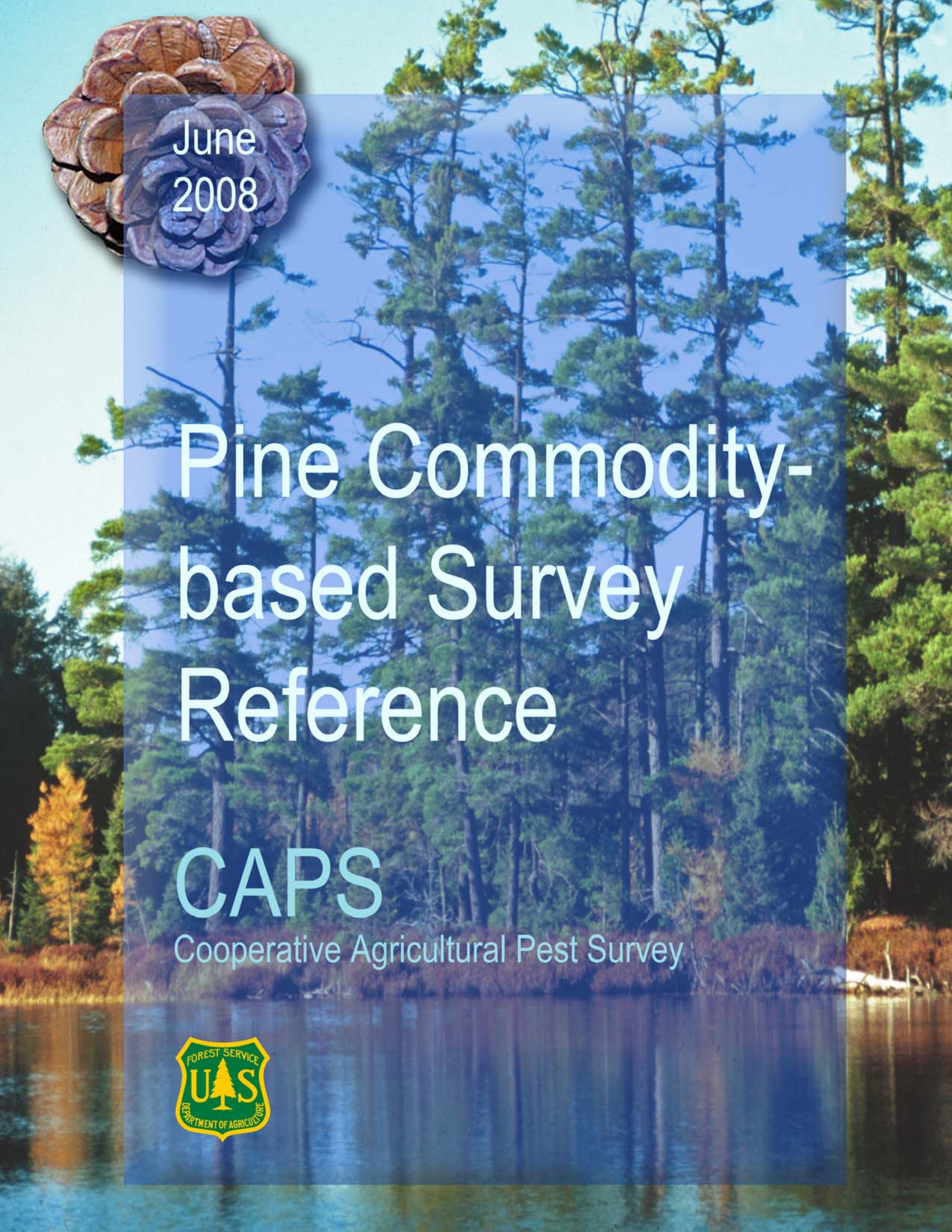

June
2008

Pine Commodity-based Survey Reference

CAPS

Cooperative Agricultural Pest Survey

FOREST SERVICE
U S
DEPARTMENT OF AGRICULTURE

On the cover: Stand of eastern white pine (*Pinus strobus*) in Ottawa National Forest, Michigan. The image was modified from a photograph taken by Joseph O'Brien, USDA Forest Service. Inset: Cone from red pine (*Pinus resinosa*). The image was modified from a photograph taken by Paul Wray, Iowa State University. Both photographs were provided by Forestry Images (www.forestryimages.org).

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Introduction

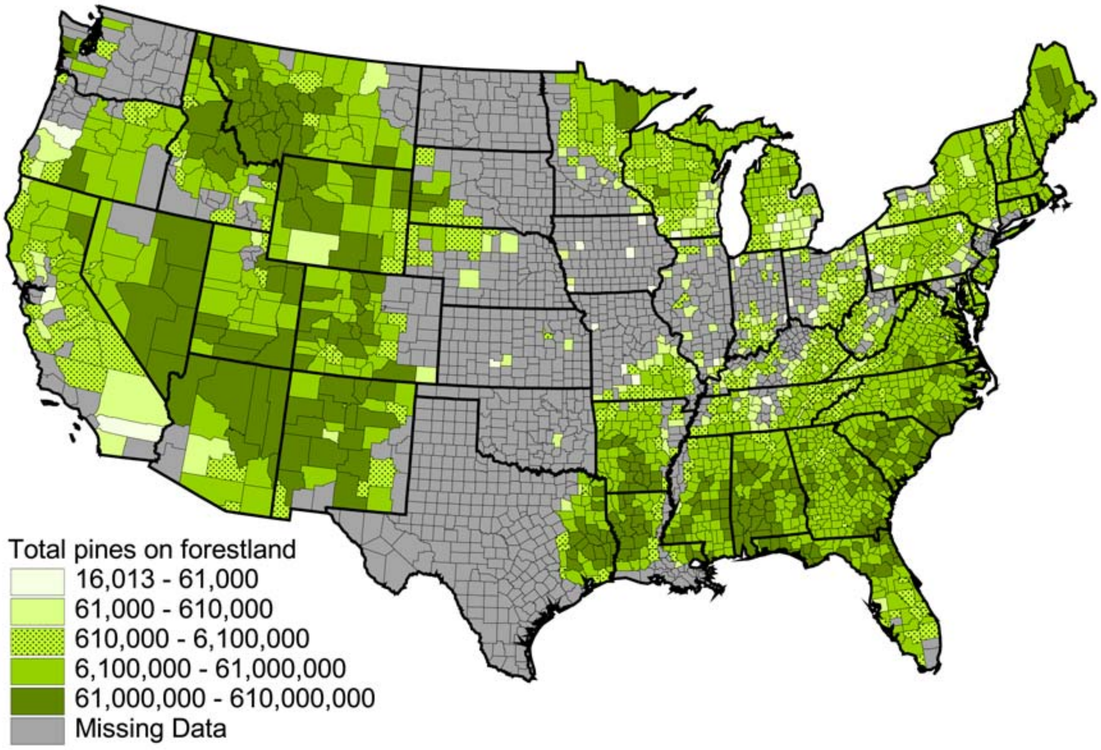

Fig. 1. Total pine trees (*Pinus* spp) on forestland based on 2004-2006 surveys (USDA Forest Service, Forest Inventory and Assessment).

Pines (*Pinus* spp.) are remarkably diverse and abundant in the United States. At least 97 species occur in the country. Some are exotic to North America, but most are native. An estimated 54 billion pines occur in the contiguous United States on forestland acres. Pines dominate four forest type groups in the western United States: ponderosa pine, western white pine, lodgepole pine, and piñon pine-juniper. In 2002, these cover types accounted for 8.6%, 0.1%, 5.1%, and 1.0%, respectively, of total forestland area in the West including Alaskan forests (Smith et al. 2004). In the eastern United States, pines dominate four cover types: white-jack-red pine, longleaf-slash pine, loblolly-shortleaf pine, and oak-pine (mixed cover type). In 2002, these cover types accounted for 3.1%, 3.6%, 14.1%, and 8.8%, respectively, of total forestland area in the East (Smith et al. 2004). No *Pinus* spp. are listed as federally threatened or endangered, but five species (*P. banksiana*, *P. echinata*, *P. pungens*, *P. resinosa*, and *P. virginiana*) are considered threatened or endangered in at least one of six states.

This document addresses 20 non-native species of insects and fungi that have the potential to adversely affect pines. Most of these species do not occur in the United States. However, at least four of the species are known to be established in pockets of the United States as a result of recent introductions. Established non-native pests continue to present risks to pine forests as they spread into previously unaffected areas. Additionally, new geographic variants of established species may arise and impact pines in ways not previously known. The 20 species addressed in this document were considered a serious threat by the Cooperative Agricultural Pest Survey or the North American Forestry Commission. This list was developed in consultation with the USDA Animal and Plant Health Inspection Service and is not intended to address all exotic pests that may attack pines.

In this document, we present biological details that are relevant to the survey and detection of each species. The following information can be found within each subsection:

Pest Description - a description of the morphology of the species. For technical accuracy, most descriptions are quoted directly from taxonomic authorities.

Biology and Ecology - a summary of the life history of each species in its native range. A particular emphasis is placed on when various life stages may be present and active.

Pest Importance - a description of the ecological and economic impact each species may have. Impacts are not always limited to pine. Some pests also may be problematic on other trees, shrubs, or crops.

Symptoms - a description of damage the species may cause on a host plant. This description may be useful for surveying pine stands.

Known Hosts - a complete listing of plants on which the pest has been reported to feed. Not all host associations have been thoroughly tested.

Known Distribution - a list of countries from where the species has been reported.

Potential Distribution within the United States - a summary of regions within the United States that may have suitable environmental conditions for the species.

Survey - available techniques that have been used to detect the species. This section also describes other species that might be confused with the target pest.

Arthropods:
Beetles

Chlorophorus strobilicola

E.E. Davis, E.M. Albrecht, and R.C. Venette

Scientific Name

Chlorophorus strobilicola Champion

Synonyms:
none known

Common Names

Slender-banded pine cone longhorn beetle, pine cone cerambycid, chir pine cone beetle

Type of Pest

Seed-feeder, long-horned beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Cerambycidae, **Subfamily:** Cerambycinae

Fig. 2. Adult *Chlorophorus strobilicola*. Photo by Steven Lingafelter (2003).

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult

“This species is a member of the large group of slender, colorful clytine longhorned beetles. This group is recognized by the long, narrow body, long legs, relatively short antennae (rarely longer than the body), and bright stripes and patterns on the outer wings. *Chlorophorus strobilicola* Champion is about 0.8-1.2 cm long. The relatively narrow bands of white pubescence in the pattern shown [in Fig. 2], is diagnostic for adults of this species” (Lingafelter 2003).

“Moderately elongate, subopaque, the elytra shining; rufous or reddish-brown, the eyes, scutellum, metasternum, and abdomen, the elytra with at least the apical portion, and sometimes the posterior femora towards the apex and the tips of the antennae, infuscate or black; the elytra each with a curved narrow fascia before the middle, extending forwards along the suture to the base and interrupted on the outer part of the disc, a short longitudinal streak within the humeral callus, a common narrow subapical fascia, and sometimes a small patch at the apex, cinereous or whitish, the rest of the pubescence of the upper surface sparser and darker, that of the under surface close, and in great part whitish or cinereous, the legs cinereo-pubescent and with a few projecting hairs; the head and prothorax closely, roughly punctate, the elytra densely, very finely punctate. Antennae rather more than half the length of the body, a little longer in ♂, joints 6-10 rapidly decreasing in length in ♀. Prothorax convex, transverse in ♀, nearly as long as broad in ♂, rounded at the sides. Elytra moderately elongate, somewhat flattened on the disc, truncate at the apex, the outer apical angle sharp. Basal joint of posterior tarsus about as long as the others united. Length 7½-9½ [mm], breadth 2-3 mm (♂♀)" (Champion 1919).

Egg

"Sausage-shaped, slightly curved on long axis, semi-opaque white in colour, 0.75 x 0.25 mm" (Champion 1919).

Larva (Fig. 3)

"Form cylindrical, broadest at the prothorax and tapering rapidly behind in the last 3 segments: white, except for the chitinised mouth-parts, and an ill-defined yellowish area in the front portion of the prothorax; rather smooth and shining, but thinly pubescent with rather long pale hairs especially anteriorly. Head strongly retracted into the prothorax; clypeus narrow; labrum broader than long, hairy; mandibles typical of subfamily, with gouge-shaped cutting edge; labial palpi 3-jointed, apical joint subconical, about 1½ times as long as broad; maxillary palpi slightly larger than the labial, 3-jointed, apical joint subconical. Antennae rather conspicuous when fully exserted, 3-jointed, basal joint trapezoidal and rapidly tapered, second cylindrical, longer than broad, and bearing the narrow cylindrical 3rd joint and a small papilla. A large single ocellus irregularly pigmented near base of antenna. Prothorax as viewed from above about three times as broad as long, and equal to the 1st abdominal segment, quite smooth and shining. Legs minute, being only about 1/10 the length of the large thoracic spiracle, 3-jointed; fold bearing the prothoracic leg extending up in front of the spiracle for a distance equalling the length of the latter. Abdomen parallel-sided, ampullae not pronounced, slightly rugose, but shining and smooth otherwise. Length fully grown 12.5 mm, width 2.5 mm, length of leg 0.04 mm" (Champion 1919).

Fig. 3. Larval *C. strobilicola* feeding in a cone of *Pinus roxburghii*. Image from Sven-Erik Spichiger, http://www.bugwood.org

Biology and Ecology

Relatively little is known about the biology of *C. strobilicola*. Known biology has been described by Champion (1919), Beeson and Bhatia (1939), Duffy (1968), and Pande and Bhandari (2006).

In India, *C. strobilicola* completes its life cycle on 2-3 year old cones of *Pinus roxburghii* (Duffy 1968, Pande and Bhandari 2006). Under optimal conditions, *C. strobilicola* has 4 overlapping generations per year. First generation adults emerge from cones in April and the first half of May (Beeson and Bhatia 1939, Duffy 1968). The first generation lasts 50-55 days. The second generation lasts 55-60 days from the end of June to the end of August, while the third generation lasts 60-65 days from mid-August to the end of October. The fourth generation overwinters as larvae and pupates in April or May of the following year. Champion (1919) notes the date of emergence may depend on altitude and other factors.

Mating occurs shortly after adults emerge from cones (Champion 1919, Pande and Bhandari 2006). There are about as many males as there are females. Adults live 11-14 days (Pande and Bhandari 2006).

Oviposition occurs toward the end of June to the beginning of July (Champion 1919, Beeson and Bhatia 1939). Females mate multiple times and deposit 4-6 eggs between scales of mature green cones after each mating (Pande and Bhandari 2006). They deposit a total of about 15-20 eggs (Champion 1919, Duffy 1968), which hatch after 4-5 days (Pande and Bhandari 2006).

Larvae bore into the cone, where they excavate galleries about 5 cm [2 in] long through the central axis and several scales. Between May and August, the larval stage lasts 30-35 days; during September and October, it lasts 40-45 days. *C. strobilicola* larvae have six instars (Pande and Bhandari 2006).

Pupation takes place in an oval-shaped chamber in the larval gallery and lasts about 8-10 days (Pande and Bhandari 2006). Adults emerge through elliptical emergence holes in the scale-head (Champion 1919, Beeson and Bhatia 1939, Duffy 1968, Pande and Bhandari 2006).

Pest Importance

Chlorophorus strobilicola attacks cones of *Pinus roxburghii*, reducing the quality and yield of seeds (Pande and Bhandari 2003, 2004). *P. roxburghii* is endemic to south Asia and is currently established as a cultivated ornamental species in western North America (California). *P. roxburghii* is closely related to *P. rigida* (pitch pine) and *P. taeda* (loblolly pine), both of which are indigenous to the United States (Sinha 2002). It is unknown whether *C. strobilicola* could successfully infest cones of these or other native pines.

Damage to pine cones is proportional to the number of larvae feeding within, with larger cones being more susceptible to attack (Champion 1919, Pande and Bhandari 2004). Seed efficiency, which is the ratio of actual to potential seed production, is diminished in cones infested with *C. strobilicola* or other cone-boring insects. Pande and Bhandari (2003) found that in cones with twenty or more larvae, seed efficiency was reduced to 0%. Singh et al. (2007) found cones of *P. roxburghii* attacked by four *C. strobilicola* larvae experienced an average weight loss of 54-74%, with greater losses occurring in late summer. Over 81%

of seeds were lost and the average weight of seeds was reduced by 58% (Singh et al. 2007).

Symptoms

Infested cones may not mature normally, usually when a dozen or more larvae are present (Champion 1919, Duffy 1968). These stunted cones are fragile and filled with "very fine wood dust" (Champion 1919). Cones infested with a few larvae may appear normal but do not produce fertile seed (Champion 1919).

Known Hosts

Chlorophorus strobilicola feeds solely on 2-3 year old cones of *Pinus roxburghii* (Duffy 1968, Pande and Bhandari 2006). There is one record of *C. strobilicola* feeding on *Pinus kesiya* (USDA/APHIS 2004), but this is questionable.

Host	**Reference**
Pinus roxburghii (=*Pinus longifolia*) (chir pine)	(Champion 1919, Beeson and Bhatia 1939, Duffy 1968, Lingafelter 2003, Pande and Bhandari 2003, 2004, Singh et al. 2005, reviewed in CAB 2006, Pande and Bhandari 2006)

Known Vectors

Chlorophorus strobilicola has not been reported as a vector of plant pathogens.

Known Distribution

Chlorophorus strobilicola is located throughout "open sunny stands" of *Pinus roxburghii* in India and is usually found at elevations of about 450-2000 m [1500-6500 ft] (Champion 1919, Beeson and Bhatia 1939, Duffy 1968, Pande and Bhandari 2006). Larval and adult *Chlorophorus strobilicola* were detected in 2003 in California, Connecticut, Florida, Massachusetts, New Jersey, New York, North Carolina, and West Virginia (Lingafelter 2003, USDA/APHIS 2004).

Location	**Reference**
Asia	
India	(Champion 1919, Beeson and Bhatia 1939, Lingafelter 2003)
North America	
United States[1]	(Lingafelter 2003)

1. Not established.

Potential Distribution within the United States

Very little information exists to support a reliable prediction of the potential distribution of *C. strobilicola* within the United States. We presume that *C. strobilicola* would require similar ecological conditions as in India to establish and cause damage. Only five biomes occur within the elevations where this insect has been reported to occur. Of these biomes, only three also occur in the

United States: temperate coniferous forests; temperate broadleaf and mixed forests; and tropical and subtropical coniferous forests. These biomes dominate the United States east of the Mississippi and are prevalent in the Intermountain West, the Pacific Northwest, and the Sierra-Nevada mountains.

Survey

Preferred Method: Visual inspection of trees and cones is the only practical way to survey for this insect. There are no known long-range aggregation pheromones, sex pheromones, or other attractants for this beetle.

Cones of *Pinus roxburghii* infested with *C. strobilicola* are easily broken off by wind and may appear glossy and immature (Champion 1919, Beeson and Bhatia 1939). The cones are light and filled with wood dust (Champion 1919). Emergence holes are oval-shaped (Beeson and Bhatia 1939). Larvae, pupae, and adults may be present simultaneously in a cone (Champion 1919).

Diagnostics

Identification depends on examination of morphological characters. Segments of antennae are particularly important to distinguish this species from close relatives. No molecular tools are available to help with diagnosis.

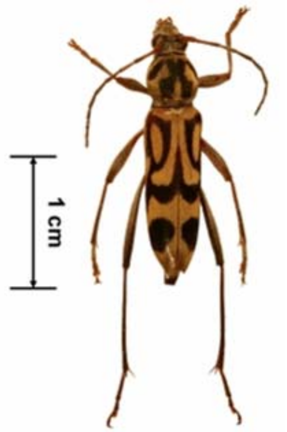

Fig. 4. Adult *C. annularis*. Image from Christopher Pierce, http://www.bugwood.org

Easily Confused Pests

Chlorophorus strobilicola may be confused with *C. annularis* (Fig. 4), which has been intercepted in the continental United States in stored bamboo products imported from China (Pierce 2006). *C. annularis* is established in Hawaii (NAPIS 2003). Duffy (1968) provides a key to distinguish between these two *Chlorophorus* spp. *C. strobilicola* has the second antennal segment “slightly longer than wide,” while that of *C. annularis* is “about one and one-half times as long as wide” (Duffy 1968). Additionally, *C. strobilicola* is confined to cones of *Pinus roxburghii*, while *C. annularis* is chiefly a pest of dry bamboo (Beeson and Bhatia 1939, Duffy 1968).

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Dendroctonus micans

E.E. Davis, E.M. Albrecht, and R.C. Venette

Fig. 5. Adult *Dendroctonus micans*. Photo by Maja Jurc, http://www.forestryimages.org

Scientific Name

Dendroctonus micans (Kugelann)

Synonyms:
Bostrichus micans Kugelann
Hylesinus ligniperda Gyllenhal
(Grüne 1979)

Common Names

Great spruce bark beetle, European spruce beetle

Type of Pest

Bark and cambium-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Scolytinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 5)

Description of the genus *Dendroctonus* Erichson 1836:
“Frons without a median groove or impression below upper level of eyes; lateral elevations of frons and transverse elevated callus of pronotum never present in either sex; epistomal process usually narrower and less prominent, lateral margins raised or not; ... Declivital interstriae smooth and shining, most punctures impressed, a few of them granulate in female; epistomal process rather narrow, distance between eyes three or more times its basal width; episternal area of prothorax punctate, granules minute or entirely absent; ... Declivital striae weakly if at all impressed, 2 apically curved toward sutural striae; declivital interstriae 1 feebly elevated, 2 as wide or wider than 1 or 3 (except near apex); discal striae less than half as wide as interstriae; epistomal process usually transversely concave (except *micans*), rather broad, lateral margins moderately oblique (less than 55 degrees from horizontal); ... frons smooth and polished, with deep close punctures, but almost entirely without granules between punctures; strial punctures on declivity rather large, three or more times as large as those of interstriae; ... epistomal process flat; body stouter, 2.3 times as long as wide; strial punctures more strongly impressed; northern Europe and Asia; 6.0-8.0 mm” (Wood 1982).

Egg

No unique features of *D. micans* eggs have been described. Eggs resemble other bark beetle eggs, which are white, oval, and slightly more than 1 mm long (Haack 2001).

Larva

"Spiracular tubercles present, sclerotized; sclerotized areas or plates present on dorsal surface of one or both abdominal segments 8 and 9 or 9 only ... a lightly sclerotized, inconspicuous dorsal plate usually present on segment 9 only" (Furniss and Johnson 1989).

Pupa

No unique features of *D. micans* pupae have been described. Pupae resemble other bark beetle pupae, which are white, mummy-like, and have some adult features (Haack 2001).

Biology and Ecology

D. micans completes a generation in one to three years, primarily depending on temperature (reviewed in CAB 2006). Grégoire (1984) observed five instars, pre-pupal, pupal, and adult stages. Under natural conditions, larval development can take a year or more. However, under laboratory conditions larvae may reach maturity in 50-60 days at temperatures between 19-23°C [66-73°F] (Grégoire and Merlin 1984). *Dendroctonus micans* overwinters in the larval or adult stage. Adult beetles freeze at -20°C [-4°F] (reviewed in CABI/EPPO 1997). Adults are not known to survive freezing.

Adults mate before emerging. The male to female ratio ranges from about 1:10 to 1:45. Consequently, mating among siblings is common (reviewed in CAB 2006). Approximately 90% of adult females emerge after mating with a sibling male within the gallery system where they developed (Vouland et al. 1984). The beetles construct round exit holes, which may be used by several individuals. Emergence may occur over 5 months depending on temperature and climate conditions (Vouland and Schvester 1994, reviewed in CAB 2006). Females initiate attacks on trees. A single mated female either re-enters an existing host or moves to a new host (reviewed in CABI/EPPO 1997, reviewed in CAB 2006). Females ordinarily attack standing, live trees, but may attack stressed trees as well (reviewed in Haack 2001).

Flight occurs during warm temperatures in summer months (reviewed in CABI/EPPO 1997). Vouland et al. (1984) reported a temperature threshold for adult flight between 21-23°C [70-73°F]. In Britain, initial and sustained flights were observed at 20°C [68°F] and 14°C [57°F], respectively (reviewed in CAB 2006). Adults are considered strong fliers and may disperse several km in search of suitable hosts. They may also be transported by wind. However, adults tend to repeatedly attack the tree from which they originally emerged or infest others nearby (reviewed in Haack 2001). Flight may not be a common means of dispersal in shaded canopies (Fielding et al. 1991).

The female bores one or more horizontal galleries and deposits eggs in clusters of 100-150 inside a brood chamber containing a protective mixture of bark pieces, sawdust, and frass (Storer et al. 1997, Lieutier 2004, reviewed in CAB 2006). Eggs are deposited on one side of the chamber (Fig. 6). Under laboratory conditions, a single female deposited 240 (±30.83) eggs on average within approximately one to three weeks. Approximately 52% of these individuals developed to adulthood (Grégoire and Merlin 1984). When population density is high and multiple females deposit eggs within a single host, larval gallery systems can converge (reviewed in CAB 2006).

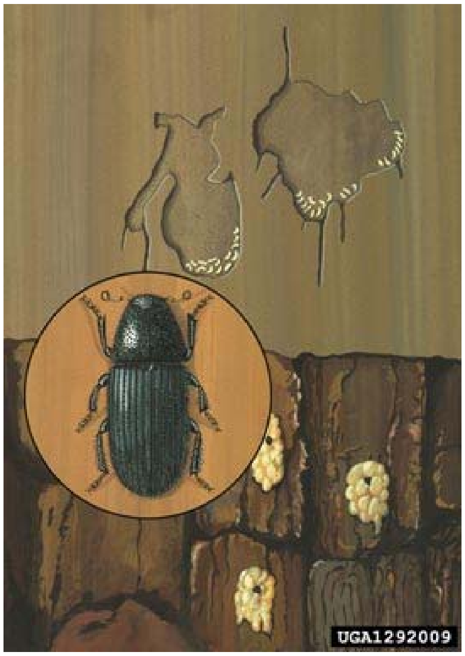

Fig. 6. Diagram of adult, eggs, pitch tubes, and gallery of *Dendroctonus micans*. Image by Robert Dzwonkowski, http://www.bugwood.org

Immediately following egg hatch, larvae aggregate in response to (-)-α-pinene and *trans*-verbenol and feed side-by-side in large groups (Grégoire et al. 1982, Deneubourg et al. 1990, Storer et al. 1997). Larvae primarily feed on phloem and periodically bore holes to the bark surface for air. Large amounts of frass become packed in the gallery behind the feeding larvae. Weakened, diseased, and dead insects become encased in the hardened frass. The feeding tunnel widens as an increasing number of larvae aggregate and advance (Grégoire and Merlin 1984, reviewed in CAB 2006).

Pest Importance

The economic and environmental importance of *Dendroctonus micans* has been reviewed by CABI/EPPO (1997), CAB (2006), and Haack (2001). *D. micans* is chiefly a secondary pest of conifers, particularly spruce (*Picea* spp.), in its native range. However, *D. micans* is capable of causing major damage and killing entire stands during periodic outbreaks that typically occur on the edges of its geographic range (reviewed in CABI/EPPO 1997, reviewed in Gilbert et al. 2001, reviewed in Haack 2001). Outbreaks in stands are thought to be associated primarily with weakened or stressed trees and poor site conditions (Voolma and Luik 1999, Gilbert et al. 2001, Gilbert et al. 2003, Gilbert and Grégoire 2003, Rolland and Lempérière 2004). Historical outbreaks have affected over 200,000 ha [494,000 A], causing significant damage to spruce forests in Europe and Asia (reviewed in Haack 2001). Outbreaks have also been reported in Scots pine (*Pinus sylvestris*) plantations of varying ages in Russia and northern Europe (reviewed in CABI/EPPO 1997, Voolma and Luik 1999, reviewed in Haack 2001). In an area of pine-dominated mixed boreal forest, *D. micans* was identified as a cause of mortality in spruce but not in pine (Rouvinen et al. 2002).

Dendroctonus micans primarily attacks healthy, standing trees, but may also attack wounded or stressed trees (Deneubourg et al. 1990, reviewed in CABI/EPPO 1997, Gilbert et al. 2001, reviewed in Haack 2001, Gilbert and Grégoire 2003). Galleries and brood chambers constructed by *D. micans* transect and drain resin ducts, leading to reduced resin pressure (Gilbert et al. 2001). Wounding also stimulates an accumulation of nitrogen and starch in host tissue as an induced defense reaction (Wainhouse et al. 1998). However, the increased amount of nitrogen makes the bark more nutritionally valuable to *D. micans*. This phenomenon may explain why beetles attack hosts near areas of previous attack (Gilbert et al. 2001). Gregarious feeding by larvae in the cambial region results in girdling and eventual tree death (reviewed in CABI/EPPO 1997). Trees that have not been heavily attacked by *D. micans* tend to survive and several generations may be completed while the tree retains green foliage (reviewed in Haack 2001, reviewed in CAB 2006). Indeed, Voolma and Luik (1999) make mention of a live, 50 cm [20 in] dbh Russian pine infested by 2,500 adults. *D. micans* is considered a “solitary” species and will only attack a host infested with other insects when *D. micans* population density is high (reviewed in CABI/EPPO 1997).

In the United Kingdom the introduction and establishment of *D. micans* since the early 1980s has necessitated the implementation of an integrated pest management program including biological, chemical, and silvicultural control measures (Evans and Fielding 1994, reviewed in CABI/EPPO 1997). The ability of *D. micans* to kill conifers in North America is not known. Establishment of this pest in the United States would present a significant threat to forests and the forest products industry. Insect-damaged trees are also vulnerable to subsequent attack by other insects and pathogens. Reduction or loss of mature conifers would negatively affect forest composition and displace native species.

Symptoms

In standing, living trees, external symptoms of attacked trees may be easily confused with damage caused by closely related species of bark beetles, longhorn beetles, and other agents causing tree decline. External symptoms include yellow, brown, or reddish-brown foliage or crown; purple-brown (when wet) or white and crusty (when dry) pitch tubes originating from entrance holes on the lower trunk; streams of resin (resinosis); patches of necrotic (discolored or black) and peeling bark; and round exit holes. These signs are caused by females boring through the bark to form a brood chamber. Internally, the hallmark sign of *D. micans* infestation is the fan-shaped larval gallery, which is unique to this species. Galleries can be as large as 60 cm long and 20 cm wide (reviewed in CAB 2006). Insects in all life stages may be present within the tree

(Bevan and King 1983, reviewed in CABI/EPPO 1997, reviewed in Haack 2001, reviewed in CAB 2006).

Stressed Scots pine (*Pinus sylvestris*) that are 18-25 years old are preferred over other age classes of the same species (Voolma and Luik 1994). Attacks are consistently in the lower bole of a tree.

Known Hosts

Dendroctonus micans is primarily a pest of spruce, *Picea* spp. It may also attack other conifer species, particularly pine, *Pinus* spp. (Wainhouse and Beech-Garwood 1994). It prefers *Picea abies*, *P. sitchensis*, and *P. orientalis* (Wainhouse et al. 1990, Voolma and Luik 1999).

Host	**Reference**
Abies spp. (fir)¹	(CIE 1983, Evans and Fielding 1994)
Abies alba (=*Abies pectinata*) (silver fir)²	(Grüne 1979, reviewed in Haack 2001, reviewed in CAB 2006)
Abies nordmanniana (Nordmann fir)	(reviewed in Haack 2001, reviewed in CAB 2006)
Abies sibirica (Siberian fir)	(reviewed in Haack 2001, reviewed in CAB 2006)
Larix spp. (larch)¹	(Evans and Fielding 1994, Wainhouse and Beech-Garwood 1994, Kolk and Starzyk 1996)
Larix decidua (common larch)²	(Grüne 1979, reviewed in Haack 2001, reviewed in CAB 2006)
Picea spp. (spruce)	(Grüne 1979, CIE 1983, Grégoire and Merlin 1984, Evans and Fielding 1994, reviewed in Haack 2001, Gilbert et al. 2003, Gilbert and Grégoire 2003)
Picea abies (= *Picea excelsa*) (Norway spruce)	(Bevan and King 1983, Grégoire and Merlin 1984, Wainhouse et al. 1990, Evans and Fielding 1994, Wainhouse and Beech-Garwood 1994, Furniss 1996, Kolk and Starzyk 1996, Storer et al. 1997, Wainhouse et al. 1998, Voolma and Luik 1999, reviewed in Haack 2001, Rolland and Lempérière 2004, reviewed in CAB 2006)
Picea asperata (=*Pinus crassifolia*) (dragon spruce)	(reviewed in Haack 2001, reviewed in CAB 2006)
Picea breweriana (Brewer spruce)	(reviewed in CAB 2006)
Picea engelmannii (Engelmann spruce)	(reviewed in CAB 2006)
Picea glauca (white spruce)	(reviewed in CAB 2006)
Picea jezoensis (Yeddo spruce)	(reviewed in Haack 2001, reviewed in CAB 2006)

Host	**Reference**
Picea mariana (black spruce)	(reviewed in CAB 2006)
Picea obovata (Siberian spruce)	(reviewed in Haack 2001, reviewed in CAB 2006)
Picea omorika (Pancic spruce)	(Evans and Fielding 1994, reviewed in Haack 2001, reviewed in CAB 2006)
Picea orientalis (oriental spruce)	(Wainhouse et al. 1990, Evans and Fielding 1994, Wainhouse and Beech-Garwood 1994, Storer et al. 1997, Voolma and Luik 1999, reviewed in Haack 2001, reviewed in CAB 2006)
Picea pungens (blue spruce)	(Evans and Fielding 1994, reviewed in CAB 2006)
Picea sitchensis (Sitka spruce)	(Bevan and King 1983, Wainhouse et al. 1990, Fielding et al. 1991, Evans and Fielding 1994, Wainhouse and Beech-Garwood 1994, Furniss 1996, Storer et al. 1997, Wainhouse et al. 1998, Voolma and Luik 1999, reviewed in CAB 2006)
Pinus spp. (pine)	(CIE 1983, Evans and Fielding 1994, reviewed in Haack 2001)
Pinus contorta (lodgepole pine)	(reviewed in Haack 2001, reviewed in CAB 2006)
Pinus mugo (=*Pinus montana*) (mugo pine)[2]	(Grüne 1979)
Pinus nigra (black pine)	(reviewed in Haack 2001, reviewed in CAB 2006)
Pinus strobus (eastern white pine)	(reviewed in Haack 2001, reviewed in CAB 2006)
Pinus sylvestris (Scots pine)[2]	(Grüne 1979, Fielding et al. 1991, Wainhouse and Beech-Garwood 1994, Kolk and Starzyk 1996, Voolma and Luik 1999, reviewed in Haack 2001, reviewed in CAB 2006)
Pinus sylvestris var. *hamata* (=*Pinus sosnowskyi*)	(reviewed in Haack 2001, reviewed in CAB 2006)
Pinus uncinata (mountain pine)	(reviewed in Haack 2001, reviewed in CAB 2006)
Pseudotsuga menziesii (Douglas-fir)[1]	(reviewed in Haack 2001, reviewed in CAB 2006)

1. *Abies* spp., *Larix* spp., and *Pseudotsuga menziesii* are infrequently attacked (Wainhouse and Beech-Garwood 1994, Kolk and Starzyk 1996).
2. Minor hosts (Grüne 1979).

Known Vectors

Dendroctonus micans is not known to be associated with pathogenic fungi (Deneubourg et al. 1990). Levieux and Cassier (1994) suggested that *D. micans* was "free of pathogenic fungi," including the bluestain fungi, *Ophiostoma* spp. However, secondary invaders including root disease fungi such as *Heterobasidion annosum* and *Armillaria* spp. have been observed in trees attacked by *D. micans* (Deneubourg et al. 1990, reviewed in Gilbert et al. 2001, reviewed in Haack 2001).

Known Distribution

Location	**Reference**
Asia	
China	(Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Georgia (Republic)	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Japan	(Kolk and Starzyk 1996, Voolma and Luik 1999, reviewed in Haack 2001, reviewed in CAB 2006)
Mongolia	(reviewed in Haack 2001)
Turkey	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Europe	
Austria	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Belgium	(Grégoire et al. 1982, CIE 1983, Grégoire and Merlin 1984, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Bosnia and Herzegovina	(CIE 1983, reviewed in CAB 2006)
Bulgaria	(reviewed in Haack 2001, reviewed in CAB 2006)
Croatia	(CIE 1983, reviewed in CAB 2006)
Czech Republic	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Denmark	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Estonia	(CIE 1983, Voolma and Luik 1999, reviewed in Haack 2001)
Finland	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
France	(CIE 1983, Grégoire and Merlin 1984, Vouland et al. 1984, Vouland and Schvester 1994, Furniss 1996, Voolma and Luik 1999, Gilbert et al. 2001, reviewed in Haack 2001,

Location	Reference
	Rolland and Lempérière 2004, reviewed in CAB 2006)
Germany	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Greece	(reviewed in Haack 2001, reviewed in CAB 2006)
Hungary	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Ireland	(reviewed in CAB 2006)
Italy	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Latvia	(reviewed in Haack 2001, reviewed in CAB 2006)
Lithuania	(reviewed in Haack 2001, reviewed in CAB 2006)
Luxembourg	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Montenegro	(CIE 1983, reviewed in CAB 2006)
Netherlands	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Norway	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Poland	(CIE 1983, Kolk and Starzyk 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Portugal	(reviewed in CAB 2006)
Romania	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Russia	(CIE 1983, Furniss 1996, Kolk and Starzyk 1996, Voolma and Luik 1999, reviewed in Haack 2001, reviewed in CAB 2006)
Serbia	(CIE 1983, reviewed in CAB 2006)
Slovakia	(CIE 1983, Furniss 1996, reviewed in Haack 2001, reviewed in CAB 2006)
Spain	(reviewed in Haack 2001, reviewed in CAB 2006)
Sweden	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Switzerland	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
Ukraine	(CIE 1983, reviewed in Haack 2001, reviewed in CAB 2006)
United Kingdom	(Bevan and King 1983, Wainhouse et al. 1990, Fielding et al. 1991, Evans

Location	Reference
	and Fielding 1994, Furniss 1996, Storer et al. 1997, Wainhouse et al. 1998, Voolma and Luik 1999, reviewed in Haack 2001, Gilbert et al. 2003, reviewed in CAB 2006)

Potential Distribution within the United States

In general, *D. micans* occurs in cool, temperate to warm climates with variable seasonal rainfall and dry periods. The currently reported distribution of *D. micans* suggests that the insect may be most closely associated with biomes characterized as: temperate broadleaf and mixed forests; and temperate coniferous forests. Both biomes occur in the United States. Consequently, approximately 47% of the contiguous United States may have a suitable climate for *D. micans*.

Survey

<u>Preferred Method:</u> Surveys for *D. micans* should rely on visual inspections of trees. No chemical attractants have been identified to bait traps (Storer et al. 1997). Unbaited interception traps have not been evaluated. In areas where the beetle is established, visual surveys have been used extensively. For example, in the United Kingdom, regional surveys were conducted by looking for spruce trees with death in the crown (Fielding et al. 1991). These trees were then examined more closely for other signs of infestation, including pitch tubes, loose bark or old galleries.

