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Forest Health Protection and State Forestry Organizations

Management Guide for

Spruce Beetle

Dendroctonus rufipennis Kirby

Topics

Host: Engelmann spruce **Occasionally Lodgepole pine**	Since the mid 1980's, large stand-replacing spruce beetle epidemics have occurred in southern and central Utah, south central Idaho, north central Washington, northwestern Wyoming and on the Kenai Peninsula in Alaska.

Outbreaks often start with wind or fire damage

Population increases are often associated with blowdown, landslides, stumps, residual large slash, and occasionally fire-weakened trees. If this susceptible host material is not available when adults emerge, they will attack and kill standing trees. As spruce beetle populations increase, susceptible landscapes can be adversely affected by spruce beetle epidemics.

Outbreaks can develop at any time in mature spruce stands throughout the susceptible Engelmann spruce component following blowdown (Holsten et al. 1999), landslides, winter damage, and improper treatment of logging residuals (Wygant & Lejeune 1967; McCambridge & Knight 1972). Epidemics are most common in overmature stands but may be sustained in large pole and immature stands (Wygant & Lejeune 1967). Spruce beetles will attack and kill trees 4-inch diameter and larger (Schmid & Mata 1996). Periodic epidemics have occurred throughout the west over the last 100 years.

Key Points

- Blowdown events are often associated with spruce beetle epidemics.
- Use hazard rating to anticipate damage.
- Reduce hazard by altering stand conditions.
- Trap trees are effective in reducing local populations.

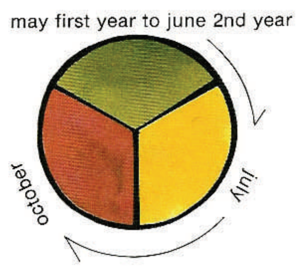
Management Brief

⇒ Prevention; Partial harvest treatments to reduce the proportion of spruce, reduce the average diameter of spruce, reduce stand density to create uneven-aged conditions.

⇒ Suppression; using trap trees, pheromone baits and lures, insecticidal sprays, sanitation and salvage harvests

⇒ Clean up spruce logging residue and blowdown.

