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Northern Spruce Engraver

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The northern spruce engraver, *Ips perturbatus* (Eichhoff) (Figure 1), is a significant tree-killing bark beetle in the boreal and sub-boreal forests of North America. Its range generally coincides with that of its primary host, white spruce, *Picea glauca*. Other hosts include Engelmann spruce, *P. engelmannii*, Lutz spruce, *P.* × *lutzii,* and in rare cases, black spruce, *P. mariana*, or Sitka spruce, *P. sitchensis*. This beetle has been recorded from Alaska, Maine, Michigan, Minnesota, Montana, Washington, and nearly all of the Canadian provinces (Figure 2).

Impacts

Adults colonize the stem and larger branches of standing trees. They are also found frequently in fallen trees, slash (i.e., material remaining from timber harvest and forest thinning operations), and larger pieces of debris (more than 2-3 inches in diameter) broken from trees that have been damaged due to heavy wind or snow load. The adults aggregate on and tunnel through the bark of spruce stems and branches, creating galleries in the phloem (inner bark). The larvae mine through the phloem as

Figure 1. Adult northern spruce engraver, Ips perturbatus *(length of specimen: 4.5 mm).*

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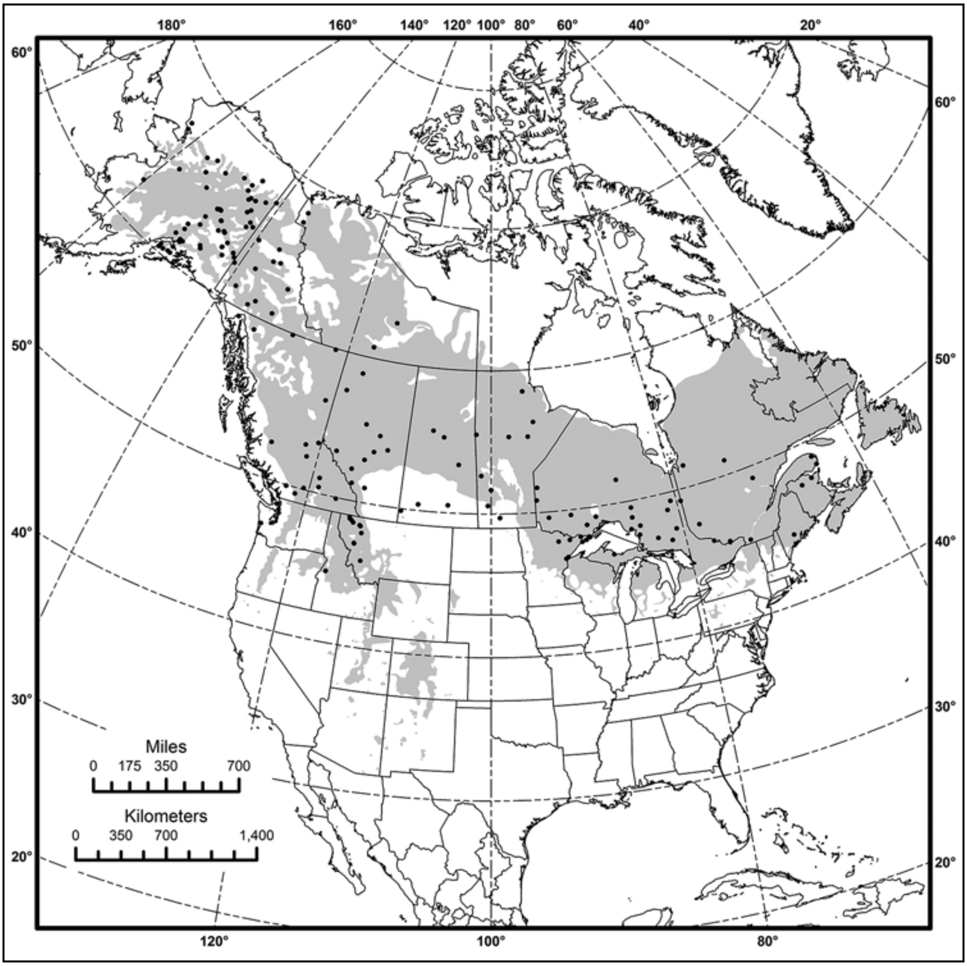