It may be possible to stratify the landscape into areas where beetle attacks are relatively more likely and where survey efforts should be concentrated. Damaged or forked trees are more likely to be infested than undamaged or straight trees (Fielding et al. 1991). Infestations are also considered likely in stands that meet one or more of the following criteria: “close” to known infestations (distance not specified); thinned within 5 years, more than 19 years-old; close to roads; near new wooden fences that had bark; or within 3 km of a sawmill (Fielding et al. 1991).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Of the 19 species of *Dendroctonus* worldwide, seventeen are indigenous to the United States (Wood 1982, Furniss 1996). The galleries of *D. micans* are similar to those of the North American species *D. rhizophagus*, *D. terebrans*, and *D. valens*. These beetles primarily infest *Pinus* spp., which is a minor host for *D. micans* (reviewed in CAB 2006). *D. micans* may be confused with *D. punctatus*, with which it is “almost identical” (Wood 1982, Bevan and King

1983, Furniss and Johnson 1989, Furniss 1996). Furniss (1996) identified 9 characteristics to differentiate adults of each species. *D. micans* may also be confused with *D. murrayanae* and *D. rufipennis*.

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Hylobius abietis

E.E. Davis, E.M. Albrecht, and R.C. Venette

Fig. 7. Adult *Hylobius abietis*. Image from Gyorgy Csoka, http://www.bugwood.org

Scientific Name

Hylobius abietis (L.)

Synonyms:
Hylobitelus abietis (L.)
Curculio abietis (L.)
Curculio pini (L.)
(reviewed in CAB 2005)

Common Names

Large pine weevil,
large brown pine weevil, fir-tree weevil

Type of Pest

Weevil; stem boring, girdling

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Molytinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2007)

Pest Description

Adult (Fig. 7)
"9-16 mm long, elytra are purple-brown in new adults, turning reddish brown to dark brown. Elytra have patches of long narrow yellow scales (ensiform) arranged in small groups in short irregular lines; surface is finely punctured. Pronotum has irregular patches of yellow ensiform scales, surface is punctured and wrinkled with a raised central line; shape is broader than long, strongly convex and constricted at the front. Head has 2 small patches of yellow scales, is extended to form a long cylindrical snout with mandibles at the tip. Antennae are elbowed and attached to the snout near the end. Legs have sharp claws with a strong tooth on the inner edge of each femur" (PaDIL 2005).

Egg
No unique features of *H. abietis* eggs have been described.

Fig. 8. Larva and pupa of *H. abietis*. Images from Gyorgy Csoka, http://www.bugwood.org

Larva (Fig. 8)
"Fully grown larvae may be 9.5-16 mm in length" (Day et al. 2004). Larvae are typical of the genus *Hylobius*. Lekander (1977) provides a description.

Pupa (Fig. 8)
No unique features of *H. abietis* pupae have been described.

Biology and Ecology

The biology of *H. abietis* is most recently reviewed by Leather et al. (1999) and Day et al. (2004).

H. abietis can live for 3-4 years or more (Guslits 1968). In Europe, the time from egg hatch to first reproduction is generally 2 years (reviewed in CAB 2005). However, development depends largely on host quality, temperature, and time of oviposition. Populations vary in size depending largely on the availability, age, and condition of host trees (Guslits 1968). In Europe, population density estimates for *H. abietis* adults in clear-cuttings have ranged from 14,000 to 220,000 ha^{-1} (Day et al. 2004).

Adult activity is strongly influenced by temperature, light and humidity. Adults are most active at early dawn and dusk when air temperatures are between 17-21°C [63-70°F] and relative humidity is high (85-95%). Activity decreases with air temperatures above 25°C [77°F]. Females are considered more "hygronegative" than males and avoid humidity extremes. Adult weevils emerge at the end of summer or in spring when temperatures rise above 8-9°C [46-48°F].

Flight occurs at temperatures above 18-19°C [64-66°F] and wind velocity of 3-4 $m\ s^{-1}$ [7-9 miles per h] (Day et al. 2004). Adults disperse in search of new hosts to feed until maturation in tree crowns (Guslits 1968, Bylund et al. 2004, Day et al. 2004, Wainhouse et al. 2004). Weevil flight muscles degenerate 2-3 weeks following dispersal. Adults are considered "photopositive" at the beginning of their dispersive period and "photonegative" at the end (Day et al. 2004). In Europe, adult weevils migrate by flight for about two weeks during late May and early June (Solbreck and Gyldberg 1979, Solbreck 1980). Weevils have been reported to migrate anywhere from tens of meters to hundreds of kilometers (Rose et al. 2005) at wind speeds up to 3 m/s (Day et al. 2004). This depends mainly on host availability and wind-assisted flight (Day et al. 2004). Adults of *H. abietis* are capable of flight up to 30-50 m above the forest canopy (Day et al. 2004).

Adults mate multiple times. Oviposition by weevils depends largely on temperature but generally occurs throughout the entire adult life span of about 1-3 years (Lekander et al. 1985). In spring, oviposition begins about 2 weeks after emergence. Reproduction is terminated in late summer, presumably triggered by shortened day length and cooler temperatures (Guslits 1968, Lekander et al.

1985, Wainhouse et al. 2001, Day et al. 2004). According to Guslits (1968), sexual maturity is achieved at the expense of fat body (energy) reserves, and oviposition ceases when energy reserves are exhausted. Fecundity depends on weevil age, size and host quality (Guslits 1968, Wainhouse et al. 2001, Day et al. 2004). Weevils oviposit during the summer months in the first year following clear-cutting. Oviposition peaks in June at a temperature of 22°C [72°F] (Lekander et al. 1985, Day et al. 2004). Adults overwinter in pupal chambers, in litter, or below the soil surface when temperatures fall below 8°C [46°F] (Leather et al. 1999, Day et al. 2004). Adults completing development before fall may emerge and maturation feed before overwintering in litter (Day et al. 2004). The sex ratio for *H. abietis* is 1:1 but may vary depending on the season (Leather et al. 1999).

Eggs are deposited in any woody tissue in contact with soil, including roots, felled stems, or stumps (Wainhouse et al. 2001). Slits are made in the bark of the trunk below ground (often the root collar or root) and eggs are deposited singly or in small, irregular groups. Eggs may also be deposited in the soil a short distance away from host roots. Under experimental conditions, deposition depth varies by soil type and ranges from 25-150 cm [10-60 in], with the majority close to the soil surface (within 10 cm [4 in]) in moist sand (Pye and Claesson 1981, Day et al. 2004). Under field conditions, eggs were deposited in peat 20-30 cm [8-12 in] beneath host roots (Day et al. 2004). One female produces between 22-71 eggs (Wainhouse et al. 2001, Day et al. 2004).

Larval development is highly variable (1-5 years) depending on several factors including host quality (Day et al. 2004). There are 5 instars. If oviposition occurs in soil, newly hatched larvae will move toward host roots to begin feeding. If oviposition occurs at or above the soil surface, larvae will bore long irregularly-shaped tunnels in the cambial region and move toward the roots (Day et al. 2004). This insect overwinters in the third or fourth larval instar or adult stages (Day et al. 2004).

Overwintering larvae can generally survive temperatures of -12 to -19°C [-2-10°F] (Day et al. 2004). Larvae have an average supercooling point of -12.6°C [9°F] (Leather et al. 1999). First instar larvae experience facultative pre-pupal diapause when temperatures fall below a threshold of 21°C [70°F], and overwinter in a quiescent state. Late instar larvae overwinter in diapause. Under experimental conditions, diapause was terminated 6 months following oviposition for larvae developing at 12°C [10°F]; however, requirements for diapause are not well known for this insect (Day et al. 2004).

Pupation occurs within 1-2 years of egg deposition depending on host quality and microclimate. Larvae pupate within oval pupal chambers that are excavated inside the bark (Day et al. 2004).

Pest Importance

Hylobius abietis can be an economically important pest of young conifer plantations in Europe and Asia, causing more than $1 million in damage annually (reviewed in Leather et al. 1999). In the United Kingdom, estimated annual control costs to the public and private forest industry totaled the equivalent of nearly $6.5 million USD in 1999, excluding replanting costs (reviewed in CAB 2005). *H. abietis* is especially problematic to newly-planted hosts near 2-3 year-old stumps or trees with downed or damaged branches (reviewed in Leather et al. 1999, reviewed in CAB 2005). Damaged tissue may release chemicals that attract emerging adults from infested trees to new hosts. Chemical control is routinely used to protect transplanted seedlings and is thought to significantly impact the environment and pose a health risk to forest workers (reviewed in Leather et al. 1999).

Seedling mortality caused by *H. abietis* and associated pathogens is lower in undisturbed natural areas than in forest plantations (Leather et al. 1999). In areas where *H. abietis* is established, control measures are recommended to prevent significant loss of newly planted seedlings (reviewed in Leather et al. 1999, reviewed in Ciesla 2001). Without control measures, plantations less than 2 years old have suffered 30-100% seedling mortality (reviewed in Ciesla 2001, reviewed in CAB 2005).

The extent of damage caused by this pest and associated pathogens is highly variable and not well understood (reviewed in Leather et al. 1999, reviewed in CAB 2005). Damage depends on numerous factors, including new host availability, age and health of transplanted seedlings, silvicultural practices (e.g., clear cutting), damage from other insect pests, and wind or lightning damage (Leather et al. 1999, reviewed in Ciesla 2001, reviewed in CAB 2005). The amount of seedling mortality that can be attributed to associated fungi is not fully known, but mortality may increase when trees are subjected to fungal infection and damage from insect feeding (reviewed in Leather et al. 1999). Adults emerging from infected trees may transmit these fungi while feeding on new hosts. Feeding wounds create an opportunity for fungal infection, particularly by *Heterobasidion annosum* and *Leptographium procerum* (Kadlec et al. 1992, Viiri 2004). See ‘Known Vectors.’

Symptoms

Young trees may exhibit signs of decline resulting from feeding damage by *Hylobius abietis* and/or infection by associated fungi (Leather et al. 1999, Day et al. 2004). External symptoms include feeding damage, dieback of affected branches, and death. Adults feed at the base and roots of transplanted seedlings and in the crown of mature trees (Schlyter 2004). Feeding on the main stem or lateral shoots can cause a characteristic “shepherd’s crook”, which can be confused with damage caused by *Tomicus piniperda* (pine shoot beetle). Heavy infestations can result in stem girdling and subsequent death (reviewed in

Leather et al. 1999, reviewed in Ciesla 2001, reviewed in CAB 2005). Maturation feeding occurs on small stems, twigs, and roots of standing trees and on remnant plant material from felled trees (reviewed in Leather et al. 1999, Wainhouse et al. 2004, Lof et al. 2005). If bark near the root collar is peeled back, long, irregularly-shaped tunnels that extend through the cambium toward the roots may be evident. Periodic fresh air "ducts" are also built between the excavated tunnel and bark surface (Day et al. 2004). The depth to which larvae tunnel depends on bark thickness and climate. In species with thin bark, pupal chambers may be constructed in wood and sealed with excavated wood chips (Day et al. 2004).

Known Hosts

Hylobius abietis is polyphagous, though its preferred host genera are *Pinus* and *Picea* (Lindelöw and Björkman 2001, Toivonen and Viiri 2006). Lof et al. (2004, 2005) found *Hylobius abietis* strongly prefers Norway spruce (*Picea abies*) to deciduous tree species such as beech, oak, ash, cherry, lime, and maple. However, adults will feed on silver birch (*Betula pendula*) even when coniferous hosts are available (Toivonen and Viiri 2006). Borg-Karlson et al. (2006) list Scots pine (*Pinus sylvestris*) as the preferred host. When there is food of similar quality above and below ground, adult *H. abietis* prefer to feed underground (Wallertz et al. 2006).

Host	**Reference**
Acer platanoides (Norway maple)	(Lof et al. 2005)
Acer pseudoplatanus (sycamore maple)[1]	(Manlove et al. 1997, Toivonen and Viiri 2006)
Alnus glutinosa (European alder)	(Lof et al. 2004, Lof et al. 2005, Toivonen and Viiri 2006)
Betula spp. (birch)	(Toivonen and Viiri 2006)
Betula pendula (common silver birch) [1]	(Manlove et al. 1997, Lof et al. 2004, reviewed in CAB 2005, Toivonen and Viiri 2006)
Calluna vulgaris (heather)	(Wallertz et al. 2006)
Fagus sylvatica (common beech)	(Lof et al. 2004, reviewed in CAB 2005, Toivonen and Viiri 2006)
Fraxinus excelsior (European ash) [1]	(Manlove et al. 1997, Lof et al. 2004, Lof et al. 2005, Toivonen and Viiri 2006)
Larix spp. (larch)	(Lof et al. 2004, reviewed in CAB 2005)
Larix decidua (European larch)	(reviewed in CAB 2005)
Picea spp. (spruce)	(Zumr and Starý 1992, Ciesla 2001, reviewed in CAB 2005)
Picea abies (Norway spruce)	(Manlove et al. 1997, Orlander and Nordlander 2003, Petersson and Orlander 2003, Lof et al. 2004, reviewed in CAB 2005, Lof et al.

Host	**Reference**
	2005, Zas et al. 2006)
Picea stichensis (Sitka spruce)	(Moore et al. 2004, reviewed in CAB 2005, Rose et al. 2006)
Pinus spp. (pine)	(Zumr and Starý 1992, Ciesla 2001, reviewed in CAB 2005)
Pinus contorta (lodgepole pine)	(Bratt et al. 2001, Lindelöw and Björkman 2001, reviewed in CAB 2005, Dillon et al. 2006)
Pinus pinaster (maritime pine)	(Ciesla 2001, reviewed in CAB 2005, Zas et al. 2005, Zas et al. 2006)
Pinus strobus (eastern white pine)	(reviewed in CAB 2005)
Pinus sylvestris (Scots pine)	(Leather et al. 1994, Manlove et al. 1997, Bratt et al. 2001, Ciesla 2001, Hannerz et al. 2002, Petersson and Orlander 2003, Lof et al. 2004, reviewed in CAB 2005, Heijari et al. 2005, Rose et al. 2005, Borg-Karlson et al. 2006, Dillon et al. 2006, Zas et al. 2006)
Populus tremula x tremuloides (hybrid aspen)	(Toivonen and Viiri 2006)
Prunus avium (sweet cherry)	(Lof et al. 2004, Lof et al. 2005)
Prunus padus (bird cherry)	(Toivonen and Viiri 2006)
Pseudotsuga menziesii (Douglas-fir)	(Ciesla 2001, reviewed in CAB 2005)
Quercus robur (common oak)	(Lof et al. 2004, reviewed in CAB 2005, Lof et al. 2005, Toivonen and Viiri 2006)
Salix spp. (willow)	(Toivonen and Viiri 2006)
Tilia cordata (lime)	(Lof et al. 2004, Lof et al. 2005)
Vaccinium myrtillis (bilberry)	(Toivonen and Viiri 2006, Wallertz et al. 2006)

1. Mortality of adults feeding on these species is greater than 70% (Manlove et al. 1997).

Known Vectors

H. abietis is associated with a number of potentially pathogenic fungi including *Graphium canum*, *Heterobasidion annosum*, *Leptographium alethinum*, *L. procerum*, *L. wingfieldii*, and *Ophiostoma piliferum* (Viiri 2004). See 'Pest Importance.'

Heterobasidion annosum is a fungal pathogen of conifers, particularly pines and firs (Viiri 2004). Kadlec et al. (1992) found live spores of *H. annosum* on the body surface and in the excrement of *Hylobius abietis*. Larvae have also been found in *Pinus sylvestris* roots infected with *H. annosum* (Viiri 2004).

Leptographium procerum, a fungus associated with bark beetles and weevils, causes root decline in *Pinus strobus* and other conifers (Jacobs and Wingfield 2001). Its pathogenicity has been debated (Jacobs and Wingfield 2001). Spores of *L. procerum* are carried on the pronotum of male and female *H. abietis* (Viiri 2004). Leather et al. (1999) suggest *L. procerum* is transmitted by adults during feeding, leading to increased seedling mortality.

Leptographium alethinum has been isolated from galleries of *H. abietis* in the UK (Viiri 2004). In France, *Leptographium wingfieldii*, *Graphium canum*, and *Ophiostoma piliferum* have been isolated from newly emerged weevils (Viiri 2004).

Known Distribution

Location	**Reference**
Australasia	
New Zealand[1]	(reviewed in CAB 2005)
Asia	
Armenia	(reviewed in CAB 2005)
Azerbaijan	(reviewed in CAB 2005)
China	(Ciesla 2001, reviewed in CAB 2005)
Georgia (Republic)	(reviewed in CAB 2005)
Japan	(Schwenke 1974, reviewed in CAB 2005)
Kazakhstan	(Schwenke 1974, reviewed in CAB 2005)
Tajikistan	(Schwenke 1974)
Turkey	(reviewed in CAB 2005)
Europe	
Austria	(Schwenke 1974, reviewed in CAB 2005)
Belarus	(reviewed in CAB 2005)
Belgium	(Schwenke 1974, reviewed in CAB 2005)
British Isles	(Ciesla 2001)
Bulgaria	(Schwenke 1974, reviewed in CAB 2005)
Czech Republic	(reviewed in CAB 2005)
Czechoslovakia (former)	(Schwenke 1974, Zumr and Starý 1992, reviewed in CAB 2005)
Denmark	(Schwenke 1974, reviewed in CAB 2005)
England	(Schwenke 1974)
Estonia	(reviewed in CAB 2005)

Location	Reference
Finland	(Schwenke 1974, reviewed in CAB 2005, Pitkanen et al. 2005)
France	(Schwenke 1974, Ciesla 2001, reviewed in CAB 2005)
Germany	(Schwenke 1974, reviewed in CAB 2005)
Hungary	(Schwenke 1974, reviewed in CAB 2005)
Ireland	(Schwenke 1974, Dillon et al. 2006)
Italy	(reviewed in CAB 2005)
Latvia	(reviewed in CAB 2005)
Lithuania	(reviewed in CAB 2005)
Moldova	(reviewed in CAB 2005)
Netherlands	(Schwenke 1974, reviewed in CAB 2005)
Norway	(Schwenke 1974, reviewed in CAB 2005)
Poland	(Schwenke 1974, reviewed in CAB 2005)
Romania	(Schwenke 1974, reviewed in CAB 2005)
Russia	(Schwenke 1974, Ciesla 2001, reviewed in CAB 2005)
Scotland	(Schwenke 1974)
Slovakia	(reviewed in CAB 2005)
Slovenia	(reviewed in CAB 2005)
Spain	(Schwenke 1974, Ciesla 2001, reviewed in CAB 2005)
Sweden	(Schwenke 1974, Lof et al. 2004, reviewed in CAB 2005, Nordlander et al. 2005, Wallertz et al. 2006)
Switzerland	(reviewed in CAB 2005)
Ukraine	(reviewed in CAB 2005)

1. Formerly present (reviewed in CAB 2005).

Potential Distribution within the United States

The known distribution of *H. abietis* suggests that the insect may be most closely associated with two biomes: (1) temperate broadleaf and mixed forests; and (2) temperate grasslands, savannahs, and shrublands. Both biomes occur in the contiguous United States and account for approximately 60% of the area, particularly in the East.

Survey

Sampling for *Hylobius abietis* will be difficult, as newly emergent adults are proficient at avoiding traps (Moore 2001) and larvae are able to burrow into sandy soils (Nordenhem and Nordlander 1994, Nordlander et al. 2003b). Surveys should be undertaken in clear-cuttings where *Pinus sylvestris* or *Picea abies* have subsequently been planted, as the roots of conifer stumps provide a breeding ground for the weevils (Nordlander et al. 2003b). Adults will not leave a site once they have entered it (Rose et al. 2005). Nordlander et al. (2003a) found *H. abietis* is more likely to feed on trees toward the center of a clear-cutting, rather than on the edges.

Preferred Method: Pitfall traps baited with α-pinene and ethanol are often used to monitor populations of *H. abietis* (Mustaparta 1975, Zumr and Starý 1992, Nordenhem and Nordlander 1994, Lof 2000, Schlyter 2004). These compounds are more attractive to larvae when used together, though ethanol alone will also attract *H. abietis* (Nordenhem and Nordlander 1994, Schlyter 2004). However, α-pinene alone will not (Lindelöw et al. 1993). Larvae are able to migrate through sandy soils and orient themselves to host odors (Nordenhem and Nordlander 1994).

Bjorklund et al. (2003) used pitfall traps consisting of polyethylene terephthalate (PET) bottles with a wounded *Picea abies* seedling in the center. The bottles are filled to 6 cm from the top with water and a drop of detergent. Water and ethylene glycol are equally effective collecting fluids for *H. abietis* (Voolma and Sibul 2006). Voolma and Sibul (2006) used a similar pitfall trap, but replaced the spruce seedling with a 6.5 ml vial of turpentine and ethanol (1:5 v/v).

Adults of *H. abietis* are attracted to volatiles from freshly-cut trees (Kindvall et al. 2000, Borg-Karlson et al. 2006) and are often seen swarming around sawmills where fresh conifer logs are processed (Schlyter 2004). *H. abietis* is also attracted to spruce turpentine, which contains α-pinene, β-pinene, and 3-carene (Lindelöw et al. 1993).

No long-range aggregation or sex pheromones of *H. abietis* have been identified. Tilles et al. (1988) found a close-range mating stimulant in female and young male pine weevils, but it is unlikely that this sex attractant can be used for mass-trapping or mating disruption (Schlyter 2004). Kalo and Nederstrom (1986) identified four female-specific compounds in the ovaries of adult *H. abietis*, but they appear to play a minor role in attracting males. To date, no work has been done to develop a pheromone-based trap for *H. abietis*.

Alternative Method: Moore (2001) developed a trap (Fig. 9) to collect newly emergent adults of *H. abietis* in clear-cuttings. The trap consists of a pyramid formed by four metal poles covered in fiberglass netting, which is placed over a cut stump. The net and poles are buried 15 cm deep in the soil. A drainpipe with two loops of copper foil is placed at the top and the foil loops are connected to two 9-V batteries in series. A funnel and a 3-L PET bottle are suspended by chains inside the trap. Additional details for the construction of a trap are provided by Moore (2001). When an adult emerges from the soil, it crawls up the netting and contacts the electrified copper loops. This causes the weevil to "feign death by becoming rigid" and fall into the collecting vessel (Moore 2001). This trap is effective at capturing all life stages of the weevil (Day et al. 2004).

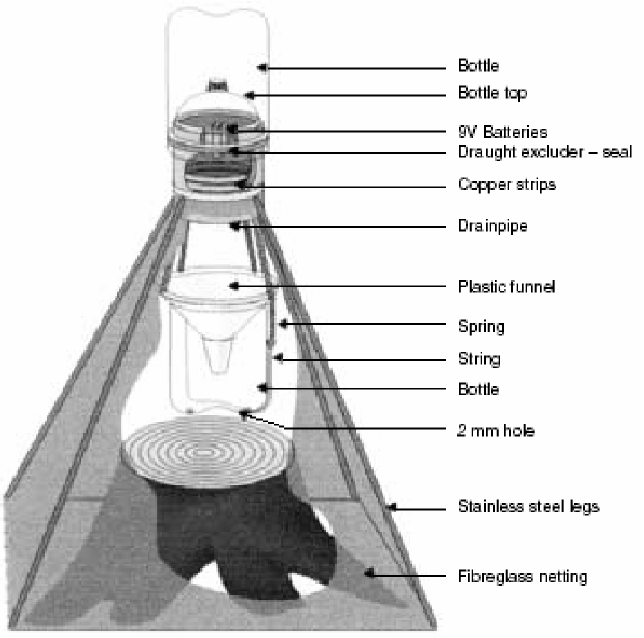

Fig. 9. Diagram of *H. abietis* emergence trap. Image reproduced from Moore (2001).

Alternative Method: Weevils can also be collected in suction traps (Solbreck and Gyldberg 1979) and trap logs (Manlove et al. 1997, Day et al. 2004). Day et al. (2004) recommend against the use of trap logs in favor of covered pitfall traps.

Not Recommended: Soil sampling can be performed in clear-cuttings. Larvae can be sampled within 10 cm of the soil surface and within 70 cm of host tree trunks (Day et al. 2004).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Hylobius abietis could be confused with the congeneric species *H. congener* and *H. pales*, which "fill a similar niche" (Drooz 1985, Leather et al. 1999, Petersson and Orlander 2003, Rose et al. 2005). Both *H. congener* and *H. pales* exist in the United States (Dixon and Foltz 1990, Nordlander et al. 2003b). *H. abietis* also closely resembles all *Pissodes* sp., particularly *P. castaneus* and *P. pini* (reviewed in CAB 2005).

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Hylurgops palliatus

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Fig. 10. Adult *Hylurgops palliatus*. Photo by Kent Loeffler, http://www.bugwood.org

Scientific Name

Hylurgops palliatus Gyllenhal

<u>Synonyms:</u>
Bostrichus abietiperda Bechstein
Hylastes abietiperda Bechstein
Hylastes fuscus Duftschmidt
Hylastes helferi Villa
Hylesinus palliatus Gyllenhal
Hylesinus fuscus Duftschmidt
Hylesinus marginatus Duftschmidt
Hylesinus abietiperda Bechstein
Hylesinus piceus Marsham
Hylesinus rufus Marsham
Hylesinus helferi Villa
Hylesinus rufescens Stephens
Hylurgops parvus Eggers
Hylurgus helferi Villa
Hylurgus rufescens Stephens
Ips piceus Marsham
Ips rufus Marsham
(Grüne 1979, reviewed in Dumouchel 2004 and CAB 2006)

Common Names

Lesser spruce shoot beetle, shoot beetle

Type of Pest

Bark and cambium boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Scolytidae, **Subfamily:** Hylesininae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

"*Hylurgops palliatus* superficially resembles other scolytids in the subfamily Hylesininae. Some of the more obvious characters are:

- elytral apex rounded, not excavated, and without marginal teeth.
- elytral basal margin raised with series of marginal flattened granules (crenulations).

- pronotum usually unarmed and with an anterior constriction.
- head usually visible from above" (Cavey et al. 1994).

Adult (Fig. 10)
"The head, underside of body and edges of elytra are blackish, the remaining parts brown, dark brown or reddish-brown in color. [Adults] are usually 2.5-3.4 mm long with a broad thorax that narrows down at the front. The head is usually visible from above. Eyes are entire and not divided" (Dumouchel 2004).

"Pronotum is wide and short, getting much narrower in the apical part, densely punctured with smooth middle line. Elytrae are about 2.5 times longer than pronotum, with uniseriate rows of dots" (Kolk and Starzyk 1996).

"Interstriae as wide as striae, with short, filiform setae, and rows of granules; pronotum slightly narrower than elytra; lateral pronotum roughly punctured" (Grüne 1979).

Egg
"Eggs are a pearly white in color" (Dumouchel 2004).

Larva
"Larvae are white, c-shaped, legless grubs with an amber colored head capsule. Larvae are similar to the closely related species, *Hylurgops glabratus* from which it can be distinguished by its smaller size and other minor characteristics" (Dumouchel 2004).

Pupa
"The pupae are white, mummy-like and have some adult features including wings that are folded behind the abdomen" (Dumouchel 2004).

Biology and Ecology

The following information on the biology and ecology of *Hylurgops palliatus* is reviewed in CAB (2005) and Dumouchel (2004). *H. palliatus* has 1-2 generations annually. With the exception of a brief period of adult dispersal, the majority of its life cycle is carried out beneath the bark of its conifer host. *H. palliatus* overwinter as late instar larvae or in the adult stage in galleries, under the bark surface, or at the base of trees in wood boring dust, forest litter, or soil.

Adult emergence and flight occurs in spring and late summer or fall, depending on temperature. Flight occurs in spring when air temperature reaches between 6-8°C. However, peak flight activity occurs between 15-25°C. Second generation adults overwinter in or near the natal host material and do not fly long distances. *H. palliatus* is monogamous and prefers to breed in moist and shady conditions. Adults will bore into the lower portion of stems from the root collar to approximately two meters above the soil line, or the underside of fallen boles and branches in contact with the ground. Adult beetles feed on phloem until they reach reproductive maturity. Adults maturation-feed individually or in groups, often within the host where they originally developed. Once maturation feeding is complete, females construct egg galleries between the bark and cambium. Galleries run 3-5 cm longitudinally above and below the entrance hole, where the gallery is widest. Eggs are laid in small, irregular groups along niches extending from each side of the gallery and are covered by a layer of fine wood boring dust. Eggs will typically be laid in stumps, cut logs, or the base of stressed/dead trees (Dumouchel 2004). One female can lay up to 63 eggs, with a mean of approximately 38.

Larvae hatch, bore long, winding galleries perpendicular to the wood grain, and feed until maturation. Because they feed gregariously, individual galleries become difficult to distinguish. There are four larval instars.

Pupation occurs late in the summer, followed by adult emergence in fall or the following spring.

Pest Importance

H. palliatus is considered a secondary or minor pest of *Pinus* and attacks cut, stressed, dead, or dying conifer hosts. Maturation feeding by adults and developing larvae occurs within the cambial region and can result in girdling of a living tree host (Volz 1988, Lindelöw et al. 1992, Schroeder et al. 1999, reviewed in Dumouchel 2004 and CAB 2006). Fungi associated with bark beetles may help the insects overcome host tree defenses (Sauvard 2004).

Little is known about the extent and frequency of damage (e.g., visible blue stain or necrotic tissue) caused by this secondary pest and its fungal associates. However, the majority of the pathogens associated with this nonaggressive pest are currently considered economically unimportant (Krokene and Solheim 1996). *Leptographium procerum* is a weakly pathogenic fungus associated with bark beetles and curculionids (Viiri 2004). In the eastern United States, it is found in a range of conifers and causes root decline in *Pinus strobus* (Viiri 2004).

There are no known reports of this bark beetle causing harm to the environment (reviewed in Dumouchel 2004).

Symptoms

Hylurgops palliatus attacks stems of *Pinus* spp. with thick bark, usually near the tree base or exposed areas of the root collar, or in moist shaded areas near the ground. External evidence of feeding by *H. palliatus* includes discoloration of stems and reddish-orange colored boring dust or pitch tubes on the bark surface. The gallery system constructed beneath the bark surface provides additional evidence of attack. Secondary infection of vascular tissue by blue-stain fungi may be observed. Adult females construct long, curving galleries in the inner bark and may etch the outer sapwood. Egg galleries are perpendicular to feeding galleries. Individual galleries converge and become difficult to distinguish. The gallery pattern is not considered diagnostic for this species (reviewed in Dumouchel 2004 and CAB 2006).

Known Hosts

Hylurgops palliatus is oligophagous on conifers in the family Pinaceae (Lindelöw and Björkman 2001, reviewed in Dumouchel 2004), though it prefers dead or dying *Picea abies* (Volz 1988, Kohnle 2004). Kolk and Starzyk (1996) report *H. palliatus* as feeding on "all coniferous species except yew."

Host	**Reference**
Abies spp. (fir)	(reviewed in Dumouchel 2004)
Abies alba (=*Abies pectinata*) (silver fir)[1]	(Grüne 1979, reviewed in Dumouchel 2004 and CAB 2006)
Abies cilicica	(reviewed in Dumouchel 2004)
Abies nordmanniana (=*Abies bornuelleriana*) (Nordmann fir)[1]	(Grüne 1979, reviewed in Dumouchel 2004 and CAB 2006)
Abies sachaliensis	(reviewed in Dumouchel 2004)
Abies sibirica (Siberian fir)	(reviewed in Dumouchel 2004 and CAB 2006)
Cedrus spp. (cedar)	(reviewed in Dumouchel 2004)
Juniperus communis (common juniper)	(reviewed in CAB 2005)
Larix spp. (larch)	(reviewed in Dumouchel 2004)
Larix decidua (=*Larix europaea*) (common larch)[1]	(Grüne 1979, reviewed in Dumouchel 2004 and CAB 2006)
Larix gmelinii (Dahurian larch)	(reviewed in Dumouchel 2004 and CAB 2006)
Larix sibirica (Siberian larch)	(reviewed in Dumouchel 2004 and CAB 2006)
Picea spp. (spruce)	(Grüne 1979, reviewed in Dumouchel 2004)
Picea abies (=*Picea excelsa*) (Norway spruce)	(Volz 1988, Lindelöw et al. 1992, Krokene and Solheim 1996, Peltonen and Heliövaara 1999, Schroeder et al. 1999, reviewed in Dumouchel 2004, Kohnle 2004, reviewed in CAB 2005)
Picea glehnii (Sakhalin spruce)	(reviewed in Dumouchel 2004 and CAB 2006)
Picea jezoensis (=*Pinus microsperma*) (Yeddo spruce)	(reviewed in Dumouchel 2004 and CAB 2006)
Picea koraiensis (Korean spruce)	(reviewed in Dumouchel 2004 and CAB 2006)
Picea obovata (Siberian spruce)	(reviewed in Dumouchel 2004 and CAB 2006)
Picea omorika (Pancic spruce)	(reviewed in Dumouchel 2004 and CAB 2006)

Host	**Reference**
Picea orientalis (oriental spruce)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus spp. (pine)[1]	(Grüne 1979, reviewed in Dumouchel 2004)
Pinus cembrus (arolla pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus contorta (lodgepole pine)	(Lindelöw and Björkman 2001)
Pinus leucodermis (=*Pinus heldreichii*) (palebark Heldreich pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus mugo (mountain pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus nigra (black pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus peuce	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus pinaster (maritime pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus pinea (stone pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus pumila (dwarf Siberian pine)	(reviewed in CAB 2006)
Pinus radiata (radiata pine)	(reviewed in Dumouchel 2004)
Pinus sibirica (Siberian stone pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus strobus (eastern white pine)	(reviewed in Dumouchel 2004 and CAB 2006)
Pinus sylvestris (Scots pine)	(Wingfield and Gibbs 1991, Byers 1992, reviewed in Dumouchel 2004, Kohnle 2004)
Pseudotsuga menziesii	(Kohnle 2004)

1. Minor hosts (Grüne 1979)

Known Vectors

Hylurgops palliatus is associated with several species of nematodes, including members of the parasitic genus *Bursaphelenchus*. Many of these species are not currently present in North America (reviewed in Dumouchel 2004 and CAB 2006).

Hylurgops palliatus is associated with a number of opportunistic, sapstain, and potentially pathogenic fungi including *Atractocolax pulvinatus*; *Ceratocystis autographa*, *C. penicilliata*, *C. polonica*; *Chionosphaera cuniculicola*; *Cylindrocarpostylus gregarius*; two unidentified *Graphium* spp.; *Leptographium procerum*, *L. truncatum*, *L. wingfieldii*; an unidentified *Leptographium* sp.; *Ophiostoma europhioides*, *O. neglectum*, *O. penicilliatum*, *O. piceae*; an unidentified *Ophiostoma* sp.; and *Phialocephala trigonospora* (Wingfield and Gibbs 1991, Krokene and Solheim 1996, reviewed in Dumouchel

2004 and CAB 2006). Adults emerging from infected trees are thought to transmit these fungi while feeding on newly selected hosts.

Known Distribution

Location	**Reference**
Africa	
Algeria	(reviewed in Dumouchel 2004 and CAB 2006)
Asia	
China	(reviewed in Dumouchel 2004 and CAB 2006)
Georgia (Republic)	(reviewed in Dumouchel 2004 and CAB 2006)
Japan	(reviewed in Dumouchel 2004 and CAB 2006)
Korea	(reviewed in Dumouchel 2004 and CAB 2006)
Turkey	(reviewed in Dumouchel 2004 and CAB 2006)
Europe	
Austria	(reviewed in Dumouchel 2004 and CAB 2006)
Belarus	(reviewed in CAB 2005)
Belgium	(reviewed in Dumouchel 2004 and CAB 2006)
Bulgaria	(reviewed in Dumouchel 2004 and CAB 2006)
Czech Republic	(reviewed in Dumouchel 2004 and CAB 2006)
Czechoslovakia (former)	(reviewed in CAB 2005)
Denmark	(reviewed in Dumouchel 2004 and CAB 2006)
England	(reviewed in Dumouchel 2004)
Estonia	(Voolma et al. 2001, reviewed in Dumouchel 2004 and CAB 2006)
Finland	(Peltonen and Heliövaara 1999, reviewed in Dumouchel 2004 and CAB 2006)
Former Yugoslavia	(reviewed in Dumouchel 2004 and CAB 2006)
France	(reviewed in Dumouchel 2004 and CAB 2006)
Germany	(Volz 1988, Kohnle 2004, reviewed in Dumouchel 2004 and CAB 2006)

Location	**Reference**
Hungary	(reviewed in Dumouchel 2004 and CAB 2006)
Ireland	(reviewed in Dumouchel 2004 and CAB 2006)
Italy	(reviewed in Dumouchel 2004 and CAB 2006)
Latvia	(reviewed in Dumouchel 2004 and CAB 2006)
Lithuania	(reviewed in Dumouchel 2004 and CAB 2006)
Netherlands	(reviewed in Dumouchel 2004 and CAB 2006)
Norway	(Krokene and Solheim 1996, reviewed in Dumouchel 2004 and CAB 2006)
Poland	(reviewed in Dumouchel 2004 and CAB 2006)
Romania	(reviewed in Dumouchel 2004 and CAB 2006)
Russia	(reviewed in Dumouchel 2004 and CAB 2006)
Scotland	(reviewed in Dumouchel 2004)
Slovakia	(reviewed in Dumouchel 2004 and CAB 2006)
Spain	(reviewed in Dumouchel 2004 and CAB 2006)
Sweden	(Byers 1992, Lindelöw et al. 1992, Schroeder et al. 1999, Lindelöw and Björkman 2001, reviewed in Dumouchel 2004)
Switzerland	(reviewed in Dumouchel 2004 and CAB 2006)
Ukraine	(reviewed in CAB 2005)
United Kingdom	(Wingfield and Gibbs 1991, reviewed in Dumouchel 2004 and CAB 2006)
North America	
United States[1]	(reviewed in CAB 2005)
NY	(Hoebeke and Acciavatti, 2006)
OH	(Hoebeke and Acciavatti, 2006)
PA[2]	(Haack 2001, reviewed in Dumouchel 2004, Hoebeke and Acciavatti, 2006)

1. Introduced, invasive (reviewed in CAB 2005).
2. Adults captured in 2001 (Hoebeke and Acciavatti, 2006). May be established.

Potential Distribution within the United States

The known distribution of *H. palliatus* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Both biomes account for approximately 47% of the area and are generally found east of the Mississippi River, and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Like many other scolytids, adults of *H. palliatus* are attracted to volatiles from dead or dying conifers. It will feed on live trees, but strongly prefers stored, debarked wood (Lindelöw et al. 1992). Adults can fly several kilometers in search of suitable hosts and may be wind-dispersed (reviewed in Dumouchel 2004). Byers et al. (1989) captured adult *H. palliatus* in sticky traps at heights up to 11.5 m above ground, but found most fly at a lower height (Byers et al. 1989).

Preferred Method: Traps baited with α- or β-pinene and ethanol are very effective at capturing this beetle, with β-pinene being the more attractive of the two terpenes (Volz 1988, Lindelöw et al. 1992, Kohnle 2004, Hoebeke and Acciavatti, 2006). High concentrations of α-pinene are repellent to *H. palliatus* (reviewed in CAB 2005). *H. palliatus* is attracted to ethanol alone and increasing concentrations of this alcohol enhance the attractivity of the host monoterpenes (Volz 1988). Stored wood releases ethanol and acetaldehyde, which increase its attractivity to *H. palliatus* (Lindelöw et al. 1992).

