ECOLOGY AND MANAGEMENT OF FOREST INSECTS AND DISEASES

INTRODUCTION

The Arapaho and Roosevelt National Forests include nearly one million acres of forested lands in Colorado. The forests that we see today have been shaped over the millennia by natural events including fire, insects and disease. In the past few thousand years, American Indians used fire to clear areas for game; however, their impact was not as obvious as that of modern humans. In more recent history, the forest has been impacted by mining and settlement.

Inventories show that the lodgepole pine (*Pinus contorta*) forest type is the most common on the Forest followed by Engelmann spruce/subalpine fir (*Picea engelmannii*/ *Abies lasiocarpa*), ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and aspen (*Populus tremuloides*) (Table 3.83). Most of these stands are mature to overmature; in fact, more than 58 percent of the stands are in this condition (Table 3.83). With the majority of the forested lands in a mature to overmature condition, fire, insects and disease will continue to play significant roles in forest succession and disturbance processes in the future despite the presence of humans. Refer to Table 3.40, Forest Structural Stages, in the Terrestrial Habitat-Coarse Filter section of this chapter.

LEGAL FRAMEWORK

The principal legal statutes governing forest pest management on National Forests are:

National Forest Management Act of 1976 (90 Stat. 356; 16 U.S.C. 1600). This act, in conjunction with the Forest and Rangeland Renewable Resources Act of 1974 and the National Environmental Policy Act of 1969, requires assessment of alternative management actions to facilitate balanced, integrated approaches to resource protection and development. The act also requires sound management practices to prevent excessive losses due to pests.

Cooperative Forestry Assistance Act of 1978 (92 Stat. 356; 16 U.S.C. 2101). Section 5 of this act sets forth the basic Federal authority for forest insects and disease control to the Secretary of Agriculture. The act recognizes the need for public and private cooperation in combating forest insects and diseases and the need for federal leadership and financial assistance on all forest lands. The act does not give federal agencies the right of entry on nonfederal lands, because such authority is regulated by states. However, it does provide for federal, state, and private cooperation.

AFFECTED ENVIRONMENT

MAJOR INSECTS AND DISEASES ON THE ARAPAHO AND ROOSEVELT NATIONAL FORESTS

Of the numerous insects and diseases that affect forests, only a few have had a significant impact on the attainment of forest management objectives and will be discussed in detail.

Major infestations of spruce beetle (*Dendroctonus rufipennis*), mountain pine beetle (*D. ponderosae*) and the western spruce budworm (*Choristoneura occidentalis*) have caused mortality over large areas of the Forest in the past and continue to play a role in forest succession. The most important diseases are caused by the dwarf mistletoes (*Arceuthobium* spp.), root disease fungi (*Armillaria* spp.) and comandra blister rust (*Cronartium comandrae*). This section will focus on the role of these organisms in the forest.

Refer to Appendix E of this document for recommended silvicultural treatments to prevent or minimize the consequences of forest insects and diseases.

Spruce Beetle

The tree killing potential of the spruce beetle, *Dendroctonus rufipennis*, has been well documented during the last 100 years. This insect infests all species of spruce in North America. On the Arapaho and Roosevelt National Forests, Engelmann spruce is the principal host. Spruce beetles generally prefer to attack green windthrown or other recently downed spruce. As a result, endemic beetle populations are always present, breeding in scattered down material, in the spruce-fir forest type. Outbreaks begin after a major forest disturbance (e.g., a large windthrow) creates an abundance of suitable breeding material. Beetle populations rapidly increase in the down material and then readily attack standing spruce. Outbreaks may persist until suitable host material is depleted. The susceptibility of a stand to spruce beetle outbreaks is dependent on:

- the physiographic location of the stand
- the average diameter of the spruce in the stand
- the basal area of the stand
- the proportion of spruce in the canopy

In general, spruce stands on well-drained creek bottoms having large diameter spruce, high basal areas, and high proportions of spruce in the canopy are susceptible to outbreaks (Schmid and Frye 1976).

History

Tree-ring evidence suggests that the earliest known spruce beetle outbreak on the White River Plateau occurred in the early 1700s (Miller 1970; Veblen 1993). In the mid 1870s, Sudworth (1900) found that 10 to 25 percent of the mature spruce on the White River Plateau and the Grand Mesa were dead. Hopkins (1909) later confirmed that the spruce beetle was the cause of this mortality. Photographic and tree-ring analysis by Baker and Veblen (1990) suggest that the mortality observed by Sudworth and Hopkins occurred between the 1850s and 1880s and affected forests from central New Mexico to north-central Colorado.