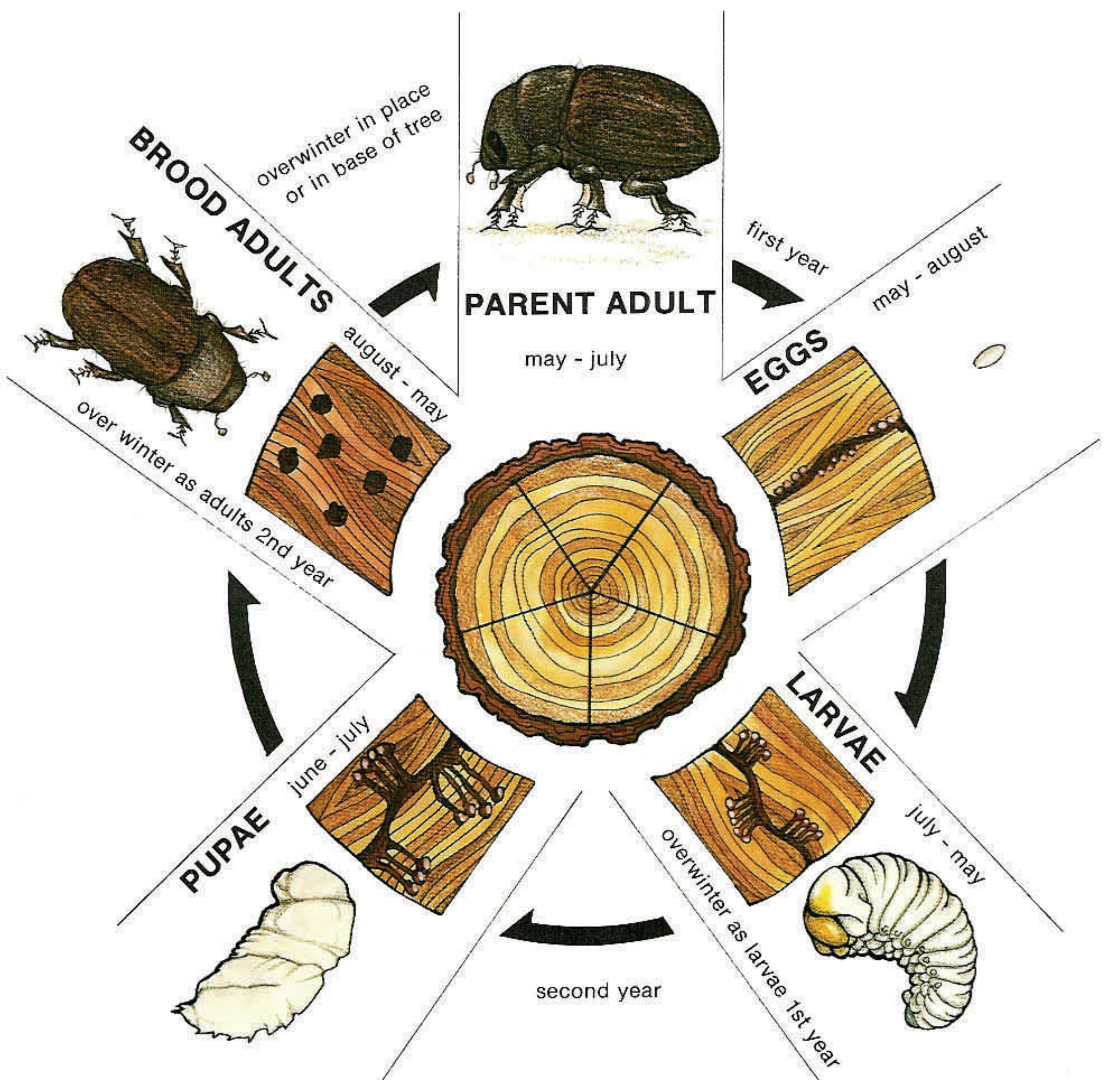
Life History

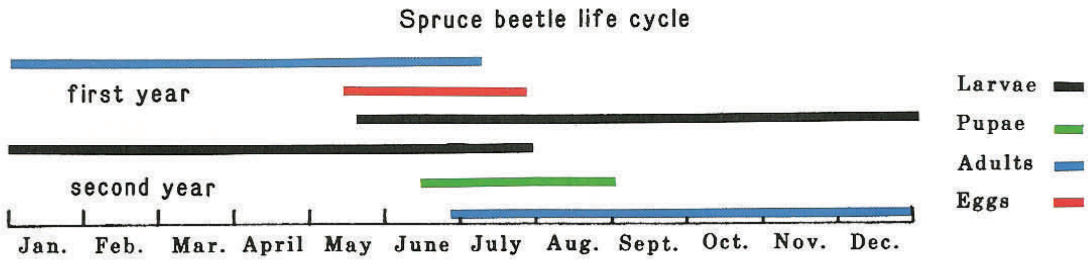


Color Cycle of Tree

Spruce beetle can have a 1 or 2-year life cycle. In the one-year cycle, larvae complete their development over the summer and overwinter as callow (teneral) adults under the outer bark. They complete their development the following spring emerging as sexually mature adults (Hansen et al. 2001). In the two-year cycle most of the beetles overwinter as larvae, although parent adults and eggs may also be present under the bark (Schmid & Frye 1977). Larvae resume feeding in the spring, then pupate in galleries during late spring-early summer of their second year. A small number of female adult beetles may reemerge and attack green trees from August through October, however most of the maturing brood adults overwinter under the outer bark. Although it varies from tree to tree, a percentage of the adults reemerge and move to the base of the tree to overwinter. Adult populations then emerge the following spring attacking host material. Beetles in downed material do not emerge and move to another site for hibernation. Most of the adult emergence occurs from mid-May to mid-July.

Spruce Beetle— typical 2-year life cycle





Management Considerations: An overview

Historically suppression efforts usually began after an infestation had caused substantial tree mortality. Suppression activities emphasized sanitation cutting, trap trees, pheromone deployment and chemical spraying. Most spruce beetle susceptible spruce stands were unmanaged with few pre-outbreak treatments designed to mitigate the effects of a spruce beetle outbreak.

Forest managers can alter these post mortem activities by initiating treatments designed to reduce the effects of a spruce beetle outbreak. Depending on resource objectives, spruce stands should be designated as a beetle-management or no-management area. Stands designated as no management sites would not be subject to silvicultural or suppression treatments. Spruce beetle populations would be allowed to fluctuate within these no management sites.

Alter stand conditions to minimize outbreak potential

Spruce stands designated as beetle management areas should be managed to minimize the effects of a spruce beetle outbreak. In beetle management areas, resource managers should hazard rate stands to determine stand susceptibility to spruce beetle which will assist them with setting treatment priorities. Suppression activities would occur within these sites if spruce beetle populations began to increase. Spruce stands with multiple use objectives (i.e. recreation, wildlife and wood fiber production) are excellent candidates as spruce beetle management areas.