Figure 2. North American distribution of northern spruce engraver (shown as black circles) assembled from historical collection records (Bright 1976, Wood 1982) and pest surveys across the range of its major hosts, white spruce and Engelmann spruce (shown in gray).

they develop. This feeding activity damages and kills the phloem and outer xylem (wood), which, depending on location, causes top killing of large diameter trees or mortality of small diameter trees. Adults carry a variety of ophiostomoid (i.e., blue-stain) fungi, which may also have deleterious effects on tree health.

Outbreaks of the northern spruce engraver are most frequently associated with forest disturbances, logging debris, and small trees (less than 6 inches diameter at breast height, dbh). In most years, endemic populations of this species infest forest debris, widely scattered individual trees, or small groups of trees (Figure 3). Consequently, losses of commercial timber are minimal. However, extensive outbreaks have been recorded in Alaska. For example, an outbreak in the 1950s north of Fort Yukon in the Alaskan interior covered more than 1,500 square miles and resulted in the death of thousands of mature white spruce. In 1986, northern spruce engraver also killed thousands of mature white spruce on more than 16,000 acres near Fairbanks following a wildfire and

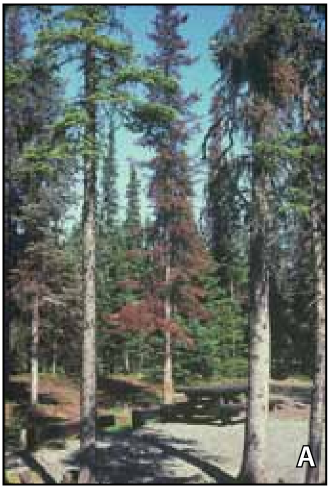


Figure 3. White spruce attacked and killed by northern spruce engraver. (A: Quartz Creek campground, AK; B: thinned white spruce plantation, MN).

extensive stem breakage due to heavy accumulations of ice and snow. Another outbreak in the late 1990s in the Granite Creek area of the Kenai Peninsula in south-central Alaska resulted in the death of about 50 percent of the residual small diameter (less than 6 inches dbh) Lutz spruce immediately after an outbreak of spruce beetle, *Dendroctonus rufipennis*, and subsequent timber harvest.

Stand structure and composition may be altered dramatically by outbreaks of northern spruce engraver. In instances where large-scale outbreaks occur and the forest canopy is removed, the diversity of understory vegetation may increase. This results in a highly altered fuel complex dominated by large pieces of dead wood and highly-flammable dry grasses, such as bluejoint reedgrass, *Calamagrostis canadensis*.

Alterations in forest stand conditions by the beetle may also impact wildlife. For example, wildlife species that depend on live, mature spruce stands as habitat include Townsend's warbler, ruby-crowned kinglet, spruce grouse, and red and flying squirrels. They may be impacted negatively by outbreaks of northern spruce engraver. Other wildlife species that depend on the early successional stages of spruce forests, such as moose, may benefit from these outbreaks.

Evidence of Infestation

The first sign of colonization is reddish-brown boring dust (frass) that accumulates at the adult entrance holes, in bark crevices, and on the ground around the trunk (Figure 4). Frass is generally found in distinct piles marking the location of individual beetle entrance holes through the bark surface. "Pitch-outs," or unsuccessful attacks, are rarely encountered with northern spruce engraver. Pitch-outs or pitch tubes are more commonly associated with spruce beetle attacks. On windthrown trees and in log decks, spruce beetle attacks are readily detected on the lower surfaces of logs and should not be confused with northern spruce engraver

Figure 4. Piles of reddish-brown boring dust on the bark surface indicate attacks by northern spruce engraver.

entrance holes, which are found more frequently on the upper surfaces. When the bark is removed, the frass-free galleries of the northern spruce engraver will also be evident. These galleries are tuning-fork- or Y-shaped, and are often etched onto the surface of the xylem (Figure 5).

