

BARK AND AMBROSIA BEETLES

INTRODUCTION

Two of the most damaging groups of forest insects are **bark beetles** and **ambrosia beetles**. They comprise two subfamilies of the Curculionidae (weevils): the Scolytinae and Platypodinae. The Scolytinae, formerly family Scolytidae, consists of about 6000 species of small, cylindrical, beetles found worldwide (Wood S.L. 1982). When adults first emerge from their pupal cases, they are amber colored, and turn red-brown to black when mature. While many species confine attacks to recently dead material and are of minor importance, species of several genera (e.g. *Dendroctonus*, *Ips*, *Scolytus*) attack and kill live trees.

Bark beetles breed in the cambium and inner bark of host trees. Pitch tubes, resin flow or fine red-brown boring dust on the bark surface are indicators of attack (Fig. 2.3, Plate 39). Most species have a symbiotic relationship with wood staining fungi (e.g. *Leptographium*, *Ophiostoma*), some of which are pathogenic. Beetles carry spores of these fungi on their bodies, often in a specialized tube-like structure known as a mycangium, and spread the fungi from tree to tree. Provided

that the beetles attack living trees, these fungi invade the tree's vascular system, discolor the wood (Fig. 9.1) and hasten tree death.

When bark beetles invade trees, they construct egg galleries and deposit eggs, usually in individual niches. With few exceptions, larvae feed in individual galleries that are more or less perpendicular to the egg galleries. The gallery patterns, produced by the attacking beetles and their brood, are often characteristic and easily recognized. While adults may be somewhat similar in appearance, gallery patterns coupled with tree species attacked is often sufficient for field identification of the beetle involved. Some bark beetles are known as engraver beetles because of the characteristic, often attractive galleries they construct. Galleries are referred to as the "signature" of the bark beetle involved.

Many bark beetles feed before they mate or initiate attacks. Depending on the species, adult feeding may occur in the cambium layer, on branch tips and/or crotches of host trees. This kills portions of branches and makes ornamental and/or Christmas trees unsightly. Others either feed on the tender bark or bore into the pith of young seedlings and kill them (see Chapter 13).

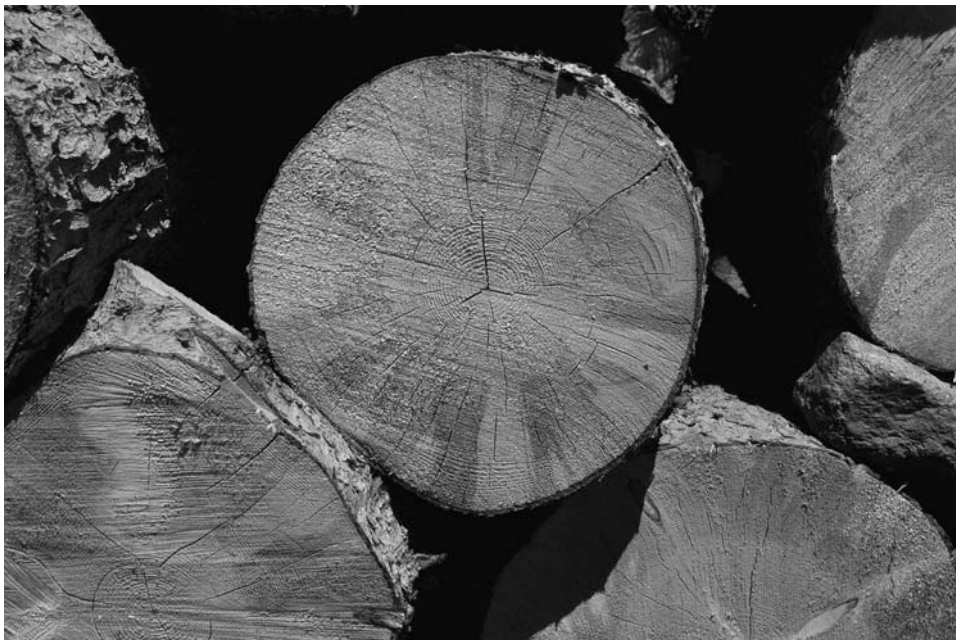


Fig. 9.1 Discoloration of wood of lodgepole pine, *Pinus contorta*, caused by blue stain fungi associated with mountain pine beetle, *Dendroctonus ponderosae* (Roosevelt National Forest, Colorado, USA).

Several bark beetles vector pathogenic fungi during adult feeding.

Ambrosia beetles make breeding attacks in the wood of host plants. After mating, females construct a network of galleries and cradles in the wood. Entrance galleries are marked by piles of fine, granular, white boring dust in bark crevices or on the ground adjacent to infested trees (Plate 40). They deposit an egg in each cradle and inoculate wood with spores of ambrosia fungi that provide food for developing larvae. Unless ambrosia beetles are associated with fungi that are pathogenic, their activity does not kill trees. In addition, most temperate species confine attacks to weakened or recently dead trees. However, a number of tropical species are capable of attacking live trees. Ambrosia beetle infestations cause loss of wood quality but, in a few cases, the galleries and wood stain can be an attractive feature in wood carvings, paneling and furniture.

One North American genus of Scolytinae, *Conophthorus*, attacks and destroys cones and seeds of pines (see Chapter 14).

Immature stages of the subfamily Scolytinae are similar in appearance and difficult, if not impossible, to separate. Eggs are tiny and pearly white in color. Larvae are legless C-shaped grubs with a white body color and an amber head capsule with darker mouthparts (Fig. 9.2). Pupae are white and have partially developed wings and legs.

Beetles of the subfamily Platypioninae are elongate, slender and cylindrical, 2–8 mm long, brown in color and with a head slightly wider than the thorax. Immature stages are similar in appearance to the Scolytinae. All are ambrosia beetles and usually confine their attacks to weakened or dying trees. They are found principally in tropical and subtropical climates. The Platypioninae can be more damaging than ambrosia beetles of the subfamily Scolytinae because their galleries are more extensive and extend deeper into the sapwood and heartwood. Dying, weakened or recently felled trees are preferred but healthy trees can be attacked, especially if areas of dead bark are present (Drooz 1985, Triplehorn & Johnson 2005).



Fig. 9.2 Larval stage of mountain pine beetle, *Dendroctonus ponderosae*.

Curculionidae (Subfamily Scolytinae – Bark Beetles)

Dendroctonus

Nineteen species comprise this genus, 17 from North and Central America, one from China and one from Eurasia (Fig. 9.3 & Table 9.1). They generally breed in conifers greater than 15 cm in diameter. Collectively, bark beetles of the genus *Dendroctonus* are the most destructive biological agents of North and Central American conifer forests. Many species attack standing trees but several attack recently felled or windthrown trees and when populations build, subsequent generations attack and kill standing trees. During outbreaks, several species attack and kill healthy, vigorous trees. All species of *Dendroctonus* are monogamous (Wood S.L. 1982).

Dendroctonus brevicomis LeConte, Western Pine Beetle

Distribution Western pine beetle is indigenous to western North America. In the USA, it occurs in Arizona, California, southwestern Colorado, Idaho, western Montana, Nevada, New Mexico, Oregon,

western Texas, Washington and Utah. In Canada, it is found in southern British Columbia. In Mexico, it occurs in the states of Chihuahua, Coahuila, Durango, Nuevo Leon and Zacatecas.

Hosts Ponderosa pine, *Pinus ponderosa*, is the primary host in Canada and the USA. In California, Coulter pine, *P. coulteri*, is also attacked. In Mexico, *P. arizonica*, *P. durangensis* and *P. estevezii* are hosts in addition to ponderosa pine.

Importance Western pine beetle is a major pest of pine forests. During outbreaks, group killing of trees is common in dense, overstocked stands of pure, even-aged, young sawtimber sized trees and among dense clumps of pine in mixed conifer forests. During outbreaks, a million or more trees may be killed annually. Tree killing depletes timber supplies, affects stocking levels, disrupts forest management and increases fire danger.

Life History This species has several generations/year. The number of generations is complicated by

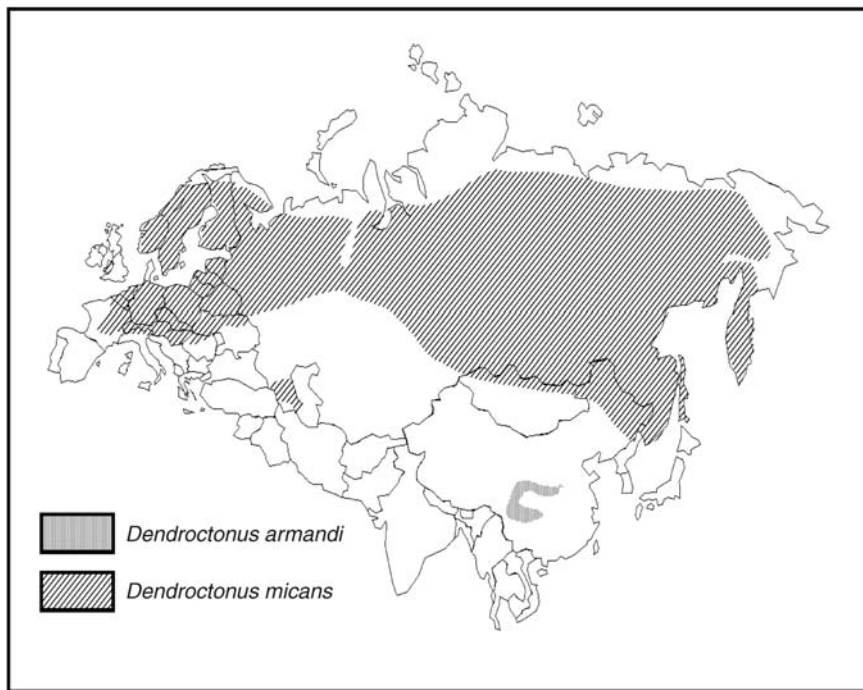


Fig. 9.3 Distribution of the two old-world species of *Dendroctonus*: *D. armandi* and *D. micans* (based on data from Critchfield & Little 1966, Bevan & King 1983, Wood & Bright 1992, Bright & Skidmore 2002, Kimoto & Duthie-Holt 2006).

climatic variability, re-emergence of parent adults to produce a second or third brood and by overlapping generations. In the northern parts of its range and at high elevations, one complete and a partial second generation can be expected. In southern California and Arizona there are three and sometimes four generations/year. Adult flight and attack can occur as early as March and as late as November, with the number of adults peaking at different times with respect to elevation.

Females initiate attacks and release minute amounts of pheromones, which attract males and other females, and cause a mass attack. During outbreaks, groups of trees are attacked. All life stages occur beneath or in the bark of infested trees, except for a brief period when adults fly to attack new trees. Adults become active when subcortical temperatures reach 7.2–10°C. During attacks, which may last 3 weeks, each female lays about 60 eggs individually in niches cut into the sides of winding S-shaped galleries (Fig. 9.4). Some parent females may emerge and re-attack elsewhere in the same tree or in neighboring trees. Eggs hatch after 1–2 weeks. Larvae feed first in the phloem, where they

construct a short gallery. They then mine into the inner bark, where most development takes place. After completing four instars, they transform into pupae and later adults. Brood adults feed in bark, and spores of blue stain fungi introduced by attacking adults collect in their mycangia to be inoculated into trees they attack.

In any given location, elevation is a determining factor where western pine beetle attacks are most abundant. In the USA, attacks occur in forests between elevations of 600 and 2230 m. In north central Arizona, attacks tend to be most abundant at elevations between 1600 and 2230 m. In Canada, infestations usually occur below 300 m and in Mexico above 2400 m.