Suppress beetle populations

Suppression activities may still occur in stands where preventative treatments occurred. Treatments designed to mitigate spruce beetle impacts often result in stands with some level of spruce beetle susceptibility. Not all beetle management designated areas will receive silvicultural treatments before insect populations increase in susceptible stands. Thus, suppression activities could become an integral part of a spruce beetle management strategy. Suppression activities may also be an option in treating sites near no management treatment areas if spruce beetle populations increase in no management zones. Wherever appropriate, suppression treatments should be linked to a silvicultural treatment to modify stand conditions that contribute to an infestation.

The effectiveness of suppression treatments varies depending upon the action taken and the scale of the infestation. Because spruce beetle attacked trees do not fade until the following year, ground and aerial surveys may not identify all the infested sites requiring treatment. In which case, spruce beetle populations would continue to expand in these non-treated sites. Suppression treatments are most effective when most, if not all of the infested areas are addressed and the suppression treatments are administered correctly.

Spruce stands should be designated as a beetle management or no-management areas, depending on resource objectives.

No-management sites are generally associated with wilderness areas, National Parks, experimental forests and some roadless areas.

Hazard Rating

Determine stand susceptibility to spruce beetle.

Develop treatment priorities.

Example:

Step One: To calculate the hazard rating for a hypothetical stand assume the following stand and site attributes:

Site Index = 100

Avg. spruce dbh =17 in.

Spruce in canopy = 70%

Evaluating these site and stand characteristics in Table 1, values of 2, 3, 3, and 3 are obtained .

Step Two: Adding these together results in a hazard rating value of 11. This is a "highly " susceptible stand and therefore at risk of sustaining significant mortality if spruce populations increased.

High Stand Risk: Indicates that the stand and site has attributes that can contribute to population increases.

Medium Stand Risk: Indicates the stand has some attributes that can contribute to significant spruce mortality. Generally stands rated moderate risk may or may not contribute to population increases, however during spruce beetle outbreaks most of the susceptible hosts within these intermediate rated stands will be killed.

Hazard/Susceptibility Rating (Schmid and Frye 1976)

Step one : To identify spruce stands susceptible to spruce beetle population increases, several stand and site attributes are used for the evaluation. The rating system is useful to determine what stand conditions could be altered to mitigate spruce beetle population increases.

Table 1	Stand Hazard		
	3	**2**	**1**
Physiographic Location	Well-drained sites in creek bottoms	Sites with site index of 80-120	Sites with site index of 40-80
Average diameter of live spruce >10 inches dbh	>16"	12-16"	<12"
Percent of spruce in canopy	>65	50-65	<50

Step two: The potential risk rating is based on the summarized hazard rating obtained from the table. Risk indicates the amount of tree mortality that could occur if spruce beetle populations increased within the rated stand.

Table 2	Stand Hazard
Summary of Hazard Rating	**Potential Hazard Rating**
11-12	High
7-9	Medium
4-5	Low

Although this tree characteristic is not important in the lower 48 states, in Alaska large diameter spruce trees with slower than average growth rates were more likely to be attacked and killed by spruce beetle than trees with growth equal to or greater than the stand average (Hard et al. 1983, Hard 1985, Holsten 1984, Doak 20).

Silvicultural Treatments

Stands with epidemic spruce beetle

Alexander (1973) suggests the following silvicultural options if spruce beetle populations pose a threat to susceptible stands.

- If spruce beetle populations are present in the stand to be cut or in adjacent stands affecting clumps of spruce

AND

- less than the recommended percentage of basal area to be removed is in susceptible trees,

Action:
Any attacked and all susceptible trees should be removed in the first cut. This silvicultural option will remove most of the larger spruce thus affecting wind firmness of the residual spruce. Non-hosts and smaller diameter spruce (<10-12” dbh) should be left on site to minimize windthrow.