Volz (1988) used flight-barrier traps baited with ethanol and one of eight host terpenes, including (±)-α-pinene, (-)-α-pinene, (-)-β-pinene, myrcene, carene, terpinolene, (-)-myrtenol, and (+)-*trans*-verbenol. The combination of ethanol, β-pinene, and terpinolene attracted the greatest number of beetles (Volz 1988). Byers (1992) found the combination of (±)-α-pinene, carene, and terpinolene to be very attractive to *H. palliatus*. Verbenone has no effect on the response of *H. palliatus* to host volatiles (Byers 1992).

Other studies have used window traps (Byers 1992), Norwegian drainpipe traps baited with ethanol, *Picea abies* bark, and wood particles (Kohnle 2004), or emergence traps (Johansson et al. 2006) to monitor adult *H. palliatus*.

No long-range aggregation or sex pheromones of *H. palliatus* have been identified. Bark beetle species that lack aggregation pheromones tend to be strongly attracted to a combination of ethanol and host tree volatiles (Volz 1988, Byers 1992, Kohnle 2004). Aggregation is diminished by angiosperm (non-host) volatiles (Kohnle 2004).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Hylurgops palliatus may be confused with *H. rugipennis rugipennis*, a species native to western North America, and *H. rugipennis pinifex*, a species native to much of North America. *H. rugipennis pinifex* ranges in size from, 3.7-5.2 mm, and is larger than *H. palliatus*. The interstrial tubercles on *H. rugipennis pinifex* are not uniseriate (Hoebeke and Acciavatti, 2006). *H. palliatus* also resembles *Hylastes* spp. (Cavey et al. 1994).

Grüne (1979) provides a key for distinguishing between *Hylurgops palliatus* and *H. glabratus*. Cavey et al. (1994) also provide a screening aid to tell *H. palliatus* from indigenous North American scolytids. To distinguish *H. palliatus* from *H. rugipennis rugipennis* and *H. rugipennis pinifex*, Hoebeke and Acciavatti (2006) note the following characters for all *Hylurgops*:

> “Scalelike elytral vestiture confined to declivity, or extending anteriorly to middle of elytral disc; interstrial raised tubercles confused, not uniseriate; total length > 3.2 mm”

and for *H. palliatus* specifically:

> “Scalelike elytral vestiture present from base of elytra to apex of declivity, more numerous on apical third; interstrial tubercles in a single row; total length 2.5-3.2 mm; New York, Pennsylvania, and Ohio (introduced from Europe).”

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Hylurgus ligniperda

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UGA2130077

Fig. 11. Adult *Hylurgus ligniperda*. Photo by Kent Loeffler, http://www.bugwood.org

Scientific Name

Hylurgus ligniperda Fabricius

Synonyms:
Hylesinus ligniperda Fabricius
Hylurgus elongatus Herbst
Hylurgus flavipes Panzer
Bostrichus elongatus Herbst
Bostrichus flavipes Panzer
(Grüne 1979, reviewed in Eglitis 2001, and Walker 2006)

Common Names

Red-haired pine bark beetle, red-haired pine beetle, golden-haired bark beetle

Type of Pest

Bark, cambium, and sapwood-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Hylesininae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 11)
"Adult 4.0-5.7 mm, black-brown, cylindrical, covered with rather long reddish hairs. The distinctive, dense hairs are thick, notched and branched. The elytral apex is convex with a slight indentation, and without teeth or other armature" (Walker 2006).

"The hairs are most conspicuous on the posterior slopes of the wing covers" (Anon. 2000).

"Antennae and legs light-brown; funicle 6-segmented; club conical; metathorax as long as abdomen; anterior elytral margin granulate, not ridged; pronotum longer than wide; pronotum and elytra with long, fine, filiform setae; interstriae with dense, filiform setae; sexual dimorphism: ♂ 2nd interstria with granules; monogamous" (Grüne 1979).

Egg

"Eggs are pearly white in color" (Eglitis 2001).

Larva

"The larvae are white, 'C'-shaped grubs with an amber colored head capsule. Mature larvae are from 5 to 8 mm long" (Eglitis 2001).

Pupa

"The pupae are white, mummy-like, and have some adult features, including wings that are folded behind the abdomen" (Eglitis 2001).

Biology and Ecology

Hylurgus ligniperda has 1-5 overlapping generations annually (Tribe 1991a, Tribe 1991b, and reviewed in Eglitis 2001). With the exception of a brief period of adult dispersal and maturation feeding, the majority of its life cycle is carried out under the bark of its conifer host (reviewed in Eglitis 2001). In South Africa, total development time is approximately 10-11 weeks, depending on temperature (Tribe 1991a, 1991b).

Fig. 12. Long, curvy gallery constructed by *Hylurgus ligniperda* adult female. Photo by William M. Ciesla, http://www.bugwood.org

Fig. 13. Galleries constructed by *Hylurgus ligniperda* larvae. Photo by William M. Ciesla, http://www.bugwood.org

H. ligniperda adults are most active when temperatures are cool and humidity is high. Adult emergence and flight occurs from spring to mid-summer and in fall, any time temperatures are between 9-20°C (48-68 °F). However, in areas where overlapping generations of *H. ligniperda* occur, adults may be found throughout the year (Tribe 1991a, 1991b). Adult beetles feed on young shoots until they reach reproductive maturity. Once maturation feeding is complete, females initiate attacks on trees, stumps, cut logs and slash in contact with the ground by constructing a nuptial chamber beneath the bark. *H. ligniperda* is considered monogamous (reviewed in Eglitis 2001). Here, mating occurs, followed by oviposition. Females construct long, curvy egg galleries in the cambial region (Fig. 12). Eggs are laid singly in niches along each side of the gallery (Tribe 1991a, 1991b, Anon. 2000). One female can lay 500 eggs (reviewed in Eglitis 2001).

Larvae hatch and create their own galleries as they feed (Fig. 13); pupation occurs within the galleries (reviewed in Eglitis 2001). Overwintering occurs as larvae, pupae or adults (Reay and Walsh 2001).

Pest Importance

H. ligniperda is noted as a secondary or minor pest of *Pinus* plantations where it has been introduced in Chile, South Africa, Australia, and New Zealand. It causes damage by maturation feeding on seedlings or young shoots and by breeding attacks on stressed or unhealthy trees. Maturation feeding can result in girdling of seedlings and tree death. Larval feeding and development occurs in the cambial region and severe attacks can cause mortality (reviewed in Eglitis 2001).

The severity of damage caused by this pest and its associated pathogens depends on various factors. *Hylurgus ligniperda* will typically attack trees affected by abiotic stressors (e.g., water stress, recent cutting, nutrient availability, fire damage) or biotic stressors (e.g., prior bark beetle attacks, infection by plant pathogens). Repeated attacks exhaust tree defenses and can ultimately kill a tree (Lieutier 2004).

In South Africa, economic damage to conifers is primarily attributed to bluestain and other fungi associated with *H. ligniperda* (Tribe 1991a, 1991b). See 'Known Vectors.' The impact of these fungi on seedling mortality is not well understood. Lieutier (2004) suggests that the rate of decline increases when trees are subjected to a combination of fungal infection and damage from insect feeding. Adults emerging from infected trees are thought to transmit these fungi while feeding on newly selected hosts. Associated fungi are thought to provide an advantage to insect vectors by helping to overcome host tree defenses (Lieutier 2004). The combined damage from bark beetle attack and infection by *Leptographium* spp. is documented as the cause of significant economic losses in European pine forests (Peverieri et al. 2006).

In Chile, *H. ligniperda* has reportedly displaced two introduced bark beetles, *Hylastes ater* and *Orthotomicus erosus*, which occupy a similar ecological niche (reviewed in Eglitis 2001). Thus, *H. ligniperda* may have the potential to displace resident bark beetles. In Sweden, *H. ligniperda* is considered a rare, protected species (CAB 2005).

Chemical control (e.g., spraying with insecticides and fungicides) is thought to pose health risks to humans as well as a significant threat to the environment (reviewed in Eglitis 2001).

Symptoms

External evidence of maturation feeding and mining by adult beetles on young shoots includes discoloration of dying or dead shoots, loosened bark, and tree death. Dark-colored boring dust on the bark surface provides evidence of breeding attacks. The gallery system constructed beneath the bark gives internal evidence of attack. Secondary infection of vascular tissue by blue-stain fungi may be observed in the xylem. Adult females construct long, curving galleries in the inner bark and outer sapwood. Galleries are not considered diagnostic for the species (see Figs 2 and 3) (Anon. 2000). Egg galleries are perpendicular to larval galleries. *H. ligniperda* may attack stems of *Pinus* spp. with thick bark, usually near the tree base or exposed areas of the root collar (reviewed in Eglitis 2001). It may be difficult to distinguish the causes of damage in areas with several populations of bark beetles (Lieutier 2004).

Known Hosts

Host	Reference
Abies spp. (fir)[1]	(Anon. 2000)
Larix spp. (larch)[1]	(Anon. 2000)
Picea spp. (spruce)[1]	(Anon. 2000)
Pinus spp. (pine)	(Grüne 1979)
Pinus brutia (Calabrian pine)	(reviewed in CAB 2005)
Pinus canariensis (Canary Island pine)	(reviewed in CAB 2005)
Pinus elliottii (slash pine)	(reviewed in CAB 2005)
Pinus halepensis (Aleppo pine)	(reviewed in CAB 2005)
Pinus montezumae (montezuma pine)	(reviewed in Walker 2006)
Pinus nigra (black pine)	(reviewed in Walker 2006)
Pinus nigra ssp. *pallasiana* (Cyprus pine)	(reviewed in Walker 2006)
Pinus patula (Mexican weeping pine)	(reviewed in Walker 2006)
Pinus pinaster (maritime pine)	(reviewed in Walker 2006)
Pinus pinea (Italian stone pine)	(reviewed in Walker 2006)
Pinus radiata (radiata pine)	(Tribe 1991a)
Pinus strobus (eastern white pine)	(reviewed in Walker 2006)
Pinus sylvestris (Scots pine)	(reviewed in Walker 2006)
Pseudotsuga menziesii (Douglas-fir)[1]	(Anon. 2000)

1. Not supported by other references. *H. ligniperda* is primarily a pest of pine and “breeds exclusively in the bark of unhealthy *Pinus*” (Tribe 1991b).

Known Vectors

In South Africa, bluestain and other fungi associated with *H. ligniperda* (Tribe 1991a, 1991b), include *Ceratocystiopsis minuta*, *Leptographium procerum*, *L. truncatum* (=*L. lundbergii*), *Ophiostoma galeiformis*, and *O. ips* (reviewed in Eglitis 2001, Zhou et al. 2004).

The spread of *H. ligniperda* to the western United States is a concern because this pest could vector *Leptographium wagneri*, a major root disease of several western pines, and increase the distribution of the less common pathogen, *L. procerum*, to conifer plantations where it has not previously occurred (reviewed in Eglitis 2001). *L. procerum* is a weakly pathogenic fungus associated with bark beetles and weevils (Viiri 2004). It can infect a range of conifers and causes root decline in *Pinus strobus* (Viiri 2004). See 'Pest Importance.'

Known Distribution

Hylurgus ligniperda is native to Eurasia and Africa (Tribe 1991b, reviewed in Petrice et al. 2004) and has been introduced to Australia, Brazil, Canada, Chile, Japan, New Zealand, Sri Lanka, Turkey, United States, and Uruguay (reviewed in Eglitis 2001). Recently established in New York and California, it is the sole representative of the genus in North America (reviewed in Eglitis 2001, Hoebeke 2001). Petrice et al. (2004) note that adults of *H. ligniperda* were collected "as early as 1994", though the first established adult population was not recognized until 2000 (Haack 2006).

Location	Reference
Africa	
Morocco	(reviewed in Walker 2006)
South Africa	(reviewed in CAB 2005)
Swaziland	(reviewed in Eglitis 2001)
Tunisia	(reviewed in CAB 2005)
Australasia	
Australia	(reviewed in Walker 2006)
New Zealand	(reviewed in Walker 2006)
Asia	
China	(reviewed in Walker 2006)
Japan[1]	(reviewed in CAB 2005)
Sri Lanka[1]	(reviewed in CAB 2005)
Turkey	(reviewed in Walker 2006)
Atlantic Islands	
Azores	(reviewed in Walker 2006)
Canary Islands	(reviewed in Walker 2006)
Madeira	(reviewed in Walker 2006)
St. Helena	(reviewed in CAB 2005)
Europe	
Austria	(reviewed in Walker 2006)
Belarus	(reviewed in CAB 2005)
Belgium	(reviewed in Walker 2006)
Czech Republic	(reviewed in Walker 2006)
Denmark	(reviewed in Walker 2006)
England	(reviewed in Walker 2006)

Location	**Reference**
Estonia	(reviewed in Walker 2006)
Finland	(reviewed in Walker 2006)
France	(reviewed in Walker 2006)
Former Yugoslavia	(reviewed in Walker 2006)
Germany	(reviewed in Walker 2006)
Greece	(reviewed in Walker 2006)
Hungary	(reviewed in Walker 2006)
Italy	(reviewed in Walker 2006)
Latvia	(reviewed in Walker 2006)
Lithuania	(reviewed in CAB 2005)
Moldova	(reviewed in CAB 2005)
Netherlands	(reviewed in Walker 2006)
Norway	(reviewed in Walker 2006)
Poland	(reviewed in Walker 2006)
Portugal	(reviewed in Walker 2006)
Russia	(reviewed in Walker 2006)
Spain	(reviewed in Walker 2006)
Sweden	(reviewed in Walker 2006)
Switzerland	(reviewed in Walker 2006)
Ukraine	(reviewed in CAB 2005)
North America	
United States	
NY[2]	(Anon. 2000, reviewed in Walker 2006)
CA[3]	(Petrice et al. 2004, Haack 2006)
South America	
Brazil	(Anon. 2000, reviewed in Walker 2006)
Chile	(Angulo 1996, reviewed in Walker 2006)
Uruguay	(Anon. 2000, reviewed in Walker 2006)

1. Introduced, invasive (reviewed in CAB 2005).
2. Colony of adults discovered in 2000 (Anon. 2000, reviewed in Walker 2006).
3. Established population of adults discovered in 2003 (Haack 2006).

Potential Distribution within the United States

The known distribution of *H. ligniperda* suggests that the insect may be most closely associated with five biomes, four of which occur in the United States: (1) temperate coniferous forests; (2) temperate broadleaf and mixed forests; (3)

Medierranean scrub; and (4) tropical and subtropical moist broadleaf forests. Collectively, these biomes account for approximately 48% of the area of the contiguous United States. These biomes are generally found east of the Mississippi River, along the Pacific Coast, and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Like many other scolytids, adults of *H. ligniperda* are attracted to pine volatiles (Reay and Walsh 2002).

Preferred Method: Traps baited with a combination of α-pinene and ethanol or β-pinene and ethanol are very effective at capturing adults of *H. ligniperda* (Reay and Walsh 2002, Brockerhoff et al. 2006). Both α- and β-pinene are attractive to *H. ligniperda*; however, ethanol has a synergistic effect on these monoterpenes and enhances their attractivity (Reay and Walsh 2002, Petrice et al. 2004). The addition of ethanol suggests adults are inclined to highly stressed, dying, or decomposing host tissue (Reay and Walsh 2002, Schlyter 2004).

Petrice et al. (2004) tested a number of attractants on *H. ligniperda*, including α-pinene, ethanol, α-pinene and ethanol (300 mg/d low-release; 750 mg/d high-release), β-pinene and ethanol (2000 mg/d), and a lure consisting of ipsdienol, *cis*-verbenol, and 2-methyl-3-buten-2-ol. The combination of high-release α-pinene and ethanol was found to be the most attractive lure of this group, while the combination of ipsdienol, *cis*-verbenol, and 2-methyl-3-buten-2-ol was the least attractive (Petrice et al. 2004).

Petrice et al. (2004) also examined the efficiency of three trap designs: 12-unit Lindgren funnel traps, Intercept panel traps, and Theysohn slot-traps. All three were baited with α-pinene and ethanol. Lindgren funnel traps captured the greatest mean number of *H. ligniperda* adults (80 ±12 adults/trap/collection period), with the panel traps and slot-traps collecting less than half the number of adults (Petrice et al. 2004). Petrice et al. (2004) suggest *H. ligniperda* may have been drawn to the cylindrical funnel traps because the beetles “find the silhouette ... the most attractive of the three designs tested.” Brockerhoff et al. (2006) observed that many *H. ligniperda* were captured in unbaited funnel traps, further substantiating the idea that visual cues are involved in host selection.

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

There are no native *Hylurgus* spp. in North America (Cavey et al. 1994). *Hylurgus ligniperda* resembles *Tomicus piniperda*, a scolytid introduced to the United States in 1991 (Haack 2001). Both share several host species, including

Pinus radiata, *P. strobus*, and *P. sylvestris* (Ciesla 2001). *H. ligniperda* is larger and “significantly hairier than *Tomicus piniperda*” (Anon. 2000).

Grüne (1979) provides a key for distinguishing between *H. ligniperda*, *H. longulus*, and *H. micklitzi*. Cavey et al. (1994) also provide a key for exotic bark beetles that includes *H. ligniperda*.

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Ips subelongatus

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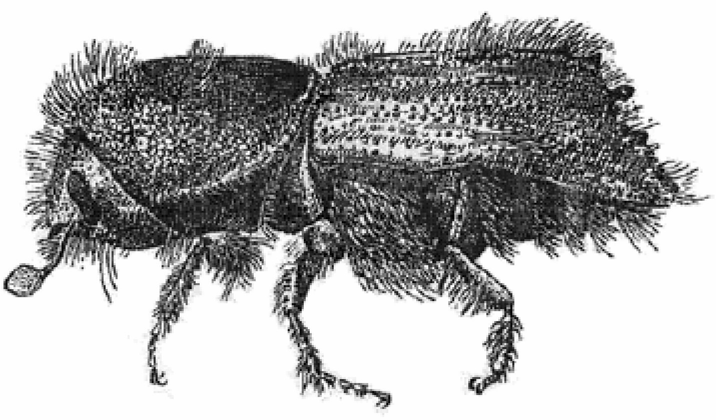

Fig. 14. Adult *Ips subelongatus*. Image from OEPP/EPPO (2005).

Scientific Name

Ips subelongatus Motschulsky

Synonyms:
Ips fallax Eggers
(reviewed in CAB 2005)

Common Names

Asian larch bark beetle, larch engraver beetle, larch bark beetle, oblong bark beetle

Type of Pest

Bark- and cambium-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Scolytinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 14)

“The beetle has an elongated body, 4.5-6.0 mm long. It is brown or dark brown and covered with thick, long, yellow-grey hairs. Frons is covered with small grains, which change into dots on the vertex. Prothorax is not narrower than the elytra. The elytra are about one fifth longer than they are wide. The first half is covered with small denticles, the back half is covered with small dots. There are thick hairs on the front part and sides of the pronotum. The hairs are thin or absent in the middle of the back side. There is no middle strip along the back side of the pronotum. Elytra are characterized by parallel side edges. Their width is equal to the space between the base of the pronotum and the upper edge of the cavity situated on the slope of the elytra (area of thick hairs). Intervals between striae are wide and covered with a number of small thin dots and unclear cross-wrinkles. Sides of elytra and edges of the cavity on their posterior slope are covered with thick long hairs. Hairs of the front and middle parts of elytra are thinner and form small rows on intervals. The cavity is bright and covered with small dots and hairs. There are two hardly visible and isolated small rows formed by hairs close to the suture within the cavity. During the life of the beetles, hairs situated on the cavity break off. There are four well-developed

teeth on the edges of each side of the cavity. They are situated the same distance from each other. The third tooth is larger than the others.
I. subelongatus is variable morphologically. It is possible to find specimens in the same stand that differ in the length and width ratio of the elytra, in degree of hairiness, in size, and also in the location and number of teeth situated on cavity edges of elytra" (CAB 2005).

"The color of just emerged adult changes gradually from milky white to light yellow, yellow, dark brown and black-brown, and its elytrum have [*sic*] changes from soft to hard. Body length of adult is in range of 4.4-6.0 mm. Length of elytron is 1.5 times the pronotum and 1.6 times the two wings' width. There are four independent teeth along each side of wing covers, the first tooth is not very thin, and the distance between the 2nd tooth and 3rd tooth is maximum.
Ips subelongatus has no tumors [*sic*] in center of the lower part of forehead" (Gao et al. 2000).

Egg
"Egg is in ellipse form, 1.1 mm in long diameter and 0.7 mm in short diameter, colored in milky white, a little transparent, and has luster" (Gao et al. 2000).

Larva
"The aging larva is 4.2-6.5 mm in body length, with bending, more folds and bristles on back and presents in milky white. Its head shows gray yellow and yellow brown. Its forehead is in triangle type with a pair of antennas on it. There is a pair of aeropyles on prothorax and each abdominal segment from first to eighth" (Gao et al. 2000).

Pupa
"Body length of pupa is 4.1-6.0 mm, colored in milky white. Feet and wings fold on abdomen. There are two spine-processus [*sic*] on the end of 9th abdomere" (Gao et al. 2000).

Biology and Ecology

Ips subelongatus has 1-2 overlapping generations annually (Gao et al. 2000, reviewed in Orlinski 2004). Development from egg to adult requires 434 degree days (dd) above a temperature threshold of 8.9°C, while egg through pupa requires 310 dd above 8.6°C. Estimates for total development time are based on interpretation of data presented in Gao et al. (2000).

Little has been reported in Western literature about the biology and ecology of *I. subelongatus*. The following information has been compiled from reviews by Orlinski (2004, 2006), CAB (2005) and OEPP/EPPO (2005). *I. subelongatus* overwinters in the adult, pupal, and larval stages. Adults overwinter in pupal chambers, galleries, under the bark of fallen trees in contact with the ground, or in forest litter. Pupae and larvae overwinter inside the tree host. Adults may disperse in search of a new host or attack the same host repeatedly.

There are two flight periods, each lasting approximately 2-3 weeks depending on temperature. In its native range, the first and second flight periods occur in late spring to early summer (mid May to late June) and midsummer (late June to late July), respectively. Flight has been observed at daytime temperatures between 16-20°C. Adults are generally weak fliers and unlikely to disperse more than 1-2 km [~⅔–1½ mi]; however, their dispersal may be aided by wind (reviewed in Orlinski 2004, reviewed in OEPP/EPPO 2005).

Males initiate mating by boring a tunnel about 21 cm [8 in] (range, 9-35 cm [3½ - 14 in]) into the host tree (Gao et al. 2000). Attacks occur preferentially in deep crevices in the bark (Zhang et al. 1992). The male releases the aggregation pheromone ipsenol, which attracts 2-5 females (El-Sayed 2007, Zhang et al. 2007). Production of ipsenol and other volatile compounds varies across attack phases, peaking during the first 4 d following the start of boring. Concentrations of ipsenol reach a high of ~600 ng/male while the nuptial chamber is constructed (Zhang et al. 2000). Qiu et al. (1988) found male beetles start producing pheromone 4 hr after feeding on bark of *Larix dahurica* (=*L. gmelinii*). Ipsenol concentration decreases with multiple matings (Gao et al. 2000).

Adults mate multiple times in nuptial chambers. Females excavate 13-17 cm-long [5-6 in] galleries perpendicular to the nuptial chamber, usually with two galleries extending in one direction and one extending the opposite direction. The size and extent of galleries depends on tree health and population density (reviewed in Orlinski 2004, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005). Females tend to make shorter galleries in more heavily-attacked trees (Zhang et al. 1992). Galleries of *Ips subelongatus* are similar to those excavated by *I. sexdentatus* (reviewed in CAB 2005). Eggs are deposited singly in notches along galleries extending from each side of the nuptial chamber. Females make up to 50 egg notches in each gallery, though eggs may not be deposited in each notch (reviewed in CAB 2005). Following mating and egg deposition, some adults will initiate a second flight and mate again. Oviposition lasts 3-4 days (Gao et al. 2000). Overwintered females deposit an average of 40 eggs (range, 30-120), while females in a subsequent generation within the same year deposit significantly fewer eggs (avg. 25). Some females die inside the gallery after oviposition (Gao et al. 2000).

Larvae create galleries perpendicular to maternal galleries and feed on cambial tissue (Gao et al. 2000, reviewed in Orlinski 2004). Larval galleries are filled with frass and wood fibers and are usually less than 5 cm [2 in] long (Gao et al. 2000, reviewed in CAB 2005). In China, the larval period lasts about 20 days in spring. In summer, it lasts 13 days (Gao et al. 2000).

Pupation takes 8 days and occurs in oval chambers at the end of larval galleries (Gao et al. 2000). Newly-eclosed adults maturation feed 10-16 days in the cambium before emerging from the tree (Gao et al. 2000). Young adults may also feed on roots, in the crown, or on young shoots (reviewed in Orlinski 2004 and CAB 2005).

Pest Importance

In its native range, *I. subelongatus* is considered a secondary pest of conifers, especially of mature, damaged, stressed trees or cut logs. However, this pest can attack apparently healthy, vigorous trees (reviewed in Stauffer et al. 2001, reviewed in CAB 2005, Zhang et al. 2007). This insect will repeatedly attack the same host plant, eventually causing death of the tree. In Asia and European Russia, *I. subelongatus* is an economically important pest of larch (*Larix* spp.). However, this pest may attack a wide variety of coniferous hosts in areas where larch also occurs. Periodically, populations outbreak. Areas with stressed trees are especially at risk (reviewed in Orlinski 2004, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005).

Damage caused by this pest includes maturation feeding by adults on cambial tissue, roots, or tender young shoots of the crown, and cambial boring by adults and larvae. Boring damage disrupts the phloem and eventually causes tree death. Insect-damaged trees are also vulnerable to subsequent attack by secondary insects and pathogens. (Stauffer et al. 2001, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005, Chung et al. 2006). Damage caused by this insect and secondary pests results in economic losses including reduced mature stand volume, wood quality, and log and timber value (reviewed in Orlinski 2004). Establishment of *I. subelongatus* in the United States would present a significant threat to forests and the forest products industry and likely result in domestic and/or international quarantines or requirements for additional treatment of potentially infested host materials (reviewed in Orlinski 2004, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005).

Reduction or loss of mature conifers would negatively impact forest composition and displace native species. This would likely necessitate biological, chemical, and silvicultural control measures. Increased tree mortality may also increase the amount of trees available to fuel wildfires (reviewed in Orlinski 2004, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005).

Symptoms

Symptoms of *I. subelongatus* are typical of other bark beetles and longhorn beetles and may resemble some of the symptoms associated with tree decline. *I. subelongatus* typically attacks stressed, dying, or recently-cut trees but may also attack apparently healthy trees. External symptoms include yellow, brown, or reddish-brown foliage; pitch tubes and boring dust; exit holes; and resinosis on the bark surface (reviewed in Orlinski 2004). Internally, a network of galleries and chambers may be observed. Characteristic galleries are typically packed with frass and wood fibers. Several life stages of this insect may be found inside the tree (reviewed in Orlinski 2004, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005).

Known Hosts

Ips subelongatus prefers dead or dying *Larix* spp., but may attack other conifers (reviewed in Orlinski 2004). Of all *Ips* species, only *I. subelongatus* and *I. cembrae* are known to favor larch (reviewed in Orlinski 2004).

Host	**Reference**
Abies spp. (fir)	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005)
Larix spp. (larch)	(Gao et al. 2000, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, Zhang et al. 2007)
Larix gmelinii (=*L. dahurica*) (Dahurian larch)	(Qiu et al. 1988, Zhang et al. 1992, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, Zhang et al. 2007)
Larix kaempferi (=*L. leptolepis*) (Japanese larch)	(Stauffer et al. 2001, reviewed in CAB 2005, OEPP/EPPO 2005, Zhang et al. 2007)
Larix olgensis (Olga Bay larch/Changbai larch)	(reviewed in Orlinski 2004, OEPP/EPPO 2005, Zhang et al. 2007)
Larix principis-rupprechtii (Prince Rupprect larch)	(Zhang et al. 2007)
Larix sibirica (=*L. altaica*, *L. rossica*, *L. sukaczevii*) (Siberian larch)	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, Zhang et al. 2007)
Picea spp. (spruce)	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005)
Picea jezoensis (Yeddo spruce)	(Qiu et al. 1988)
Pinus spp. (pine)	(reviewed in Orlinski 2004, reviewed in CAB 2005)
Pinus koraiensis (Korean pine)	(Qiu et al. 1988, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005)
Pinus sibirica (Siberian pine)	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005)
Pinus sylvestris (Scots pine)	(Qiu et al. 1988, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005)

Known Vectors

In Japan, *I. subelongatus* is associated with several fungi including *Ceratocystis laricicola* and *Ophiostoma breviusculum* (blue-stain fungi), known pathogens of larch (Stauffer et al. 2001, reviewed in CAB 2005, reviewed in OEPP/EPPO 2005, Chung et al. 2006).

Known Distribution

Ips subelongatus is indigenous to Russia and East Asia (reviewed in Orlinski 2004) and is widely distributed through Siberia, the Russian Far East, and Japan (EPPO 2006). *I. subelongatus* can be found as far as 2000 m [~6600 ft] above sea level (reviewed in CAB 2005).

Location	**Reference**
Asia	
China	(Zhang et al. 1992, Gao et al. 2000, Stauffer et al. 2001, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006)
Japan	(Gao et al. 2000, Stauffer et al. 2001, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006, Zhang et al. 2007)
Korea, Democratic People's Republic of	(Gao et al. 2000, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006)
Korea, Republic of	(Gao et al. 2000, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006)
Mongolia	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006)
Europe	
Finland[1]	(reviewed in Orlinski 2004, OEPP/EPPO 2005)
Russia	(reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005, EPPO 2006)

1. Intercepted in 1985; not established (reviewed in Orlinski 2004, OEPP/EPPO 2005).

Potential Distribution within the United States

The known distribution of *I. subelongatus* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Collectively, these biomes account for approximately 47% of the area of the contiguous United States and are generally found east of the Mississippi River and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Preferred Method: To monitor populations of *I. subelongatus*, Zhang et al. (2000) recommend baiting traps with racemic ipsenol. Ipsenol [2-methyl-6-methylene-7-octen-4-ol] is frequently used as a pheromone in the genus *Ips* and is attractive to a number of other beetles (El-Sayed 2007). *I. subelongatus* is not attracted to α-pinene, β-pinene, para-cymene, cis-verbenol, verbenone, or geranyl acetone; these compounds inhibit attraction to ipsenol (Zhang et al. 2000). A mixture of ipsenol, ipsdienol, and 3-methyl-3-buten-1-ol (331-MB) will attract the most *I. subelongatus*, but ipsenol alone is sufficient for monitoring purposes (Zhang et al. 2007).

Zhang et al. (2007) used Theysohn flight barrier traps baited with 20 μl racemic ipsenol (1.4 mg/d release rate) in open polyethylene vials. The traps are arranged in a line with 10 m between traps and 30 m between lines.

Alternative Method: Visual inspection of trees is an effective method for detecting *Ips subelongatus*. Externally, affected trees generally exhibit resin flows, yellowed and wilted leaves, and dead or dying branches in the crown (reviewed in OEPP/EPPO 2005). The tree may also show pitch tubes, exit holes, and boring dust on the bark surface (reviewed in Orlinski 2004). *I. subelongatus* tends to invade the lower bole of dying trees, while it attacks the middle and upper boles in stressed hosts (reviewed in CAB 2005). Maternal galleries, nuptial chambers, and frass-filled maturation feeding galleries can be found under the bark. All life stages of the insect may be found inside the host. Hibernating adults may be found in feeding galleries, but more often they hibernate in soil and leaf litter at the base of trees (reviewed in CAB 2005).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Ips subelongatus may be confused with the morphologically similar *I. cembrae* (OEPP/EPPO 2005). Many authors consider *I. subelongatus*, along with several other species of *Ips*, to be synonyms of *I. cembrae* (Stauffer et al. 2001, reviewed in Orlinski 2004, reviewed in CAB 2005, OEPP/EPPO 2005). However, recent phylogenetic studies have shown *I. subelongatus* and *I. cembrae* to be distinct species (Stauffer et al. 2001). Differences in responsiveness to the aggregation pheromones ipsdienol and 331-MB further support the separation of the two species. Ipsenol, ipsdienol, and 331-MB are attractive to *I. cembrae* while *I. subelongatus* responds only to ipsenol (Zhang et al. 2007).

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Monochamus alternatus

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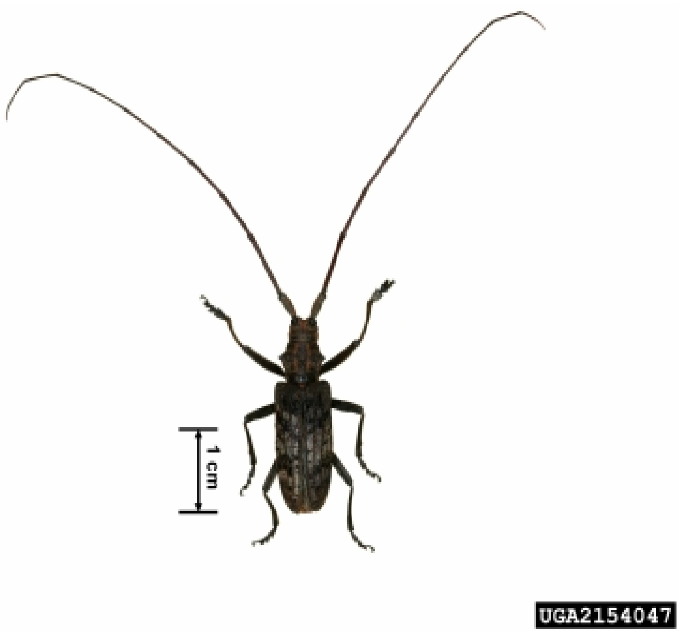

Fig. 15. Adult male *Monochamus alternatus*. Image by Christopher Pierce, http://www.bugwood.org

Scientific Name

Monochamus alternatus Hope

Synonyms:
Monochamus tesserula White
Monochammus tesserula
Monohammus alternatus
Monohammus tesserula White
(Duffy 1968, reviewed in CAB 2005)

Common Names

Japanese pine sawyer, pine sawyer beetle, rusty pine longhorn

Type of Pest

Bark, cambium, and sapwood-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Cerambycidae, **Subfamily:** Lamiinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 15)

"Adults are 15-28 mm in length and range from 4.5-9.5 mm wide. Females are larger than males but males have longer antennae. Males have antennae 2x the body length and females have antennae 1.3x the body length. The base part of the first, second and third antennal segments have grayish hairs. There are two orange stripes on the protergum, interlaced with three narrower black stripes. The elytra have five longitudinal bands of black and gray rectangular spots" (Ciesla 2001).

Egg

"Eggs are about 4 mm long, milk white in color and sickle shaped" (Ciesla 2001).

Larva
"Larvae are white, opaque legless grubs, averaging 43 mm in length when mature with an amber colored head capsule and black mouthparts" (Ciesla 2001).

Pupa
"Pupae are white, opaque and cylindrical, 20-26 mm long" (Ciesla 2001).

Biology and Ecology

M. alternatus is a major vector of the pine wood nematode *Bursaphelenchus xylophilus*, which transmits the bacterium *Pseudomonas* sp., a causal agent in pine wilt disease in Asia. When adult beetles feed to mature reproductively, they move juvenile nematodes from host to host (reviewed in Togashi and Sekizuka 1982).

M. alternatus has 1-3 generations annually (Kozima and Katagiri 1964, reviewed in CAB 2005). With the exception of a brief period for adult dispersal and maturation feeding, this long-horned beetle spends the majority of its life within a tree. Estimates for total development time are calculated from information reviewed in Kobayashi et al. (1984) and CAB (2005).

Adults emerge in spring to early fall, depending on climate, and fly to a suitable host (Ikeda et al. 1980, reviewed in Hanks 1999, reviewed in Ciesla 2001, reviewed in CAB 2005). Males emerge before females. *M. alternatus* is attracted to stressed, recently-felled, or *Bursaphelenchus xylophilus*-infested pines (Ikeda et al. 1980, Sakai and Yamasaki 1990, reviewed in Hanks 1999, Anbutsu and Togashi 2001, 2002, reviewed in CAB 2005, Fan et al. 2007). Adults can disperse several kilometers, though most will not fly more than a few hundred meters (reviewed in Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, reviewed in CAB 2005). Populations of *M. alternatus* can spread up to 20 km/yr, based on the change in distribution of trees infested with *B. xylophilus* (reviewed in Kishi 1995). Young adults may move up to 40 m/week [130 ft] within a stand of pine (reviewed in CAB 2005). However, Shibata (1986) found adult *M. alternatus* traveled only about 10 m [33 ft] on average during their lifetime in a healthy stand; observations for individual beetles ranged from 0-59 m [0-194 ft]. Adults generally disperse from diseased to healthy trees before sunrise (Shibata 1986, reviewed in Kishi 1995). Adults are also more active when sexually immature (Ito 1982, reviewed in CAB 2005). Dispersal may be aided by wind (reviewed in CAB 2005).

In its native range, larvae are the primary overwintering stage (Kozima and Katagiri 1964) and re-initiate development in early spring.. The initial sex ratio of newly emerged adults is 1 male:1 female but females significantly outnumber males by the end of the season (reviewed in Togashi and Magira 1981, reviewed in CAB 2005). Before adults reproduce, they will maturation feed during the day on the bark of tender young shoots (current year to two-year old growth) (reviewed in Hanks 1999) for 5-30 days (reviewed in Fauziah et al. 1987, reviewed in CAB 2005, Fan and Sun 2006). The duration and extent of maturation feeding is influenced by temperature (Hanks 1999) Mating and oviposition occur at night (reviewed in Fauziah et al. 1987). Males attract females by emitting a pheromone. Mating behavior in males is triggered by a contact pheromone produced on the body surfaces of both sexes (Kim et al. 1992). Adults are polygamous and copulate repeatedly with each mate (Fauziah et al. 1987). Adults survive 70-125 days under natural conditions and 100 days, on average, under laboratory conditions at a temperature of 25°C [77°F] (reviewed in Kobayashi et al. 1984).

Oviposition occurs over 20-30 days, peaking approximately 45 days after adult emergence (reviewed in Hanks 1999). The length of the oviposition period varies considerably depending on the extent of host tree decline. In early to mid-summer, the oviposition period is 1-2 months; in late summer and fall, it lasts 1-4 weeks (reviewed in CAB 2005). During oviposition, the female chews slits in the bark, deposits an egg per slit, and injects the wounds with a gel-like substance (Fauziah et al. 1987, Li and Zhang 2006). The gel deters conspecific females from depositing eggs in trees with numerous oviposition scars. The presence of larvae in a tree is a stronger deterrent than the presence of eggs alone (Anbutsu and Togashi 1996, 2001, 2002). Volatiles present in larval frass inhibit oviposition (Li and Zhang 2006). Females deposit >60% fewer eggs than normal when exposed to frass volatiles (Li and Zhang 2006). For oviposition to occur, air temperatures must be at least 21.3°C [70°F] (reviewed in Hanks 1999). The number of oviposition scars per tree decreases as the season and state of tree decline progress (reviewed in CAB 2005).