Description of Stages Adults range from 2.0 to 4.7 mm in length and are about 2.2 times as long as they are wide.

Pest Management Silvicultural tactics, designed to maintain tree and stand vigor, are most appropriate for

Table 9.1 Distribution and hosts of bark beetles of the genus *Dendroctonus* (Coleoptera: Curculionidae: Scolytinae).

Species	Distribution	Hosts
<i>D. adjunctus</i> Blandford Round headed pine beetle*	Guatemala, Mexico, southwestern USA	<i>Pinus</i> spp.
<i>D. approximatus</i> Dietz Larger Mexican pine beetle	Guatemala, Honduras, Mexico, southwestern USA	<i>Pinus</i> spp.
<i>D. armandi</i> Tsai & Li*	Central China	<i>Pinus armandii</i>
<i>D. brevicornis</i> LeConte* Western pine beetle	Southern Canada, northern Mexico, western USA	<i>Pinus coulteri</i> , <i>P. ponderosa</i>
<i>D. frontalis</i> Zimmerman* Southern pine beetle	Belize, Guatemala, Honduras, Mexico, Nicaragua, southern USA	<i>Pinus</i> spp.
<i>D. jeffreyi</i> Hopkins* Jeffrey pine beetle	Mexico: Baja California USA: California, western Nevada	<i>P. jeffreyi</i>
<i>D. mexicanus</i> Hopkins* Smaller Mexican pine beetle	Guatemala, Honduras, Mexico, USA (southeast Arizona)	<i>Pinus</i> spp.
<i>D. micans</i> Kugelann <i>D. murrayanae</i> Hopkins	Asia, Europe (including the British Isles) Central and western Canada and the USA	<i>Picea</i> spp. <i>Pinus banksiana</i> , <i>P. contorta</i> , <i>P. strobus</i>
<i>D. parallelocollis</i> Chapuis <i>D. ponderosae</i> Hopkins* Mountain pine beetle	Guatemala, Honduras, Mexico Southern Canada, western USA	<i>Pinus leiophylla</i> , <i>P. oocarpa</i> <i>Pinus</i> spp.
<i>D. punctatus</i> LeConte	Canada, USA	<i>Picea glauca</i> , <i>P. rubens</i> , <i>P. sitchensis</i>
<i>D. pseudotsugae</i> Hopkins* Douglas-fir beetle	Western Canada, northern Mexico, western USA	<i>Pseudotsuga menziesii</i> , <i>P. macrocarpa</i>
<i>D. rhizophagus</i> Thomas & Bright	Mexico: Chihuahua, Durango	<i>Pinus durangensis</i> , <i>P. engelmannii</i>
<i>D. rufipennis</i> (Kirby)* Spruce beetle	Canada, northeastern and western USA	<i>Picea</i> spp.
<i>D. simplex</i> LeConte* Larch beetle	Canada, northern USA	<i>Larix laricina</i>
<i>D. terebrans</i> (Olivier) Black turpentine beetle	Eastern and southeastern USA	<i>Pinus</i> spp.
<i>D. valens</i> LeConte** Red turpentine Beetle	Canada, China (introduced), Guatemala, Mexico, northern and western USA	<i>Pinus</i> spp.
<i>D. vitei</i> Wood	Guatemala	<i>Pinus pseudostrabus</i> , <i>P. tenuifolia</i>

Sources: Wood S.L. 1982, Wood & Bright 1992, Bright & Skidmore 2002, Furniss & Johnson 2002, Kimoto & Duthie-Holt 2006.

*Important tree killing insect in its natural range.

**Important tree killing pest in introduced range.

long-term management. These include sanitation cutting where mature trees with dead tops and branches, short, sparse and chlorotic foliage and dwarf mistletoe, *Arceuthobium* spp., infections are harvested. Other tactics include thinning and avoidance of mechanical injury to residual trees during timber harvesting. High-value trees near homes or in developed recreation sites can be sprayed in spring–early summer to prevent beetle attacks (DeMars & Roettgering 1982, Wood S.L.

1982, Cibrián Tovar et al. 1995, Fettig et al. 2004, Williams et al. 2008).

***Dendroctonus frontalis* Zimmerman, Southern Pine Beetle**

Distribution Southern pine beetle is indigenous to southern USA from Ohio, Pennsylvania and West Virginia south to Florida, west to east Texas and portions of

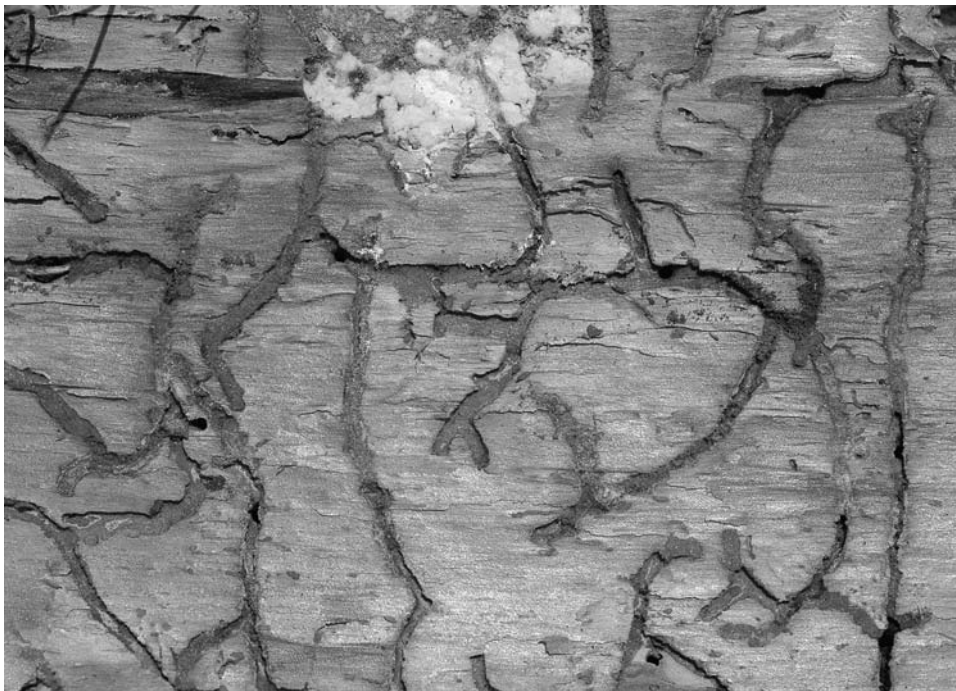


Fig. 9.4 Characteristic winding S-shaped galleries of western pine beetle, *Dendroctonus brevicomis*.

Arizona and New Mexico. It also occurs throughout Mexico and Central America, as far south as Nicaragua (Fig. 9.5).

Hosts This bark beetle can attack and kill all species of *Pinus* within its natural range. In southeastern USA, *P. echinata*, *P. rigida*, *P. serotina*, *P. taeda* and *P. virginiana* are the principal hosts. In Arizona and New Mexico, *P. engelmanni*, *P. leiophylla* var. *chihuahua* and *P. ponderosa* are attacked. Hosts in Mexico and Central America include *P. ayacahuite*, *P. arizonica*, *P. caribaea* var. *hondurensis*, *P. durangensis*, *P. maximinoi*, *P. oocarpa*, *P. pringlei*, *P. tecumani* and *P. teocote*.

Importance Southern pine beetle is one of the most destructive bark beetle pests of pine forests in North and Central America. Trees are killed in groups ranging from five to several thousand trees (Plate 41). In the USA, outbreaks have occurred in portions of Alabama, Georgia, Kentucky, Louisiana, Mississippi, North and South Carolina, Tennessee, east Texas, Virginia and West Virginia. Honduras has a history of outbreaks

beginning in the early to mid-1960s. From 1962 to 1965, more than 2 million ha of pine forests were affected. Another outbreak occurred in 1982 in naturally regenerated stands that developed after the 1960s outbreak. A regional outbreak in Central America, including Belize, Guatemala, Honduras and northern Nicaragua, occurred from 2000 to 2003. Infestations were almost exclusively in young, dense, pine forests ranging from 18 to 25 years in age with basal areas exceeding 35 m²/ha. These forests were stressed from overcrowding, recent fires and drought.

Life History Southern pine beetle is a multiple generation species and the number of generations varies with location and climate. In the northern part of its range, for example Virginia or the southern Appalachian Mountains, three generations are typical. In the Piedmont region of Alabama, the Carolinas and Georgia, four to five generations may occur. Further south, there may be six to seven generations. All life stages overwinter in the cambium or inner bark. Adults emerge in spring, when temperatures rise. They mass

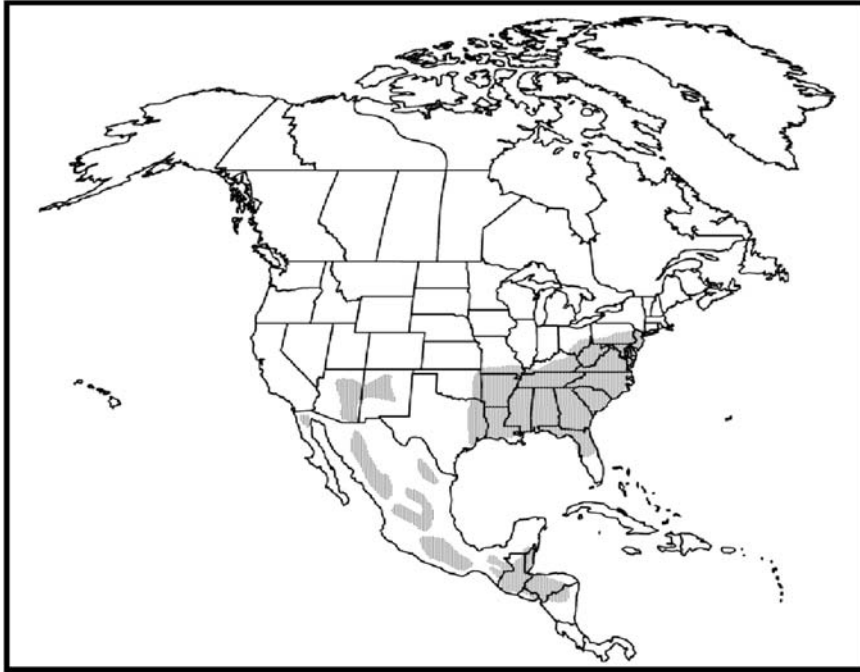


Fig. 9.5 Distribution of the southern pine beetle in southern USA, Mexico and Central America (redrawn from Clark & Nowak 2009).

attack susceptible trees and both sexes are attracted to pheromones produced by attacking females. Once they gain entrance to the cambium, mating occurs and females construct winding S-shaped egg galleries and deposit eggs singly on either side of the gallery. Galleries can be differentiated from those caused by western pine beetle, *D. brevicornis*, because pupal cells are visible in the inner bark whereas in the case of western pine beetle, they are hidden in the inner bark (Fig. 9.6). A blue stain fungus, *Ophiostoma minus* (= *Ceratocystis minor*), and an unidentified basidiomycete are associated with attacking beetles. Larvae hatch within a few days and begin feeding in the cambium. When larvae mature, they construct cells in the inner bark, pupate and develop into adults.

Description of Stages Adults are short-legged, stout beetles, range from 2.0 to 3.2 mm long and are about 2.3 times as long as they are wide. The front of the head has a distinct notch and the hind end is smooth and rounded. Mature adults are dark brown to black and newly emerged “callow” adults are soft bodied and amber colored but harden and darken quickly.