In the 1940s, the White River National Forest, Arapaho National Forest, Grand Mesa National Forest, Routt National Forest, San Juan National Forest, and the Uncompahgre National Forest were the sites of the most damaging spruce beetle outbreak ever recorded (Massey and Wygant 1954). In the White River National Forest, more than 700,000 acres were devastated by the beetle (Hinds et al. 1965). This outbreak was triggered in 1939 when a violent windstorm blew down extensive patches of subalpine forests in western Colorado (Hinds et al. 1965). The White River Plateau suffered the greatest spruce losses during this outbreak, with most of the spruce mortality occurring between 1943 and 1946 (Hinds et al. 1965). By the time the outbreak subsided in 1952, nearly all spruce eight inches in diameter and larger on the plateau—an estimated 3.8 billion board feet of timber—were killed (Massey and Wygant 1954; Hinds et al. 1965). Many of the spruce killed during the outbreak remain standing today, and the severity of the outbreak is still evident.

Although the major spruce beetle outbreaks listed above have caused significant changes in stand structure over extensive areas, not all epidemics create these extreme effects. More common are epidemics of lesser magnitude which may kill 10 to 20 percent of the stand or only the largest diameter trees within the stand (Frye and Flake 1972).

Impacts of Spruce Beetle on Resources

The most significant forest responses to the 1940s outbreak were the shift in species composition from 90 percent spruce and 10 percent fir to 20 percent spruce and 80 percent fir, and the release of previously suppressed fir and spruce (Schmid and Hinds 1974; Veblen et al. 1991). If the outbreak favored establishment of new spruce and fir seedlings, this effect was not evident approximately 40 years later (Veblen et al., 1991). Because fir is more abundant than spruce in the understory, in areas susceptible to spruce beetle outbreaks, more fir can be expected to grow into the larger size classes following an outbreak (Peet 1981; Veblen 1986). However, given the greater longevity of spruce, stands that have experienced a spruce beetle outbreak will continue to be codominated by both tree species.

Spruce beetle outbreaks may have long-term effects on ungulate populations. Yeager and Riordan (1953) found that the killing of the stands initially improves the summer forage for deer and elk. However, increasing numbers of fallen dead trees may inhibit the movement of ungulates for many decades following the outbreak. Hinds et al. (1965) found that 25 percent of the beetle-killed trees were windthrown 20 years after an outbreak.

Beetle-killed spruce become hazards for recreationists because trees decay and fall or become windthrown before decaying. The increased windthrow is also a concern to recreation managers who must contend with increased trail and campground maintenance costs.

Spruce beetle outbreaks create a large fuel source for fires. Much of the area affected by the 1940s outbreak has greater than 100 tons of dead fuel per acre (Leighty 1993). Decomposition of the dead trees is slow because of the slow rate at which the trees fall and the fact that many of the trees fall atop each other and do not contact the ground for several decades. Although heavy fuel loading means that fires in this area would be catastrophic and difficult to control, natural ignitions in the spruce-fir forests of the White River Plateau are rare due to the generally moist environment during much of the fire season.

An analysis completed for the ARNF indicates that approximately 45 percent of the spruce forest may have a high susceptability to spruce beetle. Over 60 percent of these stands are in areas not suitable for timber production or management, primarily designated wilderness areas.

Mountain Pine Beetle

The mountain pine beetle (MPB) (*Dendroctonus ponderosae*) is a native bark beetle that has a persistent outbreak history in ponderosa pine along the Colorado Front Range and in the mature and overmature lodgepole pine stands of the Arapaho National Forest. The large-scale mountain pine beetle epidemics of the 1970s and 1980s provide an example of natural forces causing large scale changes in spacing and eventual age classes of tree species and in accumulations of dead biomass. Most epidemics develop because there are large areas of unmanaged lodgepole pine forests (McGregor et al. 1985).

The MPB usually infests standing live trees larger than eight inches in diameter but may attack smaller trees that are intermixed with the larger trees. During epidemics, trees are usually killed in small groups of 3 to 10 trees but such groups may coalesce into one large group of more than 100 dead trees. Endemic MPB populations are usually associated with single trees which are diseased or stressed by any number of agents or causes. The susceptibility of lodgepole pine stands to outbreaks can be estimated by average tree diameter, average tree age, and by the elevation and latitude of their locations (Amman et al. 1977).

The MPB influences stand structure in pure pine stands. The MPB kills greater portions of large-diameter trees, lowering the average stand diameter during epidemics. Depending on the extent of the tree killing within the stand, small to large openings may be created in the canopy. Extreme epidemics may kill entire stands and convert the site to a younger age class of pine or to another seral stage.