Eggs are deposited preferentially on parts of the host with thin bark (reviewed in Hanks 1999). Each female lays 60-200 or more eggs (reviewed in Hanks 1999, reviewed in Ciesla 2001). Egg development requires 65-89 degree days (dd) above 12.7-13°C, respectively (reviewed in Hanks 1999, reviewed in CAB 2005).

Larvae complete four to five instars before pupating (reviewed in Ciesla 2001, reviewed in CAB 2005). Early instar larvae feed on the nutrient-rich cambial tissue beneath the bark. Later instars tunnel into the phloem and sapwood, but may not necessarily feed on xylem (reviewed in Hanks 1999). Larvae construct galleries that become packed with frass and wood fibers as they feed. Frass and wood shavings are expelled through slits cut in the bark surface. Larvae overwinter in diapause (reviewed in CAB 2005). Diapause is probably facultative because larvae reared at a constant 30°C successfully completed development. To break diapause larvae must be exposed to cold of at least 5-15°C (reviewed in Togashi 1991). Final instars make U- to oval-shaped pupal chambers which may be plugged with wood borings (reviewed in CABI/EPPO 1997, reviewed in Hanks 1999, Cram and Hanson 2004).

The pupal stage occurs over a period of 17-19 days; typically requiring 187 dd above 10.6°C [51°F] (reviewed in Hanks 1999). Newly-eclosed adult beetles bore round exit holes and emerge from the host tree. Immature (callow) adults must feed 1-4 weeks before reaching sexual maturation (reviewed in Kishi 1995, reviewed in Hanks 1999, reviewed in Ciesla 2001, reviewed in CAB 2005).

After 500-540 dd above 11.9-12.5°C [53-55°F], 50% of overwintering larvae will complete development and emerge as adults (Kobayashi et al. 1984).

Pest Importance

M. alternatus is often considered a beneficial decomposer of conifers and not a pest of economic importance (reviewed in CABI/EPPO 1997, reviewed in Ciesla 2001). Adults cause damage by feeding on shoots (preferably one- to two-year old growth) and creating oviposition sites; larvae disrupt phloem as they feed (CABI/EPPO 1997, reviewed in Hanks 1999, reviewed in CAB 2005, Fan and Sun 2006). This damage typically occurs on trees stressed from other causes.

Symptoms

External signs of infestation include round emergence holes ~9 mm [1/3 in] in diameter and oviposition scars on the bark. Inside a tree, larvae construct S-shaped and vertical galleries packed with frass and shredded wood. Larvae also create small slits in the bark through which the frass mixture is expressed. Prior to pupation, final-instar larvae make oval-shaped holes which they may plug with wood borings. Pupal chambers are U-shaped and are found in the xylem. All life stages may be present under the bark and mature adults can be found feeding on the bark of stressed trees and recently cut logs (reviewed in Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cram and Hanson 2004, reviewed in CAB 2005).

Pine wilt disease caused by *B. xylophilus* is characterized by decreased resin production, chlorosis, and wilting of needles. Chlorosis and wilting may initially occur on a single branch and then spread to the rest of the tree (reviewed in CABI/EPPO 1997). Tree decline and death can occur in heavily infected trees in one growing season; crowns of infected trees turn from green to reddish-brown (Mamiya 1988).

Known Hosts

Monochamus alternatus is primarily a pest of pine, but will feed on a number of other plants in the families Pinaceae and Cupressaceae (reviewed in Ciesla 2001, reviewed in CAB 2005). In Japan, *P. densiflora* and *P. thunbergii* are heavily attacked (Kobayashi et al. 1984, Fauziah et al. 1987, Mamiya 1988, Togashi 1990, reviewed in Ciesla 2001, Cesari et al. 2004, reviewed in CAB 2005). In China, the preferred host is *P. massoniana* (Fan et al. 2007, Li et al. 2007). Females prefer to oviposit in stressed trees (Fan et al. 2007) and the larvae are often found in recently killed or cut trees (Anbutsu and Togashi 1996, Togashi et al. 1997).

Host	Reference
Abies spp. (fir)	(Duffy 1968, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004, Fan and Sun 2006)
Abies fabri (Faber fir)	(reviewed in CAB 2005)
Abies firma (momi fir)	(Duffy 1968, Kishi 1995, reviewed in CAB 2005)
Acer spp. (maple)¹	(Kishi 1995)
Cedrus spp. (true cedar)	(Duffy 1968, CABI/EPPO 1997, reviewed in Ciesla 2001, Fan and Sun 2006)
Cedrus deodara (Himalayan cedar)²	(Duffy 1968, Kishi 1995, reviewed in Ciesla 2001, Fan and Sun 2006)
Cryptomeria spp. (Japanese cedar)³	(reviewed in Ciesla 2001)
Cunninghamia sinensis	(Duffy 1968)
Fagus spp. (beech)	(reviewed in Ciesla 2001)
Ginkgo biloba (maidenhair tree)	(reviewed in Ciesla 2001)
Juniperus spp. (juniper)¹	(Kishi 1995)
Larix spp. (larch)	(Duffy 1968, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004, Fan and Sun 2006)
Larix gmelinii (Dahurian larch)	(reviewed in CAB 2005)
Larix kaempferi (=*L. leptolepis*) (Japanese larch)	(Kishi 1995, reviewed in Ciesla 2001)
Liquidambar spp. (sweetgum)	(Duffy 1968)
Malus spp. (apple)	(Fan and Sun 2006)
Metasequoia spp. (dawn redwood)²	(reviewed in Ciesla 2001)
Picea spp. (spruce)	(Duffy 1968, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004, Fan and Sun 2006)
Picea abies (=*P. excelsa*) (common spruce)	(Duffy 1968, Kishi 1995, reviewed in CAB 2005)
Picea asperata (dragon spruce)	(reviewed in CAB 2005)
Picea jezoensis var. hondoensis (Hondo spruce)	(Kishi 1995, reviewed in CAB 2005)
Picea smithiana (=*P. morinda*, =*Abies smithiana*) (West Himalayan spruce)	(Duffy 1968, Kishi 1995, reviewed in CAB 2005)
Pinus spp. (pine)	(CABI/EPPO 1997, Fan and Sun 2006)
Pinus banksiana (jack pine)	(Duffy 1968, Kishi 1995, reviewed in CAB 2005)
Pinus bungeana (lace bark pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus densiflora (Japanese red pine)	(Duffy 1968, Ikeda et al. 1980, Togashi and Sekizuka 1982, Kobayashi et al. 1984, Fauziah et al.

Host	Reference
	1987, Mamiya 1988, Togashi 1991, Kishi 1995, Yamasaki et al. 1997, reviewed in Ciesla 2001, Aikawa et al. 2003, Cesari et al. 2004)
Pinus echinata (shortleaf pine)	(Kishi 1995)
Pinus elliottii (slash pine)	(Kishi 1995, reviewed in Ciesla 2001)
Pinus engelmannii (Apache pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus greggii (Gregg's pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus kesiya (=*Pinus insular*is) (khasya pine)	(reviewed in Kishi 1995, reviewed in CAB 2005)
Pinus koraiensis (fruit pine)	(reviewed in CAB 2005)
Pinus leiophylla (smooth-leaved pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus luchuensis (Luchu pine)	(Kishi 1995, reviewed in Ciesla 2001, Aikawa et al. 2003, reviewed in CAB 2005)
Pinus massoniana (masson pine)	(Duffy 1968, Kishi 1995, reviewed in Ciesla 2001, Fan and Sun 2006, Li et al. 2007)
Pinus nigra (black pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus oocarpa (ocote pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus palustris (longleaf pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus parviflora (Japanese white pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus pinaster (maritime pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus ponderosa (ponderosa pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus radiata (radiata pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus strobus (eastern white pine)	(Duffy 1968, Kishi 1995, reviewed in CAB 2005)
Pinus taeda (loblolly pine)	(Kishi 1995, reviewed in CAB 2005)
Pinus taiwanensis (Taiwan pine)	(reviewed in CAB 2005)
Pinus thunbergii (Japanese black pine)	(Togashi and Sekizuka 1982, Kobayashi et al. 1984, Fauziah et al. 1987, Mamiya 1988, Togashi 1990, 1991, Kishi 1995, reviewed in Ciesla 2001, Aikawa et al. 2003, Cesari et al. 2004, Fan and Sun 2006)
Pinus yunnanensis (Yunnan pine)	(reviewed in CAB 2005)

1. Questionable host record (Kishi 1995).
2. Listed as a non-host species by Li et al. (2007).
3. May not be a valid host (Kishi 1995, reviewed in CAB 2005).

Known Vectors

M. alternatus is a vector of the pine wood nematode, B*ursaphelenchus xylophilus*. *B. xylophilus* is indigenous to North America and is not known to be pathogenic to conifers in its native range (reviewed in CABI/EPPO 1997, reviewed in Ciesla 2001, Cram and Hanson 2004). *M. alternatus* also vectors

B. mucronatus and *B. kolymensis*. These nematodes are native to Asia and are not known to occur in North America. The pathogenicity of these and other Eurasian nematode species to North American pines is not currently known (reviewed in Ciesla 2001).

Known Distribution

Monochamus alternatus is native to the Far East and is generally found at elevations ≤1050 m [~3450 ft] above sea level (Kobayashi et al. 1984, Kishi 1995).

Location	**Reference**
Asia	
China	(Duffy 1968, Kobayashi et al. 1984, Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004, Fan and Sun 2006, Li et al. 2007)
Japan	(Duffy 1968, Ikeda et al. 1980, Togashi and Sekizuka 1982, Kobayashi et al. 1984, Fauziah et al. 1987, Mamiya 1988, Togashi 1990, 1991, Kishi 1995, CABI/EPPO 1997, Togashi et al. 1997, Yamasaki et al. 1997, reviewed in Ciesla 2001, Cesari et al. 2004)
Korea, Republic of	(Kobayashi et al. 1984, Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004)
Laos	(Kobayashi et al. 1984, Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004)
Vietnam	(Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cesari et al. 2004)

Potential Distribution within the United States

The known distribution of *M. alternatus* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate broadleaf and mixed forests; and (2) tropical and subtropical moist broadleaf forests. Collectively, these biomes account for approximately 28% of the area of the contiguous United States and are generally found east of the Mississippi River.

Survey

Preferred Method: Visual inspection of trees is of some, but limited, utility in the detection of *M. alternatus*, as the insect completes the majority of its life cycle beneath the bark. Surveys should focus on the presence of round emergence holes or small slits in the surface of the bark. If bark can be removed, larval galleries, pupal chambers, or any of the life stages might be observed. can indicate the presence of the insect (reviewed in Kishi 1995, CABI/EPPO 1997, reviewed in Ciesla 2001, Cram and Hanson 2004, reviewed in CAB 2005).

In Japan, researchers have used aerial color infrared photography to survey dead pines potentially killed by *B. xylophilus*. This may be useful for surveying for insect vectors including *M. alternatus*, but many other biotic and abiotic factors can influence pine mortality (reviewed in Kishi 1995).

Alternative Method: To collect adult *Monochamus alternatus*, Nakamura et al. (1999) used commercial crossvane traps with a funnel and a bucket placed at the bottom (Fig. 16). The traps did not employ a killing agent and about a third of the collected beetles escaped per day. Soapy water is an effective trapping agent (de Groot and Nott 2001). Polyethylene glycol should also be an effective trapping agent and will preserve specimens. De Groot and Nott (2003) suggest *Monochamus* spp. may be attracted to the traps themselves rather than the attractants in the traps.

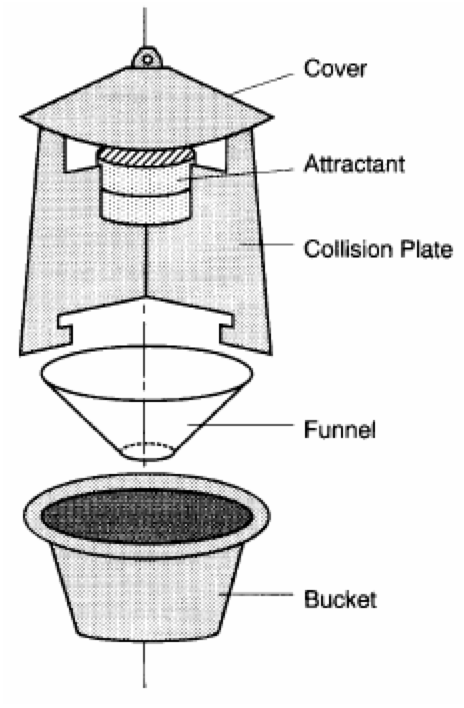

Fig. 16. Modified crossvane trap used by Nakamura et al. (1999) to capture adult *Monochamus alternatus*.

Not Recommended: Adults are attracted to monoterpenes and ethanol from stressed, recently felled, and *B. xylophilus*-infested pines (Ikeda et al. 1980, Sakai and Yamasaki 1990, Anbutsu and Togashi 2001, 2002, reviewed in CAB 2005, Fan et al. 2007). Fan et al. (2007) found (+)-α-pinene to be extremely attractive to gravid adult female *M. alternatus*. The addition of ethanol enhanced attractiveness, but the presence of other monoterpenes [(-)-β-pinene, (+)-3-carene, limonene, and terpinolene], except in very low concentrations, reduced it (Fan and Sun 2006, Fan et al. 2007). Young females (pre-oviposition) were not attracted to any of the volatiles tested by Fan et al. (2007). Adult females are also attracted to (+)-juniperol and (+)-pimaral (Sakai and Yamasaki 1990), both of which are masked by a compound isolated from healthy pines [(-)-germacrene D] (Yamasaki et al. 1997). Sakai and Yamasaki (1991) identified a male-specific pheromone [(+)-*cis*-3-pinen-2-ol] from paraquat-treated, resin-soaked pinewood. None of these compounds has been used to detect or monitor *Monochamus alternatus* populations in Japan. Future research may reveal ways to use these compounds for detection surveys.

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

One hundred fifty species of *Monochamus* are known from the Holarctic region, with about 10 indigenous to North America (CABI/EPPO 1997, reviewed in Ciesla 2001). *M. alternatus* resembles *M. carolinensis* and *M. titillator*, both of which are native North American species (reviewed in Ciesla 2001).

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Monochamus saltuarius

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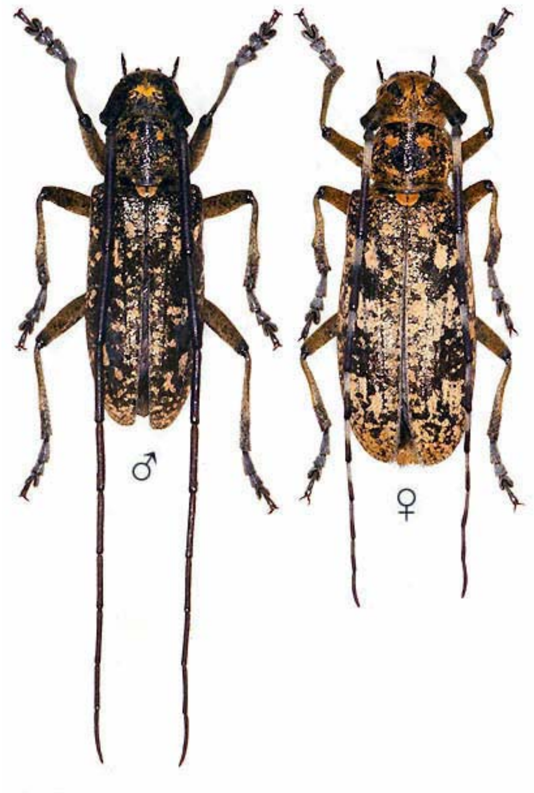

Fig. 17. Adult male and female *Monochamus saltuarius*. Image by M. Hoskovec, http://www.uochb.cas.cz/~natur/cerambyx/

Scientific Name

Monochamus saltuarius Gebler

Synonyms:
Monochammus saltuarius
Monochammus suzukii
Monohammus saltuarius
(reviewed in Ciesla 2001 and CAB 2005)

Common Names

Sakhalin pine sawyer, Sakhalin pine longicorn beetle, Japanese pine sawyer

Type of Pest

Bark, cambium, and sapwood-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Cerambycidae, **Subfamily:** Lamiinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 17)
“The body of the adult is predominantly black (11-20 mm), head with sparse yellowish-grey pubescence; pronotum and elytra in both sexes with numerous yellowish or whitish spots; legs and first antennal segments partly with grey spots; antennal segments 3 to 11 in male, uniformly black; in female basal halves of these segments with whitish-grey pubescence, antennae long...” (CAB 2005).

Elytra parallel-sided (male) or from base slightly enlarged posteriorly (female), apically separately rounded. Abdominal sternite V short, apically emarginate, at posterior angles with long dense hairs forming a cluster on each side (female) or rounded, with uniform brownish bristles (males)...” (CAB 2005).

Egg

"The eggs are white, almost parallel-sided or slightly tapering towards one pole, broadly rounded at the poles, 3.0-3.5 mm long and 0.8-1.2 mm wide..." (CAB 2005).

Larva

"The larvae are cylindrical and elongate with an oval head and no legs. Pre-diapause larvae are milky-white, whereas diapausing larvae are yellowish-white, whitish-yellow or yellow (Togashi et al. 1994). The body of late-instar larvae is 20-28 mm long; the head width is 3.5-4.0 mm.

Head flat, half retracted into the prothorax. Epistoma in anterior half reddish-rust, barely convex; in posterior half, bright, flat; at anterior margin laterally with three long bristles on each side of the longitudinal suture with a pair of staggered bristles (inner bristle slightly in front of lateral); near antennal socket with three bristles in transverse row, on disk with two bristles in transverse row. Labrum somewhat rusty, highly tapering towards the base; at anterior margin broadly rounded; in anterior half with long rusty bristles; in posterior half glabrous, medially with pair of long wide-set bristles. Mandibles black, elongate, gently sloping apically..." (CAB 2005).

Pupa

"The pupae are milky-white and 14-20 mm long; the width of the abdomen is 4.5-4.8 mm. The pupae are characterized by a large number of spinules in the frontal region and long, large sclerotized spinule at the apex of the urogomphus. Head medially with deep longitudinal trough, lateral to it in front of antennae with numerous long setiform spinules forming broad, longitudinal field; at anterior margin near base of clypeus with six spinules forming transverse row interrupted medially, occiput glabrous, lustrous. Labrum elongate, apically broadly rounded; in anterior half along margins with long acicular spinules. Upper ocular lobe with two bristles. Antennae in second half bent ventrad, here spiralled, forming two incomplete (female) or two complete loops (male).

Abdomen moderately elongate, gradually tapering towards tip. Abdominal tergites in posterior half convex in anterior half transversely depressed, medially with longitudinal groove, lateral to it in posterior half with rusty acicular spinules directed backward and forming dense transverse band divided by median longitudinal groove. Two to three rows of spinules observed in each transverse band. Tergite VII is convex, lustrous, triangular, gently rounded apically, in posterior third with solitary minute, sometimes barely perceptible, setiform spinules. Tergite semi-circular, convex, lustrous, and without spinules. Urogomphus at the tip of abdomen is highly extended, terminating in long large, slightly anteriorly curved, sclerotized spinule. Ridges bordering the tip of the abdomen laterally (ventral view) with two to five minute setigerous spinules on the ventral side. Valvifers of female spherical, basally slightly wide-set, apically with small tubercle, bent towards each other..." (CAB 2005).

Biology and Ecology

The ecology of *M. saltuarius* is similar to most *Monochamus* spp. (reviewed in Hanks 1999 and Ciesla 2001). Compared to *M. alternatus*, little is known about the specific life stages of *M. saltuarius*.

M. saltuarius has 1-2 generations annually. Under suboptimal conditions, one generation may take up to two years to complete development (reviewed in Ciesla 2001). The majority of the life cycle is carried out within the host tree, except for adult dispersal and maturation feeding (Hanks 1999). *M. saltuarius* overwinters in the larval stage (Togashi et al. 1994).

Adults emerge in spring to early summer, depending on climate, and fly to find a suitable host (reviewed in Hanks 1999 and CAB 2005). *Monochamus* spp. choose stressed host trees for oviposition and larval development, but will maturation feed on healthy hosts (Hanks 1999). Adults are strong fliers and may disperse many kilometers, potentially aided by wind. Like *M. alternatus*, most do not fly more than a few hundred meters (reviewed in Ciesla 2001 and CAB 2005).

Rate and extent of maturation feeding are strongly influenced by temperature and typically occurs during the day. Adults feed on the bark of tender young shoots (current year to two-year old growth) (reviewed in Hanks 1999). Mating and oviposition occur at night.

Under laboratory conditions, adult females survive 3-80 days (avg., 47.8; SD = 4.5) at 25°C [77°F] (Jikumaru et al. 1994). *M. saltuarius* has a mean preoviposition period of 16 d at 20°C (Nakayama et al. 1998) and 10-11 d at 25°C (Jikumaru et al. 1994, Nakayama et al. 1998). The mean oviposition period is about 42 days at 25°C [77°F] (Jikumaru et al. 1994). Nakayama et al. (1998) found no significant differences in the life span of *M. saltuarius* males and females reared at 20 or 25°C. Females produce an average of about 70 eggs (range, 0-172) at a temperature of 25°C [77°F] under laboratory conditions (Jikumaru et al. 1994). Eggs hatch within 7-8 days (Jikumaru et al. 1994).

There are four larval instars. Larvae enter diapause in the final instar. Under laboratory conditions, larval development to adult emergence requires approximately 183-244 dd above 10°C (Togashi et al. 1994, Jikumaru and Togashi 1995). In Japan, *M. saltuarius* emerges earlier in spring than *M. alternatus* due to a lower developmental threshold temperature and fewer degree days required for development (Togashi et al. 1994).

Pest Importance

By itself, *M. saltuarius* is considered a decomposer of conifers and not a pest of economic importance (reviewed in Ciesla 2001). Adults cause damage by maturation feeding on the bark of shoots (preferably current-year to two-year old growth) and by boring holes for oviposition and larval development in stressed trees (reviewed in Hanks 1999, reviewed in Ciesla 2001). Feeding damage by adults and larvae can reduce the value of wood and wood products (reviewed in Ciesla 2001).

Symptoms

Signs and symptoms of attack are similar for most *Monochamus* spp. External signs of infestation include round emergence holes and oviposition scars on the bark. Inside a tree, larvae construct galleries packed with frass and shredded wood. Larvae also create small slits in the bark through which the frass mixture is expelled. In preparation for pupation, final-instar larvae make oval-shaped pupal chambers in the xylem which they may plug with wood borings. All life stages may be present under the bark. Mature adults can be found feeding on the bark of stressed trees and recently cut logs (CABI/EPPO 1997, Hanks 1999, Ciesla 2001, Cram and Hanson 2004).

Pine wilt disease is characterized by decreased resin production, chlorosis, and wilting of needles. Chlorosis and wilting may initially occur on a single branch and then spread to the rest of the tree (reviewed in CABI/EPPO 1997). Crowns of infected trees turn from green to reddish-brown (Mamiya 1988). Tree decline and death can occur in heavily infected trees in one growing season (Mamiya 1988). Pine wilt disease is typically caused by nematodes in the genus *Bursaphelenchus*. Other vectors of *Bursaphelenchus* spp. occur in the United States, so pine wilt disease does not definitively indicate the presence of any particular *Monochamus* spp.

Known Hosts

M. saltuarius is a pest of dying and recently felled *Abies* spp., *Larix* spp., *Picea* spp., and *Pinus* spp. in its native range. In Japan, its main hosts are *Pinus densiflora* and *P. thunbergii*, while in Europe, the main host is *Picea abies* (reviewed in Ciesla 2001 and CAB 2005).

Host	**Reference**
Abies spp. (fir)	(Ciesla 2001)
Abies alba (silver fir)	(Cesari et al. 2004)
Abies holophylla (Manchurian fir)	(Ciesla 2001)
Abies nephrolepis (Khingan fir)	(Ciesla 2001)
Abies sibirica (Siberian fir)	(Ciesla 2001)
Larix spp. (larch)	(reviewed in Ciesla 2001, Cesari et al. 2004)
Larix gmelinii (Dahurian larch)	(Ciesla 2001)
Larix kaempferi (Japanese larch)	(reviewed in Ciesla 2001 and CAB 2005)
Larix sibirica (Siberian larch)	(Ciesla 2001)
Picea spp. (spruce)	(Ciesla 2001)
Picea abies (Norway spruce)	(Cesari et al. 2004, reviewed in CAB 2005)

Host	**Reference**
Picea asperata (dragon spruce)	(reviewed in CAB 2005)
Picea jezoensis (Yeddo spruce)	(Ciesla 2001)
Picea koraiensis (Korean spruce)	(Ciesla 2001)
Picea obovata (Siberian spruce)	(reviewed in Ciesla 2001 and CAB 2005)
Pinus spp. (pine)	(Ciesla 2001)
Pinus banksiana (jack pine)	(reviewed in CAB 2005)
Pinus densiflora (Japanese umbrella pine)	(Togashi et al. 1994, Jikumaru and Togashi 1995, Togashi and Jikumaru 1996, Nakayama et al. 1998, reviewed in Ciesla 2001 and CAB 2006)
Pinus nigra (Corsican pine)	(Cesari et al. 2004)
Pinus parviflora (Japanese white pine)	(reviewed in Ciesla 2001 and CAB 2005)
Pinus paviflora var. *pentaphylla*	(reviewed in CAB 2005)
Pinus sibirica (Siberian pine)	(Ciesla 2001)
Pinus sylvestris (Scots pine)	(reviewed in Ciesla 2001, Cesari et al. 2004)
Pinus thunbergii (Japanese black pine)	(Togashi et al. 1994, Jikumaru and Togashi 1995, Nakayama et al. 1998, reviewed in Ciesla 2001 and CAB 2006)
Tsuga sieboldii (Japanese hemlock)	(reviewed in CAB 2005)

Known Vectors

M. saltuarius is a vector of the pine wood nematode *Bursaphelenchus xylophilus*. *B. xylophilus* is indigenous to North America and is not known to be pathogenic to conifers in its native range (reviewed in CABI/EPPO 1997 and Ciesla 2001). *B. xylophilus* transmits the bacterium *Pseudomonas* sp., a causal agent in pine wilt disease in Asia (reviewed in Ciesla 2001). *M. saltuarius* also vectors *B. mucronatus* and *B. kolymensis*. These nematodes are native to Asia and are not known to occur in North America. *B. mucronatus* has been implicated in pine wilt disease (Togashi and Jikumaru 1996, Jikumaru and Togashi 2001, Kobayashi et al. 2003), however the potential pathogenicity of these and other Eurasian nematode species on North American pines is not currently known (reviewed in Ciesla 2001).

Known Distribution

M. saltuarius is widely distributed throughout Middle and Eastern Europe, Siberia, the Russian Far East, and East Asia (reviewed in Ciesla 2001, Cesari et al. 2004, reviewed in CAB 2005).

Location	**Reference**
Asia	
China	(reviewed in Ciesla 2001, Cesari et al.

Location	**Reference**
	2004, reviewed in CAB 2005)
Japan	(Togashi et al. 1994, Jikumaru and Togashi 1995, Togashi and Jikumaru 1996, Nakayama et al. 1998, reviewed in Ciesla 2001, Cesari et al. 2004, reviewed in CAB 2005)
Korea	(Cesari et al. 2004, reviewed in CAB 2005)
Mongolia	(reviewed in CAB 2005)
Europe	
Austria	(reviewed in Ciesla 2001 and CAB 2005)
Belarus	(Ciesla 2001)
Bosnia & Herzegovina	(Ciesla 2001)
Croatia	(reviewed in Ciesla 2001 and CAB 2005)
Czech Republic	(reviewed in Ciesla 2001 and CAB 2005)
Estonia	(Ciesla 2001)
Germany	(reviewed in Ciesla 2001 and CAB 2005)
Hungary	(Ciesla 2001)
Italy	(reviewed in Ciesla 2001 and CAB 2005)
Latvia	(Ciesla 2001)
Lithuania	(reviewed in Ciesla 2001 and CAB 2005)
Poland	(reviewed in Ciesla 2001 and CAB 2005)
Romania	(reviewed in Ciesla 2001 and CAB 2005)
Russia	(reviewed in Ciesla 2001 and CAB 2005)
Slovakia	(reviewed in Ciesla 2001 and CAB 2005)
Switzerland	(reviewed in CAB 2005)
Ukraine	(reviewed in Ciesla 2001 and CAB 2005)

Potential Distribution within the United States

The known distribution of *M. saltuarius* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Collectively, these biomes account for approximately 47% of the area of the contiguous United States and are generally found east of the Mississippi River and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Methods used to detect a related species, *Monochamus alternatus*, in the field are also effective in detecting *M. saltuarius*.

Preferred Method: Visual inspection of trees is currently the only method to detect infestations. Externally, infested trees may exhibit oviposition scars and round to oval adult exit holes. Maturing adults feed on young shoots, damaging the affected tree. Dead shoots are characterized by their reddish-brown foliage. Similar symptoms may be observed if the introduction of *M. saltuarius* also were associated with the introduction of an Asian *Bursaphelenchus* spp. Symptoms of the resulting pine wilt disease include chlorosis, wilting of needles, and decreased resin production. Many other biotic and abiotic factors can cause similar damage, so these symptoms should not be relied on exclusively for detecting the presence of *M. saltuarius* (reviewed in Ciesla 2001 and CAB 2005). If bark is removed, larval galleries packed with frass and wood shreds may be observed. The portion of bark overlying the galleries is easily depressed with slight pressure. Pupal chambers are U-shaped. All life stages can be found under the bark (reviewed in Ciesla 2001 and CAB 2005).

Currently, no attractants are known to use with traps, though this is an active area of research. The pine monoterpenes that are attractive to *M. alternatus* probably have a similar effect on *M. saltuarius*. However, there is no record in the current, available literature of the effect of plant volatiles and other semiochemicals on *M. saltuarius*. Preliminary work by Kobayashi et al. (2003) suggests the presence of a sex pheromone on the cuticle of females and virgin males.

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

One hundred fifty species of *Monochamus* are known from the Holarctic region, with about 10 indigenous to North America. *M. saltuarius* resembles *M. carolinensis* and *M. titillator*, both of which are native North American species (reviewed in Ciesla 2001). The species also resembles *M. alternatus*, with which it shares a portion of their host range and distribution (reviewed in CAB 2005).

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Monochamus sutor

E.E. Davis, E.M. Albrecht, and R.C. Venette

Fig. 18. Adult male and female *Monochamus sutor*. Image by M. Hoskovec, http://www.uochb.cas.cz/~natur/cerambyx/

Scientific Name

Monochamus sutor (Linnaeus)

Synonyms:
Cerambyx sutor Linnaeus
(reviewed in CAB 2005)

Common Names

Small white-marmorated longicorn

Type of Pest

Bark, cambium, and sapwood-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda,
Order: Coleoptera,
Family: Cerambycidae, **Subfamily:** Lamiinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 18)
“The overall body length of the adult is 15-26 mm. The body is moderately elongate with head not broader than the pronotum. Head and pronotum have a deep median longitudinal groove with deep uneven punctuation and dense or sparse grey or brownish hairs. The antennae are 2.5 times the length of the body on males and less than 1.5 times the length of the body for females. The eyes are deeply faceted, broadly emarginated, with the upper ocular lobes close to each other. The distance between the ocular lobes is less than the interspace between the antennal bases. The scutellum is whitish-yellow and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold coloured markings. Females are slightly larger than males” (CAB 2005).

“Adults superficially resemble the indigenous northern pine sawyer, *Monochamus scutellatus*. They are 15-24 mm long with a black body color with a metallic sheen. The scutellum is a whitish-yellow color and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold colored markings. The antennae are more than twice the body length on the males and about 1.5 times the body length on females. Females are slightly larger than males...” (Ciesla 2004).

Egg

"The eggs are white, matte, becoming brownish with time, elongate, slightly curved, rounded at poles, overall length 3.8 mm, width 0.8 mm" (CAB 2005).

Larva

"The larvae are white, opaque legless grubs, averaging 35-40 mm in length when mature. The head capsule is amber in colour, with well developed, black chewing mouthparts. Overall, the body length of mature larvae is 40-50 mm; the width of the head is 4.1-4.7 mm" (CAB 2005).

Pupa

"The pupae are moderately elongate, white, opaque and cylindrical. They are exarate, with antennae, legs and wings free from the body. The abdomen is elongate, gradually tapering to a posterior tip" (CAB 2005).

Biology and Ecology

The ecology of most *Monochamus* spp. is similar (reviewed in Hanks 1999 and Ciesla 2004). *Monochamus alternatus* is probably the most carefully studied species within the genus. Little has been reported on the biology of *M. sutor*.

M. sutor completes a generation in 1-3 years (Kolk and Starzyk 1996). The majority of the life cycle is carried out within the host tree, except during periods of adult dispersal and maturation feeding. *M. sutor* overwinters in the larval stage (reviewed in Hanks 1999).

Adult flight occurs from mid June-September (Kolk and Starzyk 1996). In general, adult *Monochamus* spp. are capable of flying many kilometers, potentially aided by wind. Like *M. alternatus*, most individuals probably do not fly more than a few hundred meters (reviewed in Ciesla 2004 and CAB 2005).

Adults emerge during the spring and summer to find a suitable host. *Monochamus* spp. choose stressed host trees for oviposition and larval development, but will maturation feed on healthy hosts (reviewed in Hanks 1999). Maturation feeding is strongly influenced by temperature and typically occurs during the day, while mating and oviposition occur at night. Adults feed on the bark of tender young shoots (current year to two-year old growth) (reviewed in Hanks 1999).

During oviposition, a female chews slits in the bark and deposits 1-6 eggs per slit (reviewed in USDA 1991). During her lifetime, a single female may deposit up to 50 eggs. When multiple females occur in the same area, as many as 100 eggs per meter of bark have been reported in downed logs (reviewed in Ciesla 2004). *M. sutor* can utilize much of the main stem of burned larch or pine for reproduction (Zhang et al. 1993).

There are 5 larval instars (reviewed in CAB 2005). Larvae feed within the cambial layer but may also tunnel to a depth of about 4 cm [~1½ in] in the xylem (Kolk and Starzyk 1996). Larvae overwinter as second or later instars (reviewed in CAB 2005). Mature larvae pupate near the bark surface or in the xylem and emerge as adults in the spring (Kolk and Starzyk 1996, reviewed in Hanks 1999).

Pest Importance

In their native ranges, most *Monochamus* spp. are decomposers of dead conifers and not pests of economic importance (reviewed in Ciesla 2004). Adults cause damage by maturation feeding on the bark of shoots (preferably current-year to two-year old growth) and by boring holes for oviposition and larval development in stressed trees (Zhang et al. 1993, Kolk and Starzyk 1996, Hanks 1999, reviewed in Schroeder et al. 1999, reviewed in Ciesla 2004). Feeding damage by adults and larvae can reduce the value of wood and wood products (reviewed in Kolk and Starzyk 1996, reviewed in Ciesla 2004). See 'Known Vectors.'

Symptoms

Signs and symptoms of attack are similar for most *Monochamus* spp. External signs of infestation include round emergence holes and oviposition scars on the bark. Inside a tree, larvae construct galleries packed with frass and shredded wood. Larvae also create small slits in the bark through which the frass mixture is expelled. In preparation for pupation, final-instar larvae make oval-shaped pupal chambers in the xylem which they may plug with wood borings. All life stages may be present under the bark. Mature adults can be found feeding on the bark of stressed trees and recently cut logs (reviewed in CABI/EPPO 1997, Hanks 1999, Ciesla 2004, Cram and Hanson 2004, reviewed in CAB 2005).

Pine wilt disease is characterized by decreased resin production, chlorosis, and wilting of needles. Chlorosis and wilting may initially occur on a single branch and then spread to the rest of the tree (reviewed in CABI/EPPO 1997). Crowns of infected trees turn from green to reddish-brown (Mamiya 1988) Tree decline and death can occur in heavily infected trees in one growing season (Mamiya 1988, CABI/EPPO 1997, Ciesla 2004, Cram and Hanson 2004, CAB 2005).

Known Hosts

M. sutor is a pest of dying and recently felled *Abies* spp., *Larix* spp., *Picea* spp., and *Pinus* spp. in its native range. In Europe, its main hosts are *Abies alba*, *Picea abies*, and *Pinus sylvestris.* In China, the main hosts are *Betula platyphylla*, *Larix gmelinii*, and *Pinus sylvestris* var. *mongolica*; in Russia *M. sutor* is found chiefly on *Abies holophylla*, *A. nephrolepis*, *A. sibirica*, *Larix gmelinii*, *L. sibirica*, *Picea koraensis*, *P. jezoensis*, *P. obovata*, *Pinus sylvestris*, and *P. sibirica* (reviewed in Ciesla 2004 and CAB 2005).

Host	**Reference**
Abies spp. (fir)	(reviewed in Ciesla 2004)
Abies alba (silver fir)	(reviewed in Ciesla 2004 and CAB 2005)

Host	Reference
Abies holophylla (Manchurian fir)	(reviewed in Ciesla 2004 and CAB 2005)
Abies nephrolepis (Khingan fir)	(reviewed in Ciesla 2004 and CAB 2005)
Abies sibirica (Siberian fir)	(reviewed in Ciesla 2004 and CAB 2005)
Betula platyphylla (Manchurian birch)	(reviewed in Ciesla 2004 and CAB 2005)
Larix spp. (larch)	(reviewed in Ciesla 2004)
Larix gmelinii (Dahurian larch)	(reviewed in Ciesla 2004 and CAB 2005)
Larix gmelinii var. *japonica* (kurile larch)	(reviewed in CAB 2005)
Larix sibirica (Siberian larch)	(reviewed in Ciesla 2004 and CAB 2005)
Picea spp. (spruce)	(reviewed in Ciesla 2004)
Picea abies (common spruce)	(reviewed in Ciesla 2004 and CAB 2005)
Picea jezoensis (Yeddo spruce)	(reviewed in Ciesla 2004 and CAB 2005)
Picea koraiensis (Korean spruce)	(reviewed in Ciesla 2004 and CAB 2005)
Picea obovata (Siberian spruce)	(reviewed in Ciesla 2004 and CAB 2005)
Pinus spp. (pine)	(reviewed in Ciesla 2004)
Pinus sibirica (Siberian stone pine)	(reviewed in Ciesla 2004 and CAB 2005)
Pinus sylvestris (Scots pine)	(reviewed in Ciesla 2004 and CAB 2005)
Pinus sylvestris var. *mongolica* (Mongolian pine)	(reviewed in Ciesla 2004)

Known Vectors

M. sutor is a vector of the pine wood nematode *Bursaphelenchus mucronatus*, a cause of pine wilt disease (reviewed in Ciesla 2004). *B. mucronatus* is native to Asia and is not known to occur in North America. The potential pathogenicity of this and other Eurasian nematode species on North American pines is not currently known (reviewed in Ciesla 2004).

Known Distribution

M. sutor is widely distributed throughout Europe, Siberia, the Russian Far East, and East Asia (Kolk and Starzyk 1996, Cesari et al. 2004).