Pest Management Prevention includes thinning to reduce stand density, removal of damaged and weakened trees, and harvesting trees before they reach maturity. Direct control tactics involve removal of infested trees via commercial timber sales, rapid processing of logs and destruction of bark, cut and leave, or piling and burning of infested trees. Cut and leave consists of felling all trees with fresh attacks or brood plus a buffer strip of adjacent uninfested trees. This reduces beetle survival within infested trees, disrupts pheromone production and prevents infestation spread (Moser 1975, Thatcher et al. 1980, Thatcher & Barry 1982, Wood S.L. 1982, Paine & Stephen 1987, Cibrián Tovar et al. 1995, Billings et al. 2004).

***Dendroctonus micans* (Kugelann), Great Spruce Bark Beetle**

Distribution The origin of *D. micans* is believed to be Asian boreal conifer forests. Over the past century, it has extended its range into Europe. This has been at least partially aided by increased trade in timber products, especially unprocessed logs. It was first detected



Fig. 9.6 Galleries of southern pine beetle, *Dendroctonus frontalis*. Note that pupal cells are visible in the inner bark.

in the UK in 1982 and is believed to have been introduced 10 years previously (see Fig. 9.3).

Hosts Primary hosts are species of *Picea* including *P. abies*, *P. asperata*, *P. jezoensis*, *P. obovata*, *P. omorika* and *P. orientalis*. It also attacks several North American species of *Picea* introduced into Europe, including *P. breweriana*, *P. engelmannii*, *P. glauca*, *P. mariana*, *P. pungens* and *P. sitchensis*. Attacks also occur on species of *Abies*, *Larix* and *Pinus*.

Importance *D. micans* is different from the more aggressive *Dendroctonus* species in that it usually attacks its hosts in low numbers and kills bark in patches. Successive attacks over 5–8 years may be necessary to kill a tree, except during outbreaks. Within most of its natural range, *D. micans* occurs at low levels and causes little tree mortality. However, outbreaks do occasionally occur. For example, as *D. micans* extended its range westward into Europe (France and the UK) and southwestern Asia (Republic of Georgia and Turkey) during the late 1900s, outbreaks occurred on more than 200,000 ha of spruce forests. In some cases, older trees were preferentially attacked, while in other

instances all age classes of trees were attacked. *D. micans* normally colonizes only green standing trees and attacks trees stressed by logging damage, frost, snow, wind, lightning, poor soil nutrition and drought.

Life History The time required to complete a generation varies depending on local conditions and ranges from 10 to 18 months in the UK, from 12 to 15 months in Turkey and Russia and from 2 to 3 years in Nordic countries. New adults mate under the bark before they emerge. Mating often occurs among siblings. Sex ratios are highly female biased. The typical sex ratio is 1 : 10 males : females but can be as high as 1 : 45. After mating, some females remain beneath the bark and simply initiate new galleries nearby. Others emerge and attack elsewhere on the same tree, while others fly to new host trees. Adult flight occurs throughout summer. Mated females construct individual egg galleries in living trees from April to November, depending on local conditions. Egg galleries are constructed primarily in the inner bark (phloem) and females lay from 100 to 150 eggs in a cluster. Larvae feed in a communal, fan-like gallery and pack frass behind themselves. Under laboratory conditions, larvae complete development in about 2 months and pupation in about 1 week. Larvae

and adults overwinter. In spring, brood adults feed and mate under bark for 6–7 weeks. *D. micans* does not appear to have an aggregation pheromone.

Description of Stages Adults are 6–9 mm long, dark-brown and cylindrical. Legs and antennae are yellow-brown. Morphologically, *D. micans* is difficult to distinguish from the North American species *D. punctatus* and they have been suspected of being conspecific. However, it has been established that they are distinct species.

Pest Management Direct control includes sanitation felling and insecticide applications to infested portions of trees. Classic biological control using the predaceous beetle *Rhizophagus grandis*, which is specific to *D. micans*, has been used in France, Republic of Georgia and the UK (Bevan & King 1983, Evans et al. 1984, Grégorie 1988, Furniss 1996, Fielding & Evans 1997, Kegley et al. 1997).

***Dendroctonus ponderosae* Hopkins, Mountain Pine Beetle**

Distribution Mountain pine beetle occurs in western North America from Alberta and northern British Columbia, Canada south through western USA and northern Mexico.

Hosts All pines, *Pinus* spp., within its range are attacked. Primary hosts are *P. albicaulis*, *P. contorta*, *P. flexilis*, *P. lambertiana*, *P. monticola* and *P. ponderosa*. Scotch pine, *P. sylvestris*, and several other pines exotic to western North America are also attacked.

Importance Mountain pine beetle is the most destructive insect pest of pine forests in western North America. Outbreaks have occurred every year since records were kept. Factors that lead to outbreaks vary with the host. Even-aged forests of *P. contorta* are most susceptible when they reach age 60 years and contain large numbers of trees over 20 cm in diameter with a thick phloem. *P. ponderosa* forests that are overstocked, have a high basal area and reduced increment are most susceptible to outbreaks.

Life History One generation/year is typical but 2 years may be required at high elevations. In portions of California, there are two generations/year. Adults emerge from trees attacked the previous year in late May–early June and may fly until September. Females initiate attack, produce an attractant pheromone and are joined by males. After mating, females construct a vertical egg gallery 10–122 cm long, packed with boring dust (Fig. 9.7) and introduce blue stain fungi into the tree. Eggs are laid singly in niches along both sides of the gallery. They hatch in 10–14 days and larvae feed in the phloem in galleries at right angles to the egg galleries. When mature, larvae construct oval pupation cells. By late summer, most of the current year's brood have become adults that overwinter under the bark.



Fig. 9.7 Egg and larval galleries of mountain pine beetle, *Dendroctonus ponderosae*.



Fig. 9.8 Adult mountain pine beetle, *Dendroctonus ponderosae*.

Description of Stages Adults range from 3.5 to 6.6 mm long. The body is 2.2 times as long as wide. Body color of mature adults is black (Fig. 9.8).

Pest Management Cultural, mechanical and chemical tactics are available to manage mountain pine beetle. However, during outbreaks these tactics have only limited value. Cultural controls vary depending on host tree. *Pinus contorta*, which typically occurs as even-aged fire originated forests, can be managed by creating a mosaic of age classes over the landscape via small clearcuts, which are easily regenerated by natural seeding. A mosaic of stands of different age classes will have some stands susceptible to outbreaks and others that are too small in diameter to support beetle broods. Susceptibility of *P. ponderosa* forests to beetle attack can be reduced by thinning. Cutting and burning of infested trees during winter and wrapping infested logs in plastic to create high temperatures are effective against localized infestations. Several chemicals are available to

spray boles of individual, high-value trees near home-sites or developed recreation areas to prevent attack. Sprays should be applied in mid- to late May and trees should be treated to a top diameter of about 12 cm (Sartwell & Dolph 1976, Wood S.L. 1982, Amman et al. 1990, Furniss & Johnson 2002).

***Dendroctonus pseudotsugae*, Hopkins, Douglas-fir Beetle**

Distribution Douglas-fir beetle is found throughout western North America from Alberta and British Columbia, Canada, south into Chihuahua and Durango states of northern Mexico.

Hosts The primary host is Douglas-fir, *Pseudotsuga menziesii*. Big cone Douglas-fir, *P. macrocarpa*, is a host in southern California and *P. flahaultii* is attacked in northern Mexico. It also attacks western larch, *Larix occidentalis*, and can produce broods in windthrow or freshly cut logs but not in standing trees.

Importance Douglas-fir beetle is the most damaging bark beetle pest of mature Douglas-fir forests and outbreaks have killed millions of cubic meters of Douglas-fir timber. This insect can build up in windthrown material following severe storms, reach epidemic levels and then attack and kill standing trees. It also can build up in standing trees during droughts or following defoliator outbreaks.

Life History There is one generation/year. Brood adults and some larvae overwinter. Adults emerge, fly and attack new material from April to early June, depending on local conditions. Those individuals that overwintered as larvae emerge later and adults that emerged early may make a second attack in late June–early July. After mating, females construct a single egg gallery parallel to the grain. Gallery length ranges from 20 to 25 cm. They are packed with frass and may be somewhat longer in windthrown trees. Eggs are deposited alternately along opposite sides of the gallery and hatch in 1–3 weeks. Newly hatched larvae mine in galleries more or less perpendicular to the egg gallery. When feeding is completed, larvae construct a pupal cell at the end of their gallery and pupate (Fig. 9.9). Trees may be infested at varying lengths but usually not higher than a top diameter of 15–20 cm.

Description of Stages Adults are stout, cylindrical beetles 4–6 mm long. The head and thorax are black and the elytra are red-brown but may darken with age.

Pest Management The pheromone complex has been identified and has been used with some success to manipulate populations. Frontalin and seudenol are attractants and, in combination with volatile components of Douglas-fir resin, can be used to concentrate low populations. Methylcyclohexanone (MCH) disrupts attraction and has been deployed in areas of fresh windthrow to prevent or reduce attacks. Management of Douglas-fir stands, including rapid removal and processing of windthrow, timely harvesting of mature trees and thinning to maintain tree vigor and reduce moisture stress is the most effective long-term tactic for managing this insect (Furniss & Orr 1978, Wood S.L. 1982, Cibrián Tovar et al. 1995, Furniss & Johnson 2002).



Fig. 9.9 Egg and larval galleries of Douglas-fir beetle, *Dendroctonus pseudotsugae*.

***Dendroctonus rufipennis* (Kirby), Spruce Beetle (Plate 42)**

Distribution Spruce beetle is found across the boreal forests of Canada, west to Alaska, and south into the northeastern and Rocky Mountain regions of the USA.

Hosts All species of *Picea* are hosts. In northeastern USA and adjoining Canada, outbreaks have occurred in red spruce, *P. rubens*. In the Rocky Mountain region, high-elevation forests of Engelmann spruce, *P. engelmannii*, are subject to attack and in Alaska, outbreaks have occurred in forests of white spruce, *Picea glauca*.

Importance This insect is considered the most damaging pest of mature spruce forests in North America.

Outbreaks have occurred in Arizona, Colorado, Idaho, Maine, Montana, New York, Utah and Wyoming, USA and British Columbia, Canada. In Alaska, an outbreak between 1979 and 1999 spread over 400,000 ha and killed an estimated 30 million trees/year during its peak. In the 1990s, outbreaks in Utah infested over 50,000 ha and killed more than 3 million trees. Low-level populations typically exist in fresh windthrow and outbreaks in standing trees are often the result of population increases following high wind events.

Life History Spruce beetle may complete a generation in 1 year on warm sites at low elevations or take up to 3 years in cool locations. A 2-year life cycle is most common. Adults are active from May to October but most attacks occur in early summer. Some brood adults may re-emerge and attack additional trees later in summer. Females initiate attacks and bore into bark and phloem. After mating, they construct egg galleries that range from 6 to 13 cm long. Eggs are laid along alternate sides of the gallery in rows of 4–14 eggs/cm of gallery. Most hatch by August. Larvae bore outward from the egg gallery and feed communally for the first two instars. Third and fourth instars construct individual feeding galleries. Larvae predominate during the first winter, although parent adults and eggs may also be present. During a 2-year life cycle, most larvae pupate 1 year after attack. Pupation occurs in cells at the end of larval galleries and lasts 10–15 days. During the second winter of a 2-year cycle, some adults in standing trees overwinter in their pupal cells, but most emerge, move to the base of the tree and bore into the bark near the root collar. This reduces predation by woodpeckers and winter mortality from cold temperatures. In windthrown trees, most adults overwinter in pupal cells.