MPB epidemics also influence herbage production, wildlife populations, and fire hazard. The growth of forbs and grasses increases in beetle-killed areas. Wild ungulates may benefit from the increased herbaceous production and the standing beetle-killed trees may provide habitat for cavity nesting birds. In general, the influence of MPB epidemics will vary depending on the needs of the particular species. Fire hazard is increased for several years following MPB mortality due to the dead needles remaining on the trees. The probability of higher intensity fires may be increased for a number of years as well, because dead trees fall to the ground and add to the surface fuel loading.

The frequency of MPB epidemics in a given area may range from 20 to 40 years, depending on how rapidly some trees grow into large diameter categories. However, for a given stand, the frequency between epidemics may range from 50 to 100 years depending on how much of the original stand was beetle-killed. MPB populations are currently in endemic status on the Arapaho and Roosevelt National Forests. If current suppression policies are continued and silvicultural activities are minimized in the pine types for the MPB, stands will become more susceptible to MPB epidemics.

An analysis of the ARNF indicates that approximately 10 percent of the pine forest types may have a high susceptibility to MPB and approximatey 42 percent may have a moderate susceptibility. This analysis is based on general stand characteristics rather than on past occurrence. There has been a very low occurrence of MPB epidemics in lodgepole pine on the ARNF east of the Continental Divide even though the general stand characteristics may indicate they are highly susceptible. Approximately 25 percent of the high- to moderate-rated stands are in areas not suitable for timber production or management, primarily wilderness areas.

Western Spruce Budworm

Western spruce budworm (*Choristoneura occidentalis*) has had a significant influence on the Douglas-fir stands along the Colorado Front Range including the Roosevelt National Forest. From the mid-1970s to the mid-1980s epidemic levels of this insect caused severe defoliation and mortality. Many of the mature stands in the Poudre Canyon, Estes Park, Boulder, and the I-70 corridor areas were severely defoliated and patches of dead trees are now visible. Douglas-fir stands occur in a zone where National Forest System land is intermixed with lands of other ownership. Also much of this forest type is on steep, inaccessible slopes which prevent silvicultural treatments and salvage opportunities.

Outbreaks of budworms are always associated with late successional and climax plant communities in Douglas-fir. The stands that appear to be most susceptible are those that are multi-storied, with high host densities and a wide range of stem sizes. Budworm alters stand structure by increasing mortality among defoliated understory trees, by predisposing larger trees to bark beetle attack, and by diminishing seed sources for the host species. The insect feeds on both cones and seeds of Douglas-fir and may consume most of the local seed production during an outbreak. The net result of budworm outbreaks is the temporary slowing of the successional trend toward a steady-state Douglas-fir forest (Hadley and Veblen 1993).

Budworm infestations tend to retard succession on habitat types where host trees are climax. The ecological niche of budworm has greatly expanded because of changes in natural succession caused by forest fire suppression. Fire has historically had a strong influence on the ecology and development of western forests. Ground fires, which burned frequently in the drier forest types, periodically eliminated understory trees and reduced the stocking of shade-tolerant, fire susceptible trees in the larger size classes. To some extent, budworm infestations may be replacing the regulatory role played by fire, since it appears that the frequency and intensity of outbreaks have increased in the last 40 years (Swetnam and Lynch 1989). Budworm populations are currently at endemic levels throughout the Forest.

For the most part, control of this insect is not warranted in many areas in the Rocky Mountain Region; in fact, there have been no large-scale treatment projects in the Region. Infestations generally cover vast areas of relatively low market value species. Many of the infested areas also tend to occur on steep, north-facing slopes with poor or limited access, limiting direct control measures to the aerial application of insecticides. Control by the application of insecticides may be useful to save high value trees in recreation areas and around homesites.

An analysis of the general stand characteristics of the Douglas-fir forest type indicates that approximately 56 percent of this type may be highly susceptible to western spruce budworm. Of the highly susceptible stands, approximately 23 percent are in areas that are not suitable for timber production or management.

Dwarf Mistletoes

The dwarf mistletoes are parasitic seed plants that affect most conifers in the western United States. Dwarf mistletoes and western conifers began evolving together about 25 million years ago. Today, the dwarf mistletoes are one of the most widespread and damaging groups of forest diseases in the West. Fires normally change forest composition and sanitize infested stands by killing the parasite when the host tree is killed. The new replacement forests are essentially free of mistletoes where large fires have occurred. Thus, almost half a century of fire suppression of large fires has also played a critical role in shaping these forests.