Dying trees infested with this beetle will undergo changes in the color of their foliage. Needles begin to fade from dark green to pale yellowish-green to red as early as one month after attack (e.g., by July) in the Alaskan interior (Figure 6). By the end of the first summer after attack, most foliage has faded and most needles have dropped. This rate of color change is in contrast to the color change of spruce beetle-killed trees, which usually do not fade or discolor until the year following initial attack. During the initial fall, winter, and spring following a northern spruce engraver infestation, one might also notice trees whose bark has been removed by foraging woodpeckers. These partially debarked trees may also be colonized by spruce beetles or other subcortical insects, so the diagnosis should be confirmed by removal of the bark and examination of the phloem and xylem for the characteristic galleries or adult beetles.

Identification, Biology, and Life Cycle

Adult northern spruce engravers are small (4.0 to 4.8 mm long), cylindrical, reddish-brown to black beetles with four spines along the outer margins of the posterior elytral declivity (concavity at the end of the wing covers). At first glance, northern spruce engraver may be confused with the spruce beetle. However, spruce

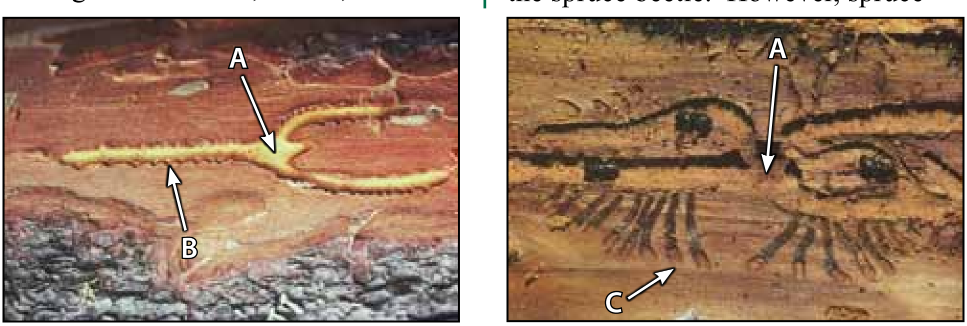


Figure 5. Typical "tuning fork"-shaped, frass-free gallery of northern spruce engraver. Arrows denote (A) central adult nuptial chamber, (B) egg niches along female egg galleries extending from the central chamber, and (C) larval galleries.

