APPENDIX E

SILVICULTURAL SYSTEMS, LOGGING SYSTEMS AND RELATED EFFECTS

INTRODUCTION

This appendix begins with information on silvicultural systems and logging systems used on the ARNF It then discusses common effects to be expected in the use of these silvicultural systems on spruce/fir, lodgepole pine, ponderosa pine, Douglas-fir, and mixed conifer stands. In addition, a discussion of effects particular to actual harvest operations is included. This information is meant to supplement information on Timber Production contained in Chapter Three—Affected Environment and Environmental Consequences.

SILVICULTURAL SYSTEMS

Silviculture may be defined as the art and science of producing and tending a forest. Classic silvicultural training and application have focused on the specifics of tending forests to produce commercial sawtimber With the current emphasis to move toward ecosystem management, a much broader view of silvicultural options is necessary to sustain biological diversity, protect soil and water resources, and fulfill humankind's material and spiritual needs of the forest environment

A silvicultural system is a combination of interrelated actions by which forests are tended, harvested, and replaced to produce a distinctive form and character Systems are classified as even-aged, two-aged, and uneven-aged.

The silvicultural system used for managing, establishing, and renewing a stand depends on two primary factors 1) whether a new stand originates from seed or vegetative reproduction (such as aspen clonal suckering), and 2) whether the stand is managed under even-aged or multi-aged conditions (Smith 1986)

An **Even-Aged** System is the combination of actions that results in the creation of stands in which trees of essentially the same age grow together. In the strictest sense, the age difference within a stand-will normally be within 20 percent of the stand's rotation age It is common practice among forestry professionals to manage stands as even-aged when all the trees in the stand are essentially the same size and can be managed as an even-aged stand. Even-aged stands are characterized by an even forest canopy, with the greatest number of tree stems found in the diameter class (usually expressed in 2-inch classes, such as 8 0" - 9.9", 10.0" - 11.9") represented by the average diameter of the stand Also, there are fewer trees in diameter classes both above and below the stand's average diameter

A **Two-Aged** System is the combination of actions that results in stands in which there are two distinct age classes being managed. Two-aged stands are characterized by two distinct layers in the tree canopy. The upper layer contributes seed and/or shelter for the younger understory as well as providing the aesthetics of maintaining high forest cover.

An **Uneven-Aged** System is a silvicultural system involving manipulation of a forest to simultaneously maintain: 1) continuous high-forest cover, 2) recurring regeneration of desirable species, and 3) the orderly growth and development of trees through a range of diameter or age classes Uneven-aged stands are characterized by broken and uneven canopies. The largest number of stems are found in the youngest/smallest age class, and the number of stems per age class decreases with increasing age/size, leaving the least number of stems in the oldest/largest age class

EVEN-AGED SILVICULTURAL SYSTEMS

The ARNF uses several even-aged systems described below.

Clearcutting/patchcutting -- All trees in the stand or area are removed at once. Natural reproduction arises from seed from adjacent stands or trees cut in the clearing operation (e.g., lodgepole pine cones from branches of cut trees); or the area may be artificially seeded or planted. Patchcuts are small clearcuts, generally ranging from two to twenty acres. Clearcutting is best suited to species that need full sunlight for optimal growth, such as lodgepole pine and aspen.

Coppice -- This is a vegetative reproduction method that relies upon sprouting from existing roots or aboveground stumps. All trees in the stand or area are removed at once and the new stand arises from sprouting. The coppice method can only be applied with tree species that have adapted the potential to vigorously sprout new stems after cutting. On the ARNF, both coppice and coppice with standards (defined under uneven-aged methods) are used only in managing aspen stands

Shelterwood -- The stand is removed in a series of harvests that occur over a short period of the rotation Reproduction and accompanying protection come from the partial shelter of seed trees. Generally, this, method consists of three cuts The preparatory cut removes approximately 1/3 of the overstory About 10-30 years later, the seed cut removes another 30-40% of the original overstory, retaining the best seed trees to seed in the site and protect future seedlings from environmental extremes. About 30 years later, the remaining overstory is removed. There are several variations of the shelterwood method They are