In the absence of fire and management, however, the status of dwarf mistletoes does not change markedly from year to year. Mistletoes spread slowly, at a rate that averages one to two feet per year in even-aged stands. Past management practices have, in some situations, accelerated the spread of the disease by perpetuating uneven-aged stand conditions that accentuate the spread of dwarf mistletoe from overstory to understory trees. The incomplete removal of infected trees, usually nonmerchantable, in timber sale areas has led to increased spread of the disease. The retention of infected trees along visual corridors and for wildlife habitat has resulted in subsequent spread to adjacent uninfested stands. Limitations on the sizes of harvest units in recent years has also had an impact. It is most effective to cut all infected trees in stands of at least 20 acres to minimize reinfection from the edges of the stand. Small harvest units can aggravate and intensify the rate of infection. The lack of markets for smaller trees that occur in heavily infested, low-volume stands has also prevented treatment of many diseased stands.

Silvicultural practices to control dwarf mistletoes have been advocated since the early part of the century; however, these efforts were limited to removing only the large, merchantable overstory trees during the course of harvesting operations. This type of partial cutting actually increased the amount of infection in residual stands. Leaving infected trees of no commercial value in regeneration areas also intensified the problem.

Forest roads and timber markets began improving in the 1950s. Improved access and markets, coupled with more specific guidelines from research, made it possible for managers to take more effective action against the dwarf mistletoes.

In the past two decades, dwarf mistletoe control programs have been more consistent. In addition, thousands of acres are treated each year through scheduled stand improvement and timber harvesting operations. Despite these efforts, our ability to substantially improve the health of the forest is limited by markets and by opposition to timber harvest by some sectors of the public.

Impacts of Dwarf Mistletoe on the Resource

The most important effect of dwarf mistletoes is volume reduction; when trees are heavily infested, dwarf mistletoes reduce both their height and diameter, and increase their mortality. The extent of loss depends on several factors including host and mistletoe species, intensity of infection, site index, stand density and stand structure. Infestation levels vary greatly from stand to stand, depending primarily on the stand's fire history and on past management practices. Significant reduction in yields of stands occurs if they are infected early in their development and if no suppression measures are taken to reduce spread and intensity of the disease.

The first symptom of infection on an individual tree is a swelling of host tissues. Later, the swellings enlarge and produce dense masses of distorted branches called witches' brooms. As the parasite spreads through the tree crown, tree growth is gradually reduced. Eventually the top weakens and dies, diameter growth ceases, and the entire tree dies. Insects, particularly bark beetles, may cause an earlier death by attacking weakened, heavily infected trees (Johnson, et al. 1976). Other pests, such as decay fungi, enter wounds and swellings created by the mistletoes.

Dwarf mistletoes not only cause losses in timber values, but also adversely affect recreation values by killing trees in campgrounds, picnic areas, etc. In addition, the decay and canker fungi associated with dwarf mistletoe infections kill or weaken branches so that they are more susceptible to wind breakage, thus increasing the hazard to recreationists.

Although the debilitating effects of the mistletoes on tree growth and forest productivity are well documented, their effects on noncommodity forest values have not been fully assessed. The effects on wildlife, for example, may be positive or negative depending on the particular ecological needs of the wildlife species. Dead trees provide nesting sites for snag-dependent bird species. Witches' brooms also provide cover and nesting sites for many birds and mammals. Large areas infested with mistletoes have a more irregular, open forest canopy, favoring certain bird and mammals species. As the openings regenerate to either the same tree species or other tree species and brush, greater vegetation diversity will occur. This results in profound changes in both stand structure and species composition. The mistletoe plants themselves provide a food source for some mammals, birds and insects.

The impacts of dwarf mistletoes on visual quality would generally be considered negative because of reduced tree vigor, increased mortality, increased fuel accumulations and susceptibility to fire. Effects on other resource values are, for the most part, unknown.

Forestwide surveys conducted in 1979 indicated that 48 percent of the lodgepole pine (220,900 acres) on the Arapaho and Roosevelt National Forests is infested with *A. americanum* (Johnson et al. 1980). More intensive stand-level surveys conducted from 1973 to 1977 on the Redfeather Ranger District indicated that more than 84 percent of the nearly 40,000 acres that had overstory lodgepole pine were infested and that nearly 30 percent of the understory pines were infected (Johnson 1978). A conservative estimate of merchantable volume loss for the Forest is more than 2.3 million cubic feet per year. Surveys conducted in 1981 and 1982 in ponderosa pine indicated that 18 percent (18,100 acres) were infested with *A. vaginatum* subspecies per year.