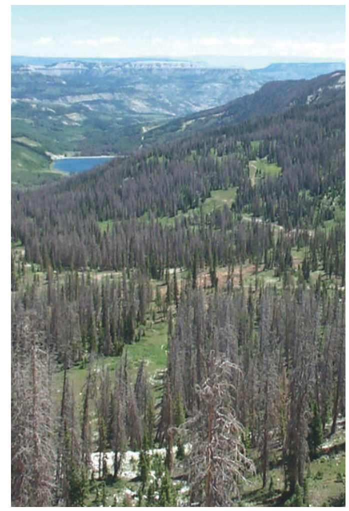
OR

- If more than the recommended percentage of basal area to be removed is in susceptible trees, three options are available:

(1) **Remove all the susceptible trees,**

(2) **Remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses**

(3) **Leave the stand uncut.** If the stand is left uncut and a spruce beetle outbreak occurs, most of the susceptible spruce basal area will be lost and surviving spruce would be smaller diameter (<5” dbh) (Dymerski et al. 2001).



Engelmann spruce killed by spruce beetle on the Manti-LaSal NF in Utah.

Stands with endemic spruce beetle

Uneven aged prescriptions for spruce-fir stands will not prevent losses caused by spruce beetle but they will mitigate the effects of an outbreak within a treated area. Table 3 summarizes post-harvest diameter class distribution where a full range of diameter classes is the objective for an uneven-aged prescription.

The uneven-aged prescription provides an average diameter of 7.5 inches, a stand density index (SDI) of 35 percent of maximum and a basal area of 134 ft^2 per acre. This spruce-fir prescription will generally meet visual and wildlife objectives while reducing stand density to a lower degree of full site utilization (thus allowing for maximum individual tree growth).

Small, ¼ acre openings will promote spruce regeneration within these uneven aged systems. Stand entry should occur before the stand reaches 60 percent maximum SDI to sustain a lower spruce beetle stand hazard rating.

Table 3	**Example: Uneven-aged stand with low spruce beetle potential**		
Mid-point dbh	**Stand Density Index**	**Basal Area**	**Trees/ acre**
2	15	4	197
6	50	25	125
10	60	33	60
14	60	37	35
18	50	35	20
Total	235	134	437

Treat Logging Residuals

Log Wizard is used to remove outer bark of spruce beetle infested logs.

Any infested down or standing material should be removed, burned or peeled following adult beetle flight.

Guidelines for addressing logging residuals were developed by Schmid (1977) to minimize spruce beetle populations increases.

- Minimize stump heights leaving stump heights of no more than 1.5 feet.
- Cull logs and tops should be limbed and the branches moved to reduce shade on bole surfaces.
- After limbing, cull logs and tops should be moved from shady sites to sunny areas and not piled unless they will be burned.
- Cutting logs and tops into short lengths (18-inches) will promote drying of the phloem reducing the amount of suitable habitat for developing larvae.
- While full-length logging removes the merchantable host material, complete removal or destruction of all cull logs and tops would eliminate suitable host material for developing life stages. If trees are logged full length, the diameter of the small end should be 4 inches.

Except for complete elimination of host material, even the previous recommendations will not keep beetles from inhabiting the bottom surfaces of logs and tops. If high beetle populations are subsequently found in these surfaces, they should be treated by removing the outer bark (peeling knife or log wizard) or burned.

If a significant spruce beetle population exists in the adjacent forest (clumps of infested trees), the logging residuals could be used to trap dispersing adults. Adult beetles prefer downed host material; however there could be a spillover effect, as some adult insects will attack adjacent standing hosts. Any infested down or standing material should be removed, burned or peeled following adult beetle flight.

The logging residual guidelines are applicable under selective, shelterwood, or clearcut silvicultural systems. The selective system provides more shade than the other treatments. Under a selective system prompt removal or destruction of suitable host material is the best strategy to minimize spruce beetle population increases.

Clean up windthrown trees

Remove infested windthrown trees from moderate to high hazard sites.

Windthrown susceptible spruce are the most important contributors to spruce beetle population increases (Schmid & Mata 1996). Windthrow events that occur in stands rated moderate to high hazard may result in outbreak populations of the insect. Not all windthrow events lead to spruce beetle population increases. Scattered windthrow in late winter or spring is the most conducive to population increases.

Windthrown trees should be sampled in late July-August following adult flight to determine attack densities in the downed material using the sampling scheme developed by Schmid (1981).

If the windthrown trees are infested, removing infested trees from susceptible sites is the preferred option. Salvage programs in Utah have used a variety of treatments to suppress spruce beetle populations in sites where windthrow occurred, including; salvage of infested trees, using Lindgren funnel traps baited with the 3-component spruce beetle attractant pheromone and trap trees (Bentz & Munson 2000).