- Uniform -- applied uniformly across the stand or area,
- Strip -- applied in strips across the stand/area, Group -- applied in groups (patches), Simulated -- applied where abundant regeneration already exists and the overstory is removed in two or more steps

The shelterwood method is best applied to species needing partial shade for optimal growth (spruce and fir). This method is also applicable on the Forest for some species rated intolerant or intermediate (of shade and root competition) where partial shade is preferred due to poor soil capability, lack of moisture, and harsh climatic conditions (ponderosa pine and Douglas-fir)

UNEVEN-AGED METHODS

Single-tree Selection -- This method maintains an uneven-aged structure in the stand by removing individual trees or exceedingly small clumps of trees, allowing regeneration to fill these small openings. This method requires rigorous inventory and control of diameter classes Single-tree selection is best applied with species tolerant of shade and root competition (subalpine fir, and to a lesser degree, Engelmann spruce).

Group Selection -- This method maintains uneven-aged conditions by removing groups of trees in the stand, providing larger openings for regeneration than found in single-tree selection This method can be diameter class-based or area-based The maximum diameter of openings created from group selection harvests should not exceed twice the height of the surrounding timber and can be as small as one or two trees (usually range from 0 1-2.0 acres). This method is best applied with species rated tolerant (Engelmann spruce), but can also be used with species rated intermediate to intolerant when larger group openings are prescribed

Neither selection method is recommended in mixed conifer stands that have elevated populations of the western spruce budworm, unless the number of trees per acre are widely spaced. Selection methods tend to create ideal habitat for western spruce budworm by maintaining a 'laddered" forest canopy (vertically adjacent canopy layers) that enables the defoliating larval stage of the budworm to move horizontally and vertically through the crowns upon which it feeds. Similarly, certain diseases that are readily transmitted from host trees to trees close by can best be controlled by silvicultural methods that open up the stand and reduce the close infection that occurs in more dense stands (For more information on insects and disease, refer to the Insects and Disease section in this Appendix.)

TWO-AGED METHODS

The Irregular Shelterwood Method and the Coppice-with-Standards Method, with their many variations, are the methods used in the two-aged silvicultural system The step that initiates regeneration is generally made when culmination of mean annual increment (CMAI) of growth has occurred. (CMAI is reached at the age in which the average annual growth is greatest for a stand of trees) Two-aged stands may require one or more intermediate entries for cultural work, commercial thinning, salvage, or sanitation.

Irregular Shelterwood Method -- Irregular shelterwood differs from other variants of the shelterwood method in that the shelterwood overstory is retained (i e., final overstory removal cut is delayed or not done at all) beyond the time necessary to regenerate the new stand. Such a stand will include two age classes for long periods and sometimes even for a whole rotation (Smith 1986). This method may be appropriately used when the intent of the treatment is to retain the shelterwood overstory beyond the time necessary to regenerate the stand (when that time exceeds 20% of the rotation age); or when the intent is to perpetuate a two-aged stand structure indefinitely. The term "irregular" refers to the variation in the tree heights within the new stand. As with the standard shelterwood method, irregular shelterwood can be uniformly applied or arranged in strip or group patterns (Smith 1986)

This method includes preparatory cuttings and seed cuttings similar to the even-aged shelterwood method It differs in the removal cutting sequence in that the removal cuttings may occur later in the rotation or not at all

The removal cut that removes the overstory (older age class) from an understory that was regenerated by the Irregular Shelterwood seed cut results in an even-aged stand which can, in the future, be managed again as a two-aged stand, as an even-aged stand, or as an uneven-aged stand using the appropriate regeneration method.

