Eastside Ecosystem Management Strategy Project

Report on Bole and Branch Herbivores

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Preface

The following report was prepared by University scientists through cooperative agreement, project science staff, or contractors as part of the ongoing efforts of the Interior Columbia Basin Ecosystem Management Project, co-managed by the U.S. Forest Service and the Bureau of Land Management. It was prepared for the express purpose of compiling information, reviewing available literature, researching topics related to ecosystems within the Interior Columbia Basin, or exploring relationships among biophysical and economic/social resources.

This report has been reviewed by agency scientists as part of the ongoing ecosystem project. The report may be cited within the primary products produced by the project or it may have served its purposes by furthering our understanding of complex resource issues within the Basin. This report may become the basis for scientific journal articles or technical reports by the USDA Forest Service or USDI Bureau of Land Management. The attached report has not been through all the steps appropriate to final publishing as either a scientific journal article or a technical report.

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Introduction

This analysis covers bole and branch herbivores. This includes insects that feed on or within the trunk and branches of forest trees. It does not include bud and shoot insects that feed on or within buds and expanding shoots. These insects are more closely associated with defoliators or canopy herbivores. Furthermore, this analysis does not include insects that feed primarily within dead stems, branches, or twigs. These insects are included among litter and soil arthopods and coarse woody debris chewers.

None of the bole and branch herbivores meet the social criteria for individual assessment. That is, none are currently listed as sensitive, threatened, endangered, or of special concern by federal or state agencies or private organizations. Furthermore, none of these species are known to be "narrow endemics" or occupy habitats that are rare, threatened, or in severe decline. However, a number of species do play ecological roles that greatly determine the structure, function, and composition of ecosystems within the Columbia River Basin (CRB). The best known among this group are those species that have been previously identified as pests. Their pest status, in fact, is attributable to their potential to alter the structure, function, and composition of ecosystems. The species that will be assessed individually are the following:

Adelges Piceae	Balsam woolly adelgid
Dendroctonus brevicomis	Western pine beetle
Dendroctonus Ponderosae	Mountain pine beetle
Dendroctonus pseudotsugae	Douglas-fir beetle
Dendroctonus rufipennis	Spruce beetle
Scolytus ventralis	Fir engraver

There are many other species which play important ecological roles in the forests within the assessment area (Furniss and Carolin 1977, Furniss and Johnson 1987, Gast et al. 1989, Furniss et al. 1992, Wood and Bright 1992). However, these species produce effects on a smaller scale, respond coincidentally with one of the above listed species, or are poorly studied. Because of these considerations and the limited time available for this analysis, these other species will be briefly discussed as groups in the second phase of this analysis. This should not be mistaken to imply that the other species are unimportant. All of these species are involved in ecosystem processes and, at certain times and places, any species may exert a great influence on ecosystem structure, function, and composition.

This report is not a comprehensive review of all pertinent literature. That would require a much greater effort than was possible with the time allocated to the work presented here. The literature on the Scolytidae and Platypodidae alone is voluminous (Wood and Bright 1987, 1992). Instead, this report presents some general conclusions regarding the distributions, ecology, and population trends of some of the important bole and branch herbivores found in the CRB. Citations are provided to justify the conclusions and provide an entry into the literature.

Balsam Woolly Adelgid (Adelges piceae (Ratzeburg))

The balsam woolly adelgid was introduced into eastern North America from Europe around 1900 (Mitchell et al. 1970). It was first discovered in the Pacific Northwest in 1930, damaging grand fir (Abies grandis (Dougl.) Lindl.) in the Willamette Valley (Mitchell 1966). It subsequently spread throughout western Oregon, Washington, and southern British Columbia. The eastward spread of the adelgid was primarily limited to the Cascades until an infestation was discovered in 1983 in northern Idaho (Mitchell 1966, Wood 1968, Gast et al. 1990). Aerial surveys conducted between 1990 and 1992 detected from 4,050 to 9,720 ha with adelgid-caused subalpine fir (A. lasiocarpa (Hook.) Nutt.) mortality in Idaho (Hofacker et al. 1991, 1992, 1993). Within the CRB, the adelgid is currently known to occur only in the Cascades along the western boundary and in northern Idaho (Appendix A). However, the extent of the Idaho infestation suggests that this insect has a greater potential to spread throughout the true fir stands in the CRB than previously recognized.

The adelgid is a small, inconspicuous sucking insect (Mitchell 1966, Hain 1988). It spends most of its life in a single location with its mouthparts inserted into the host tree. Adelgid infestations can be found on the bole, branches, twigs, and at the base of buds. Crown infestations result in stunting of terminal growth and swelling at the branch tips and nodes known as gouting. This can lead to thinning and dieback of the crown and eventually tree death. However, tree mortality is more commonly associated with infestations on the main stem that interfere with translocation in the xylem and phloem. The principal hosts in the Pacific Northwest are grand fir, Pacific silver fir (A. amabilis (Dougl.) Forbes), and subalpine fir. This insect has the potential to kill large numbers of trees and dramatically alter forest structure, composition, and ecosystem processes (Johnson et al. 1963, Mitchell 1966, Franklin and Mitchell 1967, Gast et al. 1990).

The species of fir that are infested by the adelgid in the Pacific Northwest differ in their degree of susceptibility. Grand fir is the most resistant. Grand fir may survive infestation for as long as 15 years and less than 30 percent of infested trees die (Mitchell 1966). on the eastside of the Cascades, all grand fir appear to survive infestation even when growing among more susceptible species (Mitchell 1966, Gast et al. 1990). Subalpine fir is the most susceptible species. Subalpine fir often die within 3-5 years following stem infestations and up to 90 percent of trees in infested stands may die (Mitchell 1966). Pacific silver fir is intermediate in susceptibility, but up to 70 percent of trees in heavily infested stands may be killed (Johnson et al. 1963).

Elevation, site quality, and tree age determine susceptibility to adelgid infestation in westside forests and similar relationships may exist in eastside forests also. Host trees growing at the low end of their elevational ranges appear to be most susceptible. In the Cascades, these are below 300 m for grand fir, 460 to 915 m for Pacific silver fir, and 915 to 1,675 m, for subalpine fir (Mitchell 1966). In Idaho, the first infested subalpine fir stands to be detected were at low elevations (<915 m), but infestations at high elevations (1,5251,830 m) have subsequently been identified (Gast et al. 1990). Trees growing on the highest quality sites also appear to be most susceptible (Johnson et al. 1963, Mitchell 1966). This is likely due to higher survival rates of dispersing adelgids on trees of superior nutritional value in these stands (Carrow and Betts 1973). Tree age also determines susceptibility to adelgid infestation. Grand fir less than 15-years-old are not infested and trees from 25- to 35-years-old are most susceptible. Pacific silver fir are not attacked until they are at least 50-years-old and subalpine fir become susceptible at an age of about 25 years (Mitchell 1966). The stocking of preferred host tree species will also determine the susceptibility of a given stand to adelgid infestation (Mitchell 1966, Hain 1988).

Cold winter temperatures can significantly reduce survival of overwintering adelgids. only adelgids protected by snow cover can survive temperatures of –34°C or less (Amman 1967). The lower winter temperatures found in interior forests are presumably responsible for the limited distribution of the adelgid outside of coastal regions. Widespread adelgid mortality in Idaho during the winter of 1990-1991 was apparently due, at least in part, to extremely low temperatures that occurred in some areas (Hofacker et al. 1992).

The first instar or crawler is the only motile stage of the adelgid. Long distance dispersal occurs primarily when the crawlers drop from trees and are carried by the wind to new host trees, although phoresy by birds, mammals, amphibians, and

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insects may also contribute to long distance dispersal. Crawler activity and rate of dropping increase with increasing light intensity and temperature (Smith 1958, Atkins and Hall 1969). Therefore, infested-trees along stand margins play an important role in adelgid dispersal. Human activities can also increase rates of dispersal. Movement of infested nursery stock is presumably the route by which the adelgid reached North America from Europe (Hain 1988). Harvesting of infested trees increases the rate of crawler dispersal into the surrounding stand by dislodging the nymphs and creating local air movement (Lambert and Ciesla 1967). Harvesting may also increase the rate of crawler dropping from infested residual trees or trees along unit boundaries due to increased light and temperatures. Transporting infested logs may also contribute to long distance dispersal (Atkins and Woods 1968).

The adelgid can obviously affect a number of stand characteristics and ecological processes, although these are not well documented by research. In the absence of tree mortality, the adelgid can affect stand productivity and successional processes by reducing the growth of host trees. Dropping of old foliage and branch mortality resulting from non-lethal crown infestations may affect nutrient cycling processes and provide infection courts for stem decay fungi. Seed production may also be eliminated or reduced. The timber value of trees with stem infestations is reduced due to inferior wood properties (Doerksen and Mitchell 1965, Foulger 1968). These effects are more pronounced when infestations result in host tree mortality. Furthermore, tree mortality increases standing and down woody

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debris, nutrient cycling, and fire hazard. Since host trees often occur in mixed conifer stands, adelgid-caused mortality will shift species composition to non-host species. At low elevations, this may favor Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and western hemlock (Tsuga heterophylla (Raf.) Sarg.), and, at higher elevations sites, may be occupied by Engelmann spruce (Picea engelmanii Parry ex Engelm.), lodgepole pine (Pinus contorta Dougl. ex Loud.), mountain hemlock (Tsuga mertensiana (Bong.) Carr.), or noble fir (Abies procera Rehd.) (Mitchell 1966). Adelgid-caused mortality can have a significant impact on harsh sites such as lava beds, talus slopes, and abandoned beaver marshes where subalpine fir is a pioneer species (Franklin and Mitchell 1967). Subalpine fir mortality on such sites will likely have negative impacts on watershed, wildlife, and recreational values.

Aerial surveys are inadequate to detect new adelgid infestations since it may take three years or longer before symptoms are visible from the air (Mitchell 1966). Ground surveys are the only way to detect infestations before crown dieback and tree mortality become apparent. Although the adelgid has been in the Pacific Northwest for at least 60 years, it has probably not yet become established in all potentially favorable habitats as evidenced by the recent development of the Idaho infestation. Because the adelgid reproduces parthenogenetically and is wind dispersed, it has a high dispersal capability. It is likely that new infestations or currently undetected infestations will be discovered within the CRB. Any warming associated with

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climate change will likely create a more favorable environment within the CRB for the adelgid.