Description of Stages Adults are dark brown to black with reddish-brown or black wing covers, approximately 6 mm long and 3 mm wide.

Pest Management Tactics for spruce beetle management include: (i) harvesting of infested and susceptible trees to encourage regeneration of the young; (ii) vigorous forest, salvage logging of windthrown spruce to prevent beetle attack; (iii) use of trap logs to absorb attacking beetles and prevent attacks in standing

trees; (iv) exposure of infested logging residues to direct solar radiation to kill larvae; (v) use of aggregating and anti-aggregating pheromones; and (vi) preventative spraying of high-value trees with chemical insecticides.

Most spruce forests in western North America occur at high elevations or are far from roads. Moreover, many of these forests are in designated Wilderness Areas on public lands. Therefore, pest management tactics cannot be applied, resulting in widespread tree mortality (Wood S.L. 1982, Weiss et al. 1985, Holsten et al. 1999, Furniss & Johnson 2002, Ciesla & Mason 2005).

***Dendroctonus valens* LeConte, Red Turpentine Beetle**

Distribution Red turpentine beetle is indigenous to North America and occurs across Canada, northern and western USA, Mexico, Guatemala and Honduras. This insect was introduced into China, probably during the mid-1990s, via wood packaging material. An outbreak developed in Shanxi Province in 1999 and spread to Hebei, Henan and Shaanxi Provinces.

Hosts In North America, hosts include *Abies concolor* and species of *Picea* and *Pinus*. In China, hosts are *Pinus tabulaeformis* and, occasionally, *P. armandii*.

Importance Within its native range, this bark beetle is considered a secondary invader, which attacks trees with mechanical injury due to lighting or logging or attacked by more aggressive bark beetles. It also attacks and breeds in freshly cut stumps. In China, it has become a destructive forest pest and has killed more than 6 million pines.

Life History Depending on location, red turpentine beetle may undergo one or two overlapping generations/year, except in northernmost locations where more than 1 year may be required. In the northern parts of its range, adults are active from May to October and further south activity may occur throughout the year. Attacks are confined to the lower portion of the bole, usually less than 2 m. On vigorous trees, attacks are indicated by large reddish-yellow pitch tubes. On recently dead trees or stumps, attacks are indicated by the presence of granular frass mixed with dry resin. After successful entry into the cambium and mating, females construct

a vertical egg gallery and deposit clusters of eggs on one side of the gallery. Larvae feed in a communal gallery in the phloem and cambium and produce a large cavity filled with frass. They are active for a minimum of 2 months. Pupation occurs in cells formed in the frass or in short tunnels adjacent to the cavity.

Description of Stages Red turpentine beetle is the largest member of the genus *Dendroctonus*. Adults are 5.3–8.3 mm long, about 2.1 times as long as they are wide and red-brown in color.

Pest Management Within its natural range in North America, this bark beetle is of little consequence and pest management is not needed. Efforts to manage red turpentine beetle in China include restricting movement of infested pines, population monitoring via trapping and classic biological control.

Related Species Black turpentine beetle, *D. terebrans* (Olivier) and *D. rhizophagus* Thomas & Bright, are closely related species. Black turpentine beetle occurs in southeastern USA where it attacks southern yellow pines. Adults are black and life history and habits are similar to red turpentine beetle. *D. rhizophagus* is found in Chihuahua and Durango, Mexico, where it attacks and breeds in roots of pine seedlings. Adults are similar to red turpentine beetle in overall appearance (Wood S. L. 1982, Cibrián Tovar et al. 1995, Furniss & Johnson 2002, Liu et al. 2006).

Phloeosinus

Phloeosinus is a genus of monogamous bark beetles that infest conifers of the family Cupressaceae. About 62 species are known worldwide and are found distributed throughout the northern hemisphere. Twenty-seven species and two subspecies are known from North and Central America and 35 species are known from Africa, Asia, Australia and Europe. Several species are occasional pests (Wood S.L. 1982).

Phloeosinus armatus Reitter (Plates 43 & 44)

Distribution *P. armatus* is native to the Mediterranean portions of Europe, the Near East and northern Africa. It was detected in California, USA in 1989.

Hosts Hosts include species of *Cupressus*, *Juniperus* and *Thuja*. In the Mediterranean region, the primary host is *Cupressus sempervirens*.

Importance *P. armatus* is a secondary pest and attacks and breeds in stems and large branches of trees suffering from drought, fire, root damage, infection by the canker causing fungus *Seiridium cardinalis* or plantations that have been established on poor soils. It also damages shoots of host trees during adult feeding, which makes ornamental trees unattractive and reduces tree height and diameter growth. It is a vector of *S. cardinalis* during adult feeding.

Life History Studies in Israel indicate that this species can have three to four generations/year. Early studies suggested that this insect, as well as the related species, *P. bicolor*, was bigamous. This is based largely on the presence of a pair of egg galleries radiating from a nuptial chamber. More detailed studies indicate that both *P. armatus* and *P. bicolor* are monogamous.

Description of Stages Adults are relatively large beetles, 4–4.5 mm long with a dark red-brown body color, black head and light red-brown legs (Grüne 1979, Bright & Skidmore 2002, Baruch et al. 2005, Haack 2006).

Phloeosinus bicolor (Brulle) (= *P. aubei* Perris)

Distribution *P. bicolor* has a wide distribution and is found from central and southern Europe east to China and south into northern and eastern Africa and the Near East. The author has collected this bark beetle in central Kenya.

Hosts This species feeds on and breeds in species of *Chamaecyparis*, *Cupressus*, *Juniperus*, *Platycladus orientalis*, *Sabina chinensis* and *Thuja* spp.

Importance Attacks are usually confined to broken branches or fresh cut logs. However, it can attack live trees. For example, during the early 1990s it damaged trees in portions of Hungary following several

consecutive years of drought. A report from Tunisia indicates that it can be a pest of forest and windbreak plantations of *Cupressus sempervirens*. It is also a vector of the fungus, *Seiridium cardinale*, which is spread during adult feeding.

Life History In central Europe, there are two generations/year and in Tunisia, there are two and a partial third generation/year. In Tunisia, peak adult flight is from March to mid-April with two lesser peaks in May–June and mid-August–mid-October. Adults of the first generation emerge in April and the second generation in June. They feed on shoots of host trees prior to mating. Adults are probably monogamous, despite reports that suggest they are polygamous. Egg galleries are parallel to the wood grain, 4–8 cm long and sometimes forked with two distinct egg galleries. Females may re-emerge to attack additional host material.

Description of Stages Adults are 1.4–2.5 mm long, brown in color (Grüne 1979, Mendel 1984, Bright &

Skidmore 2002, Baruch et al. 2005, Belhabib et al. 2007).

Scolytus

The genus *Scolytus* consists of about 100 species, which are found across the northern hemisphere and in South America. Individual species may invade either broad-leaf trees or conifers. All temperate species are monogamous but several tropical species are bigamous (Wood S.L. 1982). Several breed in the cambium of living trees and at least two Eurasian species are vectors of Dutch elm disease, caused by the fungi *Ophiostoma ulmi* and *O. novo-ulmi* (Table 9.2).

Scolytus multistriatus (Marshall), Smaller European Elm Bark Beetle

Distribution Smaller European elm bark beetle is native to Europe and northern Asia. It was introduced into North America during the early 1900s, probably via elm veneer logs imported from Europe. The insect is

Table 9.2 Representative species of *Scolytus* (Coleoptera: Curculionidae: Scolytinae): their distribution and hosts.

Species	Distribution	Hosts
<i>S. intricatus</i> (Ratzburg)	Europe, northern Africa, northern Asia, Near East	<i>Quercus dalechampii</i> , <i>Q. petraea</i> , <i>Q. robur</i> , other broadleaf trees
<i>S. laricis</i> Blackman Western larch beetle	British Columbia, Canada northwestern USA	<i>Larix lyallii</i> , <i>L. occidentalis</i>
<i>S. morawitzi</i> (Semenov)	Belarus, northern China, Mongolia, Russia	<i>Larix gmelinii</i> , <i>L. kamschatica</i> , <i>L. sibirica</i> , <i>L. sukaczewii</i>
<i>S. multistriatus</i> (Marshall) Smaller European elm bark beetle	Europe and northern Asia (indigenous). North America, Canada, Mexico, USA, South America: Argentina, Chile (introduced)	<i>Ulmus</i> spp.
<i>S. mundus</i> Wood	Mexico	<i>Abies religiosa</i>
<i>S. ratzeburgi</i> Janson	Europe, Japan, Mongolia, central and eastern Russia	<i>Betula</i> , <i>Ulmus</i>
<i>S. rugulosus</i> (Müller) Shothole borer	Asia, Europe, northern Africa (indigenous). Australia, North and South America (introduced)	<i>Malus</i> spp., <i>Prunus</i> spp., <i>Pyrus</i> spp.
<i>S. scolytus</i> (Fabricius) Large elm bark beetle	Europe	<i>Ulmus</i> spp.
<i>S. schevyrewi</i> Semenov Banded elm bark beetle	Asia: China, Korea, Mongolia, Central Asia (indigenous) North America (introduced)	<i>Prunus</i> , <i>Salix</i> , <i>Ulmus</i> and other broadleaf trees
<i>S. unispinosus</i> LeConte Douglas-fir engraver	Western North America	<i>Pseudotsuga menziesii</i>
<i>S. ventralis</i> LeConte Fir engraver	Western North America	<i>Abies concolor</i> , <i>A. grandis</i> , <i>A. magnifica</i>

Sources: Wood S.L. 1982, Bright & Wood 1992, Cibrián Tovar et al. 1995, Furniss & Johnson 2002, Kimoto & Duthie-Holt 2006, Wood 2007.

now distributed throughout North America, from British Columbia to Nova Scotia, Canada and from north-eastern USA south to Florida and west to California. Infestations have also been reported from Argentina, Chile and Mexico.

Hosts All species of *Ulmus* and *Zelkova serrata*, a tree native to Japan, are hosts.

Importance This insect is a vector of the fungi *Ophiostoma ulmi* and *O. novo ulmi*, which cause Dutch elm disease. This disease, which is native to Asia, has caused devastating losses to elms across much of Europe and North America.

Life History This bark beetle can complete two to three generations/year and larvae overwinter in pupal chambers in the bark. Pupation occurs with the onset of warm spring weather and adults emerge in late March–early June, about the time elm foliage is fully expanded. Adults fly directly to weakened or dying elms to breed in the inner bark or to healthy elms, where they feed in branch crotches. Adults, carrying spores of the Dutch elm disease fungus, spread the disease when they feed. Breeding attacks occur in trees weakened by drought, disease or mechanical injury. Elm logs or firewood are also attacked. Females initiate attacks and release an aggregating pheromone that attracts both males and females. After mating, females construct an egg gallery parallel to the wood grain and eggs are deposited individually in niches on either side of the gallery. Larvae feed in individual galleries, generally perpendicular to egg galleries. When fully grown, larvae construct cells in the bark and pupate. During spring and summer, a generation may be completed in 30–40 days.

Description of Stages Adults are 1.9–3.1 mm long and distinctly two-toned with red-brown elytra and a dark brown-black body. Males have a bright yellow brush of hairs on the front of the head. The underside of the posterior end of the body is concave, with a stout spine emerging from the margin of the second abdominal sternite.