Coppice-with-Standards -- In this regeneration method, selected overstory trees are reserved as "standards" (the larger, better-formed trees in the stand) at the time when each crop of coppice material is cut The coppice material is cut using a clearfelling technique or as it is more commonly known, a clearcutting technique The standards are carried on a much longer rotation than the simple coppice beneath them" (Smith 1986). The sprouts and/or seedlings that arise from this regeneration cutting form a distinct story beneath and between the standards The standards may be either conifer or hardwood.

INTERMEDIATE TREATMENTS

Cutting treatments, other than those cuttings done to harvest a mature stand, are considered intermediate treatments Such treatments include thinnings, improvement cuts, and sanitation/salvage cuts

Thinnings are prescribed primarily to reduce competition between existing stems in dense stands They may be precommercial (thinnings where trees to be cut are too small to be sold as forest products) or commercial (trees cut are sold for posts, poles, or small sawtimber) Thinnings are generally prescribed on the ARNF in dense stands of lodgepole pine reproduction or pole timber that will or have stagnated due to competition Without thinning these stands will not achieve desired size or products Improvement cuts are cuts made in stands beyond the sapling stage, to improve composition and quality, by removing trees of undesirable species, form, or condition from the main canopy (Smith 1986) Improvement cuts have been prescribed on the Forest where species of low commercial value have been removed to improve growing conditions for valuable commercial species

Sanitation and salvage cuts are prescribed for stands that are moderately to severely infected, or are at risk to such infection, from insects or disease that can cause death or deformation to commercial trees. Sanitation cutting differs from salvage cutting in that sanitation cuts are done to prevent such infections from spreading to healthy stands These treatments have been widely used on the ARNF in lodgepole pine stands affected by dwarf mistletoe.

LOGGING SYSTEMS

There are a variety of logging systems using combinations of equipment and people to accomplish cutting and transporting of trees or logs. Logging systems are initially divided into two categories ground-based and cable No cable-based systems have been used on the ARNF at least in the recent past.

Ground-based logging systems include horse logging and mechanical logging. Horse logging is mainly used where mechanized logging must be avoided because of environmental concerns. It has been rarely used in the past 30 years.

Ground-based mechanical logging can be broken into three categories: whole-tree, tree-length, and cut-to-length

Whole-tree systems deliver entire trees to landings with limbs and tops attached to the stem. The trees are then limbed and topped at the landing, and cut to lengths for hauling. Slash piles are often large Limbs, tops, and defective log segments are burned on site, hauled away for chipping, chipped and then hauled On the ARNF, this method has been used with mechanical equipment where residual timber is widely spaced and skidding damage from logs rubbing on standing trees is minimal Logging slash is generally burned at the landing

Tree-length systems deliver delimbed and topped tree stems to the landing. Limbs and tops remain at the site of the severed stump. As with whole-tree systems, tree-length logging has been allowed on the ARNF primarily in lodgepole pine clearcuts Limited delimbing and bucking of defective log segments can occur at the landing, but landing slash piles are much smaller than in whole-tree systems.

In cut-to-length systems, trees are cut, delimbed, and bucked at the stump before transport to the landing by skidding or forwarding Landing slash piles are small in comparison with other methods Commonly used on the ARNF in spruce/fir

On the ARNF, both tree-length and cut-to-length systems using chainsaw operators or mechanized equipment for cutting and track- or wheel-driven skidders for dragging logs to landings have been used

Mechanization of logging equipment has advanced to where all phases of cutting can be accomplished without the use of hand-held chainsaws. A distinct advantage of such equipment is greater control of the actual cutting of the tree, by which a boom clamp grasps the tree before cutting and sets the tree down after severing from the stump This greatly reduces damage to residual timber that might otherwise happen with a tree conventionally felled with a chainsaw Advancements in mechanization have also reduced the number of workers required for woods operations, reduced the costs for insurance and workmen's compensation, and increased production rates in the woods. This advanced logging machinery is very expensive. Ground-based mechanized equipment is limited to slopes less than 40%, smaller-diameter trees, and soils with sufficient bearing strength to support such equipment.