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Columbia River Basin - Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Adelges piceae (Ratzeburg), Balsam woolly adelgid

Geographic Area and/or Habitat Type:

SAF 206, SAF 213, SAF 226

Key Environmental Correlates

1. Tree species

Categorical

Suitable Categories: (Johnson et al. 1963, Mitchell 1966)

Damage potential moderate:
Abies grandis (Douglas) Lindley, Grand fir
Damage potential severe:
Abies amabilis (Douglas) Forbes, Pacific silver fir
Abies lasiocarpa (Hooker) Nutall, Subalpine fir

Applies seasonally? No

Theme name: ?

Attribute: ?

2. Geographic location

Categorical

Suitable Categories: (Mitchell 1966, Gast et al. 1990)

Low probability of infestation:
All other areas
High probability of infestation:
Less than 5 km east of the crest of the Cascades
Northern Idaho

Applies seasonally? No

Theme name: ?

Attribute: ?

3. Elevation

Categorical

Suitable Categories: (Mitchell 1966, Gast et al. 1990)

Low probability of infestation:
Grand fir above 300 m
Pacific silver fir above 915 m
Subalpine fir above 1,675 m

High probability of infestation:
Grand fir below 300 m
Pacific silver fir below 915 m
Subalpine fir below 1,675 m

Applies seasonally? No

Theme name: Biophysical, Subsection

Attribute: Physiography - Elevation Range

4. Low winter temperature

Categorical

Suitable Categories: (Amman 1967)

Low damage potential:
Previous winter temperature below -34°C

High damage potential:
Previous winter low temperature above -34°C

Applies seasonally? Yes

Theme name: Climate

Attribute: Daily - Min Temp

5. Tree age

Categorical

Suitable Categories: (Mitchell 1966)

Low probability of infestation:
Grand fir < 15-years-old
Pacific silver fir < 50-years-old
Subalpine fir < 25-years-old

High probability of infestation:
Grand fir > 15-years-old
Pacific silver fir > 50-years-old
Subalpine fir > 25-years-old

Applies seasonally? No

Theme name: ?

Attribute: ?

Key Ecological Functions

1. Alter stand density and composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase fire hazard

5. Increase incidence of Armillaria spp.

Key Assumptions

Key Unknowns and Monitoring or Research Needs

This insect was not expected to be a significant problem in the CRB. However, the infestation that developed in Idaho during the 1980's indicates that the adelgid does have the potential to cause large amounts of tree mortality and growth loss in some portions of the CRB. Most of our knowledge of adelgid biology and ecology comes from areas outside of the CRB. There is a need to study the Idaho infestation to better understand adelgid population dynamics in interior forests. This will help us to anticipate more accurately the potential role that the adelgid will play in interior forests in the future.

Current monitoring approaches (i.e., aerial surveys) are inadequate to identify new adelgid infestations. It is possible that the adelgid is present in many other portions of the CRB, but has not yet been detected. Ground surveys are the only way to detect the adelgid in stands that are not yet experiencing significant mortality or crown dieback. Efforts should be made to include surveys for adelgid infestations along with existing stand and forest health inventories.

Dispersal

Dispersal mode: The crawler is the only dispersing stage. The primary mode of dispersal is passively by wind. Crawlers may also be dispersed by humans transporting infested material or phoresy (on insects, mammals, birds, and amphibians) (Mitchell 1966, Hain 1988).

Requirements for dispersal: Since the crawlers are photokinetic, they are more likely to drop from trees along stand edges. These crawlers may be carried aloft by convection currents generated in adjacent openings possibly resulting in long distance dispersal (Smith 1958, Atkins and Hall 1969).

Degree of Confidence in Knowledge of Species

Medium (see comments)

Trend

Increasing

Comments:

This species has been studied intensively in other portions of its geographic range. The adelgid was not expected to become a significant problem in interior forests due to its inability to tolerate low winter temperatures. However, a major infestation developed in northern Idaho in the 1980's indicating that it does have the potential to cause significant mortality within the CRB. Most of the information on the biology and ecology of this insect is from areas outside of the CRB. The insect may behave differently in the ecosystems comprising the CRB.

Western Pine Beetle (Dendroctonus brevicomis LeConte)

The western pine beetle attacks ponderosa pine (P. ponderosa Dougl. ex Laws.) throughout the CRB (Furniss and Carolin 1977, DeMars and Roettgering 1982). At low population densities, the beetle breeds in scattered trees weakened by fire, wind, lightning, root disease, competition, secondary bark beetles, wood borers, or other causes (Miller and Keen 1960, Cobb et al. 1974, Goheen and Cobb 1980). Under these conditions, the defensive capacity of most trees is sufficient to repel bark beetle attacks (Vité 1961, and Wood 1961, Berryman 1972). However, if the beetle population increases or host tree resistance declines, more trees will be susceptible to attack (Paine et al. 1984). Beetle populations may rise to levels where they are capable of overcoming the defenses of almost any host tree. Under favorable conditions, such as extended drought, this beetle has killed over one million trees and as much as three and one-half billion board feet of timber in a single year (Miller and Keen 1960). Mortality on this scale will greatly impact resource values and ecosystem processes.

The western pine beetles preference for certain types of trees and stands was recognized during efforts to control outbreaks in the early 1900's (Miller and Keen 1960). The first attempts to manage the beetle involved various types of direct control (i.e., reduction of beetle population densities) primarily the fell-peel-burn technique (Smith 1990). This approach produced inconsistent and often unsatisfactory results. These early failures stimulated research on beetle ecology to provide the basis for developing improved management techniques. Several studies demonstrated that the beetle preferred slowgrowing trees, at least under endemic conditions (Person 1928, Miller and Keen 1960). Based upon this knowledge, several hazard and risk rating systems were developed to guide managers in prescribing silvicultural treatments to reduce timber losses (Keen 1936, Salman and Bongberg 1942, Smith et al. 1981). These systems involved visually assessing the relative growth vigor of individual trees based largely upon the size and condition of the crown. Trees that were judged to be low vigor and, therefore, most susceptible to beetle infestation were selectively removed. Various types of sanitation/salvage harvesting programs were developed based upon these risk rating systems and landowner objectives. These programs also recognized the effects of stand density and competing brush on tree growth and resistance to beetle attack (Smith et al. 1981). Current recommendations for second-growth stands are to maintain stocking levels between 55 and 70 percent of normal to minimize susceptibility to beetle attack (DeMars and Roettgering 1982).

Other factors that determine susceptibility to western pine beetle include tree size and age. Trees less than 15-18 cm dbh are rarely attacked (Miller and Keen 1960). In old-growth stands, trees between 50 and 75 cm dbh have the highest probability of infestation (Person 1928). Miller and Keen (1960) suggested that this diameter preference is related to the period of most intense intertree competition in unmanaged stands. In general, the western pine beetle infests larger trees than the mountain pine beetle (Dendroctonus ponderosae Hopkins) (Goheen and Cobb 1980). The relationship between susceptibility to beetle attack and age is not entirely clear, but trees under 75-years-old have a lower probability of becoming infested than older trees (Miller and Keen 1960).

The western pine beetle affects many ecological processes. Since the beetle prefers large, old, slow-growing trees, the ponderosa pine component in a stand following an outbreak will be smaller, younger, and faster-growing. The lower stand density may provide space and resources for accelerated growth of residual trees. on sites where ponderosa pine is a seral species, the western pine beetle will facilitate succession to shade-tolerant species. This will magnify the effects of selective logging and fire suppression that have also favored this shift in species composition. If conversion of these stands to a seral condition is the management objective, stand density management around residual pines will be required to minimize stress and reduce the probability of beetle attacks. On sites where ponderosa pine is a climax species, the western pine beetle will promote the development of an uneven-aged, multistoried stand structure. The beetle will periodically remove groups of large, slow-growing trees providing space for regeneration.

The rate at which beetle-killed trees deteriorate depends upon a variety of factors including tree size, proportion of heartwood, and prevailing weather (Keen 1955). Needles change color and drop from the tree bark loosens and falls, and the branches and main stem gradually deteriorate and fall to the ground. Many insects and microorganisms utilize beetle-killed trees and facilitate the decomposition process (Miller and Keen

1960). In one study, 85% of beetle-killed trees were standing after 5 years, 40% after 10 years, and 10% after 25 years (Keen 1955). Standing and down trees provide habitat for wildlife (Scott 1978, Scott 1979, Bull and Partridge 1986), fuel for wildfires, and chemical and physical inputs to the soil.

Observations suggest that western pine beetle-caused mortality was higher from 1910 to 1960 than it was from 1960 to 1985, although loss data for this period are inadequate to verify this conclusion (Smith et al. 1990). Possible reasons for the decline in beetle activity include changes in forest management including use of risk rating and sanitation/salvage harvests, decline in abundance of old-growth forests, and higher tree resistance resulting from more favorable weather. It is likely that a decline in susceptible forest type is, at least partly, responsible for a reduction in western pine beetle activity. Fire suppression and selective logging have converted many seral ponderosa pine stands to more shade-tolerant species over the last 80-90 years. At the same time, old-growth, climax ponderosa pine stands have been replaced by dense, second-growth stands that are just beginning to reach susceptible age and size classes. In addition, several root pathogens have increased in abundance as a result of past management practices (Hofacker et al. 1991, 1992, 1993, Hessburg et al. 1994). The high incidence of root disease centers will ensure that endemic beetle populations are dispersed throughout susceptible forest type. If conditions become favorable for the western pine beetle, these endemic populations will be able to quickly expand into the surrounding forests. Without management, these stands will eventually suffer high levels of mortality from the western pine beetle.

Columbia River Basin – Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Dendroctonus brevicomis Leconte, Western pine beetle

Geographic Area and/or Habitat Type:

SAF 215, SAF 237

Key Environmental Correlates

1. Ponderosa pine DBH

Categorical

Suitable Categories: (Person 1928, Miller and Keen 1960)

Low suitability: <18 cm
Moderate suitability: 18 cm :≤ DBH < 50 cm
High suitability: ≥50 cm

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

2. Ponderosa pine age

Categorical

Suitable Categories: (Keen 1936, Miller and Keen 1960)

Low suitability: <75 years
High suitability: ≥75 years

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

3. Stand basal area

Categorical

Suitable Categories: (DeMars and Roettgering 1982)

Low suitability: <70% of normal stocking
High suitability: ≥70% of normal stocking

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

4. Drought

Categorical

Suitable Categories: (Miller and Keen 1960)

Low suitability: None
Medium suitability: Moderate drought
High suitability: Severe drought

Applies seasonally? No

Theme name: Climate

Attribute: Annual - Total Precipitation

Key Ecological Functions

1. Alter stand density, canopy structure, age distribution, and species composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase fire hazard

Key Assumptions

Key Unknowns and Monitoring or Research Needs

Although a number of key environmental correlates are known for this insect, most of the research was conducted in old-growth forests (Miller and Keen 1960). There is a need for research in second-growth forests to better define the tree, site, and stand characteristics that identify high hazard conditions in different geographic areas.