Since 1980, more than 92,600 acres have been surveyed and 10,600 acres treated with Forest Pest Management (FPM) funds (Table 3.85) (Johnson 1986b). This summary only includes projects in which FPM was directly involved. Many more acres of control were accomplished through timber harvests and other stand entries, but no record remains of the acres treated. The FPM program consists of presuppression surveys, overstory removal, thinning and sanitation, and stand replacement. Since 1980, the program has received greater support and emphasis. Five year planning documents have been prepared and activities and funding requests have been integrated into the Forest planning and budgeting process. This strategy has insured a more continuous source of funding and program continuity than in the past, and has enabled resource managers to schedule time, resources and manpower more effectively.

The emphasis of the program in the Rocky Mountain Region has been on locating and defining those management units where infected, nonmerchantable overstory trees were left standing in older timber sale areas and pose a threat to established regeneration. In many cases, these young stands will not reach merchantable size if the infected residual trees are not felled or removed.

Dwarf mistletoe suppression yields multiple benefits including:

- insuring increased productivity of stands in the future to meet the increased demand for wood products. (Dwarf mistletoe infection delays the economic maturity of stands, adversely affecting wood quality and tree seed production.)

- protection of other forestry investments, such as site preparation, tree planting, thinning and timber stand improvement; control in infested stands prevents spread of the disease to adjacent healthy stands.

- increasing productivity per acre and thus (under intensive management) reducing acreages needed to meet timber targets. It allows harvesting activities to be concentrated on fewer acres at reduced cost. With the trend of withdrawal of forest land from timber production and harvesting, increasing the productivity of the remaining commercial forest stands is imperative.

- reducing the susceptibility of stands to insect attack (particularly bark beetles), windthrow, and natural fires.

- development of silvicultural practices that have proven to be very effective and provide control of the disease for the current and subsequent rotations.

The measures or combinations of measures used should be geared to individual stand conditions including stand age and composition, stand density, number of years to harvest, mistletoe incidence and distribution, and length of time the stand has been infested. Valuable tools—tree and stand growth models and dwarf mistletoe infection models—are available to aid the resource manager in simulating yields of infected trees and stands. Yields for a stand can be predicted under various management regimes and compared to no treatment. By comparing outputs and economic analyses of control costs, the manager can choose the best treatment for each infested stand and the appropriate priority for treatment.

Armillaria Root Disease

Root diseases are one of the most damaging classes of forest tree diseases in the western United States. These diseases cause economic loss by killing trees, slowing growth, decaying wood, predisposing trees to other harmful pests, causing trees to fail and fall over, preventing reforestation, and reducing stocking levels on regeneration sites.

In an assessment of losses caused by root disease in the western U.S., Smith (1984) estimated average annual volume loss in commercial forest lands at nearly 240 million cubic feet. This loss is approximately 18 percent of the total softwood mortality reported for the West.

Investigations of root disease losses in the Rocky Mountain Region are in their infancy (Johnson, 1984); therefore no data are available on volume loss. Although study plots have been established throughout the Region to monitor disease development in various host types, no loss estimates have been generated from these data.

Surveys of root disease on the Arapaho and Roosevelt National Forests indicate that Armillaria root disease is the most common and widespread species (James and Gillman 1980). Tree species susceptibility varies by host species, tree vigor, age, and habitat type. The fungus is commonly observed on lodgepole pine, ponderosa pine and subalpine fir. The fungus has also been recorded on pinyon pine, Engelmann spruce, white fir, aspen, Rocky Mountain juniper, and cottonwoods.

In forest types in which fire has been an important natural factor in determining species composition and stand characteristics, fire suppression may interact with silvicultural management to promote root disease by allowing regeneration of species which are more susceptible to *Armillaria*. Fire control associated with selective logging in some of the drier forests in western North America has favored regeneration of Douglas-fir and true fir stands formerly composed predominantly of ponderosa pine, western white pine and western larch; the favored species are apparently less susceptible or more tolerant to root disease. Factors that increase stress in trees such as drought and defoliation by insects may also increase the amount of root disease.

Armillaria is a natural component of the mycroflora of many forests worldwide. It commonly lives as a saprophyte on dead organic material such as old stumps left from logging. It also kills living tissues and then utilizes them as a nutrient source. As a consequence of parasitic activity or disturbance such as logging, windthrow, or fire, *Armillaria* may infect large quantities of roots, stumps and other debris on the ground.