COMMON EFFECTS FROM THE APPLICATION OF SILVICULTURAL SYSTEMS

The effects on a timber stand from an applied silvicultural system, or harvest method, will be similar under any alternative that allows that method Those effects are described by harvest method

Clearcutting/patchcutting In lodgepole pine and aspen stands, after merchantable trees are cut, the remaining unmerchantable live trees are cut. This felling of unmerchantable trees is done by the timber purchaser, as required by the timber sale contract, or by Forest Service or contracted crews With these species, it is necessary to cut all live trees in these harvested areas to ensure the successful regeneration of a new stand.

In spruce/fir, Douglas-fir/mixed conifer, and ponderosa pine stands, all merchantable trees (trees greater than or equal to 6-8 inches in diameter) are cut by a timber purchaser. Usually, small (unmerchantable) trees are left to grow as part of the future stand. Many of these trees will show dramatic growth after harvest due to the elimination of competition for water, nutrients, and sunlight by removal of the overstory. Additionally, seed will fall from mature trees adjoining the cut area, providing natural regeneration for the future stand-

On the ARNF, most clearcutting is done in small patchcuts, generally less than 20 acres in size Sharp corners are avoided along patchcut edges to prevent constriction and funneling of winds into those corners. Rounded edges reduce the risk of windthrow of mature timber along these edges Clearcutting results in high fuel loadings from the accumulation of branches, tops, and rotten unmerchantable stems (collectively called logging "slash"). Also, clearcutting results in much disturbance of understory vegetation and surface soils (unless harvesting occurs when ground is frozen and/or snow-covered) due to the concentrated movement of skidding machinery and skidded logs throughout the area Clearcut areas reflect a marked edge and contrast between the clearcut unit and adjoining timber About 2-5 years after harvesting, understory vegetation rows back to again dominate the ground surface In stands containing a mix of tree species, clearcut areas will favor regeneration of species that grow best in open conditions. New stands arising from clearcutting will exhibit a single canopy layer and uniform size and age classes

Shelterwood In the 3-step shelterwood, about 2/3 of the overstory remains after the preparatory cut In spruce/fir stands, there often remains a fully forested appearance after the first cut The impacts from skidding and slash accumulation are only about 1/3 that of similarly-sized clearcut areas.

After the seed cut, about 1/3 of the original overstory remains The seed trees left are generally the tallest, healthiest trees with the fullest crowns. These harvested areas appear as highly thinned, open, mature stands The cumulative effect of both the prep and seed cuts can result in moderate to high accumulations of slash, though in the 10-30 year period between these cuts, most prep-cut slash has been compressed to the ground by seasonal snow loading.

Between the seed cut and overstory removal, the growth of both understory vegetation and newly regenerated trees will dominate the forest floor About 30 years after the seed cut, the regenerated stand will be of a height and density that the overstory can be removed. Effects from the overstory removal in the way of slash accumulation and ground surface disturbance will be similar to the effect of either the prep or seed cut, except that the new stand may contrast sharply with adjoining pole or sawtimber stands due to short overall height and high density Nevertheless, a green forested appearance will dominate

The variations of the shelterwood method will have effects similar to the standard (uniform) method, with effects patterned after the variation chosen. For instance, effects from the strip shelterwood method will occur in strips, from the group shelterwood in groups or patches In the simulated shelterwood, the future stand is already established beneath the overstory so that there remains a visually evident understory after either prep or seed cuts.

Stands arising from shelterwood harvests will exhibit a relatively uniform canopy and similar size and age classes

Single-tree and Group Selection: In both selection methods, about 1/5 of the overstory is harvested at any one time Harvesting occurs on a cycle of about every 30 years. Compared to even-aged cuts, selection harvests result in lighter cuts over similarly-sized areas, with corresponding lesser impacts on understory vegetation and soils, slash accumulations, and visually Stands harvested with the group selection method will have many scattered small patches cut (1/4 to two acres in size) with little or no harvested trees between groups. The single-tree selection method will result in scattered trees cut throughout the harvested stand In both instances, the stand should contain a range of size and age classes and exhibit a fully forested appearance

In the 30-year period between harvests, the small (single-tree or group) openings created will regenerate from seed from adjoining timber and gradually increase in height. Species that grow best in partial to heavy shade will be favored over those that grow in more open conditions Unlike even-aged stands, uneven-aged cutting and subsequent growth between harvests results in an uneven or layered forest canopy

Intermediate Treatments: The effects from thinning are similar to effects from harvesting mature stands, though at a greatly reduced level In thinnings, smaller trees are cut and removed, and less volume is removed per acre

The effects from improvement or sanitation/salvage cuts are similar to those from harvesting mature stands, generally at a reduced level. In rare instances, sanitation/salvage cutting effects can simulate those effects from shelterwood cutting, especially when insect epidemics result in high mortality in standing trees.

EFFECTS COMMON TO HARVEST OPERATIONS

In all even-aged methods, removal of the overstory occurs over a limited period relative to the time it takes for a stand to grow from a seedling stage to a fully-sized tree stage. The effects on a clearcut stand from actual harvest operations (e.g., felling, skidding) occur only one time in the life of a stand In the 3-step shelterwood, harvest operations occur three times during the life of a stand; in 2-step shelterwood, only two times. An example could be a spruce/fir stand managed on a 180-year rotation with a 3-step shelterwood The prep cut occurs at year 0, the seed cut at year 30, and the overstory removal cut at year 60. After the overstory removal cut, this stand would not be entered again for harvest until year 180, leaving the area 120 years without harvest-related disturbance

In uneven-aged methods, removal of the overstory occurs periodically On the ARNF, the average 30-year cutting cycle will result in harvest equipment entering the stand every 30 years Hence, selection methods result in about 2-3 times more entries during the life of a stand than compared to shelterwood methods. Additionally, due to the recurring entries into a stand with harvest equipment, it is preferable to use the same skid trails and landings with each entry So, once skid trail and landing locations are agreed upon with the first entry, those locations become committed to those purposes for as long as that stand is managed under uneven-aged methods. In contrast, after the final harvest of an even-aged method has occurred (clearcut, or overstory removal of shelterwood), skid trail and landing areas become available for forest regeneration and growth

In ground-based harvest systems, the harvest operation involves several key steps cutting, skidding, decking, loading, and hauling Cutting includes cutting of the tree, cutting the tree into logs ("bucking"), and removal of limbs, tops, and defective portions (rotten, twisted, crooked, deeply cracked) from the merchantable logs Skidding is the transport of logs to a gathering point, or landing, where logs are pushed together and stacked into decks. Then logs are loaded onto trucks for removal (hauling) from the sale area. (Some harvest systems remove limbs/tops/defect at the landing.)

The cutting of standing trees ("felling") can damage overstory and understory vegetation Damage to residual timber from chain saw felling varies greatly depending upon the ability of the chain saw operator ("faller"), weather (e.g , trees are more brittle and prone to breakage in cold weather, winds can affect felling direction), and conditions of the tree and stand A falling tree can damage other live trees by stripping branches, breaking tree tops, stripping protective bark, or striking and knocking down trees. Felling with mechanized equipment results in minimal damage to residual timber because of the control provided by booms that grasp, cut, and lower trees Residual timber damage from felling is generally greater in dense stands than open stands due to constricted operating space Similarly, skidding damage is generally greater in dense stands This damage is usually limited to the stripping of bark from skidded logs rubbing against these trees In most lodgepole pine stands, spruce/fir stands, and in some Douglas-fir/mixed conifer stands, first-entry harvests require additional cutting of merchantable and unmerchantable trees for skid trails to allow skidding operations to occur Without such cutting for skid trails in dense stands, there would be greater damage to residual timber.

Logs are decked at landings, adjoining roads. Depending on road layout and terrain features, landings can vary greatly in number and size Small openings or areas of low tree density are favored for landing sites. Landings often require additional felling of trees to provide operable space Due to repeated skidding to, decking at, and loading from landing sites, most vegetation is completely disturbed from landing-associated traffic.

Newly proposed OSHA (Occupational Safety and Health Administration) regulations would require all "hazard" trees, standing within two tree lengths of areas where logging personnel are working, to be felled In clearcut areas, unmerchantable trees will often be felled or knocked down due to the concentrated harvesting in these areas. In partial-cut areas, many unmerchantable trees are not damaged from harvest operations Depending on how strictly these OSHA regulations are interpreted and enforced, and how trees are judged as hazardous, many large unmerchantable trees, both live and dead, may need to be cut to ensure safe operations

Standing dead ("snags") will be reduced in numbers in harvested areas from intentional cutting (i.e , prescribed for harvest, cut for safety, or cleared in skid trails, landings, or roads) and unintentional damage resulting in such trees knocked down and/or cut

In all ground-based harvest systems, there is some accumulation of logging slash at the landing. In whole-tree systems, much of the logging slash accumulates at the landing In tree-length or cut-to-length systems, most logging slash is left at or near the cut stump. In most harvest areas on the ARNF, there occurs substantial accumulations of slash at landings to spur piling and burning. Slash at the landing is generally piled by the timber purchaser after all merchantable logs are removed from the area. If the sale area is remote and/or demand for fuelwood is low, slash burning is done by the purchaser More often, this slash is made available to the public after the timber sale is completed. Slash remaining after fuelwood gathering is later burned by Forest crews In areas where slash accumulations may impede natural regeneration or present a fire hazard, the slash may be piled and burned or roller chopped

In order for cut logs to reach sawmills, there must be road access to timber sale areas. In areas of inadequate access, the construction of new roads results in the removal of the land within the road prism from tree production

When a timber purchaser has cut and removed all timber prescribed for harvest from a sale unit or area, the purchaser is required to perform a variety of restoration activities, collectively referred to as "cleanup". This includes felling of damaged trees (and removal of merchantable logs), cutting of slash so it lies close to the ground (usually within two feet), construction of water diverting ditches on skid trails (termed "waterbars"), and general leveling and grading of landings and roadways In-sale roads (spur roads built primarily for accessing timber stands and not meant for other resource access) are closed with gates or other physical barriers to prevent further disturbance The final task is seeding, with fast-growing grasses and forbs, of highly disturbed areas (landings, in-sale roads, cut banks, road closure barrier mounds).

RECOMMENDED SILVICULTURAL TREATMENTS TO PREVENT OR MINIMIZE THE EFFECTS OF FOREST INSECTS AND DISEASES

PREVENTION OF SPRUCE BEETLE OUTBREAKS

Most spruce beetle outbreaks began following a large forest disturbance such as blowdown or logging which created abundant breeding sites for beetle populations (Wygant and Lejeune, 1967) Spruce beetle outbreaks may be prevented by salvaging windthrown trees within two years, by removing all spruce log decks within two years of logging operations or road construction, by cutting trees as low to the ground as possible to reduce stump height, and by removing or destroying cull logs, tops, and large diameter slash immediately following cutting activities in mature spruce stands.

Where a substantial spruce beetle population already exists in adjacent stands, it may be wiser to leave logging residues rather than to remove or destroy them immediately after cutting (Schmid and Frye, 1977). These residuals will attract beetles from adjacent stands and thereby reduce the number of attacks in standing trees. After the residuals become infested, it is critical that they be removed from the area or burned.

In areas having high spruce beetle populations, living, merchantable-sized spruce may be felled to attract beetles away from living, standing trees Once these "trap trees" are infested, they can be milled, burned, or chemically treated Trap trees should be felled between September 1 and October 31. Shaded trap trees will attract more beetles than trap trees exposed to sunlight Trap trees should be of high quality and the trap tree area should be easily accessible and of sufficient size (10-20 acres) to present a logical logging unit Trap trees should be removed from the logging area between September 1 and October 31 of the year following their felling

TREATMENT OF STANDS INFESTED WITH MOUNTAIN PINE BEETLES

There is a considerable body of literature that deals with the control of this insect (Amman et al, 1977, McGregor and Cole, 1985) For the most part, treatment options are limited to direct treatment of the insect by removal, processing, peeling or burning of infested trees or application of chemicals to kill the beetles as they emerge from infested trees

Indirect methods of control include combinations of partial cutting to provide spacing for tree growth, reduction of stand basal area and average stand diameter, and clearcutting to regenerate susceptible stands. Some of the newer techniques that may have limited success in high value stands and individual trees include the application of chemicals (such as carbaryl) to prevent attack of valuable trees and the use of pheromones to disrupt beetle activities, such as mating and attack of trees in specific areas

TREATMENT OF STANDS INFESTED WITH WESTERN SPRUCE BUDWORM

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, thus direct control measures are limited 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

Silvicultural treatment of stands that encourage a greater component of less susceptible species, such as ponderosa pine, lodgepole pine and spruce will reduce the damage that occurs; also stand structures that are more even-aged and single-storied will tend to reduce the amount of damage The following silvicultural practices will reduce budworm habitat and sustain vigorous forest growth (Carlson and Wulf, 1989):

- Strive for stand diversity in species composition by favoring seral species such as pines, and removing or discriminating against the most shade-tolerant host species.

- Regulate stand density through release cuttings and thinnings to improve and maintain tree vigor and stand growth.

- Create and maintain even-aged stand structures by using even-aged regeneration systems, followed by periodic low and crown thinnings.

- Promptly remove all overstory trees once regeneration is established in seed-tree and shelterwood cuttings

- Improve stand vigor by removing diseased, heavily infested, or otherwise unhealthy trees in all cuttings

- Capitalize on phenotypic and genetic resistance to budworm by selecting the most heavily defoliated trees for removal. Retain the lightly or non-defoliated trees for seed trees, collect cones from the most resistant phenotypes

- Regenerate host stands to less susceptible species at or before maturity as indicated by the culmination of mean annual growth

- Improve the diversity of the forest by creating seral stands in homogeneous areas of the late successional or climax host stands.

The reintroduction of fire into these ecosystems to limit the amount of understory Douglas-fir and encourage pine regeneration are some long term measures that should also be helpful

Silvicultural Treatment of Stands Infested with Dwarf Mistletoe

The dwarf mistletoes are most easily and economically treated by silvicultural practices Several features of these parasites make them ideal candidates for cultural management:

•Dwarf mistletoes require a living host to survive. Once an infected tree or branch is cut, the mistletoe dies. There is no need to destroy the slash.

•Mistletoes are generally host-specific; that is they are usually confined to a single host species or group of closely related species Immune or lightly infested species can be favored during stand treatments

•Dwarf mistletoes spread slowly Seed dispersal from a tall, isolated tree is usually limited to less than 60 feet. In even-aged stands, spread is even more limited, averaging 1 to 2 feet per year

•Dwarf mistletoes have a long life cycle: mature plants take 4 to 6 years to develop from seeds. This long life cycle means the amount of disease builds slowly. If a stand is properly treated, mistletoe should not be a serious problem in subsequent rotations.

•Infected trees and stands are easy to detect because of the presence of dwarf mistletoe plants, branch and stem swellings, and witches' brooms. Heavily infested stands show decline and mortality.

Presuppression surveys are utilized to define areas in need of treatment. Once the resource manager has located general problem areas, the biological need and effectiveness of proposed suppression projects can be evaluated.

Successful silvicultural techniques have been developed specifically for dwarf mistletoe control These practices can be easily integrated into planned harvesting and intermediate stand treatments. These strategies are aimed at either prevention or suppression of the disease dependent upon the age of the stand and management objectives. Because it is more effective to prevent mistletoes from becoming established than to eradicate them from infested stands or to replace severely infested stands, the priorities in control programs should be placed on prevention Prevention can be accomplished by:

•Designing treatment units to take advantage of natural or artificial barriers (such as roads, streams, nonsusceptible forests, openings, or meadows) that prevent reinvasion from adjacent infested stands.

•Felling or killing all infected trees before an area is planted or naturally regenerated

•Using regeneration harvests when logging infested stands. Long, narrow harvest strips should be avoided

•Regenerating stands with the shelterwood method leaving mistletoe-free or lightly infected residual trees If infected trees must be retained (for instance, in areas sensitive to visual quality objectives or protection of the site from adverse microsite conditions), they should be killed as soon as the site has regenerated and before the regeneration is three feet tall or 10 years old

•Favoring nonsusceptible tree species when regenerating a stand or making intermediate stand entries.

These strategies all reduce the likelihood of dwarf mistletoe spreading into a healthy stand When a stand is already infested, all infected overstory and selected infected understory trees can be felled This technique, known as sanitation-thinning, can be applied in lightly infested stands Crop trees should be disease free. However, lightly infected trees may be retained to meet minimum stocking guides. Replacing severely infested stands with healthy stands by cutting all infected trees, roller chopping, or prescribed burning and regenerating may be recommended in some instances.

In developed sites and recreation areas, the emphasis of control programs has been to reduce spread from individual infected trees and prolong the life of trees by pruning infected branches Resistant tree species may be planted in the understory with the eventual removal of the infected overstory trees

TREATMENT OF STANDS INFESTED WITH ARMILLARIA ROOT DISEASE

Silvicultural treatment of stands consists of one or more of the following measures

•Promoting stand vigor The impacts of Armillaria, particularly on more disease-tolerant species such as ponderosa pine, are usually greater on stressed trees Such stresses include drought, overstocking and impacts from other insects and diseases Methods of reducing stand stress, such as thinning, will help increase resistance to the disease

•Silviculturally favoring more resistant or tolerant tree species In general, ponderosa pine is tolerant to damage by *Armillaria* sp. However, where damage occurs, it may be advisable to encourage a mix of other species, including aspen, spruce, and lodgepole pine

•Patch-cutting infection centers, including the removal of a 30-50 foot buffer zone This treatment method is often effective where root disease centers are well-defined (easily visible) and low in number. Removal of host trees in a buffer zone around all visibly infected trees is recommended because susceptible trees around the visible infection center are likely to be infected. A mix of disease-resistant or tolerant tree species should be encouraged in the resulting openings

•Reducing residual inoculum levels between stand rotations. This is accomplished by mechanically removing residual infected stumps and roots from the ground or by push-felling infected harvest trees This direct reduction of inoculum levels is expensive and requires careful economic analysis While these treatments are effective and may be warranted in high value sites and developed recreation areas, the cost is usually prohibitive in all other areas

•Critically evaluate disease impact to ensure that the level of loss justifies control The use of the Western Root Disease Model may aid in this effort (Stage et al, 1990)

TREATMENT OF STANDS INFESTED WITH COMANDRA RUST

Reduction of losses to this disease consists primarily of identifying heavily infested stands and harvesting as soon as management permits (Brown, 1977; Johnson, 1986a) If feasible, regenerate with tree species other than susceptible hard pines Where seed trees are used to regenerate a stand, disease-free trees should be left as seed sources. Harvest merchantable trees with cankers on the lower or mid-portion of the stem before the fungus girdles and kills the tree. Cankers occurring between the base of the trunk and a height of about 25 feet are usually lethal (Johnson, 1979)

Other than retaining more trees than stocking guides recommend, no practical control measures are available to suppress the rust in young stands Increased stocking will, over time, be offset by rust-caused mortality In marginally stocked stands, the disease may cause significant losses.

The strong association of site, stand, and alternate host factors with incidence of the disease provides managers with a means of determining rust hazard in stands of lodgepole pine. In stands where the hazard is so great that a commercial crop is marginal, the investment in intensive forest management practices should probably be reconsidered