Pest Management Overall strategy for managing smaller elm bark beetle and Dutch elm disease is to limit

supply of breeding material. Elm firewood, broken limbs, stressed trees and trees infected by Dutch elm disease are eliminated by chipping or burning. Severely stressed or dying trees can be injected with herbicides that cause bark to dry and render them unsuitable for breeding. Beetles can also be mass-trapped on sticky traps baited with aggregating pheromones (Wood S.L. 1982, 2007, Drooz 1985).

***Scolytus schevyrewi* Semenov, Banded Elm Bark Beetle**

Distribution *Scolytus schevyrewi* is indigenous to China (Heilongjiang, Hebei, Henan, Shaanxi, Ningxia and Xinjiang Provinces), Kazakhstan, Korea, southern Kyrgyzstan, Mongolia, Russia, Tajikistan, Turkmenistan and Uzbekistan. It was detected in Colorado and Utah, USA, in 2003 and is now found throughout much of central and western North America. Museum collections suggest that it had been present in some areas of the USA for at least 10 years.

Hosts In Asia, primary hosts are species of *Ulmus*, including *U. carpinifolia*, *U. davidiana* var. *japonica*, *U. laevis*, *U. macrocarpa*, *U. propinqua* and *U. pumila*. Other reported Asian hosts include *Caragana korshinskii*, *Elaeagnus* spp., *Malus pumila*, *Prunus armeniaca* var. *ansu*, *P. padus*, *P. persica*, *P. pseudocerasus*, *P. salicina*, *P. yedoensis* and *Salix* spp., including *S. babylonica*. In the USA, *U. pumila* and at least two indigenous elms, *U. americana* and *U. thomasi*, have been attacked.

Importance *S. schevyrewi* usually attacks weakened or stressed trees, although it can attack vigorous trees. Young trees tend to be more resistant to attack. Occasional outbreaks can occur that result in widespread tree mortality. In the Karamay region of Xinjiang Province, China, *S. schevyrewi* is a major pest of elm and has damaged trees in both urban and rural settings. In the USA, elms have been killed in urban settings. Its role as a vector of Dutch elm disease is still undetermined but its life history suggests that it is a potential vector.

Life History In China, *S. schevyrewi* completes two to three overlapping generations a year, depending on location. Overwintering occurs as mature larvae inside

pupal chambers or as adults under the bark. Adults emerge in late April–early May. Larvae of the first generation develop from May to June, and become adults by early July. By late August, most second-generation larvae construct pupal chambers and overwinter. However, some may continue development and complete a third generation if temperatures are favorable. New adults remain in their pupal chambers for 2–5 days before boring an exit hole through the bark. Sex ratio is slightly female biased (females : males = 1.0 : 0.9). New adults walk along the bark surface after emergence before initiating flight. Adults are most active during warm, sunny weather and feeding occurs on bark at the crotches of tender twigs. Following adult feeding, females attack host trees by constructing individual entrance holes through the bark. Mating occurs on the bark surface and both males and females can mate several times. Each female constructs a single egg gallery in the cambium, parallel to the grain. Egg niches are closely arranged on each side of the gallery and

sealed with a mixture of sawdust and adhesive secretions. Egg galleries usually contain about 60 eggs (range = 23–123 eggs) (Fig. 9.10). Eggs hatch in the order in which they were laid and larvae construct individual galleries. Initially, they are more or less perpendicular to the egg gallery but later they turn upward or downward. Some larval galleries meander or cross each other. Larvae have five instars. When feeding is completed, mature larvae construct pupal chambers in the outer bark at the end of their galleries.

Description of Stages Adults range from 3.2 to 4.2 mm long. Body color is red-brown with a black head. The frons is slightly protruding with striations running toward the clypeus in females and with yellow, inwardly curved frontal hairs on the peripheral edges in males. The elytra are red-brown to black-brown and a dark transverse band may occur on the elytra of some adults.



Fig. 9.10 Egg and larval galleries of banded elm bark beetle, *Scolytus schevyrewi* (photo by J. Negrón, USDA Forest Service).

Pest management To date, pest management has been rapid removal and destruction of infested trees (Houping Liu & Haack 2004, Negrón et al. 2005).

Scolytus ventralis LeConte, fir Engraver

Distribution Fir engraver, *Scolytus ventralis*, is found throughout much of western North America, from southern British Columbia, Canada, south to Baja California Norte, Mexico and east to western Montana, Colorado and New Mexico, USA.

Hosts Primary hosts are firs: *Abies concolor*, *A. grandis* and *A. magnifica*. Trees occasionally attacked include *A. lasiocarpa*, *Pseudotsuga menziesii* and *Tsuga mertensiana*.

Importance Fir engraver is the most important bark beetle of *Abies* in western North America. Attacks can cause top kill, branch dieback or death of the entire tree. Outbreaks cause extensive tree mortality, for example from 1977 to 1978, an outbreak killed about 1.2 million trees in northern California. Outbreaks often develop following below normal moisture or insect defoliation. Fir engraver is often associated with round headed fir borer, *Tetropium abietis*, or flat headed fir borer, *Melanophila drummondii*. During outbreaks, however, it is responsible for most of the tree mortality.

Life History Adults emerge in summer and fly in search of host material, i.e. either stressed trees, freshly cut logs or windthrow. They can fly from June to September but most are active between July and August. Females enter the tree first, construct a nuptial chamber and are followed by a male. After mating, females construct a transverse egg gallery, perpendicular to the main stem, about 10–30 cm long, and lay between 100 and 300 eggs singly in niches on either side of the gallery (Fig. 9.11). Within several days, a yellow-brown discoloration due to the fungus *Trichosporum symbioticum* appears. Eggs hatch within 9–14 days and larvae construct narrow feeding galleries perpendicular to the egg gallery. Larvae require 40–380 days to complete feeding. Pupation occurs in cells at the end of the larval galleries and lasts from 7 to 14 days. Adults remain under the bark for an additional 2 weeks, then emerge.

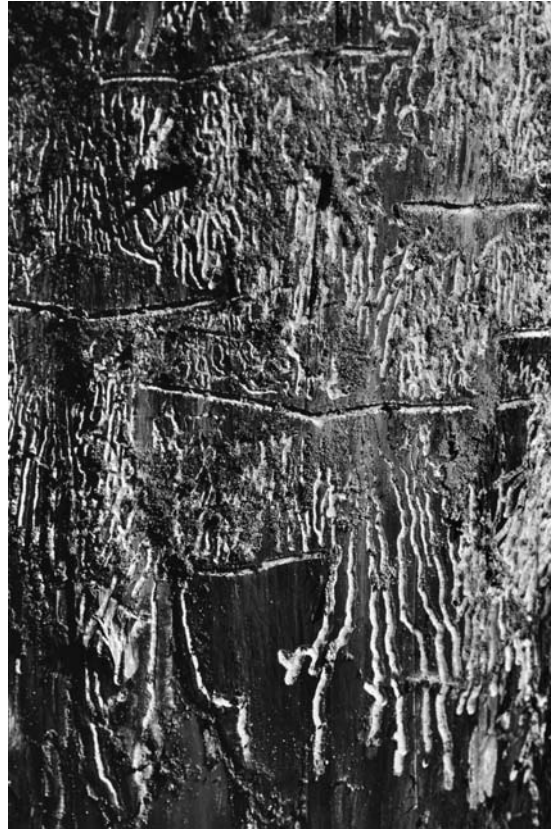


Fig. 9.11 Egg and larval galleries of fir engraver beetle, *Scolytus ventralis*.

Description of Stages Adults are shiny dark brown-black beetles, about 4 mm long. When viewed from the side, they have an incurved posterior with a small central bump that is more pronounced in males.

Pest Management Losses can be reduced via removal and utilization of infested trees, removal of fresh cut logs and/or windthrow before brood emergence, and removal of diseased or stressed trees from forests.

Related Species *S. mundus* Wood occurs in central Mexico where it attacks *Abies religiosa*. Gallery patterns are similar to those of *S. ventralis* (Ferrell 1996, Cibrián Tovar et al. 1995, Furniss & Johnson 2002).

Ips

Ips consists of about 60 species indigenous to boreal and temperate conifer forests of Eurasia and North America. Twenty-five species are indigenous to north and central America, where they attack *Picea* and *Pinus*. The others are indigenous to Eurasia. Several are important forest pests, second only to *Dendroctonus* (Table 9.3). Life history and habits of species are similar. Most have multiple generations/year. Adults are polygamous. Males initiate attacks, construct a nuptial chamber in the cambium layer and attract two to seven females. After mating, females construct longitudinal egg

galleries and deposits eggs in niches along each side of the gallery. Multiple egg galleries radiating from a common nuptial chamber often give egg galleries a Y- or X-shaped pattern (Fig. 9.12). Young larvae feed individually perpendicular to egg galleries. Larval galleries increase in width as larvae grow. Pupation occurs in round chambers constructed at ends of larval galleries. Adults are characteristic of bark beetles of the tribe Ipsinae. The head is covered by a thoracic shield and not visible when viewed dorsally. The abdominal declivity is concave with each side bearing from three to six spines (Wood S.L. 1982).

Table 9.3 Representative species of *Ips* (Coleoptera: Curculionidae: Scolytinae): their distribution and hosts.

Species	Distribution	Major hosts	Number of spines on each side of declivity
<i>I. acuminatus</i> (Gyllenhal)*	Eurasia	<i>Pinus</i>	3
<i>I. avulsus</i> (Eichhoff)*	USA: southeastern states	<i>Pinus echinata</i> , <i>P. elliotii</i> , <i>P. palustris</i> , <i>P. taeda</i>	4
<i>I. calligraphus</i> (Germar)	North and Central America, Jamaica	<i>Pinus</i>	6
Six-spined engraver			
<i>I. cembrae</i> (Heer)	Europe	<i>Larix</i> , other conifers	4
<i>I. confusus</i> (LeConte)	North America: southwestern USA, northern Mexico	<i>Pinus edulis</i> , <i>P. monophylla</i>	5
<i>I. grandicollis</i> (Germar)	North America (indigenous) Australia (introduced)	<i>Pinus</i>	5
<i>I. hauseri</i> Reitter	Asia: China, Kazakhstan, Kyrgyzstan,	<i>Larix sibirica</i> , <i>Picea schrenkiana</i> ,	4
Mountain Kyrgyz engraver	Russia, Tajikistan and Turkey	<i>Pinus sylvestris</i> , <i>P. nigra</i> ssp. <i>pallasiana</i>	
<i>I. hunteri</i> Swaine*	North America: USA: Colorado, Utah	<i>Picea pungens</i>	4
Blue spruce ips			
<i>I. lecontei</i> Swaine	Southwestern USA south through Mexico, Guatemala and Honduras	<i>Pinus</i>	5
<i>I. pini</i> (Say)*	North America: transcontinental distribution	<i>Picea</i> , <i>Pinus</i>	4
Pine engraver			
<i>I. subelongatus</i> Motschulsky	Asia: Russia, northern China, northern Mongolia	<i>Larix</i> , other conifers	4
<i>I. sexdentatus</i> (Boerner)	Asia: Turkey across Russia to China and south to Thailand. Europe	<i>Pinus</i> , other conifers	6
<i>I. typographus</i> (Linnaeus)	Eurasia	<i>Picea</i> , <i>Pinus</i>	5
Larger European spruce beetle			

Sources: Furniss & Carolin 1977, Grüne 1979, Wood S.L. 1982, Drooz 1985, Abgrall & Soutrenon 1991, Cibrián Tovar et al. 1995, Bright & Skidmore 2002, Kimoto & Duthie-Holt 2006, McMillin & DeGomez 2008, FAO 2009b.

*Indicates species capable of causing top kill.