Direct Suppression

Preventative Sprays

Carbaryl - Carbaryl (Sevin) is registered as a preventive insecticide treatment for spruce beetle. Several flowable formulations are commonly used including, Carbaryl 4L, Carbaryl 4F, Sevin XLR Plus and Sevin SL. Do not use wettable powders; they are ineffective with low residual efficacy. Carbaryl applications applied correctly, are effective for two years following treatment.

Other Insecticides - Pyrethroid field trials are currently being conducted in central Utah. Various rates of the pyrethroid formulations are being evaluated for efficacy. There are no registered pyrethroids for spruce beetle at this time.

Preventive insecticide applications must be applied before adult beetles attack the tree. Because of application costs associated with individual trees, preventative treatments are generally reserved for high value trees, i.e. recreation areas, administrative sites and ornamentals.

Preventative sprays are applied using hydraulic sprayers with pump pressures that reach 350-450 psi (pounds per square inch). Nozzle orifice sizes range from #8 to #10. The higher pump pressures are necessary to reach up to 50 feet on the tree bole of large diameter trees. Trees with abundant branching on the lower portions of the bole should be pruned up to 10-12 feet to enhance treatment performance. All bole surfaces must be sprayed to the point of runoff, including the root collar and exposed surface roots.

Remedial Sprays

Although chemical insecticides have been used in the past to kill developing larvae in infested trees, no products are currently registered for this type of treatment.

Trapping

During endemic population phases, spruce beetles maintain populations in windthrown trees. They prefer downed material to standing green trees. Trap trees are used as a suppression tactic because of this preference for downed trees. Trees selected as trap trees, are green large-diameter trees (>16 inches dbh) felled to attract attacking adult spruce beetles.

Trap trees are either burned, peeled or removed before beetle emergence the following spring to ensure that no one year brood adults will disperse to standing trees.

Trap trees should be felled in the shade and left intact and unlimbed (Hodgkinson 1985, Nagel et al. 1957, Wygant 1960). They are most effective if felled in the spring before adult beetle flight (Hebertson 2004, McComb 1955). Felled trap trees often attract 10 times or more the number of adult beetles that attack standing trees (Wygant 1960). The number of trap trees felled depends on the level of infestation and size of the infested trees. In static infestations, the number can range from 1-10 depending on the diameter of standing infested trees and the diameter of trap trees, larger diameter trap trees absorb more beetles (McComb 1953). In building infestations, the number of trap trees ranges from 1-5 based on the same parameters used for determining number of trap trees for static infestations (Nagel et al. 1957, Wygant 1960).

Standing trap trees baited with an attractant pheromone (tree bait) are effective but attract fewer beetles than downed trap trees. Adjacent to felled or standing trap trees, other susceptible host trees will often be attacked. To suppress beetle populations, all standing and down infested trees should be treated before beetle emergence the following spring.

Removing the bark from spruce beetle infested trap trees is an effective, if time-consuming, means to destroy the brood.

Trapping (continued)

Non-host trees baited with the attractant pheromone are potential trap trees.

Trap trees not treated by the following spring before adult flight, will add to further tree mortality. Forest entomologists can assist resource managers with determining the number and placement of trap trees necessary to mitigate spruce beetle population increases.

Non-host trees baited with the attractant pheromone are also potential trap trees because reproduction is prevented and many parent adults die due to the pitch produced by the non-host baited tree (Dyer & Safranyik 1977). Lethal trap trees, which are felled or standing host trees baited with the spruce beetle lure and sprayed with a preventative insecticide, have not been as effective at suppressing populations compared to the traditional trap tree approach described previously.

Pheromone strategies

MCH (3-methyl-2-cyclohexen-1-one)
The natural antiaggregant pheromone for Douglas-fir beetle repels spruce beetle attacks, particularly if populations are endemic or just beginning to increase.

Previous field studies indicate MCH can reduce attacks on MCH treated windthrown trees and logs (Rudinsky et al. 1974). MCH used as a repellent in outbreak populations of spruce beetle, is not an effective treatment (Ross et al. 2004).

Spruce beetle attractant pheromones have been used to suppress localized populations of the insect. There are two methods of deploying attractant pheromones: tree baits and spruce beetle lures.