Location	Reference
Asia	

Location	**Reference**
China	(reviewed in Ciesla 2004 and CAB 2005)
Georgia (Republic)	(reviewed in Ciesla 2004 and CAB 2005)
Japan	(reviewed in CAB 2005)
Kazakhstan	(reviewed in Ciesla 2004)
Korea, Democratic People's Republic of	(reviewed in CAB 2005)
Mongolia	(reviewed in CAB 2005)
Europe	
Albania	(reviewed in Ciesla 2004 and CAB 2005)
Austria	(reviewed in Ciesla 2004 and CAB 2005)
Belarus	(reviewed in Ciesla 2004 and CAB 2005)
Boznia & Herzegovina	(reviewed in Ciesla 2004 and CAB 2005)
Bulgaria	(reviewed in Ciesla 2004 and CAB 2005)
Croatia	(reviewed in Ciesla 2004 and CAB 2005)
Czech Republic	(reviewed in Ciesla 2004 and CAB 2005)
Denmark	(reviewed in Ciesla 2004 and CAB 2005)
Estonia	(reviewed in Ciesla 2004 and CAB 2005)
Finland	(reviewed in Ciesla 2004 and CAB 2005)
France	(reviewed in Ciesla 2004 and CAB 2005)
Germany	(reviewed in Ciesla 2004 and CAB 2005)
Hungary	(reviewed in Ciesla 2004 and CAB 2005)
Italy	(reviewed in Ciesla 2004 and CAB 2005)
Latvia	(reviewed in Ciesla 2004 and CAB 2005)
Lithuania	(reviewed in Ciesla 2004 and CAB 2005)
Montenegro	(reviewed in CAB 2005)

Location	Reference
Netherlands	(reviewed in Ciesla 2004 and CAB 2005)
Norway	(reviewed in Ciesla 2004 and CAB 2005)
Poland	(reviewed in Ciesla 2004 and CAB 2005)
Romania	(reviewed in Ciesla 2004 and CAB 2005)
Russia	(reviewed in Ciesla 2004 and CAB 2005)
Serbia	(reviewed in CAB 2005)
Slovakia	(reviewed in Ciesla 2004 and CAB 2005)
Slovenia	(reviewed in Ciesla 2004 and CAB 2005)
Spain	(reviewed in Ciesla 2004 and CAB 2005)
Sweden	(reviewed in Ciesla 2004 and CAB 2005)
Switzerland	(reviewed in Ciesla 2004 and CAB 2005)
Ukraine[1]	(reviewed in Ciesla 2004 and CAB 2005)
United Kingdom	(reviewed in CAB 2005)
Yugoslavia	(reviewed in Ciesla 2004)

1. Presence here “questionable” (reviewed in Ciesla 2004).

Potential Distribution within the United States

The known distribution of *M. sutor* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Collectively, these biomes account for approximately 47% of the area of the contiguous United States and are generally found east of the Mississippi River, and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Methods for the detection of *M. sutor* in the field are identical to methods used for *M. alternatus.*

<u>Preferred Method:</u> Visual inspection of trees is currently the only method to detect infestations. Externally, infested trees may exhibit oviposition scars and round to oval adult exit holes. Maturing adults feed on young shoots, damaging the affected tree. Dead shoots are characterized by their reddish-brown foliage. Symptoms of pine wilt disease include chlorosis, wilting of needles, and

decreased resin production. Many other biotic and abiotic factors can cause similar damage, so these symptoms should not be relied on exclusively for detecting the presence of *M. sutor* (reviewed in Ciesla 2004 and CAB 2005). If bark is removed, larval galleries packed with frass and wood shreds may be observed. The portion of bark overlying the galleries is easily depressed with slight pressure. Pupal chambers are U-shaped. All life stages can be found under the bark (reviewed in Ciesla 2004 and CAB 2005).

Currently, no known attractants are available to use with traps. It is possible that pine monoterpenes like α-pinene, which are attractive to *M. alternatus*, might have a similar effect on *M. sutor*. However, there is no record in the current, available literature of the effect of plant volatiles or other semiochemicals on *M. sutor*.

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

One hundred fifty species of *Monochamus* are known from the Holarctic region, with about 10 indigenous to North America. *M. sutor* resembles *M. scutellatus*, a native North American species (reviewed in Ciesla 2004).

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Orthotomicus erosus

A.J. Walter, E.M. Albrecht, and R.C. Venette

Fig. 19. Adult *Orthotomicus erosus.* Image from Jim Stimmel, http://www.bugwood.org

Scientific Name

Orthotomicus erosus (Wollaston)

Synonyms:
Bostrichus duplicatus Ferrari
Bostrichus laricis Perris
Ips erosus (Wollaston)
Ips erosus var. *robustus* Knotek
Ips rectangulus Eichoff
Tomicus erosus Wollaston
Tomicus rectangulus Ferrari
(Wood and Bright 1992, Bright and Skidmore 1997, reviewed in Eglitis 2000 and CAB 2005)

Common Names

Mediterranean pine engraver

Type of Pest

Bark and cambium-feeding beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Scolytinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Orthotomicus erosus was originally placed in the genus *Ips* by Wood and Bright (1992) and was later moved to *Orthotomicus* by Bright and Skidmore (1997). Depending on interpretation of characters and the key used, *O. erosus* may still be identified as a member of the genus *Ips* (Cavey et al. 1994).

Description of the genus *Orthotomicus* Ferrari 1867:
“1.6-5 mm; body cylindrical; funicle 5-segmented; frons with sparse, short, filamentous setae; elytra with rough striae; 1st interstia adjacent declivity without row of granules; declivity nearly perpendicular; tips of post elytral margin rounded, with fine indentations, not bordered; male declivity with conical spines; female declivity with granules” (Grüne 1979).

Adult (Fig. 19)
"*Orthotomicus erosus* averages 3-3.8 mm length and is reddish brown in color. The adults are typical bark beetles of the subfamily Ipinae, family Scolytidae. The head is covered by a thoracic shield and is not visible when viewed dorsally and the declivity is concave, with each side armed by four spines, the second from the top being more conspicuous [Fig. 20]. The spines on the declivity of *O. erosus* are less conspicuous than on most North American species of *Ips*" (Eglitis 2000).

"2nd elytral spine not broad; declivity with more than 3 spines or tubercles; 1 or 2 indentations between 3rd conical spine and post elytral margin; 1 tubercle between 2nd and 3rd spines; club round, with 2 slightly bowed sutures; 3 conical spines of lateral elytral declivity equidistant; male 2nd spine broad, nearly square; lateral margin of 2nd spine horizontal, tip perpendicular; 1st spine on 2nd interstria before declivity; 3rd interstria ends with granule before declivity; body black to reddish-brown, shiny, with grey filamentous setae; elytra reddish-brown; 2.7-3.5 mm" (Grüne 1979).

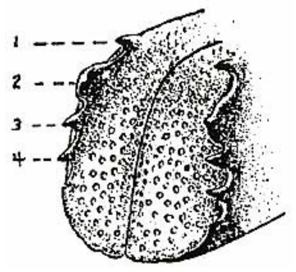

Fig. 20. Apex of elytra of male *O. erosus*. Reproduced from Cavey et al. (1994).

Egg
"Eggs are smooth, ovoid, white and translucent. The eggs of *O. erosus* are approximately 1 mm long and laid separately in niches along the egg gallery" (CAB 2005).

Larva
"The larvae are white, legless, 'C' shaped grubs with an amber colored head capsule. Mature larvae are about 5 mm long" (Eglitis 2000).

Pupa
"The pupae are white, mummy-like, and have some adult features, including wings that are folded behind the abdomen" (Eglitis 2000).

Biology and Ecology

Orthotomicus erosus is a multivoltine species and can complete up to five generations per year, depending on temperature. In parts of Israel, *O. erosus* has the potential to complete as many as seven generations per year, but averages 3-5 generations per year (Mendel 1983, Mendel et al. 1985). *O. erosus* is reported to complete 3-4 generations per year in the central valley of California (Lee et al. 2007b). Total generation development times range from 25-76 days (reviewed in Eglitis 2000).

Adults are strong fliers that may disperse several kilometers in search of hosts. They can also be dispersed by wind (reviewed in Eglitis 2000). During summer in Israel, adult flight peaks just before dawn and just after dusk (Mendel et al.

1991). In California, adults fly year-round, except during late December and January. Newly-laid eggs have been found between the first week of March and the last week of November (Lee et al. 2007b). Flight by overwintering beetles occurs at temperatures >12°C (Mendel et al. 1991). During summer, flight occurs when the temperature exceeds 21°C, with a peak of activity between 25-26°C. Flight is unlikely to occur at temperatures >34°C (Mendel et al. 1991). On the Iberian peninsula, *O. erosus* has been reported to be most abundant where the annual temperature is higher than 11°C, with mean maximum temperature exceeding 28.5°C and rainfall less than 860 mm per year (Arias et al. 2005).

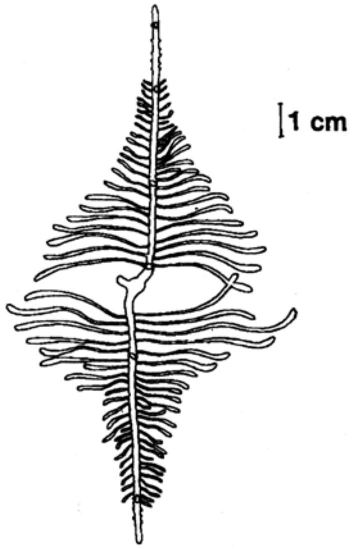

Fig. 21. Gallery system of *O. erosus*. The nuptial chamber is in the center and two egg galleries branch off in opposite directions. Larval galleries are perpendicular to the egg galleries. Reproduced from Mendel (1983).

Breeding takes place in rough-barked areas of the main trunk and in branches >5 cm in diameter (reviewed in Eglitis 2000). The lower bole of old pines is usually not used for breeding, as the bark may be too thick (reviewed in Eglitis 2000). In Spain, *O. erosus* does not attack areas of *Pinus radiata* where bark was thicker than 20 mm (Amezaga and Rodríguez 1998). However, *O. erosus* has the potential to attack thicker bark as well (A. Walter, personal observation).

After locating a suitable host, a male will bore into the phloem and construct a nuptial chamber and be joined by 1-3 females. Once mating occurs, the females excavate egg galleries parallel to the vertical axis of the tree. When two females are present, they construct their galleries in opposite directions from the nuptial chamber (Fig. 21). If 3 females are present, 2 galleries will be constructed in the same direction so that the galleries together resemble a Y. Females bore “ventilation holes” in the roof of the gallery (Mendel and Halperin 1982) and deposit eggs in niches on alternating sides of the egg galleries. If the female detects another egg gallery nearby, all of the eggs may be deposited on the side farthest away from the neighboring gallery. Each larva forms its own gallery perpendicular to the parent gallery. Egg galleries range from 10-120 mm [avg., 35-71 mm] in length. The average number of eggs deposited in each gallery is 26-75, with an average of 2-14 eggs per 10 mm of gallery (Mendel and Halperin 1982). Occasionally, a female will abandon a gallery and oviposit in a different tree (reviewed in Eglitis 2000). In California, adults have been observed excavating new galleries starting in March (Penrose et al. 2006).

Oviposition takes place when temperatures are between 18-42°C [64-108°F]. The time between initial gallery excavation and oviposition ranges from 2-10 d. Eggs hatch in 2 days at 36°C [97°F]. No hatching occurs below 16°C [61°F] or above 40°C [104°F] (Mendel and Halperin 1982). The first brood adults begin to emerge from the host tree 326-383 degree days above a base temperature of 25°C [77°F] (95% confidence interval calculated from data in Mendel and Halperin 1982) after the parent female enters the bark. In California, first brood adults emerge in June (Penrose et al. 2006).

O. erosus develops through 3 instars. The lower threshold for development is 14°C [57°F] and the upper threshold is 36°C [97°F]. Pupation takes 5-22 days, depending on temperature. Development is negatively affected at temperatures below 14°C [57°F] and above 39°C [102°F] (Mendel and Halperin 1982).

Larvae feed on the cambium of the host tree, but the pupal chamber is constructed in the inner bark. When the adult beetle emerges, it will bore back into the cambium for maturation feeding if the bark is sufficiently moist. If the bark is too dry, the insect leaves the tree to search for a new host for further maturation feeding. Maturation feeding takes place on rough-barked portions of host trees (reviewed in Eglitis 2000). When maturation feeding is complete, males construct nuptial chambers in the same or a new tree; females search for males (Mendel and Halperin 1982).

Adult beetles may form aggregations of a few to several hundred individuals in overwintering galleries under the bark of host or non-host trees (Mendel 1983, Mendel et al. 1985). This behavior may allow beetles at the center of the aggregation to stay warmer than ambient temperature. Larvae, pupae, and adults have been reported to overwinter (Mendel 1983, Lee et al. 2007b), although the cold hardiness of these stages has not been reported.

Pest Importance

In its native range, *O. erosus* is considered a secondary pest of conifers. It usually attacks stressed or wounded trees, though healthy trees may be attacked and killed when the beetle population reaches outbreak level (Mendel et al. 1985, Arias et al. 2005). A large number of hosts weakened by thinning, pruning, drought, or fire can create conditions favorable for an outbreak (Mendel 1983, Mendel et al. 1991). Trees experiencing water stress are especially susceptible to fatal attack by *O. erosus*. *O. erosus* often attacks trees that have been weakened by previous insect attack or fungal infection (reviewed in Eglitis 2000).

Orthotomicus erosus is one of the most frequently intercepted bark beetles at United States ports of entry (Brockerhoff et al. 2006, Haack 2006). Frequent introduction greatly increases the probability that the beetle will establish in the United States (Williamson 1996) The first established US populations of the beetle were reported in 2004 after *O. erosus* was detected in traps in central California (Haack 2004). Penrose et al. (2006) suggest *O. erosus* may have been present in the area for at least 2 years prior to its detection. There is concern that the beetle will spread to native coastal and mountain pines within California and to other warm regions such as the Southeast United States (Lee et al. 2007b).

Orthotomicus erosus is considered one of the principal bark beetle pests of managed pine plantations in Israel (Mendel et al. 1985) and northern Iran (Mendel 1988). It has also caused economic losses on pine plantations where it was introduced into the Southern Hemisphere (Lee et al. 2007b). Poor growing conditions in plantations may predispose pines to attack by *O. erosus* (reviewed in Eglitis 2000).

Risks associated with *O. erosus* have been evaluated previously. Eglitis (2000) considered the beetle to pose a high risk to North America, though this assessment was very uncertain. The potential for establishment, spread, and economic damage were all rated high, while the potential to cause environmental damage was rated low. *O. erosus* has a broad host range within the genus *Pinus* and is capable of killing stressed trees. It may also displace native bark beetles (Eglitis 2000). See 'Known Vectors.'

Symptoms

Infestation by *O. erosus* may be difficult to detect until a tree exhibits signs of decline and dieback. As an attacked tree dies, the foliage fades from green to yellow to reddish-brown. Reddish-brown boring dust and frass expelled from galleries may be found on smooth bark surfaces of trees. If a healthy tree is attacked, pitch tubes may form on the bark. Adult and larval galleries can be viewed by peeling back the bark, though the appearance of the galleries may be disfigured by maturation feeding. Adult emergence holes are round and about 1.5 mm [1/16 in] in diameter. Sapwood may be discolored blue by staining fungi associated with *O. erosus* (reviewed in Eglitis 2000, Lee et al. 2005).

Known Hosts

The complete host range of *Orthotomicus erosus* includes many *Pinus* spp. and may also include other trees in the families Pinaceae and Cupressaceae (Mendel and Halperin 1982, Wood and Bright 1992, Arias et al. 2005). Some reported hosts may be used for overwintering rather than oviposition or may not support complete development of the larvae (Mendel and Halperin 1982). In California, *O. erosus* colonizes and develops on *Pinus brutia*, *P. canariensis*, *P. halepensis*, *P. pinea*, *P. radiata*, and *P. sylvestris* (Mendel and Halperin 1982, Wood and Bright 1992, Bright and Skidmore 1997, reviewed in CAB 2005, Lee et al. 2005).

Hosts	**References**
Abies spp. (fir)	(reviewed in CAB 2005)
Abies pinsapo (Spanish fir)[1]	(Wood and Bright 1992)
Cedrus spp. (cedar)	(reviewed in CAB 2005)
Cedrus atlantica (atlas cedar)	(Bright and Skidmore 1997)
Cedrus libani (Lebanon cedar)[1]	(Wood and Bright 1992)
Cupressus arizonica (Arizona cypress)	(Mendel and Halperin 1982)
Cupressus sempervirens (Mediterranean cypress)	(Mendel and Halperin 1982)

Hosts	**References**
Larix spp. (larch)[2]	(Lee et al. 2005)
Larix laricina (tamarack)[2]	(Lee et al. 2007a)
Picea spp. (spruce)[2]	(reviewed in CAB 2005, Lee et al. 2005)
Picea glauca (white spruce)	(Lee et al. 2007a)
Picea mariana (black spruce)	(Lee et al. 2007a)
Picea orientalis (oriental spruce)[1]	(Wood and Bright 1992)
Pinus spp. (pine)	(Wood and Bright 1992)
Pinus armandii (Armand pine)	(reviewed in Eglitis 2000 and CAB 2005)
Pinus banksiana (jack pine)[2]	(Lee et al. 2005)
Pinus brutia (Calabrian pine)	(Mendel and Halperin 1982, Bright and Skidmore 1997, reviewed in CAB 2005, Lee et al. 2005)
Pinus brutia var. *eldarica* (=*Pinus eldarica*) (Afghan pine)	(Mendel and Halperin 1982 and reviewed in CAB 2005)
Pinus brutia var. *pityusa*	(reviewed in Eglitis 2000)
Pinus canariensis (Canary Island pine)	(Mendel and Halperin 1982, Bright and Skidmore 1997, reviewed in CAB 2005, Lee et al. 2005)
Pinus caribaea (Caribbean pine)	(Mendel and Halperin 1982)
Pinus contorta (lodgepole pine)[2]	(Lee et al. 2005)
Pinus coulteri (Coulter pine)	(reviewed in Eglitis 2000)
Pinus echinata (shortleaf pine)	(Mendel and Halperin 1982)
Pinus elliottii (slash pine)	(Lee et al. 2005)
Pinus halepensis (Aleppo pine)	(Mendel and Halperin 1982, Wood and Bright 1992, reviewed in CAB 2005, Lee et al. 2005)
Pinus jeffreyi (Jeffrey pine)	(Lee et al. 2005)
Pinus kesiya (khasia pine)	(reviewed in Eglitis 2000 and CAB 2005)
Pinus kesiya var. *langbianensis* (Szemao pine)	(Penrose et al. 2006)
Pinus lambertiana (sugar pine)[2]	(Lee et al. 2005)
Pinus maritima (French maritime pine)	(Mendel and Halperin 1982, Wood and Bright 1992)
Pinus massoniana (Chinese red pine)	(reviewed in Eglitis 2000 and CAB 2005)
Pinus monophylla (single-leaf pinyon)[2]	(Lee et al. 2005)
Pinus mugo ssp. *uncinata* (Swiss mountain pine)	(reviewed in Eglitis 2000)
Pinus nigra (European black pine)	(Mendel and Halperin 1982, Bright and Skidmore 1997, and reviewed in CAB 2005)

Hosts	References
Pinus nigra ssp. *austriaca* (Austrian black pine)	(Bright and Skidmore 1997)
Pinus nigra ssp. *salzmannii* (=*P. nigra* ssp. *cebennensis*) (Cévennes black pine)	(Bright and Skidmore 1997)
Pinus nigra ssp. *mauretanica* (Atlas Mountains black pine)	(Bright and Skidmore 1997)
Pinus nigra ssp. *pallasiana* (Crimean black pine)	(Bright and Skidmore 1997)
Pinus patula (Mexican weeping pine)	(reviewed in Eglitis 2000)
Pinus pinaster (maritime pine)	(Wood and Bright 1992 and reviewed in CAB 2005)
Pinus pinea (Italian stone pine)	(Mendel and Halperin 1982, Bright and Skidmore 1997, reviewed in CAB 2005, Lee et al. 2005)
Pinus ponderosa (ponderosa pine)[2]	(Lee et al. 2005)
Pinus radiata (Monterey pine)	(Mendel and Halperin 1982, Bright and Skidmore 1997, Lee et al. 2005)
Pinus resinosa (red pine)[2]	(Lee et al. 2005)
Pinus sabiniana (grey pine)	(Lee et al. 2005)
Pinus strobus (Eastern white pine)[2]	(Lee et al. 2005)
Pinus sylvestris (Scots pine)	(Bright and Skidmore 1997, reviewed in CAB 2005, Lee et al. 2005)
Pinus taiwanensis (Taiwan red pine)	(reviewed in CAB 2005)
Pinus tabulaeformis (Chinese red pine)	(reviewed in Eglitis 2000)
Pinus taeda (loblolly pine)[2]	(Lee et al. 2005)
Pinus uncinata (mountain pine)	(reviewed in CAB 2005)
Pinus yunnanensis (Yunnan pine)	(reviewed in Eglitis 2000 and CAB 2005)
Pseudotsuga menziesii (Douglas-fir)	(Bright and Skidmore 1997 and reviewed in CAB 2005)

1. Rarely reported in this host (Wood and Bright 1992).
2. Recorded as a host in the laboratory; not yet observed as a host in the field (Lee et al. 2007a).

Known Vectors

Other organisms associated with *O. erosus* include the nematode *Bursaphelenchus fungivorus* (Arias et al. 2005) and the fungi *Graphium pseudormiticum*, *Leptographium lundbergii* (= *L. truncatum*), *L. serpens*, and *Ophiostoma* (= *Ceratocystis*) *ips* (Zhou et al. 2002, Lee et al. 2007b). *Ophiostoma ips* has been isolated from *Orthotomicus erosus* infesting cut pine in California (Lee et al. 2007b). The pathogenicity of the fungal associates of *O.*

erosus is not currently known. *Orthotomicus erosus* is also often associated with other bark beetles and weevils (reviewed in Eglitis 2000).

Known Distribution

O. erosus is native to Eurasia (Mendel and Halperin 1982, Mendel 1988, Arias et al. 2005) and has been introduced into Africa, North America, and South America. There is currently an established population in the Central Valley of California (Lee et al. 2007a). *O. erosus* has been reported from Fiji and Norway, but this was based on a misidentification (Wood and Bright 1992, Penrose et al. 2006). It has also been noted in Scandinavia and the United Kingdom, but populations are unlikely to be established (Wood and Bright 1992, Bright and Skidmore 1997, reviewed in Eglitis 2000, Lee et al. 2005, Penrose et al. 2006).

Location	**Reference**
Africa	
Algeria	(Wood and Bright 1992)
Egypt	(Wood and Bright 1992)
Libya	(Wood and Bright 1992)
Morocco	(Wood and Bright 1992)
South Africa	(Wood and Bright 1992)
Swaziland	(reviewed in Eglitis 2000)
Tunisia	(Wood and Bright 1992)
Asia	
China	(Wood and Bright 1992, Penrose et al. 2006)
Iran	(Wood and Bright 1992)
Israel	(Wood and Bright 1992)
Jordan	(Wood and Bright 1992)
Syria	(Wood and Bright 1992)
Turkey	(Wood and Bright 1992, reviewed in CAB 2005)
Tajikistan	(reviewed in Eglitis 2000)
Atlantic Islands	
Azores	(Bright and Skidmore 1997)
Madeira	(Wood and Bright 1992)
Europe	
Bulgaria	(Wood and Bright 1992)
Cyprus	(reviewed in Eglitis 2000)
Former Yugoslavia	(Wood and Bright 1992)
France	(Wood and Bright 1992)
Greece	(Wood and Bright 1992)
Italy	(Wood and Bright 1992)
Poland	(Wood and Bright 1992)

Location	**Reference**
Portugal	(Bright and Skidmore 1997)
Romania	(reviewed in Eglitis 2000)
Sardinia	(Wood and Bright 1992)
Spain	(Wood and Bright 1992)
Switzerland	(Wood and Bright 1992)
USSR (former)	(Wood and Bright 1992)
North America	
United States	
CA	(Lee et al. 2005, Lee et al. 2007b)
South America	
Chile	(Wood and Bright 1992)

Potential Distribution within the United States

The known distribution of *O. erosus* suggests that the insect may be most closely associated with six biomes, five of which occur in the United States: (1) temperate grasslands, savannahs, and shrublands; (2) temperate broadleaf and mixed forests; (3) Medierranean scrub; (4) desert and xeric shrublands; and (5) tropical and subtropical moist broadleaf forests. Collectively, these biomes account for approximately 81% of the area of the contiguous United States. These biomes are generally found throughout the United States; each state has some area that is predicted to be suitable.

Survey

Preferred Method: The most common survey method for bark beetles involves baiting a Lindgren funnel trap with an attractive lure in order to capture flying adults. Seybold et al. (2006) evaluated several lures and found the combination of (-)-ipsdienol and 2-methyl-3-buten-2-ol to be most attractive to *O. erosus*. *Ips typographus*, another potentially invasive bark beetle, is also attracted to 2-methyl-3-buten-2-ol (Eidmann et al. 1986).

The compound (-)-ipsdienol and 2-methyl-3-buten-2-ol are the primary components of the aggregation pheromone of *O. erosus* (Eidmann et al. 1986, Kohnle et al. 1988). The addition of α-pinene to a combination of (-)-ipsdienol and 2-methyl-3-buten-2-ol enhances the attractiveness of a lure (Lee et al. 2007b). The addition of amitinol, (+)-ipsdienol, (-)-*cis*-verbenol, or verbenone decreases the attractiveness of a lure (Kohnle et al. 1988, Seybold et al. 2006).

Alternative Method: Visual inspection of trees is an effective method of detecting the presence of *Orthotomicus erosus*. Boring dust and frass may be found on smooth bark surfaces of trees and pitch tubes may form on the bark of healthy trees attacked by *O. erosus*. Galleries are found beneath the bark. Old galleries of *O. erosus* may also be used to determine whether the beetle was present at a location within the last few years (Penrose et al. 2006). Adult emergence holes are small and round (Lee et al. 2005). All life stages can be found under the bark (reviewed in Eglitis 2000). The foliage of a heavily attacked tree fades from green to yellow to reddish-brown, but this may result from any number of causes.

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

The genus *Orthotomicus* contains twelve known species (reviewed in CAB 2005). *O. erosus* might be confused with *O. caelatus*, the only species of *Orthotomicus* native to North America. It is also similar to *Ips latidens* and *I. pini*, both of which are native to North America (Cavey et al. 1994). Cavey et al. (1994) summarize morphological differences among *O. erosus* and these three species.

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Fig. 22. Adult male *Tetropium fuscum*. Photo by Michal Hoskovec, http://www.uochb.cas.cz/~natur/cerambyx/tefus.htm

Tetropium fuscum

E.E. Davis, E.M. Albrecht, and R.C. Venette

Scientific Name
Tetropium fuscum Fabricius

Synonyms:
Callidium fuscum Fabricius
(reviewed in Dobesberger 2005)

Common Names
Brown spruce longhorn beetle

Type of Pest
Bark and cambium boring beetle

Taxonomic Position
Kingdom: Animalia, **Phylum:** Arthropoda,
Order: Coleoptera,
Family: Cerambycidae,
Subfamily: Spondylidinae

Reason for inclusion in manual
CAPS Priority Pest (FY 2008)

Pest Description
Adult (Fig. 22)

“The adult is black or dark brown, with a flattened body that varies in length from 8-17 mm ... The elytra range in color from brown to reddish or yellow-brown or straw-yellow and bear 2 to 3 distinct longitudinal stripes ... A broad whitish to beige pubescent band is present at the base of the elytra ... and the 5th sternite is distinctly truncated (flat edge). Short gray-yellow densely packed hairs cover the first quarter of the elytra. The short antennae are red-brown in color and the legs are dark brown and short. A deep groove is found on the head between the antennae. The mat-like pronotum is almost as wide as it is long. Viewed from the side, the pronotum is angular and wide, with dense granulation. It also bears a dense, wrinkled and punctured plate that has a longitudinal hole ... The pronotum is usually black with a notable bulge and sometimes with a rusty border at the base and apex ... Fine short hairs cover the body and various diverse forms in color and size occur” (Dobesberger 2005).

Egg

“The egg is 1.0-2 mm long and 0.2-0.3 mm wide and oblong and oval in shape. Color is white with a tinge of green. The generally smooth egg bears a band of microsculpture about 20% of the length of the egg, towards the end with the head of the developing larva. Differentiation among eggs of various species of *Tetropium* is not possible" (Dobesberger 2005).

Larva

Larvae of *T. fuscum* are "virtually indistinguishable from other *Tetropium* species" (Smith and Humble 2000).

"The larva is yellow-white in color, with conspicuous legs on the thorax, the tarsi of which bear tiny spinules ... Mature larvae are about 14-28 mm long, and are slightly flattened. The head is about 0.8 mm wide ... Hairs on the sides of the head are sparse and the head is reddish brown in color. The head capsule bears a narrow lateral white band, typical of the genus. Long, but sparse setaceous hairs (about 10 to14 hairs per tuft) occur in the anterior half with a sclerotized base. The lateropraesternum is entirely reticulately microspiculate, without a large central smooth area ... Sclerotized spinules occur on the posterior margin of abdominal tergum IX, which look like spots and are separated by a space greater than the diameter of the spinule. The spinules are set on their tubercular base with extensive, but indistinct sclerotization" (Dobesberger 2005).

Pupa

"The pupa is white in color, about 17 mm long (range 10-17 mm) and about 3.8 mm wide ... The mesonotum is slightly raised and is devoid of large spinules. The pronotum bulges and is rounded laterally, narrowing more anteriorly (i.e., the sides become parallel), with a short longitudinally grooved fold along the sides of the disk, and minute uneven spinules. In the region of the scutellum, the mesonotum is slightly raised and minute spinules occur that are barely visible under high magnification. The abdominal tergites bulge in the posterior half, with acute spinules along the sides of a common longitudinal groove forming a transversely elongate band that narrows laterally. Tergum VII has minute spinules behind the middle form an indistinct transverse row" (Dobesberger 2005).

Biology and Ecology

The biology and ecology of *Tetropium fuscum* are similar to species indigenous to North America, including *T. abietis, T. cinnamopterum, T. parvulum, T. schwarzianus*, and *T. velutinum* (reviewed in Dobesberger 2005). *T. fuscum* is also similar to *T. castaneum*, another potentially invasive species which is not known to occur in North America (reviewed in CAB 2005). A detailed review of the biology of closely related *T. castaneum* is provided by Dobesberger (2005).

Members of the genus *Tetropium* typically have 1-2 generations annually depending on a number of biotic and abiotic factors including climate and host availability and quality (reviewed in Dobesberger 2005). In Canada, *T. fuscum* typically completes development within a year inside its host and overwinters in the larval stage (Smith and Humble 2000). Larvae can survive short (<30 min) exposure to 45°C; larvae exposed to 50°C or warmer will die in less than 30 minutes (Mushrow et al. 2004). All life stages of *T. fuscum* may be found inside the tree during the summer (Smith and Humble 2000)

Adults emerge for 6-8 weeks during the spring and summer and live for approximately three weeks. Adults are fully mature at emergence and select hosts soon thereafter. *T. fuscum* attacks stressed, dying, recently cut or apparently healthy trees. Adults will either attack their natal host or fly to find another host (Kimoto and Duthie-Holt 2006). Adults are considered “strong flyers” (reviewed in NAPPO 2000). However, this insect has not been detected more than 15 km away from the point of initial establishment in North America (Cunningham 2006). *T. fuscum* prefers tree hosts >10 cm in diameter (Cunningham 2006). Females mate and emerge ready for oviposition. On average, 80 eggs are laid singly, in pairs or groups (≤10) under bark scales or in crevices. Eggs hatch in approximately two weeks. Larvae bore irregular tunnels parallel to the bark in the cambial layer of the host, and develop over a period of about two months (reviewed in CAB 2005). Mature larvae excavate oval pupal chambers at the end of tunnels, perpendicular to the bark, and overwinter in the inner cambial region or sapwood at a depth within 4 cm of the bark surface (Kimoto and Duthie-Holt 2006). Pupation occurs in spring (reviewed in CAB 2005). Fungal associates including *Ophiostoma* spp. may be observed inside the pupal chamber. Eclosion occurs after about two weeks and adults emerge (reviewed in CAB 2005).

Pest Importance

Since its detection in North America (see Known Distribution), the risks posed to the environment and to the economy by *Tetropium fuscum* have been extensively reviewed by the Canadian Food Inspection Agency (CFIA) (Cunningham 2006, Kimoto and Duthie-Holt 2006) and Natural Resources Canada (Smith and Hurley 2000, Smith and Humble 2000). In Asia and Europe, *T. fuscum* is normally a secondary pest but occasionally can attack and kill apparently healthy trees (reviewed in Dobesberger 2005). Additional concern was raised because the range of preferred hosts expanded from Norway spruce (*Picea abies*) in Europe to Norway sprice, red spruce (*P. rubens*) and white spruce (*P. glauca*) in North America (Allen and Humble 2002, O'Leary et al. 2003, Cunningham 2006). Trees decline and die within 1-5 years of the initial attack (O'Leary et al. 2003). Population density for this pest periodically reaches outbreak proportions (reviewed in Dobesberger 2005). Outbreaks may last for 10 years (NAPPO 2003). Areas with stressed trees are especially at risk (reviewed in Dobesberger 2005).

Cambial boring by this pest disrupts the phloem and eventually causes death. Insect-damaged trees are also vulnerable to subsequent attack by secondary insects and pathogens (reviewed in Dobesberger 2005). Damage caused by this insect and secondary pests results in economic losses including reduced mature stand volume, wood quality, and log and timber value (reviewed in Dobesberger

2005). Stand volume losses attributed to this pest and related species have been estimated at 30-40% (reviewed in Dobesberger 2005).

Establishment of *T. fuscum* in the United States would present a significant threat to forests and the forest products industry and likely result in domestic and/or international quarantines or requirements for additional treatment of potentially infested host materials. In Canada, lethal temperatures to kill all life stages of *T. fuscum* were determined by Mushrow et al. (2004).

Reduction or loss of mature spruce and other conifers would negatively impact forest composition and displace native species. This would likely necessitate biological, chemical, and silvicultural control measures. Natural enemies of *T. fuscum* are known to occur in its native and introduced regions and may contribute to managing population densities of this pest, but little is known about the efficacy of these organisms as potential biological control agents in North America (reviewed in Dobesberger 2005). Increased tree mortality may also increase the amount of hazard trees available to fuel wildfires (reviewed in Dobesberger 2005, Cunningham 2006). See 'Known Vectors.'

Symptoms

Symptoms of *T. fuscum* may be easily confused with damage caused by closely related species of longhorn beetles, bark beetles and other factors causing to tree decline (Harrison et al. 2004). External symptoms of attack by *T. fuscum* include white resin streaks (resinosis) on the trunk; yellowing, brown or reddish-brown crown; and cast needles (reviewed in Smith and Humble 2000). Oval exit holes (4-6 mm in diameter) plugged with sawdust may be visible on the entire bole up to a height of approximately 7 m (O'Leary et al. 2003). Internally, a network of irregular and L-shaped galleries and chambers may be observed. Galleries are packed with frass and wood fibers. All life stages of this insect may be found inside the tree during the summer (NAPPO 2000, Smith and Humble 2000, Kimoto and Duthie-Holt 2006). In Canada, evidence of *O. tetropii* seem to indicate the current or previous presence of *T. fuscum* (Harrison et al. 2004).

Known Hosts

Tetropium fuscum feeds on conifers, especially *Picea* and *Pinus* spp., but may also feed on hardwoods (NAPPO 2003). In its native range, *T. fuscum* is a secondary pest, chiefly affecting dead or dying *Picea abies* (Jacobs et al. 2003, Sweeney et al. 2004) or trees previously attacked by the scolytid *Ips typographus* (Jacobs et al. 2003). However, it is much more aggressive where it has been introduced in Canada, attacking healthy *P. abies*, *P. glauca*, *P. mariana*, and *P. rubens* (Jacobs et al. 2003, Sweeney et al. 2004, Sweeney et al. 2006).

Host	**Reference**
Abies spp. (fir)	(Kolk and Starzyk 1996, reviewed in Dobesberger 2005)

Host	Reference
Abies alba (silver fir)	(O'Leary et al. 2003, reviewed in Dobesberger 2005)
Larix spp. (larch)	(NAPPO 2003, reviewed in Dobesberger 2005)
Picea spp. (spruce)	(Allen and Humble 2002, Hoskovec and Rejzek 2006)
Picea abies (=*Picea excelsa*) (Norway spruce)¹	(Kolk and Starzyk 1996, Sweeney et al. 2006)
Picea glauca (white spruce)¹	(Smith and Humble 2000, Sweeney et al. 2006)
Picea mariana (black spruce)¹	(Smith and Humble 2000, Sweeney et al. 2006)
Picea pungens (blue spruce)	(O'Leary et al. 2003, reviewed in Dobesberger 2005)
Picea rubens (red spruce)¹	(Smith and Humble 2000, Sweeney et al. 2006)
Picea stichensis (Sitka spruce)	(O'Leary et al. 2003, reviewed in Dobesberger 2005)
Pinus spp. (pine)	(Allen and Humble 2002, Hoskovec and Rejzek 2006)
Pinus sylvestris (Scots pine)	(Kolk and Starzyk 1996, reviewed in Dobesberger 2005)

1. New host associations for *T. fuscum* in Canada (Smith and Humble 2000).

Known Vectors

T. fuscum is associated with two fungal pathogens, *Ophiostoma tetropii* and *Pesotum fragrans* (Harrison et al. 2004, Jacobs and Seifert 2004a, 2004b). *O. tetropii* is a bluestain fungus considered to have low virulence (Humble and Allen 2006). Jacobs and Seifert (2004b) consider *O. tetropii* a saprophyte, not a pathogen. See 'Pest Importance.'

Known Distribution

Tetropium fuscum is native to Europe (O'Leary et al. 2003, Harrison et al. 2004). It was first described from North America in 1999, but it is thought to have been present since at least 1990 (Smith and Hurley 2000, Smith and Humble 2000, reviewed in Dobesberger 2005).

Location	Reference
Asia	
Japan	(reviewed in CAB 2005, reviewed in Dobesberger 2005)
Kazakhstan	(reviewed in CAB 2005)
Turkey	(reviewed in CAB 2005, reviewed in Dobesberger 2005)

Location	**Reference**
Europe	
Austria	(reviewed in CAB 2005)
Belarus	(reviewed in CAB 2005)
Belgium	(reviewed in CAB 2005)
Bosnia and Herzegovina	(reviewed in CAB 2005, reviewed in Dobesberger 2005)
Bulgaria	(reviewed in CAB 2005)
Croatia	(reviewed in CAB 2005)
Czech Republic	(reviewed in CAB 2005)
Denmark	(reviewed in CAB 2005)
Estonia	(reviewed in CAB 2005)
Finland	(reviewed in CAB 2005)
France	(reviewed in CAB 2005)
Germany	(reviewed in CAB 2005)
Hungary	(reviewed in CAB 2005)
Italy	(reviewed in CAB 2005)
Latvia	(reviewed in CAB 2005)
Lithuania	(reviewed in CAB 2005)
Moldova	(reviewed in CAB 2005)
Montenegro	(reviewed in CAB 2005)
Netherlands	(reviewed in CAB 2005)
Norway	(reviewed in CAB 2005)
Poland	(reviewed in CAB 2005)
Romania	(reviewed in CAB 2005)
Russia	(reviewed in CAB 2005, reviewed in Dobesberger 2005)
Serbia	(reviewed in CAB 2005)
Slovakia	(reviewed in CAB 2005)
Slovenia	(reviewed in CAB 2005, reviewed in Dobesberger 2005)
Sweden	(reviewed in CAB 2005)
Switzerland	(reviewed in CAB 2005)
Ukraine	(reviewed in CAB 2005)
United Kingdom	(reviewed in CAB 2005)
North America	
Canada[1]	(Smith and Hurley 2000, Allen and Humble 2002, Jacobs et al. 2003, O'Leary et al. 2003, Harrison et al. 2004, reviewed in CAB 2005, reviewed in Dobesberger 2005, Sweeney et al. 2006)

[1] Present in Halifax, Nova Scotia since at least 1990 (Allen and Humble 2002, O'Leary et al. 2003, Harrison et al. 2004).