Fig. 9.12 X-shaped gallery pattern of the six-spined engraver, *Ips calligraphus*, showing nuptial chamber and four egg galleries, each made by a different female.

Ips acuminatus (Gyllenhal)

Distribution *I. acuminatus* occurs across Eurasia. In Asia it is found from Turkey across Russia to China, Japan, Korea, Mongolia, Syria, Taiwan and Thailand. In Europe it occurs from Spain north to Finland, Norway and Sweden and east to Latvia, Romania and the Republic of Georgia.

Hosts *Pinus* spp. are the predominant hosts. In Europe and the Near East, *Pinus cembra*, *P. mugo*, *P. nigra* and *P. sylvestris* are attacked. In China, Korea and Mongolia, *P. armandii*, *P. koraiensis*, *P. sylvestris* var. *mongolica* and *P. tabulaeformis* are attacked. *P. caribaea*

(exotic) and *P. merkusii* and are hosts in Thailand. Other conifer hosts include *Abies nordmanniana* (= *A. bornuel-leriana*), *Larix decidua*, *Picea obovata* and *P. orientalis*.

Importance This insect usually attacks weakened or windthrown trees. When populations build up in this material, they can attack relatively healthy trees. In some instances, *I. acuminatus* can kill large numbers of trees. Attacks often occur first in the upper crown causing top kill and subsequent generations attack the lower bole (Plate 45).

Life History This beetle has one to two generations/year. Adult flight occurs in the northern parts of its range or at high altitudes from May to June. In the southern parts of its range or at low altitudes adults fly from April to August.

Description of Stages Adults are about 2.2–3.5 mm long and dark red-brown in color. Each side of the abdominal declivity has three spines (Grüne 1979, Vongkalung 1990, Abgrall & Soutrenon 1991, Wood & Bright 1992, Bright & Skidmore 2002).

Ips calligraphus (Germar), Six-Spined Engraver Beetle

Distribution This species is native to north and central America and parts of the Caribbean Basin. It is found in Quebec, Canada and throughout much of the USA. It is also widely distributed in Mexico and throughout the natural range of pine forests in Belize, Guatemala, Honduras and Nicaragua. In the Caribbean, it has been collected in the Bahama Islands, Dominican Republic and Jamaica.

Hosts Species of *Pinus*, including *P. caribaea*, *P. echinata*, *P. elliottii*, *P. michoacana*, *P. montezumae*, *P. occidentalis*, *P. oocarpa*, *P. ponderosa*, *P. pseudostrobus*, *P. resinosa*, *P. rigida*, *P. strobus* and *P. taeda* are hosts.

Importance *I. calligraphus* prefers to invade fresh windthrow, freshly cut stumps and large limbs of recently felled trees. It can also attack living pines stressed by drought or invaded by more aggressive bark

beetles. Attacks on living trees usually occur in the lower portions of the bole where diameters exceed 15 cm.

Life History The number of generations varies depending on local climatic conditions. In southeastern USA, a generation can be completed in as little as 25 days and there may be as many as six generations/year. Males are joined by three to five females and egg galleries radiate longitudinally from a central nuptial chamber. Larval galleries are often long and transverse.

Description of Stages Adults are 3.8–5.9 mm long and about 2.7 times as long as they are wide. Color of mature adults is red-brown. Each side of the elytral declivity is armed with six spines.

Related Species *I. sexdentatus* (Boerner) is found across Eurasia where it attacks several species of *Larix*, *Picea* and *Pinus*. This species also bears six spines on either side of the elytral declivity. It is also regarded as a secondary invader often found in association with other bark beetles (Wood S.L. 1982, Drooz 1985, FAO 2009b).

***Ips grandicollis* (Germar), Southern Pine Engraver**

Distribution This engraver beetle is widely distributed in eastern North America from Manitoba and southern Quebec, Canada, to Florida and east Texas, USA and south through Mexico to the Bahamas, Cuba, Dominican Republic, Honduras and Jamaica. It was introduced into South Australia around 1943, probably via crating or dunnage and was discovered in Western Australia in 1952. It has since spread to New South Wales, Queensland and Victoria.

Hosts *Ips grandicollis* breeds in species of *Pinus*, including *P. banksiana*, *P. caribaea*, *P. durangensis*, *P. echinata*, *P. montezumae*, *P. oocarpa*, *P. palustris*, *P. ponderosa*, *P. pseudostrobus*, *P. resinosa*, *P. rigida*, *P. strobiformis*, *P. sylvestris*, *P. taeda*, *P. tenuifolia* and *P. virginiana*. In Australia it attacks plantations of *P. radiata* and other introduced pines.

Importance Within its natural range, *I. grandicollis* confines its attacks to standing pines stressed by drought, mechanical injury or other factors. It also attacks freshly cut logs or windthrow. In southeastern USA, *I. grandicollis* is often associated with other bark beetles including *Dendroctonus frontalis*, *D. terebrans*, *I. avulsus* and *I. calligraphus*. In Australia, it also attacks stressed, recently felled and windthrown trees but tends to be somewhat more aggressive than in its natural range.

Life History The number of generations/year depends on location and local climate. In southeastern USA, there may be up to six generations/year and a generation can be completed in 25–30 days.

Description of Stages Adults are 2.6–4.6 mm long and red-brown. Each side of the elytral declivity is armed with five spines.

Pest Management In Australia, *I. grandicollis* has been the target of a classic biological control program using natural enemies imported from the USA. One parasitoid, *Roptrocercus xylophagorum*, has been established. Three other natural enemies, a parasitoid, *Dendrosoter sulcatus*, and two predaceous beetles, *Thanasimus dubius* and *Temnochila virescens*, have been reared and released but their establishment is doubtful (Wood S.L. 1982, Drooz 1985, Morgan 1989, Lawson & Morgan 1992).

***Ips pini* (Say), pine engraver (Plate 46)**

Distribution Pine engraver is a North American species with a transcontinental distribution and is one of the most common pine bark beetles.

Hosts This species can breed in almost any species of *Pinus* and also infests species of *Picea*.

Importance Pine engraver populations build in windthrow, freshly cut logs or logging residues and subsequent generations can attack standing trees. Attacks in standing trees often occur during dry weather, begin in the upper crown and cause top kill.

The lower portions of the bole may become infested by subsequent generations of pine engraver or by species of *Dendroctonus* (e.g. *D. brevicomis*, *D. ponderosae*).

Life History Depending on local conditions, there may be one to five generations/year. Parent adults often re-emerge and make attacks in two to three trees, which causes a confusing overlapping of broods. During late summer, large numbers of beetles may mine under the bark without producing brood. Winter is spent almost exclusively as adults under the bark or in the litter.

Description of Stages Adults are red-brown and 3.5–4.2 mm long. Each side of the elytral declivity has four spines.

Pest Management Cultural tactics include prompt disposal of logging residues and utilization of wind-thrown trees. Thinning of overstocked pine stands will reduce hazard of attacks by this insect (Furniss & Carolin 1977, Drooz 1985).

Ips subelongatus Motschulsky

Distribution This species is indigenous to European Russia and much of the boreal conifer forests of northern Asia including Siberia, Transbaikalia and the Russian Far East, China, North and South Korea and northern Mongolia. It has been introduced into Finland.

Hosts Primary hosts are species of *Larix*, including *L. gmelinii*, *L. leptolepis* and *L. sibirica*. It may occasionally breed in other conifers including *Abies* spp., *Picea* spp., *Pinus koraiensis*, *P. sibirica* and *P. sylvestris*.

Importance *I. subelongatus* is considered one of the most damaging pests of larch across Russia and other Asian countries. Attacks often occur in trees previously defoliated by *Dendrolimus sibiricus* and/or attacked by wood borers such as *Xylotrechus altaicus*, other insects or in forests damaged by fire.

Life History Adult flight usually occurs from mid-May to late June in the southern parts of its range and

lasts about 15–17 days. After making initial attacks and laying eggs, some mated females will attack additional host material during late June–early July. Mature adults overwinter in the litter and larvae, pupae and callow adults overwinter underneath the bark of host material. *I. subelongatus* may continue to attack the same tree over several years.

Description of Stages Adults are 4–6 mm long, brown to black in color and have four equally spaced spines on the elytral declivity. The third spine is the largest. The surface of the elytral declivity is covered with long hairs.

Related Species *I. cembrae* (Heer) is distributed throughout the *Larix* forests of the Alps and Carpathians in central Europe but has spread to plantations in the Netherlands, Scotland and other countries. Its damage, life history and morphological characteristics are similar to *I. subelongatus* (Grüne 1979, EPPO 2005b, FAO 2009b).

Ips typographus (Linnaeus), Larger European Spruce Bark Beetle (Plates 47 & 48)

Distribution This engraver beetle is widely distributed across Eurasia. It occurs over most of Europe and has been introduced into the British Isles. In Asia, it occurs in China, Japan, Korea, Turkey and Asian portions of Russia.

Hosts *I. typographus* attacks species of *Picea*. Known hosts are *P. abies*, *P. jezoensis*, *P. obovata* and *P. orientalis*. Other members of the Pinaceae are also attacked, including species of *Abies*, *Larix* and *Pinus*. According to one report, preferred hosts of *Ips typographus* in the Caucasus region are pines. *P. jezoensis*, native to Asia, is attacked by the subspecies, *I. typographus japonicus* Nijjima. The North American *P. sitchensis*, widely planted in the British Isles, is also attacked but thus far has not been subject to major outbreaks.

Importance This species is a major tree killer of Eurasian spruce forests. Adults attack fresh windthrow or logs stored in the forest for prolonged periods



Fig. 9.13 Standing Norway spruce attacked by the larger European spruce bark beetle, *Ips typographus*, following a buildup of beetle populations in windthrow (Bavarian National Park, Germany).

(Fig. 9.13). Subsequent generations attack standing trees. Outbreaks in central and northern Europe have resulted in trees being killed over large areas with losses totaling several million cubic meters of wood. A 7-year outbreak following World War II killed 30 million m³ of spruce in Germany. Some outbreaks in German and Norwegian forests have lasted for 30–50 years. In Norway, an outbreak in the 1970s, which killed 5 million m³ of spruce, led to a substantial reduction of the country's gross national product.

Life History The number of generations/year depends on temperature. In the northern parts of its range, *I. typographus* has one generation/year. It can

complete two generations/year further south. In the north, adults emerge from July to October, depending on time of brood establishment, microclimate and weather. Further south there are two peak flights: May–June for the overwintering adults and July–August for the summer generation. The second generation may emerge in November, but more typically, adults hibernate in the brood tree or forest litter and emerge the following spring. *I. typographus* overwinters as adults, usually in the duff near the tree where they developed. A few individuals remain beneath the bark during winter, especially in the southern part of its range.

Description of Stages Adults average 4–5.5 mm long and are dark brown in color. Each side of the abdominal declivity has four spines.

Pest Management Outbreaks can be prevented through reduction of the amount of host material available to the insect. Cultural tactics include prompt salvage or debarking of windthrown spruces and debarking of logs stored in the forest for extended periods. Direct control includes use of attractant or repellent pheromones to either trap out beetles or reduce attacks on suitable host material (Browne 1968, Grüne 1979, Schwerdtfeger 1981, Krivolutskaya 1983, Forsse & Solbreck 1985, Duelli et al. 1986, Christiansen & Bakke 1988, Eidmann 1992, Wood & Bright 1992, Lozzia 1993, Pfeffer & Skuhravy 1995, Yamaoka et al. 1997, Bright & Skidmore 2002).

Orthotomicus

Orthotomicus is a small genus of bark beetles closely related to *Ips* and found in Eurasia and North America. Adults resemble *Ips* but the spines on the abdominal declivity are less distinct. Twelve species are known worldwide (Wood S.L. 1982).