Tree Baits –

Polymer bubble caps containing the attractant pheromone are stapled to green susceptible host trees. Tree baits are an effective tactic if used in sites where spruce beetle populations are endemic or low. Baiting tactics are as follows:

- Spot Baiting – Used to suppress small pockets of infested trees (<30 trees). Bait 2-3 susceptible trees in the center of each spot spaced 30 to 50 feet apart.
- Mop-Up Baiting – Used to concentrate residual beetle populations following harvest. Bait trees within or surrounding the treated area at 75-150 foot intervals. Baits should be deployed for two years to effectively cover the 2-year life cycle spruce beetles.
- Grid Baiting – Used in infested sites up to 50 acres to contain beetles within currently infested boundaries. Bait single standing trees at 75 foot intervals.
- Cluster Baiting – A tree bait is placed in 3-bait clusters at 330 foot (5 chain intervals). Within each cluster, place individual baits 30-50 feet apart. This is an effective technique for low or endemic spruce beetle populations to concentrate dispersing adults.

All baited trees and adjacent attacked trees must be removed, burned or peeled to eliminate the developing life cycles from the treated areas. Because of the possibility of a one-year life cycle, the trees must be treated the same year the baits were installed following adult spruce beetle dispersal.

Spruce Beetle Lures —

Spruce beetle attractants are used for monitoring purposes and to supplement suppression efforts. Recent attractant studies in Utah indicate that the 3-component lure is a more effective attractant for spruce beetle (Ross et al. 2005). However, spillover effects on adjacent host trees are greater when the 3-component lure is used. To minimize this effect, funnel traps with lures should be placed at least 100 feet from a susceptible host tree. Trap placement should occur in clumps of non-hosts or dead spruce. Trap placement in open areas without shade, is not very effective.

Pheromone strategies (continued)

A funnel trap containing aggregative semiochemicals provides a means to assess and reduce local populations of spruce beetle.

Monitoring –

Spruce beetle lures are used in combination with Lindgren funnel traps to determine flight periodicity and population densities. A Lindgren funnel trap baited with the 2-component lure is an effective monitoring technique. Single traps placed in sites with spruce beetle activity will effectively monitor flight activity and population densities.

Suppression –

Lindgren funnel traps baited with the 3-component lure is an effective strategy to reduce local populations of the insect. This technique is most effective if used in combination with other suppression treatments (i.e. sanitation, trap trees). Traps should be placed in 3 trap clusters at 330-foot intervals (5 chains) in clumps of non-hosts or dead spruce. Distance between traps within a cluster should range between 50-75 feet.

Natural Controls

- *Temperature extremes*
- *Woodpeckers*
- *Insect predators and parasites*

Temperature extremes

Temperature is one of the most critical factors in the life of the spruce beetle; the extremes are lethal, and the intermediates influence development.

Extreme cold—

Laboratory tests showed that subcortical temperatures of -15°F will kill all adults, while -30°F will kill all larvae (Massey & Wygant 1954). Extremely low temperatures in Colorado in 1951 are frequently cited as a major factor in terminating the White River outbreak (Wygant 1956). In the northern Rocky Mountains, an average of 42 percent of the brood was killed during an unusually cold spell (Terrell 1954).

Extreme heat—

At the opposite extreme, temperatures exceeding 130°F for 30 minutes will kill all the brood in the bark subjected to such conditions. Temperatures above 110°F will kill varying percentages of the brood depending on the length of exposure (Mitchell & Schmid 1973).

Adaptation to cold—

The overwintering behavior of a percentage of the adults may have evolved in response to cold winter temperatures. When beetles leave the upper bole and reenter the bark near the base, their survival is enhanced. Under normal conditions, 6 feet or more of snow accumulates on the ground in the high elevation spruce-fir forest covering the tree base. Below this snow line, temperatures are near 32°F while above the snow line ambient air temperatures exist. Thus, beetles in the bark below the snow line are not subjected to lethal sub-freezing temperatures (Schmid & Frye 1977).

Extremely low spring temperatures in Colorado in 1951 are frequently cited as a major factor in terminating the White River outbreak

Woodpeckers

Three species of woodpeckers, the northern three-toed, the hairy, and the downy, are important predators of the spruce beetle and are listed in decreasing order of importance (Knight 1958).

Three important bird species—

- The northern three-toed is most effective because it feeds exclusively on the boles of trees, primarily on trunks of freshly attacked trees rather than old snags (Koplin 1969) and is indigenous to the spruce-fir habitat (Baldwin 1960). Its effectiveness is also greater because this species aggregates in infested areas (Koplin 1969).
- The hairy woodpecker feeds on the trunks of trees including old snags in addition to freshly attacked trees (Koplin 1969).
- The downy is the least effective spruce beetle predator of these three species of woodpeckers. It feeds mainly on the branches of infested trees (Koplin 1969) and has the least pronounced functional response to infestations (Koplin 1972).