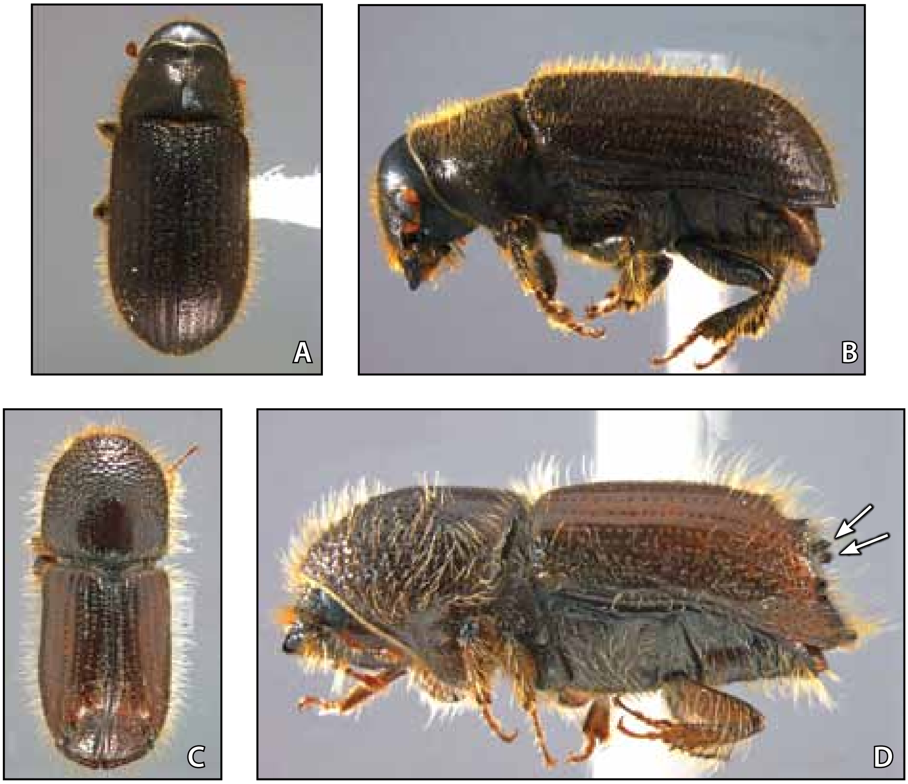
beetles are larger (about 4.4 to 7.0 mm long) with elytra (wing covers) that are evenly rounded, without spines along the elytral declivity, and have a visible head when viewed from above (Figure 7). *Ips perturbatus* is typically larger and wider than other boreal *Ips* species such as *I. borealis, I. concinnus, I. pini,* and *I. tridens.* Examination of the third spine along the elytral declivity of *I. perturbatus* is important for distinguishing *I. perturbatus* from the other *Ips* species noted above. When viewed with a hand lens or under a microscope, this spine is conical distally with an acute tip (i.e., similar in shape to the "ace of spades") (Figure 7E).

Galleries are initiated in the phloem by males, which are later joined by and mate with up to four females in a central nuptial chamber. Mated females extend egg galleries (the arms of the "tuning fork") that radiate from the central nuptial chamber and deposit about 50 eggs in individual niches along the gallery walls (Figure 5). Eggs are oblong, pearly white, and less than 1.5 mm long. Larvae hatch from eggs in 7 to 10 days and feed on phloem tissue. These larvae are stout, cylindrical, legless grubs that pass through four instars (stages) and reach a length of about 3.3 mm at maturity. They develop into pupae after 4 to 5 weeks. Pupae are opaque white, inactive, and somewhat similar in size and shape to adults (Figure 8). The pupal stage lasts approximately 10 days. Pupae transform to new adults and usually exit the host material before the onset of winter.

Figure 6. Fading foliage is indicative of tree death. In this case, spruce trees were attacked and killed by northern spruce engraver.

Northern spruce engraver normally completes its life cycle in one year throughout its range, although early observations in eastern Canada suggested that the adult stage may last nearly two years. Having overwintered as adults primarily in forest litter beneath their brood trees, dispersing beetles attack fresh host materials soon after emergence in the spring. In both Alaska and Minnesota, adults begin flying from overwintering sites in late April to late May and continue to mid-July, with peak flight in early to mid-June. The exact timing of emergence depends on temperature and normally occurs when ambient daytime temperatures exceed 62° F. Most adults disperse a short distance (~100 feet) from their overwintering sites, but some have been documented to fly up to ¼ mile from a point of dispersal.

In most cases new adults remain under the bark of the infested tree for a few weeks before emerging from the infested tree and dropping to the ground where they overwinter in the



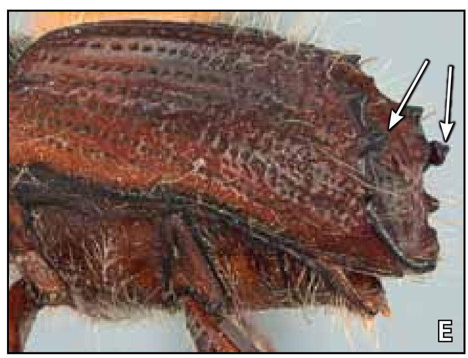


Figure 7. Comparison between the spruce beetle (A and B) and the northern spruce engraver (C, D, and E). For the spruce beetle, the head is visible from above (A), and the end of the wing covers (elytral declivity) has no spines (A and B); actual length of specimen is 6.3 mm. For the northern spruce engraver, the head is not visible from above (C), and the elytral declivity has four spines on each side (C and D); actual length of specimen is 4.8 mm. Northern spruce engraver also has a characteristic "ace of spades" third spine (arrows on D and E).

litter. Some adults may overwinter within the host log, but this is rare, and in contrast to other engraver species in boreal spruce (e.g., *I. borealis, I. tridens*) whose newly formed adults nearly all overwinter under the bark of the tree stem where they developed.