Current aerial survey techniques are inadequate for this insect. This beetle has 2-3 generations per year in the CRB, and trees that are attacked late in the summer or fall may not fade until the follwoing spring or summer. Consequently, there may be a delay in detecting changes in populations. A monitoring technique that would provide an early warning of increases in the beetle population would be useful for developing management plans. Pheromones are a potential tool that could meet this need.

A more comprehensive list of research needs was recently prepared by the USDA Forest Service, National Bark Beetle Steering Committee (USDA Forest Service 1993).

Dispersal

Dispersal mode: Adult flight. Beetles are capable of flying at least 3.2 km and and there is some evidence that beetles have flown as far as 12.9 km (Miller and Keen 1960).

Requirements for dispersal: Temperatures between 10 and 35^{o}C, daylight (Miller and Keen 1960). Successful dispersal is related to the abundance of suitable breeding material.

Degree of Confidence in Knowledge of Species

Medium to High

Trend

It is difficult to categorize the regional trend of the western pine beetle, since populations may be increasing, static, and declining in different areas at the same time. Local outbreaks of varying sizes develop almost every year. In habitat types where pines are seral species, they are declining in abundance as a result of past logging and fire suppression policies. The western pine beetle is currently less important in these situations than it was previously. In habitat types where pines are climax species, past logging and fire suppression have resulted in dense second-growth stands that are highly suitable environments for the western pine beetle. The high incidence of root disease in these stands also favors beetle infestations. Without fire or some other type of stand density management, the beetle populations will periodically remove the largest trees in these stands.

Comments:

Mountain Pine Beetle (Dendroctonus ponderosae Hopkins)

The mountain pine beetle is one of the most important and well-studied forest insects in the western United States (Furniss and Carolin 1977, Raffa 1988, Amman 1989a, Wood and Bright 1992). This beetle has the potential to kill millions of trees in a single year and dramatically alter forest-structure, composition, and ecosystem processes. The mountain pine beetle was the focus of some of the first forest insect control projects in the Pacific Northwest (Burke 1990, Wickman 1990).

The principal hosts of the mountain pine beetle are lodgepole, ponderosa, western white (P. monticola Dougl. ex D. Don), sugar (R. lambertiana Dougl.), and whitebark (R. albicaulis Engelm.) pines. A number of other species are occasionally infested. Among the principal hosts, lodgepole and ponderosa pines are the most common. For example, between 1979 and 1983, lodgepole pine accounted for 95% of all trees killed by the beetle in the western U.S. and ponderosa pine accounted for another 4% (McGregor 1985). Because the majority of mountain pine beetle-caused mortality occurs in lodgepole and ponderosa pines and most research has been based on populations infesting these tree species, this report will focus primarily on interactions between the beetle and these hosts. The mountain pine beetle may be found in association with its host trees throughout the CRB.

Although there are many natural controls that influence mountain pine beetle populations, most evidence indicates that they are regulated by the availability of food (Amman and Cole

1983). Host availability is determined by the abundance of host tree species, the susceptibility of host trees, and the beetle population (Raffa 1988). At low population densities, mountain pine beetles infest individual trees or small groups of trees that are weakened by secondary bark beetles, root or stem pathogens, or other injuries (Tkacz and Schmitz 1986, Rasmussen 1987, Schmitz 1988, Safranyik 1989). Under these conditions, the beetle population is insufficient to overcome the resistance of most potential host trees. If the beetle population increases or host resistance declines, food will become more abundant and the beetle population will rise. outbreaks develop when available host trees are both abundant and high quality. During outbreaks, the beetle population is capable of overcoming the defenses of almost any tree in the forest.

Certain types of trees, stands, and sites are more susceptible to beetle infestations than others and this knowledge has been used to develop a number of hazard and risk rating systems (Amman and Anhold 1989, Shore et al. 1989, Shore and Safranyik 1992, Schmid et al. 1994). The beetles preference for large diameter trees is well known (Hopping and Beall 1948, Cole and Amman 1969, Sheppard 1966). These trees represent a plentiful and often high quality food resource (Amman 1969). Large diameter trees are a prerequisite for the development and maintenance of outbreak populations (Cole and Amman 1980, Mitchell and Preisler 1991). Small diameter trees are attacked when they are in proximity to other mass-attacked trees, but they are unable to support outbreak populations. In general, lodgepole and ponderosa, pines with dbh $\geq$: 23 cm are required to sustain outbreaks (Sartwell and Stevens 1975, Mitchell and Preisler 1991).

Stand density can affect susceptibility to mountain pine beetle infestation in several ways. At very high densities, few, if any, trees will reach the large sizes favored by the beetle and the stand will have a low probability of infestation (Shore and Safranyik 1992). Thinning stands that have already reached a susceptible size often results in a lower probability of infestation (Sartwell and Dolph 1976, Cole et al. 1983, McGregor et al. 1987, Schmid and Mata 1992). This lower susceptibility may be due to increased resistance of residual trees resulting from less competition for site resources (Schenk et al. 1980, Larsson et al. 1983, Mitchell et al. 1983, Waring and Pitman 1985, Anhold and Jenkins 1987). However, in some cases, infestations are unrelated or only weakly related to tree vigor (Amman et al. 1988, Mitchell and Preisler 1991, Preisler and Mitchell 1993). Another possibility is that the microclimate of low density stands is less favorable for beetle dispersal and colonization (Amman et al. 1988, Amman 1989b, Bartos and Amman 1989, Schmitz et al. 1989).

Tree age is related to susceptibility to beetle infestation largely through correlations with tree size and phloem, thickness (Amman et al. 1977). As trees age, they become larger and often contain thicker phloem which is more suitable for mountain pine beetle development (Amman 1969, Amman and Pasek 1986). Young trees may also be physiologically more resistant to beetle attack than older trees (Shrimpton 1973). Trees less than 60-years-old are rarely infested. Most infestations occur in stands that are at least 80-years-old (Sartwell and Stevens 1975, Amman et al. 1977, Shrimpton and Thomson 1983).

Elevation, latitude, and longitude are also related to susceptibility to beetle infestation. The lower temperatures at higher elevations delay beetle development so that a larger proportion of the population overwinters in life stages that are vulnerable to cold winter temperatures (Amman 1973, Amman et al. 1973). As a result, beetle survival is low at high elevations and risk of tree mortality is low even when conditions are otherwise favorable for beetle infestations (Amman and Baker 1972). Moving east or north affects beetle survival similarly to an increase in elevation (Amman et al. 1977, Shore and Safranyik 1992).

The mountain pine beetle plays a number of important ecological roles (Amman 1977). By removing the largest and oldest host trees, the beetle alters stand structure and, in some cases, composition. Following an outbreak the average age, size, and density of host trees will be reduced compared to preoutbreak conditions (Amman and Baker 1972, McCambridge et al. 1982). Also, growth of surviving host and non-host trees may increase as a result of reduced competition for site resources (Romme et al. 1986, Heath and Alfaro 1990). On sites where lodgepole pine is a seral species, the mountain pine beetle promotes succession to more shade-tolerant species such as Douglas-fir, Engelmann spruce, subalpine fir, or grand fir (Cole and Amman 1980). However, if a wildfire occurs in the fuels accumulated during a beetle outbreak the stand may be regenerated to lodgepole pine. On sites where lodgepole pine is an edaphic or topoedaphic climax, periodic mountain pine beetle outbreaks will promote the development of an uneven-aged, multistoried stand structure in the absence of high-intensity fires. The mountain pine beetle can have similar effects in ponderosa pine forests. Outbreaks sometimes develop in lodgepole pine and spread to ponderosa pine at lower elevations and whitebark pine at higher elevations (Bartos and Gibson 1990, Burke 1990).

The large quantity of standing and down woody debris following an outbreak will alter nutrient cycling processes, increase fire hazard, and affect wildlife habitat (McGregor and Cole 1985). Effects on wildlife habitat can be either positive or negative. For example, an abundance of snags may improve habitat for cavity-nesting birds, but down trees may impede access for large animals such as deer and elk. Changes in the structure and composition of the vegetation will also affect wildlife habitat. Mortality in whitebark pine may reduce the seeds available as food for a variety of wildlife including grizzly bears (Bartos and Gibson 1990). The quantity and quality of water yields may be altered as a result of beetle-caused tree mortality, but these effects have not been thoroughly studied. Timber, recreation, forage, and aesthetic values will also be affected by beetle outbreaks.

Mountain pine beetle population trends are difficult to characterize since populations may be declining, static, and increasing at the same time in different areas (Hofacker et al. 1991, 1992, 1993). As a result of fire suppression over the last century, seral stands of lodgepole and ponderosa pines are being replaced by more shade-tolerant species. If this trend continues, mountain pine beetle outbreaks will become less common in these habitat types (Hessburg et al. 1994). However, the shade-tolerant trees are suffering widespread mortality from other insects and pathogens and they may inevitably be converted back to seral pine stands following stand-replacing fires. In habitat types where pines are climax, conditions are currently ideal for the mountain pine beetle. In many cases, past logging and fire suppression have resulted in dense regeneration that is currently reaching sizes susceptible to beetle infestation (Hessburg et al. 1994). Recent droughts have further stressed these dense pine stands allowing beetle populations to reach outbreak densities in some locations. In short, wherever host tree species of a susceptible size occur in dense stands, mountain pine beetle populations will increase and remain at high densities as long as food is abundant and climatic conditions are favorable.

Columbia River Basin - Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Dendroctonus ponderosae Hopkins, Mountain pine beetle

Geographic Area and/or Habitat Type:

SAF 208, SAF 212, SAF 215, SAF 218, SAF 237

Key Environmental Correlates

1. Lodgepole or ponderosa pine DBH

Categorical

Suitable Categories: (Sartwell and Stevens 1975, Amman and McGregor 1985, Mitchell and Preisler 1991)

Low suitability: <23 cm
High suitability: ≥23 cm

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

2. Lodgepole or ponderosa pine age

Categorical

Suitable Categories: (Amman et al. 1977, Sartwell and Stevens 1975, Shore and Safranyik 1992)

Low suitability: ≤60 years
Medium suitability: 61-80 years
High suitability: >80 years

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

3. Stand basal area

Categorical

Suitable Categories: (McGregor et al. 1987, Schmid and Mata 1992)

Low suitability: <27.6 m^2/ha
High suitability: $\geq$27.6 m^2/ha

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

4. Location (Y), where Y=[24.4Longitude]-[121.9Latitude][Elevation(m)]+[4545.1]

Categorical

Suitable Categories: (Shore and Safranyik 1992)

Low suitability: <-500
Medium suitability: O>Y$\geq$-500
High suitability: $\geq$O

Applies seasonally? No

Theme name: Biophysical, Subsection

Attribute: Physiography - Elevation Range

Key Ecological Functions

1. Alter stand density, canopy structure, age distribution, and species composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase fire hazard

Key Assumptions

This analysis is based upon studies of the beetle in association with lodgepole and ponderosa pines. Presumably, similar relationships exist with other host tree species, but data is not currently available to verify this assumption. Furthermore, most research has been conducted in unmanaged stands. This analysis assumes that similar relationships are likely to occur in managed stands.