***Orthotomicus erosus* (Wollaston), Mediterranean Pine Engraver**

Distribution *O. erosus* is widely distributed across northern Africa, Asia and Mediterranean Europe. It has been introduced and become established in California, USA, Chile, South Africa and Swaziland.

Hosts Primary hosts are pines: *Pinus* spp., including *P. brutia*, *P. canariensis*, *P. nigra*, *P. pinaster*, *P. pinea*, *P. sylvestris* and *P. mugo* ssp. *uncinata* (Europe); and *P. armandii*, *P. kesiya*, *P. massoniana*, *P. tabulaeformis* and *P. yunnanensis* (Asia). North and Central American pines planted in areas where this insect is native, or has become established, and have become hosts include *P. caribaea*, *P. coulteri*, *P. echinata*, *P. patula*, *P. radiata* and *P. strobus*. Occasionally, maturing beetles feed in *Abies*, *Cedrus*, *Picea* and *Pseudotsuga menziesii*. However, it does not breed in hosts other than pines.

Importance *O. erosus* is usually secondary and infests recently fallen trees, broken branches, slash and standing trees that have been wounded or are under stress. During periods of prolonged dry weather, a relatively common occurrence in its natural range, it will attack standing trees.

Life History Mediterranean pine engraver completes from two to seven generations/year, depending on temperature. Two generations/year are common in France, Morocco and Turkey. In Israel, it can complete three to five generations/year. Adults overwinter and aggregate beneath the bark of host trees. This species is polygamous. Males bore through the bark to the phloem–cambium layer where they construct a nuptial chamber and are joined by one to three females. After mating, females constructs individual egg galleries radiating from the nuptial chamber and parallel to the grain of the wood. Females lay 26–75 eggs in niches along the sides of the galleries. Larvae feed at right angles to the parent gallery and pass through three instars during their development. Pupation occurs in cells at the end of each gallery (Fig. 9.14). Brood adults feed prior to reaching sexual maturity. This occurs under the bark of the host tree or in another suitable host tree, sometimes of a different species.

Description of Stages Adults are 3–3.8 mm long and red-brown. The head is covered by the thoracic shield and not visible when viewed dorsally. Declivity is concave, with each side armed by four small spines. The second spine from the top is more conspicuous.

Pest Management Prompt treatment of logging slash, windthrow and other potential habitat will



Fig. 9.14 Egg and larval galleries of Mediterranean pine engraver beetle, *Orthotomicus erosus* (northern Cyprus).

prevent population increases. In South Africa, where *O. erosus* was introduced, a parasitic wasp, *Dendrosoter caenopachoides*, was introduced (Grüne 1979, Mendel & Halperin 1982, Mendel 1983, Tribe & Kfir 2001, Haack 2004).

Curculionidae (Subfamily Scolytinae – Ambrosia Beetles)

Gnathotrupes

Ambrosia beetles of the genus *Gnathotrupes* invade broadleaf trees and are found in Mexico, Central and South America. They are well represented in Argentina and Chile where they attack species of *Nothofagus*. About 15 species are known from this area. They are small beetles, 1.3–3.6 mm long, and brown. When

viewed from above, the head is concealed by the prothorax and they have a concave declivity.

Relatively little was known about this group of ambrosia beetles until about 2002 when several species were associated with dieback and mortality of *Nothofagus* spp. in southern Chile (11th Region). Affected trees include *N. betuloides*, *N. dombeyi* and *N. pumilio*. Attacks occur in groups of trees with chlorotic foliage, branch dieback and tree mortality. At least four species are involved. *Gnathotrupes barbifer* Schedl, *G. nanus* (Eichhoff), *G. vafer* Schedl and *G. velatus* Schedl. It is not clear if the fungi associated with this group of ambrosia beetles are pathogenic or if the beetles are a contributing factor in a decline event. Females construct galleries and larval cradles while males guard the entrance holes and keep the galleries free of frass (Wood 2007, Aguayo Silva 2008).

Trypodendron

Trypodendron is a small genus of monogamous ambrosia beetles found in Eurasia and North America, north of Mexico. About 12 species are known. Females initiate attacks and carve an entrance tunnel in a host tree prior to arrival of the male. The tunnel penetrates the bark and continues into the sapwood where it may branch several times. Larvae are reared in cradles arranged in a single series above and below the parent gallery. Cradles are enlarged by larvae as they grow and also serve as pupal chambers (Figs 9.15 & 9.16, Wood S.L. 1982).

***Trypodendron lineatum* (Olivier), Striped Ambrosia Beetle**

Distribution This ambrosia beetle is found throughout conifer forests of northern Asia, Europe and North America.

Hosts Virtually all species of *Abies*, *Larix*, *Picea*, *Pinus*, *Pseudotsuga*, *Thuja* and *Tsuga* are hosts. It has occasionally been reported from species of *Alnus*, *Betula*, *Juni-perus* and *Malus*.

Importance Infestations cause pinholes with dark stain in the sapwood and reduce lumber quality. *T. lineatum* is considered the most damaging ambrosia beetle in western North America, especially in coastal



Fig. 9.15 Galleries of an undetermined species of *Trypodendron*.

British Columbia, Canada. Populations build in wind-throw, trees killed by fire or bark beetles, logging residues and logs stored for extended periods. Logs cut in autumn and early winter are most susceptible to attack.

Life History In forests of the Pacific Coast of North America one generation/year is typical but a small portion of adults re-emerge and establish a second brood. Adults become active and attack host material beginning in March, peak in May and continue until August. Development time from egg to adult requires 6–8 weeks. Brood adults emerge from July to September and overwinter in the duff and litter.

Description of Stages Adults are dark brown-black with two yellow-brown longitudinal bands on each elytron. Females are 3.0–3.5 mm long; males are 2.7–3.2 mm long.

Pest Management Spraying logs with chemical insecticides can prevent attacks but has caused



Fig. 9.16 Individual larval cradles characteristic of ambrosia beetles of the genus *Trypodendron*.

environmental problems. Prompt processing of logs prior to, and during, beetle flight reduces attacks. Mass trapping of adults in timber storage and processing areas was developed after its aggregation pheromone was synthesized and became commercially available during the 1980s (Bletchley & White 1962, Furniss & Carolin 1977, Wood S.L. 1982, Lindgren & Borden 1983).

Xyleborus

Xyleborus is the largest and most diverse genus of the subfamily Scolytinae. Several hundred species have been described from all of the tropical and subtropical areas of the world and some species extend their ranges into temperate forest regions. In the tropics, members of this genus can cause significant damage through the destruction of sapwood of recently harvested logs, both in the forest and at sawmill sites. They typically have a wide host range and several species have been introduced and become established. They are polygamous. Males are often reduced in size, flightless and may not leave the parent gallery. Galleries are

usually of a simple branching pattern that may join galleries constructed by other individuals (Fig. 9.17). Eggs are usually placed in clusters at or near the end of branch tunnels. Larvae feed on ambrosia fungi, pupate in the galleries and emerge through entrance holes made by the parent adults (Wood & Bright 1992, Wood 2007) (Table 9.4).

***Xyleborus ferrugineus* (Fabricius)**

Distribution This species occurs from southern USA, south through much of the Caribbean, Mexico, Central and South America south to northern Argentina. It has been introduced into portions of tropical Africa, southern India, Sri Lanka and Micronesia.

Hosts A large number of broadleaf trees are reported hosts, including *Carya illinoensis*, *Coffea* spp., *Couma macrocarpa*, *Eschweilera corrugata*, *Eucalyptus* spp., *Lonchocarpus margaretensis*, *Melicoccus bijugatum*, *Pithecellobium pinnatum*, *Protium* spp., *Sacoglottis procera*, *Swietenia macrophylla* and *Theobroma cacao*.



Fig. 9.17 Galleries of an undetermined species of *Xyleborus*.

Table 9.4 Representative species of *Xyleborus* (Coleoptera: Curculionidae: Scolytinae): their distribution and hosts.

Species	Distribution	Hosts
<i>X. affinis</i> Eichhoff	Tropical America (native) Tropical Africa, southern India, Sri Lanka, Australia, Micronesia and Japan (introduced)	Several hundred broadleaf trees
<i>X. ferrugineus</i> (Fabricius)	Southern USA south through the Caribbean Basin, Mexico, Central and South America south to northern Argentina (native) Tropical Africa, southern India, Sri Lanka and Micronesia (introduced)	<i>Carya illinoensis</i> , <i>Coffea</i> spp. <i>Couma macrocarpa</i> , <i>Eschweilera corrugata</i> , <i>Eucalyptus</i> spp., <i>Lonchocarpus margaretensis</i> , <i>Melicoccus bijugatum</i> , <i>Pithecellobium pinnatum</i> , <i>Protium</i> spp., <i>Sacoglottis procera</i> , <i>Swietenia macrophylla</i> and <i>Theobroma cacao</i>
<i>X. glabratus</i> Eichhoff, Redbay ambrosia beetle	India, Japan, Myanmar and Taiwan (native) Southeastern USA (introduced)	<i>Lindera latifolia</i> , <i>Lithocarpus edulis</i> , <i>Litsea elongata</i> , <i>Phoebe lanceolata</i> , <i>Shorea robusta</i>
<i>X. perforans</i> Wollaston	Cosmopolitan in tropical regions including Africa, Asia, Australia, Caribbean Basin and South America	More than 100 host species recorded
<i>X. similis</i> Ferrari	Asia and the Pacific Islands, Mauritius, Tanzania	Numerous hosts, including tapped and injured <i>Hevea brasiliensis</i>

Sources: Browne 1968, Bright & Skidmore 2002, Wood 2007.

Importance *X. ferrugineus* aggressively attacks recently felled logs in forests, log decks and sawmill sites and causes complete destruction of sapwood. It is considered one of the most destructive ambrosia beetles of harvested timber in South America. In Mexico, it attacks pecan plantations and in Brazil it is reportedly one of several ambrosia beetles that attack *Eucalyptus* plantations. It commonly attacks small-diameter stems as well as large logs but is rare in undisturbed natural forests. It is a vector of the pathogenic fungus, *Ceratocystis fimbriata*, which causes a wilt disease of cacao.

Life History Newly emerged mated or unmated females fly to seek a new host, usually in early evening. They construct multi-branched tunnels that penetrate deep into the sapwood. Tunnels rarely enter the heartwood. Surface tunnels in the cambium, are common in wet habitats but rare in dry habitats.

Description of Stages Males are 1.6–1.9 mm long and females are 2.0–3.3 mm long. When mature, they are dark red-brown in color. The elytral declivity is steep.

Related Species *X. affinis* Eichhoff is also native to the neotropics and has been introduced to tropical Africa, southern India, Sri Lanka, Australia, Micronesia and Japan. It has a wide host range and is similar in habits to *X. ferrugineus* (Browne 1968, Flechtmann et al. 2000, Aguilar-Pérez et al. 2007, Wood 2007, Wagner et al. 2008).

***Xyleborus glabratus* Eichhoff, Redbay Ambrosia Beetle**

Distribution *X. glabratus* is indigenous to India, Japan, Myanmar and Taiwan. It was introduced into southeastern USA in about 2002, most likely via solid wood packing material. It was first collected in Georgia, USA, and has since been found in South Carolina and Florida.

Hosts This insect infests broadleaf trees and shrubs. Known host trees in its natural range include *Lindera latifolia*, *Lithocarpus edulis*, *Litsea elongata*, *Phoebe lanceolata* and *Shorea robusta*. In southeastern USA, it infests

plants of the family Lauraceae, including avocado, *Persea americana*, redbay, *P. borbonia* and sassafras, *Sassafras albidum*.