Researchers in Canada have observed females constructing multiple egg galleries, but this behavior has not been confirmed elsewhere. Egg galleries are kept clear of frass by the parent adults. This characteristic distinguishes northern spruce engraver galleries from those of the spruce beetle whose galleries can be partially blocked with frass. Research in Alberta, Canada indicated that the mean density of breeding galleries of northern spruce engraver in white spruce was 20 galleries/square foot of bark surface. In Alaska, adults have been observed to only establish a single gallery system in a brood

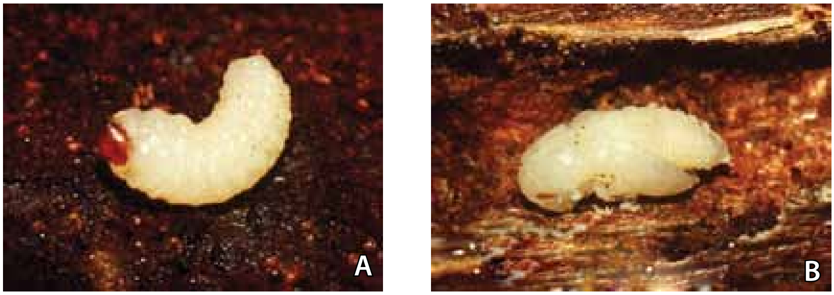


Figure 8. Immature life stages of northern spruce engraver (left: larva; right: pupa).

tree; adults do not re-emerge and re-attack the same or neighboring trees or host logs. Large diameter (more than 10 inches dbh) infested spruce can produce enormous quantities of new adults. For example, research in eastern Canada documented that 2,000 mated pairs produced as many as 22,000 beetles from a 48-foot section of infested white spruce.

Associated Insects

Many other phloem and wood-feeding beetles as well as some predatory beetles and flies, and parasitic wasps have been reported in association with northern spruce engraver beneath the bark of spruce in Alaska. For example, more than 17 species of bark and ambrosia beetles have been found in the phloem and xylem of trees colonized by this engraver. In addition to spruce beetle and the various boreal *Ips* spp., species in the genera *Dryocoetes, Pityophthorus, Polygraphus,* and *Trypodendron* are frequently present. Early larval stages of the whitespotted sawyer, *Monochamus scutellatus* (roundheaded woodborer), have been observed to consume significant amounts of spruce phloem and likely compete as an herbivore, but may also act as a predator of northern spruce engraver larvae. Other frequently observed beetles that may feed on the various life stages of this engraver include several species of checkered beetles, as well as *Cucujus clavipes puniceus* (flat bark beetle), *Rhizophagus dimidiatus* (small flattened bark beetle), *Corticeus praetermissus* (darkling beetle), and *Lasconotus borealis* (cylindrical bark beetle). Several species of predaceous flies and parasitic wasps have also been reared from logs infested with northern spruce engraver.

Conditions Conducive to Infestations

Natural disturbances in forest stands, including wildfire, wind and ice storms, heavy snow, and river flooding, may produce large volumes of dead or damaged spruce that can be ideal breeding materials for northern spruce engraver. Along many of Alaska's interior rivers, riverbank erosion, as well as seasonal flooding events that lead to siltation and soil compaction, have precipitated small- to medium-scale outbreaks. Human activities including road building, housing construction, construction of utility rights-of-way, and logging can also provide large amounts of breeding material. If favorable climatic conditions coincide with large quantities of suitable host materials (e.g., cull logs, slash piles, tops and branches), populations of northern spruce engraver may erupt and result in the mortality of apparently-healthy trees over extensive areas.