Key Unknowns and Monitoring or Research Needs

Although a number of key environmental correlates are known for this insect, there are apparently significant geographic variations (Amman and Anhold 1989, Shore et al. 1989). Research is needed to further develop and test hazard/risk rating systems that more accurately define the relationships among the beetle, host trees, and environment.

A more comprehensive list of research needs was recently prepared by the USDA Forest Service, National Bark Beetle Steering Committee (USDA Forest Service 1993).

Dispersal

Dispersal mode: Adult flight.

Requirements for dispersal: Temperatures between 16 and 30^{o}C (Gray et al. 1972). Daylight. Successful dispersal is related to the abundance of suitable breeding material.

Degree of Confidence in Knowledge of Species

Medium to High

Trend

It is difficult to categorize the regional trend of the mountain pine beetle, since populations may be increasing, static, and declining in different areas at the same time. Local outbreaks of varying sizes develop every year. In habitat types where pines are seral species, they are declining in abundance as a result of past logging and fire suppression policies. The mountain pine beetle is currently less important in these situations than it was previously. In habitat types where pines are climax species, past logging and fire suppression have resulted in dense second-growth stands that are highly suitable environments for the mountain pine beetle. Without fire or some other type of stand density management, the beetle populations will periodically remove the largest trees in these stands.

Comments:

Douglas-fir Beetle (Dendroctonus pseudotsugae Hopkins)

The Douglas-fir beetle is found throughout the range of Douglas-fir in the CRB (Furniss and Carolin 1977). The beetle occassionally attacks western larch (Larix occidentalis Hook) growing in association with Douglas-fir, but brood survives only in dead larch (Ross 1967, Furniss et al. 1981). As with other bark beetles, the population dynamics of this insect are closely associated with the availability and suitablility of breeding sites. At low population densities, the beetle breeds in recently dead trees or living trees with a limited defensive capacity such as those damaged by root pathogens, lightning, fire, wind, snow and ice, or logging activities (McMullen and Atkins 1962, Rudinsky 1963, Rudinsky 1966). As long as suitable breeding material is sparse, the population is likely to remain stable because of high adult mortality during dispersal and colonization and high larval mortality resulting from competition for limited food (McMullen and Atkins 1961). If suitable breeding material becomes abundant as a result of fire, snow or ice storms, windstorm, drought, competition, insect defoliation, logging activities or other causes, the beetle population may increase rapidly (Furniss 1965, Furniss et al. 1979, Wright et al. 1984). At high densities, the beetle is capable of attacking and successfully breeding in healthy trees as well as dead and stressed trees (Rudinsky 1966, Johnson and Belluschi 1969). Under such conditions, the beetle can dramatically alter forest structure, composition, and ecological processes.

Several tree, stand, and site characteristics determine the suitability of an environment for the Douglas-fir beetle. The beetle preferentially attacks large diameter trees (Knopf and Pitman 1972, Pitman 1973, Baker and Trostle 1973, Ringold et al. 1975). Trees under 25 cm dbh are rarely attacked unless they are in close proximity to other mass-attacked trees. The probability of infestation increases up to about 50 cm dbh beyond which all trees are equally susceptible (Baker and Trostle 1973). Tree age is also an important factor determining host tree suitability. Trees less than 80-years-old are highly resistant to attack and those over 120-years-old are the most susceptible (Furniss et al. 1981). In addition to tree size and age, stand density and percent composition of Douglas-fir are correlated with the probability of infestation. Stands with at least 80% of normal stocking and composed of over 50% Douglas-fir have the highest probability of infestation (Williamson and Price 1971, Furniss et al. 1981, Weatherby and Thier 1993). In summary, dense stands with a large component of mature Douglas-fir are the preferred habitat of the Douglas-fir beetle. These are the types of stands most likely to experience tree mortality following disturbances that allow Douglas-fir beetle populations to increase.

The Douglas-fir beetle plays a number of important ecological roles, although little research has been conducted to quantify these effects. Since the beetle selectively removes the large, old Douglas-fir trees from infested stands, it alters stand density, canopy structure, species composition, age class distribution, and successional processes. Following a Douglasfir beetle infestation, the mean size and age of the Douglas-fir component of a stand will likely be reduced compared with preoutbreak conditions. Infested trees occur in groups as a result of the beetles system of aggregation and antiaggregation pheromones (Pitman and Vité 1970, Kinzer et al. 1971, Furniss et al. 1972, Rudinsky et al. 1972, Pitman 1973). The groups or spots may range in size from several to several hundred trees depending upon initial stand structure and composition and beetle population densities (Furniss et al. 1979). Consequently, beetle activity produces canopy gaps of varying sizes. These gaps will be occupied by trees, brush, or herbaceous vegetation depending upon the composition of the understory and nearby vegetation. On sites where Douglas-fir is a seral species, beetle-caused mortality may accelerate succession to shade tolerant climax species such as grand fir. On sites where Douglas-fir is climax, beetle-caused mortality may perpetuate Douglas-fir dominance or create openings for the establishment of shade intolerant early seral species such as ponderosa pine and western larch. In all habitat types, the beetle-caused mortality may provide fuel for wildfires that return the stand to an early seral stage.

In the absence of fire, beetle-killed trees gradually deteriorate and eventually fall to the ground. The standing and down trees provide habitat for many wildlife species and help to maintain site productivity through effects on soil structure and nutrient content. Douglas-fir beetles introduce a variety of microorganisms into infested trees that facilitate the decomposition process (Rumbold 1936, Lu et al. 1957, Borden and McClaren 1970, Castello et al. 1976, Harrington et al. 1981). In addition, many other arthropods follow the Douglas-fir beetle utilizing different portions of the dead stem and inoculating other microorganisms. The Douglas-fir beetle begins a successional process involving many species of arthropods and microorganisms that eventually results in the complete deterioration and recycling of the dead tree (Kimmey and Furniss 1943, Wright and Harvey 1967). The deterioration process occurs at a slower rate if the Douglas-fir beetle and associated arthropods are excluded from dead bole sections (Edmonds and Eglitis 1989).

Past logging has removed much of the mature Douglas-fir from the forests in the CRB. The remaining mature Douglas-fir occur primarily in inaccessible or protected stands such as riparian zones. In general, compared to presettlement, conditions Douglas-fir beetle populations are probably lower now due to the lower abundance of mature trees. However, these existing stands of mature Douglas-fir may suffer high mortality when local beetle populations increase following disturbance. Drought, defoliation, root disease, and large wildfires throughout the CRB over the last several years has resulted in high Douglas-fir beetle populations in many locations (Hofacker et al. 1993). Fire suppression during the last century has increased the abundance of immature Douglas-fir throughout this region. As these Douglas-fir grow into susceptible size classes, Douglas-fir beetle activity will increase (Hessburg et al. 1994).

Although Douglas-fir beetle outbreaks often follow some natural or human-caused disturbance that creates an abundance of suitable breeding sites, they are not entirely predictable. Other factors such as weather conditions following the disturbance can limit the growth of beetle populations (Furniss 1965, Johnson 1967, Johnson and Belluschi 1969). It would be helpful for management purposes to have an early indicator of changes in beetle population densities. The traditional aerial surveys that are conducted annually in the western U.S. are of limited value with the Douglas-fir beetle. Trees that are mass attacked in the spring or early summer may remain green and undetectable from the air until the following summer or fall, after the brood has emerged and dispersed (Belluschi and Johnson 1969). Pheromones or remote sensing are potential tools that could be used to develop new monitoring systems for the Douglas-fir beetle.

Columbia River Basin - Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Dendroctonus Pseudotsugae Hopkins, Douglas-fir beetle

Geographic Area and/or Habitat Type:

SAF 206, SAF 210, SAF 213, SAF 237

Key Environmental Correlates

1. Douglas-fir DBH

Categorical

Suitable Categories: (Baker and Trostle 1973, Furniss et al. 1981, Weatherby and Thier 1993)

Low suitability: <25 cm
Medium suitability: 25-40 cm
High suitability: >40 cm

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

2. Douglas-fir age

Categorical

Suitable Categories: (Furniss et al. 1981)

Low suitability: <80 years
Medium suitability: 80-120 years
High suitability: >120 years

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

3. Stand basal area

Categorical

Suitable Categories: (Williamson and Price 1971, Furniss et al. 1979, Furniss et al. 1981)

Low suitability: <80% of normal stocking
High suitability: >80% of normal stocking

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

4. Percentage of total basal area in Douglas-fir

Categorical

Suitable Categories: (Furniss et al. 1979, Weatherby and Their 1993)

Low suitability: <25%
Medium suitability: 25-50%
High suitability: >50%

Applies seasonally? No

Theme name: ?

Attribute: ?

5. Drought

Categorical

Suitable Categories: (Furniss et al. 1981)

Low suitability: None
Medium suitability: Moderate drought
High suitability: Severe drought

Applies seasonally? No. Although seasonal or temporary droughts may affect Douglas-fir beetle populations, extended droughts lasting one to several years have a far greater impact.

Theme name: Climate

Attribute: Annual - Total Precipitation

6. Fire

Categorical

Suitable Categories: (Furniss 1965, Furniss et al. 1981)

Low suitability: None to a few recently fire injured Douglasfir >30 cm DBH within 10 km
Medium suitability: Moderate number of recently fire injured Douglas-fir >30 cm DBH within 10 km
High suitability: Large number of recently fire injured Douglas-fir >30 cm DBH within 10 km

Recently fire injured = less than 3-year-old injury.