Importance This species is the vector of a highly pathogenic fungus, *Raffaelea lauricola*, which causes a wilt disease and mortality of host plants in southeastern USA. In some locations redbay mortality has exceeded 90%. The palamedes swallowtail butterfly, *Papilio palamedes* Drury, is dependent upon redbay as a larval host.

Life History Little is known about the life history and habits of this insect. For most species of *Xyleborus*, males are rare and do not fly. Only females attack host material and construct galleries and brood cradles. If mating occurs, it takes place before adults exit the host plant and is usually between siblings or mother and son. Males are haploid and females are diploid. An unmated female produces only male offspring, with which she later mates to produce females.

Description of Stages Adults are small beetles, 2.0 mm long, slender and brown-black in color. The declivity is steep and convex, especially on the posterior portion (Wood & Bright 1992, Rabaglia 2005, Mayfield & Thomas 2009).

Curculionidae (Subfamily Platyponinae – Ambrosia Beetles)

***Megaplatypus* (= *platypus sulcatus*) *mutatus* (Chapuis)**

Distribution *M. mutatus* is native to tropical and subtropical areas of South America and reported from Argentina, Bolivia, Brazil, French Guyana, Paraguay, Peru, Uruguay and Venezuela. It has extended its range into temperate regions of the continent, as far south as Neuquén, Argentina. It was detected in Italy near Caserta (Campania) in 2000.

Hosts *M. mutatus* has a wide host range. It can invade many temperate broadleaf trees including

species of *Acer*, *Caesalpinia echinata*, *Citrus*, *Eucalyptus*, *Fraxinus*, *Laurus nobilis*, *Magnolia grandiflora*, *Malus*, *Platanus*, *Populus*, *Prunus persica*, *Persea americana*, *Pyrus communis*, *Quercus*, *Robinia pseudoacacia*, *Salix*, *Tilia* and *Ulmus*.

Importance Adults bore into living trees up to about 4 m above ground level. Trees of larger diameters are preferred. They construct long sinuous galleries lined with black fungus mycelium of the ambrosia fungus, *Raffaelea santoro*. Attacks degrade lumber and cause structural damage. Infested trees may break during high winds. This insect has caused extensive damage to *Populus* and *Salix* in Argentina. It has also been reported as a pest of Brazilwood, *Caesalpinia echinata*, plantations in Brazil. This species poses a threat to poplar plantations worldwide.

Life History Precise data on flight distances are unavailable. However, dispersal is believed to be not more than 100 m for a few individuals when there is a large infestation. After emergence, the adults must find a suitable host within 5 days. Males initiate attacks, construct a short nuptial gallery and attract one or more females. After mating, females construct galleries and cradles for brood and inoculate them with the ambrosia fungus.

Description of Stages Adults are long, thin cylindrical beetles. Body color is dark red-brown with lighter colored antennae and red-brown legs (Casaubon et al. 2006, Girardi et al. 2006, Alfaro et al. 2007, FAO 2007b, EPPO 2007).

***Myoplatypus* (= *platypus*) *flavicornis* (Fabricius)**

Distribution This species occurs in eastern USA, from New Jersey south to Florida and west to Texas and Mexico.

Hosts Hosts are species of *Pinus*. It also is occasionally found in broadleaf trees.

Importance The lower boles of dead and dying pines, especially those recently killed by bark beetles

such as *Dendroctonus frontalis*, are invaded by this insect. Stumps and logs cut during summer are also attacked. In southeastern USA, this species is so abundant that few dying pines, stumps or logs escape attack, which is indicated by copious amounts of fine white boring dust near the base of host trees (Fig. 9.18). Adult galleries and cradles and discoloration associated with the ambrosia fungus causes loss of wood quality.

Life History Galleries are initiated by males and each male is joined by a single female. Apparently pheromones are produced and simultaneous attacks follow. Mated pairs tunnel into the sapwood and introduce ambrosia fungi into the galleries, which may branch extensively and extend into the heartwood. Larvae move freely inside the parental tunnels and excavate individual pupal cells off the main tunnels. Adults emerge through the original entry hole. Normally, only one generation is produced in a tree.

Description of Stages Adults are red-brown and about 5 mm long. The front of the head is flat and clothed with moderately long hairs (Drooz 1985).

Platypus

Platypus is a large genus of ambrosia beetles. Over 500 species are recognized. They occur in both temperate and tropical forests and damaging species are known from Africa, Asia, Australia, Europe and North and Central America (Browne 1968, Bright & Skidmore 2002).

***Platypus cylindrus* (Fabricius), Oak Pinhole Borer**

Distribution Oak pinhole borer is found throughout much of Europe from southern England south to the Mediterranean region. It is also found in North Africa (Algeria, Morocco) and the Near East (Iran).

Hosts Oaks, *Quercus* spp., are preferred hosts but other members of the family Fagaceae, including *Castanea sativa* and *Fagus sylvatica*, may be attacked. Other reported hosts are *Eucalyptus* spp. and *Populus caspica*.



Fig. 9.18 Heavy boring dust at base of a loblolly pine, *Pinus taeda*, indicative of attack by the ambrosia beetle *Myoplatypus flavicornis* (east Texas, USA, photo by R. F. Billings, Texas Forest Service, courtesy of www.forestryimages.org).

Importance *P. cylindrus* invades severely stressed or recently dead trees. In Algeria, Morocco and Portugal, it is considered a contributing factor in the decline of cork oak, *Quercus suber*. In the UK, its status has changed from a rare species to a pest. As of 1987, it was listed in the British Red Data Book as rare. However, after a severe storm in 1987, there was an abundance of breeding material and numbers increased dramatically in the early 1990s with concurrent damage. Numbers have continued to be high, probably because of an abundance of oaks affected by dieback and decline.

Life History A generation usually takes 2 years to complete although some individuals may complete development in 1 year. Adults are most active between July and mid-September when males bore into logs and stumps of host trees. They are attracted to odors of fermenting sap. Males initiate attacks, bore into the wood for a short distance and then each is joined by a single female. After mating, females construct galleries in the wood and males keep them free of frass. Females lay eggs in cradles constructed in the wood, which they inoculate with ambrosia fungi. Eggs hatch after 2–6 weeks and larvae pass through four or five instars as they feed on ambrosia fungi. The later instars have large mandibles, which they use to extend the galleries.

Description of Stages Adults are 6–8 mm long, cylindrical and dark brown-black in color.

Pest Management Management of infestations includes timely removal and processing of logs to prevent attack and application of chemical sprays to logs in wood yards (Browne 1968, Bright & Skidmore 2002, Henriques et al. 2008, Tilbury 2009).

Platypus granulosis Browne

Distribution *P. granulosis* beetle is indigenous to Australia and occurs on the island of Tasmania.

Hosts Primary host is *Nothofagus cunninghamii*. Other hosts include *Anodopetalum biglandulosum*, *Antherosperma moschatum*, *Eucalyptus* spp., *Eucryphia lucida*, *Phyllocladus aspleniifolius* and *Pinus radiata*.

Importance *Nothofagus cunninghamii* apparently is killed by a fungus associated with *P. granulosis*, but not the ambrosia fungus that larvae use for food. Other

hosts are not killed but galleries and discolored wood reduce value of lumber cut from infested trees. Trees with mechanical injury or growing adjacent to recently disturbed areas, such as roads or sites where timber has been harvested, are most susceptible to attack. Recently cut logs and green lumber are also attacked.

Life History One year is required to complete a generation. Adults emerge from infested trees and logs in summer and males initiate attacks on suitable host material. After boring about 10 mm into the wood, they await arrival of a female. When females arrive, they move from entrance hole to entrance hole until they locate an unmated male. Mating occurs at the entrance hole. Females then elongate the chamber made by males and bore to the heartwood/sapwood boundary. Boring dust is expelled from the entrance hole by the males. Females lay eggs either singly or in small groups in the tunnel system. When larvae are about 4 mm long, they stop feeding, construct small chambers in the wood and pupate.

Description of Stages Adults are about 4 mm long, brown in color and cylindrical (Elliot and deLittle n.d.).

Platypus quercivorus Murayama

Distribution *P. quercivorus* is widely distributed in Asia, including temperate, subtropical and tropical portions of India, Indonesia (Java), Japan, Papua New Guinea and Taiwan. In Japan, it is found from the island of Ishigaki Shima north to Honshu.

Hosts This insect has a wide host range and invades many broadleaf trees including species of Fagaceae. *Castanopsis cuspidata*, *Pasania glabra*, *P.* (= *Lithocarpus*) *edulis*, *Prunus* spp., *Quercus acuta*, *Q. acutissima*, *Q. gilva*, *Q. glauca*, *Q. mongolica* (= *Quercus crispula*), *Quercus mongolica* var. *grosseserratus*, *Q. myrsinifolia* (shirakashi), *Q. phillyraeoides*, *Q. salicina*, *Q. serrata* and *Q. sessilifolia*. Other hosts are *Cryptomeria japonica*, *Ilex chinensis* and *Lindera erythrocarpa*.

Importance Beginning in the early 1980s, extensive mortality of oak forests has occurred in western Japan. This condition, referred to as "Japanese oak disease," is attributed to the fungus *Raffaelea quercivora*, which is a fungal associate of *P. quercivorus*. Oak mortality at the

rate of more than 200,000 trees/year has been observed on the west coast of Honshu. Oaks susceptible to the disease are the deciduous species *Quercus serrata* and *Q. mongolica*. Other trees of the family Fagaceae present in the area, for example *Q. acuta*, *Q. acutissima*, *Q. phillyraeoides* and *Castanopsis cuspidata* var. *sieboldii*, apparently are not affected.

It is believed that oaks resistant or tolerant to *Raffaelea quercivora* co-evolved under a stable relationship between the tree, fungus and beetle during a long evolutionary process. *Q. mongolica* may not have been part of this co-evolution. This is supported by the fact that *P. quercivorus* has a low preference for *Q. mongolica* but exhibits the highest reproductive success in this species. Therefore, *P. quercivorus* could spread more rapidly in stands with a high component of *Q. mongolica*. The present epidemic of *P. quercivorus* may be due to a warmer climate that began in the late 1980s. This allowed it to extend its range to more northerly latitudes and higher altitudes where *Q. mongolica* occurs.

Life History Males initiate attacks on the boles of host trees and excavate galleries for mating from June to October. Initial entry holes bored by males trigger a mass attack. Attacks generally occur near the ground level. A single female joins the male and, after mating, constructs a gallery, which is kept clean by the male. During gallery construction, females inoculate the gallery surface with fungus spores. Adult females deposit eggs at the terminal parts of tunnels 2–3 weeks after the beginning of gallery construction. Eggs are deposited in individual niches. An average of 50–60 larvae develop in a single gallery system but the number can be as high as 160. Larvae feed on the ambrosia fungus that develops on the walls of the galleries. Pupation occurs in the larval galleries. Most brood adults leave their maternal galleries in September and October but some remain until spring. In other cases larvae reach the instar V by late November and overwinter in pupal chambers. Pupation begins the following May, and adults emerge from June to July through entry holes made by parent adults.

Description of Stages Adults are red-brown to dark brown with a cylindrical, elongated body that averages 5 mm long. They have a concave declivity armed with spines. The front (prothoracic) legs are adapted for excavation (Wood & Bright 1992, Bright & Skidmore 2002, Kamata et al. 2002, Kubono & Ito 2002, Kobayashii et al. 2003).