Increased water stress in spruce may result in increased tree susceptibility to attack by northern spruce engraver, since the production and movement of defensive resin to the attack site is dependent on the tree's water balance. Spruce trees in boreal regions may experience prolonged periods of water stress during late spring and early summer due to frozen soils that limit available soil moisture. This effect is likely exacerbated by dense stand conditions. Other stand conditions that reduce tree vigor also increase the potential for an outbreak. For example, older spruce stands tend to be less vigorous than younger stands, and thus are more susceptible to attack and less able to defend against northern spruce engraver attack.

High stand densities may decrease tree vigor as a result of increased inter-tree competition for nutrients, water, and sunlight. Other factors being equal, the potential for an outbreak increases as tree density increases in a spruce stand.

Likewise, individual trees that are injured by fire, severely water stressed, or mechanically damaged are more susceptible to attack. Results from a study in the Noatak River drainage of interior Alaska showed that 8 percent of white spruce stems were killed by a combination of windthrow, porcupine feeding damage, and resultant northern spruce engraver activity. Most spruce having 60 percent or less of their circumference girdled by porcupines were able to successfully repel attacking engraver populations. Conversely, when more than 60 percent of the tree's circumference was girdled, the probability of mortality attributable to engraver attack increased.

If an infestation persists in a stand, even small diameter trees will eventually be attacked and killed. In the first year (1996) of an outbreak in the Granite Creek area in Alaska, *Ips*-killed Lutz spruce averaged 4.5 inches dbh, whereas uninfested spruce averaged 2.8 inches dbh. The next year, on average, even smaller diameter spruce were attacked. During intense outbreaks of northern spruce engraver, spruce as small as 1-2 inches dbh may be attacked and killed.

In summary, most outbreaks originate in spruce stands that have experienced some form of major disturbance during, or followed by, a period of favorable weather conditions. For example, a 1980s outbreak near Fairbanks, Alaska was believed to have developed from a combination of factors: (1) large amounts of breeding material (fire-scorched spruce) from the Rosy Creek Fire and thousands of acres of scattered broken spruce tops originating from heavy snow falls during the winter of 1984-85. Engraver populations rapidly built-up in this widely available host material during the spring and summer of 1985. This was followed by (2) an abnormally low snow fall in 1985-86 and drought-like conditions in the spring of 1986, resulting in thousands of acres of water-stressed spruce. A huge dispersal flight by the northern spruce engraver exploited the vulnerable spruce, which resulted in extensive tree mortality.

Management Strategies

Forest managers have several strategies available to prevent or reduce resource losses from northern spruce engraver. The primary preventive strategy includes thinning followed by proper slash management aimed at maintaining healthy stands with moderate growth rates. If engraver populations are increasing, then strategies involving suppression methods (silvicultural, physical, and/or chemical measures) may be appropriate. Some methods are suitable only for beetle populations in downed host materials, such as logging slash and broken tops. Other methods are better suited for infestations in standing trees. Most suppression methods are short-term tactical responses to current or projected beetle population levels and, therefore, their effectiveness is relatively short-lived. Managers should inspect vulnerable sites repeatedly for new evidence of activity by northern spruce engraver and adjust their management strategies accordingly.

Silvicultural Methods

When carrying out manipulations of spruce stands to prevent and/or minimize future infestations, it is imperative to minimize mechanical damage to residual trees and to practice good logging sanitation. Also, soil compaction or disturbance should be minimized, particularly around the root zone of residual spruce. Spruce slash should not contribute significantly to buildup of populations of northern spruce engraver when:

1) Harvest operations are scheduled after beetle flight ends, but not within 3 months of the next flight period. For example, spruce slash left on the ground after the main northern spruce engraver dispersal flight (i.e., ~mid-July or later) is less suitable breeding material than slash produced during late winter to early spring, just prior to dispersal of overwintered adults.