During an outbreak, woodpeckers can consume as much as 55% of the spruce beetle brood.

Natural Controls

- **Weather: temperature extremes have been credited with ending some spruce beetle outbreaks**
- **Woodpeckers: such as the northern three-toed woodpecker, feed exclusively on insects in the bole of trees.**
- **Insect predators and parasites: Effects are quite variable, from minimal to more than 60 percent.**

Impact on bark beetle populations—

Woodpecker effects on beetle populations are influenced by host material, density of beetle brood and extent of woodpecker feeding. During outbreak conditions in standing trees, woodpeckers may destroy 55 percent of the brood (Hutchison 1951) although beetle mortality may vary from 45 to 98 percent (Knight 1958).

During low-level infestations woodpeckers may only take about 20 percent of the brood in standing trees. In trap trees or downed material woodpeckers may consume 2 to 26 percent of the brood (Koplin & Baldwin 1970). Feeding activity on trap trees or downed material may be influenced by the presence or absence of adjacent infested standing trees. When present, feeding activity on the downed material may be reduced. When absent, woodpeckers may concentrate on the downed material.

Feeding activity of woodpeckers fluctuates with the season, day, weather, and the type and amount of infested host material. Feeding on infested standing trees is generally highest during December through March; feeding is greatly reduced on such trees from late May to September (Koplin & Baldwin 1970).

Despite high-energy needs and exclusive feeding on spruce beetle in winter, woodpeckers would be unable to eliminate all the beetles in each tree because of the overwintering behavior of a percentage of the adults in the base of the tree beneath the protective snow cover.

Natural Controls

Insect Predators and Parasites

The effects of insect parasites and predators on spruce beetle populations are quite variable. These agents are a tremendous mortality factor in some infestations; perhaps accounting for more than 60 percent beetle mortality. In other cases, the entomophagous species kill a large number of spruce beetles, but their effect on the population is minimal.

Impact on spruce beetle outbreaks—

Some forest entomologists believe insect parasites and predators are primarily responsible for keeping beetle populations at endemic levels. However, the fact remains that infestations develop from a low level to outbreak status with these organisms present. Furthermore, under outbreak conditions these organisms seldom cause a rapid reduction of the beetle population to pre-outbreak levels even though they may kill a large number of beetles.

Based on these observations, it is difficult to conclude that natural populations of insect parasites and predators regulate spruce beetle populations.

Important species—

Generally the important parasitic and predacious species are known (Massey & Wygant 1954, Jensen 1967). Their life cycles, habits, and mortality effects of some species are known either from studies of the spruce beetle or other *Dendroctonus* beetles (Schmid and Frey 1977).

- The most important *Braconid* wasp parasite is *Coeloides dendroctoni*. Two other parasitic wasps have been observed feeding on spruce beetle larvae. Both are *Pteromalididae* wasps with little known about their life history or habits. Neither species are considered to be important contributors at suppressing spruce beetle populations.

- The second most important biological mortality agent of spruce beetle besides woodpeckers is a parasitic fly *Medetera aldrichii*. Its effectiveness may be lessened by indiscriminate feeding habits because larvae feed on a variety of other insects (Massey & Wygant 1954).

- Three species of clerid beetles also feed on spruce beetle life stages, *Thanasimus undatulus, Enoclerus lecontei* and *Enoclerus sphegeus*.

- Other insect species have been observed feeding on various developmental stages of the beetle. Few of these have been adequately studied and their effectiveness as predators is not known.

Insect parasites and predators

These agents are a tremendous mortality factor in some infestations; perhaps accounting for more than 60 percent beetle mortality.

Parasitic wasps help to keep bark beetle populations in check.

Significant succession effects of spruce beetle include rapid conversion to fir cover types, and increased density and diversity of grasses and forbs.

Effects of Spruce Beetle

Vegetation—

When epidemic spruce beetle populations change stand structure, they also simultaneously alter species composition. Stands composed of 90 percent spruce and 10 percent fir in the overstory before the White River outbreak became 20 percent spruce and 80 percent fir in the overstory after the epidemic (Schmid & Hinds 1974).

In Utah on the Wasatch Plateau, the spruce beetle outbreak reduced spruce basal area more than 90 percent and decreased average spruce diameters from 14.1 inches to 8.6 inches (Dymerski et al. 2001). Affected stands become predominately fir for the next 125-175 years or until the fir begins to die (Schmid & Hinds 1974).