Potential Distribution within the United States

The known distribution of *T. fuscum* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Collectively, these biomes account for approximately 47% of the area of the contiguous United States and are generally found east of the Mississippi River and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Preferred/Experimental Method: Recent research has improved the feasibility of regional surveys with baited traps. Unlike many other beetles, *T. fuscum* is not attracted to α-pinene or ethanol alone (Sweeney et al. 2004). Sweeney et al. (2006) found a high-release lure of ethanol (275 mg/d) and "spruce blend" (2000 mg/d) attracted the most *T. fuscum*. The "spruce blend" [44% (±)-α-pinene, 19% (-)-β-pinene, 10% (+)-3-carene, 18% (+)-limonene, and 9% α-terpinolene] closely resembles the cortical volatile composition of *T. fuscum*-infested *Picea rubens* (Sweeney et al. 2006). The improved capture with the addition of ethanol suggests *T. fuscum* favors weakened hosts (Sweeney et al. 2006). Sweeney et al. (2006) recommend using Colossus traps to capture the greatest number of *T. fuscum*.

Male *T. fuscum* produce the pheromone fuscol [(E)-6,10-dimethyl-5,9-undecadien-2-ol]. Alone, fuscol is not particularly attractive; however, when combined with host volatiles (ethanol + "spruce blend"), the mixture attracts significant numbers of male and female *T. fuscum* and female *T. cinnamopterum*, a native North American member of the genus (Silk et al. 2007). Trapping methods employing this lure may prove useful in the future.

Alternative Method: Traditionally, surveys for *Tetropium fuscum* have relied on visual inspection of potentially infested hosts (Henry et al. 2005). Externally, infested trees may exhibit copious resin flows, yellowing of the crown, and loss of needles. Exit holes are ~4 mm in diameter and can be found on trees that have been infested for >1 yr. Irregular feeding tunnels up to 6 mm across are found in the cambium and are packed with frass and wood fibers (NAPPO 2000, Smith and Humble 2000, reviewed in CAB 2005, reviewed in Dobesberger 2005). *T. fuscum* has been found throughout the trunk of *Picea rubens* to a height of 7 m (Smith and Hurley 2000). Larval tunnels and pupal chambers may extend up to 4 cm into the cambium of an infested tree (Jacobs et al. 2003).

Diagnostics

Identification depends on examination of adult morphological characters. PCR assays may be useful in telling apart species of *Tetropium* (Henry et al. 2005).

The presence of *Ophiostoma tetropii*, a fungal associate of *T. fuscum* in Europe and North America, is a useful predictor of the presence of this beetle (Harrison et al. 2004, Jacobs and Seifert 2004b). *O. tetropii* can be "isolated on selective cyclohexamide-streptomycin-malt-agar or 'CSMA' medium ... and identified in about 4 weeks" (Harrison et al. 2004).

Easily Confused Pests

There are 17 species of *Tetropium* worldwide, with several present in North America (reviewed in CAB 2005, reviewed in Dobesberger 2005). *T. fuscum* may be confused with the morphologically similar *T. cinnamopterum*, which is indigenous to North America (Jacobs et al. 2003). *T. fuscum* is also similar to *T. castaneum*, another potentially invasive species not known to occur in North America (reviewed in CAB 2005).

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Tomicus destruens

E.E. Davis, E.M. Albrecht, and R.C. Venette

Scientific Name

Tomicus destruens Wollaston


Fig. 23. Damage to pines by *Tomicus destruens*. Photo by William M. Ciesla, http://www.bugwood.org

Synonyms:
Blastophagus destruens
Blastophagus piniperda
Hylurgus piniperda
Hylurgus destruens
Myelophilus destruens
Tomicus piniperda var. *destruens*
(reviewed in Lekander 1971, Faccoli 2006)

Common Names

Pine shoot beetle

Type of Pest

Bark, cambium (phloem) feeding, sapwood-boring beetle

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Coleoptera, **Family:** Curculionidae, **Subfamily:** Scolytinae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Egg

“The immature stages (eggs, larvae and pupae) lack sufficient characteristics for positive identification to species. Eggs are a pearly white color” (Ciesla 2003).

Larva

“Head capsule index [maximum head width ÷ head length to mandibles] 0.95. Frontal shield broad, triangulate with straight sides and distinct endocarinal line. Frontal setae five pairs of which pair 2 is the longest. Epistoma posteriorly limited by a continuous, slightly curved line which laterally bends backwards. Medially, on the anterior edge a large tubercle.

Antenna short and broad without differentiation. On the flat antennal field five setae of equal length, four of which are situated laterally of the antenna.

Clypeus with convex sides and gently concave anterior border. The medial of the clypeal setae about three times longer than the lateral ones.

Labrum with a rounded, flattened anterior border. The lateral pair of the antero-medial setae poorly developed, bristle-like, the medial one vigorous of equal breadth.

On the epipharynx the antero-lateral setae parallel to the anterior border of epipharynx. Medial epipharyngeal setae of equal size, in three pairs. Between the second and third pairs two groups of sensillae, each with three organs. Posterior sensillae lacking. Tormae short, broad, parallel or slightly convergent caudally.

Mentum with broadly attached arms and faintly indicated axis. Palpus with two distinct articles. On labium, the four setae of the same length and of equal breadth. Setae in the posterior pair on the ligula much closer to each other than the setae in the anterior pair. Submentum wih spines along the lateral border. The three setae situated in a triangle with the medial one exterior to the others.

The larva described is a typical *Blastophagus* larva, but it differs in some important details from both *piniperda* and *minor* larvae. It is easily distinguished from the latter by the large medial tubercle on the epipharynx, which tubercle is missing in the *minor* larvae. In the *piniperda* larva, the tubercle is only vestigeal or missing. Futher, it differs from the *piniperda* larva in the number of medial epipharyngeal setae, invariably three pairs in *destruens*, and four in *piniperda*. The relative lengths of the clypeal setae is different too, with little difference in *piniperda* and large in *destruens*. There are other differences too but those mentioned here are the most important" (Lekander 1971).

Tomicus destruens has four larval instars. "The mean value of head capsule width was 0.48 mm for the Ist instar, 0.638 mm for the IInd instar, 0.845 mm for the IIIrd instar and 1.141 mm for the IVth instar" (Peverieri and Faggi 2005).

Pupa

"The pupae are white, mummy-like and have some adult features including wings that are folded behind the abdomen" (Ciesla 2003).

Adult

"Mature colour of elytra reddish, antennal club of the same colour of the antennal funicle, third antennal segment with abundant vestiture of many setae, upper margin of the first antennal club segment with only short and regular setae, second interstriae of the declivity transversely wrinkled, with 2 or 3 rows of punctures, length/width of elytra <1.7, elytra/pronotum length <2.35, elytral length/pronotum width <1.9" (Faccoli 2006).

“Callow adults of both species [*T. destruens* and *T. piniperda*] have a similar homogeneous yellow colour, thus for young specimens other characters must be used for identification” (Faccoli 2006). “The declivity ... [is] weakly, irregularly, transversely wrinkled, most easily seen on interstiae [*sic*] 2 where no setae occur, but in most *T. destruens* specimens the sculpture of the second declivital interstriae was more wrinkled than in *T. piniperda*” (Faccoli 2006).

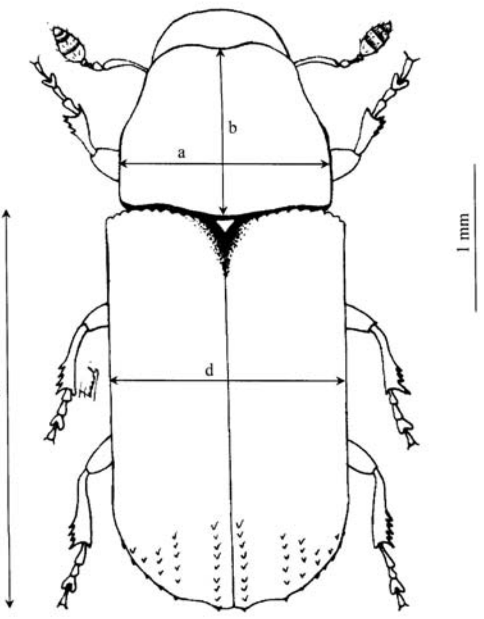

Fig. 24. Body measures taken in *Tomicus destruens* and *piniperda*: a – width of the posterior part of the pronotum; b – length of the pronotum; c – length of the elytra; d – width of elytra. Image from (Faccoli 2006).

“The ratio between length and width of the elytra was different between species, higher in *T. piniperda* (>1.7) than in *T. destruens* (<1.7). Also, the ratio between elytra and pronotum length was higher in *T. piniperda* (>2.35) than *T. destruens* (<2.35). Finally, the ratio between elytral length and pronotum width was higher in *T. piniperda* (>1.9) than *T. destruens* (<1.9)” (Fig. 24) (Faccoli 2006).

Biology and Ecology

Tomicus destruens may have up to 3 overlapping generations annually. However, each generation is difficult to differentiate and may represent multiple broods from the same female (Monleón et al. 1996, reviewed in Ciesla 2003). *Tomicus* spp. are monogamous (Poland and Haack 1998). In northern Italy, total development time is approximately 12 weeks, depending on temperature (Faccoli et al. 2005a).

Adult flight occurs in spring to mid summer and in fall to early winter at temperatures between 12-24°C (Monleón et al. 1996, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Gallego et al. 2004, Faccoli et al. 2005a, Peverieri et al. 2006). Adults are strong flyers and can fly up to 2 km (Ciesla 2003). In Italy, adults are active in early to late spring with peak activity in mid to late spring. Adult beetles feed on young shoots until they reach reproductive maturity and mate. Females initiate attacks and construct vertical galleries in the inner bark and outer sapwood. Maternal galleries are about 6-10 cm [2¼ - 4 in] long and have 2-3 ventilation holes (Monleón et al. 1996). Eggs are laid singly in niches cut along each side of the gallery, parallel to the wood grain. Oviposition occurs in fall through early winter (Kohlmayr et al. 2002, reviewed in Ciesla 2003, Faccoli et al. 2005a).

Larvae hatch, bore, and feed within horizontal galleries in the phloem. Larval galleries are perpendicular to maternal galleries, but become indistinguishable toward the end of larval development (Monleón et al. 1996). There are 4 larval instars (Monleón et al. 1996, Peverieri and Faggi 2005). In Italy, development from larva to pupa takes approximately 7-8 weeks, depending on temperature (Faccoli et al. 2005a).

Pupal chambers are constructed at the end of larval feeding galleries or close to the bark surface (reviewed in Monleón et al. 1996, reviewed in Ciesla 2003). Pupation lasts 15-20 days in northeastern Spain, depending on air temperature (Monleón et al. 1996). When conditions are favorable for emergence, newly-eclosed adults exit the tree through small round holes and search for hosts for maturation feeding and reproduction (Monleón et al. 1996, Faccoli 2007).

Pest Importance

Tomicus destruens is an economically important pest of pine forests throughout its native range (Monleón et al. 1996, Kohlmayr et al. 2002, Gallego et al. 2004). The extent of damage from *T. destruens* depends on host availablity, age and health of host trees, damage attributed to biotic factors such as feeding damage by multiple insect pests (or repeated attacks by the same insect), and abiotic factors such as stress due to drought, flooding or recent cutting (Nanni and Tiberi 1997, reviewed in Ciesla 2003, Peverieri et al. 2006). *T. destruens* has been described as either a primary or a secondary pest (Gallego and Galián 2001). In southeastern Spain, damage to approximately 100,000 acres (40,000 ha) in the early to mid 1990s was attributed to attacks by *T. destruens* following a period of drought (Gallego and Galián 2001). Economic damage of pines may be cumulative and indistinguishable in areas with concurrent populations of *T. destruens*, *T. piniperda*, and *T. minor* (Gallego et al. 2004, Vasconcelos et al. 2006). *T. destruens* may damage trees (Fig. 1) as adults maturation feed on young shoots or as adults and larvae tunnel through the cambium and feed on phloem (reviewed in Kohlmayr et al. 2002, reviewed in Ciesla 2003, Vasconcelos et al. 2006). Females will maturation feed on multiple host trees (reviewed in Ciesla 2003).

T. destruens is associated with several potentially pathogenic fungi (see ‘Known Vectors’) (Nanni and Tiberi 1997, Peverieri et al. 2006). The impact of these fungi on tree mortality is poorly understood (Sauvard 2004). The combined damage from *T. destruens* and *Leptographium* spp. has contributed to significant economic losses in European pine forests (Peverieri et al. 2006). Adults emerging from infected trees are thought to transmit these fungi while feeding on newly selected hosts (Peverieri et al. 2006). Associated fungi are thought to provide an advantage to insect vectors by overcoming the host tree defenses (reviewed in Kohlmayr et al. 2002).

Increased fire severity and soil erosion may be attributed in part to *Tomicus* spp., particularly in areas where extensive damage has resulted in significant tree mortality (reviewed in Ciesla 2003).

Symptoms

External evidence of maturation feeding and mining by adult beetles on young shoots ranges from discoloration of dying or dead shoots and leaves to tree death. Dark-colored boring dust and, in more healthy trees, pitch tubes on the bark surface provide evidence of breeding attacks. If bark is removed, the gallery system provides evidence of infestation. Secondary infection of vascular tissue by blue-stain fungi may be observed in the xylem. Females construct 6-25 cm-long [2¼ - 4 in] vertical galleries in the inner bark and outer sapwood. Larval feeding galleries are 4-9 cm in length and perpendicular to the maternal galleries (reviewed in Monleón et al. 1996, reviewed in Kohlmayr et al. 2002). *T. destruens* may attack the upper trunk and large branches of older *Pinus* spp. with thick bark, or the entire trunk of smaller trees with thin bark (reviewed in Ciesla 2003).

Known Hosts

Tomicus destruens feeds almost exclusively on Mediterranean *Pinus* spp., but has the potential to colonize other conifers (Faccoli 2007). Its main hosts are *P. halepensis* and *P. pinaster* (Horn et al. 2006).

Host	**Reference**
Pinus brutia (Calabrian pine)	(Lekander 1971, Bright and Skidmore 1997, Kohlmayr et al. 2002, reviewed in Ciesla 2003, reviewed in CAB 2005, Faccoli 2006, Horn et al. 2006, Vasconcelos et al. 2006)
Pinus canariensis (Canary Island pine)	(Bright and Skidmore 1997, reviewed in Ciesla 2003, reviewed in CAB 2005, Faccoli 2006, Vasconcelos et al. 2006)
Pinus halepensis (Aleppo pine)	(Lekander 1971, Bright and Skidmore 1997, Nanni and Tiberi 1997, Gallego and Galián 2001, Kerdelhue et al. 2002, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Vasconcelos et al. 2003, reviewed in CAB 2005, Hrašovec et al. 2005, Faccoli 2006, Horn et al. 2006, Vasconcelos et al. 2006)
Pinus pinaster (maritime pine)	(Laumond and Carle 1971, Lekander 1971, Bright and Skidmore 1997, Kerdelhue et al. 2002, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Vasconcelos et al. 2003, reviewed in CAB 2005, Peverieri and Faggi 2005, Faccoli 2006, Horn et al. 2006, Vasconcelos et al. 2006)
Pinus pinea (Italian stone pine)	(Lekander 1971, Nanni and Tiberi

Host	Reference
	1997, Kerdelhue et al. 2002, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Vasconcelos et al. 2003, Faccoli 2006, Horn et al. 2006, Vasconcelos et al. 2006)
Pinus radiata (radiata pine)	(Kerdelhue et al. 2002, Horn et al. 2006, Vasconcelos et al. 2006)
Pinus sylvestris (Scots pine)1	(Guerrero et al. 1997)

1. Main host plant of the taxonomically confused species *T. piniperda* (Faccoli et al. 2005b). *P. sylvestris* does not support development of *T. destruens* (Faccoli 2007).

Known Vectors

T. destruens is associated with several potentially pathogenic fungi including *Heterobasidion annosum*, *Leptographium guttulatum*, *L. truncatum* (= *L. lundbergii*), *L. serpens*, *L. wingfieldii*, and *Phellinus pini* (Nanni and Tiberi 1997, Peverieri et al. 2006). *H. annosum* is pathogenic to many conifers, particularly pines and firs (Viiri 2004). *L. procerum* is weakly pathogenic to many conifers and causes root decline in *Pinus strobus* (Viiri 2004). See 'Pest Importance.'

Known Distribution

Tomicus destruens and the closely related *T. piniperda* are found in France, Italy, Spain, and Portugal (Kerdelhue et al. 2002, Kohlmayr et al. 2002, Vasconcelos et al. 2006). Laumond and Carle (1971) and Gallego et al. (2004) suggest *T. destruens* is found at low altitudes (<1000 m) in the south Mediterranean.

Location	Reference
Africa	
Algeria	(Faccoli 2006, Horn et al. 2006)
Morocco	(Horn et al. 2006)
Tunisia	(Horn et al. 2006)
Asia	
Cyprus	(Laumond and Carle 1971, Lekander 1971, Wood and Bright 1992, reviewed in Ciesla 2003)
Israel	(Laumond and Carle 1971, Lekander 1971, Mendel 1986, Wood and Bright 1992, reviewed in Ciesla 2003, Horn et al. 2006)
Lebanon	(Horn et al. 2006)
Turkey	(Laumond and Carle 1971, Lekander 1971, Wood and Bright 1992, reviewed in Ciesla 2003, Horn et al. 2006)

Location	Reference
Europe	
Croatia	(Hrašovec et al. 2005, Horn et al. 2006)
France[1]	(Laumond and Carle 1971, Lekander 1971, Wood and Bright 1992, reviewed in Ciesla 2003, Duan et al. 2004, Faccoli 2006, Horn et al. 2006, Vasconcelos et al. 2006)
Greece	(Kohlmayr et al. 2002, Faccoli 2006, Horn et al. 2006)
Italy	(Laumond and Carle 1971, Lekander 1971, Wood and Bright 1992, Nanni and Tiberi 1997, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Peverieri and Faggi 2005, Faccoli 2006, Peverieri et al. 2006, Vasconcelos et al. 2006)
Portugal	(Lekander 1971, Wood and Bright 1992, reviewed in Ciesla 2003, Vasconcelos et al. 2003, Horn et al. 2006, Vasconcelos et al. 2006)
Spain	(Laumond and Carle 1971, Lekander 1971, Wood and Bright 1992, Kohlmayr et al. 2002, reviewed in Ciesla 2003, Horn et al. 2006, Vasconcelos et al. 2006)
Atlantic Islands	
Canary	(reviewed in Ciesla 2003)
Madeira	(Wood and Bright 1992, Gallego and Galián 2001, reviewed in Ciesla 2003)

1. Southern and southeastern areas.

Potential Distribution within the United States

The known distribution of *T. destruens* suggests that the insect may be most closely associated with four biomes, three of which occur in the United States: (1) temperate coniferous forests; (2) temperate broadleaf and mixed forests; and (3) Medierranean scrub. Collectively, these biomes account for approximately 48% of the area of the contiguous United States and are generally found east of the Mississippi River, along the Pacific Coast, and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Preferred Method: Baited traps. Like other members of the genus *Tomicus*, *T. destruens* is attracted to pine volatiles (Guerrero et al. 1997). *T. destruens* is strongly attracted to (-)-α-pinene (Peverieri et al. 2004). Benzyl alcohol, at concentrations of 50 µg and higher, masks the attractivity of pine volatiles and is "significantly repellent" at 500 µg (Guerrero et al. 1997). Verbenone also repels *T. destruens* (Peverieri et al. 2004).

Peverieri et al. (2004) tested a number of attractants on *T. destruens*, including "Ipm", "Tomowit", "Destruens", and α-pinene. Lures were placed in funnel-shaped traps (Witasek, Pherotech, Theysohn, and Intercept-PTBB) located 60 m from a stand of heavily-infested pines (*Pinus pinaster* and *P. pinea*) with 30 m between traps. Traps containing Tomowit, Ipm, and Destruens were replaced every 30 d; those with α-pinene were replaced every 15 d. Ipm and (-)-α-pinene (release rate 90 mg/d at 21ºC) were most attractive to *T. destruens*, while the experimental lure Destruens failed to attract a significant number of adults. Differences were not statistically significant among the four traps tested (Peverieri et al. 2004).

Alternative Method: Visual surveys should be carried out in autumn, when *T. destruens* has its reproductive flight (Gallego and Galián 2001, Peverieri et al. 2004). External signs of infestation by *T. destruens* include feeding damage on young shoots, pitch tubes on the bark surface, reddish-brown boring dust, and small round emergence holes. Maternal and larval galleries are found under the bark. The xylem may be discolored by blue-stain fungi associated with *T. destruens* (reviewed in Ciesla 2003).

Diagnostics

Identification depends on examination of adult morphological characters.

Maternal and larval galleries (Fig. 25) are distinct enough to allow identification to genus (Ciesla 2003).

Easily Confused Pests

Tomicus destruens is morphologically similar to *T. piniperda* (Faccoli 2006) and the two species are difficult to distinguish in the field (Gallego and Galián 2001, Faccoli 2006). However larvae and callow (young) adults of *T. destruens* and *T. piniperda* are easy to differentiate (Lekander 1971, Faccoli 2006). Faccoli (2006) provides a key for distinguishing *T. destruens* from *T. piniperda*. *T. piniperda* is native to Europe, Asia, and North Africa and was introduced into the United States in 1992 (Kohlmayr et al. 2002, reviewed in CAB 2005), while *T. destruens* is currently confined to the circummediterranean region. *T. piniperda* is the only representative of its genus in North America (CAB 2005). Both species are found in sympatry in France (Kerdelhue et al. 2002), Italy (Kohlmayr et al. 2002),

Fig. 25. Gallery of *Tomicus piniperda*. The gallery of *T. destruens* is similar. Image from Stanislaw Kinelski,

Spain, and Portugal (Vasconcelos et al. 2006), but generally infest different species of pine (Kohlmayr et al. 2002). Gallego et al. (2004) found *T. destruens* and *T. piniperda* coexisting in *Pinus pinaster* and *P. radiata* in northern Spain. Molecular phylogenetic studies performed by Gallego and Galián (2001), Kerdelhué et al. (2002), Kohlmayr et al. (2002), and Faccoli et al. (2005b) have validated the status of *T. destruens* as a separate species from *T. piniperda*. Early studies in France found the two species were interfertile, but individuals were identified by flight period and not morphologic or phylogenetic characteristics (Gallego and Galián 2001).

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Arthropods:
Moths

Dendrolimus pini

E.E. Davis, E.M. Albrecht, and
R.C. Venette

Fig. 26. Adult male *Dendrolimus pini*. Image by Stanislaw Kinelski, http://www.bugwood.org

Scientific Name

Dendrolimus pini Linnaeus

Synonyms:
Bombyx pini Linnaeus
Dendrolimus segregatus Butler
Gastropacha pini Linnaeus
Lasiocampa pini Linnaeus
Phalaena pini Linnaeus
(reviewed in CAB 2005)

Common Names

Pine-tree lappet, pine lappet, pine moth

Type of Pest

Moth, defoliator

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Lepidoptera, **Family:** Lasiocampidae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult (Fig. 26)
“Male reddish ochre, more or less gray: superior wings chestnut at the base and extending to the disc; before the middle is a sinuated striga with a lunular white spot upon it, and beyond the middle an oblique ochraceous fascia, the inner margin crenated with a brown line, the outer one very much sinuated and marked with strong brown spots: inferior wings pale castaneous. Female paler” (Watson and Dallwitz 2007).

“The first pair of wings are with a small white spot and wide dark strip. Antennae of females are slightly saw-shaped, while those of males are double comb-shaped” (Kolk and Starzyk 1996).

“Adults are covered with thick scales on both the wings and body. Males have a wingspan of 50-70 mm and females a wingspan of 70-90 mm. The forewings are gray-brown to brown in color. They contain a reddish brown lateral band, edged on both sides with an irregular dark-brown to black stripe. The hind wings are red

brown to gray brown in color. Body color is brown. Coloring of the males is typically darker than the females" (Ciesla 2004).
The sex of moths may be determined at eclosion (emergence from pupal cocoons) "from the form of the antennae which are more plume-like in males" (Winokur 1991).

Egg
"Eggs are about 2 mm long, blue green in color when first deposited, later turning to gray" (Ciesla 2004).

Larva (Fig. 27)
"Mature larvae range in size from 50-80 mm and are covered with soft gray or brownish hairs. Thoracic segments 2 and 3 have thick bands of hairs of alternating steel blue and black. The dorsal surface of each abdominal segment contains a black mark flanked by irregular white lines" (Ciesla 2004).

"A V-shaped spot [occurs] on the eight segment of the body" (Kolk and Starzyk 1996).

Pupa
"Pupae range from 30-35 mm in length, are brown to black in color with both ends rounded. They are enclosed in a yellow-brown spindle shaped cocoon, which also contains remnants of the steel blue thoracic hairs" (Ciesla 2004).

Fig. 27. Larva of *Dendrolimus pini*. Image from W. Ciesla, http://www.bugwood.org

Biology and Ecology

Dendrolimus pini typically has one generation per year. However, under adverse conditions (population density; climatic conditions; temperature; host availability and quality; presence of natural enemies; etc.), two years may be required to complete development. *D. pini* overwinters in the larval or pupal stages (reviewed in Malyshev 1987, Kolk and Starzyk 1996). Outbreaks are cyclical (Malyshev 1987). The density of *D. pini* between outbreaks remains higher in areas considered outside the outbreak center (Malyshev 1987). A maximum of 420-475 larvae per tree have been observed during an outbreak in Novokhoperskiye plantation (Voronezh Province, Russia; formerly European USSR) (Malyshev 1987). Sukovata et al. (2002) found a positive correlation between larval abundance and the monoterpene β-pinene.

The biology of *D. pini* is similar to that of *D. superans*, and is reviewed in Geispits (1965), Malyshev (1987), Kolk (1996), Pszczolkowski and Smagghe (1999), Winokur (1991) and Ciesla (2004).

In its native range, *D. pini* adults emerge in midsummer and live for about ten days. Flight typically occurs at night between late June and August. Mating occurs over several hours at night. Females fly after oviposition begins, however they remain flightless on the lower part of the host tree until egg deposition is partially completed. Females deposit 150-300 eggs in groups of 20-100 on needles, branches and bark crevices.

The egg incubation period is 14-25 days. Egg mortality is significant at or above 32°C.

Larvae hatch between late summer and early fall and disperse by crawling or ballooning on strands of silk carried by air currents. Caterpillars are most active at dusk and dawn. When feeding, larvae will consume all or part of a needle. Larvae feed immediately after egg hatch, initially on old growth in spring until new needles emerge, and then on new growth until late fall. Larvae complete 2-3 molts before overwintering in forest litter. Larvae move from the host to the forest floor in autumn once daylength is under 12 h. The majority of larvae will overwinter in forest litter within 1 m of a host tree. Under natural conditions diapause is induced when the temperature falls below 5°C. Larvae typically enter diapause as mid- to late-instars, and break diapause when forest litter temperature reaches 3°C. Exposure to daylengths <9 h for a period of 20-35 d can induce diapause in all instars. Diapause is inhibited by daylengths over 15-17 h. Larvae may also enter summer diapause when conditions become unfavorable for development. Early in spring, overwintered larvae return to tree crowns and resume feedling preferentially on year-old needle growth and may also feed on the tender bark of young tree shoots. Larvae feed intensely following diapause, consuming the majority of food necessary for completing development (3-5 times the amount of foliage consumed the previous fall). Feeding continues through midsummer followed by pupation.

Pupation occurs in spindle-shaped cocoons spun loosely with silk, needles and small branches, in bark crevices, tree crowns or nearby vegetation between late June and August. This stage typically requires 18-35 d under favorable conditions.

Pest Importance

Dendrolimus pini is an economically important defoliator of pine and coniferous forests in Europe and Asia (Leśniak 1976a, 1976b, 1976c, Malyshev 1987, Pszczolkowski and Smagghe 1999, reviewed in Ciesla 2004). Overwintered larvae cause more damage because they consume 3-5 times greater the volume of needles consumed in the fall (reviewed in Ciesla 2004).

Like *D. superans*, densites of *D. pini* typically build over several years, reach an outbreak condition, and then collapse (Varley 1949, Malyshev 1987). Outbreaks have been reported in pine forests and vary in size and extent depending on many factors including population density; dispersal behavior; forest type; host availability and quality; stand age; higher temperatures and lower precipitation; and soil type (e.g., outwash plains and sandy soils) (Leśniak 1976a, 1976b, 1976c, reviewed in Ciesla 2004). Cyclic outbreaks have also been observed to coincide with solar activity, though the relationship between solar radiation intensity and outbreak frequency is not well understood (Leśniak 1976c).

Outbreaks of *D. pini* are familiar in Europe and can last 7-8 years. Outbreaks have been reported in Poland since the late 18th Century. In Poland, chemical control was used between 1946-1995 to reduce damage to 233,000 ha of forests caused by *Dendrolimus pini*. In northern Germany, historic outbreaks in the 13th and 19th centuries damaged more than 170,000 ha [conversion to acres] of forest. An outbreak in northeastern Germany in the mid 1990s caused heavy defoliation to 83,700 ha. Repeated annual defoliation can result in tree mortality. Weakened, stressed trees are subject to attack by secondary pests, and areas with extensive tree mortality are vulnerable to forest fires (reviewed in Ciesla 2004).

Establishment of *D. pini* in the United States could have adverse impacts on domestic and international trade and would likely result in domestic and/or international quarantines or requirements for additional treatment of potentially infested host materials (reviewed in Ciesla 2004).

Outbreaks in Europe have stimulated the use of aerial applications of synthetic pyrethroids or naturally-derived insecticidal coumpounds for insect suppression. The non-target impacts of these practices have not been evaluated (reviewed in Ciesla 2004, EPPO 2005).

Dendrolimus pini has a moderate host range, feeding primarily on needles of coniferous hosts. However, 82% of forests in the western United States are coniferous, so the potential impact on forests is significant (reviewed in Ciesla 2004).

Though rare and not well understood, *D. pini* can potentially impact human health. Dendrolimiasis is an allergic or hypersensitivity reaction (inflammation) affecting skin and/or joints (Diaz 2005).

Symptoms

Defoliation of conifers, new and old growth. Severe or repeated defoliation over several years can result in tree death. During an outbreak, caterpillars are conspicuous and defoliation can be widespread (reviewed in Ciesla 2004).

Known Hosts

Dendrolimus pini feeds on multiple species of *Pinus* (Lindelöw and Björkman 2001). Winokur (1991) lists *Pinus sylvestris* as the preferred host for *D. pini*. This insect prefers to feed on 20 to 80 year-old pine stands (Sukovata et al. 2002).

Host	Reference
Abies spp. (fir)	(Diaz 2005)
Abies alba (silver fir)	(reviewed in Ciesla 2004)
Cedrus deodara (Himalayan cedar)	(reviewed in CAB 2005)
Juniperus communis (common juniper)	(Ciesla 2004)
Larix sibirica (Siberian larch)	(reviewed in Ciesla 2004)
Picea spp. (spruce)	(Diaz 2005)
Picea abies (Norway spruce)	(reviewed in CAB 2005)
Picea stichensis (Sitka spruce)	(reviewed in Ciesla 2004)
Pinus spp. (pine)	(Pszczolkowski and Smagghe 1999, reviewed in CAB 2005, Diaz 2005)
Pinus cembra (Swiss stone pine)	(reviewed in Ciesla 2004)
Pinus mugo (mountain pine)	(Kolk and Starzyk 1996)
Pinus nigra (black pine)	(Kolk and Starzyk 1996, reviewed in CAB 2005)
Pinus strobus (eastern white pine)	(Kolk and Starzyk 1996, reviewed in CAB 2005)
Pinus sylvestris (Scots pine)	(Priesner et al. 1984, Winokur 1991, Kolk and Starzyk 1996, Johansson et al. 2002, Sukovata et al. 2002, reviewed in Ciesla 2004, reviewed in CAB 2005)
Pseudotsuga menziesii (Douglas-fir)	(reviewed in Ciesla 2004)

Known Vectors

Dendrolimus pini is not known to vector any pathogens.

Known Distribution

Dendrolimus pini is native to central Asia and north Africa and is usually found at elevations >200 m [~660 ft] above sea level (Diaz 2005).

Location	Reference
Africa	
Morocco	(reviewed in CAB 2005)
Asia	
China	(reviewed in CAB 2005, Diaz 2005)
Georgia (Republic)	(Kovalev et al. 1993)
Atlantic Islands	
Mallorca (Spain)	(Winokur 1991)
Europe	
Austria	(reviewed in CAB 2005)

Location	Reference
Belarus	(Geispits 1965, reviewed in CAB 2005)
Czech Republic	(reviewed in CAB 2005)
Denmark	(reviewed in CAB 2005)
Finland	(reviewed in CAB 2005)
France	(Malyshev 1987, reviewed in CAB 2005)
Germany	(Gäbler 1949, Varley 1949, reviewed in CAB 2005)
Hungary	(reviewed in CAB 2005)
Italy	(Malyshev 1987, reviewed in CAB 2005)
Netherlands	(reviewed in CAB 2005)
Norway	(reviewed in CAB 2005)
Poland	(Leśniak 1976a, 1976b, 1976c, Kolk and Starzyk 1996, Johansson et al. 2002, Sukovata et al. 2002, reviewed in CAB 2005)
Russia	(Geyspits 1965, (Malyshev 1987, reviewed in CAB 2005)
Slovakia	(reviewed in CAB 2005)
Sweden	(Johansson et al. 2002, reviewed in CAB 2005)
Switzerland	(reviewed in CAB 2005)
United Kingdom[1]	(reviewed in CAB 2005)

1. Only four records of *D. pini* are known from the British Isles (reviewed in Ciesla 2004).

Potential Distribution within the United States

The known distribution of *D. pini* suggests that the insect may be most closely associated with two biomes, both of which occur in the United States: (1) temperate coniferous forests; and (2) temperate broadleaf and mixed forests. Both biomes account for approximately 47% of the area and are generally found east of the Mississippi River, and scattered throughout the Intermountain West, the Pacific Northwest, and the Sierra-Nevada Mountains.

Survey

Preferred Method: Traps baited with sex pheromones are the most effective method for monitoring adults. Priesner et al. (1984) found tetratraps baited with 1000 µg of the sex pheromone (Z,E)-5,7-dodecadienal had the highest total catch of adult male *D. pini*. Kovalev et al. (1993) improved capture of males with a 60:40 mixture of (Z,E)-5,7-dodecadienal:(Z,E)-5,7-dodecadien-1-ol over (Z,E)-5,7-dodecadienal alone. The two compounds are also the major components of the sex pheromone of the closely related *D. superans*, which is native to Asian Russia and the Far East. Klun et al. (2000) and Khrimian et al. (2002) used a 1:1

mixture of these two dienes to attract *D. superans*. The sex pheromone of *D. punctatus*, (Z,E)-5,7-dodecadien-1-yl acetate, is a "powerful inhibitor of the sex pheromone of *D. pini*" (Kong et al. 2001). (E,Z)-5,7-dodecadienal is also inhibitory (Priesner et al. 1984).

<u>Not Recommended:</u> Monitoring of populations of *D. pini* can be achieved through several methods. Soil sampling is useful for collecting overwintering larvae of *D. pini*, but Johansson et al. (2002) note this method "may be unreliable at low population densities." Overwintering larvae are generally found in litter and mineral soil within ~1m of the tree (Kolk and Starzyk 1996, reviewed in Ciesla 2004).

<u>Not Recommended:</u> A technique developed for sampling of *D. superans* in Eastern Siberia may also be useful for sampling *D. pini*. The area around a tree is cleared of understory vegetation, a tarp is placed around the base, and the tree is struck 6-8 times with a "kolot", a large, 2-3.5 m log. The larvae are dislodged from the tree and fall onto the tarp, where they are counted and identified. This method is not recommended for healthy trees as it is highly destructive to the tree being sampled (Vartanov 2002).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Dendrolimus pini may be confused with the closely-related *D. superans* (EPPO 2005). Neither species is present in the United States (reviewed in Ciesla 2004).

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Dendrolimus superans

E.E. Davis, E.M. Albrecht, and R.C. Venette

Fig. 28. Adult D*endrolimus superans*. Image from Natalia Kirichenko, http://www.bugwood.org

Scientific Name

Dendrolimus superans Butler

Synonyms:
A complete list of synonyms is reviewed in Davis et al. (2005)

Common Names

Siberian silk moth
Siberian moth
Larch caterpillar

Type of Pest

Moth, defoliator

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Lepidoptera, **Family:** Lasiocampidae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Dendrolimus superans (Fig. 28) is a significant defoliator of coniferous forests in Asia and has the potential to cause damage in the United States. We previously summarized the basic morphology, known biology, damage potential, and survey techniques for this insect (Davis et al. 2005); subsequently, new information about *D. superans* has been published. Rather than repeat information available in other summaries, this truncated data sheet refers to relevant recent publications and emphasizes particular impacts this pest may have on pines.

Pest Description

Davis et al. (2005) provide excerpts from Butler (1877) and Rozhkov (1970) to identify larvae and adults.

Biology and Ecology

Davis et al. (2005) provide a review of the general biology and ecology of *D. superans*. No details about the life history of *D. superans* on *Pinus* spp. have been reported.

Fig. 29. Defoliation of Siberian larch (*Larix*) by *Dendrolimus superans*. Image from Vladimir Petko, http://www.bugwood.org

Pest Importance

Dendrolimus superans is an economically important defoliator of conifers in Asia, with outbreaks reported in pine, fir, spruce, and larch forests (Fig. 29) (Baranchikov et al. 1997, Baranchikov and Kirichenko 2002). The importance of *D. superans* as a defoliator of coniferous forests is reviewed in Davis et al. (2005).

Symptoms

The most prominent sign of infestation by *D. superans* is defoliation of current year's growth. Early-instar larvae consume the edges of needles, while older larvae eat entire needles, cones, and bark of saplings (EPPO 2006). Caterpillars are conspicuous during outbreaks (Orlinski 2000).

Known Hosts

Dendrolimus superans is moderately host specific. The insect reportedly feeds on over 20 coniferous species, but all known hosts occur within the family Pinaceae. Research by Kirichenko and Baranchikov (2007) suggests that larch, fir, and spruce are more appropriate than pine as host plants for *D. superans*. Davis et al. (2005) provide a complete list of hosts as reported in the literature. Noted pine hosts include *Pinus thunbergii*, *P. koraiensis*, *P. sylvestris* and *P. sibirica*.