Theme name: Disturbance - Fire Locations

Attribute: Date
Size Class

7. Wind damage

Categroical

Suitable Categories: (Johnson and Belluschi 1969, Furniss et al. 1981)

Low suitability: None to a few wind damaged Douglas-fir >30 cm DBH within 10 km
Medium suitability: Moderate number of wind damaged Douglasfir >30 cm DBH within 10 km
High suitability: Large number of wind damaged Douglas-fir >30 cm, DBH within 10 km

Theme name: Disturbance - Weather (Historic)

Attribute: Wind – Extreme

8. Defoliation

Categorical

Suitable Categories: (Wright et al. 1984)

Low suitability: None to light Douglas-fir defoliation (<60%)
Medium suitability: Moderate Douglas-fir defoliation (60-90%)
High suitability: Heavy Douglas-fir defoliation (>90%)

Defoliation within the last two years.

Theme name: Disturbance - Insect/Disease/Pest (Historic)

Attribute: Period
Severity
Agent

Key Ecological Functions

1. Alter stand density, canopy structure, age distribution, and species composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase fire hazard

Key Assumptions

Key Unknowns and Monitoring or Research Needs

Although a number of key environmental correlates are known for this insect, the threshold levels for some factors have not been precisely defined and the interactions among factors are not entirely clear. Further research is needed to develop hazard/risk rating systems that more accurately define the relationships among the beetle, host trees, and environment. These studies should be conducted in different regions of the CRB since the relationships are likely to vary geographically.

Current approaches to monitoring the Douglas-fir beetle rely on aerial sketch mapping and ground reconnaissance. These methods depend upon readily visible symptoms of infestation, primarily the fading crowns of infested trees. Unfortunately, the crowns of infested trees may not fade for 12 months or longer after the initial attack depending upon weather conditions. By the time crown symptoms become apparent, the brood has usually left the infested tree in search of new breeding sites. Consequently, with currently available methods, there is usually a delay of at least one year in detecting large changes in beetle populations. New methods of detecting changes in beetle populations are needed to provide early warnings of incipient outbreaks. Potential tools include remote sensing and pheromones combined with GIS.

A more comprehensive list of research needs was recently prepared by the USDA Forest Service, National Bark Beetle Steering Committee (USDA Forest Service 1993).

Dispersal

Dispersal mode: Adult flight. These beetles are strong fliers capable of initial flights of up to 15 km. They may disperse 15-30 km per day for several days (Atkins 1961).

Requirements for dispersal: Exposure to cold temperatures to terminate diapause (Ryan 1959). Temperatures above 18°C in the spring. Daylight. Wind speed less than 5 m.p.h. (Rudinsky 1963). Successful dispersal is related to the abundance of suitable breeding material.

Degree of Confidence in Knowledge of Species

Medium to High

Trend

It is difficult to categorize the regional trend of the Douglas-fir beetle. Local outbreaks of varying sizes develop almost every year usually in association with some type of disturbance (i.e., wind storm, fire, snow and ice damage, insect defoliation, etc.). At the same time, other populations may be declining. However, as a result of the recent droughts, defoliation, and large fires, the general trend of Douglas-fir beetle populations throughout the CRB has been increasing for the last several years. With the abundance of immature Douglas-fir resulting from past fire suppression, beetle populations will likely increase in the future as these trees reach susceptible size classes.

Comments:

Spruce Beetle (Dendroctonus rufipennis (Kirby))

The spruce beetle can be found throughout the CRB infesting Engelmann spruce (Furniss and Carolin 1977, Holsten et al. 1991). This is the only host for this beetle in the CRB. Spruce beetle population dynamics are closely tied to the availability and suitability of breeding material. Endemic populations persist in scattered individual or small groups of trees that are stressed or have recently died (Schmid and Frye 1977, Safranyik 1988). Windthrown trees are ideal breeding sites because they have little or no defenses (Berryman 1972) and provide protection from several important natural controls (Schmid 1981). If suitable breeding material becomes abundant, the beetle population may increase rapidly to densities that are capable of attacking and killing healthy trees. Outbreaks of various sizes have developed following windstorms and logging operations that resulted in an abundance of high quality food for the beetle population (Fitzgerald 1954, Massey and Wygant 1954, McCambridge and Knight 1972). During severe outbreaks as much as 80-90% of the overstory may be killed in some stands. One of the largest recorded outbreaks in the western United States occurred in Colorado and-resulted in an estimated mortality of 3.8 billion board feet of Engelmann spruce timber (Schmid and Frye 1977).

Certain types of stands are more susceptible to the spruce beetle than others (Schmid and Frye 1976). Stands with large diameter trees (>41 cm.), high basal area (>34 M^2/ha), large percent composition of Engelmann spruce in the overstory (>65%), and growing on high quality sites are the most suceptible to beetle infestation. The small size and short duration of an outbreak in Colorado was attributed, in part, to the lack of large diameter trees in the infested stands (McCambridge and Knight 1972). Sites with well-drained soil in creek bottoms seem to be particularly susceptible in the Rocky Mountains. Slow tree growth is also associated with a high probability of infestation (Hard 1985). In the Rocky Mountains, stands with average diameter growth less than 1 mm during the last ten years are most susceptible to outbreaks (Schmid and Hinds 1974).

Spruce beetle outbreaks have the potential to significantly modify stand structure, composition, and ecological processes. The magnitude of these effects depends upon preoutbreak stand conditions and the severity of the epidemic. The most obvious effect of beetle-caused mortality is to reduce stand density. Mortality may range from scattered trees to almost complete removal of the overstory. Because the beetles selectively remove the large, old trees, the average and maximum tree size and age are usually reduced during an outbreak (Schmid and Frye 1977, Veblen et al. 1991). Spruce beetle-caused mortality is most often followed by a release of codominant or understory trees rather than establishment of regeneration (Miller 1970, Veblen et al. 1991). Salvage logging activities that destroy advanced regeneration and cause soil disturbance may result in some seedling establishment (Schmid and Hinds 1974). However, logging may also result in dense herbaceous vegetation that will inhibit conifer survival and growth in the absence of vegetation management. Where Engelmann spruce exists as a seral species in mixed conifer stands, spruce beetle-caused mortality will promote succession to more shade-tolerant seral or climax species such as Douglas-fir, grand fir, subalpine fir, western redcedar (Thuja plicata Donn), and western hemlock (Tsuga heterophylla (Raf.) Sarg.) (Franklin and Dyrness 1973). In some habitat types, Engelmann spruce may exist as a co-climax with subalpine fir. On these sites, the combined effects of the spruce beetle and the western balsam bark beetle (Dryocoetes confusus Swaine), a species that attacks subalpine fir (Molnar 1965), may result in alternating periods of dominance by spruce and fir until a standreplacing fire converts the stand to an early successional stage (Schmid and Hinds 1974, Aplet et al. 1988, Veblen et al. 1991).

Beetle-caused mortality affects many other resources and processes. Following an outbreak, there is an increase in standing and down woody debris. However, the increase in fire hazard is not as great as in other forest types because Engelmann spruce typically occurs on cool, moist sites with generally low fire hazard (Schmid and Hinds 1974, Schmid and Frye 1977). Snags fall at a relatively slow rate due to the limited decomposition of standing dead spruce. After 25 years, 85 percent of beetle-killed spruce were still standing in Colorado (Mielke 1950). Decomposition is much more rapid after the trees fall to the ground (Hinds et al. 1965). The rapid decomposition of downed trees may contribute to the apparent low fire hazard in beetle-killed spruce stands. Streamflow may increase for as much as 25 years after a beetle outbreak due to reduced interception and evapotranspiration (Love 1955, Bethlahmy 1975).

The effects of changes in stand structure and composition on wildlife can be either positive or negative depending upon the habitat requirements of each species (Schmid and Frye 1977). For example, deer and elk may initially benefit from an increase in forage, but as trees begin to fall their movement through affected stands may be restricted. Woodpecker populations may increase during an outbreak in response to the abundant supply of insect prey (Koplin 1969). However, as insect populations decline, food will become limiting and woodpecker populations will decline also, despite the abundance of nest sites. Squirrels that feed heavily upon spruce seed may suffer from a decline in available food following beetle outbreaks (Schmid and Frye 1977). Many other wildlife species are impacted by spruce beetle-caused changes in forest structure and composition.

It is difficult to categorize regional trends in spruce beetle populations, since they may be declining, static and increasing at the same time in different areas (Hofacker et al. 1991, 1992, 1993). On sites where spruce is a seral species, the beetle will periodically attack the largest trees as they become weakened by competition and root disease (Hessburg et al. 1994). In the absence of large scale disturbances such as fire, spruce will gradually become less 'abundant on these sites and the beetle will be less important. Continuing fire suppression may allow spruce-fir climax to expand in some areas (Romme and Knight 1981) resulting in an increase in spruce beetle populations.

Columbia River Basin - Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Dendroctonus rufipennis (Kirby), Spruce beetle,

Geographic Area and/or Habitat Type:

SAF 206, SAF 218

Key Environmental Correlates

1. Engelmann spruce DBH

Categorical

Suitable Categories: (Schmid and Frye 1976)

Low suitability: <30 cm
Medium suitability: 30-41 cm
High suitability: >41 cm

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

2. Physiographic location

Categorical

Suitable Categories: (Schmid and Frye 1976)

Low suitability: spruce on sites with SI of 40 to 80
Medium suitability: spruce on sites with SI of 80 to 120
High suitability: spruce on well-drained sites in creek bottoms

Site index in feet, base age 100 years (Alexander 1967)

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Net Primary Production

3. Stand basal area

Categorical

Suitable Categories: (Schmid and Frye 1976)

Low suitability: <23 m^2/ha
Medium suitability: 23 M^2/ha ≤ basal area ≤ 34 m^2/ha
High suitability: >34 M^2/ha

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

4. Percentage of total basal area in Engelmann spruce

Categorical

Suitable Categories: (Schmid and Frye 1976)

Low suitability: <50%
Medium suitability: 50% ≤ % basal area ≤ 65%
High suitability: >65%

Applies seasonally? No

Theme name: ?

Attribute: ?

5. Wind damage

Categroical

Suitable Categories: (Schmid and Frye 1977)

Low suitability: None to a few wind damaged spruce >30 cm DBH within 10 km
Medium suitability: Moderate number of wind damaged spruce >30 cm DBH within 10 km
High suitability: Large number-of wind damaged spruce >30 cm DBH within 10 km

Theme name: Disturbance - Weather (Historic)

Attribute: Wind - Extreme

Key Ecological Functions

1. Alter stand density, canopy structure, age distribution, and species composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase streamflow

5. Increase fire hazard

Key Assumptions

Most research with the spruce beetle has been conducted in the central Rocky Mountains, Alaska, and Canada. This analysis is based largely upon research from the Rocky Mountains and assumes that the beetle behaves similarly throughout the CRB.