From stumps it can spread to living hosts by root contacts and rhizomorphs, which are red-brown or black cords of fungus mycelium similar to shoestrings (1 to 5 mm in diameter), hence the common name shoestring root rot. Rhizomorphs can grow through the soil from the food base to the roots of living trees. The fungus then spreads from the roots to the root collar and can parasitize and girdle the tree. In late summer during wet periods, the fungus produces mushrooms which are found in clumps near the bases of infected trees or stumps. Spores released from the mushrooms infect butt and root wounds.

This root disease is relatively easy to identify. Affected trees show declining growth (especially in height), yellowing foliage, and stress crops of cones; small trees often die in groups, a characteristic of all root diseases. An exudate of resin is found on the trunk near the soil line and often is mixed with the soil at the root collar. Thick, white mycelial fans occur under the bark of roots and around the root collar. Mushrooms may or may not be present, depending on the time of year and microsite conditions.

Armillaria root disease occurs commonly in association with bark beetle and with woodborer-attacked and killed trees. A study conducted in the Colorado Front Range showed that 62 percent of ponderosa pine killed by mountain pine beetle were also infected by *Armillaria* (Fuller 1983).

Armillaria is also common in cut-over lodgepole pine stands that have regenerated naturally (Sharon 1988). An evaluation of a 31-year-old stand on the Estes Poudre Ranger District showed that 12 percent of the cumulative mortality was attributed to this fungus (Johnson and Hawksworth 1977). No disease centers were large enough to result in understocking of the stand. Annual loss of trees over a period of 18 years showed a reduction in tree mortality from nearly 2 percent per annum to less than 0.5 percent.

Surveys of naturally regenerated seedling-sapling stands indicate up to 11 percent of trees infected or killed by *Armillaria* spp. Disease incidence is not uniform throughout stands. Most diseased trees are located near stumps, which probably served as infection sources.

At this stage in development of our knowledge of this disease, it is not possible to determine the implications of the disease on timber management practices or other resources. The disease is widespread throughout the Rocky Mountain Region and has been reported on all coniferous species and some hardwoods. It has caused scattered tree mortality and predisposes its host to bark beetle attack and windthrow. It also causes decay in live trees. The disease may pose problems in the future as stands are placed under more intensive management. This has been the case in other regions of the country. On the other hand, activities that increase the vigor of the residual stand, such as thinning, may reduce losses to the disease.

Recognition and removal of trees infected with root diseases in developed recreation sites is a management concern. Other adverse effects of root diseases include buildup of woody fuels and creation of brood material for bark beetles and subsequent loss of adjacent trees as bark beetle populations increase.

Beneficial effects of root diseases include the creation of natural openings and wildlife habitat and increased diversity of plant species as regeneration of root disease centers occurs. Also, most root diseases have a saprophytic life stage that helps to decompose woody debris on the forest floor and in living infected trees creates decay and subsequent habitat for cavity-nesting animal species.

Comandra Blister Rust

Comandra blister rust causes stem and branch cankers on several species of pines, including ponderosa pine and lodgepole pine (Johnson 1979; Johnson 1986a). It occurs throughout North America, and is a serious cause of loss in many lodgepole pine stands in the central Rocky Mountains. For example, more than half of lodgepole pine basal area is in infected trees on the Wind River Ranger District of the Shoshone National Forest (Geils and Jacobi, 1984). During a 1977 disease survey for lodgepole pine dwarf mistletoe on the Medicine Bow National Forest, it was found that more than 26 percent of plots had rust infected trees and more than 17 percent of the trees on the plots were infected.

Comandra blister rust has a complex life cycle similar to that of the white pine blister rust organism, *Cronartium ribicola*. It has five different spore stages produced alternately on two hosts: a hard pine and the perennial herb for which the fungus is named, pale comandra (*Comandra umbellata*). The spores that infect the pine are produced only on the comandra plants. These plants occur in sagebrush communities at various distances from the pine stands. The delicate rust spores are wind-dispersed from the comandra plants to pines during rainy days in summer. Infection occurs through needles and young shoots. The fungus spreads into the inner bark. One to three years later, the first evidence of the disease on pine appears as small drops of thick, sticky, reddish-orange liquid on the diseased bark. These drops contain spores.

The following spring and summer, pustules form on these same cankered areas. The pustules soon rupture and release another spore stage, which infects the alternate host, comandras. Infection of comandras results in yellow, blister-like spots on the leaves which, in turn, produce spores that infect other comandra plants.

In late summer or early fall, brown, hairlike structures develop on the undersides of infected leaves. During mild, wet weather, these structures produce another spore that infects pines, thus completing the life cycle.