Known Vectors

Dendrolimus superans is not known to vector any pathogens.

Known Distribution

Dendrolimus superans is present throughout much of Asia, particularly in Asian Russia and the Far East, excluding extreme northern regions. Davis et al. (2005) provide a complete summary of countries that have reported the presence of this insect.

Potential Distribution within the United States

In general, *Dendrolimus superans* occurs in semi-arid to humid and temperate to cold climates. More than three-quarters of the continental United States would have a suitable climate for *D. superans*, with only the arid West predicted to be unsuitable. Further details are provided in Davis et al. (2005).

Survey

Preferred Method: Monitoring populations with pheromone-baited traps is a far more cost effective approach than beat sampling (Vartanov 2002). Grey rubber septa (1x2 cm; West Co., Kearney NE) are pre-cleaned with acetone and "treated with 12.2 μl of a solution containing 164 μg of a 1:1 mixture of (*Z,E*)-5,7-dodecadienal and (*Z*,*E*)-5,7-dodecadien-1-ol per 1 μl of heptane (2mg of sex attractant/septum)" (Khrimian et al. 2002). Septa are placed inside modified USDA milk carton type traps, originally designed for gypsy moth (Klun et al. 2000). Traps should be modified by expanding entrance holes to 7cm wide x

3 cm high (Klun et al. 2000) or 2.5 x 3.0 cm (Khrimian et al. 2002). Vapona© strips at the bottom of the trap will kill all incoming insects (Klun et al. 2000, Khrimian et al. 2002). Traps should be 1.5 m [5 ft] above the ground when hung in trees (Klun et al. 2000, Khrimian et al. 2002). In Russia, traps are placed every 500 m (0.3 mi) (Vartanov 2002). A similar method employed by Kong et al. (2007) uses pheromone-treated grey rubber septa placed inside sticky wing traps, which are hung 2 m [~6½ ft] above ground and spaced 15 m [50 ft] apart. However, (*Z,E*)-5,7-dodecadienal alone was found to be most attractive to males and the addition of other compounds did not increase capture.

<u>Not Recommended:</u> A modified beat sampling technique ("okolot" in Russian) has been used in the Russian Far East to monitor populations of *D. superans* (Vartanov 2002). The "kolot" refers to a large "hammer" or log (2.5-3m) that is used to strike a tree and dislodge larvae. A site around a suspect tree is prepared by clearing all understory vegetation and spreading a tarp at the base. A tree is struck 6-8 times with the kolot and larvae on the tarp are identified and counted (Vartanov 2002). With experienced labor, ten trees may be sampled in 0.7 d, including the time to prepare the kolot (Vartanov 2002). This method is not recommended for healthy trees as it is highly destructive to the tree being sampled (Vartanov 2002).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Dendrolimus superans may occur in mixed populations with closely related or other easily confused species (primarily *D. pini*) on similar hosts within its native range (EPPO 2006). *Dendrolimus pini* is also not known to occur in the United States.

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Lymantria mathura

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Fig. 31. Adult female *Lymantria mathura*.
Image from David Mohn, http://www.bugwood.org

Scientific Name

Lymantria mathura Moore

Synonyms:
Portheria mathura (Moore)
Ocneria mathura (Moore)
Lymantria aurora Butler
Lymantria fusca Leech
Lymantria mathura aurora Butler
(reviewed in EPPO 2005)

Common Names

Pink gypsy moth
Rosy gypsy moth

Type of Pest

Moth, defoliator

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Lepidoptera, **Family:** Lymantriidae

Reason for inclusion in manual

CAPS Priority Pest (FY 2007)
Exotic Forest Pest Information System – classified as a very high risk pest

Lymantria mathura has posed a serious threat to North American trees for some time. We previously summarized the basic morphology, known biology, damage potential, and survey techniques for this insect (e.g., Davis et al. 2005, 2008a, 2008b); subsequently; little new information about *L. mathura* has been published. Rather than repeat information available in other summaries, this truncated data sheet refers to relevant publications and emphasizes the impact this pest may have on pines, in particular.

Pest Description

Davis et al. (2008a) provide useful excerpts from Roonwal (1979) and Moore (1865) to identify larvae and adults. Female and male adults are depicted in Figures 31 and 32, respectively.

Biology and Ecology

Davis et al. (2005) provide a review of the general biology and ecology of *L. mathura*. No details about the specific life history of *L. mathura* on *Pinus* spp. have been reported.

Pest Importance

Lymantria mathura is a significant defoliator of deciduous trees but is a minor pest of pine, if it achieves pest status at all. The importance of *L. mathura* as a defoliator of deciduous forests is reviewed in Davis et al. (2005). On pines, larvae survived poorly when forced to feed on pine foliage under laboratory conditions (Zlotina et al. 1998, reviewed in Rosovsky 2001). Lee and Lee (1996) suggested pine is a preferred host for oviposition, but Roonwal (1979) explained that *L. mathura* will oviposit on rough surfaces including non-target or secondary host tree species, particularly when population density is high. No other reports have described *L. mathura* as a pest of pine.

Symptoms

Feeding damage by *L. mathura* on pines has not been described. Damage is likely to be similar to damage caused by other pine defoliators. Egg masses and larvae may occur on the trunks of trees (reviewed in Rosovsky 2001).

Known Hosts

Lymantria mathura has a broad host range and seems to prefer deciduous trees. However in reviewing the work of Yurchenko (1995), Zlotina et al. (1998) conclude that *Pinus koraiensis* can support development of larvae. In separate experiments, Zlotina et al. (1998) found that larvae will feed on needles of *Pinus strobus* but will not develop beyond the second instar. Lee and Lee (1996) indicate *Pinus* spp. can be used for oviposition. Davis et al. (2005) provide a complete list of hosts as reported in the literature.

Known Vectors

Lymantria mathura is not known to vector any pathogens.

Known Distribution

Lymantria mathura is present throughout much of Asia, east of Russia (inclusive). Davis et al. (2005) provide a complete summary of countries that have reported *L. mathura*.

Fig. 32. Adult male *Lymantria mathura* with yellow hind wings. Image from W. Wallner, http://www.inspection.gc.ca/english/sci/surv/data/lymmate.shtml

Potential Distribution within the United States

In general, *L. mathura* occurs in cool to warm climates with variable seasonal rainfall and dry periods. Approximately one third of the contiguous United States has a suitable climate for *L. mathura*. Suitable areas occur in the East and Pacific Northwest. Additional details are provided in Davis et al. (2005).

Survey

<u>Preferred Method:</u> Pheromone-baited traps are particularly useful for regional surveys. The major sex pheromone components include a blend of (9*R*,10*S*)-*cis*-9,10-epoxy-*Z*3,*Z*6-nonadecadiene (named (+)-

mathuralure) and (9*S*,10*R*)-*cis*-9,10-epoxy-*Z*3,*Z*6-nonadecadiene (named (-)-mathuralure) in a 1:4 ratio (Gries et al. 1999). Neither component is attractive alone (Gries et al. 1999). The pheromone is most effectively deployed using PVC-coated string dispensers with 64 μg pheromone per cm (Khrimian et al. 2004). Traps baited with (+)-disparlure will also attract male *L. mathura* (Odell et al. 1992).

Pheromone lures have been used with Delta sticky traps (Gries et al. 1999) or 3.8-L milk carton traps (Odell et al. 1992). Traps are generally hung 1.5-2 m [ca. 5-6.5 ft] above ground (Odell et al. 1992, Gries et al. 1999).

Diagnostics

Identification depends on examination of adult morphological characters. *Lymantria mathura* is not likely to be confused with other lymantrids, particularly if a specimen is an adult or late instar larva (reviewed in EPPO 2005). Eggs or neonates are incredibly difficult to distinguish, and molecular tools are being developed to aid with identification (Armstrong et al. 2003).

Easily Confused Pests

L. mathura may be confused with *L. monacha* (not known to occur in the United States) or *L. dispar*.

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Arthropods: Woodwasps

Sirex noctilio

E.E. Davis, E.M. Albrecht, and R.C. Venette

Scientific Name

Sirex noctilio Fabricius

Synonyms:
Paururus juvencus var. *noctilio*
Paururus noctilio
Sirex juvencus
(reviewed in Smith 1978, reviewed in CAB 2005)

Common Names

European woodwasp, sirex woodwasp

Type of Pest

Woodwasp

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Hymenoptera, **Family:** Siricidae

Fig. 33. Adult female *Sirex noctilio*.
Photo by L. Sukovata, http://www.bugwood.org

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Adult

Female (Fig. 33): “The female [adult] is metallic dark-blue all over, except for the amber-coloured wings and legs. A protective sheath, containing an ovipositor, projects 2 to 3 mm beyond the abdomen. [Antennae have] 21 segments and length of about 7.8 mm.” The body is about 23 mm [$^{9}/_{10}$ in] long and the wingspan is about 39 mm [1 ½ in] (Neumann and Minko 1981).

Male (Fig. 34): “The male adult is metallic dark-blue, except that wings, abdominal segments [three to seven], and front and mid-legs are chestnut brown. Antennae are setaceous and slightly pubescent, with 20 segments and a length of about 6.8 mm.” The body is about 25 mm [1 in] long and the wingspan is about 44 mm [1 ¾ in] (Neumann and Minko 1981).

“Adults are usually 20 to 35 mm [$^{4}/_{5}$ – 1 $^{2}/_{5}$ in] in length. The female is uniformly metallic bluish-black with reddish-yellow legs and has a prominent ovipositor. The male is bluish-black with an orange band on the middle segments of the abdomen. Its fore and middle legs are reddish yellow, while the hind legs are thickened and black. Antennae of both sexes are black” (reviewed in Haugen 2006a).

Fig. 34. Adult male *Sirex noctilio*. Image from Haugen and Hoebeke (2005).

"In both sexes the final abdominal segment terminates in a prominent spine" (Neumann and Minko 1981).

Egg
"The eggs are white, soft and smooth" and 1.55 mm long by 0.28 mm wide (Neumann and Minko 1981).

Larva
"Larvae are creamy-white, deeply segmented, usually distinctly S-shaped, and of near-uniform diameter. Antennae are one-segmented, thoracic legs are short, and the abdomen is devoid of appendages, except for a conspicuous dark brown sclerotic spine" (Neumann and Minko 1981).

"The yellowish-white larva is a typical siricid with a round head, rudimentary legs, and a hard black spine on the posterior segment. Fully grown larvae can exceed 30 mm [1 $^2/_5$ in] in length" (reviewed in Haugen 2006a).

Pupa
"Pupae are creamy-white [and] gradually assume the colour of the adults" (Neumann and Minko 1981).

Biology and Ecology

Much has been written about the biology and ecology of *Sirex noctilio*. General reviews of Siricidae, including *S. noctilio*, are provided in Morgan (1968), Spradbery and Kirk (1978) and Smith and Schiff (2002). Madden (1974) and Spradbery (1977) describe oviposition behavior and Madden (1981) describes egg and larval development. Madden (1977) and Talbot (1977) have written extensively about the close association among *Sirex*, its fungal symbiont (*Amylostereum areolatum*), and *Pinus* spp.

S. noctilio is closely associated with a basidiomycetous wood decay fungus, *Amylostereum areolatum* (Morgan 1968, Madden 1977, Talbot 1977, Smith and Schiff 2002). In this symbiotic relationship, the fungus is carried in specialized mycangia by females to new tree hosts and is deposited under the bark as the female penetrates the host tissue to lay eggs. Wood with certain lipids, low oleoresin pressure, and relatively low moisture favors the growth of *Amylostereum* spp. (Morgan 1968). The fungus breaks down cellulose with digestive enzymes, providing a source of nutrition for developing larvae. Whether the developing siricids feed on the digested wood or solely on the fungus is not understood (Morgan 1968, Talbot 1977, Smith and Schiff 2002). Female larvae have a specialized organ that helps to scrape fungal hyphae into the mycangia (Morgan 1968, Smith and Schiff 2002). The toxic mucus and fungal inoculum eventually kill the host plant tissue (Madden 1974, 1981). *S. noctilio* can complete one generation (egg to adult) per year. Under favorable conditions, generation time may be as short as 3-4 months. In cooler climates or less favorable conditions, development of a generation may require two to three years. This insect may overwinter in the egg-larval stages (Morgan 1968, Madden 1974, Spradbery and Kirk 1978, reviewed in CAB 2005, reviewed in Haugen 2006a).

In the United States, adult *S. noctilio* are projected to emerge between July and September. Peak emergence is expected in August (Haugen and Hoebeke 2005). In Australia, adult emergence occurs between early summer and early winter, peaking in late summer or early fall (Morgan 1968). Males emerge first through round exit holes and fly a short distance to host tree tops. Females tend to fly toward areas with high light intensity before joining males (Morgan 1968). *S. noctilio* is considered a strong flier and has the potential to move >200 km [125 mi], but most do not disperse more than 30-50 km [18-30 mi] (reviewed in CAB 2005, Hoebeke et al. 2005, reviewed in Haugen 2006b, Haugen 2006a, Borchert et al. 2007). Females that emerge late in the season disperse a greater distance than earlier-emerging females. Males generally do not move from the original emergence area unless spread by wind (Borchert et al. 2007). Adults do not feed. Females and males live approximately 4-5 and 5-12 days, respectively. Males typically outnumber females with a sex ratio ranging from 4:1-7:1 (Neumann and Minko 1981).

Siricid adult activity is greatest during warm and sunny conditions with low relative humidity (Morgan 1968). Females use a tube-like ovipositor to drill egg shafts in the bole and branches of a host tree, inoculate the host plant with arthrospores of *A. areolatum* and toxic mucus, and deposit eggs. The number of egg shafts drilled and eggs deposited depends on the osmotic pressure within the phloem (Madden 1974, 1981). Sometimes, a female will test the suitability of a tree by drilling an egg shaft without depositing eggs (Neumann and Minko 1981). Potential fecundity depends on the size of the female, with the largest females capable of laying as many as 500 eggs (average, 210-226) (reviewed in CAB 2005). Up to three eggs are deposited in each egg shaft (Morgan 1968, reviewed in CAB 2005, reviewed in Hoebeke et al. 2005, reviewed in Haugen 2006a).

Egg and larval development depend on the successful growth of *A. areolatum*. Temperature and moisture levels that are optimal for the fungus also provide optimal growing conditions and nutrients necessary for the growth and development of *S. noctilio*. The number of eggs deposited in a tree increases as tree defenses weaken (Madden 1981). Egg development depends largely on temperature (range, 6.2-25°C) and requires an average of 186.3 dd above a threshold of 6.2°C (Madden 1981). At an optimal temperature of 25°C, eggs require 10-12 days to develop (Madden 1981, reviewed in Haugen 2006a).

Unfertilized eggs become males (reviewed in CAB 2005, reviewed in Haugen and Hoebeke 2005, reviewed in Haugen 2006a). Total development time depends on temperature (range, 12.5-33.5°C). According to Madden (1981), development from egg to adult requires approximately 2,500 degree days (dd) above a threshold of 6.8°C. Under experimental conditions, the minimum time for emergence was eight to nine weeks under incubation at a temperature of 33.5°C. However, development time under high temperatures resulted in high mortality (Madden 1981).

There are 6-12 larval instars (6-7, on average) (Morgan 1968, Madden 1981). Neumann and Minko (1981) observed male *S. noctilio* emerging from small-diameter trees after 3 instars, but note that “a minimum of five moults generally appears necessary before pupation can occur.” Larvae bore into the tree and feed on *A. areolatum* and/or digested wood.

Pupation occurs inside the host tree just beneath the bark and requires between 10 days to 5 weeks, depending on temperature (reviewed in CAB 2005, reviewed in Haugen 2006a).

Pest Importance

The economic and environmental importance of *S. noctilio* has been previously reviewed by Ciesla (2003), Haugen (2006b, 2006a) and CAB (2005).

Sirex noctilio is not considered a pest in its native range and tends to attack weakened or dying trees (Rawlings and Wilson 1949, Simpson 1976, Spradbery and Kirk 1978, Ciesla 2003, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006). However, *S. noctilio* and the associated fungus *Amylostereum areolatum* are thought to cause high mortality of exotic pine plantations where they have been introduced in the Southern Hemisphere (Haugen and Hoebeke 2005, Carnegie et al. 2006). Stressed stands of 10-25 year old pine are most susceptible to attack by *S. noctilio* (reviewed in CAB 2005).

S. noctilio may be a significant cause of mortality in overstocked or stressed stands (reviewed in Haugen 2006b, 2006a). In Australia, annual economic losses attributed to *S. noctilio* and *A. areolatum* have amounted to an estimated 16-60 million US dollars. Projected economic losses from the introduction of this pest in the United States range from tens to hundreds of millions of US dollars over 30 years (reviewed in Ciesla 2003, reviewed in Haugen 2006b, Haugen 2006a).

The combination of *A. areolatum* and the toxic mucus introduced by the wasp during oviposition contributes to tree necrosis and death. The pathogenicity of *A. areolatum* to many North American conifers under local climate conditions is not known (Lundgren 2004). Additional damage is caused by larval boring in the cambium and eventual girdling of the tree. Insect-damaged trees are vulnerable to subsequent attack by insects and pathogens (reviewed in Ciesla 2003, reviewed in Hoebeke et al. 2005, reviewed in Haugen 2006b, reviewed in Haugen 2006a).

Reduction or loss of mature conifers would negatively impact forest composition and displace native species. This would likely necessitate biological, chemical, and silvicultural control measures (reviewed in Ciesla 2003, reviewed in Hoebeke et al. 2005, reviewed in Haugen 2006b, reviewed in Haugen 2006a).

Symptoms

In live, standing trees, external symptoms of attack include crown wilt (wilted, downward-pointing green needles); discoloration of foliage from green to yellow to reddish-brown; resinosis (streams and beads of resin originating from areas of drilling and oviposition on the tree trunk); oviposition drills; and round exit holes about 5.5 mm [$^1/_5$ in] in diameter (Neumann and Minko 1981). Internally, dead or dying cambial tissue can be observed radiating outward from areas penetrated by females during oviposition. The phloem and sapwood may be dry (Neumann and Minko 1981). Frass-filled larval galleries can be found under the bark and brown staining of the sapwood may be present. Insects in all life stages may be present within the tree (Rawlings and Wilson 1949, reviewed in CAB 2005, reviewed in Haugen and Hoebeke 2005, reviewed in Haugen 2006b).

Known Hosts

Sirex noctilio is chiefly a pest of *Pinus* spp. but has also been reported from *Abies*, *Picea*, and *Larix*. However, 99% of attacks occur on pine (reviewed in Haugen 2006a), particularly *P. patula*, *P. radiata*, and *P. taeda* (Carnegie et al. 2006). Ciesla (2003) considers "all conifers of the family Pinaceae indigenous to North America" to be potential hosts for *S. noctilio*.

Host	**Reference**
Abies spp. (fir)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Abies alba (silver fir)	(reviewed in Smith 1978, reviewed in CAB 2005)
Agathis spp. (kauri)[1]	(Rawlings 1948)
Dacrydium cupressinum (rimu)[1]	(Rawlings 1948, reviewed in Smith 1978)
Eucalyptus globulus (Tasmanian bluegum)[1]	(Rawlings 1948)
Larix spp. (larch)[2]	(Rawlings 1948, reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Larix decidua (European larch)	(Rawlings and Wilson 1949)
Picea spp. (spruce)	(Ciesla 2003, reviewed in CAB 2005,

Host	Reference
	Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Picea abies (common spruce)	(reviewed in CAB 2005)
Picea sitchensis (Sitka spruce)	(Rawlings and Wilson 1949)
Pinus spp. (pine)	(Rawlings 1948, Simpson 1976, Talbot 1977, reviewed in Smith 1978, Ciesla 2003, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus banksiana (jack pine)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus canariensis (Canary pine)	(reviewed in CAB 2005)
Pinus caribaea (Caribbean pine)	(reviewed in Smith 1978, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a)
Pinus chiapensis (=*P. strobus* var. *chiapensis*) (Chiapas white pine)	(Hoebeke et al. 2005, Haugen 2006a)
Pinus contorta (lodgepole pine)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus densiflora (Japenese umbrella pine)	(reviewed in CAB 2005)
Pinus echinata (shortleaf pine)	(reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus elliottii (slash pine)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Pinus halepensis (Aleppo pine)	(reviewed in CAB 2005)
Pinus jeffreyi (Jeffrey pine)	(Ciesla 2003, reviewed in CAB 2005, Hoebeke et al. 2005, reviewed in Haugen 2006b)
Pinus kesiya (kesiya pine)	(Haugen 2006a)
Pinus muricata (Bishop pine)	(reviewed in Smith 1978, Carnegie et al. 2006)
Pinus nigra (Corsican pine)	(reviewed in Smith 1978, reviewed in CAB 2005, Haugen and Hoebeke

Host	Reference
	2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus palustris (longleaf pine)	(reviewed in CAB 2005, Hoebeke et al. 2005, Haugen 2006a, reviewed in Haugen 2006b)
Pinus patula (Mexican weeping pine)	(reviewed in Smith 1978, reviewed in CAB 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Pinus pinaster (maritime pine)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Pinus pinea (Italian stone pine)	(reviewed in CAB 2005, reviewed in Haugen 2006b)
Pinus ponderosa (ponderosa pine)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Pinus radiata (Monterey pine)	(Rawlings 1948, Rawlings and Wilson 1949, Madden 1974, Simpson 1976, Simpson and McQuilkin 1976, Madden 1977, Talbot 1977, reviewed in Smith 1978, Spradbery and Kirk 1978, Madden 1981, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, reviewed in Haugen 2006b)
Pinus strobus (Eastern white pine)	(reviewed in Smith 1978)
Pinus sylvestris (Scots pine)	(reviewed in Smith 1978, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Pinus taeda (loblolly pine)	(Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, reviewed in Haugen 2006b)
Prumnopitys ferruginea (miro)[1]	(Rawlings 1948)
Pseudotsuga spp. (Douglas-fir)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Hoebeke et al. 2005)
Pseudotsuga menziesii (Douglas-fir)[2]	(Rawlings 1948, reviewed in Smith

Host	**Reference**
	1978, reviewed in Haugen 2006b)

1. Rawlings (1948) notes *S. noctilio* has been observed to oviposit in these trees, but has not "been recorded as emerging from any species other than pine."
2. Possible misidentification (reviewed in Haugen 2006b).

Known Vectors

S. noctilio is associated with *Amylostereum areolatum*, a pathogenic fungus thought to cause high mortality of exotic pine plantations where they have been introduced in the Southern Hemisphere (Haugen and Hoebeke 2005, Carnegie et al. 2006). See 'Pest Importance.'

Known Distribution

Location	**Reference**
Africa	
Algeria	(reviewed in Haugen 2006b)
Morocco	(reviewed in Carnegie et al. 2006, reviewed in Haugen 2006b)
South Africa	(Morgan 1968, Talbot 1977, reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Tunisia	(reviewed in Carnegie et al. 2006, reviewed in Haugen 2006b)
Australasia	
Australia	(Morgan 1968, Madden 1974, Simpson 1976, Simpson and McQuilkin 1976, Madden 1977, Talbot 1977, reviewed in Smith 1978, Spradbery and Kirk 1978, Madden 1981, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
New Zealand	(Rawlings 1948, Morgan 1968, Simpson 1976, Simpson and McQuilkin 1976, Talbot 1977, reviewed in Smith 1978, Spradbery and Kirk 1978, Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Hoebeke et al. 2005, Carnegie et al. 2006, Haugen 2006a, reviewed

Location	Reference
	in Haugen 2006b)
Asia	
Japan¹	(reviewed in Smith 1978)
Mongolia	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005, reviewed in Haugen 2006b)
Atlantic Islands	
Azores (Portugal)	(reviewed in Smith 1978, Ciesla 2003, reviewed in CAB 2005)
Canary	(reviewed in CAB 2005)
Europe	
Austria	(reviewed in Smith 1978, reviewed in CAB 2005)
Belgium	(reviewed in Smith 1978, reviewed in CAB 2005)
Cyprus	(reviewed in Smith 1978, reviewed in CAB 2005)
Czech Republic	(reviewed in Smith 1978, reviewed in CAB 2005)
Denmark	(reviewed in Smith 1978, reviewed in CAB 2005)
England	(reviewed in Smith 1978, Spradbery and Kirk 1978, reviewed in CAB 2005)
Estonia	(reviewed in CAB 2005)
Finland	(reviewed in Smith 1978, reviewed in CAB 2005)
France	(reviewed in Smith 1978, reviewed in CAB 2005)
Germany	(reviewed in Smith 1978, reviewed in CAB 2005)
Greece	(reviewed in Smith 1978, reviewed in CAB 2005)
Hungary	(reviewed in Smith 1978, reviewed in CAB 2005)
Italy	(reviewed in CAB 2005)
Kazakhstan	(reviewed in Smith 1978)
Latvia	(reviewed in Smith 1978)
Lithuania	(reviewed in Smith 1978)
Montenegro	(reviewed in CAB 2005)
Norway	(reviewed in Smith 1978, reviewed in CAB 2005)

Location	Reference
Poland	(reviewed in Smith 1978, reviewed in CAB 2005)
Portugal	(reviewed in CAB 2005)
Romania	(reviewed in Smith 1978, reviewed in CAB 2005)
Russia	(reviewed in Smith 1978, Madden 1981, reviewed in CAB 2005, reviewed in Haugen 2006b)
Serbia	(reviewed in CAB 2005)
Slovakia	(reviewed in Smith 1978, reviewed in CAB 2005)
Spain	(reviewed in CAB 2005)
Ukraine	(reviewed in Smith 1978)
Yugoslavia	(reviewed in CAB 2005)
North America[2]	
Canada	(reviewed in Smith 1978, reviewed in Haugen 2006b)
United States	
MI	(Dettloff 2007)
NY	(Hoebeke et al. 2005, Haugen 2006a)
PA	(reviewed in NAPIS 2008)
VT	(reviewed in NAPIS 2008)
WY	(Smith and Schiff 2002)
South America	
Argentina	(Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Brazil	(Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)
Chile	(Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, reviewed in Haugen 2006b)
Uruguay	(Ciesla 2003, reviewed in CAB 2005, Haugen and Hoebeke 2005, Carnegie et al. 2006, Haugen 2006a, reviewed in Haugen 2006b)

1. Not established (reviewed in Smith 1978)

2. Not established (Ciesla 2003, Carnegie et al. 2006, Dettloff 2007). Most records are of single specimens, though 85 females were collected from traps in Oswego County in NY (Borchert et al. 2007).

Potential Distribution within the United States

The potential distribution of *S. noctilio* has been analyzed more rigorously than most other insects addressed in this document. Carnegie et al. (2006) used CLIMEX software to predict the global distribution of this woodwasp. For North America, they predict that most locations with susceptible hosts would also have a climate suitable for establishment.

Survey

Preferred Method: Hoebeke et al. (2005) report a single female *S. noctilio* captured in the United States in a Lindgren funnel trap baited with *cis*-verbenol, ipsdienol, and methyl butenol.

S. noctilio is attracted to pine volatiles. Intercept traps baited with α- and β-pinene have also been used for detection surveys. *S. noctilio* may be attracted *cis*- and *trans*-verbenol, myrtenol, pinocarvone, pinocamphone, isopinocamphone, myrtenal, *trans*-verbenyl acetate, and a number of other compounds (Simpson 1976), though these have not been tested in field operations. Simpson and McQuilkin (1976) found concentrations of camphor, pinocamphone, isopinocamphone, and *trans*-pinocarveol increased 20-30-fold in the 3-4 wk following felling of *Pinus radiata*. These trees are attractive for up to 3 wk after felling, while girdled trees retain their attractivity for up to 4 mo (Simpson and McQuilkin 1976).

Alternative Method: Visual inspection of trees is the most effective method to detect *Sirex noctilio*. Externally, infested trees may exhibit "beads or dribbles of resin", gummosis, chlorosis and wilting of the crown, and loss of needles (reviewed in Haugen 2006b). *Sirex noctilio* adults are attracted to stressed or damaged trees, especially those exuding resin (Talbot 1977). Adult emergence holes are circular and about 5.5 mm [$^1/_5$ in] (range, 3-8 mm [$^1/_{10}$ - $^1/_3$ in]) in diameter (reviewed in CAB 2005, reviewed in Haugen 2006b). Larval galleries 5-26 cm [2-10 in] long, along with galls filled with compacted frass, can be found under the bark (reviewed in CAB 2005). The sapwood may be stained brown along the grain or vertically from sites of oviposition (Fig. 35), indicating the presence of the symbiotic fungus

Fig. 35. Cambial tissue stained by *Amylostereum areolatum*. Picture by D. Haugen, http://www.forestryimages.org/

Amylostereum areolatum (reviewed in CAB 2005, reviewed in Haugen 2006b).

In areas where *S. noctilio* is well-established, an assessment of tree mortality caused by this insect can be obtained via aerial sketch mapping (Ciesla 2003) or GIS-based surveys (López et al. 2002). High-resolution aerial imaging is useful for distinguishing healthy trees from those with decline associated with *S. noctilio* (Ismail et al. 2006).

<u>Not Recommended:</u> Small populations of *S. noctilio* can be detected and monitored with the aid of trap trees, which are injected with dicamba (Ciesla 2003). Ciesla (2003) recommends using 5 trap trees per plot located along the “leading edge of *S. noctilio* occurrence.” In Australia, trap trees are installed in November and December (Ciesla 2003). Trap trees should be used about 2 months before peak emergence of *S. noctilio* (reviewed in CAB 2005).

Diagnostics

Identification depends on examination of adult morphological characters. Schiff et al. (2006) provide a key for identifying North American genera of siricid woodwasps.

According to Schiff et al (2006), the characteristics distinguishing *S. noctilio* from other woodwasps include

- “[Females] Abdomen blue black; ovipositor is short; Ovipositor with large pits close together; mesopleuron densely punctured; legs always red”
- “[Males] Abdomen reddish, black at base and apex; hind remur red; Abdominal segments 3–7 yellow; antennae black”

No molecular tools are available to help with diagnosis.

Easily Confused Pests

S. noctilio may easily be confused with the morphologically similar *S. juvencus*, which is widespread in North America (reviewed in Lundgren 2004). Older literature places *S. noctilio* in synonymy with *S. juvencus* (Talbot 1977). A number of specimens of *S. noctilio* have been misidentified as *S. juvencus*, but the two species are distinct (Smith 1978).

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Urocerus gigas

E.E. Davis, E.M. Albrecht, and R.C. Venette

Fig. 36. Adult female *Urocerus gigas gigas*. Image from Paula Klasmer, http://www.bugwood.org

Scientific Name

Urocerus gigas L.

Synonyms:
A complete list of synonyms is reviewed in Davis et al. (2005).

Common Names

Giant woodwasp
Greater horntail

Banded horntail

Type of Pest

Woodwasp

Taxonomic Position

Kingdom: Animalia, **Phylum:** Arthropoda, **Order:** Hymenoptera, **Family:** Siricidae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Urocerus gigas (Fig. 36) is considered a secondary pest of conifers throughout the Nearctic and Palearctic regions (Chrystal 1928, Morgan 1968, Kirk 1974, Kendall 2005) and has the potential to cause damage in the United States. We previously summarized the basic morphology, known biology, damage potential, and survey techniques for this insect (Davis et al. 2005). In the time since these documents were produced, little new information about *U. gigas* has been published. Rather than repeat information available in other summaries, this truncated data sheet refers to relevant publications and emphasizes the impact this pest may have, particularly on pines.

Pest Description

Davis et al. (2005) provide excerpts from Maa (1949) and Smith and Schiff (2002) to identify larvae and adults.

Biology and Ecology

Davis et al. (2005) provide a review of the general biology and ecology of *U. gigas*. No details about the specific life history of *U. gigas* on *Pinus* spp. have been reported.

Pest Importance

Throughout its range, *Urocerus gigas* is considered a secondary pest of Pinaceae. *Urocerus gigas* typically damages conifers that have been injured previously by fire, weakened by insects or pathogens, or felled for timber (Chrystal 1928, Morgan 1968, Ciesla 2000, Ebeling 2002, Smith and Schiff 2002). The damage caused by symbiotic fungi associated with *U. gigas* may be more significant than the damage caused by the insects themselves. The importance of *U. gigas* as a pest of conifers is reviewed in Davis et al. (2005).

Symptoms

The most conspicuous sign of *U. gigas* infestation is the presence of larval and oviposition tunnels. Larvae excavate deep tunnels in the sapwood, aided by the wood-decomposing symbiotic fungus *Amylostereum chailletii*. Emergence holes are also present; however, none of these symptoms is specific to *U. gigas* (Ciesla 2000).

Known Hosts

Urocerus gigas reportedly feeds on 5 or more genera within the family Pinaceae, including *Abies* spp., *Larix* spp., *Picea* spp., *Pinus* spp, and *Pseudotsuga* spp. Davis et al. (2005) provide a complete list of hosts as reported in the literature.

Known Vectors

A review of symbiotic fungi potentially associated with *U. gigas* is provided in Davis et al. (2005).

Known Distribution

Urocerus gigas is present throughout much of Asia and Europe. Davis et al. (2005) provide a complete summary of countries that have reported the presence of this insect.

Potential Distribution within the United States

In general, *U. gigas* occurs in warm and dry to cold and temperate climates. Almost half of the continental United States would have a suitable climate for *U. gigas* (Davis et al. 2005).

Survey

<u>Preferred Method:</u> Surveys for *U. gigas* will have to rely primarily on visual inspection methods. Further details are provided in Davis et al. (2005).

Diagnostics

Identification depends on examination of adult morphological characters. No molecular tools are available to help with diagnosis.

Easily Confused Pests

Urocerus gigas could easily be confused with other siricids in North America (reviewed in Davis *et al*. 2005). While certain subspecies of *U. gigas* (*orientalis*, *tibetanus*, and *taiganus*) do not occur in the United States, one (*flavicornis*) is considered native and widespread. There is debate as to whether *U. gigas gigas* is distinct from *U. gigas flavicornis*. A susbsequent debate arises as to whether the species should be considered exotic.

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Fungi

Leptographium truncatum

E.M. Albrecht and R.C. Venette

Scientific Name

Leptographium truncatum (Wingf. and Marasas) Wingf.

<u>Synonyms:</u>
Leptographium lundbergii Lagerb. and Melin
Scopularia lundbergii (Lagerb. and Melin) Goid.
Scopularia venusta Preuss
Verticicladiella truncata Wingf. and Marasas
(Kirk 2004, reviewed in Hildebrand 2005, MycoBank 2006)

Common Names

Blue stain, root disease, vascular wilt

Type of Pest

Fungal pathogen

Taxonomic Position

Kingdom: Fungi,
Phylum: Ascomycota,
Order: Ophiostomatales,
Family: Ophiostomataceae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

Leptographium truncatum (Fig. 37) was originally described as *Verticicladiella truncata* by Wingfield and Marasas (1983), based on samples collected from the roots of dying *Pinus radiata*, *P. strobus*, and *P. taeda* in South Africa and New Zealand. Kaneko and Harrington (1990) later described *L. truncatum* from dying *P. densiflora* and *P. thunbergii* in Japan. Jacobs and Wingfield (Jacobs and Wingfield 2001) described *L. lundbergii* from strains that are now considered to represent *L. truncatum* (Jacobs et al. 2005).

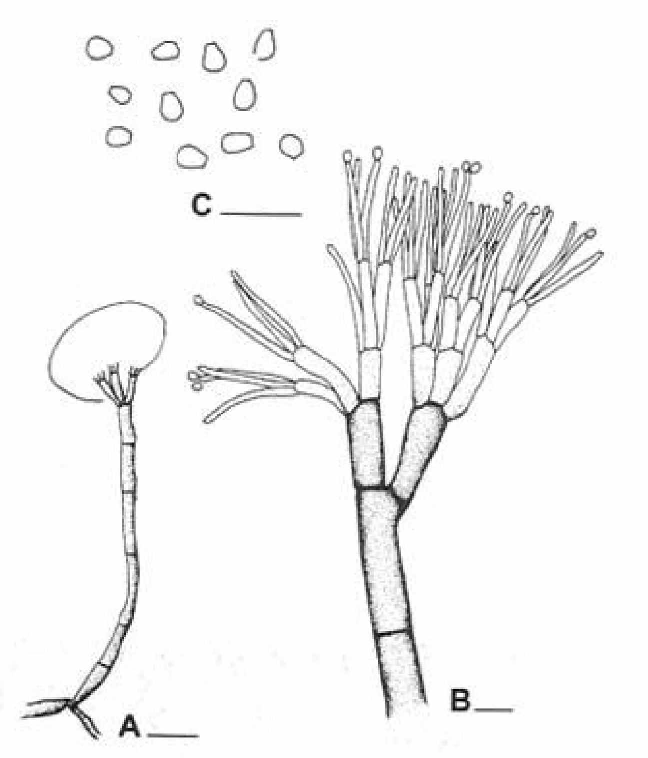

Fig. 37. Conidiophores and conidia of *L. truncatum*. A. Habit sketch (general appearance of conidiophore) (bar=100µm). B. Conidiogenous apparatus (bar=10µm). C. Conidia (bar=10µm).

The following descriptions relate to the appearance of *L. truncatum* grown in isolation in a laboratory. Color nomenclature follows Ridgway (1912).

Colony “diameter on corn meal agar (CMA) at 24° [75°F], 52 mm [2 in] after 4 days. Growth rate similar at 20° [68°F] and 24° [75°F] but reduced considerably at lower and higher temperatures. Colonies hyaline at first, becoming dark olivaceous to black. Aerial mycelium absent on CMA but well developed on Difco potato dextrose agar (PDA)” (Wingfield and Marasas 1983).

”Colonies with optimal growth at 25°C [77°F] on 2% MEA, reaching 39 mm [1.5 in] in diam. in 7 days. No growth below 5°C [41°F] or above 35°C [95°F]. Cycloheximide tolerant with a 21% reduction in growth on 0.5 g/l cycloheximide after 8 days at 20°C [68°F] in the dark. Colonies dark mouse gray (15''''k). Colony margin smooth” (Jacobs and Wingfield 2001).

Hyphae “immersed, septate, straight, smooth-walled, at first hyaline, becoming rougher with deposits and dark olivaceous, 1.8-3.7 µm diam with short branches often branching repeatedly, sometimes appearing knob-like” (Wingfield and Marasas 1983).

“Hyphae submerged in agar with very little aerial mycelium except on the edges of the colony, greenish olivaceous (23''') to olivaceous (21''m), smooth, straight, occasionally constricted at the septa, (3-)4-8(-14) µm wide” (Jacobs and Wingfield 2001).

Fig. 38. Light micrograph of conidiophores and conidia of *L. truncatum*. Conidiophore (bar=50µm). Image from Jacobs and Wingfield (2001).

Conidiophores (Fig. 37A, 38) “produced abundantly over the entire colony in cultures incubated at 20° in the dark for 10 days on CMA. One to several celled short rhizoids arise from the basal cells of the stipe and from the hyphal cells giving rise to the conidiophores” (Wingfield and Marasas 1983).

“Conidiophores occurring singly or in groups of up to six, arising directly from the mycelium, erect, macronematous, mononematous, (90-)246-409(-685) µm in length” (Jacobs and Wingfield 2001).

Stipe “erect, variable in length, 25.0-447.2 µm, with 1-11 septa and hyaline to dark olivaceous in colour. Base of stipe 3.6-12.7 µm wide and apex slightly swollen, 3.6-10.9 µm with attachment points for primary metulae well-developed, commonly branched, with branches varying from a single primary metula to well-developed side apparatus” (Wingfield and Marasas 1983).

“Stipes light olivaceous (21''k), not constricted, cylindrical, simple, 1-16-septate, (35-)214-306(-635) µm long, 2-5 µm wide below primary branches, apical cell not swollen, 2-5 (-6) µm wide at base, basal cell occasionally swollen” (Jacobs and Wingfield 2001).

Conidiogenous apparatus (Fig. 37B) “18.2-103.7 µm long, excluding the conidial mass and comprising 2-4 primary metulae 2.7-9.1 µm wide and 10.2-28.0 µm long. Two to four additional series occur above the primary metulae, each giving rise to 1-3 further metulae at the apex or from the side walls. Primary metulae paler in colour than the stipe, subsequent metulae hyaline” (Wingfield and Marasas 1983).

“Conidiogenous apparatus (35-)42-85(-150) µm long, excluding the conidial mass, with 2 to 3 series of cylindrical branches. Primary branches, 2-3, light olivaceous (21''k), smooth, cylindrical, 0-2-septate, 11-41(-57) µm long and 4-9(-11) µm wide, arrangement of the primary branches on the stipe-type B (more than two branches), secondary branches hyaline to light olivaceous (21''k), 0-1-septate, 8-30(-39) µm long, 3-7 (-9) µm wide, tertiary branches hyaline to light olivaceous (21''k), aseptate, (8-)14-17(-22) µm long, (3-)4-6(-8) µm wide” (Jacobs and Wingfield 2001).

Conidiogenous cells “discrete, hyaline, tapering from base to apex but widest at their centre, 7.3-50.0 µm long, 1.8-4.1 µm wide, appearing to elongate considerably in the apical region, distinctly roughened possibly to abcission scars which resemble annellations when viewed with the [scanning electron microscope] SEM” (Wingfield and Marasas 1983).

“Conidiogenous cells discrete, 2-3 per branch, cylindrical, tapering slightly at the apex, (11-)16-25(-37) µm long and 1-3 µm wide” (Jacobs and Wingfield 2001).

Conidia (Fig. 37C, 38) “hyaline, smooth, one-celled and pyriform to subglobose or clavate with broadly truncate bases. Under the SEM appearing hat-shaped due to a wide point of attachment at the base, ranging from 2.7-10.9 µm x 1.8-4.6 µm and often budding to produce secondary conidia. Conidia accumulate around the sporogenous apparatus in a hyaline mucilaginous mass, becoming yellow with age. Groups of conidiophores may form on aerial hyphae on PDA and primary metulae sometimes elongate, giving rise to an additional stipe and conidiogenous apparatus” (Wingfield and Marasas 1983).

“Conidia hyaline, aseptate, broadly ellipsoid with truncate bases and rounded apices, 3-5 x 2-4 µm. Conidial droplet hyaline at first, becoming cream-coloured (19'f) with age” (Jacobs and Wingfield 2001).

Biology and Ecology

Leptographium truncatum is a weakly pathogenic sapstain fungus associated with root disease of pine (Wingfield and Marasas 1983, Kaneko and Harrington 1990, Wingfield and Gibbs 1991, Zambino and Harrington 1992, Zhou et al. 2002, Eckhardt et al. 2004). It is considered a secondary pathogen and is introduced by the scolytids *Hylastes angustatus*, *Hylastes ater*, *Hylastes opacus*, *Hylurgops palliatus*, *Hylurgus ligniperda*, and *Tomicus piniperda* to trees that are already dead or dying (Wingfield and Marasas 1983, Harrington 1988, Wingfield and Gibbs 1991, Anon. 2000, Wingfield et al. 2001, Zhou et al. 2002, Hausner et al. 2005, Reay et al. 2005). *L. truncatum* is also associated with the nematode *Bursaphelenchus xylophilus*, which causes pine wilt disease in *Pinus densiflora* and *P. thunbergii* (Jacobs and Wingfield 2001). However, the exact role of *Leptographium* spp. in tree decline and death is not well understood. A combination of abiotic and biotic factors may contribute to the demise of a tree infected with *Leptographium* spp. Eckhardt et al. (2004) suggest fungi are introduced into the root system by rhizophagous insects. The lesions grow, further stressing the tree. Other scolytids are attracted to volatiles released by the stressed tree and may introduce other fungi during subsequent attacks.

Pest Importance

L. truncatum is a weak pathogen with a preference for highly stressed, wounded, or dying trees (Harrington 1988, Kaneko and Harrington 1990, USDA 1992, Wingfield et al. 2001). In an inoculation study by Zhou et al. (2002), seedlings of *Pinus elliottii*, *P. radiata*, and *P. elliottii* x *P. caribaea* developed cambial lesions an average of 29.3 mm [1.15 in] in length [range, 15.4-37.2 mm] after 6 wk. However, the seedlings were not killed outright nor did they exhibit any dieback (Zhou et al. 2002). Eckhardt et al. (2004) report similar findings on *P. taeda*, which developed lesions an average of 34.1 mm [1.34 in] in length 4 mo after inoculation with *L. truncatum*. Wingfield and Marasas (1983) found roots of *P. elliottii* “developed lesions up to 8 cm [~3 in] on either side of the inoculation point after 5 mo.” Kaneko and Harrington (1990) inoculated three-year-old *P. densiflora* with *L. truncatum* and exposed them to two levels of light intensity (200 lux and 20000 lux). Four inoculated seedlings under low-light conditions died 2 mo after *L. truncatum* was introduced, with 4 more showing mild symptoms of infection. All other inoculated and healthy seedlings remained healthy (Kaneko and Harrington 1990). Zhou et al. (2002) note that *L. truncatum* was not “pathogenic to living healthy trees” and “should not be considered [a] serious pathogen of above ground parts of [*Pinus* spp.] in South Africa.”

In temperate areas, sapstain fungi generally do not alter the structural properties of wood. However, other fungi may grow alongside them, leading to decay and loss of strength (Seifert 1993, Uzunovic et al. 1999, Bruce et al. 2003, Byrne et al. 2005).

Risks associated with *L. truncatum* in North American forests has been evaluated previously (USDA 1992, Hildebrand 2005). Hildebrand (2005) considered the fungus to pose a very high risk, but this assessment was very uncertain. The potential for establishment, spread, and economic damage were all rated high. The virulence of *L. truncatum* on potential North American hosts is unknown, but even as a weak pathogen it may contribute to the decline of stressed and damaged trees. Accordingly, the potential for environmental damage in North America is low (Hildebrand 2005). A USDA Forest Service evaluation of the risks associated with importation of *P. radiata* from New Zealand identified the primary economic threat as the removal of dead *P. radiata*, at a 30-yr cost ranging from 7 million to 69 million US dollars (USDA 1992). Wood discolored by sapstain may cause economic losses as well, as the stained wood is unsightly and may be rejected by customers (Uzunovic et al. 1999, Byrne et al. 2005). *Pinus* spp. are especially susceptible to staining (Uzunovic and Webber 1998).

Symptoms

The progression of disease caused by *L. truncatum* is poorly known. Hildebrand (2005) suggests *L. truncatum* root disease may follow a course similar to *L. procerum*, which causes root decline of white pine, *Pinus strobus* (Jacobs and Wingfield 2001). Wingfield (1986) lists the symptoms of white pine root decline as “decreased shoot growth, delayed bud break, needle wilt, exudation of resin from the root collar, and resin soaking of affected wood.” Externally, trees infected with *L. truncatum* may exhibit these and other symptoms of decline, including chlorosis, thinning of crowns, dieback, and browning and retention of needles (Alexander et al. 1988, reviewed in Hildebrand 2005). Internally, lesions develop on the roots and root collar and conidiophores may be visible between sapwood and bark. *L. truncatum* also produces a dark blue to brownish, wedge-shaped stain (“sapstain” or “bluestain”) of the sapwood. Sapstain, a blue, grey, or black discoloration of sapwood, is caused by pigmented hyphae that penetrate the ray parenchyma, resin ducts, and cell lumens of affected wood (Fig. 39; Seifert 1993, Uzunovic et al. 1999, Jacobs and Wingfield 2001, Bruce et al. 2003).

Fig. 39. Cross-section of *Pinus taeda* with wedge-shaped bluestain caused by *Ophiostoma ips*. *Leptographium truncatum* has a similar effect. Image from R.F. Billings, http://www.bugwood.org

Known Hosts

Leptographium truncatum is known mainly from *Pinus* spp. Reports from *Larix* spp., *Picea* spp., and *Pseudotsuga* sp. may be a result of confusion with *Leptographium lundbergii*.

Host	Reference
Larix spp. (larch)	(Jacobs and Wingfield 2001)
Larix leptolepis (=*L. kaempferi*)	(Jacobs and Wingfield 2001)

Host	**Reference**
(Japanese larch)	
Picea spp. (spruce)	(Jacobs and Wingfield 2001)
Picea abies (Norway spruce)	(Jacobs and Wingfield 2001)
Pinus spp. (pine)	(Wingfield and Gibbs 1991, Jacobs and Wingfield 2001, Zhou et al. 2002)
Pinus densiflora (Japanese red pine)	(Kaneko and Harrington 1990, Strydom et al. 1997, Jacobs and Wingfield 2001, reviewed in Hildebrand 2005, reviewed in Farr et al. 2006)
Pinus elliottii (slash pine)	(Wingfield and Marasas 1983, Zhou et al. 2002)
Pinus elliottii x *P. caribaea*	(Zhou et al. 2002)
Pinus patula (Mexican weeping pine)	(Zhou et al. 2002, reviewed in Farr et al. 2006)
Pinus pinaster (maritime pine)	(Jacobs and Wingfield 2001)
Pinus ponderosa (ponderosa pine)	(Jacobs and Wingfield 2001)
Pinus radiata (Monterey pine)	(Wingfield and Marasas 1983, USDA 1992, Strydom et al. 1997, Jacobs and Wingfield 2001, Zhou et al. 2002, reviewed in Hildebrand 2005, Reay et al. 2005, Thwaites et al. 2005)
Pinus resinosa (red pine)	(Harrington 1988, USDA 1992, Zambino and Harrington 1992, Strydom et al. 1997, reviewed in Hildebrand 2005, reviewed in Farr et al. 2006)
Pinus strobus (Eastern white pine)	(Wingfield and Marasas 1983, USDA 1992, Zambino and Harrington 1992, Jacobs and Wingfield 2001, reviewed in Hildebrand 2005, Jacobs et al. 2005, reviewed in Farr et al. 2006)
Pinus sylvestris (Scots pine)	(Zambino and Harrington 1992, Jacobs and Wingfield 2001, reviewed in Hildebrand 2005, reviewed in Farr et al. 2006)
Pinus taeda (loblolly pine)	(Wingfield and Marasas 1983, USDA 1992, Strydom et al. 1997, Jacobs and Wingfield 2001, Eckhardt et al. 2004, reviewed in Hildebrand 2005, Jacobs et al. 2005, reviewed in Farr et al. 2006)
Pinus thunbergii (Japanese black pine)	(Kaneko and Harrington 1990, Strydom et al. 1997, Jacobs and Wingfield 2001)

Host	Reference
Pseudotsuga spp. (Douglas-fir)	(USDA 1992)

Known Vectors

Leptographium truncatum is introduced by associated scolytids (*Hylastes angustatus*, *Hylastes ater*, *Hylastes opacus*, *Hylurgops palliatus*, *Hylurgus ligniperda*, and *Tomicus piniperda*) attacking dead or dying host trees (Wingfield and Marasas 1983, Harrington 1988, Kaneko and Harrington 1990, Wingfield and Gibbs 1991, Anon. 2000, Wingfield et al. 2001, Zambino and Harrington 1992, Zhou et al. 2002, Eckhardt et al. 2004, Hausner et al. 2005, Reay et al. 2005). *L. truncatum* is also associated with the nematode *Bursaphelenchus xylophilus*, which causes pine wilt disease in *Pinus densiflora* and *P. thunbergii* (Jacobs and Wingfield 2001).

Known Distribution

Leptographium truncatum was originally isolated from diseased roots of pines in New Zealand and South Africa (Wingfield and Marasas 1983). It has since been found on *P. densiflora* and *P. thunbergii* in Japan (Kaneko and Harrington 1990) and on *P. taeda* in the southern United States (Eckhardt et al. 2004).
L. truncatum may also be present in California (T.C. Harrington, pers. comm.).

Location	Reference
Africa	
South Africa	(Wingfield and Marasas 1983, Harrington 1988, Wingfield and Gibbs 1991, USDA 1992, Strydom et al. 1997, Jacobs and Wingfield 2001, Zhou et al. 2002, reviewed in Hildebrand 2005, Jacobs et al. 2005, reviewed in Farr et al. 2006)
Australasia	
New Zealand	(Wingfield and Marasas 1983, Harrington 1988, Wingfield and Gibbs 1991, USDA 1992, Zambino and Harrington 1992, Strydom et al. 1997, Anon. 2000, Jacobs and Wingfield 2001, reviewed in Hildebrand 2005, Jacobs et al. 2005, Reay et al. 2005, Thwaites et al. 2005, reviewed in Farr et al. 2006)
Asia	
Japan	(Kaneko and Harrington 1990, Strydom et al. 1997, Jacobs and Wingfield 2001, reviewed in

Location	Reference
	Hildebrand 2005, Jacobs et al. 2005, reviewed in Farr et al. 2006)
Europe	
England¹	(reviewed in Hildebrand 2005, reviewed in Farr et al. 2006)
North America	
Canada	(Harrington 1988, USDA 1992, Zambino and Harrington 1992, Strydom et al. 1997, Anon. 2000, Hausner et al. 2005, reviewed in Hildebrand 2005, reviewed in Farr et al. 2006)
United States	
AL²	(Eckhardt et al. 2004)
CA	(T.C. Harrington, pers. comm.)
MI	(reviewed in Hildebrand 2005)

1. Possible taxonomic confusion with *L. lundbergii*.
2. Reported in Eckhardt et al. (2004) as *L. lundbergii*, though molecular data from Jacobs et al. (2005) suggest the isolate in question is actually *L. truncatum*.

Potential Distribution within the United States

The known distribution of *L. truncatum* suggests that the pathogen may be most closely associated with two biomes, both of which occur in the United States: (1) Mediterranean scrub; and (2) temperate broadleaf and mixed forests. Collectively, these biomes account for approximately 29% of the area of the contiguous United States. These biomes are generally found in the eastern United States and portions of California.

Survey

Preferred Method: Visual surveys for *L. truncatum* likely will be difficult, as outward signs of infection may not be readily apparent. Trees may exhibit symptoms of decline, including chlorosis, wilting and browning of needles, thinning of crowns, delayed bud break, and resin exudation (Wingfield 1986, Alexander et al. 1988, Jacobs and Wingfield 2001, reviewed in Hildebrand 2005). The most conspicuous evidence of *L. truncatum* is the presence of a dark blue to brownish, wedge-shaped stain of the sapwood. *L. truncatum* conidiophores may be present between bark and sapwood, in galleries created by bark beetles, or in diseased roots (Seifert 1993).

Alternative Method: *L. truncatum* can also be isolated from its beetle vectors. The beetles are washed for 5 min in a solution of 1% sodium hypochlorite and polysorbate 80 (Tween 80), crushed, and placed on CSMA. Another method involves grinding the beetles in sterile distilled water and plating the diluted sample on CSMA (Jacobs and Wingfield 2001). Wingfield and Marasas (1983) and Jacobs and Wingfield (2001) have recorded optimal growth of cultures between 20-25°C [68-77°F], with no growth between <5°C [41°F] and >35°C [95°F].

Diagnostics

To confirm the presence of *L. truncatum*, samples of diseased host tissue are placed on cycloheximide-streptomycin-malt-agar (CSMA). After conidiophores develop, a sterile needle is used to transfer conidia to 1-2% malt extract agar (MEA) or water agar (WA). Potato dextrose agar (PDA) is not recommended. Alternately, hyphal tips can be cut and transferred to other media (Jacobs and Wingfield 2001). Final diagnosis is made based on morphological features. DNA sequences may be used to support a final diagnosis (Jacobs et al. 2005).

Easily Confused Pests

Significant confusion exists between *Leptographium truncatum* and *L. lundbergii*. Taxonomists have treated the two as synonyms because of their morphological similarity and have suggested *L. truncatum* as a synonym for *L. lundbergii*, the type species of the genus (Wingfield and Gibbs 1991, Strydom et al. 1997). Despite their similar appearance, *L. truncatum* is not synonymous with *L. lundbergii*. Jacobs et al. (2005) compared DNA sequences from several strains of *L. lundbergii* and *L. truncatum* and found them to be discrete species. The most significant morphological characters separating the two species are conidiophore length and conidia shape (Jacobs et al. 2005). *L. truncatum* has longer conidiophores and smaller, rounder conidia than *L. lundbergii* (Jacobs et al. 2005). Zambino and Harrington (1992) and Jacobs et al. (2005) also recognize differences in hyphae, with those of *L. lundbergii* being convoluted and those of *L. truncatum* being straight or slightly curved. *L. truncatum* also resembles *L. pyrinum* and *L. yunnanensis*, but has more structured conidiophores and no granular material around the hyphae (Jacobs and Wingfield 2001).

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Phellinus noxius

E.M. Albrecht and R.C. Venette

Scientific Name

Phellinus noxius (Corner) G.H. Cunn.

Synonyms:
Fomes noxius Corner
Phellinidium noxium (Corner) Bondartseva & S. Herrera
Phellinus sublamaensis (Lloyd) Ryvarden
Poria luteo-fulvus Clel. & Rodw.
Poria setuloso-crocea Clel. & Rodw.
(Cunningham 1965)

Common Names

Brown root rot, brown tea root disease, brown cocoa root rot, stem rot

Fig. 40. *Phellinus noxius* mycelial crust on a multi-trunked tree. Image by F.E. Brooks, http://www.bugwood.org

Type of Pest

Fungal pathogen

Taxonomic Position

Kingdom: Fungi, **Phylum:** Basidiomycota, **Order:** Hymenochaetales, **Family:** Hymenochaetaceae

Reason for inclusion in manual

CAPS Priority Pest (FY 2008)

Pest Description

In the field, "*Phellinus noxius* forms a thick, dark brown to black crust of mycelium around infected roots and lower stems [Fig. 40]. The leading edge of the crust is creamy white [and] glistens with drops of clear, brownish exudate" (Brooks 2007).

Culture on potato dextrose agar (Fig. 41) "[Mycelial] growth rapid, 5.8 cm in 1 week. Advancing zone white, uneven, raised. Mat white to 'naples' to 'straw yellow' in loose-cottony areas, 'amber brown' to 'Sudan brown' to 'antique brown' in farinaceous-felty areas, dark brown to 'sayal brown' in crustose areas, loose-cottony to cottony-woolly at first, floccose to farinaceous-cottony becoming farinaceous-felty later. Brown crustose areas formed within one week at some places. Reverse 'blister' to 'sepia brown' in the major portion 'pale-pinkish buff' in the rest. Odour none" (MycoBank 2006).

Basidiocarp "perennial, solitary or imbricate, sessile with a broad basal attachment, commonly resupinate" (Pegler and Waterston 1968).

<u>Pileus</u> “5-13 x 6-25 x 2-4 cm, applanate, dimidiate or appressed-reflexed; upper surface deep reddish-brown to umbrinous, soon blackening, at first tomentose, glabrescent, sometimes with narrow concentric zonation, developing a thick crust; margin white then concolorous, obtuse” (Pegler and Waterston 1968).

<u>Context</u> “up to 1 cm thick, golden brown, blackening with [potassium hydroxide], silky-zonate fibrous, woody” (Pegler and Waterston 1968).

Fig. 41. Colony morphology of *P. noxius* on potato dextrose agar (PDA). Image reproduced with permission from Ann et al. (2002).

<u>Pore surface</u> “greyish-brown to umbrinous; pores irregular, polygonal, 6-8/mm, 75-175 µm diameter, dissepiments 25-100 µm thick, brittle and lacerate; tubes stratified, developing 2-5 layers, 1-4 mm to each layer, darker than context, carbonaceous” (Pegler and Waterston 1968).

<u>Basidiospores</u> “[about] 4 x 3 µm, ovoid to broadly ellipsoid, hyaline, with a smooth, slightly thickened wall, and irregular guttulate contents. Basidia 12-16 x 4-5 µm, short clavate, 4-spored” (Pegler and Waterston 1968).

<u>Setae</u> “absent” (Pegler and Waterston 1968).

<u>Setal hyphae</u> “present both in the context and the dissepiment trama. Context setal hyphae radially arranged, up to 600 x 4-13 µm, unbranched or rarely branching, with a thick dark chestnut brown wall and capillary lumen; apex acute to obtuse, occasionally nodulose. Tramal setal hyphae diverging to project into the tube cavity, 55-100 x 9-18 µm, with a thick dark chestnut-brown wall (2.5-7.5 µm thick) and a broad obtuse apex” (Pegler and Waterston 1968).

<u>Hyphal system</u> “dimitic with generative and skeletal hyphae, non-agglutinated in the context, but strongly agglutinated in the dissepiments” (Pegler and Waterston 1968).

<u>Generative hyphae</u> “1-6.5 µm diameter, hyaline or brownish, wall thin to somewhat thickening, freely branching, simple septate” (Pegler and Waterston 1968).

<u>Skeletal hyphae</u> “5-9 µm diameter, unbranched, of unlimited growth, with a thick reddish-brown wall (up to 2.5 µm thick) and continuous lumen, non-septate” (Pegler and Waterston 1968).

Biology and Ecology

Originally considered a brown root rot, *P. noxius* is now classified as a white rot due to its ability to degrade lignin along with cellulose and hemicellulose (Nicole et al. 1982, Geiger et al. 1986, Brooks 2002, GISD 2006). The brown to black surface appearance of *P. noxius*-infected roots comes from a crust of mycelia and soil; the decayed inner tissue is white and laced with reddish-brown to black hyphae (Brooks 2002).

In the laboratory, optimal growth on potato dextrose agar (PDA) occurs between 25-31°C [77-88°F]. No growth is observed below 4°C [39°F] or above 40°C [104°F] (Abe et al. 1995, Ann et al. 1999, Brooks 2007). Maximum rate of growth on PDA can be as high as 34 mm/d (Ann et al. 1999).

P. noxius thrives in sandy, loamy sand, and sandy loam soils, though it has also been found in other soil types with <50% clay or silt (Chang and Yang 1998). Soils with a high proportion of sand tend to be well-drained. *P. noxius* has been isolated from soils with pH between 4 and 9 (Chang and Yang 1998) but thrives in soils with pH <5 (Ann et al. 1999). This pathogen does not grow in neutral to alkaline soils (pH >7.5) (Ann et al. 1999).

P. noxius is spread via root-to-root contact, contact with infected woody debris, and through infected soil. Wind may also disperse basidiospores, but this is a less common means of dispersal since fruiting bodies are rare (Brooks 2002, reviewed in Hodges 2005, GISD 2006). Transmission via root-to-root contact is slower than for similar root rot fungi like *Rigidoporus lignosus*, which has rhizomorphs capable of penetrating several meters through soil. Since *P. noxius* lacks these structures, an infected root must directly contact a healthy root or stump in order for the pathogen to be transmitted. Growth rates of the mycelial encrustation on roots of *Hevea brasiliensis* have been estimated at up to 0.7 m/y [2¼ ft] (Nandris et al. 1987). *P. noxius* does not form resting spores or sclerotia but can remain viable in woody debris in soil for many years, even after infected trees have been removed (Nandris et al. 1987, Chang 1996, Ann et al. 2002, reviewed in Hodges 2005, Brooks 2007). Mycelia in the soil can infect trees replanted on a cleared site (Ann et al. 1999). Movement of infected wood may also transmit this fungus (Hodges 2005).

In certain hosts (e.g., *Acacia* spp.), *P. noxius* causes heart rot. Wounds created by pruning or mechanical damage are infected by basidiospores. Heart rot caused by this pathogen has not been reported for *Pinus* spp.

Pest Importance

P. noxius is a widely distributed, opportunistic fungal pathogen that appears to have little or no host specificity (Chang 1995a, reviewed in CAB 2005). Indeed, over 120 genera of plants have been reported as hosts for this pathogen. The pathogenicity of *P. noxius* on *Pinus* spp. is not currently known, though one species of pine, *Pinus luchuensis* (Luchu pine), appears to be less susceptible than other species (Abe et al. 1995). Economically important crops such as *Camellia sinensis* (tea), *Coffea* spp. (coffee), *Elaeis guineensis* (oil palm), *Hevea brasiliensis* (rubber), *Swietenia* spp. (mahogany), and *Theobroma cacao* (cocoa) are particularly susceptible and infection can lead to considerable economic losses (Pegler and Waterston 1968, Ann et al. 1999, Brooks 2002, reviewed in CAB 2005, reviewed in Hodges 2005, reviewed in MycoBank 2006). Hosts vary in their susceptibility to *P. noxius* infection, ranging from 20-100% mortality in <1 y in pathogenicity tests by Chang (1995a) and Ann et al. (1999). Certain species, such as *Acacia confusa*, *Dimocarpus longana*, and *Salix babylonica*, may possess some resistance to the deleterious effects of *P. noxius* (Chang and Yang 1998, Ann et al. 1999). Environmental consequences from the establishment of this pathogen in North America are uncertain (Hodges 2005). In forests within its native range, *P. noxius* is a natural cause of mortality.

Symptoms

Aboveground symptoms of *P. noxius* infection are typical of root and collar rot disease. Leaves turn yellow and wilt as the roots die, followed by dieback of branches. In most species decline occurs rapidly, with chlorosis and browning of leaves developing in as few as 2-3 mo. A thick brown encrustation of mycelia, soil, and small stones (Figs. 1 and 3) develops around affected roots and up stems to a height of 1-2 m [3-6 ft]. The margin of this mycelial “sleeve” is creamy white and coincides with the extent of internal damage. The crust that forms on infected roots and stems is diagnostic of *P. noxius* infection. Decaying wood is white and crumbly and laced with reddish-brown hyphal strands that become brittle and black with age. Though rarely found, basidiocarps growing from the mycelial crust are crustose, irregularly zoned, and brownish-black, with a grey-brown pore surface (Figs. 40 and 42). These fruiting bodies can be reflexed (shelf-like), effused (flat), or effused-reflexed (a combination of the two). There are no rhizomorphs. Felty mats of mycelia grow between the

Fig. 42. Mycelial crust and basidiocarps on *Leucaena* spp. Image from CAB (2005).

bark and sapwood, causing girdling and eventual death of the tree (Brooks 2001, Ann et al. 2002, Brooks 2002, 2007). See 'Survey' for additional descriptions of signs and symptoms of *P. noxius* infection.

Known Hosts

P. noxius has a very wide host range and can infect numerous forest, fruit, and ornamental trees and herbaceous plants (Pegler and Waterston 1968, Ann et al. 2002, Brooks 2002). Currently, there are 286 hosts in 124 genera listed for *P. noxius* and its synonym, *Fomes noxius*, in the USDA-ARS Systematic Botany and Mycology Laboratory online database (Farr et al. 2006). Ann et al. (2002) list 121 susceptible species from Taiwan, many of which have a cosmopolitan distribution. The species listed below are primarily economically important crops.

Host	**Reference**
Acacia spp. (acacia)	(reviewed in Hodges 2005)
Acacia confusa (Taiwan acacia)	(Chang and Yang 1998, reviewed in CAB 2005)
Anacardium occidentale (cashew)	(Supriadi et al. 2004)
Annona squamosa (sugar-apple)	(Ann et al. 1999)
Araucaria spp. (araucaria)	(reviewed in Hodges 2005)
Araucaria bidwillii (bunya pine)	(reviewed in CAB 2005)
Araucaria cunninghamii (hoop pine)	(Hattori et al. 1996, Brooks 2002, reviewed in CAB 2005)
Artocarpus altilis (breadfruit)	(Brooks 2002, reviewed in CAB 2005, reviewed in Hodges 2005, 2006)
Bauhinia racemosa (mountain ebony)	(reviewed in CAB 2005)
Camellia sinensis (tea)	(reviewed in CAB 2005, reviewed in Hodges 2005)
Canarium indicum (galip nut)	(reviewed in CAB 2005)
Casuarina equisetifolia (Australian pine)	(reviewed in CAB 2005)
Ceiba pentandra (kapok)	(reviewed in CAB 2005)
Coffea spp. (coffee)	(reviewed in CAB 2005)
Cordia alliodora (Ecuador laurel)	(Neil 1986, Hattori et al. 1996, Brooks 2002, reviewed in CAB 2005)
Delonix regia (flame tree)	(Hattori et al. 1996, reviewed in Hodges 2005)
Dimocarpus longana (longan)	(Ann et al. 1999)
Diospyros kaki (persimmon)	(Ann et al. 1999)
Elaeis guineensis (African oil palm)	(reviewed in CAB 2005, reviewed in Hodges 2005)
Eriobotrya japonica (loquat)	(Ann et al. 1999)
Eucalyptus spp. (eucalyptus)	(reviewed in Hodges 2005)
Flueggea flexuosa (bushweed)	(reviewed in CAB 2005)
Garcinia mangostana (mangosteen)	(reviewed in CAB 2005)
Gmelina arborea (white teak)	(Brooks 2002)

Host	**Reference**
Hevea brasiliensis (rubber)	(Nandris et al. 1987, Hattori et al. 1996, Brooks 2002, reviewed in CAB 2005, reviewed in Hodges 2005)
Khaya ivorensis (African mahogany)	(reviewed in CAB 2005)
Liquidambar formosana (Formosan sweetgum)	(reviewed in CAB 2005)
Litchi chinensis (litchi)	(Ann et al. 1999)
Ochroma lagopus (balsa)	(Dennis 1992)
Ochroma pyramidale (balsa)	(reviewed in CAB 2005)
Pinus spp. (pine)	(reviewed in Hodges 2005)
Pinus elliottii (slash pine)	(Farr et al. 2006)
Pinus elliottii var. *elliottii* (Honduras pine)	(Farr et al. 2006)
Pinus thunbergii (Japanese black pine)	(Farr et al. 2006)
Prunus mume (Japanese apricot)	(Ann et al. 1999)
Pyrus pyrifolia var. *culta* (Asian pear)	(Ann et al. 1999)
Pyrus pyrifolia var. *yokoyama* (Asian pear)	(Ann et al. 1999)
Salix babylonica (weeping willow)	(Chang and Yang 1998)
Swietenia spp. (mahogany)	(reviewed in Hodges 2005)
Swietenia macrophylla (mahogany)	(Brooks 2002)
Taiwania cryptomerioides (taiwania)	(reviewed in CAB 2005)
Tectona grandis (teak)	(reviewed in CAB 2005)
Theobroma cacao (cocoa)	(Brooks 2002, reviewed in CAB 2005, reviewed in Hodges 2005)
Thespesia populnea (Pacific rosewood)	(reviewed in CAB 2005)

Known Vectors

There are no known vectors of *P. noxius.*

Known Distribution

P. noxius has a pantropical distribution and can be found throughout Africa, southeast Asia, Australasia, and the Pacific (reviewed in CAB 2005, reviewed in Hodges 2005, GISD 2006). Currently, the northernmost extent of this pathogen's distribution is Okinawa, Japan. In Taiwan, *P. noxius* has not been recorded at elevations greater than 800 m (Chang and Yang 1998).

Location	**Reference**
Africa	
Angola	(CAB 1980, reviewed in CAB 2005)
Benin	(CAB 1980, reviewed in CAB 2005)
Burkina Faso	(CAB 1980, reviewed in CAB 2005)

Location	Reference
Cameroon	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Central African Republic	(CAB 1980, reviewed in CAB 2005)
Congo, Democratic Republic of	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Côte d'Ivoire	(CAB 1980, Nandris et al. 1987, reviewed in CAB 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Gabon	(CAB 1980, reviewed in CAB 2005)
Ghana	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Kenya	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Liberia	(Nandris et al. 1987)
Nigeria	(CAB 1980, reviewed in CAB 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Sierra Leone	(reviewed in CAB 2005)
Tanzania	(reviewed in CAB 2005, reviewed in MycoBank 2006)
Togo	(CAB 1980, reviewed in CAB 2005)
Uganda	(CAB 1980, reviewed in CAB 2005)
Australasia	
Australia	(CAB 1980, reviewed in CAB 2005, Farr et al. 2006, reviewed in MycoBank 2006)
New Zealand	(Farr et al. 2006)
Papua New Guinea	(CAB 1980, reviewed in CAB 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Asia	
China (incl. Taiwan)	(Ann et al. 1999, Ann et al. 2002, reviewed in CAB 2005, Farr et al. 2006)
India	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Indonesia	(CAB 1980, Supriadi et al. 2004, reviewed in CAB 2005, reviewed in Hodges 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Japan	(reviewed in CAB 2005)

Location	**Reference**
Malaysia	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005, Farr et al. 2006, reviewed in MycoBank 2006)
Myanmar	(CAB 1980, reviewed in CAB 2005)
Pakistan	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005)
Philippines	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005, Farr et al. 2006)
Singapore	(reviewed in CAB 2005)
Sri Lanka	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Vietnam	(CAB 1980, reviewed in CAB 2005)
Central America & Caribbean	
Costa Rica	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005)
Cuba	(CAB 1980, reviewed in CAB 2005)2005(reviewed in Hodges 2005, Farr et al. 2006)
Puerto Rico[1]	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005, Farr et al. 2006)
Pacific Islands	
American Samoa	(CAB 1980, reviewed in CAB 2005, reviewed in Hodges 2005, Brooks 2006)
Federated States of Micronesia	(reviewed in CAB 2005)
Fiji	(CAB 1980, reviewed in CAB 2005, Farr et al. 2006)
Guam	(reviewed in Hodges 2005)
Niue	(reviewed in CAB 2005)
Northern Mariana Islands	(reviewed in CAB 2005, reviewed in Hodges 2005)
Samoa	(CAB 1980, reviewed in CAB 2005, reviewed in MycoBank 2006)
Solomon Islands	(reviewed in CAB 2005, Farr et al. 2006)
Vanuatu	(CAB 1980, Neil 1986, reviewed in MycoBank 2006)
South America	
Brazil	(Farr et al. 2006)

1. Farr et al. (2006) note a record of “brownroot disease with typical sporocarp” from *Codiaeum variegatum* in Puerto Rico, but this report is “suspect” (reviewed in Hodges 2005).

Potential Distribution within the United States

The known distribution of *P. noxius* suggests that the pathogen may be most closely associated with two biomes, both of which occur in the United States: (1) tropical and subtropical moist broadleaf forests; and (2) tropical and subtropical grasslands, savanahs, and shrublands. Collectively, these biomes account for less than 1% of the area of the contiguous United States and are generally found in southern Florida and southern Texas.

Survey

Preferred Method: Visual inspection is the only practical means of detecting *Phellinus noxius* in the field. Above-ground signs include chlorosis, wilt, and dieback of branches. These signs are not diagnostic of *P. noxius* and may reflect a variety of biotic and abiotic causes (Brooks 2001, reviewed in CAB 2005, reviewed in Hodges 2005). Externally, the most conspicuous sign of infection by *P. noxius* is the creamy white expanding margin of the mycelial crust that develops on roots and lower stems of affected plants (Figs. 40 and 42). Lateral and tap roots are affected as the infection spreads toward the collar. Diseased roots are encrusted with a 1 cm thick “sleeve” of brown mycelium, soil, and small stones that may be visible above ground, especially on exposed lateral roots (Fig. 42). The mycelial crust spreads up the stem to an average height of 1-2 m [3-6 ft], though heights of almost 5 m [16 ft] have been reported. Rarely, lightweight, woody basidiocarps (fruiting bodies) with broad bases can also be found growing from the mycelium (Figs. 42 and 43). The pileus (cap) is rough and brownish-black, with irregular zonation; below, the hymenophore (spore-producing surface) is pale grey-brown. The context (flesh of the basidiocarp) is soft and when divided is golden brown to “yellow cinnamon to ferruginous”, becoming black

Fig. 43. *Phellinus noxius* basidiocarp cultured on sawdust medium. Basidiocarps of *P. noxius* are rarely found in the field. Image reproduced with permission from Ann et al. (2002).

when potassium hydroxide is applied (Fig. 43). Within a tree, mycelium may be present between bark and sapwood. The decayed wood is soft, friable, and white with reddish-brown hyphal strands that become brittle and black with age (Fig. 44; Pegler and Waterston 1968, Brooks 2002, reviewed in CAB 2005, GISD 2006, reviewed in MycoBank 2006, Brooks 2007). See 'Pest Description' for a complete morphological description of *P. noxius*.

Fig. 44. *Dimocarpus longana* root exhibiting symptoms of white rot by *P. noxius*. Image reproduced with permission from Ann et al. (2002).

Diagnostics

P. noxius can be detected in the field by examining the root collar and exposed roots for the characteristic brown encrustation. Another method entails placing sterilized pieces of host tissue in suspect soil and retrieving them after 3 wk for laboratory study (Nandris et al. 1987). A third method involves keeping the area around the root collar moist with mulch for 3 wk to allow development of mycelia (Nandris et al. 1987, reviewed in CAB 2005). All three methods are labor-intensive, time-consuming, and imperfect.

In the laboratory, *P. noxius* can be cultured on malt agar, potato dextrose agar (PDA), or on a selective medium comprised of 20 g/l malt extract, 20 g/l agar, 10 mg/l benomyl, 10 mg/l dichloran, 100 mg/l ampicillin, 500 mg/l gallic acid, and 1000 mg/l tergitol NP-7 (Chang 1995b, Ann et al. 1999). Small pieces of infected wood (about 5 x 2 x 1 mm) from the expanding margin are surface sterilized in 0.5% sodium hypochlorite for 3 min before placing them on PDA (Ann et al. 1999). *P. noxius* can grow as fast as 35 mm/d on PDA at 30°C (Ann et al. 2002). Cultures of *P. noxius* on malt agar produce raised brown and white plaques and arthrospores (asexual spores) (Nandris et al. 1987, Ann et al. 2002, Brooks 2007). Single hyphal tip isolation can be performed after transferring *P. noxius* to 2% water agar, then culturing the hyphal tips on PDA (Ann et al. 1999).

Easily Confused Pests

Phellinus noxius may be confused with *P. lamaensis*. Both species are morphologically similar and share portions of their host range. *P. lamaensis* is not known from the United States (Cunningham 1965). The two fungi are difficult to distinguish in the field and microscopic identification may be necessary. The expanding margin of the *P. noxius* sporocarp is creamy white, while that of *P. lamaensis* is ochre. Additionally, *P. noxius* tends to grow from a thick mycelial crust, where *P. lamaensis* does not (Brooks 2002). Microscopic examination reveals *P. lamaensis* to have cone-shaped hymenial setae and narrow setal hyphae (5-7 µm wide), while *P. noxius* lacks hymenial setae and posesses wider setal hyphae (7.5-13 µm wide) (Ann et al. 1999, reviewed in MycoBank 2006).

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