2) Only spruce slash pieces less than 4 inches in diameter are left untreated, because they produce significantly fewer beetles than larger diameter slash pieces.

3) Cull logs and tops are limbed, cut into short lengths and exposed to sunlight. In addition, using a chain saw to mechanically score pieces of slash more than 4 inches in diameter or downed material should be considered to promote drying of phloem to reduce habitat, but is costly and labor intensive. As a general rule, any treatment that enhances drying and aging of the phloem is desirable.

Physical Methods

The use of prescribed fire in the late summer and early fall in interior Alaska is becoming more common as a forest management practice to reduce hazardous fuels and improve wildlife habitat. Because new adult northern spruce engravers emerge from host material and overwinter nearby in the litter layer, such burns could also provide the benefit of destroying overwintering adults. Solar heating of the phloem by placing heavy plastic sheeting over slash piles and decked logs is a remedial practice that has been used in the western U.S. to disrupt development of bark beetles. However, this method has not been shown to be effective in Alaska. Finally, firewood piles or spruce slash decks should not be located immediately next to live trees.

Chemical Methods

Chemical techniques for managing populations of northern spruce engraver include behavioral chemicals (semiochemicals such as pheromones) and insecticides, which can be applied for individual tree protection or to assist in the management of breeding material on the ground.

Males produce an aggregation pheromone (ipsenol, ipsdienol, and *cis*-verbenol) that attracts males and females to a growing aggregation on a standing or fallen tree. Synthetic versions of these attractive compounds are commercially available and have been used in research on the northern spruce engraver. These behavioral chemicals can be used as trap baits to mass trap or monitor populations during forest management operations. These applications have not been tested rigorously; however, during hazardous fuels reduction projects in interior Alaska in the early 2000s, trap-out operations were conducted with moderate success.

A behavioral chemical interruptant (*trans*-conophthorin and verbenone) has been shown to protect individual spruce trees from engraver beetle colonization in Alaska (Figure 9). This technique may be cost effective for protecting high-value spruce in residential areas, campgrounds, or administrative sites.

Figure 9. Release devices for a behavioral chemical interruptant attached to a Lutz spruce to protect the tree from northern spruce engraver. The interruptant components are: trans-*conophthorin (top) in a small polyethylene tube and verbenone (bottom) in the pouch formulation.*

The synthetic behavioral compounds for northern spruce engraver have not received registration from the U.S. Environmental Protection Agency and, as such, are only used in research or limited management activities. Behavioral chemicals used in traps, however, require no registration in the U.S. and can be used in management strategies if done in consultation with forest health professionals.

A common method of protecting trees from bark beetle attack is to saturate the tree bole with an insecticide by using a hydraulic sprayer at high pressure (more than 325 pounds per square inch). Several insecticide formulations are available, including carbaryl and permethrin, which can be applied to the boles of uninfested spruce to kill attacking beetles. For example, carbaryl applied at 2 percent provides protection of individual spruce from attacking engravers and spruce beetles for at least 2 years. These preventive insecticidal treatments should be applied from late fall to late April before the emergence and flight of dispersing adults. Under most conditions, trees should be sprayed to drip point (runoff) to a height of about 40 feet.

The use of personal protective equipment and proper clothing may be required. The insecticide label contains legal requirements that must be followed. Technical assistance concerning the use and application of semiochemicals and insecticides can be obtained from Forest Health Protection (USDA Forest Service) entomologists (www.fs.usda.gov/goto/foresthealth/), state forest entomologists, and/or county extension agents (www.csrees.usda.gov/Extension/).

Assistance

Private landowners can get more information from county extension agents, state forestry departments, or state agriculture departments. Federal resource managers should contact Forest Health Protection, USDA Forest Service (www.fs.usda.gov/goto/foresthealth/). This publication and other Forest Insect and Disease Leaflets can be found at www.fs.usda.gov/goto/fhp/fidls .

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