The rust attacks pines of all sizes and ages. Seedlings are the most susceptible and are usually killed within a few years by stem cankers. Infection of pole- and sawtimber-size trees results in growth loss and mortality that prevents those trees from becoming merchantable.

The number of years it takes the fungus to girdle the main stem equals twice its diameter, in inches, at the spot where the canker occurs.

Trunk infections in mature and overmature trees are accompanied by diagnostic crown symptoms. The first crown symptoms are dead branches in a narrow zone around the branch where the fungus entered the main stem. Above this zone, the crown thins and eventually dies, forming characteristic spike tops. These tops are resistant to decay and remain intact for many years.

A detailed study on the Laramie Ranger District showed that rust incidence was highest in stands older than 40 years along forest edges adjacent to comandra habitat, but pine stands as far as eight miles from comandra plants can be seriously infected. Spore dispersal from comandra plants to pines seems to be associated with easterly winds during long rainy periods. Disease incidence also increases with average tree height or diameter (Jacobi et al. 1993).

ENVIRONMENTAL CONSEQUENCES

EFFECTS COMMON TO ALL ALTERNATIVES

The current and projected future conditions on the Forests ensure that insects and diseases will continue to play significant roles in the development, successional processes and both the small- and large-scale level disturbance processes at work on the Forests. Most major forest vegetation types (Table 3.83) have greater than 50 percent of their structural stages in mature/overmature classes that are conducive to outbreaks of the most important insect and disease agents (Table 3.84). Growth loss and mortality will continue to occur, particularly where access, topography or other resource restraints preclude silvicultural treatment of stands.

Table 3.83 Major Forest Types on the Arapaho and Roosevelt National Forests and Their Condition

Forest Type	Acres[a]	Acres Mature/ Overmature	Percent
Lodgepole pine[b]	501,400	233,800	47
Spruce/fir[c]	248,000	190,600	77
Ponderosa Pine[c]	136,700	115,100	84
Douglas-fir[c]	57,300	40,000	70
Aspen[b]	43,600	7,200	17
TOTALS	987,000	586,700	59

[a] USDA Forest Service. 1995. Habitat structural stage by cover type, Arapaho and Roosevelt National Forests, Final data. April 12, 1995.

[b] Classified as mature/overmature if 80 years or older; includes habitat structural stages 4A, B, C and 5.

[c] Classified as mature/overmature if 120 years or older; includes habitat structural stages 4A, B, C and 5.

Table 3.84 Forest Conditions with the Greatest Potential to Incur Significant Losses to the Major Insect and Disease Organisms

Organism	Stands with Greatest Potential to Incur Significant Losses
Spruce beetle	Spruce stands located in well-drained creek bottoms having large diameter spruce, high basal areas, and high proportions of spruce in the overstory. Also extensive spruce stands where large amounts of windthrown trees have occurred.
Mountain pine beetle	Overstocked, clumpy ponderosa pine stands (stands with basal areas of 150 square feet or greater per acre measured around any individual trees); stands of low-vigor lodgepole pine that are usually overstocked and overmature (80 years or older).
Western spruce budworm	Multistoried stands with major true fir and/Douglas-fir components.
Dwarf mistletoes	Multistoried host stands with infected overstories. Pure stands that are already infected. Young stands adjacent to infected stands of the same species.
Armillaria root disease	Differs by area, but generally more severe in stands with major true fir components; may be favored by factors that stress trees such as defoliating insects, weather extremes, drought, etc.
Comandra blister rust	Pine stands adjacent to sagebrush habitats containing the alternative host plant, *Comandra*. Marginally stocked stands with a high incidence of disease.

We can influence the outcome of insect and disease outbreaks at the stand level on a project level basis. Risk-rating systems exist for most of the important insect and disease organisms, and both forest stand and pest models can be helpful in projecting future scenarios and determining management options.

With our limited ability to treat large landscapes and restrictive legislation affecting forest management activities, we will have to accept the changes that will occur across most areas of the Forests. Small-scale disturbance events will result in greater biodiversity and may help in achieving long-term forest management goals, whereas large-scale events may be catastrophic and unacceptable.

Table 3.85 Summary of Dwarf Mistletoe Program Expenditures and Accomplishments for the ARNF, 1980-1993

Fiscal Year	FPM $	Acres Surveyed	Acres Treated
1980	8,700	2,600	186
1981	61,000	14,000	1,100
1982	111,900	31,100	3,685
1983	(238,000)[a]	--	(2,045)[a]
1984	81,000	--	1,050
1985	48,300	26,300	820
1986	50,000	--	500
1987	84,600	363	763
1988	42,200	7,812	857
1989	39,300	500	430
1990	32,460	3,100	670
1991	30,340	2,400	506
1992	20,488	3,500	100
1993	4,500	1,000	--
TOTALS	614,788 (238,000)	92,675	10,667 (2,045)

[a] Funded by the Jobs Bill.