Forage production in beetle-killed stands is much greater than in green unaffected stands. Grasses and sedges showed increased density in beetle-killed stands and forbs were 2.3 times more numerous but browse plants decreased. In general, the greatest density, number of species, and index of occurrence of plants were found in beetle-killed stands (Yeager & Riordan 1953).

Elk and deer may find improved forage after a spruce beetle epidemic.

Wildlife—

The influence of spruce beetle epidemics on animal populations inhabiting spruce-fir forests has not been determined but would depend on the species requirements and the intensity and range of the epidemic (Schmid & Frye 1977). Insectivorous birds such as woodpeckers would initially increase because of the abundant food supply, however as insect populations decreased these predators would have to emigrate thus declining in abundance.

Seed eating birds and mammals are adversely affected because of the loss of spruce seed (Yeager & Riordan 1953). Spruce grouse would also decline in numbers because of the loss of suitable habitat and winter food. In contrast, elk and deer benefit from the increased forage production, although the loss of thermal cover can be detrimental to both species (Schmid & Mata 1996).

In the aftermath of a spruce beetle epidemic, the risk of increased fire intensity remains high for several decades because the large dead fuels are slow to decay.

Fire—

Spruce beetle epidemics can influence both fire hazard and fire intensity. Increased fire hazard (probability of a fire starting) created by the killing of spruce by beetles is limited to the first two years after beetle attack when the dead and dying needles increase the fine fuel component. Once these fuels fall from the dead trees, fire hazard is essentially similar to the period before the trees were attacked and killed by spruce beetle (Schmid & Mata 1996).

In contrast, fire intensity (the destructive nature of a fire) would increase after a spruce beetle infestation and remain at a higher level for decades because of the increased amount of dead fuels that are slow to decay (Schmid & Mata 1996). The probability for stand replacing fires in a spruce beetle affected site remains small because fires are infrequent in spruce-fir forests (Veblen et al. 1994). However, if a fire started under favorable or extreme fire weather coniditons the abundant fuel loads would increase fire intensity.

Effects of Spruce Beetle *(continued)*

Hydrology—

Spruce beetle epidemics influence tree-water relationships and if the epidemic is large enough, streamflow. A long-term streamflow study in Colorado following a spruce beetle epidemic found that a major increase in streamflow occurred after the epidemic (Bethlahmy 1974). Following the White River spruce beetle outbreak in Colorado, streamflow for the affected watershed increased 1.6-1.9 inches (Mitchell and Love 1973).

Loss of riparian forest canopy following a spruce beetle epidemic can result in increased stream flows.

Deterioration of Spruce—

Mielke (1950) studied the rate of tree deterioration in beetle killed Engelmann spruce. In southern Utah, 85 percent of the spruce beetle killed trees were still standing after 25 years. Mielke also studied this effect in Colorado and noted that the moisture content of heartwood and sapwood had reached such a low level in the dead spruce that decay fungi were unable to develop.

In the White River spruce beetle outbreak in Colorado (1941-1952), Hinds et al. (1965) found that about 40 percent of the original cubic volume had been lost 20 years after the trees died. About one-third of this loss was due to decay in standing trees, two-thirds to windthrow. As time passed, windthrow was a progressively more important deterioration factor.

Boring dust on the bark is often the most obvious sign of successful spruce beetle attacks. Pitch tubes may occur on the bark of attacked trees.

Recognizing Trees attacked by Spruce Beetle

Reddish-brown boring dust on bark, in bark crevices, and on the ground around the root collar from mid-May to mid-July is the most obvious sign of beetle attack. Pitch tubes may also occur around entrance sites. Boring dust and pitch tubes are most visible the first summer following initial attacks (Holsten et al. 1999). During winter, woodpeckers feeding on overwintering life stages produce bark flakes that accumulate on the ground or snow around infested trees. Egg galleries average about 6-8 inches in length, have a slight crook at the start, and extend vertically in standing trees. Eggs are deposited on alternate sides of the gallery, which is packed with frass and boring dust. Larvae feed in the phloem outward from the egg gallery, often in a radiating pattern. The needles on infested trees usually do not turn yellowish-green until the following summer, one year after the initial attacks. Needle discoloration generally takes place in late July and August. Needles drop soon after fading as a result of wind and rain. Adult beetles are dark brown to black with reddish-brown or black wing covers and are about 1/4 inch long and 1/8 inch wide (Holsten et al. 1999).

Pitch tubes may occur around beetle entrance sites on the bark.

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Forest Health Protection and State Forestry Organizations

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