Key Unknowns and Monitoring or Research Needs

Current approaches to monitoring the spruce beetle rely on aerial sketch mapping and ground reconnaissance. These methods depend upon readily visible symptoms of infestation, primarily the fading crowns of infested trees. Unfortunately, the crowns of infested trees may not fade for 1-2 years after the initial attack depending upon weather conditions. By the time crown symptoms become apparent, the brood has usually left the infested tree in search of new breeding sites. Consequently, with currently available methods, there is usually a delay of at least one year in detecting large changes in beetle populations. New methods of detecting changes in beetle populations are needed to provide early warnings of incipient outbreaks. Potential tools include remote sensing and pheromones combined with GIS.

A more comprehensive list of research needs was recently prepared by the USDA Forest Service, National Bark Beetle Steering Committee (USDA Forest Service 1993).

Dispersal

Dispersal mode: Adult flight. These beetles are strong fliers capable of initial flights of up to 11 km. Field observations suggest that they may disperse as much as 24-48 km from the site of emergence (Schmid and Frye 1977).

Requirements for dispersal: Exposure to cold temperatures to terminate diapause (Safranyik 1988). Temperatures above 13-16^{o}C in the spring (Schmid and Frye 1977, Safranyik 1988). Daylight. Successful dispersal is related to the abundance of suitable breeding material.

Degree of Confidence in Knowledge of Species

Medium to High

Trend

It is difficult to categorize the regional trend of the spruce beetle. Within the CRB, populations are declining, static, and increasing in different areas. Several areas experienced severe outbreaks in the late 1980's and early 1990's (Hofacker 1990, 1991, 1992). Local outbreaks of varying sizes develop frequently in association with some type of disturbance (i.e., wind storm, fire, snow and ice damage, etc.). Engelmann spruce occurs as a long-lived seral or climax species throughout most of its range. Continuing fire suppression should lead to a greater abundance of spruce and, therefore, spruce beetle. The increasing incidence and severity of root disease in spruce forests (Hessburg et al. 1994) will also favor the spruce beetle.

Comments:

Fir Engraver (Scolytus ventralis LeConte)

The principal hosts of the fir engraver are grand fir, white fir (A. concolor (Gord. and Glend.) Lindl. ex Hildebr.), and California red fir (A. magnifica A. Murr.) (Ferrell 1986a). The range of the fir engraver includes the combined ranges of these three host species. The latter two species are primarily distributed outside of the CRB. White fir can be found to a limited extent in the southeast and southwest corners of the CRB. The range of California red fir includes the extreme southwest corner of the CRB. Consequently, within the CRB, grand fir is the most abundant host of the fir engraver.

The primary factor regulating fir engraver populations is the availability and suitability of hosts (Ashraf and Berryman 1969, Berryman 1973, Berryman and Ferrell 1988). Endemic populations are restricted to trees that have recently died or living trees with limited defenses. Trees that are infected with root pathogens (Cobb et al. 1974, Hertert et al. 1975, Lane and Goheen 1979) or mistletoe (Phoradendron bolleanum subsp. pauciflorum) (Felix et al. 1971, Ferrell 1974) are particularly susceptible to beetle infestation. If host availability increases as a result some disturbance that reduces tree resistance, the beetle population may increase rapidly and kill large numbers of trees (Berryman 1973, Ferrell and Hall 1975, Wright et al. 1984). For example, the fir engraver killed over one million trees in northern California from 1977 to 1978 (Ferrell 1986a).

A number of tree, stand, and site characteristics have been associated with fir engraver infestations. In addition to the pathogens mentioned previously, other factors that increase susceptibility to fir engraver include defoliation (Wright et al. 1984), drought (Ferrell 1973a, Ferrell and Hall 1975), and competition (Schenk et al. 1977). All of these disturbances cause a decline in tree growth which apparently coincides with a lower threshold of resistance to beetle attack (Ferrell 1973a,b, Ferrell and Hall 1975, DeMars et al. 1988, Filip et.al. 1989). The relationship between apparent tree vigor and susceptibility to beetle infestation has been used to develop risk rating systems based upon the size and condition of the crown (Ferrell 1980, 1989). Trees growing on xeric sites are particularly susceptible to beetle infestation because drought conditions occur more frequently on these sites (Ferrell 1973b, Schenk et al. 1976, Mahoney et al. 1979, Ferrell 1986b). Trees growing in stands with a large component of the host species are more likely to become infested than those growing in more diverse stands (Schenk et al. 1977). This is probably related to the switching process associated with the pheromone system that results in the infestation of groups of adjacent trees (Ferrell 1971). In mixed species stands, the greater distance between host trees may interfere with this process and increase dispersal mortality. Large amounts of logging slash can provide abundant and highly suitable breeding sites that allow beetle populations to increase to high densities (Ferrell 1973b). The emerging brood may then attack live trees in the surrounding forest.

The fir engraver may affect many ecological processes, although these effects are not well documented by research. Because the fir engraver reduces stand density and selectively removes the slowest growing trees, the average growth rate of individual trees may increase following an outbreak. As a result of the beetles aggregation pheromone, trees are killed in groups. The number and size of these groups depends upon the density of the beetle population and the relative susceptibility of the host trees. These openings may be beneficial or detrimental to wildlife depending upon their specific habitat requirements. Unlike some other bark beetles, the fir engraver may produce successful brood without killing the host tree. In these cases, the beetle infestation may kill the top of the tree or a patch of cambium on the bole (Ferrell 1986a). These injuries may facilitate infection by stem decay fungi (Ferrell 1973b, Filip and Schmitt 1990). Trees with dead or deformed tops and stem decay are required by some wildlife such as cavity-nesting birds (Scott et al. 1977, Davis et al. 1983).

The standing dead and down trees resulting from fir engraver infestations may increase fire hazards. However, true firs decay quickly (Kimmey 1955) so increases in fire hazard will be temporary. The removal of a portion of the forest canopy and increased input of dead trees will undoubtedly affect hydrologic and nutrient cycling processes to some extent, although these effects have not been studied.

Fir engraver populations are currently increasing, static, and declining in different portions of the CRB (Hofacker et al. 1991, 1992, 1993, Hessburg et al. 1994). The present stand conditions suggest that the fir engraver will continue to be a major disturbance agent in the CRB for at least several decades. Fire suppression has increased the abundance of true firs throughout the CRB including many xeric sites that historically supported ponderosa pine stands. Many of the true fir stands are suffering from competition, drought, and defoliation. Root pathogens are also at epidemic levels in many stands (Hessburg et al. 1994) and true firs are among the most susceptible conifers in the CRB (Hadfield et al. 1986). These are ideal conditions for the fir engraver. A number of fir engraver outbreaks have occurred in recent years and others will surely occur in the future as long as these stand conditions exist.

Columbia River Basin - Panel Species Information

Date: 12/21/94 **Panelist:** Darrell Ross

Species or Species Group:

Scolytus ventralis LeConte, Fir engraver

Geographic Area and/or Habitat Type:

SAF 207, SAF 205, SAF 211, SAF 213

Key Environmental Correlates

1. Stand basal area

Categorical

Suitable Categories:

Low suitability: Low density (<75% of normal stocking?)
High suitability: High density (>75% of normal stocking?)

Applies seasonally? No

Theme name: Biogeochemical Cycles

Attribute: Above Ground Biomass

2. Percentage of total basal area in true fir

Categorical

Suitable Categories: (Schenk et al. 1977)

Low suitability: <65%
High suitability: >65%

Applies seasonally? No

Theme name: ?

Attribute: ?

3. Drought

Categorical

Suitable Categories: (Ferrell 1973, Ferrell and Hall 1975)

Low suitability: Current and preceding years precipitation < 11% below normal or spring precipitation <32% below normal
High suitability: Current and preceding years precipitation > 11% below normal or spring precipitation >32% below normal

Applies seasonally? Yes.

Theme name: Climate

Attribute: Annual - Total Precipitation

4. Site xericity

Categorical

Suitable Categories: (Schenk et al. 1976, Mahoney et al. 1979, Ferrell 1986b)

Low suitability: Mesic sites
High suitability: Xeric sites

Theme name: Climate

Attribute: Annual - Total Precipitation

5. Root disease

Categroical

Suitable Categories: (Cobb et al. 1974, Hertert et al. 1975, Lane and Goheen 1979)

Low suitability: None to low incidence of root disease
Medium suitability: Moderate incidence of root disease
High suitability: High incidence of root disease

Theme name: Disturbance Insect/Disease/Pest (Historic)

Attribute: Severity
Agent

6. Crown condition

Categorical

Suitable Categories: (Ferrell1980, 1989)

Low suitability: >40% live crown, none to few dead branches
Medium suitability: >40% live crown, moderate to high number of dead branches or <40% live crown, none to few dead branches
High suitability: Large number of dead branches, highly ragged crown, or very small live crown

Theme name: ?

Attribute: ?

7. Defoliation

Categorical

Suitable Categories: (Wright et al. 1984)

Low suitability: None to light fir defoliation (<60%)
Medium suitability: Moderate fir defoliation (60-90%)
High suitability: Heavy fir defoliation (>90%)

Defoliation within the last two years.

Theme name: Disturbance - Insect/Disease/Pest (Historic)

Attribute: Period
Severity
Agent

Key Ecological Functions

1. Alter stand density, canopy structure, age distribution, and species composition

2. Increase nutrient cycling

3. Increase standing and down woody debris

4. Increase fire hazard

5. Increase incidence of stem decay in host tree species

Key Assumptions

Key Unknowns and Monitoring or Research Needs

Although a number of key environmental correlates are known for this insect, the threshold levels for some factors have not been precisely defined and the interactions among factors are not entirely clear. The hazard and risk rating models that have been developed are limited geographically and to certain types of stands. Further research is needed to develop hazard/risk rating systems that more accurately define the relationships among the beetle, host trees, and environment. These studies should be conducted in different regions of the CRB since the relationships are likely to vary geographically.

Current approaches to monitoring the fir engraver rely on aerial sketch mapping and ground reconnaissance. These methods

depend upon readily visible symptoms of infestation, primarily the fading crowns of infested trees. The fir engraver sometimes kills only portions of the cambium which may or may not produce visible crown symptoms. Currently available methods of monitoring the fir engraver are inadequate. New methods of detecting changes in beetle populations are needed to provide early warnings of incipient outbreaks. The aggregation pheromone for the fir engraver has not yet been identified. If this pheromone were known, it would provide a valuable tool for developing new monitoring techniques.
A more comprehensive list of research needs was recently prepared by the USDA Forest Service, National Bark Beetle Steering Committee (USDA Forest Service 1993).

