocarpa*
tamarisk (or saltcedar)	*Tamarix ramosissima*
Utah juniper	*Juniperus osteosperma*
whitebark pine	*Pinus albicaulis*
white spruce	*Picea glauca*
willow	*Salix spp.*
Mammals	
bison	*Bison bison*
elk	*Cervus elaphus nelsoni*
grizzly bear	*Ursus arctos horribilis*
mule deer	*Odocoileus hemionus*
pine marten	*Martes americana*
pronghorn antelope	*Antilocarpa americana americana*

Appendix F (continued)

Common Name	*Latin Name*
Mammals	
red squirrel	*Tamiasciurus budsonicus*
white tail deer	*Odocoileus virginianus*
Birds	
Clark's nutcracker	*Nucifraga columbiana*
Insects	
Douglas-fir beetle	*Dendroctonus pseudotsugae*
fir engraver beetle	*Scolytus ventralis*
gypsy moth	*Lymantria dispar*
mountain pine beetle	*Dendroctonus ponderosae*
spruce beetle	*Dendroctonus rufipennis*
western balsam bark beetle	*Dryocoetes confusus*
western spruce budworm	*Choristoneura occidentalis*
Diseases	
comandra blister rust	*Cronartium comandrae*
dwarf mistletoe	*Arceuthobium spp.*
white pine blister rust	*Cronartium ribicola*

Appendix G

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Forest Health Monitoring Web Sites:
- **National Program: http://www.na.fs.fed.us/spfo/fhm**
- **Regional, Forest Health Protection: http://www.fs.fed.us/r2/fhm**
- **Regional, Forest Inventory/Analysis: http://www.fs.fed.us/rm/ogden/index.html**