EFFECTS ON INSECTS AND DISEASES

There are two activities that are likely to have some, although limited, effects on insects and disease. They are timber and fire management. The following two tables display the effects of expected timber and fire management activities on mature and overmature conditions by forest type over the next five decades.

Table 3.86 shows the acres which would be in a mature or overmature condition by forest type at the end of the first decade, taking into account the timber harvesting and fire management treatments which are estimated for each alternative. Table 3.87 displays the same information at the end of the fifth decade.

As can be seen in Table 3.87, the numbers of acres in mature and overmature condition are nearly always higher at the end of the fifth decade than at present. The exceptions are in lodgepole pine under Alternatives C and I and in ponderosa pine under all alternatives. The amount of lodgepole pine is reduced under Alternatives C and I as the result of timber management emphasis in that forest type. The amount of ponderosa pine is reduced under all alternatives as the result of reintroducing fire management treatments into that forest type.

Table 3.86 Resulting Overmature/Mature Acres at the end of *Decade 1* based on Full Implementation Budget

Forest Type[a]	Alternatives						
	Exist. Acres	A	B	C	E	H	I
Lodgepole Pine	233,800	234,200	236,076	231,400	247,900	241,400	230,500
Spruce/fir	190,600	197,200	195,306	202,100	197,000	195,900	196,200
Ponderosa Pine	115,100	114,600	112,156	114,600	114,600	112,600	114,600
Douglas-fir	40,000	41,300	40,619	41,300	41,300	40,800	41,300

[a] The change in aspen structural stages was not estimated; therefore no results are displayed.

The overall result of timber and fire management activities on mature and overmature conditions is not, however, very significant. Therefore, outbreaks of insects and disease in the forest types in these conditions is not likely to be lessened by timber and fire management in the foreseeable future.

Table 3.87 Resulting Overmature/Mature Acres at the end of *Decade 5* based on Full Implementation Budget

Forest Type	Alternatives						
	Exist. Acres	A	B	C	E	H	I
Lodgepole Pine	233,800	265,300	245,886	233,000	298,600	267,600	227,500
Spruce/fir	190,600	214,600	211,570	214,700	216,900	211,100	210,500
Ponderosa Pine	115,100	106,200	100,373	106,300	110,900	100,500	108,300
Douglas-fir	40,000	44,700	43,092	43,000	46,000	43,800	45,400

Timber Management

Timber harvesting and other cultural activities affect the forest structural stages and, therefore, have the potential to change the conditions that are conducive to outbreaks of the most significant insects and disease. Most timber management for the production of forest products will occur in the lodgepole pine and Engelmann spruce forest types and may have the greatest effect on mountain pine beetle, dwarf mistletoe, and spruce beetle. However it is unlikely that the number of acres treated annually under any of the alternatives will significantly influence these agents of change in the near future.

Alternatives C, A, I and B, in that order, would have the most positive effect in maintaining insects and disease at endemic levels because they will treat the most acres on suitable and available lands. The other alternatives will have little, if any, effect on altering the natural course of action of insects and diseases. Timber management for the protection or enhancement of forest health is permited on tentatively suitable and not available lands in many of the management areas on a limited basis. This would be on an as-needed basis, as indentified by landscape or project analysis, so it is difficult to estimate potential effects by alternatives.

Fire Management

Fire management treatment, including wildland fire, prescribed fire or mechanical treatments, is the other activity that is likely to have an effect on insects and diseases by changing forest structural stages. As described earlier, fire has historically played a significant role in minimizing catastrophic outbreaks of insects and diseases. This is particularly true in forest types with short fire-return intervals such as ponderosa pine and Douglas-fir.

It is anticipated that the acres burned annually from wildfires will remain relatively the same throughout all alternatives, and that the effects on insects and disease will be relatively the same as well. Acres burned may be somewhat higher in Alternative H due to limited access and human intervention.

It is desired to utilize prescribed fire as a tool to reintroduce fire into the ecosystem, particularly in the ponderosa pine and Douglas-fir forest types. In some cases it will not be possible to utilize prescribed fire safely without some type of mechanical treat prior to burning. This would have a potentially positive effect of altering structural stages to reduce the likelihood of major insect and disease outbreaks, particularly from western spruce budworm and mountain pine beetle. It is anticipated that the acres treated during the first decade will be the greatest and the effects from fire treatments most positive under Alternative B.