Dispersal

Dispersal mode: Adult flight.

Requirements for dispersal: Temperatures above 24^{o}C in the spring. Daylight. Flight decreases with increasing wind speed. Successful dispersal is related to the abundance of suitable breeding material (Ashraf and Berryman.1969, Ferrell 1971, Berryman and Ferrell 1988).

Degree of Confidence in Knowledge of Species

Medium

Trend

It is difficult to categorize the regional trend of the fir engraver. Populations are increasing, static, and declining in different portions of the CRB (Hofacker 1991, 1992, 1993). However, as a result of recent droughts and defoliation, fir engraver populations have been at high levels in some areas (Hessburg et al. 1994). Fire suppression has allowed dense stands of true fir to develop throughout the CRB including sites that are at the dry end of the ecological range for these species. Many of these stands are highly susceptible to the fir engraver due to dense stocking and abundant root disease. It seems likely that fir engraver populations will remain at high levels for some time given the current composition and age structure of forests within the CRB.

Comments:

Functional Group Assessments

In addition to the six species discussed in the first part of this report, there are a large number and variety of arthropods that feed on or within tree boles and branches (Furniss and Carolin 1977, Coulson and Witter 1984). Each species is involved in various ecological processes and is important to the normal functioning of the forest ecosystem in which it is found. Unfortunately, most species have been studied very little or not at all. For the majority of species, it is not possible to discuss their distributions, habitat associations and requirements, functional roles in the ecosystem, sensitivity to disturbance, or trends in populations in any more than very general terms. Attempting to cover these species by categorizing them into functional groups also presents problems. An analysis of functional groups by habitat conditions for all bole and branch herbivores would generate an extremely large matrix and the data for many cells would be limited or non-existent. Instead, I have chosen to discuss three broad functional groups without regard to habitat conditions. Representatives of each group can be found in each forest cover type and most successional stages.

<u>Feeding on the bole or branches</u>

A number of insects feed by inserting their mouthparts into the bole or branch and sucking fluids out of the host tree. This includes spittlebugs, aphids, adelgids, scales, and mealybugs. The balsam woolly adelgid is one of the most well-studied examples of this group and was discussed in the first part of this report. Other representatives found in the CRB include the following:

Aphrophora permutata	Western pine spittlebug
Cinara spp.	Giant conifer aphids
Mindarus abietinus	Balsam twig aphid
Adelges tsugae	Hemlock woolly adelgid
Matsucoccus bisetosus	Ponderosa pine twig scale
Puto cupressi	Fir mealybug

The effects of feeding by these insects are to reduce tree growth, kill portions of the canopy, or cause stem deformities. The balsam woolly adelgid is one of the few species to cause significant tree mortality. No outbreaks of these insects have been reported in the last several years within the CRB with the exception of the balsam woolly adelgid in northern Idaho (Hofacker et al. 1991, 1992, 1993). When outbreaks do occur they are usually localized and short-lived. occurrence of these insects can be highly variable within a tree, among adjacent trees within a stand, among adjacent stands, and from year to year (Coulson and Witter 1984).

Little is known about the population dynamics of most of the sucking insects found in the CRB (Coulson and Witter 1984). Some species may be more common in early successional stages than in mature forests (Schowalter 1989). Natural controls include parasites and predators, extreme cold temperatures, and the quantity and quality of host trees (Carrow and Betts 1973, McClure 1980, Hain 1988, McClure 1988).

These insects are involved in many ecological processes, although most of these effects have not been quantified by research. They can potentially reduce stand productivity and alter succession by reducing growth and survival of host trees.

They also may predispose trees to attacks by other insects and diseases. They typically excrete large amounts of a nutrient rich fluid know as honeydew. The honeydew is utilized by sooty mold fungi and various species of ants. Other arthropods and vertebrates feed upon the immature and adult stages of these insects. At high densities, these insects may significantly affect nutrient cycling processes (Schowalter 1989).

Feeding within or under bark

A variety of insects feed within and under the bark of stems of all sizes (Furniss and Carolin 1977). This includes bark and twig beetles, twig weevils, twig and pitch moths, bark maggots, and wood borers. Among this group, the bark beetles are some of the most important ecologically and economically. Five of the most aggressive bark beetle species were discussed in the first part of this report. over 100 other species of bark beetles are found within the CRB (Furniss and Johnson 1987, Gast et al. 1989, Furniss et al. 1992). Most species of bark beetles respond similarly to environmental conditions and cause similar effects on ecosystem processes. The species differ with respect to their host range (one to many tree species), age of trees attacked, size of stems or bark thickness utilized, and whether they attack dead, dying, or live trees (Rudinsky 1962, Wood 1982).

Twig weevils are classified in the Curculionidae family. The larvae of these insects mine the cambium on 1-to 2-year-old branches killing the distal portion of the stem. Adults may also feed on stems or foliage, but the most significant damage results from larval mining. Examples of twig weevils found in the CRB include the following:

Cylindrocorturus eatoni	Pine reproduction weevil
Cylindrocopturus furnissi	Douglas-fir twig weevil
Pissodes strobi	White pine weevil
Pissodes terminalis	Lodgepole terminal weevil

Twig weevils are most common in young trees. The Cylindroconturus spp. apparently prefer trees stressed by competition with brush or drought (Furnisss and Carolin 1977). The Pissodes spp. prefer open-growing, even-aged stands of host trees. The major effect of twig weevils is to kill or stunt the growth of terminal branches (Berisford and Ross 1990). Consequently, they can have significant impacts on stand productivity and succession on sites with high populations.

Some species of Lepidoptera also feed on cambium and bark. These insects are known as pitch, twig, or bark moths. Examples of species found within the CRB include the following:

Vespamima secruoiae	Sequoia pitch moth
Vespamima novaroensis	Douglas-fir pitch moth
Petrova albicapitana	Northern pitch twig moth
Dioryctria abietivorella	Fir coneworm
Dioryctria ponderosae	Ponderosa twig moth

Most of these species attack small- to medium-sized trees. Their primary effect is to weaken trees, although they may kill all or a portion of their host. Little is known about most of these species and none reach high densities in forest settings. They are probably most important in predisposing trees to other insects and pathogens.

The early instar larvae of flatheaded and roundheaded wood borers in the Buprestidae and Cerambycidae, respectively, feed on cambium before tunneling into the xylem during the later larval stages. Most species feed on dead and dying trees, but a few such as the flatheaded fir borer are able to attack and kill healthy trees. There are many species found in the CRB, but a few examples are:

<u>Chalcophora angulicollis</u>	Sculptured pine borer
<u>Buprestis aurulenta</u>	Golden buprestid
<u>Melanophila californica</u>	California flatheaded borer
<u>Melanophila drummondi</u>	Flatheaded fir borer
<u>Tetropium abietis</u>	Roundheaded fir borer
<u>Leptura obliterata</u>	
<u>Acanthocinus Princeps</u>	Ponderosa pine bark borer
<u>Monochamus scutellatus</u>	Whitepotted sawyer

Most borers infest trees that have recently died. They are often found in association with bark beetles and may compete with the bark beetle larvae for the cambium food resource. Because most of the borers are larger than bark beetles and possess powerful mandibles, they may kill bark beetle larvae coincidentally while feeding in the cambium.

The ecological roles of the wood borers are similar to those of bark beetles. They may increase the rate of decomposition by introducing microorganisms and creating conditions that are favorable for a succession of arthropods and microorganisms that are involved in the decomposition process (Kimmey and Furniss 1943, Kimmey 1955, Edmonds and Eglitis 1989, Zhong and Schowalter 1989). They are also an important source of food for many arthropods and vertebrates including cavity-nesting birds. These insects are discussed in more detail in the assessment of coarse woody debris chewers.

<u>Feeding within wood</u>

Many insects feed on or live within the wood in boles and branches. This includes ambrosia beetles, wood borers, powderpost beetles, sapwood weevils, carpenterworm and clearwing moths, ants, and horntails. Most of these insects infest dead and dying trees and are discussed in the assessment of coarse woody debris chewers. Their primary ecological roles are to facilitate decomposition processes, serve as food for predators, and predispose trees to attacks by other insects and diseases.

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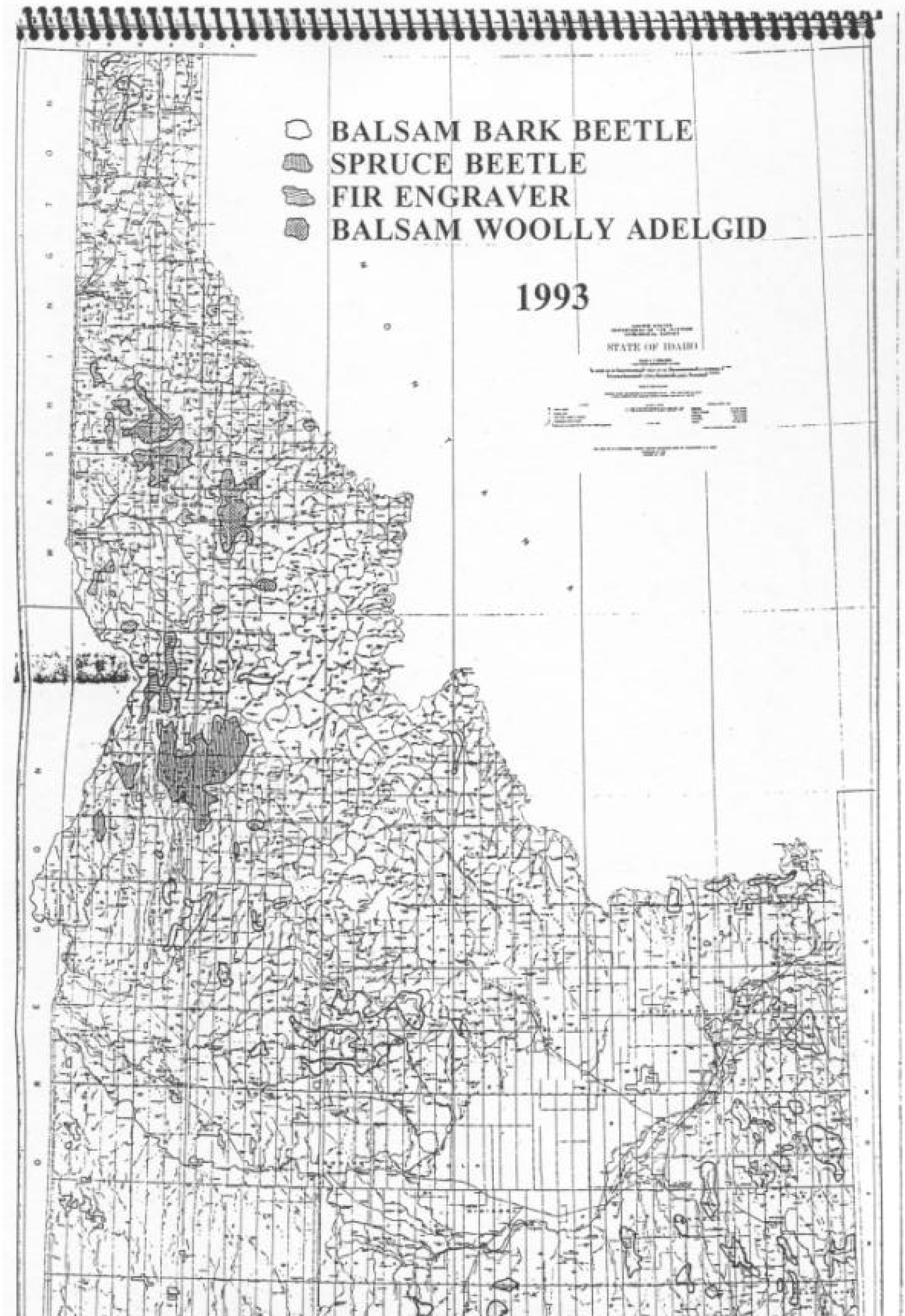
Appendix A - Known distribution of the balsam woolly adelgid in Idaho.


BALSAM BARK BEETLE
SPRUCE BEETLE
FIR ENGRAVER
BALSAM WOOLLY ADELGID
1993
STATE OF IDAHO

Appendix B - Forested Habitats Forms.

Adelges piceae	Balsam woolly adelgid
Dendroctonus brevicomis	Western pine beetle
Dendroctonus Ponderosae	Mountain pine beetle
Dendroctonus pseudotsugae	Douglas-fir beetle
Dendroctonus rufipennis	Spruce beetle
Scolytus ventralis	Fir engraver

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Adelges piceae

Panelist Darrell Ross
Date 12/21/94

Value	VegType	VegName SAF Forest Cover Types	SI	SEO	SEC	UR	YF	OFM	OFS	CTR	HTS	SHS	GRS	BAR	Notes
			Structural Stage							Understory					
8	SAF206	Englem. spruce-Subalpine fir		■	X	X	X	X	X	X		X	X	X	
9	SAF208	Whitebark pine			■										
10	SAF210	Interior Douglas-fir		■											
11	SAF211	White fir		■											
12	SAF212	Western larch		■											
13	SAF213	Grand fir		■	X	X	X	X	X	X		X	X	X	
14	SAF215	Western white pine		■											
15	SAF217	Aspen													
16	SAF218	Lodgepole pine						■	■						
17	SAF221	Red alder													
18	SAF225	Coastal true fir-Hemlock		■	X	X	X	X	X	X		X	X	X	
19	SAF227	W. Redcedar-W. Hemlock		■											
20	SAF229	Pacific Douglas-fir		■											
21	SAF230	Douglas-fir-W.hemlock		■											
22	SAF233	Oregon white oak			■										
23	SAF234	Doug-fir-Tanoak-Pac madrone		■											
24	SAF235	Cottonwood-willow				■									
25	SAF237	Interior Ponderosa pine													
26	SAF242	Mesquite				■	■	■	■						
27	SAF243	Sierra Nevada mixed conifer			■										
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine			■										

Notes:

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Dendroctonus brevicomis

Panelist Darrell Ross
Date 12/21/94

Value	VegType	VegName SAF Forest Cover Types	Structural Stage: SI	SEO	SEC	UR	YF	OFM	OFS	Understory: CTR	HTS	SHS	GRAS	BAR	Notes
8	SAF206	Englem. spruce-Subalpine fir		■											
9	SAF208	Whitebark pine			■										
10	SAF210	Interior Douglas-fir		■											
11	SAF211	White fir		■											
12	SAF212	Western larch		■											
13	SAF213	Grand fir		■											
14	SAF215	Western white pine		■	X	X	X	X	X	X		X	X	X	
15	SAF217	Aspen													
16	SAF218	Lodgepole pine						■	■						
17	SAF221	Red alder													
18	SAF226	Coastal true fir-Hemlock		■											
19	SAF227	W. Redcedar-W. Hemlock		■											
20	SAF229	Pacific Douglas-fir		■											
21	SAF230	Douglas-fir-W.hemlock		■											
22	SAF233	Oregon white oak			■										
23	SAF234	Doug-fir-Tanoak-Pac madrone		■											
24	SAF235	Cottonwood-willow				■									
25	SAF237	Interior Ponderosa pine			X	X	X	X	X	X		X	X	X	
26	SAF242	Mesquite				■	■	■	■						
27	SAF243	Sierra Nevada mixed conifer			■										
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine			■										

Notes:

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Dendroctonus ponderosae

Panelist Darrell Ross
Date 12/21/94

			Structural Stage							Understory					
Value	VegType	VegName SAF Forest Cover Types	SI	SEO	SEC	UR	YP	OFM	OFS	CTR	HTS	SHS	GRS	BAR	Notes
8	SAF206	Englem. spruce-Subalpine fir			X	X	X	X	X	X		X	X	X	
9	SAF208	Whitebark pine													
10	SAF210	Interior Douglas-fir													
11	SAF211	White fir													
12	SAF212	Western larch			X	X	X	X	X	X		X	X	X	
13	SAF213	Grand fir													
14	SAF215	Western white pine			X	X	X	X	X	X		X	X	X	
15	SAF217	Aspen													
16	SAF218	Lodgepole pine		X	X	X	X			X		X	X	X	
17	SAF221	Red alder													
18	SAF226	Coastal true fir-Hemlock													
19	SAF227	W. Redcedar-W. Hemlock													
20	SAF229	Pacific Douglas-fir													
21	SAF230	Douglas-fir-W.hemlock													
22	SAF233	Oregon white oak													
23	SAF234	Doug-fir-Tanoak-Pac madrone													
24	SAF235	Cottonwood-willow													
25	SAF237	Interior Ponderosa pine		X	X	X	X	X	X	X		X	X	X	
26	SAF242	Mesquite													
27	SAF243	Sierra Nevada mixed conifer													
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine													

Notes:

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Dendroctonus pseudotsugae

Panelist Darrell Ross
Date 12/21/94

			Structural Stage							Understory					
Value	VegType	VegName SAF Forest Cover Types	SI	SEO	SEC	UR	YF	OFM	OFS	CTR	HTS	SHS	GRS	BAR	Notes
8	SAF206	Englem. spruce-Subalpine fir		■				X	X	X		X	X	X	
9	SAF208	Whitebark pine			■										
10	SAF210	Interior Douglas-fir		■				X	X	X		X	X	X	
11	SAF211	White fir		■											
12	SAF212	Western larch		■											
13	SAF213	Grand fir		■				X	X	X		X	X	X	
14	SAF215	Western white pine		■											
15	SAF217	Aspen													
16	SAF218	Lodgepole pine						■	■						
17	SAF221	Red alder													
18	SAF225	Coastal true fir-Hemlock		■											
19	SAF227	W. Redcedar-W. Hemlock		■											
20	SAF229	Pacific Douglas-fir		■											
21	SAF230	Douglas-fir-W.hemlock		■											
22	SAF233	Oregon white oak			■										
23	SAF234	Doug-fir-Tanoak-Pac madrone		■											
24	SAF235	Cottonwood-willow				■									
25	SAF237	Interior Ponderosa pine						X	X	X		X	X	X	
26	SAF242	Mesquite				■	■	■	■						
27	SAF243	Sierra Nevada mixed conifer			■										
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine			■										

Notes:

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Dendroctonus rufipennis

Panelist Darrell Ross
Date 12/21/94

Value	VegType	VegName SAF Forest Cover Types	SI	SEO	SEC	UR	YF	OFM	OFS	CTR	HTS	SHR	GRS	BAR	Notes
			Structural Stage							Understory					
8	SAF206	Englem. spruce-Subalpine fir		■	X	X	X	X	X	X		X	X	X	
9	SAF208	Whitebark pine			■										
10	SAF210	Interior Douglas-fir		■											
11	SAF211	White fir		■											
12	SAF212	Western larch		■											
13	SAF213	Grand fir		■											
14	SAF215	Western white pine		■											
15	SAF217	Aspen													
16	SAF218	Lodgepole pine			X	X	X	■	■	X		X	X	X	
17	SAF221	Red alder													
18	SAF226	Coastal true fir-Hemlock		■											
19	SAF227	W. Redcedar-W. Hemlock		■											
20	SAF229	Pacific Douglas-fir		■											
21	SAF230	Douglas-fir-W.hemlock		■											
22	SAF233	Oregon white oak			■										
23	SAF234	Doug-fir-Tanoak-Pac madrone		■											
24	SAF235	Cottonwood-willow				■									
25	SAF237	Interior Ponderosa pine													
26	SAF242	Mesquite				■	■	■	■						
27	SAF243	Sierra Nevada mixed conifer			■										
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine			■										

Notes:

FORESTED HABITATS FORM

SPECIES/SPECIES GROUP Scolytus ventralis

Panelist Darrell Ross
Date 12/21/94

Value	VegType	VegName SAF Forest Cover Types	Structural Stage: S I	S E O	S E C	U R	Y F	O F M	O F S	Understory: C T R	H T S	S H R	G R S	B A R	Notes
8	SAF206	Englem. spruce-Subalpine fir													
9	SAF208	Whitebark pine													
10	SAF210	Interior Douglas-fir													
11	SAF211	White fir			X	X	X	X	X	X		X	X	X	
12	SAF212	Western larch													
13	SAF213	Grand fir			X	X	X	X	X	X		X	X	X	
14	SAF215	Western white pine													
15	SAF217	Aspen													
16	SAF218	Lodgepole pine													
17	SAF221	Red alder													
18	SAF225	Coastal true fir-Hemlock													
19	SAF227	W. Redcedar-W. Hemlock													
20	SAF229	Pacific Douglas-fir													
21	SAF230	Douglas-fir-W.hemlock													
22	SAF233	Oregon white oak													
23	SAF234	Doug-fir-Tanoak-Pac madrone													
24	SAF235	Cottonwood-willow													
25	SAF237	Interior Ponderosa pine													
26	SAF242	Mesquite													
27	SAF243	Sierra Nevada mixed conifer													
28	SAF245	Pacific Ponderosa pine													
29	SAF250	Blue oak-Digger pine													

Notes: