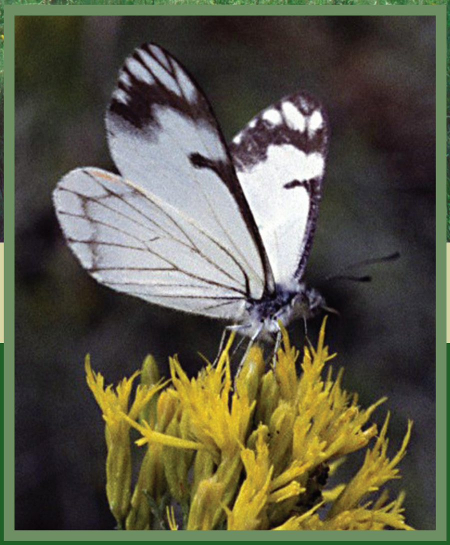
Forest Pest Insects in North America: A Photographic Guide



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September 2013

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The University of Georgia Center for Invasive Species and Ecosystem Health
Warnell School of Forestry and Natural Resources
College of Agricultural and Environmental Sciences

The University of Georgia

Forest Pest Insects in North America: A Photographic Guide

Forest Pest Insects in North America

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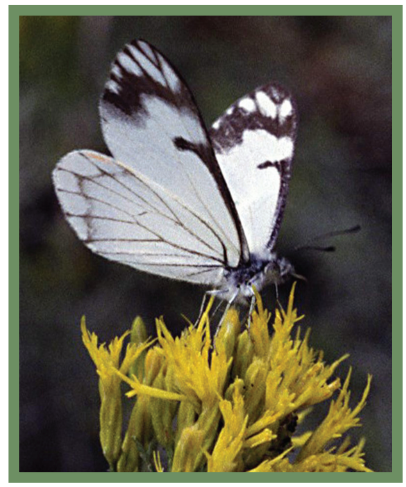

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Ponderosa pine stand; Chris Schnepf, University of Idaho, Bugwood.org

Male pine butterfly, *Neophasia menapia*; Terry Spivey, USDA Forest Service, Bugwood.org

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Preface

The information in this publication is intended to help foresters, urban landscaping employees, or others working with trees recognize some of the common native and nonnative pest insects affecting trees in North America, and understand their life cycles and how they damage trees. Recognition is based on photographs of the pest in various lifestages rather than on technical keys, and the user's identification of a pest may not be accurate if there are many similar species in a group. The information was drawn from books, websites, factsheets, and some original literature. This publication is not a guide for specialists. In many groups, such as the bark beetles and aphids, confirmation of species identity requires attention to details not visible in photos with comparisons to other similar species and use of keys. Information on important biological control agents of each species is provided when available. Sources for further information (websites and articles) are given at the bottom of each species' page; however, an exhaustive review of the literature was beyond the scope of this project. In most cases, pages on individual species were reviewed by experts with direct knowledge of the species. While any residual mistakes remain mine (Roy Van Driesche), I am deeply indebted to the many people who greatly improved pages on particular insects with their comments, photos, and edits. I would also like to thank Wendy Harding for design and layout of this printed version.

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1. Pear Thrips, *Taeniothrips inconsequences* (Uzel) (Thysanoptera: Thripidae)

Orientation to Pest

Pear thrips, *Taeniothrips inconsequences* (Uzel), is an invasive species in North America from Europe, first being recorded in the USA in California in 1900. Pear thrips have rasping/sucking mouthparts and use them to feed in early spring on buds and young leaves of hardwood trees. Potential for damage to sugar maples (*Acer sacchrum* Marshall) has been the greatest concern. Feeding injuries to embryonic or developing leaves result in mature leaves being deformed or tattered. Damage may spike in some years (e.g., the late 1980s) when thrips emerge earlier with respect to timing of bud break of key species, but such events are weather-dependent and do not occur regularly. In general the damage from this species is light.

Hosts Commonly Attacked

Sugar maples (*A. sacchrum* Marshall) and other hardwoods.

Distribution

No map available. The species is found in California, the northeast USA and southern Canada.

Images of Pear Thrips

Figure 1. Adult pear thrips, *Taeniothrips inconsequences*. (Left: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org; right: Pennsylvania Bureau of Forestry)

Figure 2. Larva of pear thrips. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Pear Thrips (continued)

Figure 3. Leaf deformities on sugar maple due to feeding of pear thrips on buds. (Left: Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org; right: Margaret Miller-Weeks, USDA Forest Service)

Important Biological Control Agents Related to this Pest Species

No specialized natural enemies of this thrips are known and the minor and irregular damage caused by this pest suggests that it is best left unmanaged or controlled only on limited acreage with pesticides if need be in years of unusually high damage.

Web Links for Information on Pear Thrips

http://ento.psu.edu/extension/factsheets/pear-thrips-PA; bulletin from Pennsylvania State University on biology and control.

http://ecommons.cornell.edu/bitstream/1813/14346/2/Pear%20Thrips.pdf; bulletin from Cornell University on biology and control.

http://www.na.fs.fed.us/spfo/pubs/pest_al/pt/pt.htm; bulletin of the United States Department of Agriculture.

http://www.onlinegardener.com/pests/Pear%20thrips.pdf; bulletin of Bartlett Tree Company on biology and control.

http://www.dec.ny.gov/docs/lands_forests_pdf/thrips.pdf; article from "New York Forest Owner" 1993 discussing impact of pear thrips on forests.

Articles

None

2. Introduced Basswood Thrips, *Thrips calcaratus* Uzel (Thysanoptera: Thripidae)

Orientation to Pest

Introduced basswood thrips, *Thrips calcaratus* Uzel, is a European species invasive in eastern North America. Basswood thrips have rasping/sucking mouthparts and in early spring feed on buds, especially of American basswood (*Tilia americana* L.). Such bud-feeding causes mature leaves to be deformed or tattered and defoliation may occur. Repeated defoliation of American basswood reduces tree growth and increases rates of dieback from other causes. The species is of importance in northern Wisconsin, where outbreaks of damage occur.

Hosts Commonly Attacked

In North America, this species feeds on American basswood (*T. americana*).

Distribution

The species is found in New England and Quebec, westward through Ontario, Pennsylvania, New York, and the Great Lake States.

Images of Introduced Basswood Thrips

Figure 1. Adult of introduced basswood thrips, *Thrips calcaratus*. (Kenneth Raffa, University of Wisconsin, Bugwood.org)

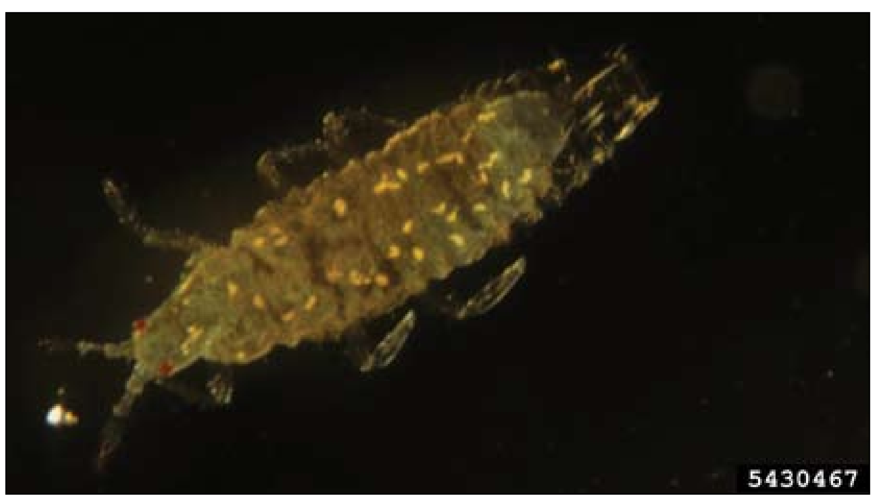

Figure 2. Larva of introduced basswood thrips. (Kenneth Raffa, University of Wisconsin, Bugwood.org)

Images of Introduced Basswood Thrips (continued)

Figure 3. Typical damage to basswood buds from thrips feeding (here by another thrips, *Neohydratothrips tiliae* [Hood]). (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 4. Defoliation of American basswood by introduced basswood thrips. (Steven Katovich, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No specialized natural enemies of this thrips are known.

Web Links for Information on Introduced Basswood Thrips

http://www.na.fs.fed.us/spfo/pubs/howtos/ht_bassthrips/ht_bassthrips.htm; USDA Bulletin on biology of introduced basswood thrips.

Articles

Raffa, K.F. and D.J. Hall. 1988. *Thrips calcaratus* Uzel (Thysanoptera: Thripidae), a new pest of basswood trees in the Great Lakes region. *Canadian Journal of Forest Research* 19: 1662-1663.

Raffa, K.F. 1991. Biology and impact of *Thrips calcaratus* Uzel in the Great Lakes region. In: Parker, B.L., M. Skinner, and T. Lewis (eds.). *Towards Understanding Thysanoptera*. USDA Forest Service General Technical Report NE-147: 317-324.

Werner, S.M., M.A. Albers, T. Cryderman, D. Diminic, R. Heyd, B. Hrašovic, S. Kobro, S. Larsson, R. Mech, P. Niemela, M. Rousi, K.F. Raffa, K. Scanlon, and S. Weber. 2006. Is the outbreak status of *Thrips calcaratus* Uzel in North America due to altered host relationships? *Forest Ecology and Management* 225: 200-206.

3. Redbanded Thrips, *Selenothrips rubrocinctus* (Giard) (Thysanoptera: Thripidae)

Orientation to Pest

Redbanded thrips, *Selenothrips rubocinctus* (Giard), is an invasive polyphagous tropical thrips of Asian origin found in Hawaii, Florida, and Puerto Rico. A sucking/rasping insect, its damage is similar in some regards to that of mite damage on foliage, consisting of a mixture of discolored areas and the dark areas that result from the liquid deposited where eggs are inserted in plant tissues. Affected leaves may be distorted or may drop from plant. Dense thrips populations may defoliate plants. Thrips also produce honeydew, which leads to growth of sooty molds.

Hosts Commonly Attacked

Hosts of redbanded thrips include various fruits (cashew, grape, mango, avocado, guava), ornamentals, and shade trees.

Distribution

Redbanded thrips is found in Hawaii, Florida, and Puerto Rico.

Images of Redbanded Thrips

Figure 1. Adult of redbanded thrips, *Selenothrips rubocinctus*. (Lyle Buss, University of Florida, Bugwood.org)

Figure 2. Pupae of redbanded thrips. (Lyle Buss, University of Florida, Bugwood.org)

Images of Redbanded Thrips (continued)

Figure 3. Damage by redbanded thrips. (James L. Castner, University of Florida)

Figure 4. Damage of redbanded thrips on mango. (Scot Nelson, University of Hawaii at Manoa, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Goetheana shakespearei Girault is a self-introduced eulophid parasitoid of redbanded thrips found in Florida since 1992, originally detected in a greenhouse. The same parasitoid under the name *Dasyscapus parvipennis* was shipped from Trinidad to Puerto Rico in the 1930s and established. In Australia, a weaver ant is cited as of importance, while in South Africa, a species of predatory bug (*Orius thripoborus* [Hesse]) has been noted as a predator of this thrips.

Web Links for Information on Redbanded Thrips

http://edis.ifas.ufl.edu/pdffiles/IN/IN25600.pdf; University of Florida factsheet.

https://transact.nt.gov.au/ebiz/dbird/TechPublications.nsf/56FBE080115393C669256EFF004B540D/$file/752.pdf; an Australian bulletin on redbanded thrips.

Articles

Dennill, G.B. 1992. *Orius thripoborus* (Anthocoridae), a potential biocontrol agent of *Heliothrips haemorrhoidalis* and *Selenothrips rubrocinctus* (Thripidae) on avocado fruits in the eastern Transvaal. *Journal of the Entomological Society of Southern Africa* 55(2): 255-258.

Bennett, F.D., H.A. Glenn, and R.M. Baranowski. 1993. *Goetheana shakespearei* (Hymenoptera: Eulophidae) an immigrant parasitoid of thrips in Florida and Guadeloupe. *Florida Entomologist* 76: 395-397.

Peng, R.K. and K. Christian. 2004 The weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), an effective biological control agent of the red-banded thrips, *Selenothrips rubrocinctus* (Thysanoptera: Thripidae) in mango crops in the Northern Territory of Australia. *International Journal of Pest Management* 50(2): 107-114.

4. Slash Pine Flower Thrips, *Gnophothrips fuscus* (Morgan) (Thysanoptera: Phlaeothripidae)

Orientation to Pest

The biology of slash pine flower thrips, *Gnophothrips fuscus* (Morgan), is poorly known. It is assumed to be widespread throughout the eastern United States but has only been of concern in seed orchards of slash pine (*Pinus elliottii* var. *elliottii* Engelm.), where feeding on female cones destroys about a quarter of the potential seed set.

Hosts Commonly Attacked

The principal hosts are slash (*P. elliottii* var. *elliottii*), jack (*P. banksiana* Lamb.), and loblolly (*P. taeda* L.) pines.

Distribution

Slash pine flower thrips is found in the southeastern United States, from Florida to east Texas, north to Ohio and Maryland.

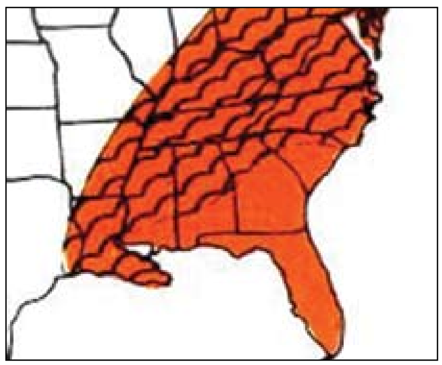

Figure 1. U.S. distribution of slash pine flower thrips, *Gnophothrips fuscus*. (USDA Forest Service, “Seed and Cone Insects of Southern Pines”)

Images of Slash Pine Flower Thrips

Figure 2. Slash pine flower thrips. (István Mikó and the NCSU Insect Museum)

Images of Slash Pine Flower Thrips (continued)

Figure 3. Young female slash pine cone showing damage from slash pine flower thrips. (Bernard H. Ebel, USDA Forest Service, Bugwood.org)

Figure 4. Damage of slash pine flower thrips as seen in mature cones. (USDA Forest Service, "Seed and Cone Insects of Southern Pines")

Important Biological Control Agents Related to this Pest Species

Nothing is known about specialized natural enemies of this species.

Web Links for Information on Slash Pine Flower Thrips

http://216.166.86.145/pubs/seed-and-cone/page7.html; USDA Forest Service bulletin "Seed and cone insects of southern pines."

Articles

Fatzinger, C.W. and W.N. Dixon. 1991. Development of sampling methods for the slash pine flower thrips, *Gnophothrips fuscus* (Morgan) (Thysanoptera: Phlaeothripidae). In: Parker, B.L., M. Skinner, and T. Lewis (eds.). *Towards Understanding Thysanoptera*. USDA Forest Service General Technical Report NE-147: 149-161.

5. Northern Walkingstick, *Diapheromera femorata* (Say) (Phasmatodea: Heteronemiidae)

Orientation to Pest

The northern walkingstick, *Diapheromera femorata* (Say), is the only walkingstick of economic importance in the USA. While young nymphs feed on shrubs of various species, older nymphs and adults feed on leaves of a wide variety of hardwood trees. Populations at times are dense enough to completely defoliate affected trees. Eggs fall from trees and when populations are dense, sounds of falling eggs are readily noticed. Overwintering occurs in the egg stage.

Hosts Commonly Attacked

Species fed on by the northern walkingstick include black (*Quercus velutina* Lamb.) and red (*Q. rubra* L.) oaks, American basswood (*Tilia americana* L.), American elm (*Ulmus americana* L.), black locust (*Robinia pseudoacacia* L.), cherry (*Prunus* spp.), and other hardwoods.

Distribution

This walkingstick is found in southern Canada and most of the eastern United States, west to Texas and the Great Plains.

Images of Northern Walkingstick

Figure 1. Adult of the northern walkingstick, *Diapheromera femorata*. (Kenneth Raffa, University of Wisconsin, Bugwood.org)

Images of Northern Walkingstick (continued)

Figure 2. Mating pair of the northern walkingstick; small male mounted on large female. (Kenneth Raffa, University of Wisconsin, Bugwood.org)

Figure 3. Seed-like eggs of the northern walkingstick being examined by an ant. (Photo copyright Alex Wild/alexanderwild.com)

Images of Northern Walkingstick (continued)

Figure 4. Oak foliage showing feeding of the walkingstick. (Both photosl: James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Forest in Mena, Arizona partially defoliated by the walkingstick. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The parasitoid *Mesitiopterus kahlii* (Ashmead) (Hymenoptera: Chrysididae) attacks the *D. femorata*. Also, birds can feed heavily on walkingsticks when their population densities are high.

Web Links for Information on Northern Walkingstick

http://wiki.bugwood.org/Archive:South/Walkingstick

http://www.na.fs.fed.us/spfo/pubs/fidls/walkingstick/walkingstick.htm; Forest Insect & Disease Leaflet 82, U.S. Department of Agriculture, Forest Service.

Articles

Ignoffo, C.M., D.L. Hostetter, and W.H. Kearby. 1973. Susceptibility of walkingstick, orangestriped oakworm, and variable oakleaf caterpillar to *Bacillus thuringiensis* var. *alesti*. *Environmental Entomology* 2: 807-809.

Giese, R.L. and K.H. Knauer. 1977. Ecology of the walkingstick. *Forest Science* 23: 45-63.

6. Oak Lace Bug, *Corythucha arcuata* (Say) (Hemiptera: Tingidae)

Orientation to Pest

Oak lace bug, *Corythucha arcuata* (Say), is a minor pest of various oaks in its native range in North America. The insect may overwinter as either adults or eggs. Adults have lacey wings held flat over the body with an ornate pronotum. Nymphs are mostly black with spines. Feeding begins in early spring at leaf expansion. Eggs are laid on the underside of leaves. Nymphs and adults occur in colonies on foliage where they feed by sucking sap from plant tissues. Damage is similar to the yellow stippling produced by spider mite feeding, but without webbing. Black fecal spots are also present on foliage infested by lace bugs. Dense populations can cause premature leaf drop. There are multiple generations per year.

Hosts Commonly Attacked

The main hosts of this species are white (*Quercus alba* L.), bur (*Q. macrocarpa* Michx.), and chestnut oaks (*Q. prinus* L.).

Distribution

This bug occurs from Alabama and the Carolinas north to southern Canada.

Images of Oak Lace Bug

Figure 1. Adult of oak lace bug, *Corythucha arcuata*. (Joseph Berger, Bugwood.org)

Images of Oak Lace Bug (continued)

Figure 2. Nymphs of oak lace bug on underside of oak leaf. (Jim Baker, North Carolina State University, Bugwood.org)

Figure 3. Oak foliage showing damage (yellow stippling) on the upper leaf surface from feeding of oak lace bug. (Jim Baker, North Carolina State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the specific natural enemies of the oak lace bug. One generalist predator associated with the species is the mirid *Deraeocoris nebulosus* (Uhler).

Web Links for Information on Oak Lace Bug

http://www.fs.fed.us/r8/foresthealth/pubs/oakpests/p30.html

Articles

Horn, K.F., C.G. Wright, and M.H. Farrier. 1979. The lace bugs (Hemiptera: Tingidae) of North Carolina and their hosts. North Carolina Agricultural Experiment Station Technical Bulletin No. 257: 22 p.

Wheeler, A.G., Jr., B.R. Stinner, and T.J. Henry. 1975. Biology and nymphal stages of *Deraeocoris nebulosus* (Hemiptera: Miridae), a predator of arthropod pests on ornamentals. *Annals of the Entomological Society of America* 68: 1063-1068.

7. Sycamore Lace Bug, *Corythucha ciliata* (Say) (Hemiptera: Tingidae)

Orientation to Pest

Sycamore lace bug, *Corythucha ciliata* (Say), is a minor pest of American sycamore (*Planatus occidentalis* L.) in its native range in North America but is very important in Europe as an invasive species on urban plane trees. It has also invaded Australia, China, Turkey, and Chile. Adults overwinter under the bark flakes of sycamores. Feeding activity begins in early spring at leaf expansion of host plants. Eggs are laid on the underside of leaves. Nymphs and adults occur in colonies on the underside of foliage where they feed by sucking sap from plant cells. Feeding by low densities of lace bugs results in yellow stippling, starting along the mid-veins, similar in appearance to the damage caused by spider mites, but without webbing. Black fecal spots are also present on the undersides of leaves infested by lace bugs. Dense populations can cause a white or bronzed appearance to the leaves and premature leaf drop. In the northeast United States, there are two to four generations per year.

Hosts Commonly Attacked

The principal host of sycamore lace bug is American sycamore (*P. occidentalis*), but it occasionally feeds on ash (*Fraxinus*), hickory (*Carya*), and mulberry (*Morus*).

Distribution

This bug is native throughout the eastern USA and southern Canada. It is also invasive in Europe, Turkey, Australia, China, and Chile. Spread is likely due to tendency of adults to secrete themselves into crevices for overwintering, allowing them to be easily moved in crates or cargo between countries.

Images of Sycamore Lace Bug

Figure 1. Adult of sycamore lace bug, *Corythucha ciliate*. (Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org)

Images of Sycamore Lace Bug (continued)

Figure 2. Adults of sycamore lace bug feed in groups on the undersides of leaves (note the black fecal spots). (Jim Baker, North Carolina State University, Bugwood.org)

Figure 3. Nymphs of sycamore lace bug. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 4. Size of mature nymphs of sycamore lace bug (black, on left) as compared to adults. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Sycamore Lace Bug (continued)

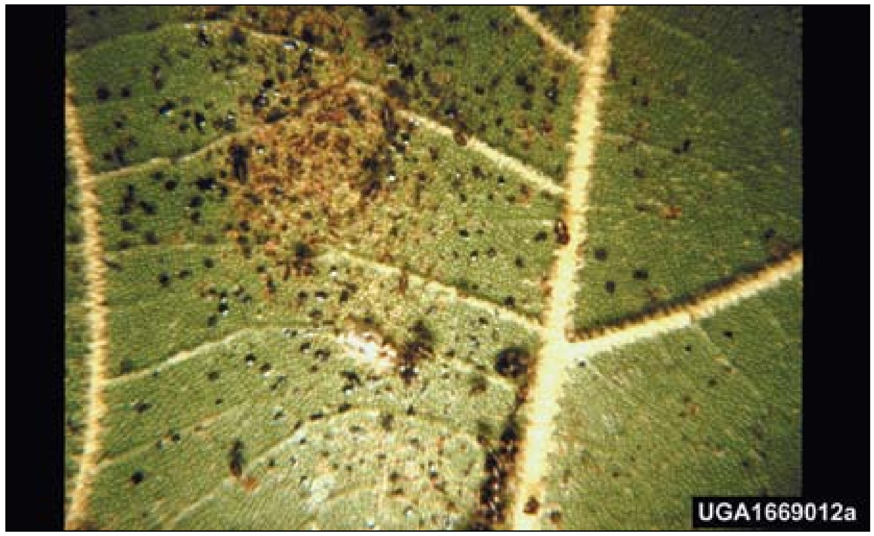

Figure 5. Close up showing the black fecal spots deposited by sycamore lace bug. (Bruce W. Kauffman, Tennessee Department of Agriculture, Bugwood.org)

Figure 6. Yellow stippling and bronzing of foliage caused by sycamore lace bug. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 7. Sycamore trees bronzed by feeding of sycamore lace bug. (Terry S. Price, Georgia Forestry Commission, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the specific natural enemies of the sycamore lace bug. The generalist predatory mirid *Deraeocoris nebulosus* (Uhler) is known to feed on sycamore lace bugs.

Web Links for Information on Sycamore Lace Bug

http://entnemdept.ufl.edu/creatures/trees/sycamore_lace_bug.htm; fact sheet of the University of Florida.

Articles

Halbert, S.E. and J.R. Meeker. 1998. The Sycamore Lace Bug, *Corythucha ciliata* (Say) (Hemiptera: Tingidae). Entomology Circular No.387. Florida Dept. Agric. & Consumer Services, Division of Plant Industry. (Available at http://www.fl-dof.com/publications/fh_pdfs/Sycamore%20Lace%20Bug.pdf).

Wheeler, A.G., Jr., B.R. Stinner, and T.J. Henry. 1975. Biology and nymphal stages of *Deraeocoris nebulosus* (Hemiptera: Miridae), a predator of arthropod pests on ornamentals. *Annals of the Entomological Society of America* 68: 1063-1068.

Horn, K.F., C.G. Wright, and M.H. Farrier. 1979. The lace bugs (Hemiptera: Tingidae) of North Carolina and their hosts. North Carolina Agricultural Experiment Station Technical Bulletin No. 257: 22 p.

8. Shield-backed Pine Seed Bug, *Tetyra bipunctata* (Herrich-Schäffer) (Hemiptera: Scutellaridae)

Orientation to Pest

The shield-backed pine seed bug, *Tetyra bipunctata* (Herrich-Schäffer), feeds on seeds in cones of various pines and thus causes losses in seed orchards. There is one generation a year, and nymphs and adults feed in groups. Most damage to seeds is done in late summer or fall and is not visible, even after the seeds have been extracted from cones.

Hosts Commonly Attacked

This insect feeds on various pines, including loblolly (*Pinus taeda* L.), slash (*Pinus elliottii* Engelm.), shortleaf (*Pinus echinata* Mill.), Virginia (*Pinus virginiana* Mill.), eastern white (*Pinus strobus* L.), red (*Pinus resinosa* Sol. ex Aiton), jack (*Pinus banksiana* Lamb.), and sand (*Pinus clausa* [Chapm. ex Engelm.] Sarg.) pines.

Distribution

The shield-backed pine seed bug occurs from Virginia north to Ontario and Quebec and west to Minnesota and Oklahoma.

Images of the Shield-backed Pine Seed Bug

Figure 1. Adult shield-backed pine seed bug, *Tetyra bipunctata*. (John Maxwell, Marlton, NJ, USA, Bugguide.net)

Figure 2. Eggs of shield-backed pine seed bug. (Texas Forest Service Archive, Texas Forest Service, Bugwood.org)

Images of the Shield-backed Pine Seed Bug (continued)

Figure 3. Nymph of shield-backed pine seed bug. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 4. Shield-backed pine seed bug adults feeding on cones. (Larry R. Barber, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Specific natural enemies of this species are unknown.

Web Links for Information on Shield-backed Pine Seed Bug

http://www.forestpests.org/nursery/seedandcone.html; fact sheet "Seed and Cone Insects" by Larry R. Barber, Entomologist, Region 8, USDA Forest Service, Asheville, North Carolina.

Articles on Shield-backed Pine Seed Bug

DeBarr, G.L. 1979. Importance of the seedbugs *Leptoglossus corculus* (Say) (Hemiptera: Coreidae) and *Tetyra bipunctata* (H.-S.) (Hemiptera: Pentatomidae) and their control in southern pine seed orchards. Proceedings: a symposium on flowering and seed development in trees. Starkville, Mississippi: Southern Forest Experiment Station: 330-341.

Gilbert, B.L., S.J. Barras, and D.M. Norris. 1967. Bionomics of *Tetyra bipunctata* (Hemiptera: Pentatomidae: Scutellerinae) as associated with *Pinus banksiana* in Wisconsin. *Annals of the Entomological Society of America* 60: 698-701.

Goyer, R.A. and V.G. Williams.1981. The effects of feeding by *Leptoglossus corculus* (Say) and *Tetyra bipunctata* (Herrich and Schaffer) on loblolly pine (*Pinus taeda* L.) conelets. *Journal of Georgia Entomological Society* 16: 16-21.

Turgeon, J.J., P. de Groot, and J.D. Sweeney. 2005. Insects of seed cones in eastern Canada; field guide. Ontario Ministry of Natural Resources/ Forestry Canada, Toronto: 127 p.

9. Leaffooted Pine Seed Bug, *Leptoglossus corculus* (Say) (Hemiptera: Coreidae)

Orientation to Pest

The leaffooted pine seed bug, *Leptoglossus corculus* (Say), is a sucking insect that damages cones in pine seed orchards in the southern United States. Both adults and nymphs fed on seeds in cones of various pines, greatly reducing production of viable seed. There are several generations per year in the southern United States.

Hosts Commonly Attacked

The leaffooted pine seed bug commonly attacks cones of loblolly (*Pinus taeda* L.), slash (*P. elliottii* Engelm.), shortleaf (*P. echinata* Mill.), Virginia (*P. virginiana* Mill.), eastern white (*P. strobus* L.), pitch (*P. rigida* Mill.) and Table Mountain (*P. pungens* Lamb.) pines, as well as cones of some spruce (*Picea*).

Distribution

The leaffooted pine seed bug occurs throughout the eastern United States.

Images of Leaffooted Pine Seed Bug

Figure 1. Adult leaffooted pine seed bug, *Leptoglossus corculus*. See the flat, expanded lower section of hind legs. (R. Scott Cameron, Advanced Forest Protection, Inc., Bugwood.org)

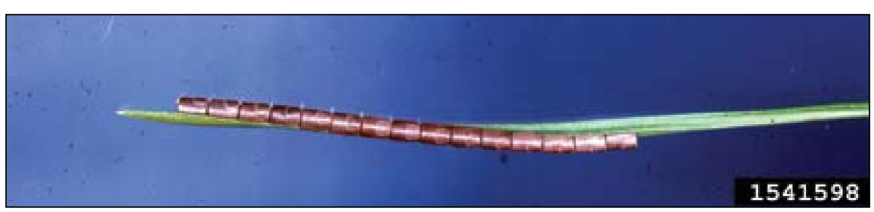

Figure 2. String of eggs of leaffooted pine seed bug. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Leaffooted Pine Seed Bug (continued)

Figure 3. Nymph of leaffooted pine seed bug. (Tim Tigner, Virginia Department of Forestry, Bugwood.org)


Figure 4. Leaffooted pine seed bug adult feeding on immature cone of pine. (Larry R. Barber, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The parasitoid *Ooencyrtus leptoglossi* Yoshimoto is known to attack the eggs of this species.

Web Links for Information on Leaffooted Pine Seed Bug

http://www.forestpests.org/nursery/seedandcone.html; fact sheet "Seed and Cone Insects" by Larry R. Barber, Entomologist, Region 8, USDA Forest Service, Asheville, North Carolina.

Articles

DeBarr, G.L. 1979. Importance of the seedbugs *Leptoglossus corculus* (Say) (Hemiptera: Coreidae) and *Tetyra bipunctata* (H.-S.) (Hemiptera: Pentatomidae) and their control in southern pine seed orchards. Proceedings: a symposium on flowering and seed development in trees. Starkville, Mississippi. Southern Forest Experiment Station: 330-341.

10. Royal Palm Bug, *Xylastodoris luteolus* Barber (Hemiptera: Thaumastocoridae)

Orientation to Pest

Royal palm bug, *Xylastodoris luteolus* Barber, is a sucking bug that feeds on immature leaves of royal palm (*Roystonea regia* [Kunth] O.F. Cook). If densities are high, this feeding may cause browning of affected foliage.

Hosts Commonly Attacked

This sucking bug feeds on royal palm (*R. regia*), sometimes called Florida royal palm or Cuban royal palm.

Distribution

This insect’s native range is Cuba, but it also occurs in southern Florida.

Images of Royal Palm Bug

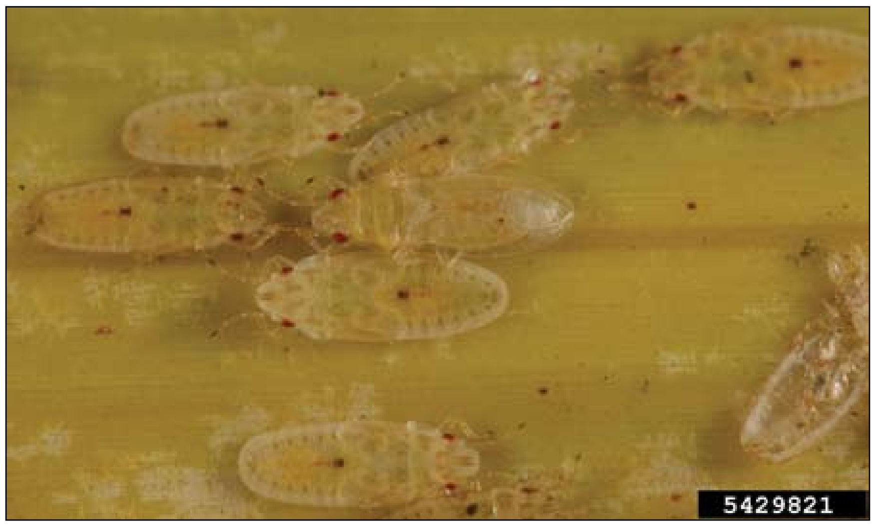

Figure 1. Adults of royal palm bug, *Xylastodoris luteolus*. (Lyle Buss, University of Florida, Bugwood.org)

Figure 2. Close view of damage to Florida royal palms by the royal palm bug. (Doug Caldwell, University of Florida, Bugwood.org)

Images of Royal Palm Bug (continued)

Figure 3. Damage to Florida royal palm frond by the royal palm bug. (Doug Caldwell, University of Florida, Bugwood.org)

Figure 4. Whole tree view of damage to Florida royal palm frond by the royal palm bug. (Both photos: Dr. A. D. Ali, Davey Tree Expert Company, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Specialized natural enemies of this species are unknown.

Web Links for Information on Royal Palm Bug

http://entnemdept.ufl.edu/creatures/orn/palms/royal_palm_bug.htm

http://edis.ifas.ufl.edu/in254; fact sheet of University of Florida IFAS Extension.

Articles

Weissling, T.J., F.W. Howard, and A.W. Meerow. Royal palm bug, *Xylastodoris luteolus* Barber (Insecta: Hemiptera: Thaumastocoridae). EENY-097 University of Florida IFAS Extension. (Available at http://edis.ifas.ufl.edu/in254).

Ali, A.D. and D. Caldwell. 2010. Royal palm bug *Xylastodoris luteolus* (Hemiptera: Thaumastocoridae) control with soil-applied systemics. *Florida Entomologist* 93: 294-297.

11. Saratoga Spittlebug, *Aphrophora saratogensis* (Fitch) (Hemiptera: Cercopidae)

Orientation to Pest

Saratoga spittlebug, *Aphrophora saratogensis* (Fitch), is a native insect in North America whose adults damage certain pines, especially red pine (*Pinus resinosa* Sol. ex Aiton), usually when grown in plantations. Damage also occurs on jack (*P. banksiana* Lamb.) and Scots pines (*P. sylvestris* L.). Adult feeding damages pines because toxics injected into the plant kill tissues, causing dead pockets of xylem and phloem tissue. Extensive feeding kills branches, stunts and deforms shoots, and may sometimes kill trees. This species is generally considered the most serious sap-feeding pest of red pine plantations. In contrast, nymphs are not pests because they feed on different plants. Young nymphs feed on understory plants such as brambles (species of *Rubus*), orange hawkweed (*Pilosella aurantiaca* [L.] F.W. Schultz and Schultz-Bip), pearly everlasting (*Anaphalis nubigena* DC.), and asters (*Aster*), while older nymphs are found on sweetfern (*Comptonia peregrine* [L.] J.M. Coulter) and young willows (*Salix*). Saratoga spittlebug has one generation each year. On red pine, eggs are laid under the outer scales of buds in the upper branches. Selection criteria have been developed that use information on nymphal host plant abundance to pick sites for new red pine plantations that will have low risk of damage from Saratoga spittlebug. A site-risk diagram has been developed for this purpose (see figure in USDA Forest Service leaflet at http://www.na.fs.fed.us/spfo/pubs/fidls/saratoga/saratoga.htm).

Hosts Commonly Attacked

Saratoga spittlebug is known as a pest of some pines, especially red pine (*P. resinosa*) grown in plantations.

Distribution

This insect occurs where ever its hosts grow, from Maine to Minnesota in the United States and in the southern portions of the adjacent Canadian Provinces. It is of particular importance in Michigan and Wisconsin.

Images of Saratoga Spittlebug

Figure 1a. Adults of Saratoga spittlebug, *Aphrophora saratogensis*. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Saratoga Spittlebug (continued)

Figure 1b. Adult Saratoga spittlebug, *Aphrophora saratogensis*. (Tom Murray)

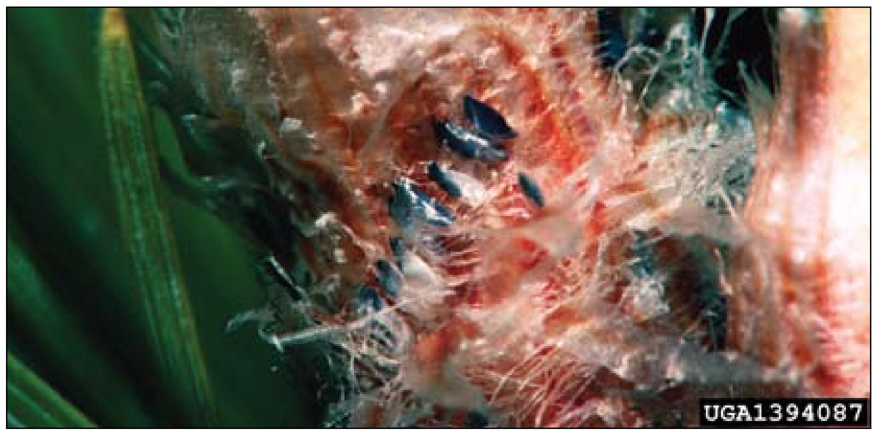

Figure 2. Eggs of Saratoga spittlebug (dark bodies in woolly mass). (James B. Hanson, USDA Forest Service, Bugwood.org)

Figure 3. Spittle masses of Saratoga spittlebugs at base of stems of sweetfern, the favorite host of older nymphs. (Linda Haugen, USDA Forest Service, Bugwood.org)

Images of Saratoga Spittlebug (continued)

Figure 4. Saratoga spittlebug feeding damage to red pine (Both photos: USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Eggs of Saratoga spittlebug are attacked by two parasitoids, *Ooctonus aphrophorae* Milliron and *Tumidiscapus cercopiphagus* Milliron, but attack rates are low (<5 percent). A fly in the family Pipunculidae, *Verrallia virginica* Banks, may be a significant source of mortality (causing up to 50 percent mortality).

Web Links for Information on Saratoga Spittlebug

http://www.na.fs.fed.us/spfo/pubs/fidls/saratoga/saratoga.htm; a USDA Forest Service pest leaflet.

http://www.maine.gov/doc/mfs/saratoga.htm; Maine fact sheet.

Articles

Wilson, L.F. 1971. Risk-rating Saratoga spittlebug damage by abundance of alternate-host plants. Research Note NC-110, North Central Forest Experiment Station, Forest Service, United States Department of Agriculture: 4 p.

Linnane, J.P. and E.A. Osgood. 1977. *Verrallia virginica* (Diptera: Pipunculidae) reared from the Saratoga spittlebug in Maine. *Proceedings of the Entomological Society of Washington* 79(4): 622-623.

12. Pine Spittlebug, *Aphrophora parallela* (Say) (Hemiptera: Cercopidae)

Orientation to Pest

Pine spittlebug, *Aphrophora parallela* (Say), is a native insect in North America that is found in most of the eastern United States and adjacent southern Canada. Adults and nymphs develop on the same plant species. The most favored host is Scots pine (*Pinus sylvestris* L.). Eggs are deposited under bark and are the overwintering stage. Nymphs initially feed on twigs, but later move to the trunk, forming protective spittle masses each time they move. Adults return to twigs to feed. There is a single generation per year. Feeding of this spittlebug promotes the spread of a pathogenic fungus, *Sphaeropsis sapinea* (synonyms *S. ellisii* and *Diplodia pinea*), which invades weakened trees through spittlebug feeding punctures. This fungus is responsible for a considerable part of the dead branches associated with this insect.

Hosts Commonly Attacked

Pine spittlebugs seem to prefer Scots pine but are also found on six other pines, three species of spruce (*Picea*), balsam fir (*Abies balsamea* [L.] Miller), larch (*Larix*), and eastern hemlock (*Tsuga canadensis* (L.) Carrière).

Distribution

Pine spittlebug is found throughout the eastern United States and adjacent parts of southern Canada.

Images of Pine Spittlebug

Figure 1. Adult of pine spittlebug, *Aphrophora parallela*. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 2. Spittle mass pushed aside to show nymph of pine spittlebug. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The fungus *Entomophora aphrophorae* Rostrup at times causes high mortality to nymphs.

Web Links for Information on Pine Spittlebug

http://wiki.bugwood.org/Aphrophora_parallela; short fact sheet by BugwoodWiki.

http://www.entomology.umn.edu/cues/Web/199Spittlebugs.pdf; fact sheet with a comparison among spittlebug species.

http://ipm.illinois.edu/diseases/rpds/625.pdf; report on *Sphaeropsis* blight or *Diplodia* tipblight of pines.

http://www.maine.gov/doc/mfs/pinespit.htm; Maine government fact sheet.

Articles

Wilson, L.F. and D.G. Mosher. 1981. How to identify and control pine spittlebug [*Aphrophora parallela*]. North Central Forest Experiment Station, USDA Forest Service, St. Paul, Minnesota: 6 p.

13. Thorn Bug, *Umbonia crassicornis* (Amyot and Serville) (Hemiptera: Membracidae)

Orientation to Pest

The thorn bug *Umbonia crassicornis* (Amyot and Serville) is a sucking bug that is an occasional pest of ornamentals and fruit trees in southern Florida. Colonies of these insects may be very visible on the twigs of their hosts. Feeding may lead to defoliation or twig death in some species of plants. Also, thorn bugs produce honeydew, which leads to growth of sooty mold. Eggs are laid in bark of tender twigs and, most interestingly for insects, females show maternal care by actively tending their offspring. Young nymphs have three horns instead of the one seen on the adults. Colonies of insects are chemically defended against predators.

Hosts Commonly Attacked

Among plants that suffer important injury when infested with thorn bugs are species of *Hibiscus*, powder-puff (*Calliandra*), woman's tongue tree (*Albizzia lebbek* [L.] Benth.), and species of *Acacia*. Other hosts suitable for reproduction include wild tamarind (*Lysiloma bahamensis*), tamarind (*Tamarindus indica* L.), *Casuarina* sp., *Crotalaria* sp., rayado bundleflower (*Desmanthus virgatus* Benth.), bottle brush (*Callistemon* sp.), Jerusalem thorn (*Parkinsonia aculeate* L.), and dwarf date palm (*Phoenix roebelenii* O'Brien).

Distribution

This thorn bug is subtropical or tropical and found in Mexico, Central and South America. In the United States, it is found only in southern and central Florida.

Images of Thorn Bug

Figure 1. Adult of the thorn bug *Umbonia crassicornis*. (Lyle Buss, University of Florida, Bugwood.org)

Images of Thorn Bug (continued)

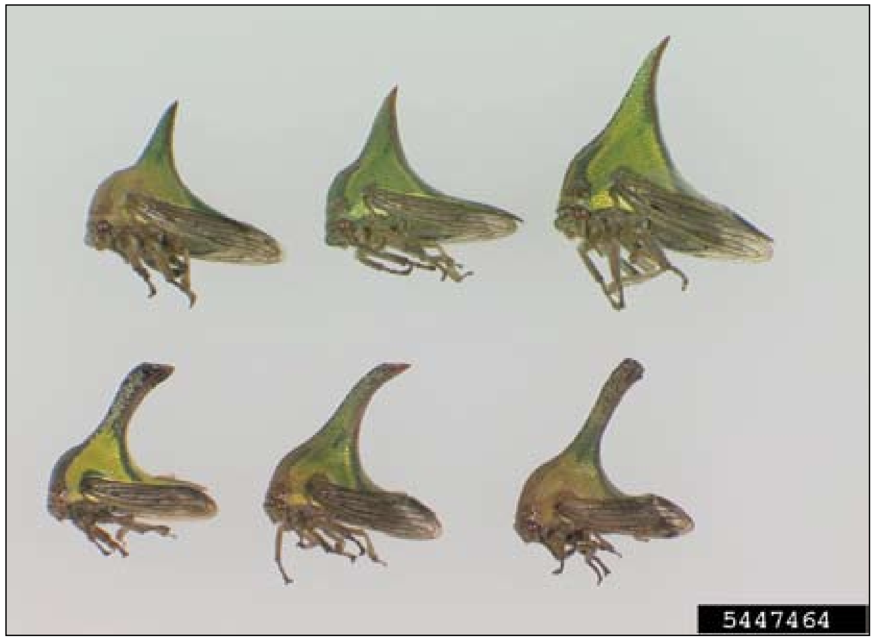

Figure 2. Adults of this thorn bug are variable in terms of the shape and size of their horn. (Lyle Buss, University of Florida, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on specialized natural enemies of this species.

Web Links for Information on Thorn Bug

http://edis.ifas.ufl.edu/pdffiles/IN/IN33200.pdf; fact sheet of the University of Florida.

Articles

Wood, T.K. 1976. Alarm behavior of brooding female *Umbonia crassicornis* (Homoptera: Membracidae). *Annals of the Entomological Society of America* 69: 340-344.

14. Periodical Cicada, *Magicicada septendecim* L. (Hemiptera: Cicadidae)

Orientation to Pest

The periodical cicada, *Magicicada septendecim* L., is the largest of periodically emerging cicada species (adult, 40 mm in length). Females are black on top and males are black with a pattern of 4 or 5 orange-brown abdominal segments when viewed from below. The female has a stout ovipositor that is used to insert eggs into the bark of small branches and twigs. Eggs are laid in batches of 25-30, and many batches may be laid in the same twig. After eggs hatch, nymphs drop to the ground and burrow into the soil, where they feed on the plant's roots. Nymphs require 17 years to complete their development. Emergence of last instar nymphs is synchronous, producing mass swarms of adults at 17-year intervals. Broods (populations in different areas) are not necessarily in synchrony. Effect of nymphal feeding on roots has not been quantified. The only significant injury caused by this insect is the dieback of small branches ("flagging") from the cuts made for oviposition. While this injury can be highly visible it is not harmful to larger trees and shrubs since it only occurs every 17 years and large plants can tolerate this level of damage. On smaller trees, however, extensive oviposition may be harmful. Homeowners who need to protect small trees and shrubs from damage can do so by covering plants with netting to exclude cicadas, which should be left in place until most cicadas have died off (about four weeks from their first appearance). Periodical cicadas are often too numerous to make applications of pesticides practical. The mass emergences of this insect are much appreciated as a wildlife phenomenon and this species is best viewed as an impressive act of nature rather than as a pest.

Hosts Commonly Attacked

This cicada lays its eggs in more than 70 species of trees or other plants, but the most affected trees are oaks (*Quercus*), hickory (*Carya*), honeylocust (*Gleditsia triacanthos* L.), dogwood (*Cornus*), apple (*Malus domestica* Borkh.), and peach (*Prunus persica* [L.] Batsch.). But many other species may also be attacked at times.

Distribution

Magicicada septendecim is widely distributed in the eastern United States.

Images of the Periodical Cicada

Figure 1. Adult of the periodical cicada, *Magicicada septendecim*, a 17-yr cicada. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 2. Oviposition scars made by the periodical cicada in a branch. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 3. Nymph of periodical cicada, the below-ground life stage. (Bill Gallup, Bugwood.org)

Images of the Periodical Cicada (continued)

Figure 4. Holes in soil made by emerging last instar nymphs of the periodical cicada. (Jim Occi, BugPics, Bugwood.org)

Figure 5. Adult of a periodical cicada as it begins to molt from the last nymphal instar after its emergence from the soil. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 6. Cast skins of periodical cicada nymphs produced during the insect's mass emergence. (Jim Occi, BugPics, Bugwood.org)

Images of the Periodical Cicada (continued)

Figure 7. Flagging of branches due to oviposition wounds of periodical cicada. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 8. Close up of branch flagging from oviposition wounds of periodical cicada. (Jim Occi, BugPics, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Almost everything seems to eat periodical cicadas including birds, squirrels, snakes, spiders, etc. The massive populations of periodical cicadas, however, are able to satiate such predators and they appear to have little effect in reducing cicada densities.

Web Links for Information on the Periodical Cicada

http://insects.ummz.lsa.umich.edu/fauna/michigan_cicadas/periodical/index.html; discusses the various species of periodical cicadas.

http://www.magicicada.org/about/species_pages/m_sdecim.php; has sound files of cicada songs.

Articles

Miller, F.D. 1997. Effects and control of periodical cicada *Magicicada septendecim* and *Magicicada cassini* oviposition injury on urban forest trees. *Journal of Arboriculture* 23(6): 225-232.

Miller, F. and W. Crowley. 1998. Effects of periodical cicada ovipositional injury on woody plants. *Journal of Arboriculture* 24(5): 248-253.

15. Eastern Spruce Gall Adelgid, *Adelges abietis* (L.) (Hemiptera: Adelgidae)

Orientation to Pest

Eastern spruce gall adelgid, *Adelges abietis* (L.), is a pest of the introduced Norway spruce (*Picea abies* [L.]) and of various native North American spruces, especially white spruce (*P. glauca* [Moench]). It is an invasive species believed to be of European origin. Damage is caused by induction of galls on new growth. Adults, which are wingless, deposit their eggs near buds in spring and newly developing needles are stimulated by developing nymphs to become enlarged, fusing into a pineapple-shaped gall, within which nymphs mature. In summer and early fall, the chambers of the gall open and nymphs emerge and transform themselves into winged adults, which lay eggs. These hatch and nymphs overwinter at the base of needles and buds. In spring, when the gall is newly formed, it is light green in color, but after it matures and insects emerge, it dries and turns brown, remaining on the branch as a sign of earlier infestation. Damage results from twig deaths induced by galls, which makes the tree misshapen. Heavily infested trees may die.

Hosts Commonly Attacked

This adelgid feeds on black (*P. mariana* (Mill.) Britton, Sterns & Poggenburg), Norway (*P. abies*), and white (*P. glauca*) spruces.

Distribution

Eastern spruce gall adelgid occurs widely in the eastern United States from Maine to Tennessee and Illinois, as well as in northern Minnesota, Wisconsin, and Michigan, and adjacent parts of Canada. Localized infestations also occur in parts of Montana, Wyoming, and South Dakota. A map of this distribution is available at http://www.fs.fed.us/nrs/tools/afpe/maps/ESGA.pdf.

Images of Eastern Spruce Gall Adelgid

Figure 1. Close view of living galls of eastern spruce gall adelgid, *Adelges abietis*. (E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Images of Eastern Spruce Gall Adelgid (continued)

Figure 2. Living galls of eastern spruce gall adelgid cut in cross section and showing chambers where insects feed. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Dead galls of eastern spruce gall adelgid. (E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 4. Openings in gall of eastern spruce gall adelgid after insect emergence. (Stanislaw Kinelski, Bugwood.org)

Images of Eastern Spruce Gall Adelgid (continued)

Figure 5. Adult of eastern spruce gall adelgid, *Adelges abietis*. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Because damage from this species is not severe, natural enemies have not been imported from the pest's native range into North America for control. Predacious flies have been observed feeding on this adelgid in Europe (the syphid *Cnemodon* sp.) and, in Turkey, *Leucopis* species have been recorded feeding on related adelgids, but in general little is known about the natural enemies of this species.

Web Links for Information on Eastern Spruce Gall Adelgid

http://www.ravageursexotiques.gc.ca/ins_details_eng.asp?pestType=ins&lang=en&geID=5306; website of Environment Canada on invasive forest insects.

http://ohioline.osu.edu/hyg-fact/2000/2550.html; fact sheet of Ohio State University, includes information on control.

Articles

Flaherty, L., D. Quiring, and J.A. Kershaw, Jr. 2010. Post-gall induction performance of *Adelges abietis* (L.) (Homoptera: Adelgidae) is influenced by clone, shoot length, and density of colonising gallicolae. *Ecological Entomology* 35: 9-15.

16. Balsam Woolly Adelgid, *Adelges piceae* (Ratzeburg) (Hemiptera: Adelgidae)

Orientation to Pest

Balsam woolly adelgid, *Adelges piceae* (Ratzeburg), attacks only true firs (*Abies*). It is native to Eurasia and is a serious invasive pest in both eastern and western North America. Balsam woolly adelgids are small, <1 mm in size, and covered with white, woolly wax. Adults and nymphs feed on both the bole and twigs and inject hormones with their saliva that causes gouty twigs and growth of compression wood on the bole. These deformities disrupt water conduction and reduce tree growth and market value. Heavy infestations eventually kill the tree. Extensive damage to Fraser fir (*Abies fraseri* [Pursh] Poir.) in the southern Appalachian Mountains caused severe ecological damage to unique mountain-top habitats created by stands of this species. Damage to balsam (*A. balsamea* (L.) Mill.) and western firs has caused significant economic losses due to a combination of elevated rates of tree mortality and reduced growth. Various predators imported and released during the 1950s from the European Alps failed to bring the pest under biological control. However, it is possible that the Alps themselves were an invaded area and that the true native range is the Caucasus Mountains. Thus, this region has potential as a source of effective natural enemies for this pest.

Hosts Commonly Attacked

The host plants of balsam woolly adelgid are Fraser fir (*A. fraseri*), balsam fir (*A. balsamea*), subalpine fir (*A. lasiocarpa* [Hooker] Nuttall), Pacific silver fir (*Abies amabilis* Douglas ex J. Forbes), and grand fir (*A. grandis* [Douglas ex D. Don] Lindley).

Distribution

Balasm woolly adelgid is found in New York, New England, the Canadian Maritimes, British Columbia, the Pacific northwestern U.S. states, and limited areas of the southern Appalachian Mountains and the central coast of California.

Figure 1. Distribution of balsam woolly adelgid, *Adelges piceae*, in North America. (USDA Forest Service, Forest Insect & Disease Leaflet 118 revised May 2006)

Images of Balsam Woolly Adelgid

Figure 2. Bole of fir tree infested with balsam woolly adelgid. (USDA Forest Service - Ashville Archive, USDA Forest Service, Bugwood.org)

Figure 3. Close view of balsam woolly adelgids on bark of fir tree. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 4. High magnification of crawler (first instar) of balsam woolly adelgid. (USDA Forest Service - Ashville Archive, USDA Forest Service, Bugwood.org)

Images of Balsam Woolly Adelgid

Figure 5. Goutiness of Fraser fir twigs due to feeding by balsam woolly adelgid. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 6. Fraser fir trees killed by balsam woolly adelgid. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

More than 23 species of natural enemies were imported and released into the United States against this pest. Six species established, but remain rare: *Aphidecta obliterata* (L.) (Coleop.: Coccinellidae), *Scymnus impexus* (Mulsant) (Coleop.: Coccinellidae), *Laricobius erichsonii* (Rosenhauer) (Coleop.: Derodontidae), *Aphidoletes thompsoni* Möhn (Diptera: Cecidomyiidae), *Cremifania nigrocellulata* Czerny (Diptera: Chamaemyiidae), and *Leucopis obscura* (Hal.) (Diptera: Chamaemyiidae).

Web Links for Information on Balsam Woolly Adelgid

http://www.na.fs.fed.us/pubs/fidls/bwa.pdf; U.S. Department of Agriculture, Forest Service Forest Insect & Disease Leaflet 118 (Revised May 2006).

http://pubs.ext.vt.edu/3006/3006-1452/3006-1452.pdf; Virginia Cooperative Extension bulleting on balsam woolly adelgid by Scott Salom and Eric Day.

http://www.ces.ncsu.edu/fletcher/programs/xmas/ctnotes/ctn020.html; North Carolina State University Cooperative Extension (a short bulletin discussing how to manage this pest in Christmas trees).

Articles

Harris, J.W.E. and A.F. Dawson. 1979. Predator release program for balsam woolly aphid, *Adelges piceae* (Homoptera: Adelgidae), in British Columbia, 1960-1969. *Journal of the Entomological Society of British Columbia* 76: 21-26.

Schooley, H.O. and L. Oldford. 1981. An annotated bibliography of the balsam woolly aphid (*Adelges piceae* [Ratzeburg]). Information Report N-X-196, Canadian Forestry Service: 97 p.

Schooley, H.O., J.W.E. Harris, and B. Pendrel. 1984. *Adelges piceae* (Ratz.) balsam woolly adelgid (Homoptera: Adelgidae). In: Kelleher, J.S. and M.A. Hulme (eds.). *Biological Control Programmes against Insects and Weeds in Canada, 1969-1980.* Commonwealth Agricultural Bureaux, Farnham Royal, England: 229-234.

McManamay, R.H., L.M. Resler, J.B. Campbell, and R.A. McManamay. 2011. Assessing the impacts of balsam woolly adelgid (*Adelges piceae* Ratz.) and anthropogenic disturbance on the stand structure and mortality of Fraser fir [*Abies fraseri* (Pursh) Poir.] in the Black Mountains, North Carolina. *Castanea* 76(1): 1-19.

17. Hemlock Woolly Adelgid, *Adelges tsugae* Annand (Hemiptera: Adelgidae)

Orientation to Pest

Hemlock woolly adelgid, *Adelges tsugae* Annand, is an invasive insect in eastern North America. DNA evidence suggests that the invasive eastern U.S. population came from Japan and not the western United States, where the species is also present. Hemlock woolly adelgids are small in size and to the naked eye only their woolly coverings are easily visible. The insect has two generations per year and growth occurs from fall through late spring. Insects in summer are inactive and scarcely visible at the bases of needles as black dots. Woolly masses (the sign allowing the species to be recognized) develop in October and are present thereafter through June of the following year. In the western United States, *A. tsugae* feeds on western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) but is believed to be native and is not a pest. In the eastern USA, hemlock woolly adelgid is killing eastern (*T. canadensis* [L.] Carrière) and Carolina (*T. caroliniana* Engelm.) hemlocks in large numbers from Connecticut south along the Appalachian Mountains. From Massachusetts north, or at high elevations, tree mortality has been restrained by higher rates of mortality of adelgids in winter due to low temperatures. A biological control program is in progress against this pest, based on specialized predatory beetles that feed only on adelgids, collected in western North America (*Laricobius nigrinus* Fender) or China/Japan (species of *Laricobius* and various *Scymnus* ladybird beetles). To date, releases have not demonstrated any reductions in adelgid densities from predators. Populations of *L. nigrinus* have become well established and abundant in some areas of western North Carolina.

Hosts Commonly Attacked

In North America, this species feed only on eastern hemlock (*T. canadensis*), Carolina hemlock (*T. caroliniana*), and western hemlock (*T. heterophylla*).

Distribution

The hemlock woolly adelgid is found as a native species in the western United States in the Pacific northwestern states (Oregon, Washington, Idaho, and Montana) and as an invasive species from Japan in the eastern United States, from southern Maine to northern Georgia.

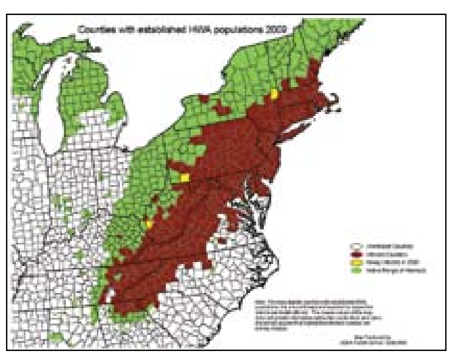

Figure 1. Distribution of hemlock woolly adelgid, *Adelges tsugae*, in the eastern United States in 2009. (USDA Forest Service, Northeastern Area, Forest Health Protection - Distribution Maps)

Images of Hemlock Woolly Adelgid

Figure 2. Hemlock woolly adelgid on hemlock. (Michael Montgomery, USDA Forest Service, Bugwood.org)

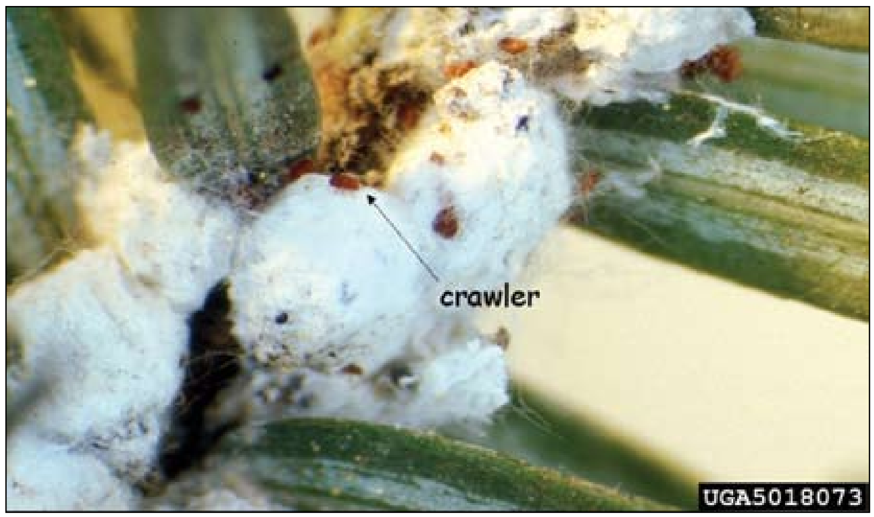

Figure 3. Individuals of hemlock woolly adelgid covered with white wool (see crawler emerging, arrow). (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Figure 4. High magnification of the aphid-like body of an adult hemlock woolly adelgid after removal of the wool. (Michael Montgomery, USDA Forest Service, Bugwood.org)

Images of Hemlock Woolly Adelgid (continued)

Figure 5. Eggs of hemlock woolly adelgid (wool pulled aside for viewing). (Lorraine Graney, Bartlett Tree Experts, Bugwood.org)

Figure 6. Damage from hemlock woolly adelgid is seen as needle loss, leading to branch death. (Chris Evans, River to River CWMA, Bugwood.org)

Figure 7. Dead or dying hemlock in Joyce Kilmer area, North Carolina due to hemlock woolly adelgid feeding. (Jason VanDriesche, Bugwood.org)

Images of Hemlock Woolly Adelgid (continued)

Figure 8. *Laricobius nigrinus*, which feeds only on adelgids, is the most promising agent released so far against hemlock woolly adelgid. (Ashley Lamb, Virginia Polytechnic Institute and State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

There is an on going classical biological control project against this pest. As of 2010, the principal species introduced against this pest have been the following four species: *Sasajiscymnus tsugae* (Sasaji and McClure) (Coleop.: Coccinellidae), *Scymnus sinuanodulus* Yu and Yao (Coleop.: Coccinellidae), *Scymnus ningshanensis* Yu and Yao (Coleop.: Coccinellidae), and *Laricobius nigrinus* Fender (Coleop.: Derodontidae).

Web Links for Information on Hemlock Woolly Adelgid

http://na.fs.fed.us/fhp/hwa/biology/biological_control.shtm; information on hemlock woolly adelgid's biology, impacts, distribution, and control (chemical and biological).

http://www.na.fs.fed.us/spfo/pubs/pest_al/hemlock/hwa05.htm; a brief printable summary of life history and control;

http://www.dcnr.state.pa.us/forestry/woollyadelgid/index.aspx; contains an annual life cycle diagram.

Articles

Zilahi-Balogh, G.M.G., L.T. Kok, and S.M. Salom. 2002. Host specificity of *Laricobius nigrinus* Fender (Coleoptera: Derodontidae), a potential biological control agent of the hemlock woolly adelgid, *Adelges tsugae* Annand (Homoptera: Adelgidae). *Biological Control* 24: 192-198.

Zilahi-Balogh, G.M.G., S.M. Salom, and L.T. Kok. 2003. Development and reproductive biology of *Laricobius nigrinus*, a potential biological control agent of *Adelges tsugae*. *BioControl* 48: 293-306.

Mausel, D.L., S.M. Salom, L.T. Kok, and G.A. Davis. 2010. Establishment of the hemlock woolly adelgid predator, *Laricobius nigrinus* (Coleoptera: Derodontidae), in the eastern United States. *Environmental Entomology* 39: 440-448.

Articles on Hemlock Woolly Adelgid (continued)

Krapfl, K.J., E.J. Holzmueller, and M.A. Jenkins. 2011. Early impacts of hemlock woolly adelgid in *Tsuga canadensis* forest communities of the southern Appalachian Mountains. *Journal of the Torrey Botanical Society* 138: 93-106.

Montgomery, M.E., S. Shiyake, N.P. Havill, and R.A.B. Leschen, 2011. A new species of *Laricobius* (Coleoptera: Derodontidae) from Japan with phylogeny and a key for native and introduced congeners in North America. *Annals of the Entomological Society of America* 104: 389-401.

18. Cooley Spruce Gall Adelgid, *Adelges cooleyi* (Gillette) (Hemiptera: Adelgidae)

Orientation to Pest

Cooley spruce gall adelgid, *Adelges cooleyi* (Gillette), is native to the Rocky Mountain region of North America, where it galls various species of spruce (*Picea*). It is also found in Europe, where it was accidentally introduced through movement of North American conifers for use in plantations, and where it is a pest in plantations of Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco). In North America, damage occurs principally on landscape trees and in plantations. Damage is not important in native forests. Galls are formed on the apical portion of shoot, in contrast to eastern spruce gall adelgid (*Adelges abietis* [L.]) galls that are found on the basal portion of the twig. Damage is merely aesthetic, but may be economically significant in Christmas tree plantations.

Hosts Commonly Attacked

The most important host is blue spruce (*Picea pungens* Engelm.), but other species attacked include white spruce (*P. glauca* [Moench] Voss), Sitka spruce (*P. sitchensis* [Bong.] Carr.), Engelmann spruce (*P. engelmannii* Parry ex Engelm.), and as an alternate host, Douglas-fir (*P. menziesii*)

Distribution

This species occurs from coast to coast in the northern United States and throughout the range of white spruce in Canada. Populations occur in the eastern United States where blue spruce is planted as an ornamental.

Images of Cooley Spruce Gall Adelgid

Figure 1. Appearance of the large (2-3 cm long) galls caused by Cooley spruce gall adelgid, *Adelges cooleyi*. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Cooley Spruce Gall Adelgid (continued)

Figure 2. Close view of living galls of Cooley spruce gall adelgid. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 3. Living galls of Cooley spruce gall adelgid cut in cross section and showing chambers where insects feed. (Chris Schnepf, University of Idaho, Bugwood.org)

Figure 4. Overwintering adults of Cooley spruce gall adelgid. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Cooley Spruce Gall Adelgid (continued)

Figure 5. Appearance of Cooley spruce gall adelgids on its alternate host, Douglas-fir. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 6. Heavy infestation of Cooley spruce gall adelgid on Christmas trees. Such trees are not saleable. (Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little to nothing is known of the natural enemies of this species. Investigations in its native range in the Rocky Mountains of North America may be useful as a source of natural enemies for importation to Europe, where this species is an invasive pest.

Web Links for Information on Cooley Spruce Gall Adelgid

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=5307; website of Environment Canada on invasive forest insects.

http://ohioline.osu.edu/hyg-fact/2000/2551.html; fact sheet of Ohio State University that includes information on control.

Articles

Lasota, J.A. and D.J. Shetlar. 1986. Assessing seasonal and spatial abundance of *Adelges cooleyi* (Gillette) (Homoptera: Adelgidae) by various sampling techniques. *Environmental Entomology* 15: 254-257.

Cranshaw, W.S. 1989. Patterns of gall formation by the Cooley spruce gall adelgid on Colorado blue spruce. *Journal of Arboriculture* 15(11): 277-280.

19. Pine Bark Adelgid, *Pineus strobi* (Hartig) (Hemiptera: Adelgidae)

Orientation to Pest

Pine bark adelgid, *Pineus strobi* (Hartig), populations are at times dense and strikingly visible; however, this native adelgid is generally only a minor pest of eastern white pine (*Pinus strobus* L.). Even dense populations do little harm if the tree is otherwise healthy. In plantations and on Christmas trees, pine bark adelgid infestations may reduce growth and induce excessive branching, reducing the value of Christmas trees. The species may have up to five generations per year.

Hosts Commonly Attacked

The host of this species is eastern white pine (*P. strobus*).

Distribution

This adelgid is found widely in North America throughout the range of eastern white pine.

Images of Pine Bark Adelgid

Figure 1. An infestation of pine bark adelgid, *Pineus strobi*, on the trunk of eastern white pine. (Petr Kapitola, State Phytosanitary Administration, Bugwood.org)

Figure 2. Closer view of pine trunk infested with pine bark adelgid. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Pine Bark Adelgid (continued)

Figure 3. Pine bark adelgids infesting pine branch. (Petr Kapitola, State Phytosanitary Administration, Bugwood.org)

Figure 4.Excess bud formation from pine bark adelgid feeding can cause shoot proliferation in tree top. Note also the lady beetle feeding on the adelgids. (Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 5. *Laricobius rubidus* (Coleop.: Derodontidae) is an important predator of pine bark adelgid in the eastern United States. (Jim McClarin, BugGuide.net)

Important Biological Control Agents Related to this Pest Species

Because damage from this species is generally not important in North America, natural enemies of this species have not been well studied. However, some predators of this adelgid, have been noted in the eastern United States, including the derodontid beetle *Laricobius rubidus* LeConte and chamaemyiid fly *Leucopis pinicola* Mall.

Web Links for Information on Pine Bark Adelgid

http://pubs.ext.vt.edu/2907/2907-1402/2907-1402.pdf; Virginia Tech extension leaflet updated by Scott Salom.

Articles

Sluss, T.P. and B.A. Foote. 1973. Biology and immature stages of *Leucopis pinicola* and *Chamaemyia polystigma* (Diptera: Chamaemyiidae). *The Canadian Entomologist* 105: 1443-1452.

20. Pine Leaf Adelgid, *Pineus pinifoliae* (Fitch) (Hemiptera Adelgidae)

Orientation to Pest

Pine leaf adelgid, *Pineus pinifoliae* (Fitch), is native to North America and feeds alternatively on spruce (*Picea*) and pine (*Pinus*). On spruce, galls are produced. On pine, nymphs feeds openly on terminal foliage. In the eastern United States, red (*Picea rubens* Sargent) and black (*P. mariana* [Miller] Britton, Sterns and Poggenburg) spruce are the initial hosts, with adults produced there, migrating to white pine (*Pinus strobus* L.). In the western United States, the initial hosts are Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), black spruce, blue spruce (*P. pungens* Engelm.), and white spruce (*P. glauca* [Moench] Voss), and the pine host is western white pine (*Pinus monticola* Douglas ex D. Don). Two years are required to complete this cycle among tree hosts. Pine leaf adelgid can be an important pest in white pine plantations on young trees. Heavy infestations can reduce growth of pine or even kill trees. Galls on spruce do not damage the health of the tree.

Hosts Commonly Attacked

This species feeds on red (*Picea rubens*), black (*P. mariana*), Engelmann (*P. engelmannii*), blue (*P. pungens*), and white (*P. glauca*) spruce as primary hosts and eastern white (*Pinus strobus*) and western white (*P. monticola*) pines as alternate hosts.

Distribution

This adelgid is found widely in North America wherever the ranges of its primary and alternative hosts overlap.

Images of Pine Leaf Adelgid

Figure 1. Close view of pine leaf adelgid, *Pineus pinifoliae*, on a spruce host. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Pine Leaf Adelgid (continued)

Figure 2. Fresh gall of pine leaf adelgid on a spruce host. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 3. Old gall of pine leaf adelgid on a spruce host, after adelgid emergence. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 4. Adults of pine leaf adelgid on a pine host. (E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Images of Pine Leaf Adelgid (continued)

Figure 5. Flagging tip on pine, a symptom of feeding of pine leaf adelgid. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on the natural enemies of this adelgid. They are likely to be similar to those recorded for other *Pineus* and *Adelges* species in North America.

Web Links for Information on Pine Leaf Adelgid

http://www.forestpests.org/vermont/pineleafadelgid.html; fact sheet of the state of Vermont of biology and control.

http://www.maine.gov/doc/mfs/pineleaf.htm; fact sheet of the state of Maine on biology and control.

Articles

Dimond, J.B. 1974. Sequential surveys for the pine leaf chermid, *Pineus pinifoliae*. Technical Bulletin No. 68, Life Sciences and Agriculture Experiment Station, University of Maine; Orono, Maine, USA: 15 p.

21. White Pine Aphid, *Cinara strobi* (Fitch) (Hemiptera: Aphidae)

Orientation to Pest

White pine aphid, *Cinara strobi* (Fitch), is a native insect in North America that feeds on white pine (*Pinus strobus* L.). It is easily recognized by its large size (3-4 mm), slightly dull metallic grey color with a white stripe on middle of the thorax and spots of white wax on each side of the abdomen. Eggs are laid in the fall, end-to-end along the needle and hatch in the spring. White pine aphid feeds on branches and upper trunks. Because it forms large colonies and is large, it produces copious amounts of honeydew. It is usually attended by ants. Other than the honeydew being a nuisance and fostering sooty mold, direct damage to the tree itself is rare; but occasionally dense aphid populations damage young pines or individual branches of large trees.

Hosts Commonly Attacked

This aphid is only found on white pine (*P. strobus*).

Distribution

White pine aphid is found in the United States from New England to the Great Lakes states, south to the Carolinas in association with eastern white pine.

Images of White Pine Aphid

Figure 1. Close view of white pine aphid, *Cinara strobi*. (Jim Baker, North Carolina State University, Bugwood.org)

Images of White Pine Aphid (continued)

Figure 2. Colony of white pine aphid. (William H. Hoffard, USDA Forest Service, Bugwood.org)

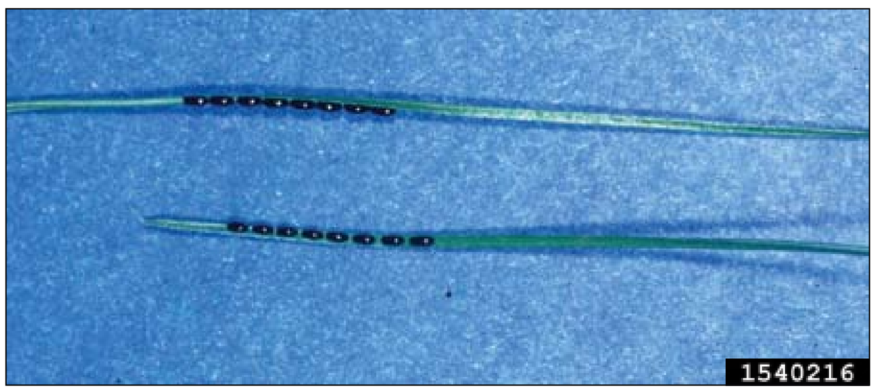

Figure 3. Eggs of white pine aphid on pine needle. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The braconids *Pauesia bicolor* (Ashmead) and *Pausia xanthothera* (Smith) are known as parasitoids of this and other aphids in the genus *Cinara*.

Web Links for Information on White Pine Aphid

http://wiki.bugwood.org/Cinara_strobi

Articles

None

22. Woolly Elm Aphid, *Eriosoma americanum* (Riley) (Hemiptera: Aphididae; Eriosomatinae)

Orientation to Pest

Woolly elm aphid, *Eriosoma americanum* (Riley), is a native insect in North America whose primary hosts are American elm (*Ulmus americana* L.) and secondary, summer hosts are serviceberry (called saskatoon in Canada) and other species of *Amelanchier* spp. This aphid flies to elm in the fall where it mates and lays overwintering eggs. These hatch in the spring and nymphs feed on the edges of young elm leaves, causing them to roll inward and form a gall over the colony. In early summer, winged-forms migrate to *Almelanchier* species where they form colonies on the roots. Two other species of *Eriosoma* may also be found on elm, *E. lanigerum* (Hausmann) that causing terminal shoots to form rosettes and *E. rileri* Thomas, which forms woolly clusters on limbs and trunks. This aphid is a minor pest on *Amelanchier alnifolia* (Nutt.), which is a fruit crop in Manitoba, Canada.

Hosts Commonly Attacked

American elm (*U. americana*) is the primary host, and species of serviceberry (*Amelanchier*) are the alternative hosts.

Distribution

Woolly elm aphid is widely distributed throughout the eastern United States and Canada in the range of elm and serviceberry species.

Images of Woolly Elm Aphid

Figure 1. Winged adult of woolly elm aphid, *Eriosoma americanum*. (Government of Alberta, Agriculture and Rural Development, agriculture.alberta.ca)

Figure 2. Elm leaf galled by woolly elm aphid. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Woolly Elm Aphid (continued)

Figure 3. Stem of serviceberry infested by woolly elm aphid. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Given this aphid's native status and limited damage, little is known about its natural enemies. In North America, some predators have been observed feeding on it, including the mirid *Saileria irrorata* Henry and the coccinellid *Scymnus brulleri* Mulsant.

Web Links for Information on Woolly Elm Aphid

http://www.gov.mb.ca/agriculture/crops/insects/fad92s00.html; gives details of biology and effect on saskatoon (*A. alnifolia*),which is grown for its fruit in Manitoba, Canada.

http://wiki.bugwood.org/Eriosoma_americanum; entry in Bugwood Wiki.

Articles

Miranpuri, G.S. and G.G. Khachatourians. 1996. Bionomics and fungal control of woolly elm aphid, *Eriosoma americanum* (Riley) (Eriosomatidae: Homoptera) on Saskatoon berry, *Amelanchier alinifolia*. *Journal of Insect Science* 9: 33-37.

Fry, K.M. 2001. *Eriosoma americanum* (Riley), woolly elm aphid (Homoptera: Pemphigidae). Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000*. CABI Publishing, Wallingford, UK: 120-123.

23. Woolly Beech Aphid, *Phyllaphis fagi* (L.) (Hemiptera: Aphidae)

Orientation to Pest

Woolly beech aphid, *Phyllaphis fagi* (L.), is an invasive aphid in North America, likely of European origin. It feeds on all species of beech, but high densities are usually only found on European beech (*Fagus sylvatica* L.), which is widely used in landscape plantings. The aphid is usually not a problem in the United States on the American beech, *F. grandifolia* Ehrh., growing in forests or low stress sites. This woolly aphid, which feeds on the undersides of leaves, can be confused with the beech blight aphid (*Grylloprociphilus imbricator* [Fitch]), which begins feeding on the leaves and then moves onto stems. The woolly beech aphid eggs hatch in the spring and there are about ten generations per year of apterous and winged forms, which occur together. Huge populations can occur year after year without causing visible harm to the tree. The massive amounts of honeydew produced by large colonies can be a nuisance.

Hosts Commonly Attacked

This aphid is found most often on European beech (*F. sylvatica* L.) planted in urban or residential landscapes.

Distribution

This aphid is widely distributed in both eastern and western North America, where ever beech is grown.

Images of Woolly Beech Aphid

Figure 1. Colony of woolly beech aphid, *Phyllaphis fagi*, on undersurface of leaves of European beech. (Haruta Ovidiu, University of Oradea, Bugwood.org)

Images of Woolly Beech Aphid (continued)

Figure 2. Close up of woolly beech aphid showing nymphs and older stages with wool. (Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org)

Figure 3. Leaf rolling on European beech, a symptom of damage by woolly beech aphid. (Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The braconid parasitoids *Praon flavinode* (Haliday) and *Trioxys phyllaphidis* Mackauer are known to attack this species in Europe, but are not reported from North America.

Web Links for Information on Woolly Beech Aphid

http://www.plante-doktor.dk/boegebladluseng.htm; Danish fact sheet on control of this species.

Articles

Iversen, T. and S. Harding. 2007. Biological and other alternative control methods against the woolly beech aphid, *Phyllaphis fagi* L., on beech, *Fagus sylvatica*, seedlings in forest nurseries. *Journal of Pest Science* 80: 159-166.

24. Tuliptree Aphid, *Illinoia liriodendri* (Monell) (Hemiptera: Aphididae)

Orientation to Pest

Tuliptree aphid, *Illinoia liriodendri* (Monell), is a relatively large aphid (1.7-2.0 mm), spindle-shaped, pale green and lightly dusted with wax, that is native to the eastern United States. It occurs east of the Mississippi River, except northern New England, wherever its hosts, the tuliptree (*Liriodendron tulipifera* L.) and some species of magnolia (*Magnolia*), are endemic. It is also invasive in many areas where tuliptrees have been planted as ornamentals outside their native range, including California and other parts of the western USA, Europe (France, Germany, Italy, Slovenia, UK), Japan, and Canada (Ontario, British Columbia). This aphid is of little or no concern in its native range, but in parts of its invaded range, high aphid densities occur that produce unsightly coatings of honeydew and sooty mold.

Hosts Commonly Attacked

This aphid's hosts are the tuliptree (*L. tulipifera* L.) and some species of magnolia (*Magnolia*).

Distribution

Tuliptree aphid is found throughout the eastern USA and in urban areas of California and other western states where tuliptrees have been planted.

Image of Tuliptree Aphid

Figure 1. Adult and nymphs of tuliptree aphid, *Illinoia liriodendra*. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Parasitoids of this aphid in its native range (the eastern United States) include a species of *Praon*, *Ephedrus incompletus* Provancher, *Aphidius polygonaphis* (Fitch), *A. nigripes* Ashmead, and *A. rosae* Haliday. Three parasitoids—a *Praon* species, *E. incompletus*, and *A. polygonaphis*—were imported from the eastern United Statees and released in California, where *A. polgonaphis* established but did not completely control the aphid population.

Web Links for Information on Tuliptree Aphid

http://meta.arsia.toscana.it/meta/meta?id_cms_doc=1&id_news=201; an Italian site covering this species as a pest of ornamentals.

Articles

Zuparko, R.L. and D.L. Dahlsten. 1993. Survey of the parasitoids of the tuliptree aphid, *Illinoia liriodendri* (Hom: Aphididae), in northern California. *Entomophaga* 38: 31-40.

25. Norway Maple Aphid, *Periphyllus lyropictus* (Kessler) (Hemiptera: Aphidae)

Orientation to Pest

Norway maple aphid, *Periphyllus lyropictus* (Kessler), is a European species that is invasive in the United States, where it occurs on Norway maple (*Acer platanoides* L.). This aphid is widespread in eastern North America, wherever Norway maple is planted. Given that Norway maple is now considered an invasive forest pest in many areas, this aphid's damage to the tree might be considered beneficial. Large populations can cause leaves to become brown or wrinkled and cause premature leaf drop. However, the primary concern is usually the large amount of honeydew it can produce, which is a nuisance to sidewalks and cars beneath the trees. Both winged and wingless forms occur and the latter form has a yellow-green body with a "lyre"-shaped brownish marking on the abdomen.

Hosts Commonly Attacked

Its only host in North America is the imported species Norway maple (*A. platanoides*).

Distribution

This aphid is found widely in eastern North America, wherever Norway maple has been planted.

Images of Norway Maple Aphid

Figure 1. Colony of Norway maple aphid, *Periphyllus lyropictus*. (Michael Montgomery, USDA Forest Service, Bugwood.org)

Images of Norway Maple Aphid (continued)

Figure 2. Sooty mold and cast skins of Norway maple aphid. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In its native range in Europe, three species of parasitoids have been recorded that are believed to be specialized on this genus of aphid: *Aphidius setiger* Mackauer, *Trioxys falcatus* Mackauer, and *Praon silvestre* Starý. Of these, only *A. setiger* is known to be present in North America.

Web Links for Information on Norway Maple Aphid

None

Articles

Starý, P. 1972. Host life-cycle and adaptation of parasites of *Periphyllus aphids* (Homoptera, Chaitophoridae; Hymenoptera, Aphidiidae). *Acta Entomologica Bohemoslovaca* 69(2): 89-96.

26. Linden Aphid, *Eucallipterus tiliae* (L.) (Hemiptera: Aphididae)

Orientation to Pest

Linden aphid, *Eucallipterus tiliae* (L.), is invasive in the United States. It is native to Eurasia, but now occurs worldwide, wherever species of native or introduced linden trees (*Tilia*) occur. The winged adults are easily recognized by the black stripe along the body and the cloudy-black at the wing edge. Trees planted along streets and by parking areas are frequently attacked, and the honeydew produced by the aphid makes walkways and cars parked beneath them sticky. Sooty mold growing on honeydew blackens the leaves. Progeny are produced continuously during the growing season. It is attacked by several genera of parasitoids as well as lady beetles and other generalist predators.

Hosts Commonly Attacked

Basswood, also called American linden, (*Tilia americana* L.) and its variety, white basswood (*T. americana* var. *heterophylla*) are North American trees that are fed on by this aphid. However, damage to these plants is rarely serious because they are less susceptible to this aphid than are the introduced species of *Tilia* commonly planted in urban landscapes. Damage to such introduced species is the main focus of concern with this aphid.

Distribution

This aphid is found widely in eastern North America on basswood and on exotic species of *Tilia* in landscape plantings. California, especially, has problems with this aphid on exotic *Tilia* and has introduced parasitoids for its biological control.

Images of Linden Aphid

Figure 1. Winged adult linden aphid, *Eucallipterus tiliae*. (Bob Gaia)

Images of Linden Aphid (continued)

Figure 2. Nymph of linden aphid. (Bob Gaia)

Figure 3. Group of winged adult linden aphids on underside of *Tilia* leaf. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 4. Honeydew and sooty mold on linden, typical signs of linden aphid. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Linden Aphid (continued)

Figure 5. Dark discoloration on cement caused by sooty mold growing on honeydew dripping from linden tree infested by linden aphid. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In California, where this is an invasive aphid on exotic street trees, a species of European parasitoid, *Trioxys curvicaudus* Mackauer, was introduced and anecdotal information suggests this introduction lowered density of aphids on street lindens. In Europe, parasitoids seem not to be the primary regulator of linden aphid numbers, and generalist predators and density-dependent feedback from the tree are believed to be important. This aphid and seven related species occur in northern China and the Russian Far East; hence, this area may be a good source of natural enemies. There are ten parasitoid species in the superfamily Ichneumonoidea and nine in the Chalcidoidea recorded from aphids in the genus *Eucallipterus*.

Web Links for Information on Linden Aphid

None found that provide significant information.

Articles

Dixon, A.F.G. and N.D. Barlow. 1979. Population regulation in the lime aphid. *Zoological Journal of the Linnean Society* 67: 255-237.

Zuparko, R. 1983. Biological control of *Eucallipterus tiliae* [Hom.: Aphididae] in San Jose, California, through establishment of *Trioxys curvicaudus* [Hym.: Aphidiidae]. *Entomophaga* 28: 325-330.

Hajek, A.E. 1986. New North American records of European parasitoids (Hymenoptera) of the linden aphid, *Eucallipterus tiliae* (Aphidoidea: Drepanosiphidae). *Journal of the New York Entomological Society* 94: 443-446.

Blackman, R.L. and V.F. Eastop. 1994. *Aphids on the World's Trees: An Identification and Information Guide*. CAB International, Oxfordshire, United Kingdom.

Zuparko, R.L. and D.L. Dahlsten. 1996. New potential for classical biological control of *Eucallipterus tiliae* (Homoptera: Drepanosiphidae. *Biological Control* 6: 407-408.

Foottit, R.G., S.E. Halbert, G.L. Miller, E. Maw, and L.M. Russell. 2006. Adventive aphids (Hemiptera: Aphididae) of America North of Mexico. *Proceedings of the Entomological Society of Washington* 108(3): 583-610.

27. Spruce Aphid, *Elatobium abietinum* (Walker) (Hemiptera: Aphidae)

Orientation to Pest

Spruce aphid, *Elatobium abietinum* (Walker) (known as "green spruce aphid" in some places), is native to part of Europe, where it feeds on Norway spruce (*Picea abies* [L.] H. Karst). It is seldom a pest on this species in Europe, causing only infrequent, very minor local outbreaks. However, it is a major pest in northwestern Europe in plantations of North American Sitka spruce (*P. sitchensis* [Bong.] Carr. Outside of Europe, spruce aphid is invasive in many areas with maritime climates and also the montane forests of the southwestern United States. In North America, spruce aphid occurs in natural forests on various spruce species, mostly in coastal areas of the Pacific northwestern United States and British Columbia. It also occurs in Arizona, where spruce aphid outbreaks damage Engelmann spruce (*P. engelmannii* Parry ex Engelm.), killing 10 to 24 percent of infested trees, depending on the severity of injury. In maritime areas, spruce aphid is parthenogenic (females only), but in its native range and in Arizona the life cycle includes both parthenogenic and sexual forms.

Hosts Commonly Attacked

Spruce aphid feeds on virtually all spruce, including Norway (*P. abies*), Sitka (*P. sitchensis*), Englemann (*P. engelmannii*), and Colorado blue spruce (*P. pungens* Englmann).

Distribution

In addition, to its native range in Europe, this aphid has invaded parts of Russia, Australia, New Zealand, Chile, and North America. It is found in British Columbia, Ontario, Quebec, California, North Carolina, Oregon, Arizona, Utah, and Washington.

Images of Spruce Aphid

Figure 1. Spruce aphid, *Elatobium abietinum*. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Images of Spruce Aphid (continued)

Figure 2. Damage to Sitka spruce from spruce aphid. (Elizabeth Willhite, USDA Forest Service, Bugwood.org)

Figure 3. Stand of Sitka spruce in Alaska showing damage of spruce aphid (areas in brown). (Andris Eglitis, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Generalist predators of this species have been noted, but parasitoids have not been studied. Pathenogenic fungi, especially species of Entomophthorales, are important natural enemies of spruce aphid.

Web Links for Information on Spruce Aphid

http://www.fs.fed.us/r3/resources/health/field-guide/sap/spruce.shtml

http://apps.rhs.org.uk/advicesearch/Profile.aspx?pid=520; a control factsheet from the UK Royal Horticultural Society.

http://www.oregon.gov/ODF/privateforests/docs/fh/SpruceAphid.pdf?ga=t

www.science.ulster.ac.uk/lnsrg/elatobium_abietinum.html; University of Ulster, Northern Ireland. Includes photos of some natural enemies of spruce aphid.

Articles on Spruce Aphid

Straw, N.A., J.E.L. Timms, and S.R. Leather. 2009. Variation in the abundance of invertebrate predators of the green spruce aphid *Elatobium abietinum* (Walker) (Homoptera: Aphididae) along an altitudinal transect *Elatobium abietinum*. *Forest Ecology and Management* 258: 1-10.

Lynch, A.M. 2004. Fate and characteristics of *Picea* damaged by *Elatobium abietinum* (Walker) (Homoptera: Aphididae) in the White Mountains of Arizona. *Western North American Naturalist* 64: 7-17.

28. Beech Scale, *Cryptococcus fagisuga* Lindinger (Hemiptera: Eriococcidae)

Orientation to Pest

Beech scale, *Cryptococcus fagisuga* Lindinger, is invasive in the United States and very likely also invasive in Europe. Its native range is believed, based on studies of mitochondrial DNA, to be in western Asia (Turkey and the Caucasus Mountains) or southeastern Europe, where its host is oriental beech (*Fagus orientalis* Lipsky). It is a moderately damaging pest in Europe on European beech (*F. sylvatica* L.) and a devastating pest in North America of American beech (*F. grandifolia* Ehrh.). The insect infests the trunk of beech, inducing cracking which allows invasion by fungal pathogens (genus *Neonectria*), which kill the trunk. Roots survive and trees regenerate, but the disease cycle is too frequent to permit most trees to reach large size. Trunks are deformed by cracking and the development of cankers. Visible signs are the white woolly coverings of scales and the red fruiting bodies of the *Neonectria* fungus. About 1 percent of American beech are naturally immune from attack and remain healthy. Following the accidental introduction of the scale to the Halifax Arboretum in the late 1800s, an epidemic of beech bark disease has spread south and west, and now covers a substantial part of the range of American beech. This insect is apparently completely parthenogenetic; no males have ever been found.

Hosts Commonly Attacked

Oriental beech (*F. orientalis*) is believed to be the native host. European beech (*F. sylvatica*) and American beech (*F. grandifolia*) are hosts acquired in invaded areas.

Distribution

In North America, beech scale occurs from Nova Scotia to central Pennsylvania, with infested pockets in West Virginia, North Carolina, and Michigan, but continues to spread. In Eurasia, the scale is found from the United Kingdom to Iran. It is found throughout Europe; however, this area is no longer believed to be the native range. Of areas studied so far, mitochondrial haplotype diversity is greatest in the Caucasus Mountains and that area may be part of the original range of this insect. Surveys are underway in the Caucasus Mountains of Georgia for parasitoids of this scale.

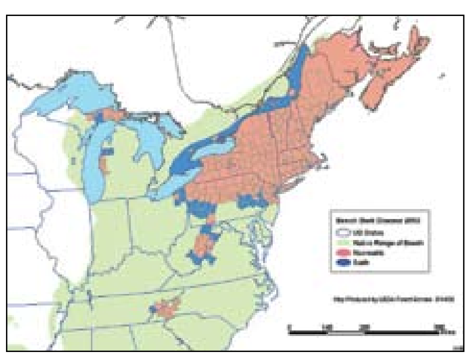

Figure 1. Distribution of beech scale, *Cryptococcus fagisuga*, and its associated invasive pathogen in North America in 2005, following its introduction in about 1890 in Halifax, Nova Scotia. (USDA Forest Service, Northeastern Area, Forest Health Protection: Beech Bark Disease)

Images of Beech Scale

Figure 2. Close up of beech scales under their woolly coverings (left) and with wool removed, showing orange scale bodies (right). (Both photos: Chris Malumphy, The Food and Environment Research Agency, Bugwood.org)

Figure 3. First instar nymph (crawler) of beech scale. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Figure 4. View of trunk of American beech infested with beech scale (light colored material). (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of Beech Scale (continued)

Figure 5. Beech scale on bark of severely damaged American beech (left) (note also lumpy cankers on trunk caused by beech bark disease); close up of colonies of beech scale (right). (Left: Joseph O'Brien, USDA Forest Service, Bugwood.org; right: Chris Malumphy, The Food and Environment Research Agency, Bugwood.org)

Figure 6. Beech trees in forest killed by beech bark disease. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Figure 7. Cracked bark of tree with beech bark disease (left) compared to smooth grey bark of healthy American beech (right). (Both photos: Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of Beech Scale (continued)

Figure 8. Bark cracking and growth of epiphytes (here, moss) on trunk are other signs of beech bark disease. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 9. Dark weeping spots are also a sign of beech bark disease. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Figure 10. Discoloration under bark due to *Neonectria* cankers. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of Beech Scale (continued)

Figure 11. Orange fruiting bodies of *Neonectria* on beech bark. (Andrej Kunca, National Forest Centre - Slovakia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No parasitoids of this scale are known from either North America or Europe. Studies in both regions found only generalist predators attacking the scale. Currently efforts to find parasitoids are underway in the Caucasus Mountains, the region now believed to be at least part of the native range of the scale.

Web Links for Information on Beech Scale

http://www.ecostudies.org/people_sci_lovett_beech_bark_disease.html; ecosystem effects of beech bark disease.

http://nrs.fs.fed.us/disturbance/invasive_species/bbd_resistant_beech/; research on resistance in American beech to beech bark disease.

http://threatsummary.forestthreats.org/threats/threatSummaryViewer.cfm?threatID=117

http://en.wikipedia.org/wiki/Beech_bark_disease

http://www.sel.barc.usda.gov/catalogs/eriococc/Cryptococcusfagisuga.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles on Beech Scale

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A Review and Recommendations.* FHTET-96-19. USDA Forest Service, Morgantown, West Viriginia, USA: 20-22.

Forrester, J.A., G.G. McGee, and M.J. Mitchell. 2003. Effects of beech bark disease on aboveground biomass and species composition in a mature northern hardwood forest, 1985 to 2000. *Journal of the Torrey Botanical Society* 130(2): 70-78.

Gwiazdowski, R.A., R.G. Van Driesche, A. Desnoyers, S. Lyon, San-an Wu, N. Kamatad and B.B. Normark. 2006. Possible geographic origin of beech scale, *Cryptococcus fagisuga* (Hemiptera: Eriococcidae), an invasive pest in North America. *Biological Control* 39: 9-18.

29. Gillette's Eriococcin, *Eriokermes gillettei* (Tinseley) (Hemiptera: Kermesidae, formerly Eriococcidae)

Orientation to Pest

Gillette's eriococcin, *Eriokermes gillettei* (Tinseley) (syn. is *Eriococcus gillettei*), is a native North American scale. This species is found on native junipers (*Juniperus*) but is not damaging. Occasionally higher densities develop on junipers planted as ornamentals. Adult females are yellowish before forming an ovisac but then turn brownish purple. In Maryland, there is one generation per year and the scale overwinters in the egg stage.

Hosts Commonly Attacked

This scale is restricted to feeding on species of juniper (*Juniperus*).

Distribution

This scale is known from Florida, Maryland, Virginia, and several western states, but likely has a larger U.S. distribution, including most of the southeastern United States.

Image of Gillette's Eriococcin

Figure 1. Gillette's eriococin, *Eriokermes gillettei*, on juniper. (Raymond Gill, California Department of Food and Agriculture, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Parasitoids of this scale have not been reported but its characteristic low density in natural habitats suggests it may be kept under control by specialized parasitoids.

Web Links for Information on Gillette's Eriococcin

http://www.sel.barc.usda.gov/catalogs/kermesid/Eriokermesgillettei.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information.

Articles

Miller, D.R. and G.L. Miller. 1993. Description of a new genus of scale insect with a discussion of relationships among families related to the Kermesidae (Homoptera: Coccoidea). *Systematic Entomology* 18: 237-251. (This article introduced the current name of the species.)

30. Pine Bast Scale, *Matsucoccus matsumurae* (Kuwana) (Hemiptera: Matsucoccidae)

Orientation to Pest

Pine bast scale, *Matsucoccus matsumurae* (Kuwana), (formerly referred to as red pine scale, *Matsucoccus resinosae*, in the United States) is a Japanese scale that is invasive in the United States. Along with six Asian species of pines, it attacks red pine (*Pinus resinosa* Sol. ex Aiton), its only native North American host. It occurs in plantations of red pine planted south of their native range in Connecticut, New York, New Jersey, and Pennsylvania. The infested area is expanding slowly.

Hosts Commonly Attacked

Pine bast scale attacks several Asian pines, but its only North American native host is red pine (*P. resinosa*).

Distribution

This scale is native to Japan and is invasive in China, South Korea, Sweden, and eastern North America.

Image of Pine Bast Scale

Figure 1. Pine bast scale, *Matsucoccus matsumurae*. (USDA APHIS PPQ CPHST)

Important Biological Control Agents Related to this Pest Species

Natural enemies associated with pine bast scale in North America are principally generalist predators (coccinellids, anthocorid bugs, and cecidomyiid flies). In China, predation on eggs and young nymphs by the anthocorid *Elatophilus nipponensis* Hiura is a critical factor affecting the pest. Also in both China and Japan, the generalist predatory coccinellid *Harmonia axyridis* Pallas is believed to suppress this scale's density. This coccinellid in now found as an invasive species throughout the range of red pine scale in the northeast United States but definitive studies on its impact on this scale are lacking.

Web Links for Information on Pine Bast Scale

http://www.sel.barc.usda.gov/catalogs/matsucoc/Matsucoccusmatsumurae.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Cheng, H.Y. and W.J. Ming. 1979. Population dynamics and biological control of *Matsucoccus matsumurae* Kuwana (Homoptera: Margarodidae). *Acta Entomologica Sinica* 22: 149-155.

McClure, M.S. 1986. Role of predators in regulation of endemic populations of *Matsucoccus matsumurae* (Homoptera: Margarodidae) in Japan. *Environmental Entomology* 15: 976-983.

Ming, W.J., Q.J. Ge, and H.Y. Zheng. 1983. Studies of some major predaceous natural enemies of *Matsucoccus matsumurae* (Kuwana). *Journal of Nanjing Technological College of Forest Products* 3: 19-29.

31. Tuliptree Scale, *Toumeyella liriodendri* (Gmelin) (Hemiptera: Coccidae)

Orientation to Pest

Tuliptree scale, *Toumeyella liriodendri* (Gmelin), is native to the eastern United States, where it is widely distributed. It also occurs in urban areas in California, where it is invasive. It mainly feeds on twigs of tuliptree (*Liriodendron tulipifera* L.) and magnolia (*Magnolia*). Heavy infestations are common and these can (1) kill seedlings, (2) destroy leaders or branches leading to bushy form, and (3) remove nutrients and lower tree vigor. The scale has one generation per year except in the southern part of its range and it generally overwinters as young nymphs on twigs.

Hosts Commonly Attacked

This scale feeds on tuliptree (*L. tulipifera*) and species of magnolia (*Magnolia*), as well as hosts in eight other plant families.

Distribution

This scale is found from New York south to Florida and west to the Mississippi River (see Burns and Donley [1970] for a distribution map), and has invaded urban areas of California.

Images of Tuliptree Scale

Figure 1. Group of mature female tuliptree scales, *Toumeyella liriodendri*, on twig of host. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Images of Tuliptree Scale (continued)

Figure 2. Mature female of tuliptree scale surrounded by crawlers. (Gerald J. Lenhard, Louiana State Univ, Bugwood.org)

Figure 3. Overwintering second instar nymphs of tuliptree scale on twig. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Empty cast skins of male "pupae" of tuliptree scale. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many species of parasitoids and predators are reported attacking tuliptree scale in the United States, but at the same time, the scale is reported as frequently being abundant and damaging. Its ability to thrive in spite of its many enemies may be because it is very frequently tended by ants.

Web Links for Information on Tuliptree Scale

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-92.pdf; USDA Forest Service leaflet #92 with photos of damage to tree form.

http://ento.psu.edu/extension/factsheets/tuliptree-scale; fact sheet from Pennsylvania State University; discusses control.

http://www.ca.uky.edu/entomology/entfacts/ef435.asp; fact sheet from University of Kentucky; discusses control.

http://cfextension.ifas.ufl.edu/agriculture/nursery_production/documents/Magnolia.pdf; University of Florida; discusses control on magnolia.

http://www.sel.barc.usda.gov/catalogs/coccidae/Toumeyellaliriodendri.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Burns, D.P. and D.E. Donley. 1970. Biology of the tuliptree scale, *Toumeyella liriodendri* (Homoptera: Coccidae). *Annals of the Entomological Society of America* 63: 228-235.

Simpson, J.D. and P.L. Lambdin. 1983. Life history of the tuliptree scale, *Toumeyella liriodendri* (Gmelin), on yellow-poplar in Tennessee. *Tennessee Farm and Home Science* 125: 2-5.

32. Pine Tortoise Scale, *Toumeyella parvicornis* (Cockerell) (Hemiptera: Coccidae)

Orientation to Pest

The pine tortoise scale, *Toumeyella parvicornis* (Cockerell), is native to the United States and is found widely over the northeastern, north central, and southeastern portions of the country. It is also invasive in Puerto Rico and the Turks and Caicos Islands in the Caribbean. It has one generation per year in the northern parts of its range, and four or more generations in the southern portions. The first instars (crawlers) are the mobile dispersal stage. Crawlers eventually settle either on the shoot or on the needles. The choice of settling site may be host-specific. Settled females on shoots are brown with dark markings and have the hemispherical tortoise shape for which they are named. Females developing on the needles are elongate and initially are light green with darker green stripes, eventually turning brownish. The males develop on the same plant part as the females. Adult males are winged and smaller than the females. The scales excrete honeydew, which provides a growth medium for sooty mold. Heavy infestations may result in tree mortality.

Hosts Commonly Attacked

Most pines within its range can be infested by this scale but important hosts include Scotch (*Pinus sylvestris*), Jack (*P. banksiana*), Virginia (*P. virginiana*), loblolly (*P. taeda*), and slash (*P. elliottii*) pines.

Distribution

This scale is found from eastern New York, south to Florida and west through the Dakotas, Colorado, and Texas wherever its hosts are found. It is also known to occur in Manitoba and Ontario, Canada, and has been introduced into parts of the Caribbean.

Images of Pine Tortoise Scale

Figure 1. Pine tortoise scales, *Toumeyella parvicornis*; note the tortoise shell shape and color pattern. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Pine Tortoise Scale (continued)

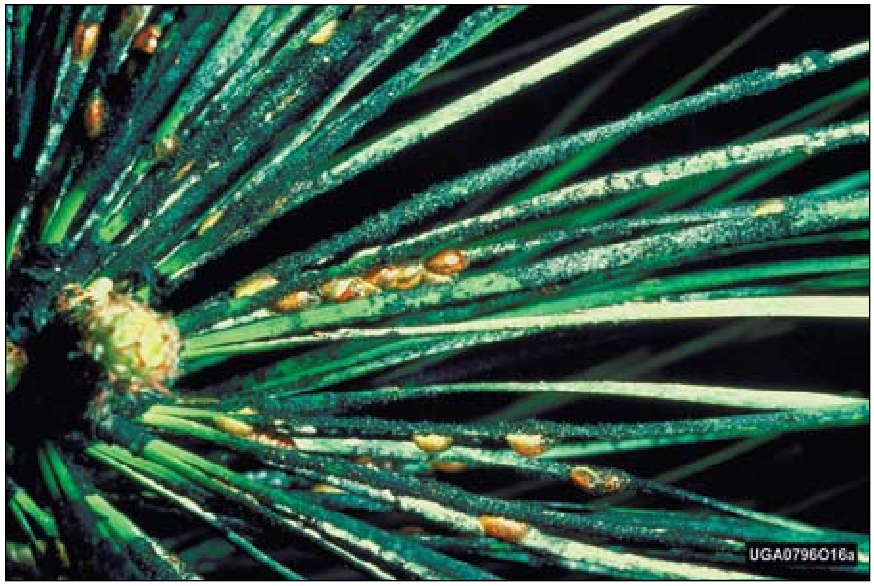

Figure 2. Sooty mold growing on honeydew excreted by pine tortoise scales on pine needles. (R. Scott Cameron, Advanced Forest Protection, Inc., Bugwood.org)

Figure 3. Adult (shoot form) of the female pine tortoise scale with emerging crawlers (left) and the needle form female with settled crawlers (right). (Left: Jill O'Donnell, MSU Extension, Bugwood.org; right: Albert (Bud) Mayfield, USDA Forest Service, Bugwood.org)

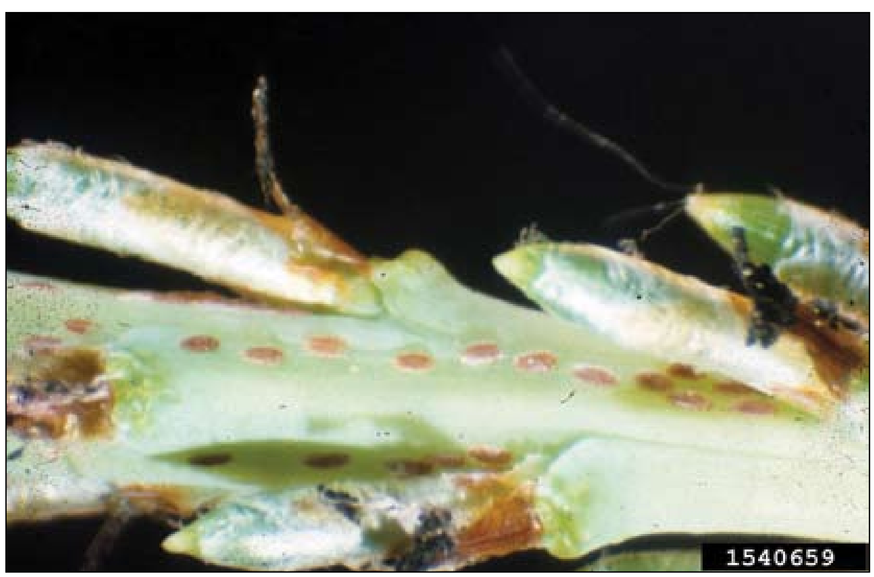

Figure 4. Settled crawlers of pine tortoise scale. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Pine Tortoise Scale (continued)

Figure 5. Young nymphs of pine tortoise scale. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 6. Damage to Virginia pine from pine tortoise scale. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 7. Ladybird beetles feeding on pine tortoise scales. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many species of parasitoids and predators are reported attacking pine tortoise scale in the United States, and in most settings, natural enemies are sufficient to maintain the scale at low densities. Damaging scale populations develop either when ants tend scale colonies (see Wilkinson and Chellman, 1979) or where dust or insecticides reduce natural enemy numbers in seed orchards or Christmas tree farms (see Clarke et al., 1992).

Web Links for Information on Pine Tortoise Scale

http://www.na.fs.fed.us/spfo/pubs/fidls/pine_tort_scale/pine_tort_scale.htm; USDA FS leaflet, with information on biology, life cycle and control of this scale.

http://www.plantpath.cornell.edu/trees/PTortSc.html; fact sheet from Cornell University.

http://www.entomology.umn.edu/cues/Web/186PineTortoiseScale.pdf; fact sheet from University of Minnesota.

Articles

Wilkinson, R.C. and C.W. Chellman. 1979. *Toumeyella* scale, red imported fire ant, reduce slash pine growth. *Florida Entomologist* 62: 71-72.

Clarke, S.R., J.F. Negron, and G.L. DeBarr. 1992. Effects of four pyrethroids on scale insect (Homoptera) populations and their natural enemies in loblolly and shortleaf pine seed orchards. *Journal of Economic Entomology* 85: 1246-1252.

33. Tessellated Scale, *Eucalymnatus tessellatus* (Signoret) (Hemiptera: Coccidae)

Orientation to Pest

Tessellated scale, *Eucalymnatus tessellatus* (Signoret), occurs as an invasive species in the southern United States and parts of Africa, Australia, Asia and Europe. It is believed to be native to South America. The adult female is oval or pear-shaped and is reddish to dark brown in color. There are one or two generations per year. All scales are female and give birth directly to crawlers through egg retention.

Hosts Commonly Attacked

Tessellated scale has an extremely broad host range, attacking more than 50 families of plants, including many monocots and dicots used as ornamentals or as fruit trees. Common host plants include palms, figs, and mango (*Mangifera indica* L.).

Distribution

In the United States, this scale is found outdoors in various southern states, particularly Florida. In northern areas, the scale is found in greenhouses.

Image of Tesselated Scale

Figure 1. Closer view of a single adult of tessellated scale, *Eucalymnatus tessellatus*. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The parasitic wasp *Metaphycus stanleyi* Compere is a natural enemy of tessellated scale.

Web Links for Information on Tesselated Scale

http://edis.ifas.ufl.edu/pdffiles/IN/IN82600.pdf; fact sheet of the University of Florida.

http://www.entomology.umn.edu/cues/inter/inmine/Scalet.html; fact sheet from University of Minnesota.

http://www.sel.barc.usda.gov/catalogs/coccidae/Eucalymnatustessellatus.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Article on Tesselated Scale

Ray, C.H. and M.L. Williams. 1981. Redescription and lectotype designation of the tessellated scale, *Eucalymnatus tessellatus* (Signoret) (Homoptera: Coccidae). *Proceedings of the Entomological Society of Washington* 83: 230-244. (Provides descriptions of three immature stages and adult female, a key for the separation of instars, a list of hosts, and information on distribution.).

34. Elongate Hemlock Scale, *Fiorinia externa* Ferris (Hemiptera: Diaspididae)

Orientation to Pest

Elongate hemlock scale, *Fiorinia externa* Ferris, an invasive scale in the USA, is native to Japan and China that is a pest of eastern hemlock (*Tsuga canadensis* [L.] Carrière) in the eastern United States. The scale has long-lived adult females that reproduce slowly over much of the year, leading to a population with highly overlapping life stages. In New England there is one generation per year but there are two in North Carolina. Damage can be serious in the eastern United States on hemlock, with densities one- to three-thousand-fold higher than in Japan, causing chlorosis, needle drop, and tree mortality.

Hosts Commonly Attacked

This scale attacks principally eastern hemlock (*T. canadensis*), but sometimes species of spruce or fir (*Abies*), Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco), or yew (*Taxus*) are infested.

Distribution

Elongate hemlock scale is native to Japan and China but is invasive in North America from New Hampshire to Georgia and west to Michigan, within range of eastern hemlock. This scale is also invasive in Europe (UK, France).

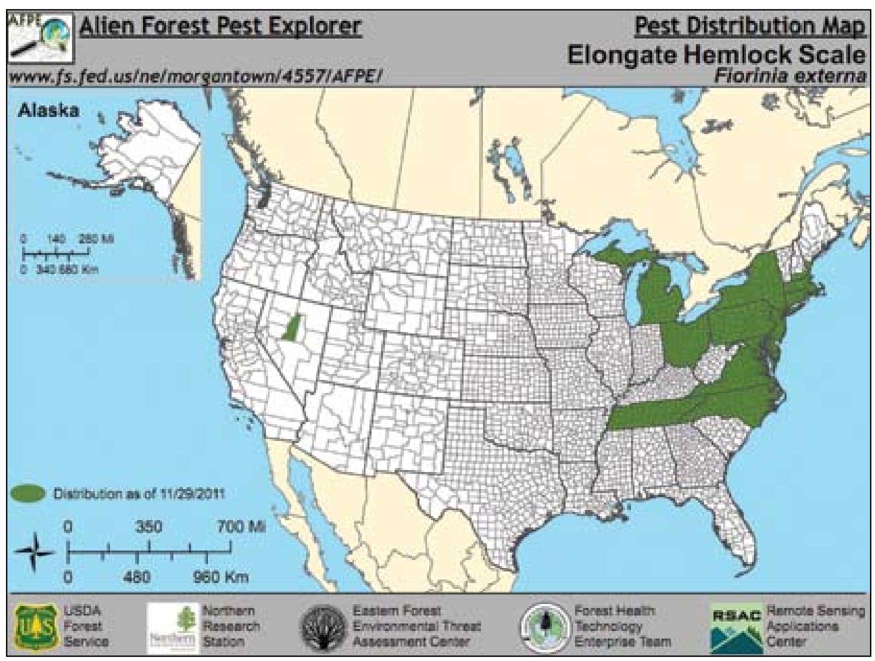

Figure 1. North American distribution of elongate hemlock scale, *Fiorinia externa*. (USDA Forest Service - AFPE Online Mapping)

Images of Elongate Hemlock Scale

Figure 2. Heavy infestation of elongate hemlock scale on eastern hemlock, showing many white males and some brown adult females. (Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 3. Adult female elongate hemlock scales (brown). (Kristopher Abell, University of Massachusetts, Bugwood.org)

Figure 4. Eggs (yellow) of elongate hemlock scale inside opened scale cover of adult female. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Figure 5. Settled first instar nymphs (“crawlers”, see light colored, upper right quarter of photo) of elongate hemlock scale. (Rich Cowles, Connecticut Agricultural Experiment Station)

Images of Elongate Hemlock Scale (continued)

Figure 6. Second instar nymph (mid sized, yellow stages) of elongate hemlock scale; also showing brown adult females and white males. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Figure 7. Adult female elongate hemlock scales (left) with parasitoid emergence holes; adult *Encarsia citrina* (right), an often abundant but generally ineffective polyphagous parasitoid found attacking elongate hemlock scale in both North America and Japan. (Both photos, Kristopher Abell, University of Massachusetts, Bugwood.org)

Figure 8. *Cybolephalus* nr. *nipponicus* Endrody-Younga, an introduced predatory beetle that sometimes preys on elongate hemlock scale. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Studies by Kristopher Abell (Ph.D. dissertation, Entomology, University of Massachusetts, 2010) have shown that *Encarsia citrina* (Crawford), a polyphagous aphelinid parasitoid commonly found attacking elongate hemlock scale in both eastern North America and Japan, is only one of many *Encarsia*, *Aphytis* and other parasitoid species that attack the scale in Japan, which, except for *E. citrina*, are not present in North America. In addition, this same research has confirmed that *E. citrina* and the susceptible life stage of the scale are asynchronous throughout North America, even where two complete generations of the scale occur as Japan. The lack of synchrony was attributed to overlapping generations and delayed senescence of the adult female scale. Importations of species of parasitoids from Japan has potential to reduce densities of elongate hemlock scale in North America.

Web Links for Information on Elongate Hemlock Scale

http://ento.psu.edu/extension/factsheets/elongate-hemlock-scale; fact sheet from Pennsylvania State University.

http://www.na.fs.fed.us/spfo/pubs/pest_al/ehscale/ehscale.htm; fact sheet from USDA Forest Service, Northeastern Area.

http://www.hgic.umd.edu/_media/documents/hg81.pdf; fact sheet from Maryland Cooperative Extension Service.

http://www.fcla.edu/FlaEnt/fe89p527.pdf; article on results of predator survey in North Carolina and Tennessee, USA.

Articles

McClure, M.S. and M.B. Fe. 1977. *Fiorinia externa* and *Tsugaspidiotus tsugae* (Homoptera: Diaspididae): distribution, abundance, and new hosts of two destructive scale insects of eastern hemlock in Connecticut. *Environmental Entomology* 6: 807-811.

Preisser, E.L., J.S. Elkinton, and K. Abell. 2008. Evolution of increased cold tolerance during range expansion of the elongate hemlock scale *Fiorinia externa* Ferris (Hemiptera: Diaspididae). *Ecological Entomology* 33: 709-715.

Abell, K. 2010. Population dynamics and biological control of elongate hemlock scale, *Fiorinia externa*. Ph.D. dissertation, Entomology, University of Massachusetts, Amherst, Massachusetts.

35. Oystershell Scale, *Lepidosaphes ulmi* (L.) (Hemiptera: Diaspididae)

Orientation to Pest

Oystershell scale, *Lepidosaphes ulmi* (L.), is a widespread species of uncertain origin, now found in almost every temperate area in the world. It is known to be invasive in North America, Australia, New Zealand, South Africa, and Japan. It is also found, potentially as a native species, in North Africa and throughout temperate regions of Europe and Asia. It is one of the most polyphagous insects known, reported from 72 different families of plants. Oystershell scale is found mostly on branches and trunks of broadleaf shrubs and trees, in both natural habitats and planted landscapes. The coloration of the adult female varies with the host species. The life history of the species also varies with host, with more generations per year on some hosts and fewer on others. The species overwinters as eggs on all host species. Dense populations may kill branches, whole trees, or even forest stands. This variable cosmopolitan species may in reality be a complex of several biotypes that are being lumped together (see Gharib, 1978). Some populations are parthenogenetic, consisting entirely of females.

Hosts Commonly Attacked

Oystershell scale is a polyphagous species that attacks many broad leaf woody species, including apple (*Malus*), ash (*Fraxinus*), beech (*Fagus*), birch (*Betula*), elm (*Ulmus*), maple (*Acer*), poplar (*Populus*), species of *Prunus*, and willow (*Salix*).

Distribution

This invasive species is found throughout the United States and southern Canada.

Images of Oystershell Scale

Figure 1. Oystershell scale, *Lepidosaphes ulmi*, is named for the shape of the scale covering, resembling an oyster shell. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Images of Oystershell Scale (continued)

Figure 2. View of dense colony of oystershell scales. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Figure 3. Adult oystershell scale inverted to reveal masses of white eggs, the overwintering stage. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 4. One female oystershell scale surrounded by recently settled crawlers. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Oystershell Scale (continued)

Figure 5. Dense population of oystershell scale on aspen in Colorado. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 6. Willows in natural habitat killed by oystershell scale. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Despite a large literature on this species, relatively little is known about its potential for classical biological control because the species is principally of concern in apple orchards, where the perception is that no scales can be tolerated. But in a forestry or shade tree context, that concern should not apply. Two natural enemies are frequently mentioned in connection with this scale, the predatory mite *Hemisarcoptes malus* (Shimer) and the aphelid parasitoid *Aphytis mytilaspidis* (Le Baron). While both of these occur in North America, neither were deliberately introduced. Indeed, little to no work has been done to determine the native range of this scale (likely Central Asia or the Russian Far East) and then determine which species of natural enemies in that area are most effective against low density scale populations. Also, this species of scale may in reality be a complex of species or races and this should be sorted out with DNA methods to show which races are of concern in North America and where are they found in the native range. Finally, even some natural enemies like *A. mytilaspidis*, which is present in the United State, might be improved by a new introduction of the species that is better adapted to cold areas, where the existing race does not do well but where much of the damage from oystershell scale occurs.

Web Links for Information on Oystershell Scale

http://www.ext.colostate.edu/pubs/insect/05513.html; fact sheet from Colorado State University.

http://ento.psu.edu/extension/factsheets/oystershell-scale; fact sheet from Pennsylvania State University.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Lepidosaphesulmi.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Gharib, B. 1978. On two new distinct biological races of *Lepidosaphes ulmi* L. (Homoptera, Coccoidea, Diaspidinae). *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences, D* 286(18): 1313-1314. (In French).

36. San José Scale, *Diaspidiotus perniciosus* (Comstock) (Hemiptera: Diaspididae)

Orientation to Pest

San José scale, *Diaspidiotus perniciosus* (Comstock), is native to Asia (northern China, Korea, the Russian Far East) and is invasive in North America and in other temperate and subtropical areas throughout the world. It is found throughout the United States and Canada. It is a highly polyphagous species, reported from 43 different families of plants, but is economically most troublesome on members of the rose family. The scale has multiple generations per year in many areas and, if not suppressed by parasitoids, can be very damaging, killing heavily infested trees. It is not a pest in native forests, but is common on ornamental, shade, and fruit trees.

Hosts Commonly Attacked

Common hosts include many rosaceous plants, especially apple (*Malus*), plums and cherries (*Prunus*), peaches (*P. persica* (L.) Batsch), almonds (*P. dulcis* [Mill.] D.A.Webb), pear (*Pyrus*), and *Pyracantha*.

Distribution

This invasive species, while native to northeastern Asia, is found throughout North America, and more generally around the world in temperate and subtropical regions.

Images of San José Scale

Figure 1. Adults (left) of San José scale, *Quadraspidiotus perniciosus*; females (right) with scale cover removed to show scale body. (Left: United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org; right: Washington State University)

Images of San José Scale (continued)

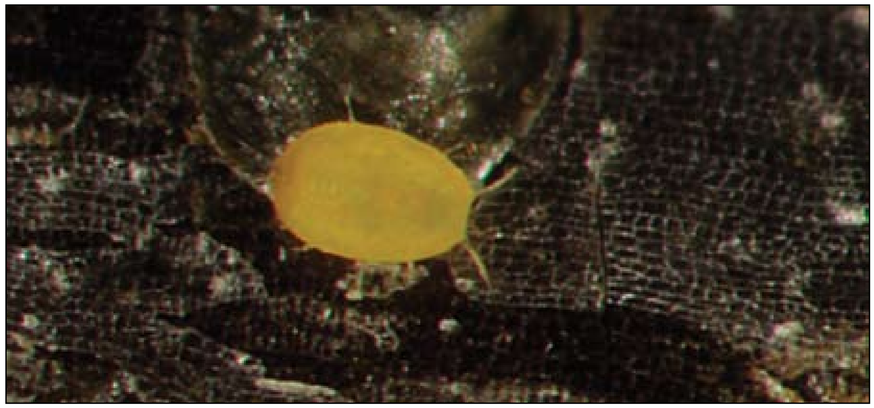

Figure 2. Crawler of San José scale. (Washington State University)

Figure 3. Nymphs of San José scale settled around two adult females. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

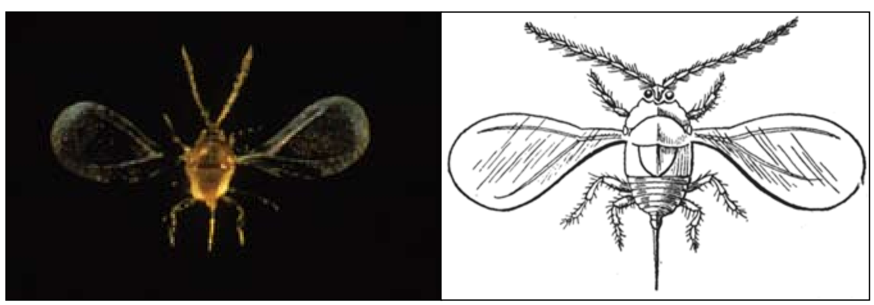

Figure 4. Adult male of San José scale (left); drawing of male (right). (Left: Washington State University; right: FCIT - http://etc.usf.edu/clipart)

Images of San José Scale (continued)

Figure 5. View of twig infested by San José scale. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Figure 6. Damage on apples from San José scale. Note both scales and red discoloration around scales. (Central Science Laboratory, Harpenden Archive, British Crown, Bugwood.org)

Figure 7. *Encarsia perniciosi*, an important parasitoid of San José scale. (HYPPZ)

Images of San José Scale (continued)

Figure 8. Twice stabbed ladybird, *Chilocorus orbus* Drea, a predator of San José scale. (Jack Kelly Clark, University of California - Statewide IPM Program, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

As San José scale moved around the world into various apple growing regions, it came in contact with local parasitoids, some of which adopted this scale as a new host. Also, several of the Asian parasitoids associated with this scale in its native range moved naturally with the scale to new regions (on apple breeding stock). Worldwide, the list of parasitoids is long and complex (see Van Driesche et al., 1996, pp. 28-31, see under web links for URL). Of these many parasitoids, the most important in North America are two North American species, *Aphytis diaspidis* (Howard) and *A. mytilaspidis* (Le Baron) and two Chinese parasitoids, *Encarsia perniciosi* (Tower) and *Coccophagoides kuwanae* (Silvestri). In much of the United States, this scale is now generally held at acceptable levels by some combination of these parasitoids, unless they are absent naturally or have been suppressed by local use of pesticides.

Web Links for Information on San José Scale

http://www.fs.fed.us/foresthealth/technology/pdfs/FHTET_96_19.pdf; Van Driesche et al. 1996; see pages 28-31.

http://www.virginiafruit.ento.vt.edu/SJS.html; fact sheet from Virginia Tech.

http://www.inra.fr/hyppz/RAVAGEUR/6quaper.htm; good photographs.

http://jenny.tfrec.wsu.edu/opm/displaySpecies.php?pn=490; Washington State University—lengthy, high quality fact sheet; excellent photo gallery on species.

http://www.nysipm.cornell.edu/factsheets/treefruit/pests/sjs/sjs.asp; fact sheet from Cornell University.

http://www.ipm.ucdavis.edu/PMG/r4301911.html; University of California at Davis fact sheet covering life history and use of pesticides for control on fruit.

http://www.canr.msu.edu/vanburen/sanjosefs.html; fact sheet from Michigan State University.

http://www.caf.wvu.edu/kearneysville/pest_month/insectfocusapril98.htm; fact sheet of University of California.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Diaspidiotusperniciosus.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

CAB (Commonwealth Agricultural Bureaux). 1986. International Institute of Entomology, Distribution maps of pests, No. 7. Commonwealth Agricultural Bureaux, United Kingdom. [Map of world distribution of San José scale].

37. Willow Scale, *Diaspidiotus gigas* (Thiem and Gerneck) (Hemiptera: Diaspididae)

Orientation to Pest

Willow scale, *Diaspidiotus gigas* (Thiem and Gerneck), is an invasive scale found in North America. It is also widely distributed across the northern temperate zone in the Old World, from Algeria and western Europe to Siberia and China. It has one generation per year in the northern United States and overwinters as partly grown nymphs or young adults. It feeds on branches of species of willow (*Salix*) and poplar (*Populus*) and is found on both shade trees and in natural vegetation.

Hosts Commonly Attacked

Willow scale feeds on species of willow (*Salix*) and poplar (*Populus*).

Distribution

This scale is found across the United States, with specimens recorded from both western parts of the country (Oregon, Washington, Idaho, Montana, Colorado, Utah, and Wyoming), the midwest (Wisconsin, Ohio) and the northeast (New York, Pennsylvania, Rhode Island). It is also found in eastern Canada (Nova Scotia, New Brunswick, Ontario).

Images of Willow Scale

Figure 1. Mixed stages of willow scale, *Diaspidiotus gigas*, on trunk of an aspen tree. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 2. Close up view of mixed stages of willow scale on aspen. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Willow Scale (continued)

Figure 3. Crawlers of willow scale escaping from female scale. (Bob Hammon, Bugwood.org)

Figure 4. Overwintering stage (2nd instar nymphs) of willow scale on bark. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 5. Two views of damage from willow scale to aspen bark; left view of whole trunk showing “bubbling” or pitting effect on bark (middle of photo) and on right, close up of damage. (Both photos: Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Willow Scale (continued)

Figure 6. Aspen trees in Aspen, Colorado, that are heavily infested with willow scale. (Bob Hammon, Bugwood.org)

Figure 7. *Chilocorus kuwanae*, a predator of willow scale in its native range in China. (Tom Murray, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The aphelinid parasitoids *Pteroptrix longgiclava* (Girault) and *Encarsia gigas* (Tshumakova) attack willow scale in China and are attracted to volatiles from the scale, suggesting these may be specialized species of value in biological control. Other parasitoids known to attack this scale in Europe or other regions include *Aphytis mytilaspidis* (Le Baron), *Pteroptrix dimidiatus* (Westwood), and *Azotus matritensis* Merc. *Aphytis mytilaspidis*, however, is a widely distributed polyphagous species that attacks many diaspidids. Predators known to feed on this scale include *Chilocorus kuwanae* Silvestri (an Asian ladybird already introduced into North America for control of another invasive scale, *Unaspis euonymi* [Comstock]), *Chilocorus bipustulatus* (L.) and *Coccinella bipunctata* (L.). The native North American species *Chilocorus stigma* has been observed feeding on *D. gigas* in Colorado. Other potential willow scale predators known from Europe include the predatory bugs *Loricula pselaphiformis* Curt. and *Loricula elengatula* Baerensprung (Microphysidae) and the anthocorids *Ectemnus nigriceps* E. Wagner and *Temnostethus longirostris* (Horv.).

Web Links for Information on Willow Scale

http://www.fs.fed.us/r1-r4/spf/fhp/publications/bystate/BFO-PR-08-01_woodriver.pdf; photos and description of recent problems on aspen from willow scale in Idaho.

http://wci.colostate.edu/shtml/AspenScale.shtml; Colorado State University factsheet.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Diaspidiotusgigas.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Lelláková-Dusková, F. 1963. The morphology, metamorphosis, and lifecycle of the scale insect *Quadraspidiotus gigas* (Thiem and Gerneck). *Acta Entomologica Musei Nationalis Prague* 5: 611-648.

Nakahara, S. 1982. *A Checklist of the Armored Scales of the Coterminous United States*. Plant Protection and Quarantine Animal and Plant Health Inspection Service, United States Department of Agriculture. 110 p.

Chi, D.F., S.C. Yan, X.H. Zhao, and Z.H. Wen. 2003 The taxis of chalcid parasitoids to their host and analysis of the volatile[s] from fixed first instar nymph[s] of *Quadraspidiotus gigas* (Thiem & Gerneck). *Journal of Northeast Forestry University* 31(2): 20-22.

Chi, D.F., R.O. Rubio, S.C. Yan, D.D. Zhang, and Z.H. Wen. 2002. Foraging behavior of parasitoid chalcid to the essential oil from bark of *Populus pseudo-simonii* × *P. nigra* and *Quadraspidiotus gigas*. *Journal of Forestry Research* 13(4): 255-259.

Ma, L., C.D. Li, J.Q. Liu, Y. Sun, X.L. Wang, Y.J. Ji, W.S. Du, L. Yang, G.L. Su, and B.H. Zhao. 1997. Predatory function of *Chilocorus kawanae* Silvestri on *Quadraspidiotus gigas* (Thiem et Gerneck). *Journal of Northeast Forestry University* 25(2): 64-67.

38. Camphor Scale, *Pseudaonidia duplex* (Cockerell) (Hemiptera: Diaspididae)

Orientation to Pest

Camphor scale (also called camellia scale), *Pseudaonidia duplex* (Cockerell), is an invasive Asian scale found in the southern United States. The scale infests leaves, twigs and fruit of various plants, but especially the camphor tree (*Cinnamomum camphora* [L.] Sieb.). In Asia, it is a pest of tea plantations. In Louisiana, the scale has three generations per year and overwinters primarily as mated adult females.

Hosts Commonly Attacked

This scale feeds on over 200 different host plants in Louisiana alone, including the camphor-tree (*C. camphora*) and some species of citrus (*Citrus*). In Asia it is a pest of tea (*Camellia sinensis* [L.] Kuntze).

Distribution

The United States distribution of this scale reaches from Florida and Georgia, west to Texas.

Images of Camphor Scale

Figure 1. Camphor scale, *Pseudaonidia duplex*, adults; adult and one nymph on fruit (left) and adults and several nymphs on foliage (right). (Both photos: Lyle Buss, University of Florida, Bugwood.org)

Figure 2. Camphor scales on Virginia creeper (*Parthenocissus quinquefolia* [L.] Planch.) leaf. (Lyle Buss, University of Florida, Bugwood.org)

Images of Camphor Scale (continued)

Figure 3. Camphor scales on wax-myrtle (*Myrica* spp.), with scale covers turned over to reveal scale bodies (orange). (Lyle Buss, University of Florida, Bugwood.org)

Figure 4. Camphor scales on wax-myrtle twig. (Lyle Buss, University of Florida, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Taiwan in tea plantations, this scale is attacked by the parasitoid *Neochrysocharis* sp., which can cause 42-61 percent mortality (Shiao, 1978).

Web Links for Information on Camphor Scale

http://www.doacs.state.fl.us/pi/enpp/ento/entcirc/ent028.pdf; a Florida entomology circular that gives a host list.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Pseudaonidiaduplex.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles on Camphor Scale

Shiao, S.N. 1977. Bionomics of the camellia scale, *Pseudaonidia duplex* (Cockerell), in northern parts of Taiwan. I. Life history and mortality factors. *Plant Protection Bulletin, Taiwan* 19(2): 65-77.

Shiao, S.N. 1978. Bionomics of the camellia scale, *Pseudaonidia duplex* (Cockerell) (Homoptera: Diaspididae) in northern parts of Taiwan. II. Natural enemies. *Plant Protection Bulletin, Taiwan* 20(3): 210-223.

39. Coconut Scale, *Aspidiotus destructor* Signoret (Hemiptera: Diaspididae)

Orientation to Pest

Coconut scale, *Aspidiotus destructor* Signoret, has an extremely broad host range, feeding on over 60 different families of plants. As a pest of coconut (*Cocos nucifera* L.), it normally feeds on the undersurfaces of fronds, but when infestations are very dense, even fruits may be infested. Palms may be killed by heavy infestations, but in most cases, predators suppress the scale to less destructive levels.

Hosts Commonly Attacked

Coconut scale is a common pest of coconut (*C. nucifera*) and banana (*Musa*), and also infests avocado (*Persea americana* Miller), bird of paradise (*Strelitzia*), breadfruit (*Artocarpus altilis* [Parkinson] Fosberg), cassava (*Manihot esculenta* Crantz), cotton (*Gossypium*), ginger (*Zingiber officinale* Roscoe), guava (*Psidium*), mango (*Mangifera indica* L.), mock orange (*Philadelphus*), mountain apple (*Syzygium malaccense* [L.] Merr. and L.M. Perry), oil palm (*Elaeis*), papaya (*Carica papaya* L.), pandanus (*Pandanus*), frangiapani (*Plumeria*), rubber trees (*Hevea brasiliensis* Müll. Arg.), sugarcane (*Saccharum*), and tea (*Camellia sinensis* [L.] Kuntze).

Distribution

At a world level, this scale is widely distributed in tropical areas, including Puerto Rico. The mainland United States distribution of this scale includes Florida, Georgia, North Carolina, and Virginia.

Images of Coconut Scale

Figure 1. Several adults of coconut scale, *Aspidiotus destructor*, on a palm frond. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

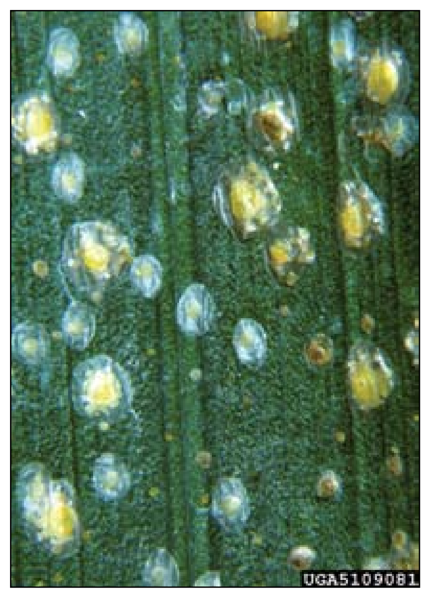

Figure 2. Crawlers of coconut scale interspersed among large adults. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Images of Coconut Scale (continued)

Figure 3. Colonies of various density of coconut scale on palm fronds. (Both photos: United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

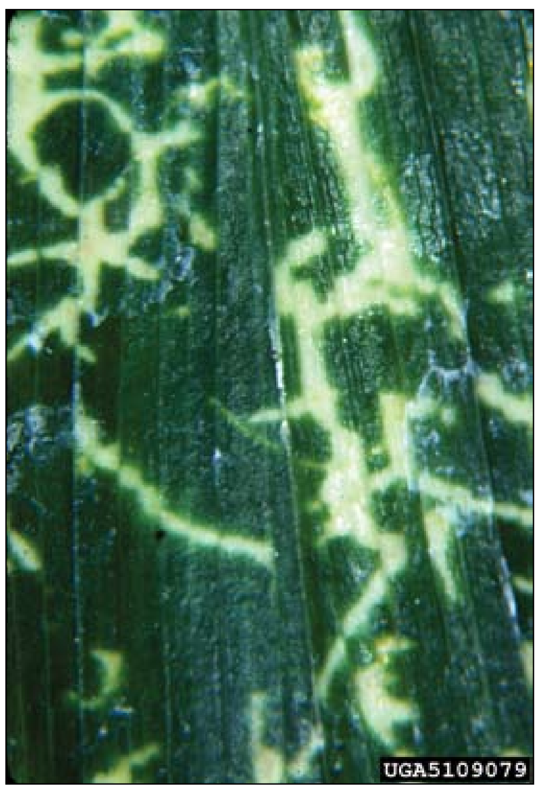

Figure 4. Discolored streaks in palm fronds are a sign of coconut scale damage. (United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org)

Images of Coconut Scale (continued)

Figure 5. Coconuts heavily infested with coconut scale. (Infonet B. Loehr)

Figure 6. *Encarsia citrina* is a polyphagous aphelinid that attacks many diaspidid scales, including coconut scale. (Kristopher Abell, University of Massachusetts, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A great many natural enemies of coconut scale have been reported (see summary in Waterhouse and Norris, 1987). See also discussion in Frank and Foltz (1996) for specific natural enemies present in Florida and Puerto Rico (see articles below for URL). Among the most important of these are the ladybird beetle *Cryptognatha nodiceps* Marshall and the parasitoid *Encarsia citrina* (Crawford).

Web Links for Information on Coconut Scale

http://www.spc.int/pps/pest_of_the_month_-_january_2005.htm; discusses biology and control of coconut scale with reference to islands of the Pacific.

http://www.extento.hawaii.edu/kbase/crop/type/a_destru.htm; fact sheet from the Hawaiian Extension Service.

http://www.ctahr.hawaii.edu/adap/Publications/ADAP_pubs/2000-5.pdf; fact sheet of ADAP (Agricultural Development in American Pacific).

http://www.fs.fed.us/foresthealth/technology/pdfs/FHTET_96_20.PDF; Frank and Foltz (1996); FHTET Bulletin of USDA Forest Service, see page 13.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Aspidiotusdestructor.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect (over 470 references).

Article

Waterhouse, D.F. and K.R. Norris. 1987. *Biological Control: Pacific Prospects*. ACIAR, Inkata Press, Melbourne, Australia: 62-71.

40. Florida Red Scale, *Chrysomphalus aonidum* (L.) (Hemiptera: Diaspididae)

Orientation to Pest

Florida red scale, *Chrysomphalus aonidum* (L.), is an Asian scale invasive in the United States. It is one of the most polyphagous insects known, recorded from 70 families of plants. It is most often reported on agricultural or ornamental plants but occurs in natural vegetation as well. The scale feeds on foliage, producing yellow areas. Heavy infestations may cause foliage to drop.

Hosts Commonly Attacked

Citrus (*Citrus*), holly (*Ilex*), and palms are the more commonly affected groups of plants.

Distribution

The U.S. distribution of this scale is from North Carolina, south and west to Texas, as well as Hawaii. It is common in greenhouses throughout the country. It is also common in most tropical and subtropical parts of the world, including Puerto Rico.

Images of Florida Red Scale

Figure 1. Florida red scale, *Chrysomphalus aonidum*, on dragontree (*Dracaena marginata* Lam.) (left) and on citrus leaf (right). (Left: United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org; right: Pedro Torrent Chocarro, Bugwood.org)

Figure 2. Florida red scale on an orange. (Pedro Torrent Chocarro, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

This scale has been the focus of parasitoid introductions in Texas and Florida. The aphelinid *Aphytis holoxanthus* DeBach from Israel has provided substantial control in both locations.

Web Links for Information on Florida Red Scale

http://www.biosecurity.govt.nz/pests-diseases/plants/florida-red-scale/frs-report.htm; a New Zealand fact sheet.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Chrysomphalusaonidum.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Clancy, D.W., A.G. Selhime, and M.H. Muma. 1963. Establishment of *Aphytis holoxanthus* as a parasite of Florida red scale in Florida. *Journal of Economic Entomology* 56: 603-605.

Steinberg, S., H. Podoler, and D. Rosen. 1986. Biological control of the Florida red scale, *Chrysomphalus aonidum*, in Israel by two parasite species: Current status in the coastal plain. *Phytoparasitica* 14: 199-204.

41. Magnolia White Scale, *Pseudaulacaspis cockerelli* (Cooley) (Hemiptera: Diaspididae)

Orientation to Pest

Magnolia white scale, *Pseudaulacaspis cockerelli* (Cooley) (known formerly as the false oleander scale), is an invasive Asian scale found in the southern United States. It is one of the most polyphagous insects known, reported from 75 different plant families.

Hosts Commonly Attacked

Common host plants include magnolia (*Magnolia*), bird of paradise (*Strelitzia*), oleander (*Nerium oleander* L.), azalea (*Azalea*), plumeria (*Plumeria*), mango (*Mangifera indica* L.), kukui (*Aleurites moluccana* [L.] Willd.), cycads, and palms.

Distribution

This scale is likely native to southern Asia, but is invasive in many parts of the world, including Hawaii and Puerto Rico. In North America, it is invasive in the southern United States (Florida to Maryland, west to Texas and Kansas).

Images of Magnolia White Scale

Figure 1. Adults of magnolia white scale, *Pseudaulacaspis cockerelli*, on areca palm (*Areca* sp.) (left); close up of magnolia white scale adults (right). (Left: United States National Collection of Scale Insects Photographs Archive, USDA Agricultural Research Service, Bugwood.org; right: Gillian W. Watson, California Department of Food & Agriculture)

Images of Magnolia White Scale (continued)

Figure 2. Parasitoid emergence hole in cover of white magnolia scale. (Charles Olsen, USDA APHIS PPQ, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Some specialized parasitoids of this scale are known from its native south Asian range, but none have been used for biological control of this scale in North America.

Web Links for Information on Magnolia White Scale

http://edis.ifas.ufl.edu/pdffiles/IN/IN30600.pdf; fact sheet of the University of Florida.

http://www.extento.hawaii.edu/kbase/crop/Type/p_cocker.htm; fact sheet of the Hawaiian Cooperative Extension Service on biology and control.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Pseudaulacaspiscockerelli.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Rosen, D. and P. DeBach. 1986. Three new species of *Aphytis* (Hymenoptera: Aphelinidae), parasites of *Pseudaulacaspis* spp. (Homoptera: Diaspididae) in India and Australia. *Entomophaga* 31: 139-151.

42. White Peach Scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Hemiptera: Diaspididae)

Orientation to Pest

White peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti), is an invasive scale found in the southeast United States, likely native to Japan or China. It has one of the broadest host ranges reported for any insect, attacking 85 families of plants, including more than 115 genera in Florida alone. The scale has four generations per year in Florida and three in the northern parts of its U.S. range.

Hosts Commonly Attacked

A polyphagous species, white peach scale is common on peach (*Prunus persica* [L.] Batsch), mulberry (*Morus*), persimmon (*Diospyros virginiana* L.), catalpa (*Catalpa*), hibiscus (*Hibiscus*), and privet (*Ligustrum*).

Distribution

In the United States, white peach scale is found from Florida west to Texas and north to Maryland and Tennessee. It also occurs in Puerto Rico and Hawaii.

Images of White Peach Scale

Figure 1. Close up of adults of white peach scale, *Pseudaulacaspis pentagona*. (Left: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org; right: Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 2. Adult female of white peach scale with scale cover removed, showing eggs. (Lyle Buss, University of Florida, Bugwood.org)

Images of White Peach Scale (continued)

Figure 3. Dense bark infestations of white peach scale. (Both photos: Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Two species of *Encarsia* (*E. berlesei* Howard and *E. diaspidicola* Silvestri) are important parasitoids of white peach scale.

Web Links for Information on White Peach Scale

http://entnemdept.ufl.edu/creatures/orn/scales/white_peach_scale.htm; fact sheet of the University of Florida.

http://www.sel.barc.usda.gov/catalogs/diaspidi/Pseudaulacaspispentagona.htm; ScaleNet catalog, giving a complete list of all recorded natural enemies, hosts, and distribution records, and an index to all other information published on this insect.

Articles

Neumann, G., P.A. Follett, R.G. Hollingsworth, and J.H. de León. 2010. High host specificity in *Encarsia diaspidicola* (Hymenoptera: Aphelinidae), a biological control candidate against the white peach scale in Hawaii. *Biological Control* 54: 107-113.

León, J.H. de, G. Neumann, P.A. Follett, and R.G. Hollingsworth. 2010. Molecular markers discriminate closely related species *Encarsia diaspidicola* and *Encarsia berlesei* (Hymenoptera: Aphelinidae): biocontrol candidate agents for white peach scale in Hawaii. *Journal of Economic Entomology* 103: 908-916.

Kreiter, P. and A. Panis. 1998. Inventory of the natural enemies of the white peach scale *Pseudaulacaspis pentagona* (Targioni-Tozzetti, 1886) in the world (Homoptera, Diaspididae). *Bulletin de la Société Entomologique de France* 103: 263-271.

Hanks, L.M. and R.F. Denno. 1993. The white peach scale, *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Hemiptera: Diaspididae): life history in Maryland, host plants, and natural enemies. *Proceedings of the Entomological Society of Washington* 95: 79-88.

43. Citrus Whitefly, *Dialeurodes citri* (Ashmead) (Hemiptera: Aleyrodidae)

Orientation to Pest

Citrus whitefly, *Dialeurodes citri* (Ashmead), is a polyphagous invasive whitefly of Asian origin that was once a major pest of citrus in the United States, as well as infesting a range of other plants. Like all whiteflies, this species has sessile nymphs that are affixed to plant surfaces, where they feed by removing plant sap, debilitating the host. Citrus whitefly secretes honeydew, leading to growth of sooty molds on infested plants.

Hosts Commonly Attacked

Citrus whitefly attacks many species, most of which are themselves introduced crops or ornamentals. These include citrus (*Citrus*), allamanda (*Allamanda*), banana shrub (*Michelia figo* [Lour.] Spreng), cape jasmine (*Gardenia jasminoides* J. Ellis), chinaberry (*Melia azedarach* L.), laurel cherry (*Prunus laurocerasus* L.), crape myrtle (*Lagerstroemia* spp.), *Ficus macrophylla* Desf. ex Pers., gardenia (*Gardenia jasminoides* J. Ellis), myrtle (*Myrtus* spp.), mock olive (*Notelaea*), and pear (*Pyrus*). Among the native North American plants attached are osage orange (*Maclura pomifera* [Raf.] Schneid.), water oak (*Quercus nigra* L.), persimmon (*Diospyros*), and green ash (*Fraxinus pennsylvanica* Marshall).

Distribution

In North America, citrus whitefly is found in the southeastern United States, from Florida west to Texas and north to Virginia, and also in California.

Images of Citrus Whitefly

Figure 1. Adults of citrus whitefly, *Dialeurodes citri*. (Both photos: Lyle Buss, University of Florida, Bugwood.org)

Figure 2. Nymph of citrus whitefly. (Florida Division of Plant Industry Archive, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Images of Citrus Whitefly (continued)

Figure 3. Cast skin (top) of citrus whitefly. (Florida Division of Plant Industry Archive, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 4. Leaf infested with citrus whitefly (white dots dispersed over leaf). (Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Images of Citrus Whitefly (continued)

Figure 5. Sooty mold growing on honeydew produced by citrus whitefly. (INRA: Alain Fraval)

Figure 6. The aphelinid parasitoid *Encarsia lahorensis*, the key natural enemy of citrus whitefly. (Jeffrey W. Lotz, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

This invasive whitefly has come under virtually complete biological control, at least on citrus, due the influence of the introduced parasitoid *Encarsia lahorensis* Howard.

Web Links for Information on Citrus Whitefly

http://entnemdept.ufl.edu/creatures/citrus/citrus_whitefly.htm; a University of Florida fact sheet on biology, hosts, distribution and control of citrus whitefly.

http://edis.ifas.ufl.edu/pdffiles/IN/IN42700.pdf; a fact sheet of the University of Florida, discussing the biology and life history of the parasitoid *Encarsia lahorensis*.

Articles

Bellows, T.S. and C. Meisenbacher. 2007. Field population biology of citrus whitefly, *Dialeurodes citri* (Ashmead) (Heteroptera: Aleyrodidae), on oranges in California. *Population Ecology* 49: 127-134.

44. The Mealybug *Oracella acuta* (Lobdell) (Hemiptera: Pseudococcidae)

Orientation to Pest

The mealybug *Oracella acuta* (Lobdell) is native to the southeastern United States. It has up to five generations per year in the southern part of the range. First generation crawlers are the mobile dispersal stage. Once female crawlers finish dispersing, they either settle on the shoot or occasionally between the needles near the fascicle. Females secrete a characteristic white resin cell that covers their body. The tips of new shoots are the preferred settling site, though the entire shoot may be colonized when populations are high. The resin cells, shoots, and needles may become covered with black, sooty mold growing on honeydew produced by the mealybug. Males develop on the shoot within a covering called a test. First generation males are apterous, with subsequent generation males being alate. Infestations rarely cause tree mortality, but they may severely retard growth. *Oracella acuta* is a secondary pest, usually becoming a problem following insecticide applications targeting other insects.

Hosts Commonly Attacked

Hosts of this mealybug include loblolly (*Pinus taeda* L.), slash (*P. elliottii* Engelm.), Virginia (*P. virginiana* Miller), shortleaf (*P. echinata* Miller), and longleaf (*P. palustris* Miller) pine.

Distribution

In North America, this mealybug occurs from Florida north to Virginia and west to Texas. It is also invasive in China, where it has become a major pest in slash pine plantations.

Images of the Mealybug *Oracella acuta*

Figure 1. A colony of the mealybug *Oracella acuta* on slash pine. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Images of the Mealybug *Oracella acuta* (continued)

Figure 2. Close up of the mealybug *Oracella acuta*, showing an adult female and her eggs. (Steve Clarke, USDA Forest Service, Bugwood.org)

Figure 3. A resin cell, formed by feeding of the mealybug *Oracella acuta*. (Steve Clarke, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Three native parasitoids, *Zarhopalus debarri* Sun, *Acerophagus coccois* E. Smith, and *Allotropa oracellae* Masner, help regulate this mealybug's population size in the southeast United States. All three parasitoids were imported to China and released in heavily infested slash pine plantations, but failed to suppress the pest. One hypothesis about this failure is that it is due to the lack of mealybugs available as hosts in the summer months in China.

Web Links for Information on the Mealybug *Oracella acuta*

None

Articles

Clarke, S.R., G.L. Debar, and C.W. Berisford. 1990. Life history of *Oracella acuta* (Homoptera: Pseudococcidae) in loblolly pine seed orchards in Georgia. *Environmental Entomology* 19: 99-103.

Sun, J.-H., S.R. Clarke, G.L. Debarr, and C.W. Berisford. 2004. Parasitoid complex of the mealybug *Oracella acuta* (Lobdell) (Hemiptera: Pseudococcidae) in Georgia, USA. *Journal Entomological Science* 39(1): 11-22. (Available at http://www.srs.fs.usda.gov/pubs/ja/ja_sun005.pdf).

Clarke, S.R., H.-B. Yu, M.-R. Chen, G.L. Debarr, and J.-H. Sun. 2010. Classical biological control program for the mealybug *Oracella acuta* in Guangdong Province, China. *Insect Science* 17: 129-139. (Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1744-7917.2009.01292.x/pdf).

45. Cottonwood Leaf Beetle, *Chrysomela scripta* Fabricius (Coleoptera: Chrysomelidae)

Orientation to Pest

Cottonwood leaf beetle, *Chrysomela scripta* Fabricius, is a native insect in North America that feeds on various species of poplar (*Populus*), willow (*Salix*), and alder (*Alnus*) and is found throughout the United States. Adults and larvae feed on leaves, and the yellow eggs are laid in clusters on foliage. Young larvae feed in groups and are leaf skeletonizers. Young larvae emit chemical exudates for defense against predators. Older larvae and adults feed individually. Pupation is on the host plant or nearby materials. Adults overwinter under bark, litter or forest debris, and there are several generations per year (3-4 in the midwestern United States and up to 6-8 in the southern United States). Feeding results in reduced growth and multi-forked tops. Damage is of greatest concern in cottonwood or willow plantations.

Hosts Commonly Attacked

Various species of poplar (*Populus*) and occasionally willow (*Salix*) are attacked by this beetle.

Distribution

Cottonwood leaf beetle is found throughout the United States.

Images of Cottonwood Leaf Beetle

Figure 1. Adults (left) of the cottonwood leaf beetle, *Chrysomela scripta*, on leaf, and close up of adult beetle (right). (Left: Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org; right: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 2. An egg mass (yellow) of cottonwood leaf beetle on leaf (left); a close view of an egg mass (right). (Left: James Solomon, USDA Forest Service, Bugwood.org; right: Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Cottonwood Leaf Beetle (continued)

Figure 3. A group of cottonwood leaf beetle larvae feeding on leaf (left); a close view of a single larva (right). (Left: Lacy L. Hyche, Auburn University, Bugwood.org; right: Gerald J. Lenhard, Louisiana State University, Bugwood.org)

Figure 4. Dorsal view of pupa of cottonwood leaf beetle. (Gerald J. Lenhard, Louiana State University, Bugwood.org)

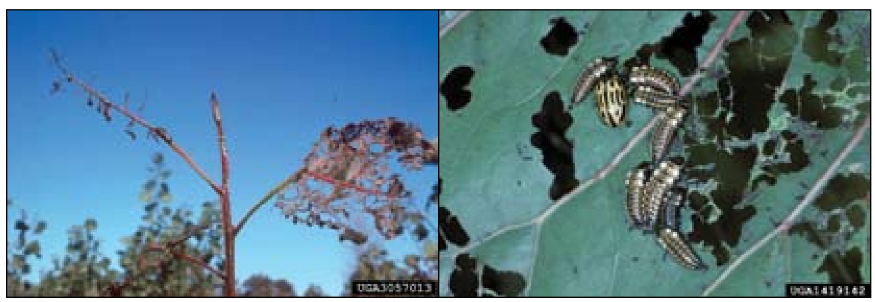

Figure 5. Damage to eastern cottonwood terminal from cottonwood leaf beetle (left); and close up of damage to leaf from group of feeding larvae (right). (Left: James Solomon, U.S. Forest Service, Bugwood.org; right: Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 6. Eggs of cottonwood leaf beetle are preyed on by many generalist predators; here, by the ladybird beetle *Neoharmonia venusta* (Melsheimer). (James Solomon, U.S. Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this beetle include the microsporidian *Nosema scripta* Bauer and Pankratz, the ladybird beetle *Coleomegilla maculata* (De Geer), and the pteromalid parasitoid *Shizonotus latus* (Wlk.).

Web Links for Information on Cottonwood Leaf Beetle

http://wiki.bugwood.org/Archive:South/Chrysomela_scripta; article in Bugwood Wiki.

http://www.ento.okstate.edu/ddd/insects/leafbeetle.htm; a fact sheet of Oklahoma State University compares willow leaf beetle, *Chrysomela knabi* with cottonwood leaf beetle, *Chrysomela scripta*.

http://aces.nmsuledu/pubs/_circulars/circ552.html; provides information on control.

Articles

Bauer, L.S. and H.S. Pankratz. 1993. *Nosema scripta* n. sp. (Microsporida: Nosematidae), a microsporidian parasite of the cottonwood leaf beetle, *Chrysomela scripta* (Coleoptera: Chrysomelidae). *Journal of Eukaryotic Microbiology* 40(2): 135-141.

Andersen, D.C. and S.M. Nelson. 2002. Effects of cottonwood leaf beetle, *Chrysomela scripta* (Coleoptera: Chrysomelidae), on survival and growth of Fremont cottonwood (*Populus fremontii*) in northwest Colorado. *American Midland Naturalist* 147: 189-203.

Tenczar, E.G. and V.A. Krischik. 2006. Management of cottonwood leaf beetle (Coleoptera: Chrysomelidae) with a novel transplant soak and biorational insecticides to conserve coccinellid beetles. *Journal of Economic Entomology* 99: 102-108.

Coyle, D.R., E.R. Hart, J.D. McMillin, L.C. Rule, and R.B. Hall. 2008. Effects of repeated cottonwood leaf beetle defoliation on *Populus* growth and economic value over an 8-year harvest rotation. *Forest Ecology and Management* 255(8/9): 3365-3373.

46. Imported Willow Leaf Beetle, *Plagiodera versicolora* (Laicharting) (Coleoptera: Chrysomelidae)

Orientation to Pest

Imported willow leaf beetle, *Plagiodera versicolora* (Laicharting), is an introduced insect in North America of European or Asian origin. Adults overwinter in protected locations near host trees. Adults begin feeding in early spring at leaf expansion and lay clusters of oval yellow eggs on leaves. Both larvae and adults are foliage feeders, skeletonizing and causing shot hole damage, respectively, to the leaves of willows and poplars in both landscape plantings and natural habitats. There are two (northern climates) to four (southern climates) generations per year.

Hosts Commonly Attacked

Hosts of imported willow leaf beetle include various species of poplar (*Populus*) and willow (*Salix*).

Distribution

This insect is found in North America (throughout the eastern United States and southern Canada, and in parts of Alaska), Central Europe, Japan, and China. The exact native range is not known.

Images of Imported Willow Leaf Beetle

Figure 1. Adult of imported willow leaf beetle, *Plagiodera versicolora*. (Jim Baker, North Carolina State University, Bugwood.org)

Figure 2. Shot-hole type feeding damage caused by adults of imported willow leaf beetle. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Imported Willow Leaf Beetle (continued)

Figure 3. Larvae and feeding damage of imported willow leaf beetle. (Paul Weston, Cornell University, Bugwood.org)

Figure 4. Clump of willow showing branches defoliated by imported willow leaf beetle. (U.S. Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 5. The coccinellid *Neoharmonia venusta*, a predator of imported willow leaf beetle eggs. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In North America, the chalcids *Schizonotus rotundivenris* (Girault) and *Schizonotus latus* (Walker) parasitize the imported willow leaf beetle. Eggs are eaten by predators, especially the coccinellid *Neoharmonia venusta* (Melsheimer).

Web Links for Information on Imported Willow Leaf Beetle

http://wiki.bugwood.org/Archive:Poplar/Plagiodera_versicolora

Articles

Wade, M.J. and F. Breden. 1986. Life history of natural populations of the imported willow leaf beetle, *Plagiodera versicolora* (Coleoptera: Chrysomelidae). *Annals of the Entomological Society of America* 79: 73-79.

47. Elm Leaf Beetle, *Xanthogaleruca luteola* (Müller) (Coleoptera: Chrysomelidae)

Orientation to Pest

Elm leaf beetle, *Xanthogaleruca luteola* (Müller), is an introduced insect in North America of European or Asian origin that feeds on elms (*Ulmus*). It overwinters as an adult in protected locations. Eggs are laid in clusters on elm leaves and larvae feed as leaf skeletonizers, while adults produce shot-hole damage to leaves. Eggs are pointed, rather than oval in outline. Pupation occurs at the base of infested trees. Two generations may occur per year.

Hosts Commonly Attacked

This beetle feeds on various imported or native elms (*Ulmus*), and is important as a pest of American elm (*Ulmus americana* L.).

Distribution

This invasive insect is found throughout the United States and southern Canada, wherever elms occur naturally or have been planted as ornamentals.

Images of Elm Leaf Beetle

Figure 1. Adults of elm leaf beetle, *Xanthogaleruca luteola*. (Both photos: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Figure 2. Cluster of elm leaf beetle eggs. (Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Images of Elm Leaf Beetle (continued)

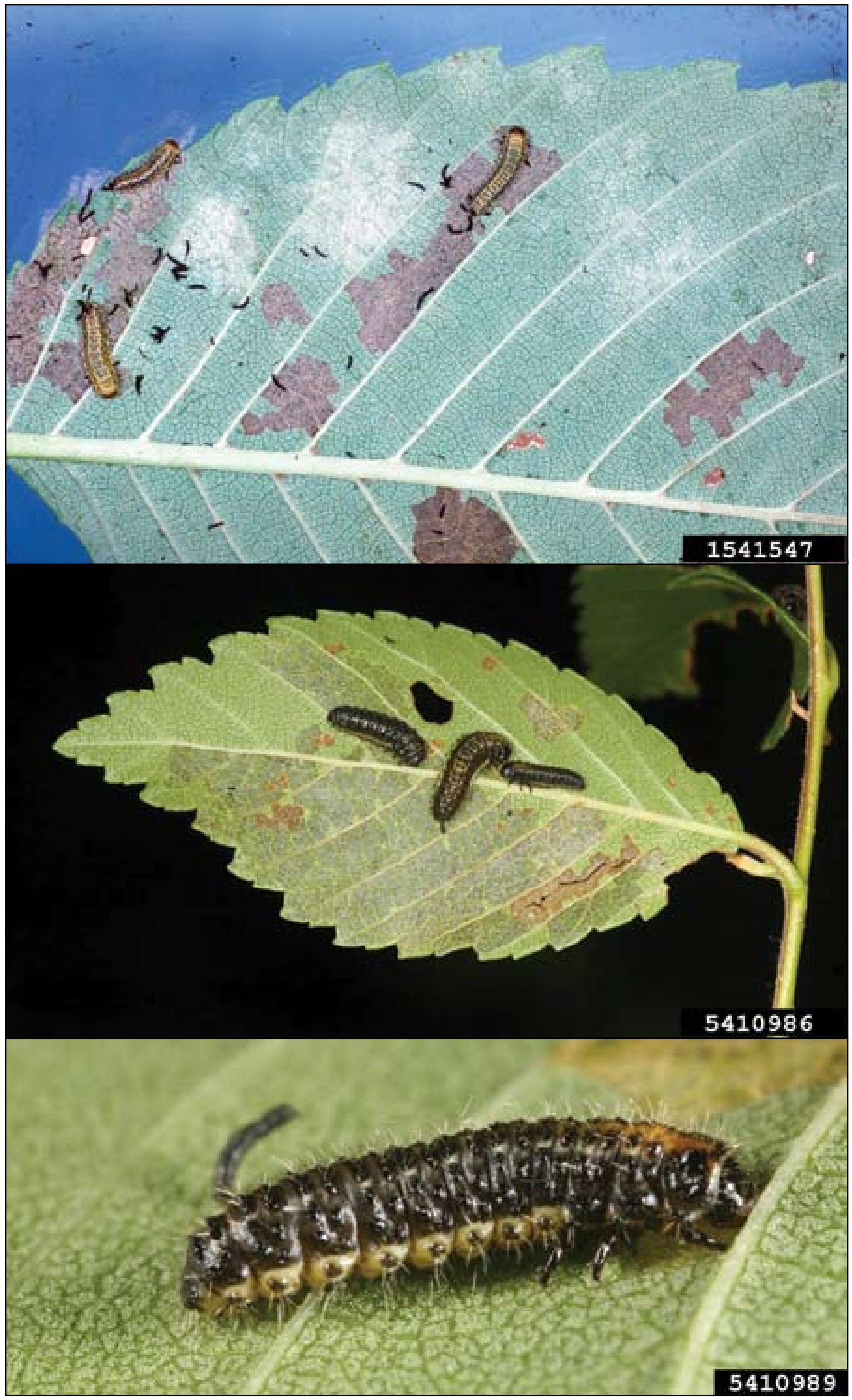

Figure 3. Larvae of elm leaf beetle (young larvae, top; older larvae, middle; close up of mature larva, bottom). (Top: Lacy L. Hyche, Auburn University, Bugwood.org; middle, bottom: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Images of Elm Leaf Beetle (continued)

Figure 4. Pupae of elm leaf beetle. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 5. Elm leaves (top) skeletonized by elm leaf beetle larvae, and with shot-hole damage from adult feeding (below). (Top: James Solomon, USDA Forest Service, Bugwood.org; bottom: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Elm Leaf Beetle (continued)

Figure 6. *Oomyzus gallerucae* is an important egg parasitoid affecting elm leaf beetle populations in some parts of the United States. (Bruno Lavoue)

Figure 7. The tachinid *Erynniopsis antennata* is an introduced larval parasitoid of elm leaf beetle. (Jack Kelly Clark, University of California - Statewide IPM Program, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Oomyzus gallerucae (Fonscolombe) (=*Tetrastichus gallerucae* [Boy]) is an introduced egg parasitoid of elm leaf beetle that is found in Missouri, where it is of major importance, and in California. The tachinid *Erynniopsis antennata* (Rondani) is an introduced larval parasitoid of elm leaf beetle that is established in California and of moderate importance there.

Web Links for Information on Elm Leaf Beetle

http://californiaagriculture.ucanr.org/landingpage.cfm?article=ca.v052n02p18&fulltext=yes; an IPM plan for control of elm leaf beetle or street trees in California.

http://www.ext.colostate.edu/pubs/insect/05521.html; fact sheet from Colorado State University Extension.

http://extension.missouri.edu/publications/DisplayPub.aspx?P=g7356; fact sheet from University of Missouri Extension.

http://www.hgic.umd.edu/_media/documents/hg113_000.pdf; fact sheet from Maryland Cooperative Extension Service.

Articles

Dreistadt, S.H. and D.L. Dahlsten. 1990. Distribution and abundance of *Erynniopsis antennata* (Dipt.: Tachinidae) and *Tetrastichus brevistigma* (Hym.: Eulophidae), two introduced elm leaf beetle parasitoids in northern California. *BioControl* 35: 527-536.

Dreistadt, S.H. and D.L. Dahlsten. 1991. Establishment and overwintering of *Tetrastichus gallerucae* (Hymenoptera: Eulophidae), an egg parasitoid of the elm leaf beetle (Coleoptera: Chrysomelidae) in northern California. *Environmental Entomology* 20: 1711-1719.

Meiners, T. and M. Hilker. 1997. Host location in *Oomyzus gallerucae* (Hymenoptera: Eulophidae), an egg parasitoid of the elm leaf beetle *Xanthogaleruca luteola* (Coleoptera: Chrysomelidae). *Oecologia* 112: 87-93.

Puttler, B. and W.C. Bailey. 2003. Establishment of *Oomyzus gallerucae* (Hymenoptera: Eulophidae), an egg parasite of the elm leaf beetle (Coleoptera: Chrysomelidae), in Missouri and adjacent states. *Biological Control* 27: 20-24.

48. Larger Elm Leaf Beetle, *Monocesta coryli* (Say) (Coleoptera: Chrysomelidae)

Orientation to Pest

The larger elm leaf beetle, *Monocesta coryli* (Say), is a native insect in the United States that is of concern in Florida as an occasional pest of elms (*Ulmus*). It has a similar biology to the invasive elm leaf beetle, *Xanthogaleruca luteola* (Müller), but is not as damaging, in part because it has only one generation per year. Young larvae feed in groups on elm leaves but older larvae disperse and feed singly. Larval feeding causes leaves to become skeletonized, giving trees a brown or defoliated look. Mature larvae leave trees to pupate in the soil.

Hosts Commonly Attacked

The larger elm leaf beetle feeds on various elms (*Ulmus*).

Distribution

This beetle occurs spottily from Florida to Pennsylvania, and west to Ohio and Kansas.

Images of Large Elm Leaf Beetle

Figure 1. Views of the adult larger elm beetle, *Monocesta coryli*. (Both photos: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Figure 2. Female of larger elm leaf beetle with egg mass. (North Carolina Forest Service Archive, Bugwood.org)

Images of Large Elm Leaf Beetle (continued)

Figure 3. Young larvae of larger elm leaf beetle (left) feed in groups; close up of one larva (right). (Both photos: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 4. Defoliated elms fed on by larger elm leaf beetle. (Both photos: Jim Baker, North Carolina State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No natural enemies of this species have been well documented, but the tachinid *Icelia triquetra* (Olivier) is reported to attack this species.

Web Links for Information on Larger Elm Leaf Beetle

http://entnemdept.ufl.edu/creatures/trees/le_leaf_beetle.htm; fact sheet of the University of Florida.

Articles

Anderson, D. and C.S. Papp. 1961. The larger elm leaf beetle, *Monocesta coryli* (Say). *Proceedings of the Entomological Society of Washington* 63: 203-207.

Kelsheimer, E.G. 1945. Notes on the great elm leaf beetle. *Florida Entomologist* 28: 25-27.

Kelsheimer, E.G. 1957. Larger elm leaf beetle (*Monocesta coryli*). Cooperative Economic Insect Report, Plant Pest Control Division, Agricultural Research Service, U.S. Department of Agriculture 7: 650.

Madden, A.H. 1940. Larger elm leaf beetle (*Monocesta coryli* Say). Insect Pest Survey Bulletin, Bureau of Entomology and Plant Quarantine, U.S. Department of Agriculture 20: 408.

49. Giant Palm Weevil, *Rhynchophorus cruentatus* (F.) (Coleoptera: Curculionidae)

Orientation to Pest

Giant palm weevil (also called palmetto weevil), *Rhynchophorus cruentatus* (F.), is native to the West Indies, South America, and coastal areas of the southern United States. This species attacks various introduced and native palms. The adult is variable in color pattern. Adults emit aggregation pheromones to concentrate attack on stressed trees. Eggs are laid in the bases of leaves or in wounds in a dying palm. Larvae feed primarily in the soft tissue surrounding the apical meristem. Mature grubs migrate to the periphery of the stem or petioles and prepare a cocoon from palm fibers. The weevil attacks lightning-struck or stressed palms, such as ones that have recently been transplanted. Healthy palms in natural settings are rarely damaged.

Hosts Commonly Attacked

The giant palm weevil is closely associated with cabbage palmetto (*Sabal palmetto* [Walker] Loddiges ex J.A. et Schultes), which is native to the southeastern United States. The native saw palmetto (*Serrenoa repens* [Bart.] Small) is an alternate host. Infestations have also been found in several introduced palms such as the Canary Island date palm (*Phoenix canariensis* Hortorum ex Chabaud), *Phoenix dactylifera* L., *Pritchardia* sp., *Washingtonia* sp., royal palms (*Roystonea* sp.), *Latania* sp., coconut palm (*Cocos nucifera* L.), and *Caryota* sp.

Distribution

This weevil is found in the United States in areas where palms grow, from Florida to Texas and north along the coast to South Carolina.

Images of Giant Palm Weevil

Figure 1. Adult of giant palm weevil (also called palmetto weevil), *Rynchophorus cruentatus*. The adult is variable in color (right). (Left: Jim Occi, BugPics, Bugwood.org; right: Doug Caldwell, University of Florida, Bugwood.org)

Images of Giant Palm Weevil (continued)

Figure 2. Larvae of giant palm weevil in Bismark palm (*Bismarckia nobilis* Hildebrandt and H.Wendl.). (Left: Wikipedia Commons; right: Lyle Buss, University of Florida, Bugwood.org)

Figure 3. Cocoon of giant palm weevil, inside of which the larva pupates. (Lyle Buss, University of Florida, Bugwood.org)

Figure 4. Left: Sabal palm (*Sabal* sp.) killed by giant palm weevil; bottom: Canary island date palm, *Phoenix canariensis*, killed by giant palm weevil. (Both photos: Robin M. Giblin-Davis)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this species are not reported from North America but some have been noted in other parts of its range. However, since this weevil is a native species in the United States and since damage occurs principally in planted palms in landscapes, the use of pesticides is likely to be an adequate and more efficient method of control.

Web Links for Information on Giant Palm Weevil

http://entnemdept.ufl.edu/creatures/orn/palmetto_weevil.htm; fact sheet of the University of Florida.

http://www.doacs.state.fl.us/pi/pest_alerts/pdf/giantpalmweevils.pdf; fact sheet "Giant palm weevils of the genus *Rhynchophorus* (Coleoptera: Curculionidae) and their threat to Florida palms"; FDACS-Division of Plant Industry, March 2010.

Articles

Giblin-Davis, R.M. and F.W. Howard. 1989. Vulnerability of stressed palms to attack by *Rhynchophorus cruentatus* (Fabricius) (Coleoptera: Curculionidae) and insecticidal control of the pest. *Journal of Economic Entomology* 82: 1185-1190.

Giblin-Davis, R.M., A.C. Oehschlager, A. Perez, G. Gries, R. Gries, T.J.Weissling, C.M. Chinchilla, J.E. Peña, R.H. Hallett, and H.D. Pierce, Jr. 1996. Chemical and behavioral ecology of palm weevils. *Florida Entomologist* 79: 153-167. (Available at http://www.fcla.edu/FlaEnt/fe79p153.pdf)

50. Red Palm Weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Dryophthoridae)

Orientation to Pest

The red palm weevil, *Rhynchophorus ferrugineus* (Olivier), is native to south Asia and Melanesia, where it is a serious pest of palms. Since the 1980s, this weevil has spread rapidly throughout many other parts of the world, reaching the United States (southern California) in 2010. The adult is 2-5 cm long and usually rusty red, but color variants are common. Larvae feed by tunneling in the trunks of palm trees, weakening and eventually killing trees. Red palm weevil is a major pest of date palms (*Phoenix dactylifera* L.) and coconut palms (*Cocos nucifera* L.). Palms damaged by red palm weevil show (1) foliage injuries that include straight edges instead of pointed tips, notching of lateral pinnae, and sometimes a linear series of "windows" across pinnae, (2) tunnels in the trunk or at the base of fronds, (3) oozing of viscous fluids from tunnels; (4) frass at entrance of feeding tunnels, (5) empty pupal cases and the bodies of dead adults around heavily infested palms, and (6) breaking of the trunk, or toppling of the palm crown. This weevil is a pest of both cultivation (agricultural or landscaping palms) and native palms in wildlands.

Hosts Commonly Attacked

The red palm weevil is especially damaging economically to date palms (*P. dactylifera*) and coconut palms (*C. nucifera*). Other hosts that have been recorded include palms in the genera *Areca*, *Arenga*, *Borassus*, *Caryota*, *Corypha*, *Livistona*, *Metroxylon*, *Oreodoxa*, *Sabal*, *Trachycarpus*, and *Washingtonia*. Of potential concern in the United States is the risk to native palms in the genera *Washingtonia* and *Sabal*.

Distribution

Red palm weevil is from south Asia and Melanesia, but since the 1980s, it has spread to Africa, Mediterranean Europe, the Caribbean, and southern California (USA).

Images of Red Palm Weevil

Figure 1. Adult red palm weevil (dark form found in California), *Rhynchophorus ferrugineus*. (John Kabashima, UC Cooperative Extension, Bugwood.org)

Images of Red Palm Weevil (continued)

Figure 2. Larva and pupa of red palm weevil (red form of adult, from France). (Christina Hoddle, University of California - Riverside, Bugwood.org)

Figure 3. Red palm weevil lava in open pupal cell. (Mike Lewis, Center for Invasive Species Research, Bugwood.org)

Images of Red Palm Weevil (continued)

Figure 4. Palm frond with typical damage from red palm weevil. (Mike Lewis, Center for Invasive Species Research, Bugwood.org)

Figure 5. Landscape palm damaged by invasive red palm weevils. (Christina Hoddle, University of California - Riverside, Bugwood.org)

Images of Red Palm Weevil (continued)

Figure 6. Native California fan palms, *Washingtonia filifera* (Lindl.) H.Wendl., at Mountain Palm Springs in Anza Borrego State Park in southern California may be hosts for red palm weevil. (Bill Sullivan for ABDNHA, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Biological control of the red palm weevil has so far been focused on control methods that can be applied to agricultural palm plantations or landscape palms in urban areas. Should native palms in wildlands be affected, classical biological control (based on importation of parasitoids of the weevil from its native range) should be investigated.

Web Links for Information on Red Palm Weevil

http://www.palms.org/palmsjournal/2002/redweevil.htm; a fact sheet about this pest in the Mediterranean region.

http://cisr.ucr.edu/red_palm_weevil.html; University of California fact sheet with photos of red palm weevil and its damage.

http://www.cdfa.ca.gov/phpps/rpw/index.html; California Department of Agriculture site with photos of pest.

Articles

Murphy, S.T. and B.R. Briscoe. 1999. The red palm weevil as an alien invasive: biology and the prospects for biological control as a component of IPM. *Biocontrol News and Information* 20(1): 35N-46N. (Available at http://www.iraqi-datepalms.net/uploadedfiles/review%20article.pdf).

Faleiro, J.R. 2006. A review of the issues and management of the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International Journal of Tropical Insect Science* 26 (3): 135-154.

51. Pales Weevil, *Hylobius pales* (Herbst) (Coleoptera: Curculionidae)

Orientation to Pest

The pales weevil, *Hylobius pales* (Herbst), is native to North America, where it is the most serious pest of young seedling pines in both cutover lands undergoing regeneration and in recently planted plantations or Christmas tree plantations where stumps have not been removed. This weevil is also the vector of *Leptographium procerum*, the causal agent of *Leptographium* root disease. The species overwinters as adults beneath litter or as larvae in roots. Eggs are laid in the roots of fresh stumps, where larvae then create galleries and feed. Pupation occurs in the outer sapwood. There is usually one generation per year and adults can live up to 2 years. Adult feeding on young seedlings (up to 1 cm in diameter) is the most important type of damage because it may cause girdling and tree death. Adult feeding can also kill tips of branches. In cut over forest land, damage can be lowered by delaying replanting for 1 or 2 years to allow adults to emerge from infested stumps and leave the area. In Christmas tree plantations, damage can be lowered by delaying replanting of cut areas, treating stumps with pesticides to kill adult weevils, or maintaining stumps in a living condition to prevent breeding (as in coppice harvesting of Christmas trees).

Hosts Commonly Attacked

The pales weevil affects all pines (*Pinus* spp.) native to North America and also many exotic pines. It is also found in spruce (*Picea* spp.), fir (*Abies* spp.), juniper (*Juniperus* spp.), larch (*Larix* spp.), hemlock (*Tsuga* spp.), northern white cedar (*Thuja occidentalis* L.), and Douglas fir (*Pseudotsuga menziesii* [Mirbel] Franco).

Distribution

The pales weevil is found throughout eastern North America, west to the Great Plains and north to southern Canada.

Images of Pales Weevil

Figure 1. Adult of the pales weevil, *Hylobius pales*. (Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Images of Pales Weevil (continued)

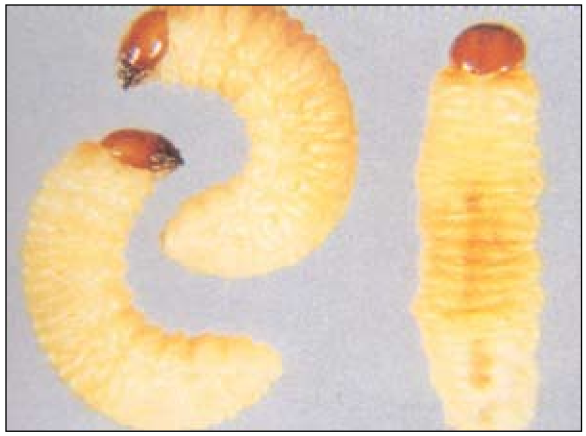

Figure 2. Larvae of pales weevil, removed from galleries. (USDA Forest Service publication "Weevils")

Figure 3. Left, pale weevil larvae develop in roots of stumps left after harvest; right, bark removed from stump to show the breeding galleries of pales weevil. (Left: Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org; right: Mary Ann Hansen, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 4. Feeding by adult pales weevils can girdle and kill seedlings (left) or branches (right), destroying forest regeneration or damaging the shape and appearance of Christmas trees. (Left: USDA Forest Service - Northeastern Area Archive, USDA Forest Service; right: Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The only known specialized natural enemy of this species is the euphorine braconid parasitoid *Microctonus pachylobi* Muesebeck, which develops in the adult weevil.

Web Links for Information on Pales Weevil

http://www.forestpests.org/nursery/weevils.html; fact sheet on weevils of forestry importance.

http://wiki.bugwood.org/Hylobius_pales; fact sheet on biology and control of pales weevil.

http://pubs.ext.vt.edu/2902/2902-1102/2902-1102.pdf; fact sheet from Virginia Tech.

http://www.fl-dof.com/publications/fh_pdfs/pine%20reproductive%20weevils.pdf; short article on pine reproduction weevils.

Articles

Zanzot, J.W., G. Matusick, and L.G. Eckhardt. 2010. Ecology of root-feeding beetles and their associated fungi on longleaf pine in Georgia. *Environmental Entomology* 39: 415-423.

Nevill, R.J. and S.A. Alexander. 1992. Transmission of *Leptographium procerum* to eastern white pine by *Hylobius pales* and *Pissodes nemorensis* (Coleoptera; Curculionidae). *Plant Disease* 76: 307-310.

Dixon, W.N. and J.L. Foltz. 1990. Pine reproduction weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar) (Coleoptera: Curculionidae). Entomology Circular #332, University of Gainesville, Florida.

Lynch, A.M. 1984. The pales weevil, *Hylobius pales* (Herbst): a synthesis of the literature. *Journal of the Georgia Entomological Society* 19 (3, Suppl. 1).

Corneil, J.A. and L.F. Wilson. 1981. How to identify and control pales weevil [*Hylobius pales*] in Christmas tree plantations. St. Paul, Minnesota: North Central Forest Experiment Station, USDA Forest Service: 5 p.

52. Pine Root Collar Weevil, *Hylobius radicis* (Buchanan) (Coleoptera: Curculionidae)

Orientation to Pest

The pine root collar weevil, *Hylobius radicis* (Buchanan), is native to eastern North America, where it is damaging in Scots pine (*Pinus sylvestris* L.) Christmas tree farms and in red pine (*Pinus resinosa* Sol. ex Aiton) plantations, but not natural forests. Eggs are laid in the root collar zone of healthy trees. Larval feeding may kill young trees or badly stress older trees. That stress can predispose mature trees to lethal attacks by bark beetles. This weevil is associated with several fungi linked to red pine decline. Damage may be reduced in a young stands before canopy closure by pruning away lower branches and removing litter and soil around the base of trunks to reduce weevil oviposition.

Hosts Commonly Attacked

The most frequently affected species is Scots pine (*P. sylvestris*), followed by red pine (*P. resinosa*), when grown in plantation.

Distribution

The pine root collar weevil is found from Newfoundland in Canada, south to Virginia and west to Minnesota and Manitoba.

Images of Pine Root Collar Weevil

Figure 1. Adult of the pine root collar weevil, *Hylobius radicis*. (Jennifer C. Giron Duque, University of Puerto Rico, Bugwood.org)

Images of Pine Root Collar Weevil (continued)

Figure 2. Larva of pine root collar weevil dissected out of wood. (James B. Hanson, USDA Forest Service, Bugwood.org)

Figure 3. Damage of pine root collar weevil in a mixed red and Scots pine stand. (Steven Katovich, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Very few natural enemies have been recorded attacking pine collar weevil, the main ones being the braconids *Bracon radicis* Shenefelt and Miller and *Microctonus pachylobi* Muesebeck.

Web Links for Information on Pine Root Collar Weevil

http://wiki.bugwood.org/Archive:Northeast/Hylobius_radicis; fact sheet from Bugwood Wiki.

Articles

Wilson, L.F. and I. Millers. 1983. Pine root collar weevil – its ecology and management. Technical Bulletin No. 1675, United States Department of Agriculture, Washington, DC: 34 p.

Klepzig, K.D., K.F. Raffa, and E.B. Smalley. 1991. Association of an insect-fungal complex with red pine decline in Wisconsin. *Forest Science* 37(4): 1119-1139.

Rieske, L.K. and K.F. Raffa. 1993. Potential use of baited pitfall traps in monitoring pine root weevil (*Hylobius pales*, *H. radicis*, and *Pachylobius picivorus*) populations and infestation levels. *Journal of Economic Entomology* 86: 475-485.

53. Pitch-eating Weevil, *Pachylobius picivorus* (Germar) (Coleoptera: Curculionidae)

Orientation to Pest

The pitch-eating weevil, *Pachylobius picivorus* (Germar), is native pest of pines in the eastern United States that is especially important in southern states. This weevil's biology and damage are very similar to that of the pales weevil, *Hylobius pales* (Herbst). Damage occurs in cut-over stands of various kinds of pines, where adults feed either on the inner bark of small stems of the remaining trees or on planted or naturally regenerated pine seedlings. Seedling death is the most important kind of damage. Eggs are laid in green roots of recently cut stumps or those of dead or dying trees. Adults dig through soil to reach roots for oviposition. Larvae feed in the roots' cambial layer and eventually pupate there, after having constructed a cell of wood chips. Harvest creates abundant stumps, allowing population increase of this insect and focusing damage on cut-over sites. This weevil is one of several species associated with fungi believed to be the cause of decline of red pine (*Pinus resinosa* Sol. ex Aiton).

Hosts Commonly Attacked

This weevil feeds on various pines, but especially shortleaf (*P. echinata* Mill.), loblolly (*P. taeda* L.), and slash pines (*P. elliottii* Engelm.) in the southern United States, and Scots pine (*P. sylvestris* L.), in the northeastern/northcentral part of the country.

Distribution

The pitch-eating weevil is found throughout the eastern United States, but is most common from Virginia to Florida and west to Oklahoma and Texas.

Images of Pitch-eating Weevil

Figure 1. Pitch-eating weevil, *Pachylobius picivorus*, on a pine stem (left), the adult's feeding site; and close up (right). (Left: Terry S. Price, Georgia Forestry Commission, Bugwood.org; right: Marvin Smith)

Images of Pitch-eating Weevil (continued)

Figure 2. Feeding on pine stem by adults of the pitch-eating weevil. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Figure 3. Larva of pitch-eating weevil, extracted from a root, the larval feeding site. (Wayne N. Dixon, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Very few specialized natural enemies have been recorded attacking pitch-eating weevil, the main one being *Microctonus pachylobi* Muesebeck, which attacks the adult stage.

Web Links for Information on Pitch-eating Weevil

http://wiki.bugwood.org/Pachylobius_picivorus; Bugwood Wiki fact sheet.

Articles

Walker, A.I. 1975. The biology and habits of the pales weevil, *Hylobius pales* (Herbst), and the pitcheating weevil, *Pachylobius picivorus* (Germar). Dissertation Abstracts International, B 35(8): 3962.

Dixon, W.N. and J.L. Foltz. 1990. Pine reproduction weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar) (Coleoptera: Curculionidae). *Entomology Circular* #332, University of Gainesville, Florida.

Rieske, L.K. and K.F. Raffa. 1990. Use of a monitoring system to evaluate pesticide efficacy and residual activity against two pine root weevils, *Hylobius pales* and *Pachylobius picivorus* (Coleoptera: Curculionidae), in Christmas tree farms. *Great Lakes Entomology* 23: 189-193.

Rieske, L.K. and K.F. Raffa. 1991. Effect of varying ethanol and turpentine levels on attraction of two pine root weevil species, *Hylobius pales* and *Pachylobius picivorus* (Coleoptera: Curculionidae). *Environmental Entomology* 20: 48-52.

54. White Pine Weevil, *Pissodes strobi* (Peck) (Coleoptera: Curculionidae)

Orientation to Pest

White pine weevil, *Pissodes strobi* (Peck), is native to North America. This weevil can breed in a wide range of native and introduced pine and spruce species. Eastern populations attack especially eastern white pine (*Pinus strobus* L.) and Norway spruce (*Picea abies* (L.) H. Karst.). In the western United States, Engelmann spruce (*P. engelmanni* Hopkins) and Sitka spruce (*P. sitchensis* [Bong] Carr.) are attacked. These western populations were formerly felt to be separate species and were studied under the names *Pissodes engelmanni* Hopkins and *Pissodes sitchensis* Hopkins, respectively. Cross breeding experiments, however, found all populations to be inter-fertile and thus these western populations were synonymized under the name *P. strobi*, which is how the name is used here. The important damage by this species is caused by larvae, which tunnel in and kill leaders, inducing branching and crooked trunks. Adults overwinter in the litter and feed on the cambium of the main terminals of their hosts. Eggs are laid in these terminals and larvae feed as cambial borers, often then girdling and killing the terminal. Larvae pupate in chambers made in the woody part of the stem. This species is considered the most serious pest of eastern white pine regeneration. Losses can be very high (up to 40 percent) to merchantable timber in heavily infested stands over the life of a cohort of trees. Attack is recognized by oozing of pitch from the terminal, followed by wilting and terminal death (and change of color to reddish brown). Signs of former attacks are seen in bushy or crooked tree form. Damage to young white pines may be partially reduced by maintaining a shady over-story of hardwoods, as weevil oviposition is greatest in full sun. Natural enemies are not sufficient to prevent significant losses when silvicultural factors present are favorable to this insect.

Hosts Commonly Attacked

A variety of native and introduced pines and spruces, especially eastern white (*Pinus strobus*), and jack (*P. banksiana* Lamb.) pines and Norway (*Picea abies*), white (*P. glauca* [Moench] Voss), Engelmann (*P. engelmanni*), and Sitka (*P. sitchensis*) spruce.

Distribution

The white pine weevil is found widely in both the eastern and western United States and Canada, in the ranges of its principal pine and spruce hosts.

Images of White Pine Weevil

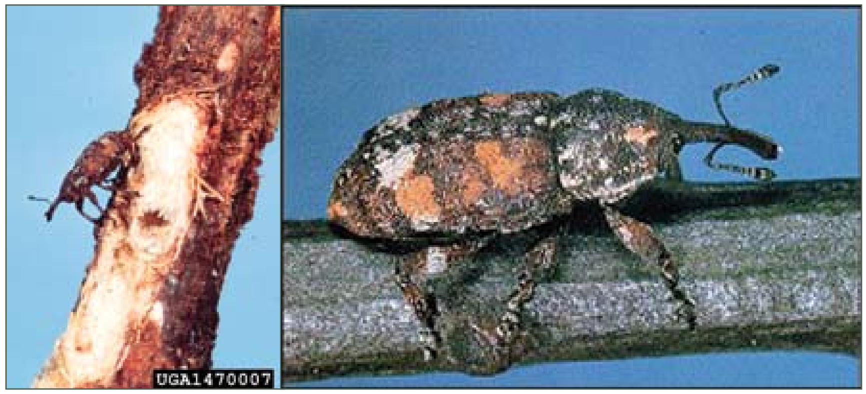

Figure 1. Adult of white pine weevil, *Pissodes strobi* (left), feeding on terminal; close up (right) of adult. (Left: A. Steven Munson, USDA Forest Service, Bugwood.org; right: U.S. Department of Agriculture Forest Service)

Figure 2. Group of white pine weevil larvae feeding in a stem (left), and close up (right). (Left: Dave Powell, USDA Forest Service, Bugwood.org; right: Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of White Pine Weevil (continued)

Figure 3. Leader of spruce (left) killed by white pine weevil; and close up (right) of pitch oozing from pine leader fed on by adults of white pine weevil. (Left: Troy Kimoto, Canadian Food Inspection Agency, Bugwood.org; right: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 4. Damage to form of pines from white pine weevil injury. Left, old pine with multiple crooked trunks; right, bush-like pines with many leaders. (Left: Steven Katovich, USDA Forest Service, Bugwood.org; right: Joseph O'Brien, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Not surprisingly, given that this native insect has a large geographical range and feeds on several tree genera, a variety of parasitoids and predators have been found associated with white pine weevil brood, including the parasitoids *Eurytoma pissodes* Girault, *Microbracon* (now *Bracon*) *pini* Muesebeck, *Dolichomitus terrebrans nubilipennis* (Viereck), *Coeloides pissodes* (Ashmead), and *Allodorus crassigaster* (Provancher). The principal predator of importance is *Lonchaea corticis* Taylor. See Mills and Fischer (1986) for a summary and discussion of white pine weevil natural enemies. However, none of these species reduce populations of white pine weevil to non-damaging levels. Consequently, the concept of introducing new natural enemies from *Pissodes* species native to Europe was studied (Kennis and Mills, 1994), but no species were ever actually introduced.

Web Links for Information on White Pine Weevil

http://cfs.nrcan.gc.ca/subsite/weevil/home-accueil; fact sheet of Natural Resources Canada.

http://www.na.fs.fed.us/spfo/pubs/howtos/ht_white/white.htm; USDA Forest Service bulletin on how to manage white pine weevil damage.

http://ir.library.oregonstate.edu/xmlui/handle/1957/11007; thesis providing a hazard rating system for white pine weevil risk to Sitka spruce in Oregon, USA.

Articles

Mills, N.J. and P. Fischer. 1986. The entomophage complex of *Pissodes* weevils, with emphasis on the value of *P. validirostris* as a source of parasitoids for use in biological control, pp. 297-307. In: Roques, A. (ed.). Proceedings of the 2nd Conference on the Cone and Seed insects Working Party, Briancon, France, September 3-5, 1986.

Kenis, M. and N.J. Mills. 1994. Parasitoids of European species of the genus *Pissodes* (Col: Curculionidae) and their potential for the biological control of *Pissodes strobi* (Peck) in Canada. *Biological Control* 4(1): 14-21.

Daoust, G. and M.J. Mottet. 2006. Effect of white pine weevil (*Pissodes strobi* Peck) on plantations of Norway spruce (*Picea abies* [L.] Karst.). Part 1: Productivity and quality of stems. *Forestry Chronicle* 82(4): 538-549.

55. Eastern Pine Weevil, *Pissodes nemorensis* Germar (Coleoptera: Curculionidae)

Orientation to Pest

Eastern pine weevil, *Pissodes nemorensis* Germar, is now the name that is applied to what was formerly known as northern pine weevil (*Pissodes approximatus* Hopkins), which is no longer considered a valid species. Eastern pine weevil is native to North America, where it feeds on cedars (*Cedrus*) and pines (*Pinus*). In the southern United States, adults are active in fall, winter and spring, and are inactive in summer. Eggs are laid in the spring in stems or branches. The northern form appears to commonly breed also in stumps of cut trees and becomes a pest in plantations as numbers build up. Larvae feed in the cambium and pupate in the wood in cells make of wood chips. Adults feed on branches and terminals, which may be killed, leading to bushiness or crooked stems. Small trees may be killed by larval feeding.

Hosts Commonly Attacked

In the northern part of its range, eastern pine weevil breeds in pines, especially red (*Pinus resinosa* Sol. ex Aiton) and Scots (*P. sylvestris* L.) pines. In the southern United States, both cedars and pines are attacked. Cedars used as hosts include both native species and exotic cedars such as deodar cedar (*Cedrus deodara* [Roxb.] G. Don), Atlas cedar (*C. atlantica* [Endl.] Manetti ex Carrière), and cedar of Lebanon (*C. libani* A. Rich.). In the southern USA, various North American pines are used as hosts, especially loblolly (*P. taeda* L.), shortleaf (*P. echinata* Mill.), and longleaf (*P. palustris* Mill.)

Distribution

The southern form of this weevil is found in the southeastern United States, north to Pennsylvania. The northern form (the old *P. approximatus*) is found from the Atlantic coast to Manitoba and Minnesota and south to North Carolina. The species is not present in the western United States. It is an invasive pest in some countries, including South Africa, where it is a pest in plantations of exotic pines.

Images of Eastern Pine Weevil

Figure 1. Adult of eastern pine weevil, *Pissodes nemorensis*. (Gerald J. Lenhard, Louiana State University, Bugwood.org)

Images of Eastern Pine Weevil (continued)

Figure 2. Eggs of eastern pine weevil. (Mark Fontaine, University of Florida, Bugwood.org)

Figure 3. Larvae of eastern pine weevil feeding in gallery (left) and mature larva (right) ready for pupation. (Left: Rayanne Lehman, Pennsylvania Department of Agriculture, Bugwood.org; right: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 4. Pupa of eastern pine weevil in cocoon (left), and cocoons on trunk with bark removed (right). (Left: Gerald J. Lenhard, Louiana State University, Bugwood.org; right: Chris Evans, River to River CWMA, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The braconid parasitoid *Coeloides pissodis* (Ashmead) is an important natural enemy of eastern pine weevil.

Web Links for Information on Eastern Pine Weevil

http://wiki.bugwood.org/Archive:South/Pissodes_nemorensis; Bugwood Wiki fact sheet on general biology of insect.

http://www.eppo.org/QUARANTINE/insects/Pissodes_nemorensis/PISONE_ds.pdf; quarantine data sheet on species for Europe; detailed information on biology and other topics.

http://www.fabinet.up.ac.za/tpcpweb/pamphlets/pissodes.pdf; fact sheet on weevil as pest in South Africa providing considerable detail on biology and management.

Articles

Gebeyehu, S. and M.J. Wingfield. 2003. Pine weevil *Pissodes nemorensis*: threat to South African pine plantations and options for control. *South African Journal of Science* 99(11/12): 531-536.

56. Whitefringed Beetles (*Naupactus* spp.) (Coleoptera: Curculionidae)

Orientation to Pest

Whitefringed beetles, formerly regarded as a separate genus (*Graphognathus*), are now an informal "species group" within a much larger genus (*Naupactus*). The name whitefringed beetle comes from the white lines that run the length of the grey-to-brown body, two on each side, one above and one below the eye. There are four species, all invasive, in the United States: *Naupactus leucoloma* (Boheman), *N. peregrinus* (Buchanan), *N. minor* (Buchanan), and *N. fecundus* (Buchanan). These beetles are pests of various agricultural crops, but also injure young pine seedlings when trees are planted into converted farmland in the southern United States. Adults feed on the foliage of hundreds of plant species, but damage is of minor importance. Larvae feed on roots and their damage is more serious, especially on crops or young pines in plantations and nurseries. Like the adults, the larvae feed on a diverse set of hosts, although their full host range is more difficult to document. The U.S. populations of all four species contain only females, although populations with males are found in the native range in southern South America. Adults have fused wing covers and cannot fly. Eggs are laid in masses on objects on or near the soil. Larvae drop into the soil where they feed on roots and then and pupate in earthen cells where they overwinter. There is only one generation per year.

Hosts Commonly Attacked

Adults feed on nearly 400 species of plants, including many crops. Larvae feed on roots of some trees, such as peach (*Prunus persica* [L.] Batsch), pecan (*Carya illinoinensis* [Wangenh.] K.Koch), tung (*Vernicia fordii* [Hemsl.] Airy Shaw), willow (*Salix*), and pine (*Pinus*).

Distribution

Originally from southern South America (Argentina, Peru, Chile, Uruguay), whitefringed beetles are found as invasive species in the United States from Florida north to Virginia and Illinois and west to Texas.

Images of Whitefringed Beetles

Figure 1. Adult of one of the whitefringed beetles, *Naupactus peregrinus*; see the enhanced white lines in drawing on right. (Left: Russ Ottens, University of Georgia, Bugwood.org; right: Department of Entomology and Nematology, University of Florida)

Images of Whitefringed Beetles (continued)

Figure 2. Larva of a species of whitefringed beetle in root (left) and close up (right). (Left: Terry S. Price, Georgia Forestry Commission, Bugwood.org; right: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 3. Feeding damage of adult whitefringed beetles (left), and close up of adult feeding on blueberry leaf (right). (Left: Louis Tedders, USDA Agricultural Research Service, Bugwood.org; right: Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org)

Figure 4. Feeding damage of larvae of whitefringed beetles on root of sycamore tree. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Whitefringed Beetles (continued)

Figure 5. “Scalping” is the use of machinery to remove a thin layer of thatch and top soil before planting a new block of pine seedlings. (Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 6. Unscalped pine plantation (left), showing loss of seedling establishment vs. scalped plot (right), where whitefringed beetles have been removed and pine seedling survival increased. (Both photos: Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 7. Scalped plot (left of man) vs unscalped plot (right of man) in slash pine (*Pinus elliottii* Engelm.) plantation, showing cumulative effect of larvae of whitefringed beetles on growth of slash pines when beetle are suppressed before planting via “scalping” (removal of thatch and bit of top soil just before planting) or not. (Edward L. Barnard, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information was located on specialized natural enemies of this group of beetles.

Web Links for Information on Whitefringed Beetles

http://entnemdept.ufl.edu/creatures/field/beetles/whitefringed_beetles.htm; University of Florida fact sheet on biology and control.

http://www.eppo.org/QUARANTINE/insects/Naupactus_leucoloma/GRAGLE_ds.pdf; EPPO datasheet on this quarantine pest (from Europe's point of view) containing information on biology and damage.

http://keys.lucidcentral.org/keys/sweetpotato/key/Sweetpotato%20Diagnotes/media/html/TheProblems/Pest-Root&StemInsects/WhitefringedBeetles/whitefringed%20beetle%20home.htm; factsheet of University of Queensland (Australia) with information on recognition, biology, ecology, and control.

Articles

Anderson W.H. 1938. A key to separate the larvae of the white-fringed beetle, *Naupactus leucoloma* Boh., from the larvae of closely related species. USDA Bureau of Entomology and Plant Quarantine Circular E-422. 3 p.

Ahmad, R. 1974. Studies on *Graphognathus leucoloma* (Boh.) Col.: Curculionidae) and its natural enemies in the central provinces of Argentina. Technical Bulletin No. 17, Commonwealth Institute of Biological Control: 19-28.

Harlan, D.P. and J.W. McGuire. 1977. Separation of four species of whitefringed beetles by measuring the length and width of the eggs (Coleoptera: Curculionidae). *Journal of the Georgia Entomological Society* 12: 125-128.

Lanteri, A.A. and A.E. Marvaldi. 1995. *Graphognathus* Buchanan a new synonym of *Naupactus* Dejean and systematics of the *N. leucoloma* species group (Coleoptera: Curculionidae). *Coleopterists Bulletin* 49(3): 206-228.

57. Yellow-poplar Weevil, *Odontopus calceatus* (Say) (Coleoptera: Curculionidae)

Orientation to Pest

Yellow-poplar weevil, *Odontopus calceatus* (Say), feeds on yellow-poplar (*Liriodendron tulipifera* L.), magnolia (*Magnolia*), and sassafrass (*Sassafras albidum* [Nuttall] Nees.). The weevil overwinters as an adult and upon emergence, adults feed on buds or developing leaves. Eggs are laid in leaf veins and larvae feed as leafminers. Multiple larvae may coexist in a single common mined area. Outbreaks in yellow-poplar have occurred since 1960 in eastern Kentucky, Tennessee, Ohio, West Virginia, and Virginia.

Hosts Commonly Attacked

This weevil feeds on yellow-poplar (*L. tulipifera*), magnolia (*Magnolia*), and sassafras (*S. albidum*).

Distribution

This weevil is found throughout the eastern United States within the range of its hosts.

Images of Yellow-poplar Weevil

Figure 1. Adults of yellow-poplar weevil, *Odontopus calceatus*, on leaf and (inset) close up. (Lacy L. Hyche, Auburn University, Bugwood.org; inset: Rich Kelly)

Images of Yellow-poplar Weevil (continued)

Figure 2. Oviposition wounds (left) and eggs of yellow-poplar weevil (revealed by dissection) (right) in leaf vein. (Both photos: Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 3. Larval mine (left) and larvae (right) (seen by opening mine) of yellow-poplar weevil. (Both photos: Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Cocoons in leaf (left) and pupa (right) (revealed by opening cocoon) of yellow-poplar weevil. (Both photos: Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Unspecified species of parasitoids have been noted to destroy up to 50 percent of larvae in mines.

Web Links for Information on Yellow-poplar Weevil

http://www.ca.uky.edu/entomology/entfacts/ef414.asp; University of Kentucky fact sheet.

http://www.ag.auburn.edu/enpl/bulletins/lmweevil/lmweevil.htm; fact sheet of Auburn University, with extensive photos.

http://www.fs.fed.us/outernet/r6/nr/fid/fidls/fidl-125.pdf; USDA Forest Service Pest Leaflet.

Articles on Yellow-poplar Weevil

Burns, D.P. and L.P. Gibson. 1968. The leaf mining of yellow-poplar. *The Canadian Entomologist* 100: 421-429.

Hyche, L.L. 1994. The yellow-poplar leaf-mining weevil. A guide to recognition and habits in Alabama. Bulletin No. 622 of the Alabama Agricultural Experiment Station, Alabama Agricultural Experiment Station, Auburn University: 13 p.

58. Native Elm Bark Beetle, *Hylurgopinus rufipes* (Eichhoff) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Native elm bark beetle, *Hylurgopinus rufipes* (Eichhoff), is a native North American insect associated with various species of elm and other trees. Before the introduction of the exotic pathogen causing Dutch elm disease, this insect was of minor importance. During the historical period of mass epidemics of Dutch elm disease, this native bark beetle served as a vector of the pathogen. This process continues in wild lands where native elms survive and reproduce before succumbing to Dutch elm disease. Although *H. rufipes* has been displaced over much of its range by the introduced smaller European elm bark beetle (*Scoytus multistriatus* [Marsham]), *H. rufipes* remains the dominant vector of Dutch elm disease in northern areas where *S. multistriatus* is limited by low temperatures. Adult beetles emerge in early spring and fly to healthy elms to feed for a short period in the bark of branches and twigs. After feeding, beetles fly to dying and recently dead trees for oviposition. Females construct egg galleries that are oriented horizontally, across the grain of the wood. Eggs are laid along the egg gallery and larvae feed in tunnels that run parallel to the grain and perpendicular to the egg gallery. Larvae pupate in small cells at the ends of the feeding gallery. In some instances, larvae and newly developed adults will overwinter in these galleries, with adults emerging the following spring through small round exit holes. At other times, adults emerge before winter; these adults fly to healthy elm trees to feed on branches and to chew overwintering galleries in the bark, generally of the lower stem. If as larvae these adults had developed in trees dying from Dutch elm disease, they are very likely to carry spores of the fungus that causes Dutch elm disease. When they visit healthy elm trees to feed on branches or to create overwintering galleries, these beetles can transmit the pathogen. There are one to two generations of this bark beetle per year, depending on location.

Hosts Commonly Attacked

Rock (*Ulmus thomasii* Sarg.) and American elm (*U. americana* L.) are the major hosts of this bark beetle, but it also attacks American basswood (*Tilia americana* L.), and species of ash (*Fraxinus*).

Distribution

This native bark beetle was formerly common throughout eastern North America from northern Alabama and Mississippi to southern Canada, but it has been displaced over most of this area by the introduced smaller European elm bark beetle. It is, however, still common in colder areas such as northern New York, New England, northern Minnesota, and southern Canada, where the smaller European elm bark beetle does not survive winter temperatures.

Images of Native Elm Bark Beetle

Figure 1. Adult native elm bark beetle, *Hylurgopinus rufipes*. (J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Figure 2. Egg gallery (horizontal) and larval galleries (vertical) of the native elm bark beetle. (John A. Williams, USDA Forest Service, Bugwood.org)

Images of Native Elm Bark Beetle (continued)

Figure 3. Historical record of the change the new pathogen made in the importance of this bark beetle. (Darren Blackford, USDA Forest Service, Bugwood.org)

Figure 4. Two views of American elms dying of Dutch elm disease. (Left: Linda Haugen, USDA Forest Service, Bugwood.org; right: Roland J. Stipes, Virginia Polytechnic Institute and State University, Bugwood.org)

Images of Native Elm Bark Beetle (continued)

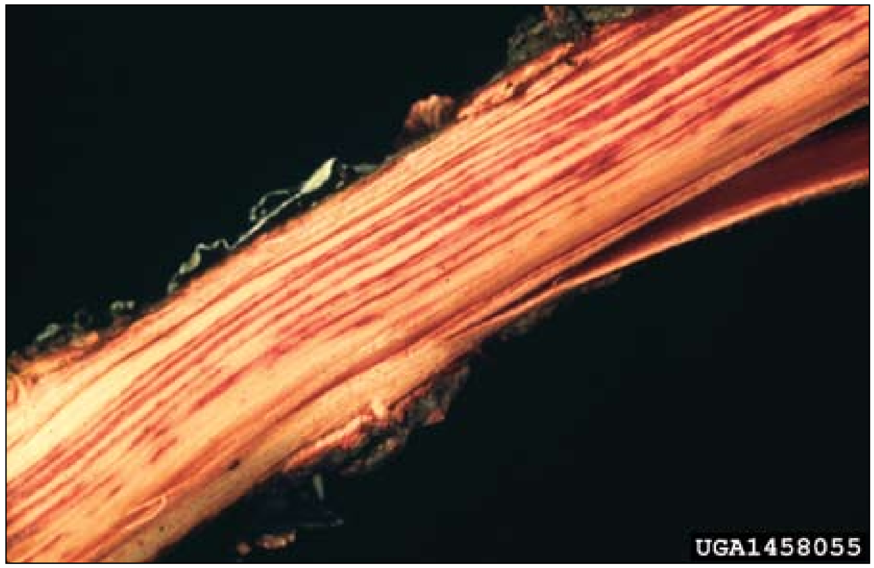

Figure 5. Streaking and discoloration of the vascular tissue in elms infected with Dutch elm disease. (North Carolina Forest Service Archive, Bugwood.org)

Figure 6. The clerid *Enoclerus nigripes*, an important predator of the native elm bark beetle. (Charley Eiseman, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The major predator of this bark beetle in Connecticut is the clerid *Enoclerus nirgripes* Say and the principal parasitoid is *Spathius canadensis* Ashmead.

Web Links for Information on Native Elm Bark Beetle

http://www.extension.umn.edu/distribution/horticulture/DG1420.html; fact sheet from the University of Minnesota.

http://www.na.fs.fed.us/spfo/pubs/howtos/ht_ded/ht_ded.htm#intro; recognition and management of Dutch elm disease.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=2850. Natural Resources Canada fact sheet.

Articles

Thompson, H.E. and J.G. Matthysse. 1972. Role of the native elm bark beetle, *Hylurgopinus rufipes* (Eichh.), in transmission of the Dutch elm disease pathogen, *Ceratocystis ulmi* (Buisman) C. Moreau. *Search Agriculture (Entomology)* 2(1,V): 16 p.

Gardiner, L.M. 1981. Seasonal activity of the native elm bark beetle, *Hylurgopinus rufipes*, in central Ontario (Coleoptera: Scolytidae). *The Canadian Entomologist* 113: 341-348.

59. Smaller European Elm Bark Beetle, *Scolytus multistriatus* (Marsham) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), is an introduced bark beetle that is one of the two main vectors of Dutch elm disease (along with the native elm bark beetle, *Hylurgopinus rufipes* [Eichhoff]) in the eastern United States and Canada. It was brought to North America through the importation of unbarked elm logs containing live brood of the pest. It breeds in various species of elm, but the greatest damage is done to American elm (*Ulmus americana* L.). It is widely distributed in the United States. The biology of this species is much the same as for the native elm bark beetle. Adults fly to healthy elm trees in the spring, where they feed on twigs, infecting them with the fungal pathogen (*Ophiostoma ulmi* [Buisman] Melin and Nannf.) that causes Dutch elm disease. Trees that are stressed by this disease or other factors are attacked by females for breeding. Eggs are laid in galleries that females dig under the bark of the tree. Larvae develop in galleries, feeding in the cambium. Mature larvae overwinter in their galleries, pupating in spring and producing a new flight of adults. Emergence holes have a characteristic "shot hole" appearance. Mass attack on stressed trees is mediated, as in many bark beetles, via an aggregation pheromone. This beetle has displaced the native elm bark beetle in many parts of North America, except in the coldest areas.

Hosts Commonly Attacked

Smaller European bark beetle attacks all species of Elm (*Ulmus*) and the Japanese species *Zelkova serrata* (Thunb.) Makino.

Distribution

This invasive bark beetle is found in southern Canada and most of the United States except some parts of Florida and Maine.

Images of Smaller European Bark Beetle

Figure 1. Adult of smaller European elm bark beetle, *Scolytus multistriatus*. (Left: J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org; right: Maja Jurc, University of Ljubljana, Bugwood.org)

Images of Smaller European Bark Beetle (continued)

Figure 2. Elm branch with feeding in crotch from adults of smaller European elm bark beetle. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Figure 3. Galleries and brood of smaller European elm bark beetle; central galleries between "wings" are oviposition galleries and the two "wings" are groups of larval galleries; larvae are visible at ends of many galleries in photo on left. (Left: Joseph O'Brien, USDA Forest Service, Bugwood.org; right: Beat Forster, Swiss Federal Institute for Forest, Snow and Landscape Research, Bugwood.org)

Figure 4. Round emergence holes of the smaller European elm bark beetle. (J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Images of Smaller European Bark Beetle (continued)

Figure 5. Two views of American elms dying of Dutch elm disease. (Left: Linda Haugen, USDA Forest Service, Bugwood.org; right: Roland J. Stipes, Virginia Polytechnic Institute and State University, Bugwood.org)

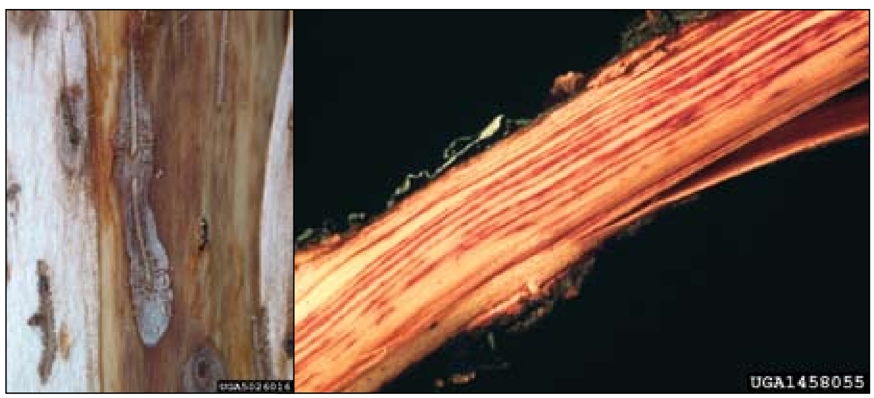

Figure 6. Two views of the streaking and discoloration of the vascular tissue in elms infected with Dutch elm disease. (Left: Joseph LaForest, University of Georgia, Bugwood.org; right: North Carolina Forest Service Archive, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Europe, several parasitoids are known to attack *S. multistriatus*. Three of these—*Dendrosoter protuberans* (Nees), *Ecphylus silesicacus* (Ratzburg), and *Coeloides scolyticida* Wesm.—have been introduced into the United States. However, densities of this invasive bark beetle have not been compared between Europe and North America, to see if they were higher in North America than Europe at the time of these introductions. Nor have studies determined if these introductions (some of which did result in establishment) reduced the abundance of this bark beetle. Until recently whether or not this biological control effort had any effect on the target insect was a moot point, as sufficient elm bark beetles remained to allow the Dutch elm disease epidemic to go unchecked, destroying most native elms. The picture is further complicated by the fact that the pathogen, believed to be of Asian origin, has recently evolved to form a new, more aggressive form, *Ophiostoma novo-ulmi* Brasier. This new pathogen has spread from the American midwestern states into other regions of North America, replacing the form of the pathogen introduced in North America in the 1940s. Nevertheless, the dynamics of this system in the context of replanting disease-resistant American elms in wildlands should now be revisited.

Web Links for Information on Smaller European Bark Beetle

http://www.ento.okstate.edu/ddd/insects/smeurelmbark.htm; fact sheet of Oklahoma State University.

http://crawford.tardigrade.net/bugs/BugofMonth38.html; Bug of the Month fact sheet.

http://aces.nmsu.edu/ces/plantclinic/documents/o-03-barkbeetles.pdf; New Mexico fact sheet on bark beetles in general.

Articles

Schroder, D. 1974. Investigations on the prospects for biological control of scolytids on elms as a means of reducing Dutch elm disease. *Zeitschrift für Angewandte Entomologie* 76(2): 150-159. (In German).

60. Spruce Beetle, *Dendroctonus rufipennis* (Kirby) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Spruce beetle, *Dendroctonus rufipennis* (Kirby), is a native North American bark beetle that usually develops in wind-thrown, over mature, or weakened trees, resources that normally occur at low densities in forests. The biology of the beetle is similar to that of many bark beetles, with females laying eggs in tunnels (egg galleries), from which larvae then begin to feed, forming larval galleries. In this species young larvae often feed in common galleries, but then produce individual galleries as they mature. Larvae pupate at the end of their galleries, and overwinter as either larvae or new adults in the galleries. Spruce beetles generally require two years to complete their life cycle. However, when temperatures are warmer than normal a generation can be completed in one year. When two years are required, development is not synchronized and beetles emerge and attack trees each year. Spruce beetle outbreaks are associated with warmer than usual weather, and are often triggered by disturbance events such as avalanches, storms, and logging. Outbreaks tend to occur in areas with an abundance of large spruce trees. Outbreaks occur several times each century, thinning large trees from stands over extensive areas. More severe outbreaks in which trees of most sizes and vigor classes are killed occur less frequently. Important outbreaks historically have occurred in Alaska and Utah.

Hosts Commonly Attacked

Spruce beetle attacks various species of native North America spruce (*Picea*).

Distribution

This bark beetle is found throughout the spruce forests of North America.

Images of Spruce Beetle

Figure 1. Adult of spruce beetle, *Dendroctonus rufipennis*. (David McComb, USDA Forest Service, Bugwood.org)

Images of Spruce Beetle (continued)

Figure 2. Female spruce beetle digging an oviposition gallery, with white eggs visible in upper left. (Edward H. Holsten, USDA Forest Service, Bugwood.org)

Figure 3. Spruce beetle larvae at ends of tunnels. (Edward H. Holsten, USDA Forest Service, Bugwood.org)

Figure 4. Pupae of spruce beetle in galleries. (Edward H. Holsten, USDA Forest Service, Bugwood.org)

Images of Spruce Beetle (continued)

Figure 5. Oviposition (vertical) and larval (horizontal) galleries of spruce beetle etched in wood under bark of spruce tree. (Darren Blackford, USDA Forest Service, Bugwood.org)

Figure 6. Pitch tubes (left) and frass (right) on spruce trunks are signs of spruce beetle attack. (Left: Darren Blackford, USDA Forest Service, Bugwood.org; right: A. Steven Munson, USDA Forest Service, Bugwood.org)

Images of Spruce Beetle (continued)

Figure 7. Adult spruce beetles in galleries. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Figure 8. Burning of stumps (left) or logging slash (right) after felling infested trees is intended to limit spruce beetle outbreaks. (Left: A. Steven Munson, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Figure 9. Views of spruce trees killed by spruce beetle, at various physical scales (dead trees denoted in artificial color in photo on right). (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: William M. Ciesla, Forest Health Management International, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A variety of natural enemies have been recorded in the literature attacking spruce beetle brood (see Van Driesche et al., 1996 in USDA FS publication FHTET-96-19, URL given below), including several species of braconid parasitoids in the genus *Coeloides*. Also the role of woodpecker predation on brood has been studied. But the fundamental determinants of outbreaks of spruce beetle do not seem to be driven by natural enemies, but rather to be responses to weather, the amount of breeding material for the beetle at a site, and local and regional spruce stand conditions.

Web Links for Information on Spruce Beetle

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=2819; fact sheet of Natural Resources Canada.

http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf; USDA Forest Service publication FHTET-96-19, Van Driesche et al., 1996; see pages 55-57 for information on natural enemies of this species.

http://na.fs.fed.us/spfo/pubs/fidls/sprucebeetle/sprucebeetle.htm; USDA Forest Service Forest Insect and Disease Leaflet on spruce beetle.

Articles

Schmid, J.M. and R.H. Frye. 1976. Stand ratings for spruce beetles. Res. Note RM-309. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado: 4 p.

Schmid, J.M. and R.H. Frye. 1977. Spruce beetle in the Rockies. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-49. Ft. Collins, Colorado: 38 p.

Linton, D. A. and L. Safranyik, L. 1988. The spruce beetle *Dendroctonus rufipennis* (Kirby): an annotated bibliography 1885-1987. Information Report - Pacific Forestry Centre, Canadian Forestry Service (BC-X-298): 39 p.

61. Black Turpentine Beetle, *Dendroctonus terebrans* (Olivier) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Black turpentine beetle, *Dendroctonus terebrans* (Olivier), is a native, North American bark beetle that attacks various pines. Adults of this species are strongly attracted to odors of freshly cut pine stumps, where they are able to breed. In whole trees, eggs are primarily laid in the bottom 1-2 meters of the boles as well as roots of weakened trees. Eggs are laid in large oviposition galleries created by females with the help of males. Larvae feed collectively in large galleries. Pupation takes place in pupal cells constructed in the corky bark or between the bark and the wood. In the northern part of the range, adults are the overwintering stage. In southern areas, all stages may be present all year. Damage can occur in healthy trees as well as stressed trees, and damage in turpentine orchards can be severe. The black turpentine beetle is often found attacking trees in association with the southern pine beetle (*Dendroctonus frontalis* Zimmermann) or various species of southern pine engraver beetles (*Ips* spp.).

Hosts Commonly Attacked

Hosts of black turpentine beetle include all species of southern pines, but especially loblolly (*Pinus taeda* L.) and slash (*P. elliottii* Engelm.) pines. In the northern part of its range, black turpentine beetle attacks various conifers, including black (*P. thunbergiana* Franco) and pitch (*P. rigida* Miller) pines and red spruce (*Picea rubens* Sargent).

Distribution

This bark beetle is found in the eastern United States from Florida west to Missouri and Texas and north to coastal areas of southern New England.

Images of Black Turpentine Beetle

Figure 1. Adults of black turpentine beetle, *Dendroctonus terebrans*. (Left: David T. Almquist, University of Florida, Bugwood.org; right: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Images of Black Turpentine Beetle (continued)

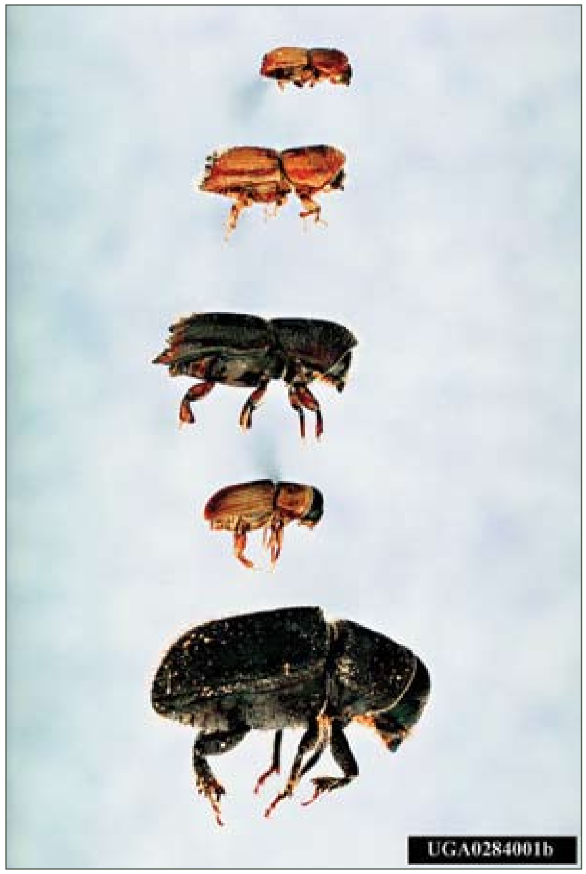

Figure 2. Black turpentine beetle (bottom) is the largest of the five species of southern pine bark beetles. The other species (from top down) are: *Ips avulsus* (Eichhoff), *Ips grandicollis* (Eichhoff), *Ips calligraphus* (Germar), and *Dendroctonus frontalis* (Zimmermann). (Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 3. Eggs of black turpentine beetle (white, above beetle on left). (Terry S. Price, Georgia Forestry Commission, Bugwood.org)

Images of Black Turpentine Beetle (continued)

Figure 4. Larvae of black turpentine beetle in common feeding gallery (left); larvae enlarged (right). (Left: James R. Meeker, USDA Forest Service, Bugwood.org; right: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 5. Pupae of black turpentine beetle, in pupal cells, lower left.
(Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 6. Pitch tubes (left) are created by the tree where black turpentine beetles bore in the tree; during mass attack, there may be many pitch tubes in the lower bole area (right). (Left: USDA Forest Service Archive, USDA Forest Service, Bugwood.org; right: Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Black Turpentine Beetle (continued)

Figure 7. Dying loblolly pines infested with both *Ips* beetles and black turpentine beetles. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 8. The clerid *Thanasimus dubius* (red larva in lower center, top; and close up, bottom) is a common predator of brood of black turpentine beetles. (Top: North Carolina State University Archive, North Carolina State University, Bugwood.org; bottom: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known about the specific natural enemies of this species. The clerid *Thanasimus dubius* (Fabricius) and the trogositid *Temnochila virescens* (Fabricius), predatory beetles that prey on many southern pine bark beetles, are found attacking brood of black turpentine beetles.

Web Links for Information on Black Turpentine Beetle

http://entnemdept.ufl.edu/creatures/trees/beetles/black_turpentine_beetle.htm; fact sheet of the University of Florida.

Articles

Barras, S.J. and T. Perry. 1971. *Leptographium terebrantis* sp. nov. associated with *Dendroctonus terebrans* in loblolly pine. *Mycopathologia* 43: 1-10.

Foltz, J.L., E.P. Merkel, and R.C. Wilkinson. 1984. Annotated bibliography of *Dendroctonus terebrans* (Oliver), *Ips avulsus* (Eichhoff), *Ips grandicollis* (Germar) in the southeastern USA. Monograph No. 12. Agricultural Experiment Station, University of Florida: 47 p.

62. Eastern Larch Beetle, *Dendroctonus simplex* (LeConte) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Eastern larch beetle, *Dendroctonus simplex* (LeConte), is a native North American bark beetle whose only important host is eastern larch, *Larix larcina* (Du Roi) K. Koch. The species overwinters as larvae or adults in galleries. Eggs are laid in groups along an egg gallery made by the female in the inner bark and outer sapwood. Larval tunnels are short and occur in the inner bark. There are up to three generations per year. Before the 1970s, this bark beetle was only known to attack dying or recently felled trees. Since then, however, a series of large outbreaks in healthy stands have occurred in both Canada and the United States. Some of these bark beetle outbreaks followed outbreaks of the defoliating larch sawfly *Pristiphora erichsonii* (Hartig), which had produced many stressed or dying larch trees. While the exact causes of these population fluctuations are unknown, some authors have attributed outbreaks to the maturing of larch stands over large areas, which lowers host resistance.

Hosts Commonly Attacked

Hosts of this species are eastern larch (*L. larcina*), and occasionally red spruce (*Picea rubens* Sargent).

Distribution

This bark beetle is found in the United States from New England south to West Virginia, and west to Minnesota. It is also found in Alaska and in Canada from the Atlantic to the Pacific coast.

Images of Eastern Larch Beetle

Figure 1. Adults of eastern larch beetle, *Dendroctonus simplex*, in galleries. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Eastern Larch Beetle (continued)

Figure 2. Eggs of eastern larch beetle. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Larva of eastern larch beetle. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 4. Pupa of eastern larch beetle. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Eastern Larch Beetle (continued)

Figure 5. Larval galleries at surface of wood made by eastern larch beetle. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Eastern larch beetle has a large complex of natural enemies that have been studied in a number of locations (see Van Driesche et al. 1996 for a review). Some of the natural enemies reported include the dolichopodid fly, *Medetera gaspensis* Bickel, and the rhizophagid beetle, *Rhizophagus dimidiatus* Mannerheim, (both predators), and the parasitoids *Spathius canadensis* Ashmead (Braconidae), *Rhopalicus tutela* (Walker), and *Roptrocerus xylophagorum* (Ratzeburg).

Web Links for Information on Eastern Larch Beetle

http://www.na.fs.fed.us/spfo/pubs/fidls/elb/elb.htm; a USDA Forest Service fact sheet, Forest Insect and Disease Leaflet #175, providing extensive detail on biology, hosts, distribution, and control of eastern larch beetle.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=2820; a Natural Resources Canada fact sheet.

Articles

Duncan, B. 1987. An illustrated guide to the identification and distribution of the species of *Dendroctonus* Erichson (Coleoptera: Scolytidae) in British Columbia. *Journal of the Entomological Society of British Columbia* 84: 101-112.

Langor, D.W. and A.G. Raske. 1988. Annotated bibliography of the eastern larch beetle, *Dendroctonus simplex* LeConte (Coleoptera: Scolytidae). Information Report - Newfoundland Forestry Centre, Forestry Canada (N-X-266), 1988: 38 p.

Langor, D.W. and A.G. Raske. 1988. Mortality factors and life tables of the eastern larch beetle, *Dendroctonus simplex* (Coleoptera: Scolytidae), in Newfoundland. *Environmental Entomology* 17: 959-963.

Articles (continued)

Langor, D.W. and A.G.A. Raske. 1989. A history of the eastern larch beetle, *Dendroctonus simplex* (Coleoptera: Scolytidae), in North America. *Great Lakes Entomologist* 22: 139-154.

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. Biological control of arthropod pests of the northeastern and north central forests in the United States: a review and recommendations. USDA FS, FHTET-96-19, Morgantown, West Virginia: 58-59. (Available at http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

63. Southern Pine Beetle, *Dendroctonus frontalis* (Zimmermann) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Southern pine beetle, *Dendroctonus frontalis* (Zimmermann), is the most destructive bark beetle attacking pines in the southern United States. It is a native North American species that also occurs in Mexico and Central America. Its principal hosts are yellow pines, especially shortleaf (*Pinus echinata* Mill.), loblolly (*P. taeda* L.), Virginia (*P. virginiana* Mill.), and pitch (*P. rigida* Mill.) pines. Beetles overwinter in all stages and timing of adult emergence in spring varies with location, from mid-March to June. Bark areas from which adults have emerged have a shot-hole-like appearance. Attack by adults during warm days in winter is usually on previously attacked trees and is focused initially on the mid to upper part of the tree. Females construct a nuptial chamber, where they are later joined by males. An S-shaped oviposition gallery is then constructed, along which eggs are laid. Larval galleries are at right angles to the oviposition gallery and score the wood. Larval tunnels are primarily in the bark and pupation occurs at the end of the larval gallery. With each new generation, infested areas expand, sometimes covering very large areas. In western North Carolina there are three to five generations per year and up to seven per year further south. The generations overlap, so in active infestations, all life stages of the beetle are present at any one time and adult beetles emerge and attack new trees daily when temperatures allow. Trees under 15 years of age or 5 cm in diameter are rarely attacked. Infestations typically begin in stands of trees stressed by high tree density, logging damage, lightning, dryness, flooding, or disease. Trees die either because they are girdled by larval galleries, or because of the effects of a blue stain fungus (*Ceratocystis minor* [Hedgc.] Hunt), which is vectored by the beetle. Damage from outbreaks is reduced somewhat by managing stands to reduce tree stress and by halting the expansion of initial spots using salvage (cut-and-remove) or cut-and-leave control methods.

Hosts Commonly Attacked

Principal species in which reproduction of southern pine beetle occurs are the yellow pines, especially shortleaf (*P. echinata*), loblolly (*P. taeda*), Virginia (*P. virginiana*), and pitch (*P. rigida*) pines. The beetle also attacks species such as longleaf (*P. palustris* Miller) and slash (*P. elliottii* Engelm.) pines, but reproduction is often less successful due to heavy resin flow.

Distribution

This bark beetle is found throughout the southeastern and southern parts of the United States, as well as Mexico and parts of Central America.

Figure 1. Distribution of southern pine beetle, *Dendroctonus frontalis*. (Eastern Forest Environmental Threat Assessment Center • Threat Summary)

Images of Southern Pine Beetle

Figure 2. Adults of southern pine beetle; left, beetle in flight. (Both photos: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

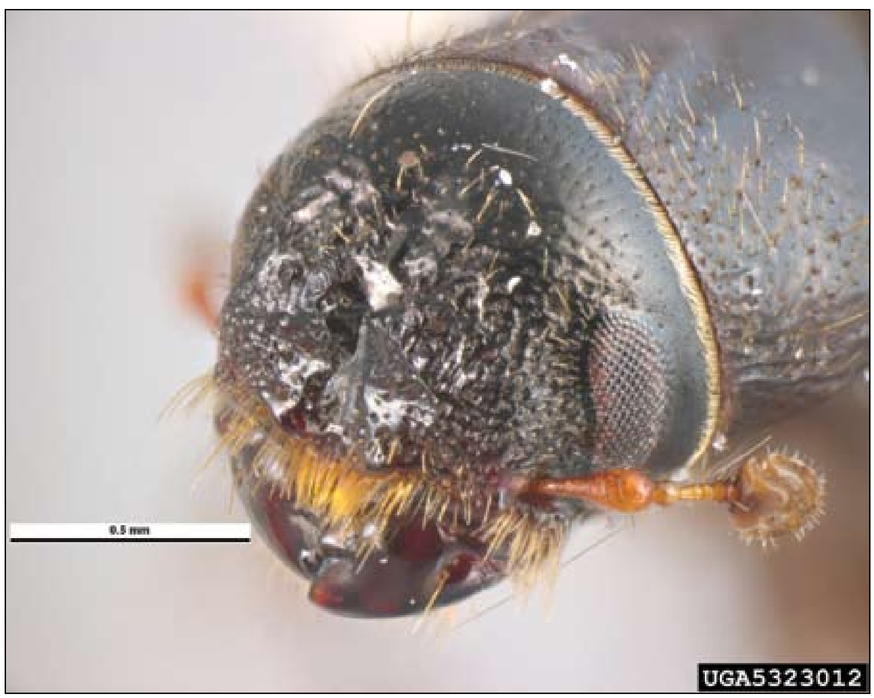

Figure 3. The head of the southern pine beetle is diagnostic for the species. The head is broad, with a distinct notch or frontal groove on male beetles, bordered by distinct projections or tubercules on either side of the groove. The antennae are seven-segmented, consisting of the basal pedicel, elongated scape, four-segmented funicle, and an enlarged club. (Pest and Diseases Image Library, Bugwood.org)

Images of Southern Pine Beetle (continued)

Figure 4. Egg of southern pine beetle. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Figure 5. Life cycle diagram of southern pine beetle (left), showing various larval stages; view of southern pine beetle larva in wood (right). (Left: Ronald F. Billings, Texas Forest Service, Bugwood.org; right: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Figure 6. Pupae of southern pine beetle. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Southern Pine Beetle (continued)

Figure 7. Young adults of southern pine beetle in galleries, ready to emerge. (Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Figure 8. Pitch tubes on pines (left) are a sign of bark beetles such as southern pine beetle; close-up of pitch tube (center), and female southern pine beetle with entrance hole in pitch tube, right. (All photos: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Figure 9. Galleries of southern pine beetle and associated blue stain (left), and view of blue stain fungus (right) in cross section slice of trunk. (Left: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org; right: Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Southern Pine Beetle (continued)

Figure 10. Initial point of outbreak ("spot") of southern pine beetle (left) and larger area of damage, to loblolly pine (right). (Left: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org; right: William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 11. Tree felling is a control method (left) used to prevent expansion of spot infestations (right, spot after infested trees have been removed). Infested trees and uninfested trees in a buffer zone are either cut and removed or cut and left in place, in either case for the purpose of stopping spot expansion. (Both photos: Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 12. Larva of checkered beetle, *Thanasimus dubius* (Fabricius) (Cleridae) eating a southern pine beetle larva (top left) and close up of *T. dubius* larva (top right); adult of *T. dubius* with prey (bottom). (Top left: John Moser, USDA Forest Service, Bugwood.org; top right: Gerald J. Lenhard, Louiana State University, Bugwood.org; bottom: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The most important natural enemies of southern pine beetles are predacious clerid beetles. These predators are attracted to the aggregation pheromone and host volatiles used in traps to assess southern pine beetle densities in particular stands. Comparison of pest and predator numbers caught in traps is used each spring throughout the southern and eastern United States to forecast southern pine beetle population trends (outbreaks or population declines) (Figure 13).

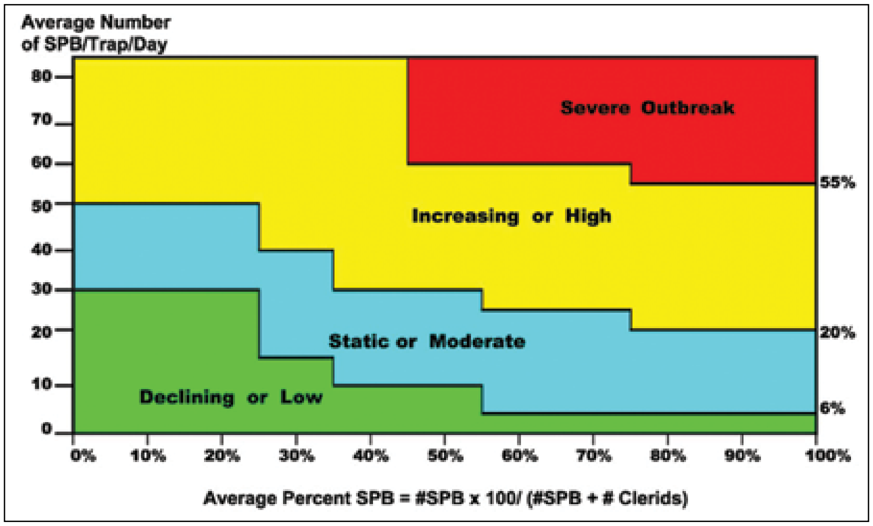

Figure 13. A decision chart to forecast southern pine beetle outbreaks, using information on density of the bark beetle and its clerid predator in traps baited with aggregation pheromone (developed by Ron Billings, Texas Forest Service) (see Billings and Upton, 2010).

Web Links for Information on Southern Pine Beetle

http://entnemdept.ufl.edu/creatures/trees/southern_pine_beetle.htm; University of Florida fact sheet.

Fidgen, J. (2000). Southern pine beetle information directory. http://everest.ento.vt.edu/~salom/SPBinfodirect/spbinfodirect2.html (5 July 2001).

http://www.barkbeetles.org/spb/spbbook/Index.html; a web rendering of the U.S. Department of Agriculture, Expanded Southern Pine Beetle Research and Applications Program, Forest Service, Science and Education Administration, Technical Bulletin 1631: [1980].

ftp://ftp.fao.org/docrep/fao/011/i0640e/i0640e10e.pdf; Bulletin of the United Nations, Food and Agriculture Organization.

http://www.barkbeetles.org/centralamerica/0605e.html; management of southern pine beetle in Central America.

Articles on Southern Pine Beetle

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Dixon, W.N. and T.L. Payne. 1979. Aggregation of *Thanasimus dubius* on trees under mass-attack by the southern pine beetle. *Environmental Entomology* 8: 178-181.

Billings, R.F. and H.A. Pase III. 1979. A field guide for ground checking southern pine beetle spots. U.S. Department of Agriculture, Combined Forest Pest Research and Development Program, Agriculture Handbook No. 558: 19 p.

Swain, K.M. and M.C. Remion. 1981. Direct control methods for the southern pine beetle. U.S. Department of Agriculture, Combined Forest Pest Research and Development Program, Agriculture Handbook No. 575: 15 p.

Billings, R.F. and W.W. Upton. 1993. Effectiveness of synthetic behavioral chemicals for manipulation and control of southern pine beetle infestations in East Texas. USDA Forest Service, Southern Forest Experiment Station. General Technical Report: 555-568.

Clarke, S.L. and J.T. Nowak. 2009. Southern pine beetle. Forest Insect and Disease Leaflet No. 49, USDA Forest Service, Portland, Oregon, United States. 8 p.

Billings, R.F. and W.W. Upton. 2010. A methodology for assessing annual risk of southern pine beetle outbreaks across the Southern Region, using pheromone traps, p. 73-85. In: Pye, J.M., H.M. Rauscher, Y. Sands, D.C. Lee, J.S. Beatty (tech. eds.). 2010. Advances in threat assessment and their application to forest and rangeland management. General Technical Report PNW-GTR-802. U.S. Department of Agriculture, Forest Service, Pacific Northwest and Southern Research Stations, Portland, Oregon, United States. 708 p., 2 vol. (Image available at http://www.threats.forestencyclopedia.net/p/p3291).

64. Western Pine Beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Western pine beetle, *Dendroctonus brevicomis* LeConte, is a native bark beetle of the western United States that attacks and kills ponderosa (*Pinus ponderosa* Douglas ex P & C. Lawson) and Coulter (*P. coulteri* D. Don) pines greater than 15 cm in diameter, regardless of age or vigor, including apparently healthy trees. Outbreaks are most common in dense, even-age stands, but also occur in areas of mixed conifer species. Mortality is often subtle yet significant when large old trees are killed individually by the beetle. Large outbreaks are common and over one million trees (more than 1 billion board feet of timber) may be killed each year during outbreaks. Outbreaks have been known to occur following wildfires in ponderosa pine stands. Beetle attacks are first visible due to pitch tubes that form at the sites where female beetles bore into the tree to create oviposition galleries. However, pitch tubes of this species are less conspicuous than for other bark beetles and frequently are not seen at all. Attacking adult beetles carry spores of a blue-staining fungus, *Ceratocystis minor* (Hedg.), which contributes to tree death by blocking the water-conducting vessels in the wood. The egg galleries are about the width of an adult beetle and are usually tightly packed with boring dust. There are two to four generations per year, depending on latitude and altitude. Eggs are laid singly along the oviposition gallery and larvae then make short lateral galleries as they feed. As is true for many bark beetles, aggregation pheromones produced by the beetle coordinate a mass attack on selected trees. Thinning of trees to reduce density can be used to reduce stand susceptibility to mortality from western pine beetle.

Hosts Commonly Attacked

This beetle attacks ponderosa (*P. ponderosa* Douglas ex P & C. Lawson) and Coulter (*P. coulteri* D. Don) pines.

Distribution

Western pine beetle is most damaging in California, but its range extends northward into Oregon, Washington, Idaho, and southern British Columbia, as well as eastward into Montana, Nevada, Utah, Colorado, Arizona, New Mexico, and western Texas. It also occurs in northwestern Mexico.

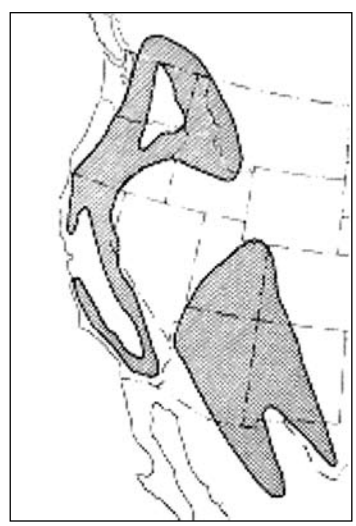

Figure 1. Distribution (in western North America) of the western pine beetle, *Dendroctonus brevicomis*. (USDA Forest Service • Forest Insect & Disease Leaflet 1)

Images of Western Pine Beetle

Figure 2. Adult of western pine beetle, *Dendroctonus brevicomis* (left), and close up of head (right); note lack of rows of tubercules on either side of the frontal groove, as are present in the southern pine beetle, *Dendroctonus frontalis* (Zimmermann). (Left: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org; right: Pest and Diseases Image Library, Bugwood.org)

Figure 3. Pitch tubes of western pine beetle. (Kenneth E. Gibson, USDA Forest Service, Bugwood.org)

Images of Western Pine Beetle (continued)

Figure 4. Larvae of western pine beetle. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 5. Galleries of western pine beetle in ponderosa pine. (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 6. Shot holes formed in ponderosa pine by emergence of western pine beetles. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Images of Western Pine Beetle (continued)

Figure 7. Two views of stands of ponderosa pines killed by western pine beetle. (Top: William M. Ciesla, Forest Health Management International, Bugwood.org; bottom: James Everitt, Bugwood.org)

Figure 8. The predacious clerid beetle *Enoclerus lecontei*, a predator of western pine beetle. (Brytten Steed, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Important predators of brood of western pine beetle are the clerid beetles *Enoclerus lecontei* (Wolcott) and *Enoclerus sphegeus* Fabricius, as well as the blue-green ostomid *Temnochila chlorodia* Mannerheim and the fly *Medetera aldrichii* Wheeler. Common parasites are *Roptrocerus xylophagorum* Ratzeburg, *Dinotiscus burkei* Crawford, and *Coeloides* sp. nr. *brunneri* Vierick.

Web Links for Information on Western Pine Beetle

http://www.forestpests.org/acrobat/fidl1.pdf; USDA Forest Service, Forest Insect and Disease Leaflet #1.

http://forestry.nv.gov/forestry-resources/forest-health/western-pine-beetle/; fact sheet of the Nevada Division of Forestry.

Articles

Miller, J.M. and F.P. Keen. 1960. Biology and control of the western pine beetle. U.S. Department of Agriculture Misc. Publ. 800, Washington, DC: 381 p.

Stark, R.W. and D.L. Dahlsten (eds.). 1970. Studies on the population dynamics of the western pine beetle, *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae). University of California, Division of Agricultural Science, Berkeley, California, USA: 174 p.

Wallin, K.F., T.E. Kolb, K.R. Skov, and M. Wagner. 2008. Forest management treatments, tree resistance, and bark beetle resource utilization in ponderosa pine forests of northern Arizona. *Forest Ecology and Management* 255(8/9): 3263-3269.

65. Jeffrey Pine Beetle, *Dendroctonus jeffreyi* Hopkins (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Jeffrey pine beetle, *Dendroctonus jeffreyi* Hopkins, is a native North American bark beetle that attacks only Jeffrey pine (*Pinus jeffreyi* Grev. and Balf.) and it is that tree's most serious insect pest. This pine beetle occurs in the Sierra Nevada wherever Jeffrey pine is present. In most cases this beetle occurs at low densities and attacks only small numbers of slow growing trees with reduced vigor. However, large outbreaks can occur when forest conditions are favorable, especially during extended droughts. Adults emerge from infested trees in April or May. Mass attack is initiated by colonizing beetles, which release aggregation pheromones. Females bore in and excavate a vertical gallery where they lay their eggs. The oviposition gallery is packed with boring dust, and larvae later form short individual lateral tunnels where they feed. Jeffrey pine beetles overwinter as larvae or as pupae in chambers excavated at the end of larval galleries. Depending on local climate there are one or two generations per year. Beetles infect trees with a blue-stain fungus, which kills the tree by clogging the tree's vascular system. Signs of attack include pitch tubes on the mid or lower trunk. In weak trees pitch tubes may be absent.

Hosts Commonly Attacked

This beetle attacks only Jeffrey pine (*P. jeffreyi*).

Distribution

Jeffrey pine beetle is found within the range of Jeffrey pine, principally in California, with the exceptions of the San Jacinto, Santa Rosa, and Luguna mountain ranges of southern California, where this bark beetle has not been observed.

Images of Jeffrey Pine Beetle

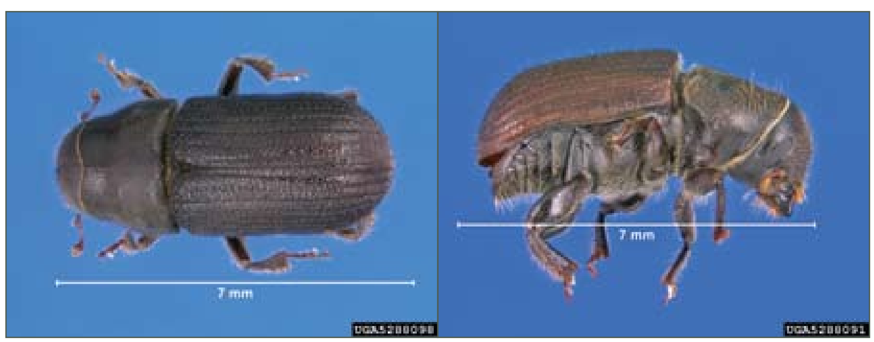

Figure 1. Adults of Jeffrey pine beetle, *Dendroctonus jeffreyi*. (Both photos: Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Images of Jeffrey Pine Beetle (continued)

Figure 2. Eggs of Jeffrey pine beetle in oviposition gallery (above dark line of gallery). (Dave Powell, USDA Forest Service, Bugwood.org)

Figure 3. Larva of Jeffrey pine beetle, removed from gallery. (Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Images of Jeffrey Pine Beetle (continued)

Figure 4. Pupa of Jeffrey pine beetle. (tia smith, Bugwood.org)

Figure 5. Galleries of adults (vertical) and larvae (horizontal) of Jeffrey pine beetle. (Darren Blackford, USDA Forest Service, Bugwood.org)

Images of Jeffrey Pine Beetle (continued)

Figure 6. Pines killed by Jeffrey pine beetle near Lake Tahoe, California. (Darren Blackford, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this bark beetle have received little attention, but likely are similar to those groups attacking western pine beetle (*Dendroctonus brevicomis* LeConte).

Web Links for Information on Jeffrey Pine Beetle

http://forestry.nv.gov/forestry-resources/forest-health/jeffery-pine-beetle/; fact sheet of the Nevada Division of Forestry.

http://www.fs.fed.us/r6/nr/wildlife/decaid/IandDSpecies/Jeffrey%20pine%20beetle.html; USDA Forest Service fact sheet.

http://www.unce.unr.edu/publications/files/ho/other/fs9840.pdf; fact sheet of the University of Nevada at Reno.

Articles

Smith, R.H., B.E. Wickman, R.C. Hall, C.J. DeMars, and G.T. Ferrell. 1981. The California pine risk-rating system: its development, use and relationship to other systems. In: Hedden, R.L., S.J. Barras, J.E. Coster. (tech. coords.). Hazard-rating systems in forest insect pest management: symposium proceedings. Athens, Georgia, July 31-August 1, 1980. General Technical Report WO-27, USDA Forest Service, Washington, DC: 53-69.

Smith, S.L., R.B. Borys, and P.J. Shea. 2008. Jeffrey pine beetle. USDA Forest Service, Forest Pest Leaflet 11: 7 p.

66. Mountain Pine Beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Mountain pine beetle, *Dendroctonus ponderosae* Hopkins, a native North American species, is the most destructive bark beetle of the western United States and Canada, where it occurs widely on a variety of pines, including lodgepole (*Pinus contorta* Douglas), ponderosa (*P. ponderosa* Douglas ex C. Lawson), western white (*P. monticola* Douglas ex D. Don), whitebark (*P. albicaulis* Engelmann) and sugar (*P. lambertiana* Douglas) pines. Historically, highly destructive outbreaks of this species have occurred repeatedly, decimating mature forests of such species as lodgepole pine over extensive areas. All trees above 10 cm in diameter are susceptible to attack. Beetle attacks are usually concentrated along the main trunk, from about one meter above the ground up to the middle branches. As with many bark beetles, signs of infestations include pitch tubes on the trunk, red boring dust in bark crevices, discoloration of foliage as trees die, and blue discoloration of the wood caused by several associated fungi: *Grosmannia clavigera* (Robinson-Jeffrey and Davidson) Zipfel, de Beer, and Wingfield; and *Ophiostoma montium* (Rumbold) von Arx. Females dig egg galleries under the bark and lay eggs on alternate sides of the gallery. Larvae excavate short feeding tunnels at right angles to the egg gallery. Mature larvae construct pupal cells at the ends of the larval galleries, where larvae pupate and from which new adults later emerge. Most commonly there is one generation per year but there may be only one every two years in the coldest parts of the species' range. Larvae and adults are the overwintering stages.

Hosts Commonly Attacked

The principal hosts of this beetle are lodgepole (*P. contorta*), sugar (*P. lambertiana*), western white (*P. monticola*), ponderosa (*P. ponderosa*), and whitebark (*P. albicaulis*) pines, but *Pinus aristata* Engelmann, *P. balfouriana* Balfour, *P. coulteri* D. Don, *P. edulis* Engelmann, *P. flexilis* E. James, *P. strobiformis* Engelm., *P. longaeva* D.K. Bailey, and *P. monophylla* Torr. and Frém. have also been recorded as hosts.

Distribution

Mountain pine beetle is found throughout the pine forests of western Canada, the western United States and northern Mexico (Baja California).

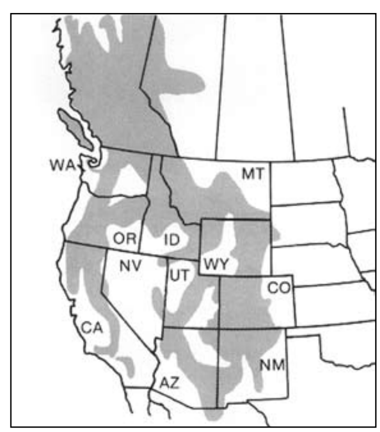

Figure 1. Distribution of mountain pine beetle, *Dendroctonus ponderosae*, in North America. (USDA Forest Service • Forest Insect & Disease Leaflet 2)

Images of Mountain Pine Beetle

Figure 2. Adults of mountain pine beetle. (Left: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org; right: Ron Long, Simon Fraser University, Bugwood.org)

Figure 3. Pitch tubes of mountain pine beetle during initiation of attack. (Left: Steven Katovich, USDA Forest Service, Bugwood.org; right: Leslie Chong, Simon Fraser University, Bugwood.org)

Figure 4. Larvae of mountain pine beetle in their galleries. (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Images of Mountain Pine Beetle (continued)

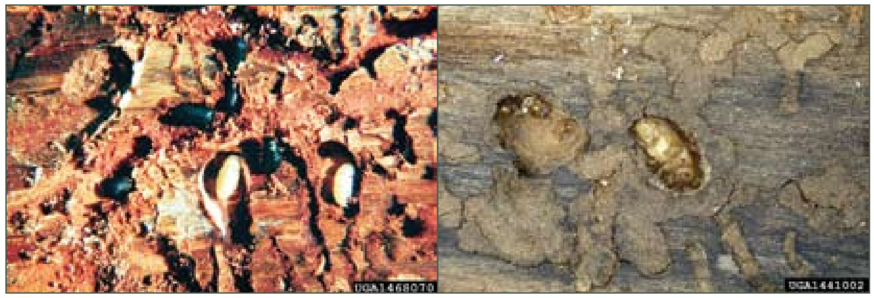

Figure 5. Pupae and adults (left) of mountain pine beetle; callow adult (right). (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

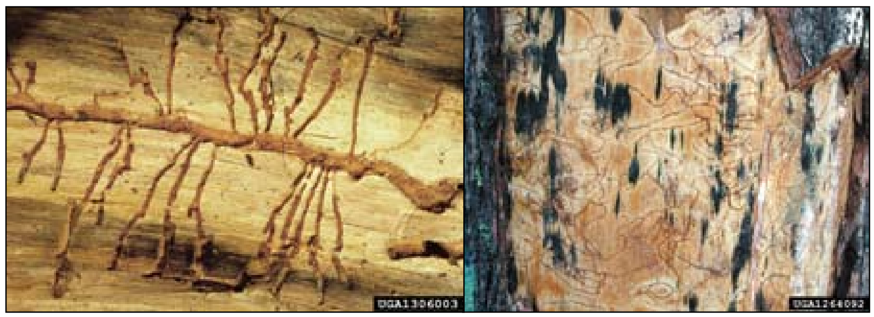

Figure 6. Galleries of mountain pine beetle (left) and galleries and blue staining of wood (right). (Left: Leslie Chong, Simon Fraser University, Bugwood.org; right: Carl Jorgensen, USDA Forest Service, Bugwood.org)

Figure 7. Lodgepole pines (left) killed by mountain pine beetle; view of infested pines (right). (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Images of Mountain Pine Beetle (continued)

Figure 8. Adult of *Enoclerus sphegeus* Fabricus, a predator of mountain pine beetle. (Brytten Steed, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of mountain pine beetle include predaceous insects such as *Enoclerus sphegeus* Fabricius, *Temnochila chlorodia* Mannerheim, and *Medetera aldrichii* Wheeler; and the parasitoid *Coeloides dendroctoni* Cushman.

Web Links for Information on Mountain Pine Beetle

http://en.wikipedia.org/wiki/Mountain_pine_beetle; Wikipedia article, including comments on implications of current massive outbreak in Canada.

http://www.ext.colostate.edu/pubs/insect/05528.html; factsheet of Colorado State University.

http://forestry.nv.gov/forestry-resources/forest-health/mountain-pine-beetle/; Nevada Division of Forestry.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-2.pdf; USDA Forest Service Forest Pest and Disease Leaflet #2. 2009 revision; provides updated, more detailed distribution map.

http://www.usu.edu/beetle; USDA Forest Service, Rocky Mountain Research Station, Western Bark Beetles website including literature.

Articles

Safranyik, L., A.L. Carroll, and B. Wilson. 2006. The biology and epidemiology of the mountain pine beetle in lodgepole pine, p. 3-66. In: Safraynyik, L. and W.R. Wilson (eds.). *The Mountain Pine Beetle: A synthesis of the biology, management and impacts on lodgepole pine.* Natural Resources Canada, Canadian Forest Service, Pacific Centre, Victoria, British Columbia: 304 p.

Robertson, C., T.A. Nelson, D.E. Jelinski, M.A. Wulder, and B. Boots. 2009. Spatial-temporal analysis of species range expansion: the case of the mountain pine beetle, *Dendroctonus ponderosae*. *Journal of Biogeography* 36(8): 1446-1453.

67. Douglas-fir Beetle, *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, a native North American bark beetle, is the most important pest of Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) in western North America and the only bark beetle attacking this important timber species. Like many bark beetles, this species often persists at low levels, breeding primarily in felled, injured or diseased trees and doing little damage to any particular stand. However, at times populations develop that are able to kill even healthy trees, over large areas. Such outbreaks may develop after extensive wind damage, droughts, or large fires that greatly increase the number of susceptible trees. The signs of this bark beetle include reddish or yellowish boring dust caught in bark crevices. Live trees may respond to attack with abundant resin flow. A male and female beetle work together to dig an oviposition gallery, where the female lays her eggs, which are deposited in groups (10-36), spaced out at intervals along the oviposition gallery. Larval dig feeding galleries that diverge from the oviposition gallery in groups that resemble fans. Larvae pupate in cells constructed at the ends of the larval galleries. The Douglas-fir beetle has one generation per year. The insect mostly overwinters as adults, but with some large larvae present as well. Adult emergence from the wood occurs from April to June, depending on location and altitude, and newly emerged beetles attack new trees in July and August. In coastal areas, host tree resistance is usually adequate to check population growth of this species. But in inland areas, where trees are subject to greater environmental stress, outbreaks are more common.

Hosts Commonly Attacked

The only breeding host of this beetle is Douglas fir (*P. menziesii*).

Distribution

Douglas-fir beetle is found throughout the range of its principal host in the western United States, Mexico, and Canada.

Images of Douglas-fir Beetle

Figure 1. Pair of adult Douglas-fir beetles, *Dendroctonus pseudotsugae*, inside gallery. (Constance Mehmel, USDA Forest Service, Bugwood.org)

Images of Douglas-fir Beetle (continued)

Figure 2. Larvae of Douglas-fir beetle in their galleries. (Left: Scott Tunnock, USDA Forest Service, Bugwood.org; right: Malcolm Furniss, Bugwood.org)

Figure 3. Red boring dust (left) and resin flow (right) on the bark of a Douglas-fir produced by adult Douglas-fir beetles. (Left: Doug Page, USDI Bureau of Land Management, Bugwood.org; right: Constance Mehmel, USDA Forest Service, Bugwood.org)

Figure 4. Galleries of Douglas-fir beetles. (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: Kenneth E. Gibson, USDA Forest Service, Bugwood.org)

Images of Douglas-fir Beetle (continued)

Figure 5. Douglas-fir killed by Douglas-fir beetle. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Figure 6. Adult of *Enoclerus sphegeus* Fabricus. (Brytten Steed, USDA Forest Service, Bugwood.org)

Figure 7. The braconid parasitoid, *Coeloides vancouverensis* (Dalla Torre), ovipositing through shaved Douglas-fir bark onto Douglas-fir beetle larvae. (Roger Ryan, USFS PNW Station, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Among the important natural enemies of the Douglas-fir beetle are *Enoclerus sphegeus* Fabricius, *Thanasimus undatulus* Say, *Temnochila chlorodia* Mannerheim, *Coeloides brunneri* Viereck, and *Medetera aldrichii* Wheeler.

Web Links for Information on Douglas-fir Beetle

http://www.forestry.ubc.ca/fetch21/FRST308/lab6/dendroctonus_pseudotsugae/douglas.html; fact sheet of the University of British Columbia.

http://www.forestpests.org/acrobat/fidl5.pdf; fact sheet of the USDA Forest Service, Insect pest and disease leaflet #5.

Articles

Furniss, M.M. 1979. An annotated bibliography of the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins). USDA Forest Service General Technical Report (INT-48): 40 p.

68. Engraver Beetle, *Ips typographus* (L.) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The engraver beetle, *Ips typographus* (L.), is native to Europe and has not yet invaded North America, but is a species of concern as a potentially serious pest of spruce (*Picea*). It is also referred to as the European spruce bark beetle. This species is the most damaging bark beetle in Europe, and historically many widespread infestations of long duration have occurred. As with many bark beetles, attack on living trees is facilitated by chemically coordinated mass attack and the vectoring of a tree-killing fungus, in this case *Ceratocystis polonica* Siem. The biology and life cycle of the insect is typical of bark beetles. Females dig oviposition galleries and deposit eggs along their length. Larvae then dig feeding galleries at right angles to the oviposition gallery, creating a fan-like appearance. Larvae pupate in chambers at the ends of larval galleries. Outbreaks are apparently initiated by events or conditions that increase quickly the number of stressed or dead trees available as breeding sites. Storms, drought, and logging (which increases the number of wind-thrown trees subsequently) have all been suggested as factors able to stimulate outbreaks. It has been suggested that natural enemies do not control low density populations, and that the regulatory factor is mortality from competition among larvae when breeding trees are scarce. However, other authors find that natural enemies cause up to 82 percent mortality to brood, suggesting they may indeed be important. Damage may be reduced by prompt removal of recently attacked trees because as many as 80 percent of parent beetles start a "sister brood" within weeks. Mass trapping with a synthetic pheromone blend is also employed.

Hosts Commonly Attacked

This beetle attacks spruces (*Picea*), such as Norway spruce (*Picea abies* [L.] H. Karst.).

Distribution

Engraver beetles are found throughout much of central Europe, Scandinavia, and east into Russia, northeastern China, Korea, and Japan.

Images of Engraver Beetle

Figure 1. Adults of the engraver beetle, *Ips typographus* (left: light brown, young adults; right: fully darkened, mature specimen). (Left: Bjørn Økland, Norwegian Forest Research Institute, Bugwood.org; right: Maja Jurc, University of Ljubljana, Bugwood.org)

Images of Engraver Beetle (continued)

Figure 2. Close-up of one egg of the engraver beetle. (Daniel Adam, Office National des Forêts, Bugwood.org)

Figure 3. Larvae of engraver beetle (in a medium density infestation). (Left: SRPV, Limoges Archive, Les Services Régionaux de la Protection des Végétaux, Bugwood.org; center: Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org; right: Daniel Adam, Office National des Forêts, Bugwood.org)

Images of Engraver Beetle (continued)

Figure 4. Pupae (left) of the engraver beetle in chambers at tips of larval galleries (in a low density infestation); right, close up of one pupa. (Left: Daniela Lupastean, University of Suceava, Bugwood.org; right: Maja Jurc, University of Ljubljana, Bugwood.org)

Figure 5. Galleries of engraver beetles: left, adults cutting oviposition galleries; right, finished larval galleries branching off oviposition gallery with pupation chambers at tips. (Both photos: Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 6. Spruce trees in Slovakia killed by the engraver beetle. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Images of Engraver Beetle (continued)

Figure 7. Traps used to detect engraver beetles (left) or for mass trapping (right, in logged area). (Both photos: Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

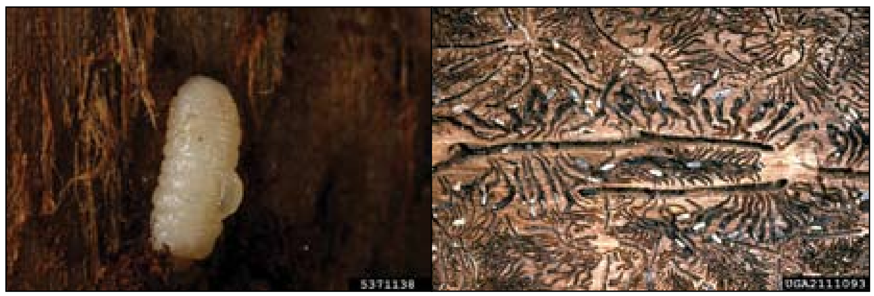

Figure 8. Left, larva of external parasitoid on larva of engraver beetle; right, multiple cocoons of ichneumonid parasitoid formed in larval galleries of engraver beetle. (Also visible in photo on right in upper and lower areas are the galleries of the smaller, very common European species, *Pityogenes chalcographus* [L.]). (Left: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org; right: Petr Kapitola, State Phytosanitary Administration, Bugwood.org)

Figure 9. Larva of the long-legged fly *Medetera signaticornis* Loew, a specialized predator of bark beetle larvae, known only from *Ips typographus*, usually in high abundance in Western Europe. (Jiri Hulcr, Michigan State University, Bugwood.org)

Images of Engraver Beetle (continued)

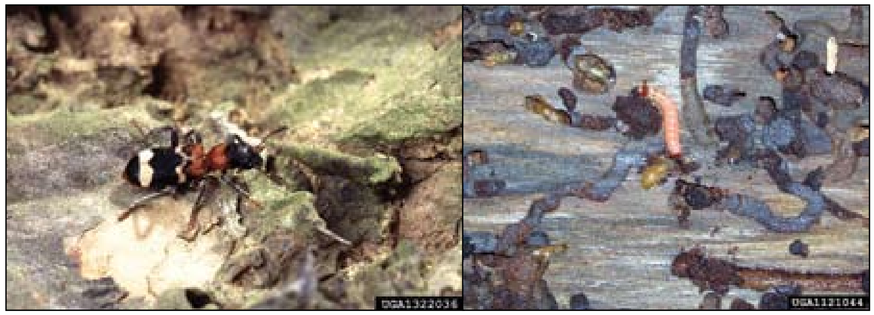

Figure 10. The red-bellied clerid beetle, *Thanasimus formicarius* (L.), is an important predator of the engraver beetle in Europe (left, adult; right, larva). (Left: Scott Bauer, USDA Agricultural Research Service, Bugwood.org; right: Daniela Lupastean, University of Suceava, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of the engraver beetle have been reported from many locations and a large number of species of parasitoids and predators have been observed. Among the commonly reported species are the red-bellied clerid beetle (*Thanasimus formicarius* [L.]), the long-legged fly *Medetera signaticornis* Loew, and various braconid and ichneumonid parasitoids. See the review by Mills and Schlup (1989).

Web Links for Information on Engraver Beetle

http://www.barkbeetles.org/exotic/htypgrph.html; fact sheet describes characters for species recognition.

http://www.fs.fed.us/foresthealth/technology/invasives_ipstypographus_riskmaps.shtml; USDA website that describes forests in the United States at potential risk from this bark beetle.

http://www.issg.org/database/species/ecology.asp?si=1441&fr=1&sts=&lang=EN; factsheet of the Global Invasive Species Database, with information on biology and method of movement between countries.

Articles

Mills, N.J. and M. Schlup. 1989. The natural enemies of *Ips typographus* in central Europe: Impact and potential use in biological control. In: Kulhavy, D.L. and M.C. Miller (eds.). *Potential for Biological Control of Dendroctonus and Ips Bark Beetles.* Published by the Center for Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas, USA: 131-146.

Wermelinger, B. 2004. Ecology and management of the spruce bark beetle *Ips typographus* – a review of recent research. *Forest Ecology and Management* 202(1/3): 67-82.

Grégoire, J.-C. and H.F. Evans. 2004. Damage and control of Bawbilt organisms - an overview, pp. 19-37. In: Lieutier, F., K.R. Day, A. Battisti, J.-C. Grégoire, and H.F. Evans (eds.). *Bark and Wood Boring Insects in Living Trees in Europe, a Synthesis.* Springer, Netherlands.

69. Pine Engraver Beetle, *Ips pini* (Say) (Coleoptera: Curculionidae [formerly Scolytidae])

Orientation to Pest

The pine engraver beetle, *Ips pini* (Say), is a native bark beetle with a very wide distribution in North America. In natural forests, this species is of little importance and is mainly associated with smaller diameter (12-20 cm) pine or spruce trees that are dying or have been recently killed by storms or logging. Under these conditions the species is beneficial and contributes to recycling of stressed or dying trees. Its numbers may increase when logging, thinning, or storms increase the amount of breeding material that is locally available. When this happens, healthy trees in the area may also be attacked. This species is considered the most important bark beetle attacking red pine (*Pinus resinosa* Sol. ex Aiton) in the Great Lakes states of the USA. Male beetles bore into trees and create a nuptial chamber. Each male produces pheromones that attract multiple females of the same species. After mating, 3 to 6 females construct oviposition galleries in the inner bark that radiate out from the nuptial chamber in a “Y” or “H” shaped pattern. Larval galleries branch off the oviposition galleries, and pupation takes place in cells at the end of the larval galleries. Pine engraver beetles can vector a blue stain fungus, which aids the beetle in killing the host tree by clogging the water-transporting elements in the tree. Symptoms and signs of pine engraver attack are essentially the same as those of many bark beetles, including yellow, red, and brown foliage of dying trees, together with boring dust and pitch tubes on the bark. Commonly, there are 3 to 4 generations per year.

Hosts Commonly Attacked

Ips pini breeds in all the species of pines and spruce in its range and is of greatest concern in lodgepole (*P. contorta* Douglas), ponderosa (*P. ponderosa* Douglas ex C. Lawson), Jeffrey (*P. jeffreyi* Balf.), and red (*P. resinosa*) pines.

Distribution

The pine engraver is found from northern Canada and Alaska to northern Mexico. It occurs throughout most of the coniferous forests of North America except the Pacific Coastal forests, the southern pine forests, and Mexico. In the eastern United States, it is widespread in the north and extends along the Appalachian Mountains south to Georgia.

Images of Pine Engraver Beetle

Figure 1. Adult of pine engraver beetle, *Ips pini*. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Pine Engraver Beetle (continued)

Figure 2. Nuptial chamber with five oviposition galleries branching off, with females in galleries at 2 and 10 o' clock. (Scott Tunnock, USDA Forest Service, Bugwood.org)

Figure 3. Larval galleries of the pine engraver projecting at right angles to the oviposition galleries. (USDA Forest Service - Region 6 - Pacific Northwest Archive, USDA Forest Service, Bugwood.org)

Figure 4. Frass ejected from bore holes by adult pine engravers. (Brytten Steed, USDA Forest Service, Bugwood.org)

Images of Pine Engraver Beetle (continued)

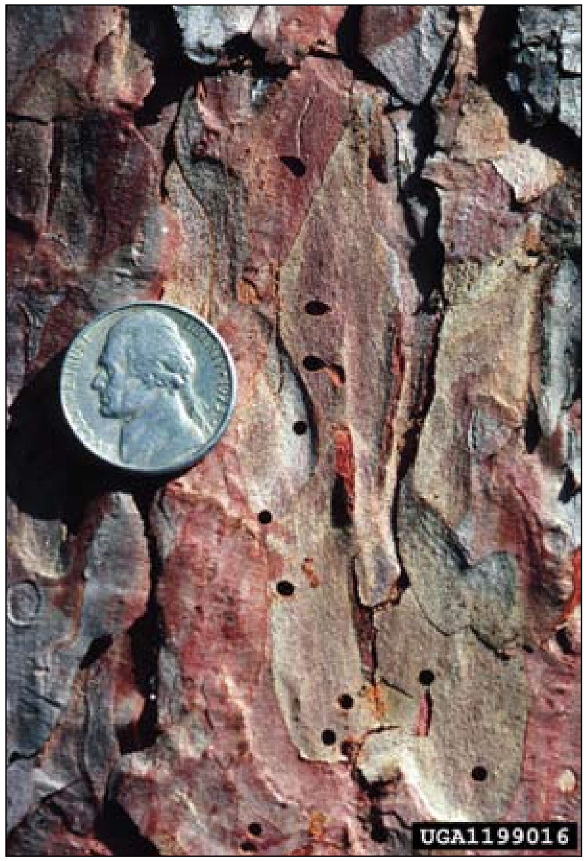

Figure 5. Adult emergence holes of pine engraver beetles. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 6. Lundgren funnel trap used to detect pine engraver beetles at a slash pile. (Brytten Steed, USDA Forest Service, Bugwood.org)

Images of Pine Engraver Beetle (continued)

Figure 7. Group of red pines (*Pinus resinosa* Soland.) in Minnesota killed by pine engraver beetle. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 8. Larva (left) and adult (right) of *Thanasimus dubius*, a common predator of the pine engraver beetle. (Left: Gerald J. Lenhard, Louiana State Univ, Bugwood.org; right: USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Figure 9. Larva (left) and adult (right) of *Enoclerus sphegeus*, a common predator of the pine engraver beetle. (Left: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org; right: Brytten Steed, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of the pine engraver beetle are similar to those of many bark beetles and include several predatory clerids, such as *Thanasimus dubius* (Fabricius) and *Enoclerus sphegeus* (Fabricius), as well as such parasitoids as the braconid *Coeloides dendroctoni* Cushman and the pteromalids *Pachyceras xylophagorum* Ratz., *Rhopalicus pulchripennis* (Crawford), and *Tomicobia tibialis* Ashmead.

Web Links for Information on Pine Engraver Beetle

http://wiki.bugwood.org/Ips_pini; a Bugwiki fact sheet on *Ips pini*.

http://www.fs.fed.us/r6/nr/fid/fidls/f122.htm; a USDA Forest Service Forest and Insect Disease Leaflet: Gibson, K.E., Kegley, S.J., and Livingston R.L. 1997. Pine Engraver, *Ips pini*, in the Western United States. Forest Insect and Disease Leaflet No. 122. USDA Forest Service.

http://www.ext.colostate.edu/pubs/insect/05558.html; perspective on other species of *Ips* (11 species in Colorado, featured on this website).

Articles

Erbilgin, N., E.V. Nordheim, B.H. Aukema, and K.F. Raffa. 2002. Population dynamics of *Ips pini* and *Ips grandicollis* in red pine plantations in Wisconsin: within- and between-year associations with predators, competitors, and habitat quality. *Environmental Entomology* 31: 1043-1051.

Dahlsten, D.L., D.L. Six, N. Erbilgin, K.F. Raffa, A.B. Lawson, and D.L. Rowney. 2003. Attraction of *Ips pini* (Coleoptera: Scolytidae) and its predators to various enantiomeric ratios of ipsdienol and lanierone in California: Implications for the augmentation and conservation of natural enemies. *Environmental Entomology* 32: 1115-1122.

70. Southern Pine Engraver, *Ips grandicollis* (Eichhoff) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The southern pine engraver (also called the eastern five-spined Ips), *Ips grandicollis* (Eichhoff), is a native bark beetle that occurs in the eastern parts of Canada and the United States, in Central America, and on some Caribbean islands. It is also invasive in Australia, where it is a pest of plantations of Monterey pine (*Pinus radiata* D. Don). The elytra (hardened forewings) end in a scoped out area with typically 5 teeth on each side. It breeds most often in recently felled trees and logging slash, but can also breed in limbs and trunks of live trees that are under attack by other bark beetle species. Most breeding occurs in limbs and the upper crown. Drought and logging both can potentially stimulate outbreaks of this species, causing small infestations to expand in area. The biology of this species is similar to that of *Ips pini* (Say). Male beetles create a nuptial chamber beneath the bark and produce pheromones that attract multiple females. After mating, the females construct 3 to 5 oviposition galleries that branch off from the nuptial chamber. The parent galleries are kept free of boring dust, unlike those of the southern pine beetle (*Dendroctonus frontalis* Zimmermann). Larval galleries branch off the oviposition galleries and are usually run horizontally across the tree trunk. Pine engraver beetles can vector a blue stain fungus, which aids the beetle in killing the host tree by clogging the water-transporting elements in the tree. Symptoms and signs of pine engraver attack are essentially the same as those of many bark beetles, including the yellow, red or brown foliage characteristic of dying trees, together with boring dust and pitch tubes on the bark. There are six or more generations per year in the southern United States.

Hosts Commonly Attacked

Ips grandicollis breeds in most of the pine species in the southern United States. North of the southern pines region, this species is principally found associated with pitch pine (*Pinus rigida* Mill.).

Distribution

The southern pine engraver is found in eastern Canada and in the eastern United States from Massachusetts west to Minnesota, Nebraska and Texas, and throughout the southern states.

Images of Southern Pine Engraver

Figure 1. Adult of southern pine engraver, *Ips grandicollis*. Right, see the scoped out area of the fore wings and the surrounding teeth. (Both photos: Pest and Diseases Image Library, Bugwood.org)

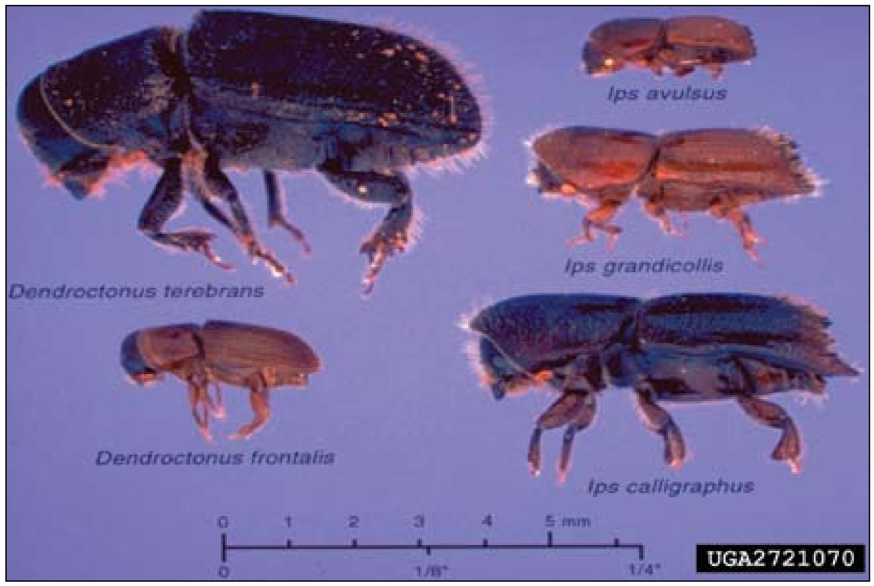

Figure 2. Comparative size of southern pine engraver (*Ips grandicollis*) relative to other southern pine bark beetles. (John L. Foltz, University of Florida, Bugwood.org)

Figure 3. Egg of southern pine engraver. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Southern Pine Engraver (continued)

Figure 4. Callow adult (left), larva (middle), and pupa (right) of southern pine engraver. (Roger Anderson, Duke University, Bugwood.org)

Figure 5. Left, nuptial chambers (see arrows) of southern pine engraver, with five and four oviposition galleries branching off; right, larval galleries branching off oviposition galleries, with pupation cells at end of each gallery. (Left: Jeffrey Eickwort, Florida Department of Agriculture and Consumer Services, Bugwood.org; right: Texas Forest Service Archive, Texas Forest Service, Bugwood.org)

Figure 6. Group of Monterey pines (*P. radiata*) in Australia, killed by southern pine engraver. (Dennis Haugen, Bugwood.org)

Images of Southern Pine Engraver (continued)

Figure 7. The predatory checkered beetle *Thanasimus dubius* is a common predator of the southern pine engraver. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of the southern pine engraver include the predatory clerid *Thanasimus dubius* (Fabricius), the predatory trogositid beetle *Temnochila virescens* (Fabricius), as well as various parasitoids, including *Roptrocerus xylophagorum* Ratzeburg. *Thanasimus dubius* and *Temnochila virescens* have been introduced into Australia against this bark beetle.

Web Links for Information on Southern Pine Engraver

http://www.na.fs.fed.us/spfo/pubs/fidls/ips/ipsfidl.htm; a USDA Forest Service leaflet on *Ips* pine bark beetles in the southern USA, comparing several species, including *I. grandicollis*.

http://www.eppo.org/QUARANTINE/insects/Ips_grandicollis/IPSXGR_ds.pdf; EPPO data sheet on *Ips grandicollis*.

Articles

Foltz, J.L., E.P. Merkel, and R.C. Wilkinson. 1984. Annotated bibliography of *Dendroctonus terebrans* (Oliver), *Ips avulsus* (Eichhoff), *Ips grandicollis* (Germar) in the southeastern USA. Monograph #12, Agricultural Experiment Station, University of Florida: 47 p.

Lawson, S.A. and F.D. Morgan. 1992. Rearing of two predators, *Thanasimus dubius* and *Temnochila virescens*, for the biological control of *Ips grandicollis* in Australia. *Entomologia Experimentalis et Applicata* 65: 225-233.

Abbott, I. 1993. Review of the ecology and control of the introduced bark beetle *Ips grandicollis* in Western Australia, 1952-1990. *CALMScience* 1: 35-46.

71. Six-spined Ips, *Ips calligraphus* (Germar) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The six-spined Ips, *Ips calligraphus* (Germar), is a native bark beetle found in both the eastern and western United States. Two subspecies of *I. calligraphus* are recognized that occur in the United States. *Ips calligraphus ponderosae* is found attacking ponderosa pine (*Pinus ponderosa* Douglas ex C. Lawson) in the Black Hills of South Dakota, the eastern Rocky Mountains, and the northern Sierra Madre Oriental of Mexico. *Ips calligraphus calligraphus* is found in the eastern United States and California (where it likely was introduced from the eastern United States). The subspecies found in the eastern United States may attack all species of southern pines, including pitch pine (*P. rigida* Millar). The eastern and western subspecies of *I. calligraphus* breed in trees that have been felled, are dying, under drought stress, or attack from other bark beetles. Trunks, stumps, and large limbs may be attacked. Trunks of apparently healthy pines may sometimes be attacked, especially in concert with other *Ips* or *Dendroctonus* species. In the southern United States, this is one of the first species to attack drought-stressed trees. Infestations may consist of scattered trees or fairly large groups of trees, particularly during periods of drought. In general, however, infestations of *Ips* species do not expand continuously as is typical of southern pine beetle (*Dendroctonus frontalis* Zimmermann) infestations. In the western United States, this species is most often found in the thick-barked portion of the boles of ponderosa pines. Male beetles construct a nuptial chamber where they attract and mate with two to six females. The females then dig individual oviposition galleries that radiate out from the nuptial chamber and are oriented vertically along the trunk. Larval galleries are broad, long, and winding, and typically run horizontally across the trunk. In the southern United States there are up to 6 or more generations per year. In California, there are typically four generations per year.

Hosts Commonly Attacked

Ips calligraphus in the eastern United States may attack all native pine species, but is found most commonly in loblolly (*P. taeda* L.), slash (*P. elliotii* Engelm.), shortleaf (*P. echinata* Mill.), longleaf (*P. palustris* Mill.), and pitch (*P. rigida*) pine. In the western United States, the principal host is ponderosa pine (*P. ponderosa*).

Distribution

The six-spined Ips subspecies found in the eastern United States occurs from Florida, north to Massachusetts, and west to Minnesota and eastern Texas. The western subspecies is found in Montana and South Dakotas, south along the eastern Rocky Mountains.

Images of Six-spined Ips

Figure 1. Adult of six-spined Ips, *Ips calligraphus*, the largest of the southern U.S. *Ips* species. (Left: David T. Almquist, University of Florida, Bugwood.org; right: John L. Foltz, University of Florida, Bugwood.org)

Figure. 2. The six teeth found at the end of the depressed area at the end of the body are diagnostic for six-spined Ips populations (see discussion of subspecies in Orientation to Pest section). (J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Figure 3. Eggs of six-spined Ips. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Six-spined Ips (continued)

Figure 4. Pupae of six-spined Ips. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 5. Nuptial chamber (at tip of pen) of the six-spined Ips, with four oviposition galleries. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Six-spined Ips (continued)


Figure 6. Larval galleries branching off the oviposition galleries (vertical) of six-spined Ips. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 7. Small pitch tube made by six-spined Ips. (G. Keith Douce, University of Georgia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of the six-spined Ips include *Thanasimus dubius* (Fabricius), *Temnochila virescens* (Fabricius), and *Medetera* spp., species that prey on a variety of *Ips* and *Dendroctonus* bark beetles. Woodpeckers (Picidae), including the endangered red-cockaded woodpecker (*Picoides borealis*), also may destroy *I. calligraphus* broods. The impact of woodpecker feeding on infested trees is greatest during winter months, when few other sources of food are available.

Web Links for Information on Six-spined Ips

http://www.barkbeetles.info/index.php; technical information on recognition, distribution and biology of bark beetles, especially those of the southern United States and Mexico.

http://www.na.fs.fed.us/spfo/pubs/fidls/ips/ipsfidl.htm; USDA Forest Service Pest and Disease Leaflet No. 129 "*Ips* bark beetles in the South".

http://entnemdept.ufl.edu/creatures/trees/beetles/ips_beetles.htm; fact sheet of the University of Florida covering various species of *Ips* bark beetles.

Articles

Wilkinson, R.C. and J.L. Foltz. 1980. A selected bibliography (1959-1979) of three southeastern species of *Ips* engraver beetles. *Bulletin of the Entomological Society of America* 26: 375-380.

Conner, M.D. and R.C. Wilkinson. 1983. *Ips* bark beetles in the South. *Forest Insect and Disease Leaflet No.129.* U.S. Department of Agriculture, Forest Service. 12 p.

Miller, M.C. 1984. Mortality contribution of insect natural enemies to successive generations of *Ips calligraphus* (Germar) (Coleoptera, Scolytidae) in loblolly pine. *Zeitschrift für Angewandte Entomologie* 98(5): 495-500.

Lanier, G.N., S.A. Teale, and J.A. Pajares. 1991. Biosystematics of the genus *Ips* (Coleoptera: Scolytidae) in North America: review of the *Ips calligraphus* group. *The Canadian Entomologist* 123: 1103-1124.

72. Small Southern Pine Engraver, *Ips avulsus* Eichhoff (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The small southern pine engraver, *Ips avulsus* Eichhoff, is a native North American bark beetle found throughout the eastern United States. It is the smallest of the various species in this genus that breed in eastern pines. Attacks are concentrated on sections of trees with thin-bark, such as young pines or the limbs and tops of older trees. Attacks may occur in young trees and the tops of large living trees, which may be killed. However, when large living trees are attacked, the infestation is usually limited to the upper crown, and the mid- and lower boles of the same tree are often colonized by other species of *Ips* (*Ips calligraphus* Germar, *Ips grandicollis* Eichhoff, or the southern pine beetle [*Dendroctonus frontalis* Zimmermann]). Any tree cutting or accidental injury that creates a pitch flow can induce attack by this species. Adults are very small (2-3 mm) and the tip of the abdomen (the depressed area) is shallow, with deep knobs and four small teeth on each margin. Males create a nuptial chamber and produce a pheromone that attracts one or more females. After mating, each female constructs a linear oviposition gallery in the inner bark that parallels the grain of the wood. Larval galleries are short and transverse, and each ends in a pupal cell in the phloem when the larva completes development. Pine engraver beetles can vector a blue stain fungus, which aids the beetle in killing the host tree by clogging the water-transporting elements in the tree. Symptoms and signs of pine engraver attack are essentially the same as those of many bark beetles, including the yellow, red, or brown foliage characteristic of dying trees, together with boring dust and pitch tubes on the bark. In the southern United States, there may up to 10 or more generations per year.

Hosts Commonly Attacked

Ips avulsus breeds in various southern pines, including eastern white (*Pinus strobus* L.), loblolly (*P. taeda* L.), longleaf (*P. palustris* Miller), pitch (*P. rigida* Miller), pond (*P. serotina* Michx.), sand (*P. clausa* [Chapm. ex Engelm.] Sarg.), shortleaf (*P. echinata* Miller), slash (*P. elliottii* Engelm.), and Virginia (*P. virginiana* Miller) pines.

Distribution

The small southern pine engraver occurs from Pennsylvania to Florida and west to Texas.

Images of Small Southern Pine Engraver

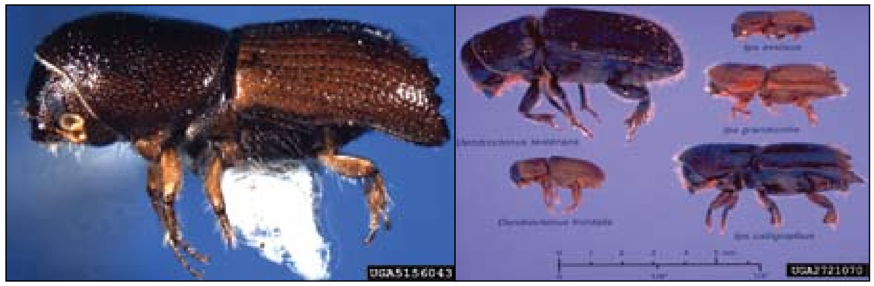

Figure 1. Adult (left) of the small southern pine engraver, *Ips avulsus*, which is the smallest of the eastern *Ips* species, as seen in relation to the other southern pine bark beetle species (right). (Left: J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org; right: John L. Foltz, University of Florida, Bugwood.org)

Figure 2. The depressed region at the posterior of the small southern pine engraver is shallow, with strong knobs on its surface and four teeth along each side. (J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Figure 3. The pitch tube of the small southern pine engraver (center of photo, small). (David J. Moorhead, University of Georgia, Bugwood.org)

Images of Small Southern Pine Engraver (continued)

Figure 4. A pair of small southern pine engraver beetles in their nuptial chamber, showing associated oviposition galleries. (Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org)

Figure 5. Short galleries made by larvae radiating out from linear oviposition galleries of the small southern pine engraver. (Jeffrey Eickwort, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Figure 6. Galleries, pupae, and larvae of the small southern pine engraver. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Small Southern Pine Engraver (continued)

Figure 7. Pupal cells of small southern pine engraver give a paddle-like appearance to the larval galleries. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Figure 8. Attacks of the small southern pine engraver on larger trees are concentrated in the tops of trees (here, a loblolly pine [*Pinus taeda*]). (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of the small southern pine engraver have not been reported but likely are similar to those of other *Ips* species.

Web Links for Information on Small Southern Pine Engraver

http://www.na.fs.fed.us/spfo/pubs/fidls/ips/ipsfidl.htm; a fact sheet on southern *Ips* in general; gives list of host trees and map of range by *Ips* species.

http://edis.ifas.ufl.edu/in701; a University of Florida fact sheet on various southern *Ips* species.

Articles

Foltz, J.L., E.P. Merkel, and R.C. Wilkinson. 1984. Annotated bibliography of *Dendroctonus terebrans* (Oliver), *Ips avulsus* (Eichhoff), *Ips grandicollis* (Germar) in the southeastern USA. Monograph #12, Agricultural Experiment Station, University of Florida: 47 p.

Birch, M.C., P. Svihra, T.D. Paine, and J.C. Miller. 1980. Influence of chemically mediated behavior on host tree colonization by four cohabiting species of bark beetles. *Journal of Chemical Ecology* 6: 395-414.

73. Silver Fir Beetle, *Pseudohylesinus sericeus* (Mannerheim) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The silver fir beetle, *Pseudohylesinus sericeus* (Mannerheim), is a minor pest that attacks windthrown, felled, injured, and severely suppressed trees. The damage it causes is rarely important. However, in the 1940s and 1950s, large outbreaks occurred on Pacific silver fir (*Abies amabilis* Douglas ex J.Forbes) in the Pacific Northwest of the United States. In Oregon, there is one generation per year, but in Washington, a generation requires two years. The egg gallery is transverse. In large trees, attacks occur in the upper bole and limbs. The beetle often attacks trees that are infected with brown-stain or root-rotting fungi such as *Armillaria* sp., *Heterobasidion annosum* (Fr.) Bref., and *Phellinus weirii* (Murrill) Gilbert.

Hosts Commonly Attacked

The principal hosts of the silver fir beetle are various fir (*Abies*), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Distribution

The silver fir beetle ranges principally from British Columbia to California and eastward to northern Idaho. It also may occur in southeast Alaska and western Montana.

Image of Silver Fir Beetle

Figure 1. Adult of *Pseudohylesinus* sp. (Province of British Columbia, Minstry of Forests and Range, Forest Practices Branch)

Important Biological Control Agents Related to this Pest Species

The natural enemies of silver fir beetle are unknown.

Web Links for Information on Silver Fir Beetle

http://www.for.gov.bc.ca/hfp/publications/00198/silver_fir_beetle.htm; fact sheet of the forestry department of the province of British Columbia, Canada.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-60.pdf; USDA Forest Service pest leaflet on silver fir beetle.

Articles

Gara, R.I. 1982. Insect pests of true firs in the Pacific Northwest. In: Oliver, C.D. and R.M. Kenady (eds.). Proceedings of the biology and management of true fir in the Pacific Northwest. Seattle-Tacoma, Washington, February 24-26, 1981. Contribution, Institute of Forest Resources, University of Washington (45): 157-160.

74. Fir Engraver, *Scolytus ventralis* LeConte (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The fir engraver, *Scolytus ventralis* LeConte, is a pest of true firs in western North America. Adults are about 4.0 mm long, making this one of the largest species in the genus *Scolytus*. The egg galleries dug by females are transverse to the trunk and galleries are deep enough to deeply score the wood, especially close to the nuptial chamber. Eggs are laid along the oviposition galleries, from which larvae dig lateral galleries up or down the trunk after hatching. Pupation occurs in the inner bark at the end of the larval galleries. Fir engraver attacks trees of varying ages and transmits the brown-stain fungus *Trichosporium symbioticum* Wright, which is essential for successful brood development. Stressed trees that are infected with various fungi or that have been damaged by outbreaks of other insects are likely to be attacked by the fir engraver. Effects of this bark beetle vary, with some trees dying quickly, while others are just top-killed or recover, even from repeated attacks. There is one generation per year, or in some areas, only one in two years. In intensively managed areas, prompt removal or treatment of infested trees may help protect remaining trees for a time, but in most areas control is best achieved by trying to lower sources of stress and maintain high tree vigor.

Hosts Commonly Attacked

The principal hosts of the fir engraver are various species of fir (*Abies*), especially white (*Abies concolor* [Gordon] Lindley ex Hildebrand), grand (*A. grandis* [Douglas ex D. Don] Lindley), and red fir (*A. magnifica* A. Murray). Occasionally Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco), hemlock (*Tsuga*), or spruce (*Picea*) are attacked.

Distribution

The fir engraver ranges from British Columbia to California, Wyoming, Colorado, Arizona, and New Mexico.

Images of Fir Engraver

Figure 1. Adult of the fir engraver, *Scolytus ventralis*. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Images of Fir Engraver (continued)

Figure 2. Pitch streamers on trunk are a sign of attack on fir by the fir engraver. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Figure 3. Bubbled bark is a sign of previous fir engraver attacks survived by a tree. (Chris Schnepf, University of Idaho, Bugwood.org)

Images of Fir Engraver (continued)

Figure 4. Galleries of the fir engraver. Note the horizontal oviposition gallery, with multiple larval galleries above and below. (Dave Holland, USDA Forest Service, Bugwood.org)

Figure 5. White fir (*Abies concolor*) killed by the fir engraver. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Images of Fir Engraver (continued)

Figure 6. Top kill is a sign of attack of fir engraver on large, otherwise healthy, trees. (Kenneth E. Gibson, USDA Forest Service, Bugwood.org)

Figure 7. Damage at the stand level from the fir engraver. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of fir engraver are relatively unstudied.

Web Links for Information on Fir Engraver

http://forestry.nv.gov/forestry-resources/forest-health/fir-engraver-beetle/; Nevada Division of Forestry fact sheet.

www.oregon.gov/ODF/privateforests/docs/fh/FirEngraver.pdf?ga=t; Oregon Department of Forestry website.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-13.pdf; USDA Forest Service Forest Insect and Pest Leaflet on fir engraver.

Articles

Berryman, A.A. 1973. Population dynamics of the fir engraver, *Scolytus ventralis* (Coleoptera: Scolytidae). I. Analysis of population behavior and survival from 1964 to 1971. *The Canadian Entomologist* 105: 1465-1488.

75. Columbian Timber Beetle, *Corthylus columbianus* Hopkins (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Columbian timber beetle, *Corthylus columbianus* Hopkins, is a native North American ambrosia beetle, one of a group of beetles that vector wood-destroying fungi, which the beetle larva then eats. Unlike most ambrosia beetles, Columbian timber beetles attack live trees rather than dead, dying, or newly felled trees. Trees, however, do not die, since trees are able to fill galleries with callus tissue. However, losses occur from lowered quality of timbers cut from infested trees, due to the presence of callus-filled galleries and fungal-stained wood.

Hosts Commonly Attacked

Columbian timber beetles attack a wide range of hardwoods, including various oaks (*Quercus*) and maples (*Acer*), sycamore (*Platanus occidentalis* L.), poplar (*Populus*), elm (*Ulmus*), beech (*Fagus*), and others.

Distribution

The Columbian timber beetle ranges in the United States from Massachusetts to Georgia, west to Michigan and Missouri.

Images of Columbian Timber Beetle

Figure 1. Callow adult (left) and pupae of the Columbian timber beetle, *Corthylus columbianus*. (Jack C. Nord, USDA Forest Service, Bugwood.org)

Images of Columbian Timber Beetle (continued)

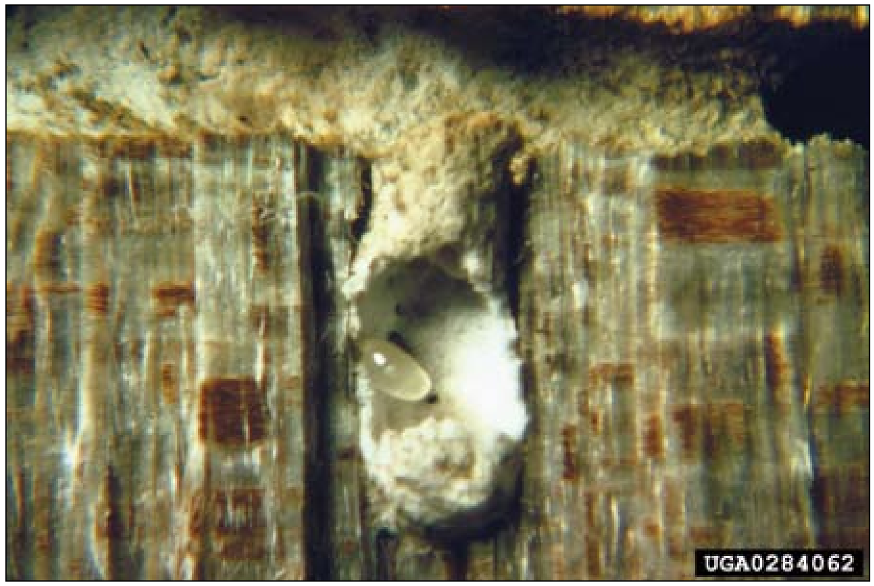

Figure 2. Egg of Columbian timber beetle in chamber prepared by adult. Note the ambrosia fungus (*Ambrosiella eylebori* Brader) coating the chamber, which is inoculated into the gallery by the adult. (Jack C. Nord, USDA Forest Service, Bugwood.org)

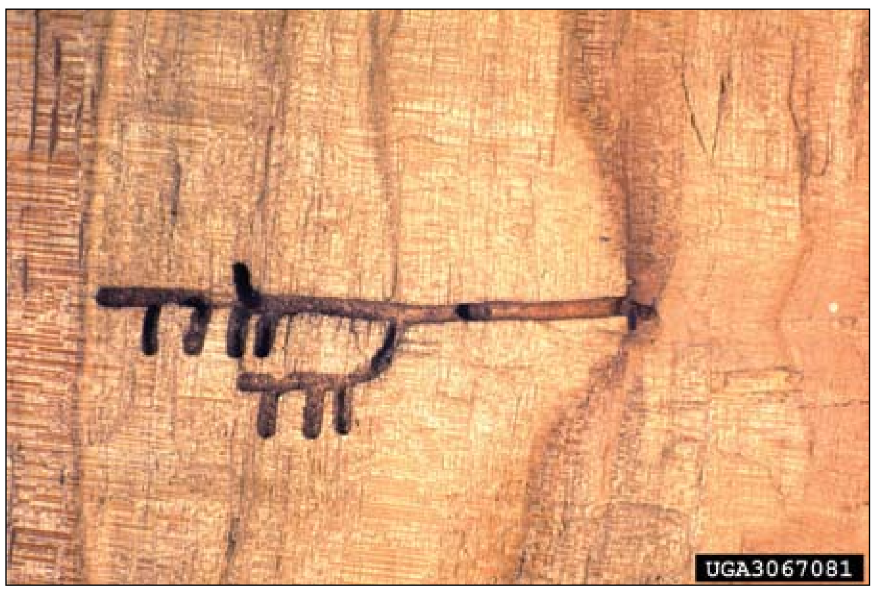

Figure 3. Galleries of Columbian timber beetle. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Columbian Timber Beetle (continued)

Figure 4. Emergence holes and sap-soaked patches on trunk are signs of Columbian timber beetles. (Left: Jack C. Nord, USDA Forest Service, Bugwood.org; right: James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Milled maple timber shows the callus-filled galleries of Columbian timber beetle, and blue staining of associated ambrosia fungus. (Left: Jack C. Nord, USDA Forest Service, Bugwood.org; right: James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of Columbian timber beetle have not been reported.

Web Links for Information on Columbian Timber Beetle

http://wiki.bugwood.org/Archive:South/Corthylus_columbianus; Bugwiki fact sheet.

Articles

Milne, D.H. and R.L. Giese. 1969. The Columbian timber beetle, *Corthylus columbianus* (Coleoptera: Scolytidae). IX. Population biology and gallery characteristics. *Entomological News* 80(9): 225-237.

76. Ambrosia Beetles, *Xyleborus* spp. (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pests

Xyleborus ambrosia beetles are a genus of wood-boring beetles that carry fungi that colonize their galleries and serve as food for their larvae. Other genera of beetles that have similar symbiotic relationships with fungi are also referred to as ambrosia beetles. The genus *Xyleborus* appears to be a collection of poorly related beetles that is in need of revision. As currently constructed, there are at least 17 species in the United States and Canada (16 in the eastern United States), mostly native but with several invasive species. Many of these species breed in both coniferous and deciduous trees and shrubs of all sizes. Trees preferred for attack are ones that are unhealthy, dying, or that have recently been wounded or felled. Dead areas in living trees can also be attacked. Because this group of beetles inoculate their larval galleries with wood-decay fungi, which are eaten by their larvae, these beetles are able to make their larval galleries in heartwood (a zone of low nutrition), in contrast to bark beetles, which feed in the more nutritious sapwood. Notes on the biology and distribution of four species of *Xyleborus* are given here. Many new invasive species within this group have been detected recently in North America. One invasive species, the redbay ambrosia beetle (*Xyleborus glabratus* Eichhoff), is discussed separately elsewhere in this publication.

Species	Comments on Biology and Gallery Shape
Xyleborus celsus Eichh.	The largest member of the genus in the United States, this species' galleries extend directly into the wood to a depth of 12 to 18 mm, then branch one or several times.
Xyleborus ferrugineus (F.)	Galleries similar to *X. celsus* but smaller; galleries may also be longer, more winding, and branch less frequently.
Xyleborus affinis Eichh.	Galleries consist of elongate tunnels, off of which many transverse galleries branch.
Xyleborus xylographus (Say)	Attacks are commonly initiated at edges of wounds, deep crevices, or burrows made by other insects. Galleries run obliquely across the grain to depths of an inch or more.

Hosts Commonly Attacked

Species	Hosts
Xyleborus celsus Eichh.	Breeds in dead, dying, and recently felled trees and stumps of hickory.
Xyleborus ferrugineus (F.)	Breeds in dead, dying, or felled trees of a wide range of species including oak, hickory, ash, cypress, walnut, pine, beech, and sweetgum.
Xyleborus affinis Eichh.	Breeds in dying trees and in green logs and lumber of various hardwood trees such as oak, hickory, sweetgum, river birch, hackberry, mimosa, persimmon, cypress, and black locust. Very destructive of sweet gum in southeastern United States along the Gulf of Mexico.
Xyleborus xylographus (Say)	Attacks the lower portions of dying trees and the stumps, roots, and slash of its hosts. Found especially in oak, but also in hickory, chestnut, walnut, and pine.

Distribution

Species	Distribution
Xyleborus celsus Eichh.	Found in eastern United States, west to Kansas.
Xyleborus ferrugineus (F.)	Occurs from New York and Michigan, south to Florida and Texas.
Xyleborus affinis Eichh.	Occurs in eastern United States east of a line from Michigan to Texas and south of New York.
Xyleborus xylographus (Say)	Occurs in eastern Canada and in the United States, west to Kansas.

Images of *Xyleborus* Ambrosia Beetles

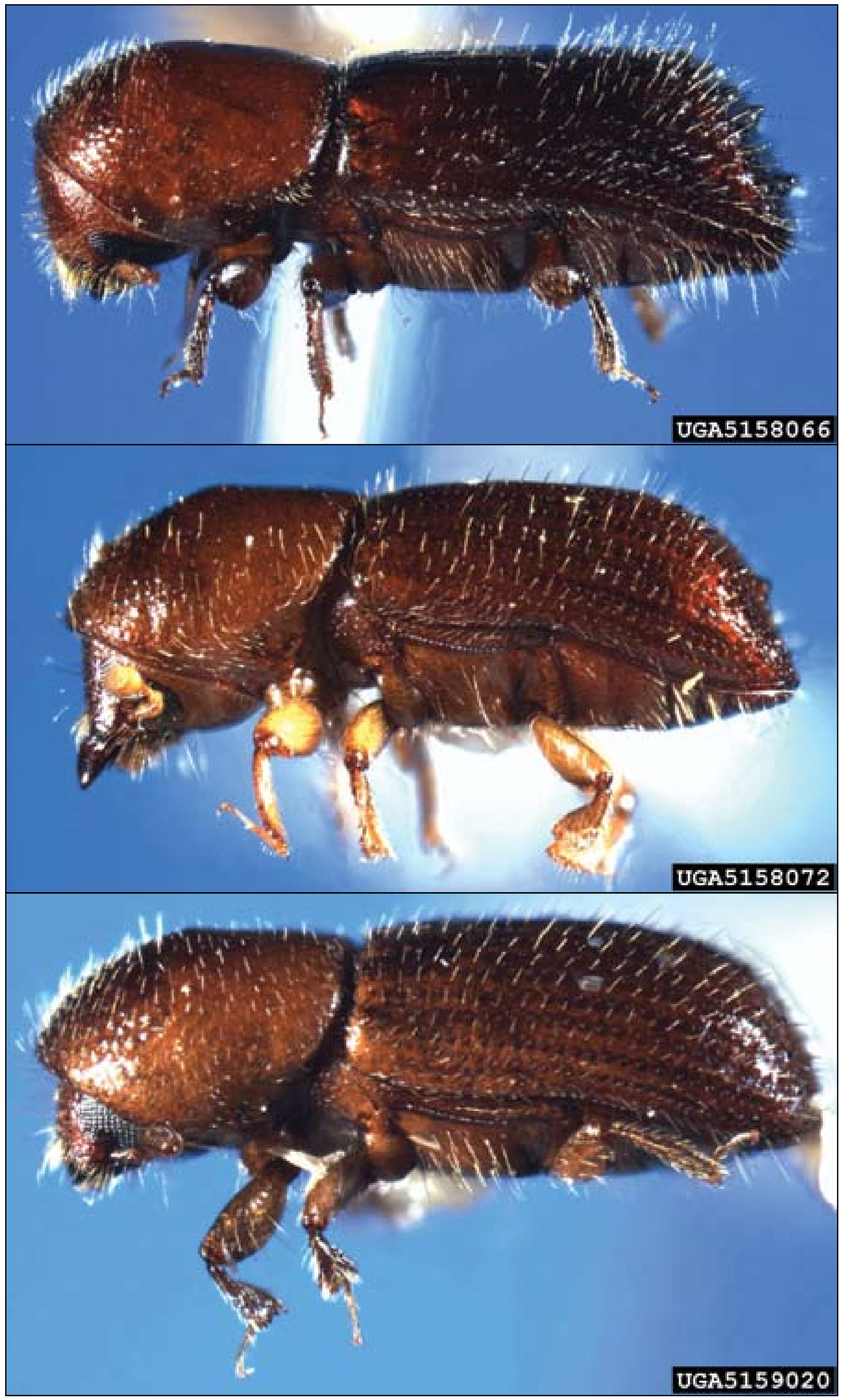

Figure 1. Adults of *Xyleborus celsus* (top), *Xyleborus ferrugineus* (middle), and *Xyleborus xylographus* (bottom). (All photos: J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Images of *Xyleborus* Ambrosia Beetles (continued)

Figure 2. Galleries of *Xyleborus celsus* in cross sections of hickory (*Carya*) stems, showing intial deep pentration in the wood, with formation of branched galleries in the heart wood. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of these beetles are poorly known.

Web Links for Information on *Xyleborus* Ambrosia Beetles

None

Articles

Atkinson, T.H., R.J. Rabaglia, and D.E. Bright. 1990. Newly detected exotic species of *Xyleborus* (Scolytidae) in eastern North America, with a revised key to species. *The Canadian Entomologist* 122: 93-104.

Haack, R.A. 2006. Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research* 36(2): 269-288.

77. Redbay Ambrosia Beetle, *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The redbay ambrosia beetle, *Xyleborus glabratus* Eichhoff, was detected in the United States for the first time in 2002 and has since caused extensive mortality of redbay (*Persea borbonia* [L.] Spreng.) and sassafras (*Sassafras albidum* [Nutt.] Nees) in coastal areas of South Carolina, Georgia, and parts of Florida. This ambrosia beetle is the vector of a lethal fungal pathogen (*Raffaelea lauricola* Harrington, Fraedrich and Aghayeva) that affects various species in the Lauraceae. Infected trees wilt and die within a few weeks or months of initial infection. This disease has been designated as "laurel wilt," and it is believed to have arrived along with the redbay ambrosia beetle in wood packing material (crates and pallets) used in trade. *Xyleborus glabratus* is about 2 mm long, dark brown to almost black in color, nearly glabrous (shiny, without hairs), and has an abruptly slanting depression at the tip of it abdomen. However, positive confirmation of this species' presence in a new area requires confirmation by a taxonomic specialist. Very little is known specifically about the biology of this beetle but it is likely similar to that of other members of this genus (see other insects in this publication). Adults and larvae inoculate new galleries with spores of a symbiotic pathogenic fungus, which are carried in special pockets at the base of the beetles' mandibles. Males are flightless. Females can attack healthy hosts, and, in Florida and Georgia, female beetles fly throughout the year although at very low numbers in the winter. Signs of redbay ambrosia beetle attack include small strings of compacted sawdust protruding from the bark at the point of attack, but these strings soon disintegrate and are not unique to this species. Small holes the diameter of a paperclip wire in redbay are usually redbay ambrosia beetle entrance holes. Foliage of infested trees wilts because the fungal infection is systemic in the vascular elements of the tree, and foliage turns reddish brown. As infected trees start to die, they may also be attacked by other species of ambrosia beetle, particularly *Xylosandrus crassiusculus* (Motschulsky). In Florida, up to 90 percent of redbay trees died in less than two years following initial beetle invasion of a new site. Loss of redbay will likely severely harm populations of the Palamedes swallowtail (*Papilio palamedes* [Drury]), which feeds primarily on species of *Persea*. There is also considerable concern about the potential impact of laurel wilt on avocado (*P. americana* Miller), which is an economically important crop in Florida and California.

Hosts Commonly Attacked

In addition to redbay (*P. borbonia*) and sassafras (*S. albidum*), the wilt pathogen spread by the redbay ambrosia beetle has been recovered in the United States from avocado (*P. americana*), swampbay (*P. palustris* [Raf.] Sarg.), pondspice (*Litsea aestivalis* [L.] Fernald), pondberry (*Lindera melissifolia* [Walter] Blume) and camphor (*Cinnamomum camphora* [L.] Sieb.). Pondspice and pondberry are of special concern because they are rare or endangered species. Avocado is of concern because of its economic importance.

Distribution

The redbay beetle is native to South Asia (India, Myanmar) and East Asia (Japan, Taiwan). The invaded range in the United States includes coastal and adjacent areas of Georgia, South Carolina, and Florida, as well as parts of North Carolina, one area in Mississippi, and two counties in Alabama.

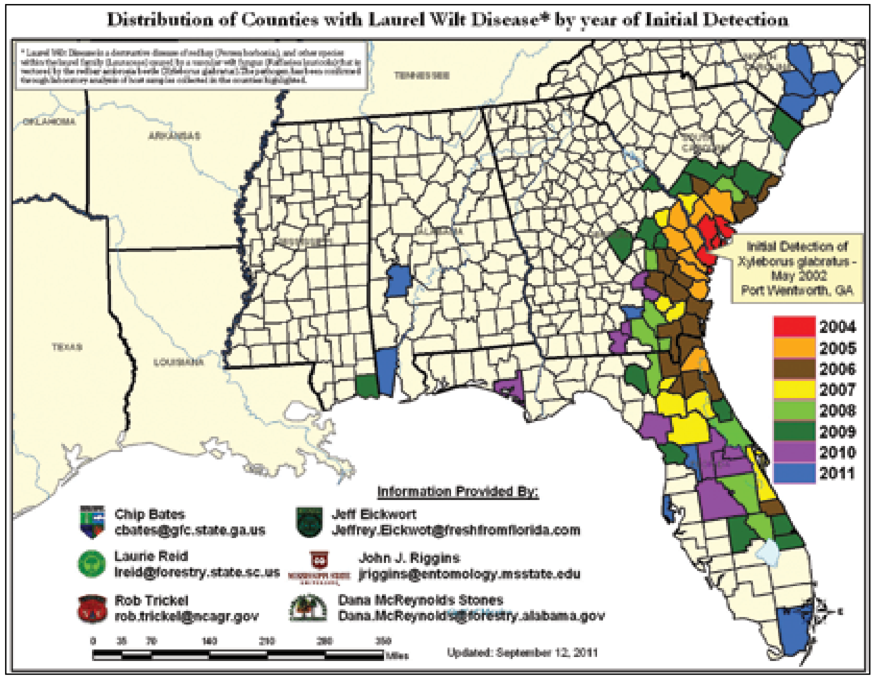

Figure 1. Map of the range of redbay ambrosia beetle, *Xyleborus glabratus*, in the United States. (USDA Forest Service - Southern Region • Forest Health Protection - Laurel Wilt)

Images of Redbay Ambrosia Beetle

Figure 2. Adult of the redbay ambrosia beetle; bottom, insect in natural position. (Top: Michael C. Thomas, Florida Department of Agriculture and Consumer Services, Bugwood.org; bottom: Shipher Wu)

Images of Redbay Ambrosia Beetle (continued)

Figure 3. Egg of redbay ambrosia beetle, inside gallery cut by female beetle. (Karolynne Griffiths, USDA APHIS PPQ, Bugwood.org)

Figure 4. Larva of redbay ambrosia beetle. (Bettaman/Shipher at shipher@gmail.com)

Figure 5. Ambrosia beetles produce frass tubes at points of entrance for adult beetles during the construction of their galleries. The long tubes are *Xyleborus crassiusculus*, while the very short tubes in the debarked area are redbay ambrosia beetle. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Redbay Ambrosia Beetle (continued)

Figure 6. Galleries of redbay beetle in redbay tree trunk, seen in cross section. (James Johnson, Georgia Forestry Commission, Bugwood.org)

Figure 7. Dark staining of the vascular tissue is a sign of the fungus associated with the redbay ambrosia beetle. (Both photos: Albert [Bud] Mayfield, USDA Forest Service, Bugwood.org)

Images of Redbay Ambrosia Beetle (continued)

Figure 8. Dead redbay killed by redbay ambrosia beetle and its associated fungus. The percentage of redbay mortality in this section of Florida forest increased from 10 percent to 81 percent within a year. (Albert [Bud] Mayfield, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of redbay ambrosia beetle are unknown at this time.

Web Links for Information on Redbay Ambrosia Beetle

http://www.freshfromflorida.com/pi/enpp/ento/x.glabratus.html; fact sheet of the Florida Department of Agriculture and Consumer Services, Division of Plant Industry.

http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=148&langdisplay=english; fact sheet of Exotic Forest Pest Information System for North America.

http://www.invasivepests.org/products/gallery/xylgl1; fact sheet about risks to trees of moving firewood.

http://www.redorbit.com/news/science/1685690/tiny_beetle_threatens_floridas_avocado_industry/; redbay ambrosia beetle as a threat to avocado industry in the United States.

http://www.invasive.org/browse/subinfo.cfm?sub=10998; fact sheet of Bugwood Wiki.

http://www.public.iastate.edu/~tcharrin/LaurelWilt.html; factsheet on the wilt pathogen and links to PDF versions of relevant articles.

Articles on Redbay Ambrosia Beetle

Douce, G.K. and J. Johnson. 2005. *Xyleborus glabratus* in Georgia's coastal forests. *Georgia Forestry Commission Pest Alert*, October 31, 2005.

Hanula, J.L., A.E. Mayfield, III, S.W. Fraedrich, and R.J. Rabaglia. 2008. Biology and host associations of redbay ambrosia beetle (Coleoptera: Curculionidae: Scolytinae), exotic vector of laurel wilt killing redbay trees in the southeastern United States. *Journal of Economic Entomology* 101: 1276-1286.

Fraedrich, S.W., T.C. Harrington, R.J. Rabaglia, M.D. Ulyshen, A.E. Mayfield, III, J.L. Hanula, J.M. Eickwort, and D.R. Miller. 2008. A fungal symbiont of the redbay ambrosia beetle causes a lethal wilt in redbay and other Lauraceae in the southeastern United States. *Plant Disease* 92: 215-224. (Available at http://www.public.iastate.edu/~tcharrin/LaurelWilt.html).

Harrington, T.C., S.W. Fraedrich, and D.N. Aghayeva. 2008. *Raffaelea lauricola*, a new ambrosia beetle symbiont and pathogen on the Lauraceae. *Mycotaxon* 104: 399-404. (Available at http://www.public.iastate.edu/~tcharrin/LaurelWilt.html).

Mayfield, A.E, T.C. Harrington, S. Fraedrich, J. Hanula, and others. 2009. Recovery plan for laurel wilt on redbay. In: *Plant Diseases that Threaten U.S. Agriculture.* Prepared for the National Plant Disease Recovery System, USDA and the American Phytopathological Society. 27 p. (Available at http://www.public.iastate.edu/~tcharrin/LaurelWilt.html).

78. Walnut Twig Beetle, *Pityophthorus juglandis* Blackman (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The walnut twig beetle, *Pityophthorus juglandis* Blackman, is the vector of a newly recognized fungal species, *Geosmithia morbida* Kolarík, Freeland, Utley, and Tisserat (Ascomycota: Hypocreales). This insect-pathogen complex causes a fatal disease of eastern black walnut (*Juglans nigra* L.) and certain other species of walnut (*Juglans*). The common name for the disease is "thousand cankers" because death results from the coalescing of a great many small, separate cankers that originate at multiple points of twig beetle entry into twigs, branches, and main stems. Walnut twig beetle, a type of bark beetle native to the southwestern United States and parts of Mexico, is the only confirmed vector of the pathogen. In its early stages this disease appears as circular-to-oblong cankers that develop at the site of each walnut twig beetle gallery. Over time, cankers expand in the phloem, coalesce, and girdle twigs or branches. *Geosmithia morbida* does not move systemically within the tree and the pathogen is moved between trees only by the insect vector. Relatively large numbers of walnut twig beetles are needed to cause enough cankers to kill trees. The origin of this newly recognized pathogen is uncertain, but isolates from walnut species in the western United States show high genetic diversity, suggesting the fungus may be native to that region. Why the walnut twig beetle has recently increased to levels able to unleash a wave of walnut mortality is unknown, but is likely linked to its invasion of new parts of the country and attacks there on new species of walnut, some of which are highly susceptible. On black walnut in Colorado, the walnut twig beetle overwinters as adults in cavities excavated in the bark. Beetles colonize new hosts by attacking branches with rough bark, on the warmer side (exposed to sun). There are two overlapping generations per year in Colorado. Mass attacks are mediated by aggregation pheromones. Females dig oviposition galleries, inoculate with the galleries with their *Geosmithia* fungus, and then lay eggs along the gallery. Larvae emerge and dig tunnels, where they feed on fungus-infected wood.

Hosts Commonly Attacked

Trees that are highly susceptible to walnut twig beetle attack and fungal infection in the western United States include the California walnut (*J. californica* S. Wats.), Hinds walnut (*J. hindsii* [Jeps.] Jeps. ex R.E. Sm) (both native to California), and black walnut (*J. nigra*) (native only to the eastern United States). English walnut (*J. regia* L.) is moderately susceptible, while Arizona walnut (*J. major* [Torr.] A. Heller)—believed to be the original host for the beetle—appears to be quite tolerant. Two other important members of the walnut family—butternut (*J. cinerea* L.) and pecan (*Carya illinoinensis* [Wangenh.] K. Koch)—appear to be resistant to the pathogen.

Distribution

Walnut twig beetle and its associated pathogen are now reported from eight states in the western USA and three in the east (Tennessee, Virginia, and Pennsylvania). To what extent the western distribution reflects the native range versus recent spread into new locations is not certain.

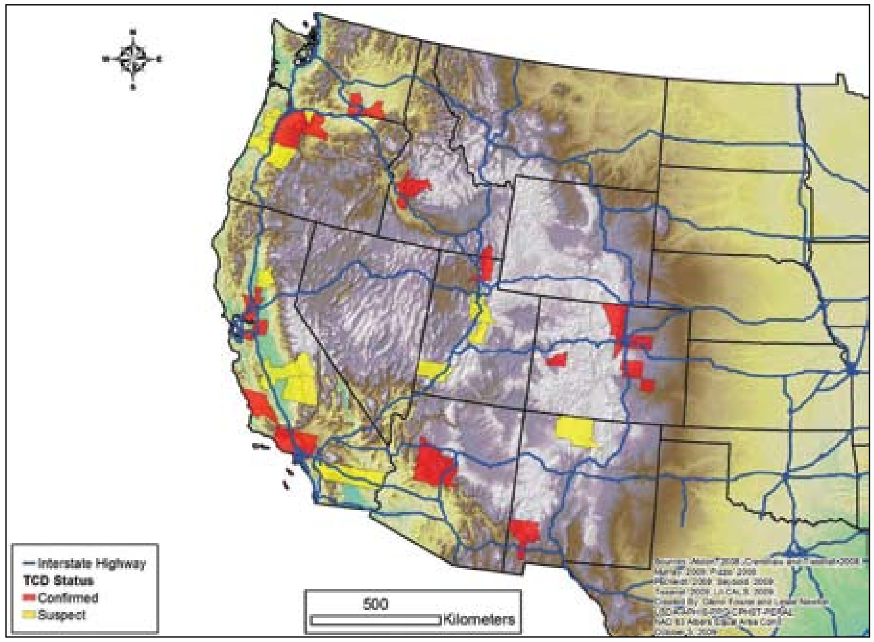

Figure 1. Distribution of the thousand cankers disease (plus, one eastern location in Knoxville, Tennessee). (USDA APHIS)

Images of Walnut Twig Beetle

Figure 2. Adult of the walnut twig beetle, *Pityophthorus juglandis*. (Steven Valley, Oregon Department of Agriculture, Bugwood.org)

Images of Walnut Twig Beetle (continued)

Figure 3. Piles of boring dust at entrance of points of adult walnut twig beetle attack. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 4. Adults of walnut twig beetles, in nuptial chamber. (Curtis Utley, CSUE, Bugwood.org)

Figure 5. Egg gallery of walnut twig beetle. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Walnut Twig Beetle (continued)

Figure 6. Larvae of walnut twig beetle. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 7. Galleries of walnut twig beetle in branch. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 8. Larva and pupa of walnut twig beetle, with a view of its fungal associate, *Geosmithia morbida*, which is sporulating profusely around the pupal cells. (Curtis Utley, CSUE, Bugwood.org)

Images of Walnut Twig Beetle (continued)

Figure 9. Weeping wounds are signs of attack by walnut twig beetle on English walnut, *Juglans regia*. Symptoms on black walnut are different. (Ned Tisserat, Colorado State University, Bugwood.org)

Figure 10. Emergence holes of walnut twig beetle. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Walnut Twig Beetle (continued)

Figure 11. Cankers that have developed around the galleries of walnut twig beetle. (Ned Tisserat, Colorado State University, Bugwood.org)

Figure 12. Branch death and dieback are early symptoms of walnut twig beetle attack (seen here on Arizona walnut). (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 13. Black walnut trees dying or dead due to thousand cankers disease. (Curtis Utley, CSUE, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of walnut twig beetle have not been reported.

Web Links for Information on Walnut Twig Beetle

http://tn.gov/agriculture/publications/regulatory/tc_pathwayanalysis.pdf; a Tennessee website where a USDA APHIS document is posted that gives background information on vector and thousand cankers pathogen, plus an analysis of likely means of further spread.

http://caforestpestcouncil.org/wp-content/uploads/2009/05/steven-seybold-walnut.pdf; a Power Point presentation from a meeting that covers various aspects of impact of walnut twig beetle in California.

http://caps.ceris.purdue.edu/webfm_send/854; provides a pictorial key for identification of walnut twig beetle from its many con-generic species.

http://www.invasivepests.org/products/gallery/pitju1.html.

http://www.michiganloggingcompany.com/Black-Walnut-Black-Death; contains a video on aspects of the problem.

http://www.ext.colostate.edu/pubs/insect/0812_alert.pdf; fact sheet of the Colorado State University.

http://www.fs.fed.us/foresthealth/fhm/sp/tcd/tcd.shtml; USDA Forest Service page on thousand cankers disease and walnut twig beetle.

Articles

Tisserat, N., W. Cranshaw, D. Leatherman, C. Utley, and K. Alexander. 2009. Black walnut mortality caused by the walnut twig beetle and thousand cankers disease. *Plant Health Progress.* August 11, 2009. 10 p.

Grant, J.F., M.T. Windham, W.G. Haun, G.J. Wiggins, and P.L. Lambdin. 2011. Initial assessment of thousand cankers disease on black walnut, *Juglans nigra*, in eastern Tennessee. *Forests* 2: 741-748.

79. Striped Ambrosia Beetle, *Trypodendron lineatum* (Olivier) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The striped ambrosia beetle, *Trypodendron lineatum* (Olivier), has long been considered the most damaging ambrosia beetle in the western United States (but see also the walnut twig borer, *Pityophthorus juglandis* Blackman). It is particularly important in coastal areas of British Columbia in Canada. Attacks are principally on dead and dying timbers created by wind storms, fire, bark beetle attack, or long in-field storage of cut logs. Females bore into the xylem and then larvae make lateral galleries where they feed, pupate, and later emerge. There is generally one generation per year.

Hosts Commonly Attacked

Striped ambrosia beetles attack conifers in *Abies*, *Picea*, *Pseudotsuga*, *Tsuga*, *Larix*, and *Pinus*. They rarely attack hardwoods.

Distribution

The striped ambrosia beetle is Holarctic in distribution. In the western United States, it is found from New Mexico and southern California to the northern edge of the boreal forest in Canada. In the eastern United States, it is found in New England and along the Appalachians to the mountains of western North Carolina.

Images of Striped Ambrosia Beetle

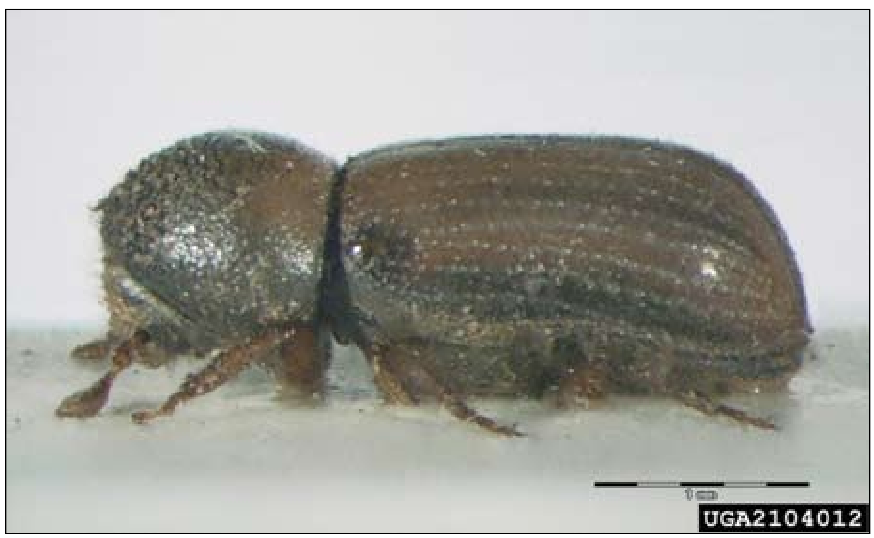

Figure 1. Adult of the striped ambrosia beetle, *Trypodendron lineatum*. (Maja Jurc, University of Ljubljana, Bugwood.org)

Images of Striped Ambrosia Beetle (continued)

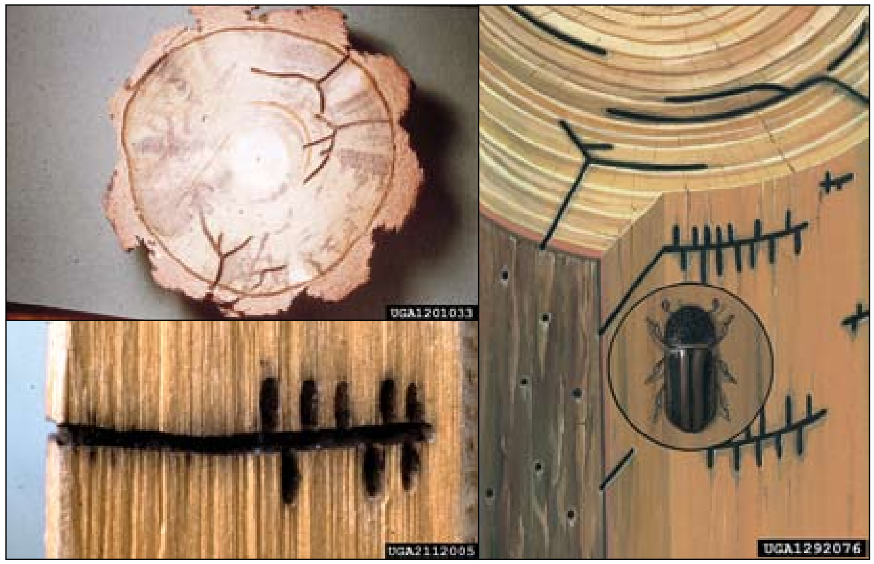

Figure 2. Galleries of striped ambrosia beetle. Top left: galleries made by females to access interior of log; bottom left: the up and down galleries off the adult's gallery made by larvae; right: diagram of the spatial relation of the two types of galleries inside a log. (Top left: Wayne Brewer, Auburn University, Bugwood.org; bottom left: Petr Kapitola, State Phytosanitary Administration, Bugwood.org; right: Robert Dzwonkowski, Bugwood.org)

Figure 3. Emergence holes (see sawdust) of striped ambrosia beetles in felled Norway spruce (*Picea abies* [L.] Karst.). (Both photos: Beat Forster, Swiss Federal Institute for Forest, Snow and Landscape Research, Bugwood.org)

Images of Striped Ambrosia Beetle (continued)

Figure 4. Emergence holes of striped ambrosia beetles. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 5. *Thanasimus formicarius*, a clerid predator that likely feeds on striped ambrosia beetle. (Scott Bauer, USDA Agricultural Research Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the natural enemies of this ambrosia beetle. The clerid *Thanasimus formicarius* (L.) responds to the pheromone of *T. lineatum*, which suggests that it may use the striped ambrosia beetle as food.

Web Links for Information on Striped Ambrosia Beetle

http://www.forestry.ubc.ca/fetch21/FRST308/lab7/trypodendron_lineatum/striped.html; fact sheet of the University of British Columbia, which includes a short video of damage from this beetle to stored logs.

http://www.barkbeetles.org/biocontol/stripedambrosiabeetle.html; fact sheet from Bugwood Wiki on this beetle.

Articles

Lindgren, B.S., S.E.R. Hoover, A.M. MacIsaac, C.I. Keeling, and K.N. Slessor. 2000. Lineatin enantiomer preference, flight periods, and effect of pheromone concentration and trap length on three sympatric species of *Trypodendron* (Coleoptera: Scolytidae). *The Canadian Entomologist* 132: 877-887.

Park, J. and M.L. Reid. 2007. Distribution of a bark beetle, *Trypodendron lineatum*, in a harvested landscape. *Forest Ecology and Management* 242(2/3): 236-242.

80. Black Twig Borer, *Xylosandrus compactus* (Eichhoff) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The black twig borer, *Xylosandrus compactus* (Eichhoff), is an invasive ambrosia beetle from Asia present in Hawaii and coastal regions of the southeastern United States. Females bore into healthy twigs of over 200 hardwood species, where they lay loose clusters of eggs and inoculate their galleries with a symbiotic fungus (*Fusarium solani* [Mart.] Sacc.) on which their larvae later feed. Twigs may be colonized by one or several females, depending on twig size. Mature larvae pupae in the gallery and males, which are flightless, mate with females in the twig before new females emerge. Males never leave the twig. Attacked trees or other plants are usually not killed but may suffer considerable damage. In Hawaii, this species is an important pest of coffee (*Coffea canephora* Pierre [esp. var. *robusta* Ineac]).

Table 1. Characteristics of 4 *Xylosandrus* species present in the southeastern United States (from University of Florida fact sheet on black twig borer seen at http://entnemdept.ufl.edu/creatures/trees/black_twig_borer.htm)

Characteristic	*X. compactus*	*X. crassiusculus*	*X. germanus*	*X. zimmermanni*
Female size	1.4-1.9 mm	2.1-2.9 mm	2.0-2.4 mm	1.3-1.5 mm
Surface of declivity	Shining and smooth	Dull and granulate	Shining	Shining
Hair tuft on base of pronotum	Forms *transverse* row	—	—	Tuft oriented *longitudinally*
Geographic location	Throughout Florida and from North Carolina to eastern Texas	Throughout Florida and from North Carolina to eastern Texas	From Connecticut to Missouri, east Texas, and central Georgia. Might appear in North Florida	Subtropical South Florida and Mexico to Venezuela.
Common host material	In small twigs on healthy, cut and stressed plants	In wood of large twigs, small branches and stems	In wood of large twigs, small branches and stems	Only in unhealthy, cut, or broken branches 1-3 cm diameter

Hosts Commonly Attacked

Hosts are quite varied but include maple (*Acer* spp.), hickory (*Carya* spp.), magnolia (*Magnolia* spp.), dogwood (*Cornus* spp.), oaks (*Quercus* spp.), and willows (*Salix* spp.), among others.

Distribution

Black twig borer has been reported from Hawaii and in North America from coastal parts of North Carolina to Texas (USA). Globally this species has a wide distribution in tropical and subtropical areas.

Images of Black Twig Borer

Figure 1. Adult of black twig beetle, *Xylosandrus compactus*; right, adult on coffee. (Left: J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org; right: Scot Nelson, University of Hawaii at Manoa, Bugwood.org)

Figure 2. Entrance and exit holes of adult black twig beetles in a branch of a koa tree (*Acacia koa* Gray) in Hawaii. (Scot Nelson, University of Hawaii at Manoa, Bugwood.org)

Images of Black Twig Borer (continued)

Figure 3. Galleries of black twig beetle larvae in magnolia. (Forrest L. Oliveria, USDA Forest Service, Bugwood.org)

Figure 4. Cross-sectional views of galleries of *Xylosandrus germanus* (Blandford) in pecan. (Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org)

Images of Black Twig Borer (continued)

Figure 5. "Toothpick" frass ejected from bore hole of *Xylosandrus crassiusculus* (Eichhoff). (G. Keith Douce, University of Georgia, Bugwood.org)

Figure 6. Death of small cypress branch (left) caused by black twig borer; injury to *Acacia koa* branch (right). (Left: Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org; right: Scot Nelson, University of Hawaii at Manoa, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the natural enemies of black twig borer.

Web Links for Information on Black Twig Beetle

http://www.extento.hawaii.edu/kbase/crop/type/xylosand.htm; fact sheet of the University of Hawaii Extension Service.

http://entnemdept.ufl.edu/creatures/trees/black_twig_borer.htm; fact sheet of University of Florida.

Articles

Ngoan, N.D., R.C. Wilkinson, D.E. Short, C.S. Moses, and J.R. Mangold. 1976. Biology of an introduced ambrosia beetle, *Xylosandrus compactus*, in Florida. *Annals of the Entomological Society of America* 69: 872-876.

Masuya, H. 2007. Note on the dieback of *Cornus florida* caused by *Xylosandrus compactus*. *Bulletin of the Forestry and Forest Products Research Institute, Ibaraki* 402: 59-63.

81. Larger Pine Shoot Beetle, *Tomicus piniperda* (L.) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The larger pine shoot beetle, *Tomicus piniperda* (L.), is an invasive species in North America that is found throughout much of Europe, as well as parts of North Africa (Algeria, Canary Islands) and Asia (China, Japan, Korea, and Turkey). Both larvae and adults are damaging to a wide variety of pines. Larvae develop under bark of branches and trunks of suppressed or recently fallen trees, as well as in recently cut stumps. Adults cause more important damage by tunneling in live shoots and leaders of healthy pine trees, reducing growth and deforming tree shape, which can cause important losses in Christmas tree production. Larger pine shoot beetles overwinter as adults in short galleries in the outer bark of host trees near the ground. Adults emerge in late winter or early spring and construct brood galleries in suitable host material. At times, these parent adults (P_1) will emerge, shoot feed, and then construct another brood gallery. The brood adults (F_1) emerge in summer and fly to the shoots of pine trees where they feed until fall. A single brood adult (F_1 generation) will feed in multiple shoots during the summer months. Brood adults do not become sexually mature until they overwinter.

The larger pine shoot beetle is also believed to vector or be associated with several fungi that are pathogens in conifers, including *Ophiostoma minus* (Hedgc.) Syd. et P. Syd., and various blue-staining fungi such as species of *Leptographium*. Outbreaks of this pest are triggered when there is a sudden increase in the amount of breeding material available in early spring, such as following severe winter storms, winter logging operations, or Christmas tree plantations with recently cut stumps or piles of unsold trees. Silvicultural practices during fall and winter such as reducing the amounts of pine logging slash left in the forest and cutting stumps low to the ground will limit number of breeding sites available for this bark beetle.

Hosts Commonly Attacked

The preferred host in Europe and so far in North America is Scots pine (*Pinus sylvestris* L.), but other native pines such as red pine (*Pinus resinosa* Sol. ex Aiton) are commonly infested. However, all native North American pines are potential hosts.

Distribution

Native to Eurasia, this species is invasive in parts of the United States, from Wisconsin to Maine and south to West Virginia.

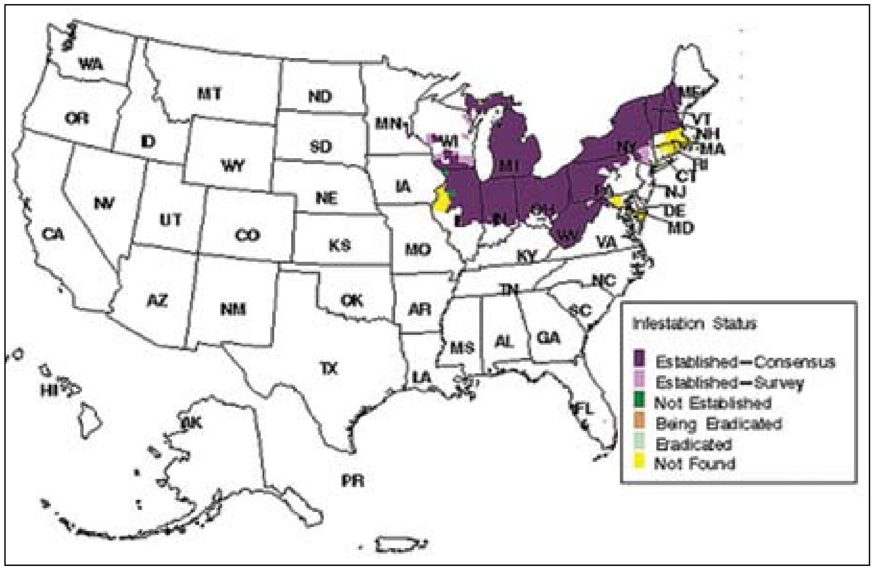

Figure 1. Distribution of the larger pine shoot beetle as of 2005. (National Agricultural Pest Information System)

Images of Larger Pine Shoot Beetle

Figure 2. Adult of larger shoot beetle, *Tomicus piniperda*. (Pest and Diseases Image Library, Bugwood.org)

Images of Larger Pine Shoot Beetle (continued)

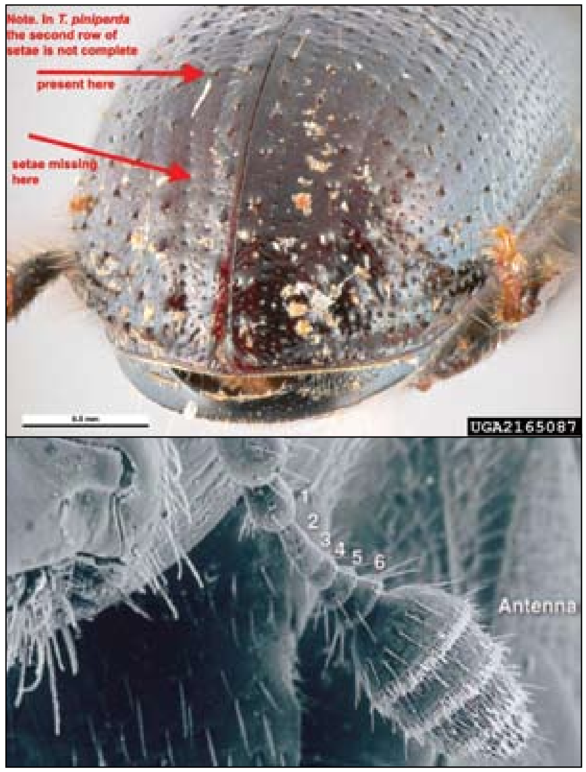

Figure 3. Diagnostic characters for recognition of larger pine shoot beetle: (a) absence of setae in the second row (counting from the midline), toward the rear of the beetle (top) and (b) a six-segmented funicle preceeding the anntennal club (bottom). (Top: Pest and Diseases Image Library, Bugwood.org; bottom: Eric Allen - Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia)

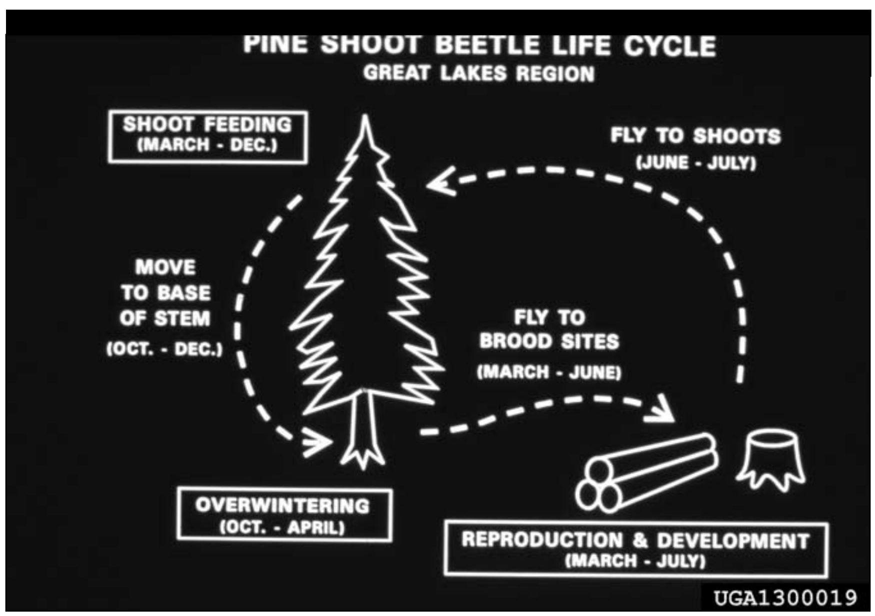

Figure 4. Seasonal life history of the larger shoot beetle in the Great Lakes region of the United States. (E. Richard Hoebeke, Cornell University, Bugwood.org)

Images of Larger Pine Shoot Beetle (continued)

Figure 5. Adults of larger shoot beetle, showing how adults bore into shoots causing then to die and fall off. Top, adult boring into shoot; bottom left, adult inside feeding tunnel in shoot; bottom right, opening in shoot made by adult beetle to enter feeding site. (Top: Steve Passoa, USDA APHIS PPQ, Bugwood.org; bottom left and right: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Figure 6. Pitch tubes of larger shoot beetle on trunk. (Petr Kapitola, State Phytosanitary Administration, Bugwood.org)

Images of Larger Pine Shoot Beetle (continued)

Figure 7. Galleries of the larger pine shoot beetle; left, see the deeply etched vertical oviposition galleries and right, larval galleries radiating out horizontally from the vertical oviposition gallery. (Left: Hannes Lemme, Bugwood.org; right: Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 8. Blue stain damage in logs affected by the larger shoot beetle. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Images of Larger Pine Shoot Beetle (continued)

Figure 9. Exit holes of the larger shoot beetle. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 10. Tops of pines (left) showing loss of branches from feeding of adults of larger shoot beetle; fallen branches (right) caused by adult feeding. (Left: E. Richard Hoebeke, Cornell University, Bugwood.org; right: Hannes Lemme, Bugwood.org)

Figure 11. An important predator in Europe of the engraver beetle, the red-bellied clerid beetle, *Thanasimus formicarius* (L.) (left, adult; right, larva). (Left: Scott Bauer, USDA Agricultural Research Service, Bugwood.org; right: Jiri Hulcr, Michigan State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A variety of natural enemies have been recorded attacking the larger pine shoot beetle in Europe, especially the clerid predator *Thanasimus formicarius* (L.) and the pteromalid parasitoid *Rhopalicus suspensus* Ratz., both of which at some times and places have been observed to kill 70-80 percent of the larger shoot beetles' larvae or pupae.

Web Links for Information on Larger Pine Shoot Beetle

http://www.na.fs.fed.us/spfo/pubs/pest_al/shootbeetle/shootbeetle.htm; USDA Forest Service pest leaflet.

http://warehouse.pfc.forestry.ca/pfc/5134.pdf; fact sheet of the Canadian Forest Service, British Columbia.

http://entnemdept.ufl.edu/creatures/trees/beetles/pine_shoot_beetle.htm; fact sheet of the University of Florida.

http://en.wikipedia.org/wiki/Tomicus_piniperda; page from Wikipedia.

http://www.na.fs.fed.us/spfo/pubs/pest_al/shootbeetle/shootbeetle.htm; pest alert of the USDA Forest Service, Northeastern Area.

http://www.issg.org/database/species/ecology.asp?si=1200; fact sheet of the Global Invasive Species Database, with a discussion of routes of introduction of this species to new areas.

Articles

Morgan, R.E., P. de Groot, and S.M. Smith. 2004. Susceptibility of pine plantations to attack by the pine shoot beetle (*Tomicus piniperda*) in southern Ontario. *Canadian Journal of Forest Research* 34(12): 2528-2540.

Kennedy, A.A. and D.G. McCullough. 2002. Phenology of the larger European pine shoot beetle *Tomicus piniperda* (L.) (Coleoptera: Scolytidae) in relation to native bark beetles and natural enemies in pine stands. *Environmental Entomology* 31: 261-272.

82. White Pine Cone Beetle, *Conophthorus coniperda* (Schwarz) (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

The white pine cone beetle, *Conophthorus coniperda* (Schwarz), infests cones of eastern white pine (*Pinus strobus* L.) and is an important pest of seed production in natural stands and in seed orchards. Cones are initially attacked by adult female beetles that start tunneling in the cone stalk or base. This severs the conductive tissue that connects the twig and cone, killing the cone. A small pitch tube generally marks the entry point. Individual female beetles extend an egg gallery down the central axis of a cone. Eggs are laid along this gallery. Larvae feed on seeds and associated tissues until they reach maturity. Larvae then pupate, and later emerge as adults, which darken over a few days. Development from egg to adult occurs in one growing season, and there is one generation per year. Female beetles can attack and oviposit in more than one cone. Infested cones stop growing in length after they are attacked. So, cones attacked in the early spring will be very small when they die, while cones attacked late in the summer are much larger in size. Infested cones shrivel, turn brown, and become hard. Because stalks of infested cones are severed, they can easily be removed by hand from a branch. Uninfested cones or cones attacked by other seed and cone insects, in contrast, adhere tightly to branches and may require a hand-clipper to remove. Infested cones eventually fall from trees, and beetles spend the winter within infested cones on the forest floor. In early spring, beetles chew emergence holes and fly from cones on the ground into tree crowns where they locate new host material. This is the most important pest of white pine seed orchards, sometimes destroying most or all of a developing seed crop. Damage is concentrated on second year cones, but first year conelets are also attacked. Beetles, when they are on the ground, can be killed using a low-intensity ground fire, a practice that is employed for control in seed orchards.

Hosts Commonly Attacked

Eastern white pine (*P. strobus*) is the only host of this species, but there are other species of *Conophthorus* associated with other pines.

Distribution

The white pine cone beetle is found throughout the range of eastern white pine, from eastern Canada (Quebec, Ontario, Nova Scotia), south to North Carolina, and west to Minnesota.

Images of White Pine Cone Beetle

Figure 1. Adult white pine cone beetle, *Conophthorus coniperda*. (J.R. Baker and S.B. Bambara, North Carolina State University, Bugwood.org)

Figure 2. A female beetle can be seen initiating an attack at the base of a white pine cone where the cone stalk enters the cone. (Larry R. Barber, USDA Forest Service, Bugwood.org)

Images of White Pine Cone Beetle (continued)

Figure 3. Egg-laying gallery of a cone beetle (*Conophthorus* sp.) in the center of a cone that has been cut in half. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 4. Damage inside a white pine cone caused by feeding of larvae of white pine cone beetle. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Figure 5. Dead white pine cones, infested by larvae of white pine cone beetle may hang on trees for a period of time before dropping to ground. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of White Pine Cone Beetle (continued)

Figure 6. The length of dead infested cones can vary greatly. Small dead cones are those attacked in early spring and larger dead cones are those attacked in late summer. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 7. Low intensity burns can be used in spring to control adults of white pine cone beetle before they emerge from cones on the ground. (Larry R. Barber, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this insect have not been reported.

Web Links for Information on White Pine Cone Beetle

None

Articles on White Pine Cone Beetle

Wade, D.D., G.L. Debarr, L.R. Barber, and E. Manchester. 1989. Prescribed fire - a cost effective control for white pine cone beetle. In: MacIver, D.C., H. Auld, and R. Whitewood (eds). *Proceedings of the 10th Conference on Fire and Forest Meteorology.* Forestry Canada, Petawawa National Forestry Institute (PNFI), Chalk River, Ontario: 117-121.

De Groot, P. 1990. The taxonomy, life history and control of *Conophthorus* (Coleoptera: Scolytidae) in eastern North America. *Proceedings - Cone and seed pest workshop, 4 October 1989.* Information Report N-X-274, Forestry Canada, Newfoundland and Labrador Region, St. John's, Newfoundland, Canada: 37-46.

Trudel, R., C. Guertin, and P. De Groot. 2004. Use of pityol to reduce damage by the white pine cone beetle, *Conophthorus coniperda* (Col., Scolytidae) in seed orchards. Journal of Applied Entomology 128: 403-406.

83. Lodgepole Cone Beetle, *Conophthorus ponderosae* Hopkins (Coleoptera: Curculionidae, Scolytinae)

Orientation to Pest

Western cone beetles (*Conophthorus* spp.) were historically described based on their principal host trees. The sugar pine cone beetle (*Conophthorus lambertianae* Hopkins) was described from *Pinus lambertiana* Douglas, but it was later declared a junior synonym of *Conophthorus ponderosae* Hopkins, which was formerly known as the ponderosa cone beetle, but is now referred to as the lodgepole cone beetle (Wood 1977). Later work based on similarities among beetle cuticular hydrocarbons (Page et al. 1990), however, suggested that the sugar pine-feeding population of *C. ponderosae* may indeed be a separate species (the former *C. lambertianae*), but it was not formerly reinstated taxonomically. The possible validity of a sugar pine-feeding species is consistent with recent DNA studies that shown that there likely have been more speciation events in this genus than were formerly suspected. But these appear to have been driven by geographic isolation, not affinity to particular host species (Cognato et al., 2005), although sometimes the two go together. The ponderosa cone beetle (*C. ponderosae* in the wide sense), as discussed here, is composed of several populations as noted above, whose relatedness is not certain. The population associated with ponderosa (*Pinus ponderosa* Douglas ex C. Lawson), lodgepole (*P. contorta* var. *latifolia* Douglas), and Jeffrey (*P. jeffreyi* Balf.) pines is found from Washington to California, and in Arizona and New Mexico. The population associated with sugar pine (*P. lambertiana* Douglas) is found in California, Nevada and Oregon, where it feeds mostly on *P. lambertiana* and sometimes on western white pine (*P. monticola* Douglas ex D. Don).

For purposes of this presentation, we discuss *C. ponderosae* in the wide sense, inclusive of *C. lambertianae*. Regardless of their specie-level status, the biologies of these populations are very similar. In broad terms, their biology is similar to that of the white pine cone beetle (*Conophthorus coniperda* [Schwarz]) in the eastern United States. Adults bore into the pedicles of immature, second year pine cones in the spring and dig a tunnel along the length of the cone, where the female deposits her eggs. Larvae feed on the scales, seeds, and tissues of the cone. Pupation occurs within the cone and adults overwinter on the soil in fallen cones. For the sugar-pine feeding population ("*C. lambertianae*"), adults emerge from cones in the fall and move to twigs, boring into them to feed, where they remain over winter.

Orientation to Pest (continued)

The *C. ponderosae* population associated with sugar pine is the most destructive of the western *Conophthorus* cone beetles. It sometimes destroys up to 75 percent of sugar pine seeds in some years, making it an important pest in sugar pine seed orchards. Similarly, the *C. ponderosae* population associated with western white pine in British Columbia, Washington, and Idaho has caused important losses in seed collection stands and seeds orchards of that species. The other populations of *C. ponderosae* have similar effects on other species of pines in seed orchards, but the typical rate of seed destruction is lower.

Hosts Commonly Attacked

The lodgepole cone beetle, in the wide sense, attacks ponderosa (*P. ponderosa*), lodgepole (*P. contorta* var. *latifolia*), Jeffrey (*P. jeffreyi*), sugar (*P. lambertiana*), and western white (*P. monticola*) pines.

Distribution

The lodgepole cone beetle, in the wide sense, is found from British Columbia to California, as well as in Idaho, Nevada, Arizona, and New Mexico.

Images of Lodgepole Cone Beetle

Figure 1. Adult of lodgepole cone beetle (*Conophthorus ponderosae*). (D. Manastyrski, Bugwood.org)

Figure 2. Adult cone beetles (*Conophthorus* sp.) tunnel in pine cones and their larvae feed on the immature seeds and other tissues. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Lodgepole Cone Beetle (continued)

Figure 3. Pitch tube of *Conophthorus ponderosae* at base of cones in western white pine (*P. monticola*) at site of adult entrance. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 4. Internal appearance of pine cones infested by larvae of lodgepole cone beetles. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Images of Lodgepole Cone Beetle (continued)

Figure 5. Late instar *Conophthorus ponderosae* larva exposed in a dissected western white pine (*P. monticola*) cone. (Canadian Forest Service Archive, Canadian Forest Service, Bugwood.org)

Figure 6. Reduced size of cones of ponderosa pine (top) and western white pine (bottom) infested by the lodgepole cone beetle compared to the larger, normal cones. (Top: Sandy Kegley, USDA Forest Service, Bugwood.org; bottom: Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the natural enemies of populations of lodgepole cone beetle. But larvae of the population found on sugar pine ("*C. lambertianae*") are attacked in the cone by the bethylid wasp *Cephalonomia utahensis* Brues. Adult beetles are attacked by both the predatory clerid *Enoclerus lecontei* Wolcott and are parasitized by the pteromalid wasp *Tomicobia tibialis* Ashmead.

Web Links for Information on Lodgepole Cone Beetle

http://www.barkbeetles.org/biocontol/sugarpineconebeetle.html; fact sheet from University of California with an emphasis on potential for biological control of this pest.

http://www.fgcouncil.bc.ca/PM-Factsheet11-Conophthorus-ponderosae.pdf; fact sheet from the provincial forest council of British Columbia, Canada.

Articles

Wood, S.L. 1977. New synonymy and new species of American bark beetles (Coleoptera: Scolytidae), part V. *Great Basin Naturalist* 37: 383-394.

Page, M., L.J. Nelson, M.I. Haverty, and G.J. Blomquist. 1990. Cuticular hydrocarbons of eight species of North American cone beetles, *Conophthorus* Hopkins. *Journal of Chemical Ecology* 16: 1173-1198.

Furniss, M.M. 1997. *Conophthorus ponderosae* (Coleoptera: Scolytidae) infesting lodgepole pine cones in Idaho. *Environmental Entomology* 26: 855-858.

Bennett, R. 2000. Management of cone beetles (*Conophthorus ponderosae*, Scolytidae) in blister rust resistant western white pine seed orchards in British Columbia. Seed and Seedlings Extension Topics 12: 16-18. (Available at http://www.for.gov.bc.ca/hti/publications/newsletters/Vol1201Aug20.pdf).

Cognato, A.I., N.E. Gillette, R. Campos Bolaños, and F.A.H. Sperling. 2005. Mitochondrial phylogeny of pine cone beetles (Scolytinae, *Conophthorus*) and their affiliation with geographic area and host. *Molecular Phylogenetics and Evolution* 36: 494-508.

85. May and June Beetles, *Phyllophaga* spp. (Coleoptera: Scarabaeidae)

Orientation to Pest

May and June beetles (*Phyllophaga* spp.) are a group of scarab beetles whose larvae feed on the roots of trees and other plants, which can significantly affect survival of seedlings or young trees in plantations. This is a very large group of beetles native to North America. There are more than 250 *Phyllophaga* species in North America. Most U.S. species occur in the eastern half of the country. In the western part of the country, this group is most numerous in Arizona. Many species occur in Mexico. Here, we present a general view of the biology of the group and mention a few species that are sometimes forestry pests. Adults of several important species emerge in spring and early summer (May and June, especially, hence their name). Adults are large, often brown, beetles that are active in evening or early night and are big enough to be easily noticed (1-3 cm long). Eggs are laid in groups in the soil, about 8-18 cm deep, with each egg enclosed in a ball of dirt. Newly hatched larvae feed on organic matter in the soil but soon switch to feeding on rootlets of tree seedlings, grasses, or other plants. Winter is spent in the soil and larvae move up and down to stay below the frost line. Mature larvae pupate in the soil. One to three years are required to reach maturity in the southern states, 2-3 years in mid-latitudes of the United States, and 3-4 years in northern states and Canada. Because of the multi-year life cycle and large number of species, relatively little is known of the population dynamics of particular species.

Damage from *Phyllophaga* species can occur from either adults or larvae. Adults feed at night on the foliage of many plants including broad-leaved trees, shrubs, and some conifers. Damage from adults is spotty, but when populations are high trees can be heavily defoliated in woodlots or forest edges. Larvae, called white grubs (a name applied to the whole scarab family), feed in the soil on roots of both grasses and woody plants. Damage from *Phyllophaga* grubs occurs in forest nurseries and plantations the southern and eastern United States. In the western United States, damage from *Phyllophaga* grubs is less common but is occasionally significant to coniferous seedlings in plantations and nurseries on newly broken sandy land. In the eastern United States, damage to forest nurseries and young plantations can be severe at times. In Michigan and Wisconsin in red pine plantations on sandy soils, as few as 0.75 grubs per cubic foot of soil were found to kill 15-45 percent of red pine seedlings.

Hosts Commonly Attacked and Distribution of Some *Phyllophaga* Species

Common Species	Comments on Biology (from Drooz 1985)
Phyllophaga crenulata (Froclich)	*P. crenulata* occurs throughout the eastern United States. Adults feed on a wide variety of hardwoods, especially persimmon, hickory, basswood, willow, birch, and buckeye. The larvae are often serious pests in coniferous nurseries in the Lake States.
Phyllophaga drakei (Kirby)	*P. drakei* occurs throughout most of the eastern United States and southern Canada. Adults feed on the leaves of beech, birch, dogwood, maple, basswood, elm, and willow. The larvae are important pests in forest nurseries and plantations in the Lake States and Canada.
Phyllophaga forsteri (Burmeister)	*P. forsteri* occurs throughout the eastern United States. Adults feed on a wide variety of hardwoods such as beech, birch, elm, magnolia, maple, tupelo, walnut, and willow. There are also reports of their feeding on pine. The larvae are often destructive in nurseries in the southern United States.
Phyllophaga implicita (Horn)	*P. implicita* occurs mostly in the Mississippi and Ohio River Valleys. Adults feed on beech, dogwood, elm, sycamore, tupelo, walnut, willow, basswood, maple, and other plants. The larvae killed millions of seedlings in nurseries in Iowa in the 1930s.
Phyllophaga luctuosa (Horn)	*P. luctuosa* occurs primarily along the Atlantic and Gulf coasts in sandy, oak-pine regions, but also farther north and inland to Tennessee, Oklahoma, and Iowa. Adults feed on persimmon, mulberry, tupelo, walnut, willow, beech, birch, and loblolly and longleaf pines. The larvae are often destructive in nurseries and, probably, plantations.
Phyllophaga prununculina (Burmeister)	*P. prununculina* occurs in the South Atlantic and Gulf Coast States. It is especially common in the Sand Hills of South Carolina. Adults feed on pines, especially loblolly and longleaf, and sometimes oaks and persimmon. The larvae have caused serious losses in pine nurseries and plantations in South Carolina.
Phyllophaga prunina (LeConte)	*P. prunina* occurs throughout the central United States east of the Rocky Mountains. Adults feed on hardwoods, including beech, elm, walnut, basswood, and willow. Feeding on pine has also been observed. Larvae are injurious in nurseries in the Lake states.
Phyllophaga rugosa (Melsheimer)	*P. rugosa* occurs mostly in the northern United States and southern Canada. Adults feed on a wide variety of hardwoods. The larvae are often destructive in coniferous nurseries in the Lake States.
Phyllophaga tristis (F.)	*P. tristis* occurs throughout the eastern United States and in southern Canada. Adults prefer the foliage of oaks but also feed on maple, persimmon, hickory, elm, and willow. Larvae have caused serious losses in nurseries in the Lake States.

Images of May and June Beetles

Figure 1. Adults of two species of *Phyllophaga* beetles, showing general body form shared by most species in genus. (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: Whitney Cranshaw, Colorado State University, Bugwood.org)

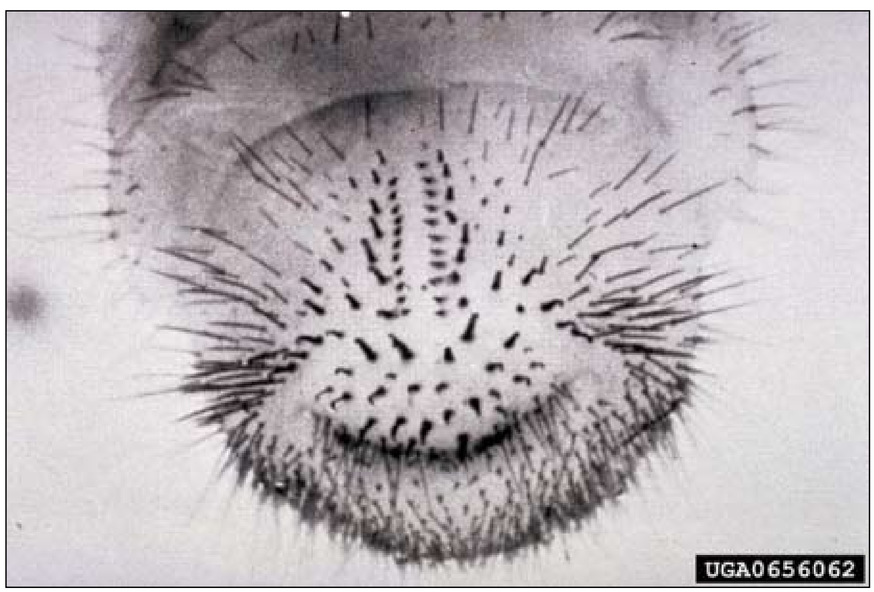

Figure 2. Species identification of larval scarabs (white grubs) is largely based on the setal patterns on the tip of the abdomen (the raster) (here a white grub in another genus, the oriental beetle *Anomala orientalis* [Waterhouse]). (H. Sawada, Bugwood.org)

Images of May and June Beetles (continued)

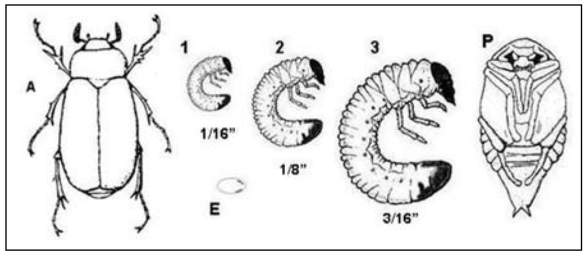

Figure 3. Diagram of life cycle of *Phyllophaga implicita*. (North Dakota State University Extension Service)

Figure 4. The C-shape form of a "white grub" and visible legs are typical of *Phyllophaga* larvae. (Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Figure 5. Damage from adult *Phyllophaga* species consists of defoliation, usually on hardwoods, but sometimes on conifers. (Top: Darren Blackford, USDA Forest Service, Bugwood.org; bottom: Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of May and June Beetles (continued)

Figure 6. The most important damage from *Phyllophaga* species as forest pests is death of seedlings or small trees whose roots are eaten by larvae in the soil. Here, pine seedings whose roots have been eaten by *Phyllophaga* larvae. (W.H. Bennett, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Parasitoids of May and June beetles include wasps in the genus *Tiphia* (Tiphiidae), especially *Tiphia inornata* (Say), as well as several species of tachinid parasitoids such as *Microphthalma disjuncta* Wiedman. Grubs of *Phyllophaga* species are also attacked in the soil by various bacteria, fungi and nematodes, some of which have been formulated as biopesticides with varying levels of success in practical use.

Web Links for Information on May and June Beetles

http://www.ag.ndsu.nodak.edu/aginfo/entomology/entupdates/whitegrub/whitgrub.htm; fact sheet of the North Dakota State University of prevention and management of white grub damage.

http://en.wikipedia.org/wiki/Phyllophaga_(genus); Wikipedia article providing overview of white grubs in the genus *Phyllophaga*.

http://www.unl.edu/museum/research/entomology/Guide/Scarabaeoidea/Scarabaeidae/Melolonthinae/Melolonthinae-Generic-pages/Melolonthini/Phyllophaga/Phyllophaga.html; a guide to New World scarab genera, including profiles of several *Phyllophaga* species.

http://www.freshfromflorida.com/pi/enpp/ento/scarab-pest-alert.html; two pest *Phyllophaga* species newly invasive in Florida.

http://www.forestpests.org/nursery/whitegrubs.html; USDA Forest Service fact sheet on white grubs as pests in forest nurseries.

Articles

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Ives, W.G.H. and G.L. Warren. 1965. Sequential sampling for white grubs. *The Canadian Entomologist* 97: 596-604.

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Liesch, P.J. and R.C. Williamson. 2010. Evaluation of chemical controls and entomopathogenic nematodes for control of *Phyllophaga* white grubs in a Fraser fir production field. *Journal of Economic Entomology* 103: 1979-1987.

86. Black Vine Weevil, *Otiorhynchus sulcatus* (Fabricius) (Coleoptera: Curculionidae)

Orientation to Pest

The black vine weevil, *Otiorhynchus sulcatus* (Fabricius), is a weevil that is likely native to some or all of Europe that has invaded North America, Japan, New Zealand, Australia, and parts of southern South America. The mechanism of these invasions has been movement of the insect in balled nursery stock plants. This species feeds on over 100 species of plants. Larvae are the main damaging stage, feeding in the soil on plant roots. Young larvae eat the fine roots, but the following year, mature larvae destroy the larger roots as well. Unlike the white grubs of scarabs such as Japanese beetle (*Popillia japonica* Newman), weevil larvae such as those of black vine weevil, are less C-shaped and lack legs. Adults feed at night, notching the leaves of their host plants, but damage from adult feeding is not severe. Leaf notching is, however, a useful indicator of the presence of this nonflying, nocturnal insect whose larvae are out of sight in the soil. The most common overwintering stage of this insect is the young larva, but sometimes adults too overwinter. In general, in the eastern United States, adults emerge in June. Black vine weevils are pests in greenhouses and forestry nurseries where planting stock is produced, to both potted and field-grown plants.

Hosts Commonly Attacked

Plants fed on by black vine weevil include many woody and non-woody species, including strawberry (*Fragaria*), yew (*Taxis*), spruce (*Picea*), hemlock (*Tsuga*), rhododendron (*Rhododendron*), grape (*Vitis*), and cyclamen (*Cyclamen*).

Distribution

The black vine weevil is found in the northeastern and north central parts of the United States and adjacent parts of eastern Canada, and from Alaska south to California.

Images of Black Vine Weevil

Figure 1. Adults of black vine weevil, *Otiorhynchus sulcatus*, are flightless (wing covers do not open) and nocturnal. (Left: Kent Loeffler, Cornell University, Bugwood.org; right: Cheryl Moorehead, individual, Bugwood.org)

Images of Black Vine Weevil (continued)

Figure 2. Larvae of black vine weevil are cream colored, with a brown head and no legs. (Left: Peggy Greb, USDA Agricultural Research Service, Bugwood.org; right: Mike Reding and Betsy Anderson, USDA Agricultural Research Service, Bugwood.org)

Figure 3. Pupae of black vine weevil occur naked in the soil. (Left: Mike Reding and Betsy Anderson, USDA Agricultural Research Service, Bugwood.org; right: Jim Baker, North Carolina State University, Bugwood.org)

Figure 4. Adult black vine weevils notch edges of host leaves (left, sedum plants and right, rhododendrons). (Left: Mike Reding and Betsy Anderson, USDA Agricultural Research Service, Bugwood.org; right: Jim Baker, North Carolina State University, Bugwood.org)

Images of Black Vine Weevil (continued)

Figure 5. Damage to yew seedling roots from black vine weevil larvae. (Jim Baker, North Carolina State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Specialized parasitoids or predators of this species have not been reported. Most attention has been on various species of nematodes (e.g., *Heterorhabditis heliothidis* [Kahn, Brooks, and Hirschman]) and fungal entomopathogens (e.g., *Metarhizium anisopliae* [Metchnikoff] Sorokin), which have been developed for use as biopesticides against this species with varying degrees of success depending on such things as soil temperature.

Web Links for Information on Black Vine Weevil

http://woodypests.cas.psu.edu/factsheets/insectfactsheets/html/black_vine_weevil.html; fact sheet of Pennsylvania State University.

http://www.umassgreeninfo.org/fact_sheets/root_shoot_feeders/black_vine_weevil.html; fact sheet of the University of Massachusetts.

http://www.coopext.colostate.edu/TRA/PLANTS/blackvine.shtml; fact sheet of the Colorado State University.

Articles

Haukeland, S. and T. Lola-Luz. 2010. Efficacy of the entomopathogenic nematodes *Steinernema kraussei* and *Heterorhabditis megidis* against the black vine weevil *Otiorhynchus sulcatus* in open field-grown strawberry plants. *Agricultural and Forest Entomology* 12(4): 363-369.

Ansari, M.A., F.A. Shah, and T.M. Butt. 2008. Combined use of entomopathogenic nematodes and *Metarhizium anisopliae* as a new approach for black vine weevil, *Otiorhynchus sulcatus*, control. *Entomologia Experimentalis et Applicata* 129: 340-347.

von Reibnitz, C. and G.F. Backhaus. 1992. Analysis of the incidence and control of *Otiorhynchus sulcatus* in tree nurseries. Results from a survey in Lower Saxony and Schleswig-Holstein. *Gesunde Pflanzen* 45(2): 54-60. (In German).

87. Strawberry Root Weevil, *Otiorhynchus ovatus* (L.) (Coleoptera: Curculionidae)

Orientation to Pest

The strawberry root weevil, *Otiorhynchus ovatus* (L.), is invasive in North America. It is polyphagous, and larvae feed on plant roots, while adults feed nocturnally on the foliage, buds and young shoots of a wide range of host plants. Adults do not fly and all are females. Unlike white grubs (larvae of scarabs), weevil larvae such as those of strawberry root weevil are less C-shaped and lack legs. Black vine weevil, *Otiorhynchus sulcatus* (Fabricius), is a similar appearing species, but whose larvae are much larger than those of strawberry root weevil. In Oregon, strawberry root weevil overwinters as partially grown larvae or as adults. Adults emerge in late May and early June and begin laying eggs about two weeks later. Larvae feed from September through April of the following year and cause the most damage from late March to mid-May. Strawberry root weevil is a forestry pest only in the context of forest nurseries, where infestations may build up. Larvae feed on roots of tree seedlings and can be controlled by soil applications of chemical insecticides, nematodes, or entomopathogenic fungi.

Hosts Commonly Attacked

Adult beetles feed on foliage, especially of arborvitae (*Thuja*). The larvae feed on the roots of hemlock (*Tsuga*) and various other conifers, such as spruce (*Picea*), pine (*Pinus*), yew (*Taxus*), and arborvitae, as well as a variety of agricultural crops.

Distribution

The strawberry root weevil is found in most parts of the United States and southern Canada.

Images of Strawberry Root Weevil

Figure 1. Adult of strawberry root weevil, *Otiorhynchus ovatus*. (Left: Pest and Diseases Image Library, Bugwood.org; right: Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Strawberry Root Weevil (continued)

Figure 2. Larva of strawberry root weevil. (Russell Karow, Oregon State University)

Figure 3. Pupa of strawberry root weevil. (Russell Karow, Oregon State University)

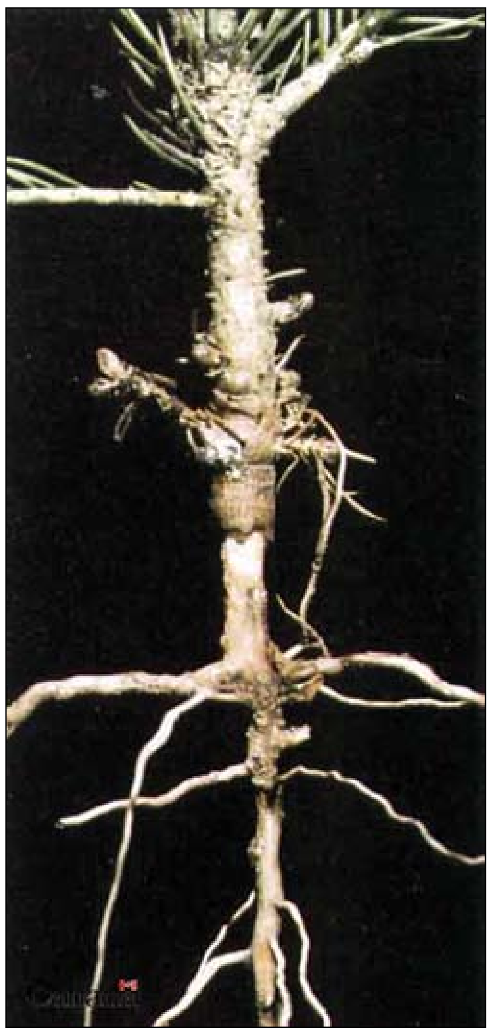

Figure 4.Girdling of bare root spruce seedling by adults of strawberry root weevil. (Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

The only parasitoid known to attack this species in North America is the braconid *Triaspis kurtogaster* Martin, but that parasitoid's importance in controlling populations of the weevil is unknown. Various entomopathogenic fungi have been found attacking larvae of strawberry root weevil, such as *Isaria fumosorosea* Wize (Ifr.) (formerly known as *Paecilomyces fumosoroseus* [Wize] Brown and Smith) and *Metarhizium anisopliae* (Metchnikoff) Sorokin. Various nematodes also attack larvae of this species, *Heterorhabditis bacteriophora* Poinar being the species most promising for control. Several species of both fungi and nematodes have been assessed as biopesticides against larvae of strawberry root weevil in various settings, including forest nurseries, cranberry bogs, and potted nursery stock in and around greenhouses. In general, control has been better in potted plants than open fields, and in warmer soils versus cold soils. Cool temperatures (11-14 °C) reduce efficacy of some species of nematodes.

Web Links for Information on Strawberry Root Weevil

http://mint.ippc.orst.edu/srwfact.pdf; fact sheet of Oregon State University on biology and management.

http://whatcom.wsu.edu/ipm/manual/rasp/weevil.html; fact sheet of Washington State University comparing several species in the genus *Otiorhynchus*.

http://www.pfc.cfs.nrcan.gc.ca/diseases/nursery/pests/rootweev_e.html; fact sheet of Natural Resources Canada discussing root weevils as pests in forest nurseries.

Articles

Nielsen, D.G. 1989. Minimizing *Otiorhynchus* root weevil impact in conifer nurseries. In: Alfaro, R.I. and S.G. Glover (eds.). *Proceedings of Conference: Insects affecting reforestation: biology and damage.* Forestry Canada, Pacific and Yukon Region, Victoria, British Columbia: 71-79.

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Berry, R.E., J. Liu, and E. Groth. 1997. Efficacy and persistence of *Heterorhabditis marelatus* (Rhabditida: Heterorhabditidae) against root weevils (Coleoptera: Curculionidae) in strawberry. *Environmental Entomology* 26: 465-470.

88. Japanese Beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae)

Orientation to Pest

The Japanese beetle, *Popillia japonica* Newman, is an invasive insect in North America (United States and Canada) that is native to Japan. It is also invasive in China, Russia and Portugal. Adults fly during the summer and may occur in large numbers, defoliating raspberries, strawberries, roses, grapes, and other plants. Adults burrow into the soil, especially in grassy areas, and lay eggs several inches underground, where larvae then develop, feeding on the roots of grass plants and damaging the turf. There is usually one generation per year and partly grown larvae in the soil are the overwintering stage.

Hosts Commonly Attacked

Adults defoliate a wide range of plants including grapes, roses, and various shade and fruit trees. Larvae eat the roots of grasses and are major pests of turf, especially on golf courses. Larvae can be pests in tree nurseries or on ornamental nursery stock.

Distribution

In North America, the Japanese beetle is found in most states east of the Mississippi River and the invaded area continues to expand. One important pathway by which this pest is spread is the movement of larvae in nursery stock shipped with soil. The beetle is not found in California or the Pacific Northwest states.

Images of Japanese Beetle

Figure 1. Adult Japanese beetle, *Popillia japonica*. (David Cappaert, Michigan State University, Bugwood.org)

Images of Japanese Beetle (continued)

Figure 2. Larva of the Japanese beetle (left); three species of “white grubs” (right) to show relative size, from left to right: Japanese beetle, European chafer (*Rhizotrogus majalis* [Razoumowsky]), and June beetle (*Phyllophaga* sp.). (Both photos: David Cappaert, Michigan State University, Bugwood.org)

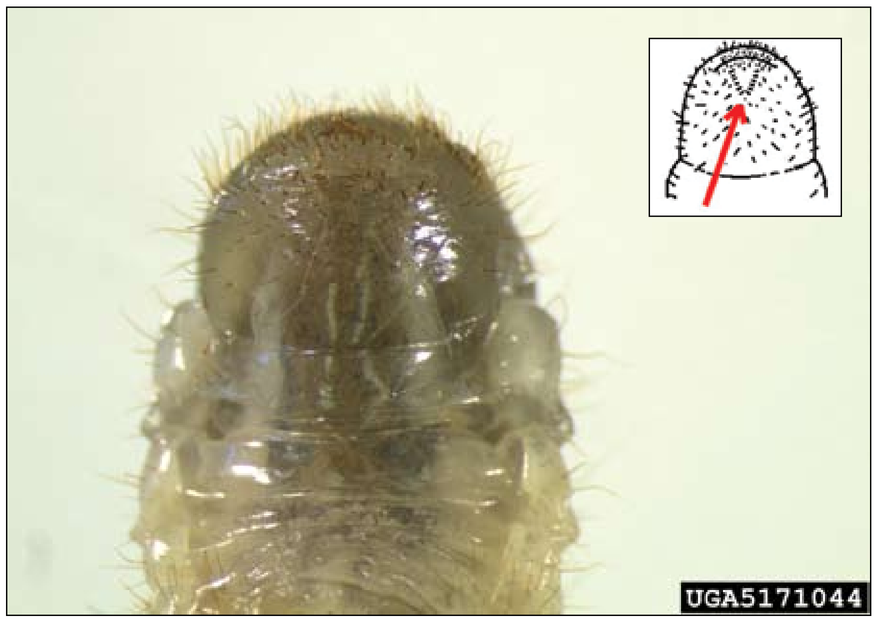


Figure 3. The V-shaped pattern of the “raster” (a group of hairs on underside of the rear tip of larval body) is used to identify larvae of Japanese beetles. (Mike Reding and Betsy Anderson, USDA Agricultural Research Service, Bugwood.org; inset: Clemson University, Cooperative Extension Fact Sheet)

Figure 4. Adult Japanese beetles feeding on rose flower (left) and foliage of other plants (right). (Left: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org; right: Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Images of Japanese Beetle (continued)

Figure 5. Turf infested by Japanese beetle larvae and then dug up by skunks or other mammals to eat grubs. (M.G. Klein, USDA Agricultural Research Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A large scale effort to achieve biological control of this pest, based on searching for natural enemies in Japan and China, was made in the 1920s and 1930s. Several parasitoids were imported and established, the most important of which were three tachinid flies (especially *Istocheta aldrichi* [Mesnil]) and several tiphiid wasps (especially *Tiphia popilliavora* Rohwer and *Tiphia vernalis* Rohwer). Several pathogens of this beetle were also discovered and attempts were made to turn them into biopesticides. These included the bacterium that causes milky spore disease (*Paenibacillus popilliae* [Dutky]) and the nematode *Steinernema glaseri* (Steiner). It was the study of this nematode that stimulated the development of this family of nematodes as successful biopesticides against soil insects. For a detailed history of the biological control efforts against Japanese beetle, see Van Driesche et al. (1996).

Web Links for Information on Japanese Beetle

http://en.wikipedia.org/wiki/Japanese_beetle; Wikipedia article on biology and control.

http://edis.ifas.ufl.edu/in630; fact sheet of the University of Florida, discussing biology and control.

http://www.aphis.usda.gov/publications/plant_health/content/printable_version/jbidcard5-07.pdf; USDA fact sheet including a life cycle diagram.

Articles on Japanese Beetle

Van Driesche, R.G., S. Healy, and R.C. Reardon. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations.* FHTET-96-19. USDA Forest Service, Morgantown, West Virginia: 43-48. (Available at http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

Power, K.T., R.S. An, and P.S. Grewal. 2009. Effectiveness of *Heterohabditis bacteriophora* strain GPS11 applications targeted against different instars of the Japanese beetle *Popillia japonica*. *Biological Control* 48: 232-236.

Oliver, J.B., M.E. Reding, N.N. Youssef, M.G. Klein, B.L. Bishop, and P.A. Lewis. 2009. Surface-applied insecticide treatments for quarantine control of Japanese beetle, *Popillia japonica* Newman (Coleoptera: Scarabaeidae), larvae in field-grown nursery plants. *Pest Management Science* 65: 381-390.

89. Twolined Chestnut Borer, *Agrilus bilineatus* (Weber) (Coleoptera: Buprestidae)

Orientation to Pest

Twolined chestnut borer, *Agrilus bilineatus* (Weber), is native to North America and occurs throughout southeastern Canada and the eastern and central United States. Adults are recognizable as dark colored buprestids with two golden stripes running lengthwise along their back. Adult beetles fly from April to August, depending on the location, and there is one generation per year. In Michigan and surrounding areas, adult emergence peaks in mid-to late June. Females lay eggs in small clusters in bark cracks and crevices. Newly hatched larvae burrow into the tree and form feeding galleries under the bark. Larvae are light colored and up to 2.5 cm long when mature, and have two spines at the tip of the abdomen, as is typical for all *Agrilus* larvae. Larvae construct meandering galleries that are packed tightly with feces mixed with boring dust. These feeding galleries interrupt the transport of food and water in the phloem (inner bark) and xylem (outer sapwood) and eventually girdle individual branches or the entire tree. Attacks occur in stressed or dying chestnut (*Castanea dentata* [Marsh.] Borkh.) or oak (*Quercus*). Live healthy trees are typically not infested. Attacks usually begin in the crown of the tree, with some branches dying in the first year. Infestations progress downward, and the trees usually die in the second or third year. Incidence of attack by twolined chestnut borer increases following stress such as drought or defoliation from insects such as gypsy moth (*Lymantria dispar* [L.]).

Hosts Commonly Attacked

American chestnut (*C. dentata*) and various species of oak, especially white (*Quercus alba* L.), scarlet (*Q. coccinea* Muenchh.), northern pin (*Q. ellipsoidalis* E. J. Hill), bur (*Q. macrocarpa* Michx.), chestnut (*Q. prinus* L.), northern red (*Q. rubra* L.), post (*Q. stellata* Wangenh.), black (*Q. velutina* Lamb.), and live (*Q. virginiana* Miller) oaks are hosts of twolined chestnut borer.

Distribution

Twolined chestnut borer is widespread in the eastern and central United States and southeastern Canada.

Figure 1. Probable range of the twolined chestnut borer, *Agrilus bilineatus*, based on the combined distribution of its oak host species. (USDA Forest Service • Forest Insect and Disease Leaflet 168)

Images of Twolined Chestnut Borer

Figure 2. Adult of twolined chestnut borer, showing the two golden stripes along the back. (Robert A. Haack, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of twolined chestnut borer in galleries (left) and close up of larva (right), showing the two projections from the rear end of the body (found in all *Agrilus* species). (Left: James Solomon, USDA Forest Service, Bugwood.org; right: Robert A. Haack, USDA Forest Service, Bugwood.org)

Figure 4. The exit hole of the twolined chestnut borer, like that of other species of *Agrilus*, is D shaped rather than round or oval. (USDA Forest Service • Forest Insect & Disease Leaflet 168)

Figure 5. View of the long winding larval galleries of twolined chestnut borer. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Images of Twolined Chestnut Borer (continued)

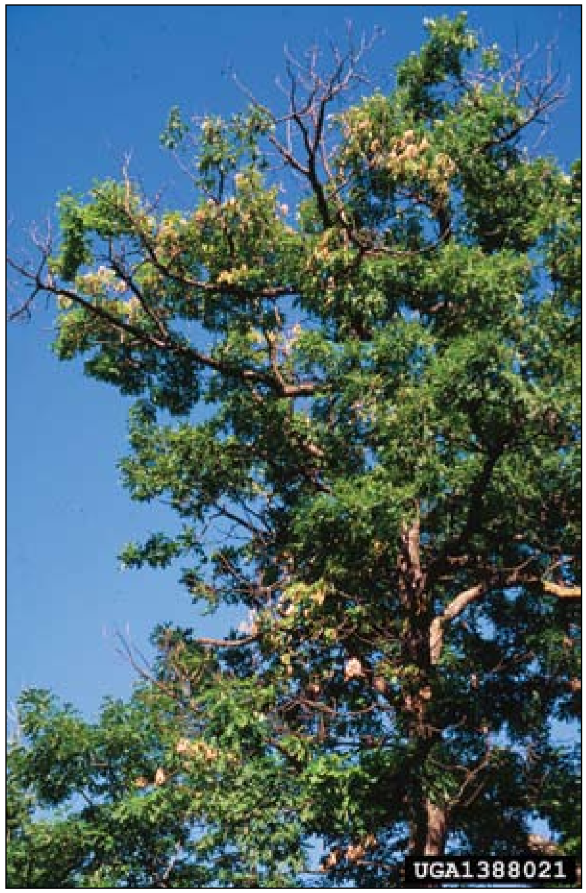


Figure 6. The earliest signs of twolined chestnut borer attack are wilting of foliage in later summer and then death of upper limbs of tree. (Steven Katovich, USDA Forest Service, Bugwood.org)

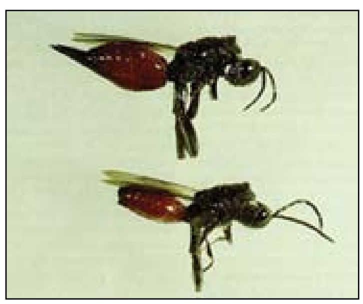


Figure 7. *Phasgonophora sulcata* is a common larval parasite of the twolined chestnut borer in Wisconsin. (USDA Forest Service • Forest Insect & Disease Leaflet 168)

Important Biological Control Agents Related to this Pest Species

Larval parasites provide limited natural control of the twolined chestnut borer. One larval parasite, the chalcid wasp *Phasgonophora sulcata* Westwood, causes up to 10 percent larval mortality.

Web Links for Information on Twolined Chestnut Borer

http://www.na.fs.fed.us/spfo/pubs/fidls/chestnutborer/chestnutborer.htm; USDA Forest Service Forest Insect and Disease Leaflet No. 168.

Articles

Dunbar, D.M. and G.R. Stephens. 1976. The bionomics of the twolined chestnut borer. In: Anderson, J.F. and H.K. Kaya (eds.) *Perspectives in Forest Entomology.* New York, New York. Academic Press: 73-83.

Cote, W.A., III and D.C. Allen. 1980. Biology of twolined chestnut borer, *Agrilus bilineatus*, in Pennsylvania and New York. *Annals of the Entomological Society of America* 73: 409-413.

Articles (continued)

Haack, R.A., D.M. Benjamin, and B.A. Schuh. 1981. Observations on the biology of *Phasgonophora sulcata* (Hymenoptera: Chalcididae), a larval parasitoid of the twolined chestnut borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), in Wisconsin. *The Great Lakes Entomologist* 14: 113-116.

Haack, R.A. and D.M. Benjamin. 1982. The biology and ecology of the twolined chestnut borer, *Agrilus bilineatus* (Coleoptera: Buprestidae), on oaks, *Quercus* spp., in Wisconsin. *The Canadian Entomologist* 114: 385-396.

Dunn, J.P., T.W. Kimmerer, and G.L. Nordin. 1986. The role of host tree condition in attack of white oaks by the twolined chestnut borer, *Agrilus bilineatus* (Weber) (Coleoptera: Buprestidae). *Oecologia* 70: 596-600.

Muzika, R.M., A.M. Liebhold, and M.J. Twery. 2000. Dynamics of twolined chestnut borer, *Agrilus bilineatus*, as influenced by defoliation and selection thinning. *Agricultural and Forest Entomology* 2: 283-289. (Available at http://onlinelibrary.wiley.com/doi/10.1046/j.1461-9563.2000.00077.x/pdf).

90. Bronze Birch Borer, *Agrilus anxius* Gory (Coleoptera: Buprestidae)

Orientation to Pest

Bronze birch borer, *Agrilus anxius* Gory, adults are slender, olive-bronze beetles, with a coppery reflection. The species is native to North America and is widespread in the eastern and central United States and southeastern Canada. Before 1950, bronze birch borer and another species, now called aspen borer (*Agrilus liragus* Barter and Brown) were considered to be the same species; so records from before this period need to be segregated based on the genus of tree attacked, with only *Betula*-attacking records being bronze birch borer. The biology of this species is similar to that of other *Agrilus* species, with adults emerging in late spring or early summer, laying eggs in bark cracks or under bark flaps, and larvae tunneling through the bark to the phloem and cambium layers, where they construct and feed in long meandering galleries. Full-grown larvae construct shallow cells in the xylem (outer sapwood) in autumn where they overwinter. They pupate the following spring and adults emerge shortly thereafter. There is usually one generation per year, but it may require two years to reach maturity in some areas. Bronze birch borer develops in weakened trees of various species of birch (*Betula*), especially the white-barked species. Individual branches or entire trees are killed by the girdling action of the larvae. Bronze birch borer is considered the most serious pest of paper birch (*Betula papyrifera* Marsh.) and extensive outbreaks occurred in New Brunswick in 1939 and in the Great Lakes states in the 1990s. In both cases, outbreaks were in large stands of older birch trees stressed by defoliating insects or drought. Bronze birch borer may attack healthy trees during outbreaks, especially isolated trees, and ones on the edges of clearings. Ornamental birches, especially those of Asian and European origin, are often highly susceptible to bronze birch borer attack.

Hosts Commonly Attacked

Species that are severely attacked include European white birch (*B. pendula* Roth) and whitebarked Himalayan birch (*B. jacquemontii* D. Don). Commonly attacked species include paper birch (*B. papyrifera*), gray birch (*B. populifolia* Marsh.), sweet birch (*B. lenta* L.), and yellow birch (*B. alleghaniensis* Britt.).

Distribution

Bronze birch borer occurs across Canada from Newfoundland to British Columbia and south to New Jersey, Ohio, Colorado, Idaho, and Utah in the United States.

Images of Bronze Birch Borer

Figure 1. Adult bronze birch borer, *Agrilus anxius*. (John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 2. Larva of bronze birch borer. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 3. Larval galleries of bronze birch borer in a limb (top) and the trunk (bottom). (Top: William M. Ciesla, Forest Health Management International, Bugwood.org; bottom: Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Bronze Birch Borer (continued)

Figure 4. Mature larvae tunnel a short way into the wood (left) to overwinter and pupate in spring; right, pupa of bronze birch borer in outer sapwood. (Left: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org; right: Jim Baker, North Carolina State University, Bugwood.org)

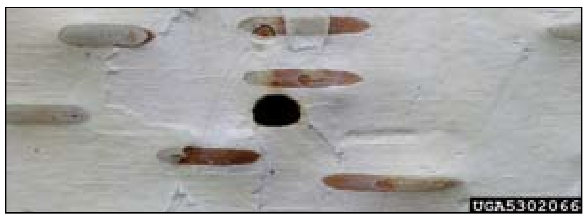


Figure 5. D-shaped exit hole made by adult bronze birch borer. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 6. Landscape trees with infestations of bronze birch borer. (Left: Steven Katovich, USDA Forest Service, Bugwood.org; right: Randy Cyr, Greentree, Bugwood.org)

Images of Bronze Birch Borer (continued)

Figure 7. Damage from bronze birch borer in a forest birch stand in Minnesota. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of bronze birch borer have been studied in New Brunswick and Pennsylvania. Egg parasitism by several species (the signiphorid *Thysanus* sp. and the encrytid *Coccidencyrtus* sp.) was common (about 50 percent) and was considered important. Important larval parasites included the braconid *Atanycolus charus* (Riley) and the chalcidid *Phasgonophora sulcata* Westwood, which together killed about 18 percent of the larvae.

Web Links for Information on Bronze Birch Borer

http://ipm.illinois.edu/landturf/insects/bronze_birch_borer/index.html; IPM fact sheet from Illinois.

http://www.na.fs.fed.us/spfo/pubs/fidls/bbb/bbb.htm; USDA Forest Service Forest Insect & Disease Leaflet 111.

http://wiki.bugwood.org/Agrilus_anxius; Bugwood Wiki fact sheet.

http://www.eppo.org/QUARANTINE/Alert_List/insects/agrilus_anxius.htm; EPPO fact sheet on risk of bronze birch borer as a potential risk for invasion to Europe.

http://www.eppo.org/QUARANTINE/Pest_Risk_Analysis/PRA_documents.htm; EPPO fact sheet on risk of bronze birch borer to European birches.

Articles

Anderson, R.F. 1944. The relation between host condition and attacks by the bronze birch borer. *Journal of Economic Entomology* 37: 588-596.

Barter, G.W. 1957. Studies of the bronze birch borer, *Agrilus anxius* Gory, in New Brunswick. *The Canadian Entomologist* 89: 12-36.

Ball, J. and G. Simmons. 1980. The relationship between bronze birch borer and birch dieback. *Journal of Arboriculture* 6: 309-314.

Akers, R.C. and D.G. Nielsen. 1984. Predicting *Agrilus anxius* Gory (Coleoptera: Buprestidae) adult emergence by heat unit accumulation. *Journal of Economic Entomology* 77: 1459-1463.

Jones, E.A., D.D. Reed, G.D. Mroz, H.O. Liechty, and P.J. Cattelino. 1993. Climate stress as a precursor to forest decline: paper birch in northern Michigan, 1985-1990. *Canadian Journal of Forest Research* 23: 229-233.

91. Emerald Ash Borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae)

Orientation to Pest

Emerald ash borer, *Agrilus planipennis* Fairmaire, is an invasive borer from northeast Asia threatening North American ash trees (*Fraxinus*). It was first detected near Detroit, Michigan and likely was introduced in the 1990s. It is now found in 14 other states and two Canadian provinces, and the infested range is expanding rapidly. Emerald ash borer attacks and kills healthy ash trees from ones several inches in diameter to mature trees. Massive mortality to ash of several species has occurred since the species' invasion in both landscape plantings and natural ash-dominated communities, especially in riparian areas. Larvae feed on phloem and make serpentine galleries that girdle and kill trees when the larval densities are high. Mature larvae tunnel into sapwood to pupate. In northern areas (e.g., Michigan), a single generation may require two years, but in mid-Atlantic states (e.g., Maryland), a generation can be completed each year. In dense populations, woodpeckers consume many larvae.

Hosts Commonly Attacked

Most North American *Fraxinus* species are susceptible, but so far the most affected species have been white (*Fraxinus americana* L.), green (*F. pennsylvanica* Marshall), and black (*F. nigra* Marshall) ash.

Distribution

The North America infested area is centered on Michigan. Extensive infestations exist in Ontario, Illinois, Indiana, Ohio, Kentucky, Pennsylvania, and Maryland, and smaller infested areas are found in Quebec, Minnesota, Iowa, Wisconsin, Missouri, Tennessee, New York, Virginia, and West Virginia (as of 2010).

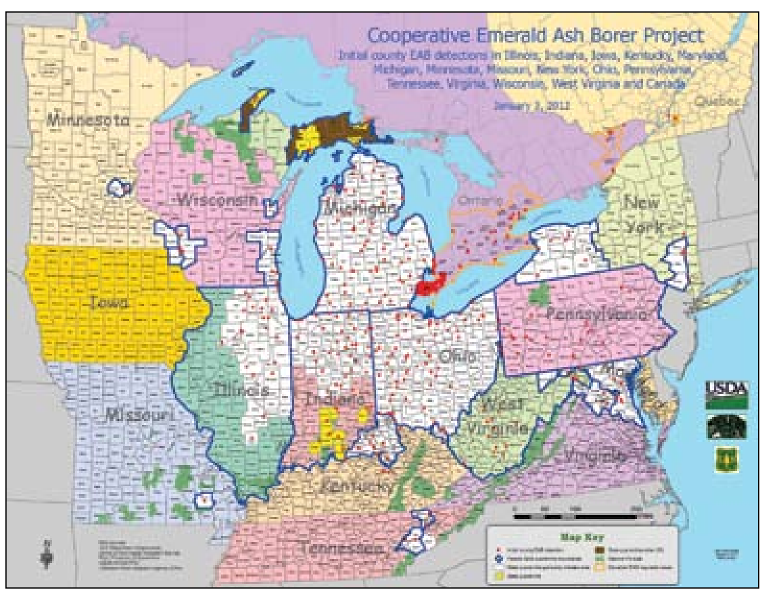


Figure 1. Distribution of emerald ash borer, *Agrilus planipennis*, in 2010. (Cornell University, Cooperative Extension • The New York Invasive Species Clearinghouse)

Images of Emerald Ash Borer

Figure 2. Adults of emerald ash borer. (Top left: Howard Russell, Michigan State University, Bugwood.org; top right and bottom: David Cappaert, Michigan State University, Bugwood.org)

Figure 3. Emerald ash borer eggs are white when freshly laid (top), but turn tan as they age (bottom). (Both photos: Houping Liu, Michigan State University, Bugwood.org)

Images of Emerald Ash Borer (continued)

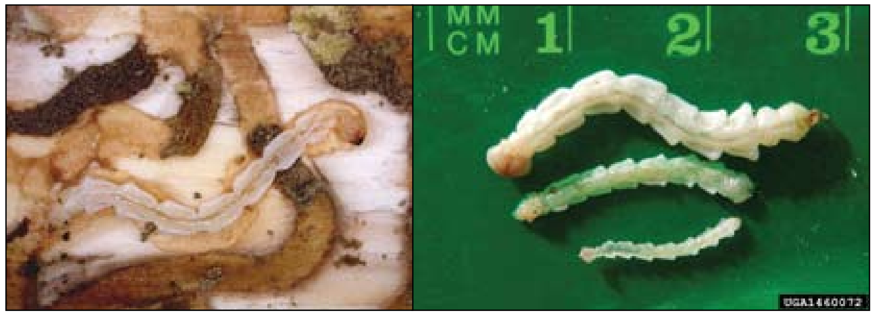


Figure 4. Feeding stage larvae of emerald ash borer: full grown 4th instar (left); second, third and 4th instars (right). (Both photos: David Cappaert, Michigan State University, Bugwood.org)

Figure 5. Larval galleries of emerald ash borer. (Top left: Troy Kimoto, Canadian Food Inspection Agency, Bugwood.org; top right: Michigan Department of Agriculture, Bugwood.org; bottom: Edward Czerwinski, Ontario Ministry of Natural Resources, Bugwood.org)

Images of Emerald Ash Borer (continued)

Figure 6. Prepupae in chambers formed in sap wood by mature larvae. (Brian Sullivan, USDA APHIS PPQ, Bugwood.org)

Figure 7. Prepupa of emerald ash borer in chamber in sap wood. (David Cappaert, Michigan State University, Bugwood.org)

Figure 8. D shaped emergence hole of emerald ash borer (left) and hole made by woodpecker (right) where an emerald ash borer larva was removed. (David Cappaert, Michigan State University, Bugwood.org)

Images of Emerald Ash Borer (continued)

Figure 9. Signs of infestation: left, suckering; right, bark splits. (Left: Joseph O'Brien, USDA Forest Service, Bugwood.org; right: Michigan Department of Agriculture, Bugwood.org)

Figure 10. Dead and dying ash in forest area due to emerald ash borer. (Troy Kimoto, Canadian Food Inspection Agency, Bugwood.org)

Figure 11. Dying or dead landscape trees affected by emerald ash borer. (Left: Steven Katovich, USDA Forest Service, Bugwood.org; right: David Cappaert, Michigan State University, Bugwood.org)

Images of Emerald Ash Borer (continued)

Figure 12. Tree removal was tried, unsuccessfully, as a means to eradicate emerald ash borer populations. (Top: David Cappaert, Michigan State University, Bugwood.org; bottom: Daniel Herms, The Ohio State University, Bugwood.org)

Figure 13. Girdling trees can be an effective survey method to detect emerald ash borers. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Emerald Ash Borer (continued)

Figure 14. The Chinese parasitoid of emerald ash borer eggs, *Oobius agrili*. (Debbie Miller, USDA Forest Service, Bugwood.org)

Figure 15. The Chinese larval parasitoid *Tetrastichus planipennisi*. (Houping Liu, Michigan State University, Bugwood.org)

Figure 16. The Chinese emerald ash borer larval parasitoid, *Spathius agrili*. (Jennifer Ayer, Bugwood.org)

Images of Emerald Ash Borer (continued)

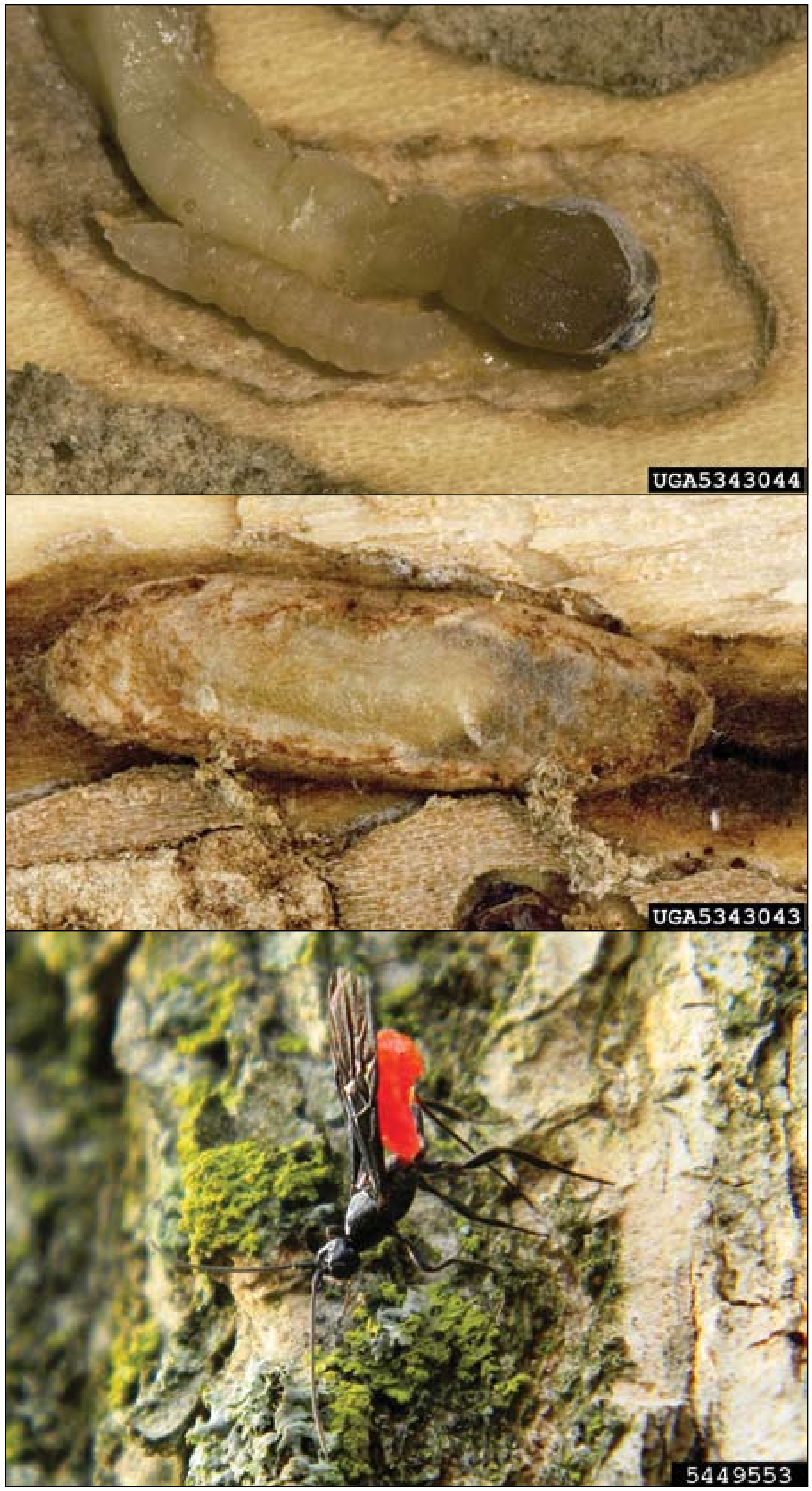


Figure 17. Larva, pupa (in cocoon), and adult of the native North American parasitoid *Atanycolus cappaerti* Marsh and Strazanac. (Top and middle: David Cappaert, Michigan State University, Bugwood.org; bottom: Jian Duan, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of emerald ash borer that have been collected in the native range (especially in China and Russia) include two larval parasitoids (the eulophid *Tetrastichus planipennisi* Yang and the braconid *Spathius agrili* Yang), and an egg parasitoid, *Oobius agrili* Zhang and Huang (Hymenoptera: Encyrtidae). Additional parasitoids have been identified and are under consideration for importation, including *Spathius* n. sp. and *Antanycolus picipes* Telenga from Russia. One group of native North American parasitoids, braconids in the genus *Atanycolus*, has adopted emerald ash borer and causes up to 20-40 percent mortality of the larvae in some areas.

Web Links for Information on Emerald Ash Borer

http://www.invasiveforestinsectandweedbiocontrol.info/target_pests/insects_mites/Emeraldashborer.htm; University of Massachusetts fact sheet on biological control of emerald ash borer.

http://www.nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/biological_control/; USDA Forest Service website on biological control of emerald ash borer.

http://www.dec.ny.gov/animals/7253.html; fact sheet of the New York Department of Environmental Conservation.

Articles

Liu, H-P, L.S. Bauer, D.L. Miller, L-W. Song, Q-S. Luan, S-H. Sun, and R.Z. Jin. 2007. Seasonal abundance and population dynamics of *Agrilus planipennis* (Coleoptera: Buprestidae) and its natural enemies *Oobius agrili* (Hymenoptera: Encyrtidae) and *Tetrastichus planipennisi* (Hymenoptera: Eulophidae) in China. *Biological Control* 42: 61-71.

Yang, Z-Q, J.S. Strazanac, P.M. Marsh, C. van Achterberg, and W-Y. Choi. 2005. First recorded parasitoid from China of *Agrilus planipennis*: A new species of *Spathius* (Hymenoptera: Braconidae, Doryctinae). *Annals of the Entomological Society of America* 98: 636-642.

Yang, Z-Q., J.S. Strazanac, Y-X. Yao, and X-Y. Wang. 2006. A new species of emerald ash borer parasitoid from China belonging to the genus *Tetrastichus* Haliday (Hymenoptera: Eulophidae) parasitizing emerald ash borer from China. *Proceedings of the Entomological Society of Washington* 108: 550-558.

Zhang,Y.Z., D.W. Huang, T.H. Zhao, H.P. Liu, and L.S. Bauer. 2005. Two new species of egg parasitoids (Hymenoptera: Encrytidae) of wood-boring beetle pests from China. *Phytoparasitica* 33: 253-260.

Duan, J.J., L.S Bauer, J.R. Gould, and J.P. Lelito. 2011. Biological control of emerald ash borer in North America: Current progress and potential for success. *IOBC Newsletter*, November 2011.

Duan, J.J., L.S Bauer, K.J. Abell, and R.G. Van Driesche. 2011. Population responses of hymenopteran parasitoids to the emerald ash borer (Coleoptera: Buprestidae) in north central United States. *BioControl* 57: 199-209.

92. Goldspotted Oak Borer, *Agrilus auroguttatus* Schaeffer (Coleoptera: Buprestidae)

Orientation to Pest

Goldspotted oak borer, *Agrilus auroguttatus* Schaeffer, is an oak-attacking buprestid native to mountains in southern Arizona. This pest invaded southern California, likely having been moved in firewood taken by campers into public campgrounds in the region. It has killed more than 80,000 oaks in California's native oak-savannahs and is of concern as an ecological pest. It is still spreading due to unrestricted movement of firewood out of the affected parts of southern California, and the ultimate extent of potential damage is not yet known. The biology of this species is very similar to that of other *Agrilus* species, such as the better known emerald ash borer (*Agrilus planipennis* Fairmaire). In southern California, most goldspotted oak borers complete their development in one year, but some may require longer. Adults have an extended emergence period, but most do so in late June or early July. Adults have a pre-oviposition period during which they feed on oak foliage. Eggs are likely laid in crevices in the bark, and larvae after hatching bore through the bark. Young larvae feed in the outer phloem, while older larvae feed in the cambial layer. Pupation occurs in a chamber made by larvae in the outer phloem. Affected trees experience death of limbs, die back, and loss of vigor. Attacked trees often die within 2-3 years.

Hosts Commonly Attacked

The species most affected are coast live oak (*Quercus agrifolia* Née) and California black oak (*Q. kelloggii* Newb.). Canyon live oak (*Q. chrysolepis* Liebm.) is affected to a lesser degree. See http://en.wikipedia.org/wiki/Agrilus_coxalis - cite_note-npag-0.

Distribution

Goldspotted oak borer occurs as a native species in southern Arizona and as an invader in southern California. A related species, now known as *Agrilus coxalis* Waterhouse, is native to southern Mexico and Guatemala.

Figure 1. Known distribution of goldspotted oak borer, *Agrilus auroguttatus*, in California (invaded range-large circle) and Arizona (native range-small circles). (Tom Coleman, USDA Forest Service, Bugwood.org)

Images of Goldspotted Oak Borer

Figure 2. Adult goldspotted oak borer. (Mike Lewis, Center for Invasive Species Research, Bugwood.org)

Figure 3. Feeding larva of goldspotted oak borer, as seen in the larval gallery. (Mark S. Hoddle, University of California - Riverside, Bugwood.org)

Figure 4. Mature, "J"-shaped larva of goldspotted oak borer (see folded "hairpin" position of body). (Mark S. Hoddle, University of California - Riverside, Bugwood.org)

Images of Goldspotted Oak Borer (continued)

Figure 5. Larval galleries of goldspotted oak borer under bark. (Tom Coleman, USDA Forest Service, Bugwood.org)

Figure 6. Wet stains on bark (left) caused by feeding of larvae, and scaled areas (right) where woodpeckers have removed larvae, are signs of goldspotted oak borer infestations. (Left: Tom Coleman, USDA Forest Service, Bugwood.org; right: Mark S. Hoddle, University of California - Riverside, Bugwood.org)

Images of Goldspotted Oak Borer (continued)

Figure 7. Exit holes of goldspotted oak borer have the “D”-shape typical of buprestids. (Mark S. Hoddle, University of California - Riverside, Bugwood.org)

Figure 8. Dead oaks in California oak-savannah due to attack by goldspotted oak borer. (Mike Lewis, Center for Invasive Species Research, Bugwood.org)

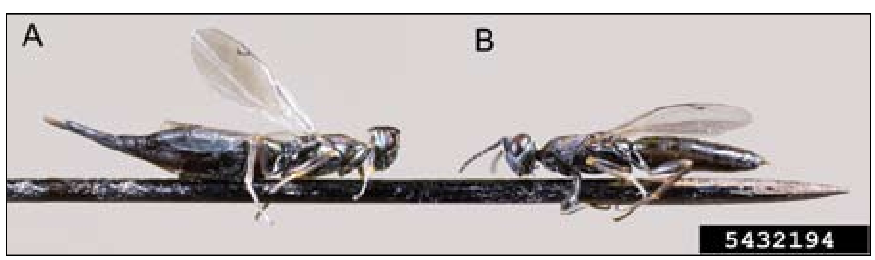


Figure 9. The eupelmid *Calosota elongata*, a larval ectoparasitoid of *Agrilus auroguttatus* (left, female; right, male). (Mike Lewis, Center for Invasive Species Research, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this species are relatively unknown, but surveys are being conducted in the pest's native range in southern Arizona to discover species suitable for importation to California. To date, insects reared from logs infested with goldspotted oak borer have mostly been generalist predators or parasitoids use not suitable for use as classical biological control agents (for California). The euplemid *Calosota elongata* Gibson is a larval parasitoid, collected from Arizona, that appears to be more specialized and whose host range is under investigation. The same species has been found in California in association with goldspotted oak borer and may have been introduced along with its host. DNA studies are underway to compare the California population of *C. elongata* to ones in Arizona. No egg parasitoids are known.

Web Links for Information on Goldspotted Oak Borer

http://cisr.ucr.edu/goldspotted_oak_borer.html; University of California, Riverside, Center for Invasive Species Research article on goldspotted oak borer.

http://en.wikipedia.org/wiki/Agrilus_coxalis; Wikipedia article, under a related but mistaken name of *Agrilus coxalis*.

http://ucanr.org/sites/SoCalOaks_NeedsAssessment2011/files/71253.pdf; bibliographic list of articles about goldspotted oak borer.

Articles

Coleman, T.W. and S.J. Seybold. 2008. New pest in California: The goldspotted oak borer, *Agrilus coxalis* Waterhouse. USDA Forest Service, Pacific Southwest Region, State and Private Forestry. Pest Alert R5-RP-022: 4 p.

Hishinuma, S., T.W. Coleman, M.L. Flint, and S.J. Seybold. 2011. Gold-spotted oak borer field identification guide. University of California Agriculture and Natural Resources Statewide Integrated Pest Management Program: 6 p. (Available at http://www.ipm.ucdavis.edu/PDF/MISC/GSOB_field-identification-guide.pdf).

93. Soapberry Borer, *Agrilus prionurus* Chevrolat (Coleoptera: Buprestidae)

Orientation to Pest

The soapberry borer, *Agrilus prionurus* Chevrolat, is a Mexican wood-boring buprestid about which very little is known. It has moved out of its native range in Mexico into Texas, where it is now killing western soapberry trees (*Sapindus saponaria* var. *drummondii* [Hook. and Arn.] L.D. Benson). How it got to Texas is not known, but movement of firewood is a likely explanation. The biology of the insect is not well known but is likely very similar to other invasive *Agrilus* (e.g., goldspotted oak borer [*A. auroguttatus* Schaeffer] and emerald ash borer [*A. planipennis* Fairmaire]). The adults are about 1.3 cm long, black, with four distinctive white dots on the wing covers. The larvae feed immediately under the bark. While not certain, it is likely that the insect has one generation per year, with adults emerging between May and August. The insect probably overwinters as a mature larva or pupa in a cell in the wood of the soapberry trees, with adult beetles later emerging through a D-shaped exit hole and laying their eggs on the tree trunk.

Hosts Commonly Attacked

The only reported host in Texas is western soapberry (*S. saponaria* var. *drummondii*). Western soapberry trees larger than 5 cm in diameter at breast height are susceptible and infestation usually results in tree death within 1 to 3 years following initial attack. Hosts in Mexico have not been recorded.

Distribution

Native to Mexico, within the United States this species is currently found only in Texas in 42 counties.

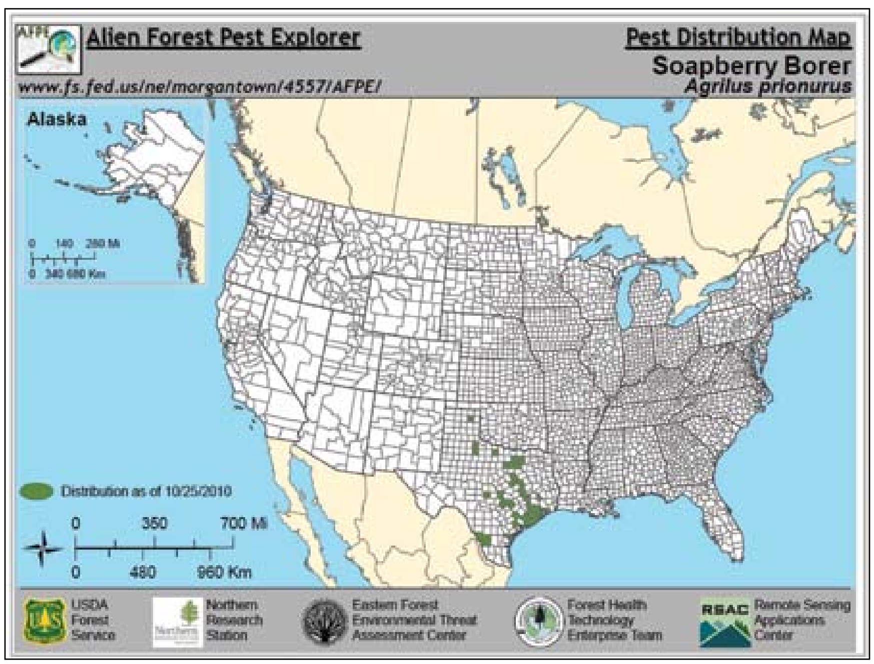


Figure 1. Distribution of soapberry borer, *Agrilus prionurus*, in the United States. (USDA Forest Service • AFPE Online Mapping)

Images of Soapberry Borer

Figure 2. Adults of soapberry borer. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 3. Damage on the trunk (top) of a western soapberry tree from soapberry borer is highly visible, appearing as scaled patches where birds have picked off the bark in search of larvae, exposing galleries; larva visible in photo below. (Both photos: Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Soapberry Borer (continued)

Figure 4. Emergence hole of the soapberry borer, showing typical “D” shape characteristic of buprestids. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 5. Western soapberry tree showing branches killed by the soapberry borer and epicormic sprouts along lower trunk. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Images of Soapberry Borer (continued)

Figure 6. Damage to group of western soapberry trees by soapberry borer in Houston, Texas. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of western soapberry borer are unknown.

Web Links for Information on Soapberry Borer

http://tfsweb.tamu.edu/main/popup.aspx?id=5316; fact sheet of the Texas Forest Service.

http://elpasonaturally.blogspot.com/2009/06/wanted-location-of-soapberry-borer.html; website of "El Paso Naturally," which includes photos of western soapberry borer.

http://www.texasinvasives.org; website providing description of insect and questionnaire to report new infestations.

Articles

Wellso, S.G. and J.A. Jackman. 2006. A new species of *Anthaxia* (*Haplanthaxia*) Reitter (Coleoptera: Buprestidae) and new North American buprestid distributional and host records. *Pan-Pacific Entomologist* 82(2): 262-268. (First record in the USA).

Billings, R.F. and H.A. Pase, III. 2010. Soapberry borer continues to spread in Texas. *Texas Forestry*, February issue: 7 p.

94. Hickory Spiral Borer, *Agrilus torquatus* LeConte (Coleoptera: Buprestidae)

Orientation to Pest

Hickory spiral borer, *Agrilus torquatus* LeConte, is a native beetle found over a wide area in the eastern United States, feeding principally on pecan (*Carya illinoinensis* [Wangenh.] K. Koch) and hickory (other *Carya* spp.). There are a group of four closely species that previously were considered subspecies of *Agrilus arcuatus*, but all of which have now been raised to full species status, using their former subspecies names. These include *A. arcuatus torquatus*, the focus of this page, which attacks hickory and pecan; *A. arcuatus fulgens* from hazel (*Corylus*); *A. arcuatus corylicola*—also from hazel (*Corylus*); and *A. arcuatus arcuatus* from oak (*Quercus*) and American beech (*Fagus grandifolia* Ehrh.). *Agrilus torquatus* requires two growing seasons to complete its development, emerging in the spring or summer (May to July) of the third year. After emerging, adults feed on host foliage, making large irregular holes in the leaves. Eggs are deposited singly on the bark surface of terminals or lateral twigs, usually near the base of small shoots of the current season's growth and are covered with a transparent secretion that glues them in place. Larvae tunnel beneath the bark, where they feed for two growing seasons. In late autumn, they begin spiral burrows, encircling the stem until reaching the center and severing the twigs by spring. Larvae pupate in cells constructed in the pith of the stem. The most distinctive aspect of the damage of this species is the spiral track made by the larvae, which is characteristic in form and good for identification of the pest. This track is a winding concentric gallery that moves from the inner bark to the heart of the branch or stem. Branches and terminals are usually severed in late winter or spring and the portion beyond the girdle typically dies before new foliage appears in spring, making damaged terminals easy to spot. Most severed branches break and fall to the ground around the time that buds open. Attacked twigs are usually from ca 1-4 cm in diameter and 0.5 to 2.5 m long. While most damage is to twigs and small branches, when seedlings are attacked they may be killed. Extensive damage to large pecan trees reduces nut production, and gives trees a ragged appearance. Repeated attacks on young trees may make them stunted, misshapen, or crooked.

Hosts Commonly Attacked

The hosts of this species are pecan (*C. illinoinensis*) and species of hickory (*Carya*).

Distribution

This species has been recorded from New York, Ohio, North Carolina, and Mississippi.

Images of Hickory Spiral Borer

Figure 1. Adult of the closely related *Agrilus arcuatus*. (Tom Murray, Bugwood.org)

Figure 2. Larva of hickory spiral borer *Agrilus torquatus*. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Distinctive spiraling pattern of larval galleries of hickory spiral borer. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Five insect parasitoids are known to attack this borer: *Labena apicalis* Cresson, *Labena grallator* (Say), *Monogonogastra agrili* (Ashmead), *Tetrastichus rugglesi* Rohwer, and *Zatropis* sp. near *nigroaeneus* (Ashmead).

Web Links for Information on Hickory Spiral Borer

None

Articles

Nelson, G.H. and H.A. Hespenheide. 1998. A re-evaluation of some *Agrilus* Curtis species (Coleoptera: Buprestidae). *Coleopterists Bulletin* 52(1): 31-34.

95. Flatheaded Appletree Borer, *Chrysobothris femorata* (Olivier) (Coleoptera: Buprestidae)

Orientation to Pest

Flatheaded appletree borer, *Chrysobothris femorata* (Olivier), is a common, well known native borer affecting many species of hardwood trees in North America. Adults emerge in summer and feed on foliage of their host trees. Eggs are deposited under bark scales or in crevices on the main trunk or larger branches. The larvae bore into the bark and feed in the phloem and outer sapwood. In older trees, tunnels are most often in the thick inner bark. Mature larvae build pupation cells in the outer wood in late summer, where they pass the winter and pupate the following spring. There is one generation per year. This borer is especially damaging to newly planted trees and trees stressed by drought or other factors. Young trees may be girdled and killed. Larger trees may show injuries through loss of large patches of bark on trunks.

Hosts Commonly Attacked

This species attacks a wide range of trees species, including sycamore (*Platanus occidentalis* L.), silver maple (*Acer saccharinum* L.), boxelder (*A. negundo* L.), black walnut (*Juglans nigra* L.), willow (*Salix*), white oak (*Quercus alba* L.), black oak (*Q. velutina* Lamb.), yellow-poplar (*Liriodendron tulipifera* L.), elm (*Ulmus*), American beech (*Fagus grandifolia* Ehrh.), hickory (*Carya*), hackberry (*Celtus*), apple (*Malus domestica* Borkh.), and pear (*Pyrus*).

Distribution

This species is found throughout most of Canada and the United States.

Images of Flatheaded Appletree Borer

Figure 1. Adult of the flatheaded apple tree borer, *Chrysobothris femorata*. (Joseph Berger, Bugwood.org)

Images of Flatheaded Appletree Borer (continued)

Figure 2. Mature larva of flatheaded apple borer. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Sap spot over feeding site of flatheaded apple borer larva in Nuttall oak (*Quercus texana* Buckl.). (James Solomon, USDA Forest Service, Bugwood.org)

Images of Flatheaded Appletree Borer (continued)

Figure 4. Damage to red maple (*Acer rubrum* L.) from flatheaded apple borer. (John Ruter, University of Georgia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies known to attack the flatheaded apple borer include the ichneumonids *Labena grallator* Say and *Crytohelcostizus chrysobothridis* Cushman, the chalcid *Phasgonophora sulcata* Westwood, and the braconid *Atanycolus rugosiventris* Ashmead. Predators include the clerids *Chariessa pilosa* (Foster) and *Chariessa pilosa onusta* Say, the asilid *Andrenosoma fulvicauda* Say, and various woodpeckers.

Web Links for Information on Flatheaded Appletree Borer

http://insects.tamu.edu/extension/publications/epubs/eee_00027.cfm; fact sheet of the Texas A&M University covering biology and control.

http://ipm.illinois.edu/greenhouse/insects/flat_headed_apple_tree_borer/index.html; fact sheet of the University of Illinois.

http://www.utextension.utk.edu/publications/spfiles/SP503-I.pdf; guide to the identification of apple flathead borer and other buprestids in Kentucky.

http://wiki.bugwood.org/Archive:Hickory/Chrysobothris_femorata; Bugwiki factsheet.

Articles

Potter, D.A., G.M. Timmons, and F.C. Gordon. 1988. Flatheaded apple treeborer (Coleoptera: Buprestidae) in nursery-grown red maples: phenology of emergence, treatment timing, and response to stressed trees. *Journal of Environmental Horticulture* 6(1): 18-22.

96. Red Oak Borer, *Enaphalodes rufulus* (Haldeman) (Coleoptera: Cerambycidae)

Orientation to Pest

Red oak borer, *Enaphalodes rufulus* (Haldeman), is a native borer to North America, which attacks various species of oak (*Quercus*), primarily those in the red oak subgenus. Red oak borer has a 2-year life cycle that is unique in that adults only emerge during odd numbered years. Mating takes place on the host tree and females lay eggs in midsummer on roughened areas or near wounds, in bark crevices, or under lichen or vines. Young larvae bore through the bark and spend their first year in the phloem making small tunnels. The 2-year-old larvae enlarge these phloem galleries and then bore into the xylem where pupation takes place. The adult eventually emerges near the original oviposition site. Fine frass is one of the first signs of attack. As the larvae bore into the tree, wet spots can appear on the bark as sap oozes from the bore hole in the bark. Larval galleries increase in size over time, reaching 1.5 cm in diameter. Tunnels are 15 to 25 cm long and penetrate directly through the oak xylem. Larval tunnels cause lumber cut from infested logs to be downgraded, reducing log value by up to 40 percent compared to top quality wood.

Hosts Commonly Attacked

This species attacks various oaks, including black (*Quercus velutina* Lamb.), northern red (*Q. rubra* L.), and scarlet (*Q. coccinea* Muenchh.) oaks.

Distribution

Red oak borer is found throughout southern Canada and the eastern United States.

Images of Red Oak Borer

Figure 1. Adult of the red oak borer, *Enaphalodes rufulus*. (Jessica Lawrence, Eurofins Agroscience Services, Bugwood.org)

Images of Red Oak Borer (continued)

Figure 2. Eggs of red oak borer. (University of Arkansas Forest Entomology Lab Archive, University of Arkansas, Bugwood.org)

Figure 3. Young 1st-year red oak borer larva creating gallery in phloem. (University of Arkansas Forest Entomology Lab Archive, University of Arkansas, Bugwood.org)

Images of Red Oak Borer (continued)

Figure 4. Late stage red oak borer larva in xylem gallery. (Fred Stephen, University of Arkansas)

Figure 5. Gallery of red oak borer. (Fred Stephen, University of Arkansas)

Figure 6. Galleries of older red oak borer larvae in the heart wood, seen in cross section. (University of Arkansas Forest Entomology Lab Archive, University of Arkansas, Bugwood.org)

Images of Red Oak Borer (continued)

Figure 7. Emergence holes of red oak borer. (University of Arkansas Forest Entomology Lab Archive, University of Arkansas, Bugwood.org)

Figure 8. Healed scars showing damage from red oak borer. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 9. Lumber cut from infested trees is downgraded because of the galleries of red oak borer. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of Red Oak Borer (continued)

Figure 10. View of trees killed by red oak borer. (Gerald J. Lenhard, Lousiana State Univ, Bugwood.org)

Figure 11. View of red oaks killed in the Arkansas Ozarks during outbreak, September 2000. (Fred Stephen, University of Arkansas)

Important Biological Control Agents Related to this Pest Species

Parasitoids of this species are mostly generalists on wood borers and are not well known. Woodpeckers are an important predator of red oak borer larvae.

Web Links for Information on Red Oak Borer

http://www.eppo.org/QUARANTINE/Alert_List/insects/enaphalodes_rufulus.htm; fact sheet of EPPO on red oak borer as a potential invasion threat to Europe.

Articles

Riggins, J.J., L.D. Galligan, and F.M. Stephen. 2009. Rise and fall of red oak borer (Coleoptera: Cerambycidae) in the Ozark mountains of Arkansas, USA. *Florida Entomologist* 92: 426-433.

Haavik, L.J. and F.M. Stephen. 2010. Historical dynamics of a native cerambycid, *Enaphalodes rufulus*, in relation to climate in the Ozark and Ouachita Mountains of Arkansas. *Ecological Entomology* 35: 673-683.

97. Black Fir Sawyer Beetle, *Monochamus urussovii* (Fischer von Waldheim) (Coleoptera: Cerambycidae)

Orientation to Pest

Black fir sawyer beetle, *Monochamus urussovii* (Fischer von Waldheim), is native to Eurasia and is not present in North America. Male black fir sawyer beetles have antennae approximately twice as long as body, whereas those of females are just a bit longer that the body. This beetle attacks all species in the family Pinaceae. Firs (*Abies*) are especially vulnerable to damage. It is the capability of *M. urussovi* to vector phytopathogenic fungi that poses the greatest threat to North American forests. Reproduction of this beetle occurs in weakened or dying trees that have been affected by drought or fire, or have been wind thrown or recently cut. Outbreaks can occur, however, in live, healthy trees. The life cycle begins when beetles feed in the crown, removing strips of bark. This feeding infects branches with the blue-stain fungus *Leptographium sibiricum* Jacobs and Wingfield. Dieback of branches in the crown weakens the tree and reduces resin flow. These changes make the tree suitable for beetle oviposition and larval feeding. In the summer, female beetles excavate oviposition niches, often in the branches, and lay a single egg beneath the bark. Larvae dig sinuous galleries, up to 2.5 cm wide, under. These galleries are filled with frass. In the spring, overwintered larvae dig into the sapwood and create a pupal chamber, from which adults later emerge. As an infested host tree dies, its needles turn yellow and then red.

Hosts Commonly Attacked

This species is most damaging to fir (*Abies*), but larch (*Larix*), spruce (*Picea*), pine (*Pinus*), and birch (*Betula*) species are also commonly attacked.

Distribution

This beetle occurs in Sweden, Norway, Finland, eastern Poland, Estonia, Latvia, Lithuania, Belarus, Ukraine, Russia, Kazakhstan, Mongolia, northeastern China, Korea, and northern Japan.

Images of Black Fir Sawyer Beetle

Figure 1. Adult of black fir sawyer beetle, *Monochamus urussovii*. (Vitaly Gumenuk, Bugwood.org)

Images of Black Fir Sawyer Beetle (continued)

Figure 2. The circular emergence holes of black fir sawyer beetles are large, ca 1.2 cm in diameter. (Stanislaw Kinelski, Bugwood.org)

Figure 3. Brown foliage is sign of attack by black fir sawyer beetle. (Stanislaw Kinelski, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Some information is available in Russian language publications on the natural enemies of this species in Russia (see Isaev et al., 1988).

Web Links for Information on Black Fir Sawyer Beetle

http://www.inspection.gc.ca/english/plaveg/pestrava/monuru/tech/monurue.shtml; fact sheet of Canadian food inspection agency, proving information on life history and damage.

Articles

Vetrova, V.P., A.S. Isaev, N.V. Pashenova, and N.Yu Konstantinov. 1998. Estimating the threat of a mass outbreak of *Monochamus urussovii* in the dark coniferous stands of the Lower Angara region after damage by *Dendrolimus sibiricus*. *Lesovedenie* 3: 58-67.

Jacobs, K., M.J. Wingfield, N.V. Pashenova, and V.P. Vetrova. 2000. A new *Leptographium* species from Russia. *Mycological Research* 104: 1524-1529.

Isaev, A.S., T.M. Ovchinnikova, and V.G. Sukhovol'skii. 2001. Modeling the population dynamics of the longhorn *Monochamus urussovii* in the dark central-taiga forests of Siberia. *Lesovedenie* 4: 15-24.

Isaev, A.S., A.S. Rozhkov, and V.V. Kiselev. 1988. The fir longhorn *Monochamus urussovi*. (Chernyi pikhtovyi usach *Monochamus urussovi* [Fisch.]). *Novosibirsk: Nauka*, No. 270. (In Russian)

98. Japanese Pine Sawyer, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae)

Orientation to Pest

Japanese pine sawyer, *Monochamus alternatus* Hope, is native to Asia, principally China, Japan and Korea. In Asia, this species has proven to be an important vector of an introduced pathogenic nematode, the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle, which kills Asian pines. Japanese pine sawyer is not yet present in the United States. Japanese pine sawyers overwinter as large larvae in galleries in infested trees. Pupation occurs at the end of winter, and adults emerge in spring and feed on foliage of hosts (termed maturation feeding). This feeding occurs on two-year old shoots of healthy trees. This feeding is important because it provides locations for nematode invasion of live healthy trees. Nematode larvae emerge from beetle spiracles, fall onto damaged twigs, and penetrate the woody tissue through the feeding wounds. Once mature, adult beetles lay their eggs in trees that are stressed or have recently been killed by bark beetles, lightening, disease, or other factors. Eggs are placed singly in slots in bark cut by females. Each female may lay 100-200 eggs. Young larvae feed in the cambium and mature larvae tunnel into the heartwood to complete the cycle. There is one generation per year. Infestations damage wood of recently dead and downed conifers, causing degradation and loss of value for lumber.

The consequences of a potential introduction of Japanese pine sawyer to the United States by itself may not have severe consequences for two reasons. First, there are a number of other species of conifer-infesting *Monochamus* beetles already present in North America (e.g. *M. caroliniensis*, *M. marmorator* Kirby in Richardson, *M. notatus* Drury, *M. titillator* Fabricius, *M. scutellatus* Say), all of which attack recently killed or severely stressed trees. If introduced and established in North America, Japanese pine sawyer would likely compete with these species for the same set of hosts. Secondly, the pine wood nematode, *B. xylophilus*, which is native to North America and is vectored by native *Monochamus*, does not kill North American conifers. However, an invasion of Japanese pine sawyer might also introduce an Asian species of *Bursaphelenchus*, such as *Bursaphelenchus mucronatus* (Mamiya and Enda) or *Bursaphelenchus kolymensis* Korentchenko, occur in Asia on species of *Abies*, *Larix* and *Pinus* (the former species has been found in Canada). These are not known to cause widespread mortality of their native hosts, but may be more pathogenic to some North American conifers, due to lack of evolutionary association and hence lack of selection for resistance. Such an effect is predicted by the damage caused to Asia conifers by an introduced American species of *Bursaphelenchus*. Detection of invasion must be based on collection and identification of adult beetles, as symptoms of infestation by *M. alternatus* are identical to those caused by native North American *Monochamus* species.

Hosts Commonly Attacked

Japanese pine sawyer is known to attack seventeen species of pines (*Pinus*), including, in Japan, Japanese red pine (*Pinus densiflora* Siebold and Zucc.), Japanese black pine (*P. thunbergii* Parl.), luchu pine (*P. luchuensis* Mayr), and, in China, Mason pine (*P. massoniana* Lambert). It has also been reported to attack three species of spruce (*Picea* spp.), and one species each of fir (*Abies*), true cedar (*Cedrus*), and larch (*Larix*). Under laboratory conditions, fresh logs of the North American slash pine (*Pinus elliottii* Engelmann) were preferred over the native Japanese *P. densiflora* for oviposition, but larval survival was lower.

Distribution

Japanese pine sawyer is native to Asia and is found mainly in Japan, China, and Korea.

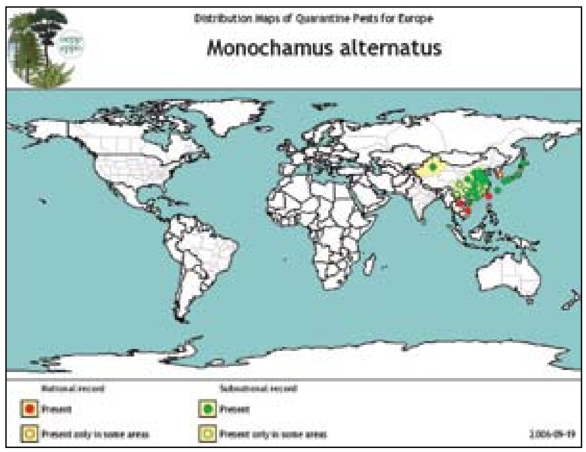


Figure 1. World distribution of Japanese pine sawyer, *Monochamus alternatus*. (EPPO • EPPO Plant Quarantine Data Retrieval System [PQR])

Images of Japanese Pine Sawyer

Figure 2. Adult of Japanese pine sawyer showing adult feeding on needles. (Jijing Song and Juan Shi, Beijing Forestry University, Bugwood.org)

Images of Japanese Pine Sawyer (continued)

Figure 3. Various North American species are similar in appearance and biology to Japanese pine sawyer; for example, *Monochamus notatus* (Drury) (top), *Monochamus scuttelatus* (Say) (middle), and *Monochamus marmorator* Kirby (bottom). (Top: J. Tomminen, University of Helsinki, Bugwood.org; middle: Laura Lazarus, North Carolina Division of Forest Resources, Bugwood.org; bottom: Natasha Wright, Florida Department of Agriculture and Consumer Services, Bugwood.org)

Images of Japanese Pine Sawyer (continued)

Figure 4. Adults of Japanese pine sawyer feed on foliage after emergence to obtain food to develop eggs. (William M. Ciesla, Forest Health Management International, Bugwood.org)

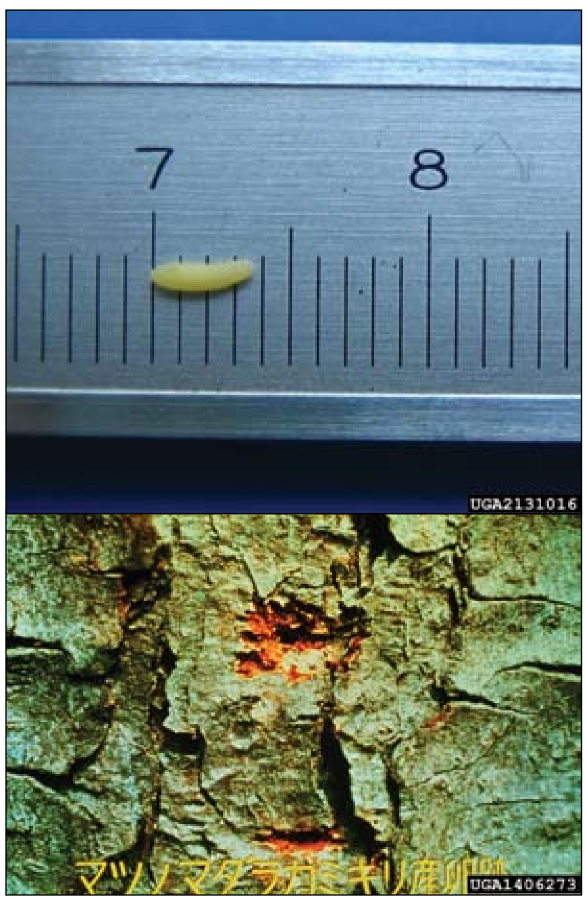


Figure 5. Egg of Japanese pine sawyer (top), and bark chewing at oviposition site (bottom). (Top: Jijing Song and Juan Shi, Beijing Forestry University, Bugwood.org; bottom: USDA Forest Service - North Central Research Station Archive, USDA Forest Service, Bugwood.org)

Images of Japanese Pine Sawyer (continued)

Figure 6. Larva of Japanese pine sawyer. (Jijing Song and Juan Shi, Beijing Forestry University, Bugwood.org)

Figure 7. Pupa of Japanese pine sawyer in the pupal chamber. The pupa is the stage that attracts the pine wood nematode, which attacks the trachea system of the pupa. (USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Figure 8. Tail of male pine wood nematode, *Bursaphelenchus xylophilus*, showing characteristic spicule. (L.D. Dwinell, USDA Forest Service, Bugwood.org)

Images of Japanese Pine Sawyer (continued)

Figure 9. Exit hole of Japanese pine sawyer (top), and adult exiting hole (bottom). (Top: Jijing Song and Juan Shi, Beijing Forestry University, Bugwood.org; bottom: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Figure 10. Mason pine (*Pinus massoniana*) in China killed by Japanese pine sawyer. (Jijing Song and Juan Shi, Beijing Forestry University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In China, a recently recognized predator affecting Japanese pine sawyer is the *Cryptalaus berus* (Coleoptera: Elateridae), and in Japan, the predator *Dastarcus helophoroides* (Fairmaire) is believed to be an important source of mortality.

Web Links for Information on Japanese Pine Sawyer

http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=77&langdisplay=english; a web site of the USDA Forest Service, with extensive detail on biology and risks.

Articles

Kobayashi, F., A. Yamane, and T. Ikeda. 1984. The Japanese pine sawyer beetle as the vector of pinewood nematode disease. *Annual Review of Entomology* 29: 115-135.

Mota, M.M. and P. Vieira (eds.). 2008. *Pine Wilt Disease: a Worldwide Threat to Forest Ecosystems*. Springer, New York.

99. Asian Longhorned Beetle, *Anoplophora glabripennis* Motschulsky (Coleoptera: Cerambycidae)

Orientation to Pest

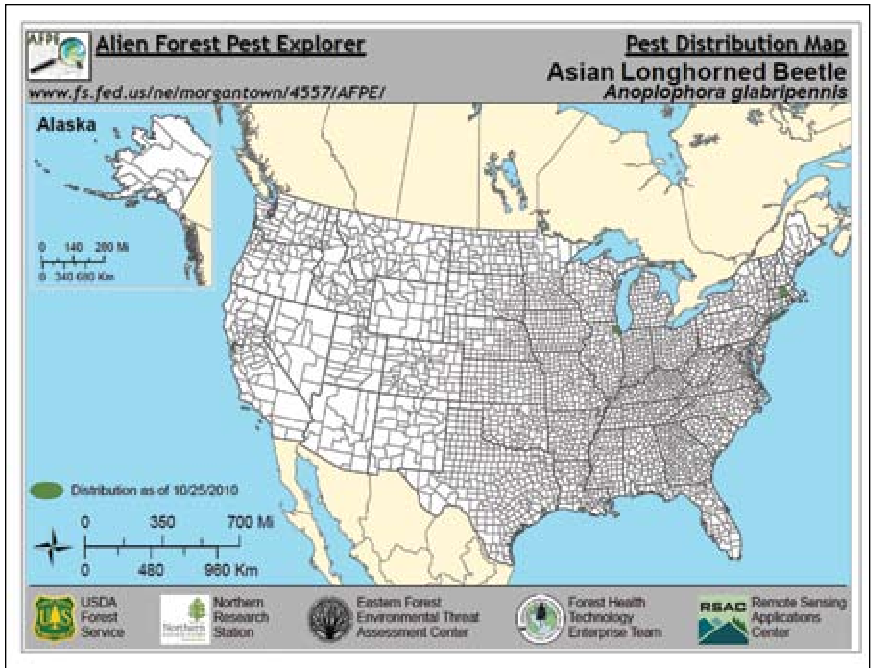
Asian longhorned beetle, *Anoplophora glabripennis* Motschulsky, is native to Asia (principally China) and invasive in parts of western Europe, and in several American cities, where eradication efforts are underway. This borer attacks a variety of hardwood trees. In China, Asian longhorned beetles are not damaging in forests, but because of extensive planting of certain poplars (exotic varieties) that proved highly susceptible to the species, the insect increased in abundance. This action facilitated the beetle's dissemination to other countries because infested wood was used for packing material. The biology of the species is typical of many longhorn beetles. Adults emerge over an extended period from spring to fall, but especially in late June to early July. Adults remain on or near their emergence tree and engage in maturation feeding on leaves, petioles, and tender bark. Eggs are laid singly under the bark, in egg sites chewed by females. Larvae feed in the cambium layer of the tree and later into the heartwood. Larvae dig pupation chambers inside the tree, which can be filled with frass. Adults emerge via large (1 cm dia) round exit holes, which are a visible sign of infestation. In southern Asia, a generation requires one year, but in northern areas, two years are required. Generations may be overlapping. Unlike many cerambycids, *A. glabripennis* attacks healthy trees as well as those under stress. Several generations can develop within an individual tree, eventually killing it.

Hosts Commonly Attacked

In China (the native range), the major hosts of *A. glabripennis* are certain species of *Populus*, especially *Populus nigra* L., *P. deltoides* W. Bartram ex Marshall, *Populus* x *canadensis* and the Chinese hybrid *P. dakhuanensis*. Other important hosts are the willows *Salix babylonica* L. and *S. matsudana* Koidzumi. Other species also recorded as hosts in China include species of *Acer*, *Alnus*, *Malus*, *Morus*, *Platanus*, *Prunus*, *Pyrus*, *Robinia*, *Rosa*, *Sophora*, and *Ulmus*. In urban areas in North America invaded by this species, the hosts attacked by this beetle have been species of maple (*Acer negundo* L., *A. platanoides* L., *A. pseudoplatanus* L., *A. rubrum* L., *A. saccharinum* L., and *A. saccharum* Marshall) and *Aesculus hippocastanum* L. However, it has also been found on a range of other hardwoods, including *Liriodendron tulipifera* L., *Morus alba* L., *Robinia pseudacacia* L., and species of *Betula*, *Fraxinus*, *Populus*, *Salix*, and *Ulmus*.

Distribution

Asian longhorned beetle is native to Asia. It has been detected in parts of Europe and in North America (Toronto, Canada, Illinois, the greater New York City area, New Jersey, and Massachusetts).



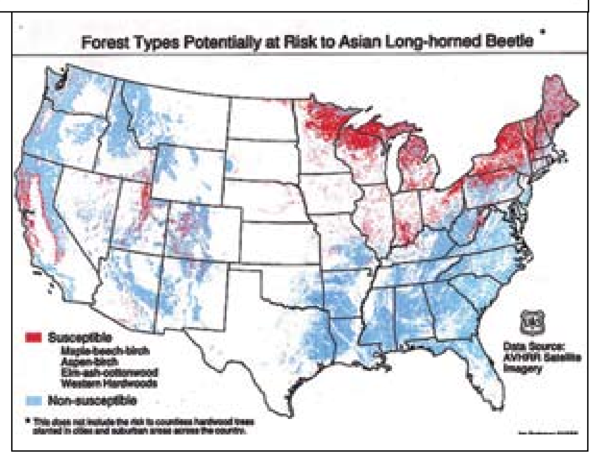
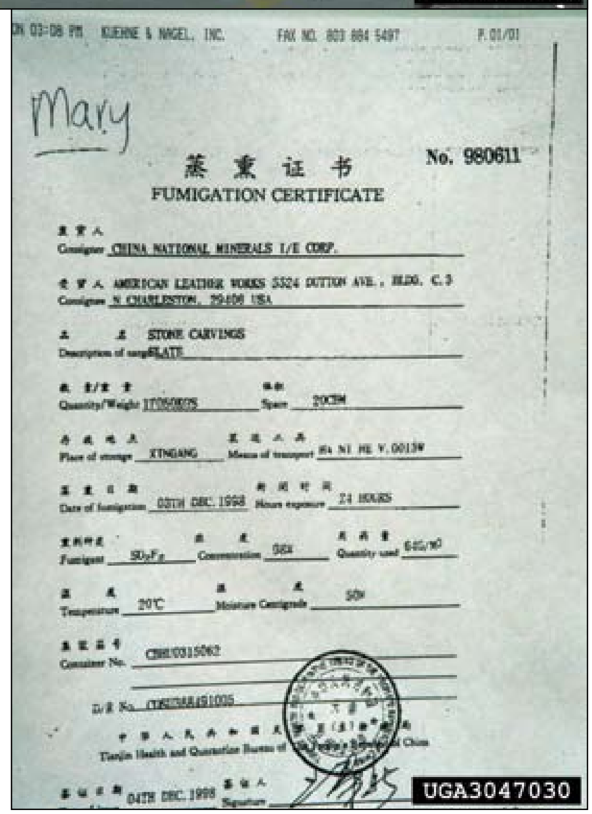


Figure 1. Current infestations (blue dots, top map) of Asian longhorned beetle, *Anoplophora glabripennis*, in the United States; potential areas at risk of becoming infested (red, on bottom map). (Top: USDA Forest Service • AFPE Online Mapping; bottom: USDA APHIS)

Images of Asian Longhorned Beetle

Figure 2. Adult of Asian longhorned beetle. (Michael Bohne, Bugwood.org)

Images of Asian Longhorned Beetle (continued)



KUEHNE & NAGEL, INC. FAX NO. 803 884 5497 P.01/01

Mary

No. 980611

蒸熏证书

FUMIGATION CERTIFICATE

Consignor CHINA NATIONAL MINERALS I/E CORP.

Consignee AMERICAN LEATHER WORKS 5324 DUTTON AVE., BLDG. C.3 N CHARLESTON, 29406 USA

STONE CARVINGS

Description of cargo SLATE

Quantity/Weight

Space 20CBM

Place of storage XINGANG

Means of transport

Date of fumigation 03TH DEC. 1998

Hours exposure 24 HOURS

Fumigant SO_2F_2

Concentration

Quantity used

Temperature 20℃

Moisture Centigrade

Container No.

B/L No.

Tianjin Health and Quarantine Bureau of ... China

04TH DEC. 1998

Signature

Figure 3. The invasion of North America by Asian longhorned beetle was likely caused by the shipment of massive quantities of raw wooden packing material from Asia (top). To reduce risks of further such invasions, wooden packing material must now be fumigated (bottom) or heat treated to kill larvae or other stages in wood. (Both photos: Larry R. Barber, USDA Forest Service, Bugwood.org)

Images of Asian Longhorned Beetle (continued)

Figure 4. Chewed bark on twig, caused by maturation feeding of adult Asian longhorned beetles. (Dean Morewood, Health Canada, Bugwood.org)

Figure 5. Left, sign of oviposition (chewed pit) on the trunk; right, eggs of Asian longhorned beetle. (Left: Kenneth R. Law, USDA APHIS PPQ, Bugwood.org; right: Melody Keena, USDA Forest Service, Bugwood.org)

Figure 6. Mixed age (top) and mature (bottom) larvae of Asian longhorned beetle. (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: Kenneth R. Law, USDA APHIS PPQ, Bugwood.org)

Images of Asian Longhorned Beetle (continued)

Figure 7. Pupa of Asian longhorned borer: left, extracted; right, in a pupal chamber, with frass. (Left: Michael Bohne, Bugwood.org; right: Kenneth R. Law, USDA APHIS PPQ, Bugwood.org)

Figure 8. Larva feeding tunnels of Asian longhorned beetles in small trunk (top), and tunnels as seen in cross section of cut branch (bottom). (Top: Larry R. Barber, USDA Forest Service, Bugwood.org; bottom: E. Richard Hoebeke, Cornell University, Bugwood.org)

Images of Asian Longhorned Beetle (continued)

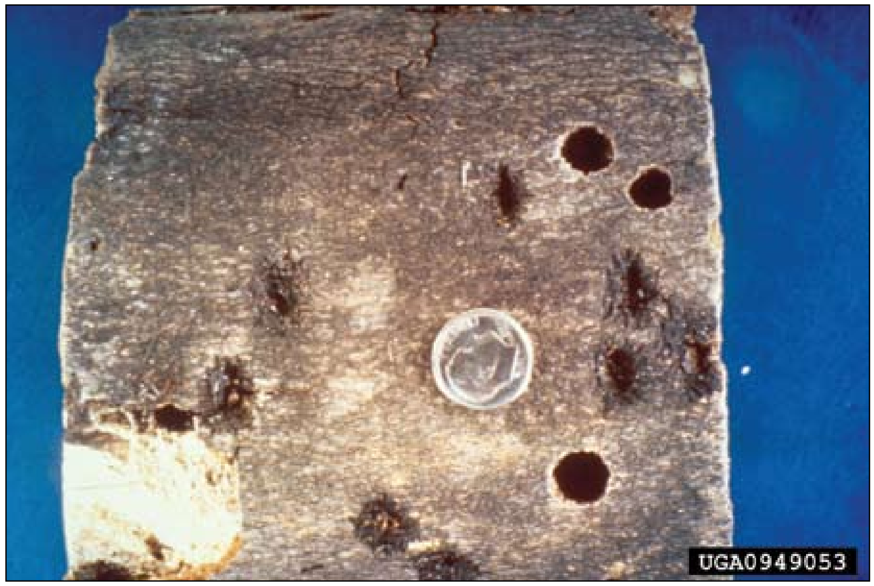


Figure 9. Emergence holes of Asian longhorned beetles. (E. Richard Hoebeke, Cornell University, Bugwood.org)

Figure 10. Dead branches in tops of trees are a sign of Asian longhorned beetle infestation. (Dennis Haugen, USDA Forest Service, Bugwood.org)

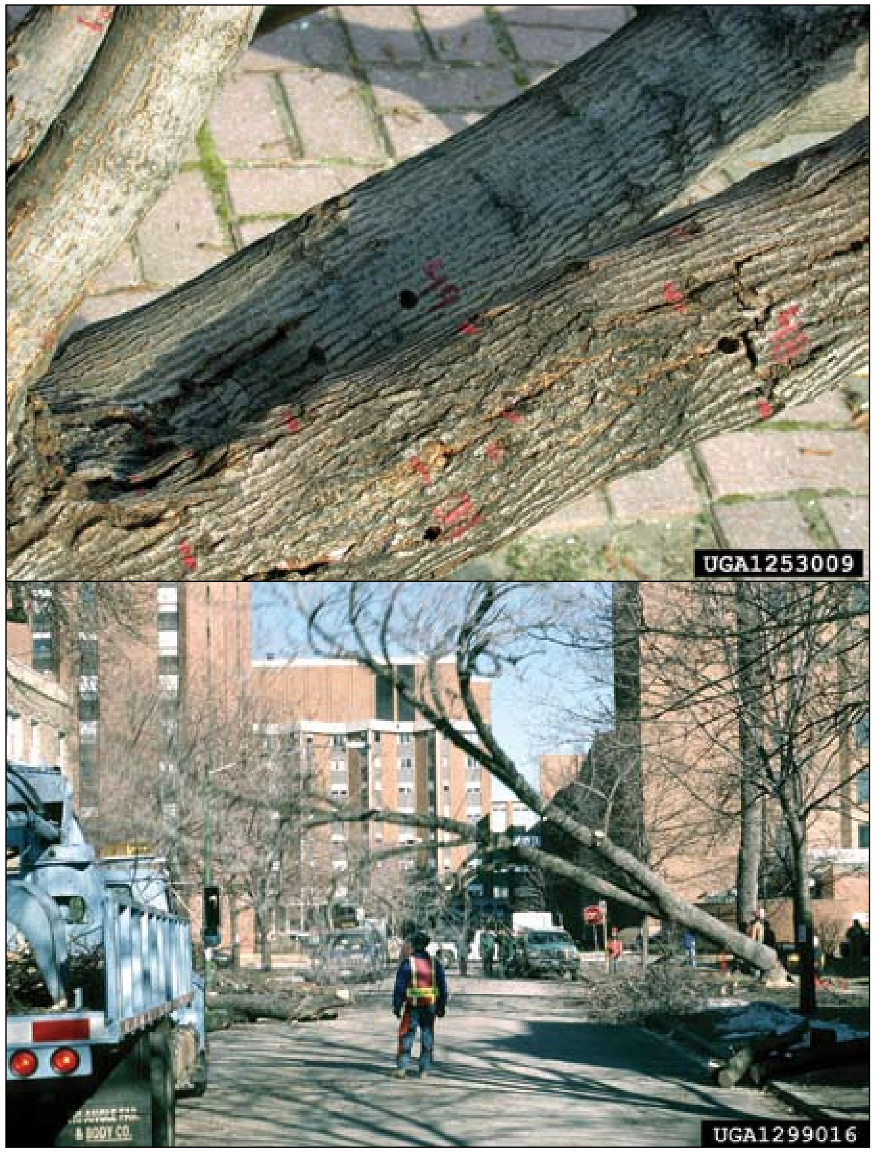


Figure 11. Suvey for Asian longhorned beetle infestations are based on visual detection of all signs of infestation; eradication efforts includes implementing a regulated area (quarantine), conducting surveys of host trees, removing of infested trees, and using treatment applications. (Top: Thomas B. Denholm, New Jersey Department of Agriculture, Bugwood.org; bottom: USDA Agricultural Research Service Archive, USDA Agricultural Research Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Compared with other longhorned beetles, relatively few natural enemies of ALB have thus far been identified. Egg parasitoids are unknown. Larval parasitoids include *Dastarcus longulus* Sharp (Coleoptera: Colydiidae), *Scleroderma guani* Xiao et Wu (Hymenoptera: Bethylidae), *Bullaea* sp. (Diptera: Tachinidae), and *Megarhyssa* sp. (Hymenoptera: Ichneumonidae). Pupal parasitoids include *D. longulus*, *S. guani*, and *Aprostocetus* sp. (Hymenoptera: Eulophidae). Among these, *D. longulus* and *S. guani* appeared to be the most promising for biological control purposes (see websites mentioned on next page for further details).

Web Links for Information on Asian Longhorned Beetle

http://www.eppo.org/QUARANTINE/insects/Anoplophora_glabripennis/ANOLGL_ds.pdf; EPPO factsheet on Asian longhorned beetle as European quarantine pest.

http://www.umassgreeninfo.org/fact_sheets/wood_attackers/asian_longhorned_beetle.html.

http://www.massnrc.org/pests/pestFAQsheets/asianlonghorned.html; Massachusetts fact sheet focusing on biology and recognition.

http://en.wikipedia.org/wiki/Asian_long-horned_beetle; Wikipedia article.

http://www.uvm.edu/albeetle/research/biocontrol.html#NaturalEnemies; discussion of natural enemies of Asian longhorn borer found in surveys in China.

www.beetlebusters.info; USDA Asian longhorned beetle website.

www.aphis.usda.gov; eradication program information.

Articles

Cavey, J.F., E.R. Hoebeke, S. Passoa, and S.W. Lingafelter. 1998. A new exotic threat to North American hardwood forests: an Asian longhorned beetle, *Anoplophora glabripennis* Motschulsky (Coleoptera: Cerambycidae): I. Larval description and diagnosis. *Proceedings of the Entomological Society of Washington* 100(2): 373-381.

Haack, R.A., K.R. Law, V.C. Mastro, H.S. Ossenbruggen, and B.J. Raimo. 1997. New York's battle with the Asian long-horned beetle. *Journal of Forestry* 95(12): 11-15.

Li, W. and C. Wu. 1993. *Integrated Management of Longhorn beetles Damaging Poplar Trees.* Beijing, China. Forest Press. 290 p.

Nowak, D.J., J.E. Pasek, R.O. Sequeira, D.E. Crane, and V.C. Mastro. 2001. Potential effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on urban trees in the United States. *Journal of Economic Entomology* 94(1): 116-122.

Hu, J.F., S. Angeli, S. Schuetz, Y.Q. Luo, and A.E. Hajek. 2009. Ecology and management of exotic and endemic Asian longhorned beetle *Anoplophora glabripennis*. *Agricultural and Forest Entomology* 11: 359-375.

100. Poplar Borer, *Saperda calcarata* Say (Coleoptera: Cerambycidae)

Orientation to Pest

Poplar borer, *Saperda calcarata* Say, is a native North American insect found throughout Canada and the United States, attacking poplars (*Populus*) and on occasionally willows (*Salix*). It can become a significant pest of both eastern cottonwood (*Populus deltoides* Bartr. Ex Marsh) in southern regions and quaking aspen (*P. tremuloides* Michx.) further north. Overwintered adults emerge from June until August. Females lay eggs in slits chewed into the bark, most often in isolated, trees growing in full sun or in trees along stand edges where they are more exposed to sunlight. Trees stressed by over-maturity, grass competition, or poor site conditions are more likely to be attacked. Larval development typically takes 3-4 years, but can vary from two to five. Signs and symptoms of this pest include swollen areas on trunks and larger branches, exit holes, and woodpecker excavations. Infested trees may have varnish-like stains on the bark below the points of attack, where reddish sap has oozed out. Fresh sap and coarse, fibrous frass are good indicators of an active larval gallery. Infestations often do not kill trees outright, but the trunk or branches may be weakened and break in wind, ice, or snow storms. Small trees may be killed by girdling from joining of several larval galleries. Surveys in northern states and Canadian provinces have found attack rates on quaking aspen by poplar borer to be quite high (>50 percent), especially in more open park-like settings where trees are open-grown. Maintaining well-stocked stands and avoiding poor-quality sites reduces the likelihood of infestation. Removal of infested trees was not shown to be helpful in reducing infestation levels since it resulted in lower stand density that encouraged further attack. It is recommended that poplar stands be well-stocked and clear cut at maturity.

Hosts Commonly Attacked

Poplars (*Populus*) are the preferred hosts of this borer. Quaking aspen (*P. tremuloides*) is favored in northern areas, cottonwood in southern areas. Balsam poplar (*P. balsamifera* L.) is another favored host where it occurs. Willow (*Salix*) has been reported as a host.

Distribution

This species is found throughout Canada and the United States where poplars are present.

Images of Poplar Borer

Figure 1. Adults of poplar borer, *Saperda calcarata*. (Left: Whitney Cranshaw, Colorado State University, Bugwood.org; right: James Solomon, USDA Forest Service, Bugwood.org)

Images of Poplar Borer (continued)

Figure 2. Larvae of poplar borer in galleries and pupa in pupal chamber, surrounded by characteristic coarse fibrous frass (left); close up of poplar borer larvae (right). (Left: James Solomon, USDA Forest Service, Bugwood.org; right: Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 3. Sap leakage and bark staining on quaking aspen is a sign of poplar borer infestation. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Poplar Borer (continued)

Figure 4. Internal appearance of poplar borer damage, with bark cut open. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 5. Frass being expelled from larval gallery of poplar borer. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Poplar Borer (continued)

Figure 6. Eastern cottonwood trees (*Populus deltoides* ssp. *deltoides* Bartram ex Marsh.) broken due to tunneling of poplar borer. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural mortality of the poplar borer is frequently high and a variety of parasitoids have been reared from this species in various locations. Studies in Canada revealed that egg infertility, climate, excessive sap flow, and natural enemies destroyed 81 percent of the population of this borer. Woodpeckers can remove many late-stage larvae. However, while descriptive work has been done in some locations, no fundamental understanding exists of the importance of natural enemies as control agents for this borer.

Web Links for Information on Poplar Borer

http://www.colostate.edu/Dept/CoopExt/4dmg/Pests/popborer.htm; fact sheet of the Colorado State University extension service.

http://wiki.bugwood.org/Archive:Borers/Saperda_calcarata; fact sheet of Bugwood Wiki.

Articles

Solomon, J.D. 1995. Guide to insect borers of North American broadleaf trees and shrubs. Agricultural Handbook 706. Washington D.C.: U.S. Department of Agriculture, Forest Service: 735 p. (*Saperda calcarata*, pages 334-338).

Broberg, C.L. and J.H. Borden. 2005. Host preference by *Saperda calcarata* Say (Coleoptera: Cerambycidae). *Journal of the Entomological Society of British Columbia* 102: 27-34.

102. Cottonwood Borer, *Plectrodera scalator* (Fabricius) (Coleoptera: Cerambycidae)

Orientation to Pest

Cottonwood borer, *Plectrodera scalator* (Fabricius), is a native insect that attacks cottonwoods and poplars (*Populus*), willows (*Salix*), and species of *Platanus*, *Albizia*, and *Helianthus*. Adults first emerge in late spring and feed on the shoots of young trees. Mating and egg-laying occur throughout the summer. Females dig away soil from the base of the tree, where they cut a niche in the bark, and deposit one or several eggs. Larvae feed in the bases and roots of live trees of all sizes. At first larvae mine the inner bark, but by fall larvae bore into the wood. Two or more growing seasons are required for larval development. In their last year, the large larvae create tunnels at the base of the tree, where they pupate the falling spring. New adults emerge by chewing through the pupal chamber and digging their way out of the soil. Young trees may be hollowed out, partially severed, or girdled near the root collar, causing breakage. Greatest damage occurs to trees in plantations and nurseries, and young stands on sandy soils.

Hosts Commonly Attacked

This borer attacks cottonwoods and poplars (*Populus*), willows (*Salix*), and species of *Platanus*, *Albizia*, and *Helianthus*.

Distribution

The cottonwood borer is found New York to Montana and south to Texas. Damage is greatest in the southern United States.

Images of Cottonwood Borer

Figure 1. Adult of cottonwood borer, *Plectrodera scalator*. (Top: Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org; bottom: Donald Duerr, USDA Forest Service, Bugwood.org)

Images of Cottonwood Borer (continued)

Figure 2. Adult female of cottonwood borer deposting an egg below the soil line into a young cottonwood shoot. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of cottonwood borer in root of eastern cottonwood (*Populus deltoides* ssp. *deltoides* Bartram ex Marsh.) (left) and in stem of young tree (right). (Both photos: James Solomon, USDA Forest Service, Bugwood.org)

Images of Cottonwood Borer (continued)

Figure 4. Pupa of cottonwood borer in cottonwood shoot. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Two views of damage from cottonwood borer at base of cottonwood rootstocks. (Both photos: James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the natural enemies of this species, except that cottonwood borer is sometimes parasitized by the sarcophagid fly *Sarcophaga vericauda* Hungerford, or parasitic wasps in the genera *Ibalia*, *Rhyssa*, or *Megarhyssa*. It is also susceptible to applications of the fungal biopesticide *Beauveria bassiana*.

Web Links for Information on Cottonwood Borer

http://www.ento.okstate.edu/ddd/insects/cottonwoodborer.htm; fact sheet of the Oklahoma State University.

http://www.forestpests.org/nursery/cwborers.html; fact sheet of the USDA Forest Service.

Articles

Solomon, J.D. 1980. Cottonwood borer (*Plectrodera scalator*) - a guide to its biologv, damage, and control. Research Paper SO157. New Orleans, LA, U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 10 p.

Forschler, B.T. and G.L. Nordin. 1989. Impact of *Beauveria bassiana* on the cottonwood borer *Plectrodera scalator* (Coleoptera: Cerambycidae), in a commercial cottonwood nursery. *Journal of Entomological Science* 24(2): 186-190.

103. Banded Hickory Borer, *Knulliana cincta* (Drury) (Coleoptera: Cerambycidae)

Orientation to Pest

Banded hickory borer, *Knulliana cincta* (Drury), is native to North America and is found in the southern United States, west to Texas, and in northern Mexico. Three subspecies of this beetle have been named: *Knulliana c. cincta* (Drury), found in eastern North America west to Texas; *Knulliana cincta ochracea* (Bates), found in the southeastern United States, northeastern Mexico, and the Bahamas; and *Knulliana cincta sonorensis* (Schaeffer), found from Texas to Arizona, and adjacent regions in Mexico. This borer breeds in the dead branches and trunks of many hardwoods. The adult is dark brown and 1.6-3.0 cm long. The body is covered with gray hairs, and there are short sharp spines on the corners of the thorax. Each wing cover has a yellow spot across it, giving the appearance of a band across the back. Eggs are laid in summer beneath the bark or directly on the wood of recently felled, dying, or dead trees. The larvae feed under the bark during the remainder of the summer, forming galleries in the wood and ejecting frass through openings in the bark. During the fall and following summer larvae continue to feed in the wood and pupate in the fall or spring between lumps of frass at the end of the larval gallery. The life cycle most likely requires two years for completion. Cordwood, logs, posts, and rustic work may be damaged by this species. Adults are attracted to lights.

Hosts Commonly Attacked

This borer attacks hickory (*Carya*), pecan (*Carya illinoinensis* [Wangenh.] K. Koch), walnut (*Juglans*), oak (*Quercus*), eastern hophornbeam (*Ostrya virginiana* [Mill.] K. Koch), plum (*Prunus*), apple (*Malus*), chestnut (*Castanea*), hackberry (*Celtis*), pear (*Pyrus*), willow (*Salix*), mesquite (*Prosopis*), orange (*Citrus*), *Sapindus*, and *Leucaena*. Hickory appears to be preferred.

Distribution

This species is found in the United States from Virginia south to Florida and west to Oklahoma and Texas, and in northern Mexico.

Images of Banded Hickory Borer

Figure 1. Adult banded hickory borer, *Knulliana cincta*. (Maury J. Heiman)

Images of Banded Hickory Borer (continued)

Figure 2. Larva of banded hickory borer. (Lacy L. Hyche, Auburn University, Bugwood.org)

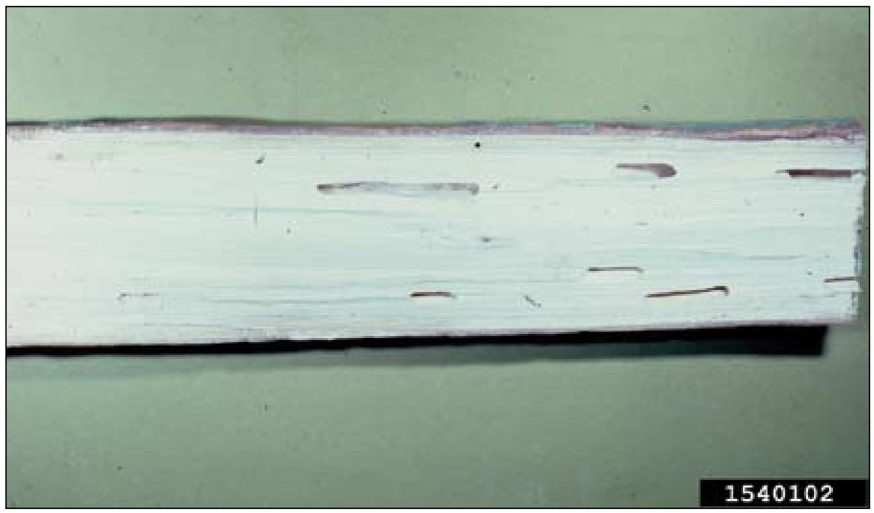


Figure 3. Larval galleries of banded hickory borer. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is known of the natural enemies of this species, except that it is sometimes parasitized by the ichneumonid wasp *Labena grallator* (Say).

Web Links for Information on Banded Hickory Borer

http://www.texasento.net/Knulliana.htm; a collector's website about beetles from Texas.

http://www.insectsofwestvirginia.net/b/knulliana-cincta.html.

Articles

None

104. Locust Borer, *Megacyllene robiniae* (Forster) (Coleoptera: Cerambycidae)

Orientation to Pest

Locust borer, *Megacyllene robiniae* (Forster), is native to the United States and bores in black locust (*Robinia pseudoacacia* L.) trunks. Attacks occur most often in young trees or in older trees stressed by drought or poor soil, or that have been overtopped by other trees. This borer formerly was limited to its native range in Pennsylvania, south in the Appalachian Mountains to Georgia and in the Ozark Mountains of Arkansas and Missouri. However, black locust has been widely planted outside this range and the borer is now found in those locations as well. Black locusts have been widely planted for restoration of strip-mined areas. Adults of locust borer emerge in late summer and are commonly seen feeding on pollen on field goldenrod (*Solidago canadensis* L.). Females lay their eggs in crevices of rough bark and around wounds of living trees. Larvae bore into the bark and construct overwintering cells. In the following spring, larval activity is resumed and sap may be seen oozing from the larval entry holes. Larvae bore into the wood and feed until they mature in mid-summer. During their feeding period, larvae tunnel extensively throughout the heartwood. Maturing larvae construct a tunnel to the exterior, through which adults later emerge. There is one generation per year. Attack is most common on stressed trees, such as those on reclaimed mining sites. Borer activity often results in wind breakage of trees, followed by excessive branching. Attack rates increase as the proportion of black locust in the stand increases, and larval to adult survivorship increases as the attack rate increases.

Hosts Commonly Attacked

Locust borer is a specialist that feeds only on black locust (*R. pseudoacacia*).

Distribution

Locust borer is found throughout the United States wherever black locust grows naturally or has been introduced.

Images of Locust Borer

Figure 1. Adult locust borer, *Megacyllene robiniae*. (Jon Yuschock, Bugwood.org)

Images of Locust Borer (continued)

Figure 2. Locust borer feeding on pollen of goldenrod (*Solidago* sp.). (David Cappaert, Michigan State University, Bugwood.org)

Figure 3. Larva of locust borer in feeding gallery. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Pupa of locust borer in pupation chamber. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Locust Borer (continued)

Figure 5. Cracks, frass at base of tree, and emergence holes are signs of of locust borer activity. (Left: James Solomon, USDA Forest Service, Bugwood.org; right: Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 6. Locust borer larval galleries seen in cross and lateral sections. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Two species of wasps, *Dolichomitus irritator* (Fabricius) and *Habrolepoidea depressa* (Girault), have been recorded parasitizing locust borer larvae at low rates (<1 percent). Natural enemies of locust borer have not been studied extensively.

Web Links for Information on Locust Borer

http://www.na.fs.fed.us/spfo/pubs/fidls/locust/locust.htm; USDA Forest Service leaflet; extensive information on the biology, life cycle, and damage of the insect.

http://www.treesforyou.org/Planting/TreeCare/Healthy/Locust-B.htm; Washington state extension service leaflet.

http://www.dec.ny.gov/docs/lands_forests_pdf/locustb.pdf; extension article of the New York Department of Environmental Conservation.

http://www.ces.ncsu.edu/depts/ent/notes/O&T/trees/note18/note18.html; fact sheet of North Carolina State University Entomology Department; information on chemical control provided.

Articles

Harman, D.M., M.A. van Tyne, and W.A. Thompson. 1985. Comparison of locust borer *Megacyllene robiniae* Forster (Coleoptera: Cerambycidae) attacks on coal strip-mined lands and lands not mined. *Annals of the Entomological Society of America* 78: 50-53.

Harman, D.M., P. Rudolf, and K.R. Dixon. 1985. Influence of stand composition on locust borer (Coleoptera: Cerambycidae) attack rates. *Journal of Entomological Science* 20: 207-211.

Echaves, V.D., D.M. Harman, and A.L. Harman. 1998. Site quality in relation to damage by locust borer, *Megacyllene robiniae* Forster in black locust. *Journal of Entomological Science* 33: 106-112.

105. White Oak Borer, *Goes tigrinus* (De Geer) (Coleoptera: Cerambycidae)

Orientation to Pest

White oak borer, *Goes tigrinus* (De Geer), is native to North America and is found in much of the eastern United States in association with white (*Quercus alba* L.) and overcup (*Q. lyrata* Walter) oaks. Damage is greatest to younger trees and losses from this species are important in oak stands grown for veneer or cooperage (barrels). Reproduction is often concentrated in selected trees (brood trees) and removing brood trees can help control the pest at the stand level. Adult beetles emerge in May and June. Eggs are deposited in niches 6 mm in diameter that are cut singly into the bark. As the larvae tunnel directly into the wood, sap often oozes from the entrance holes in the tree and fine moist frass is pushed out of the tunnels to the outside. Larval galleries are about 12 mm in diameter and 15 cm long. Pupation occurs within the gallery. One generation takes about 3 to 5 years.

Hosts Commonly Attacked

White oak borer breeds in white (*Q. alba*) and overcup (*Q. lyrata*) oaks.

Distribution

White oak borer is found in the eastern United States from New York to Florida and west to Michigan and Louisiana.

Images of White Oak Borer

Figure 1. Adult white oak borer, *Goes tigrinus*. (James B. Hanson, USDA Forest Service, Bugwood.org)

Images of White Oak Borer (continued)

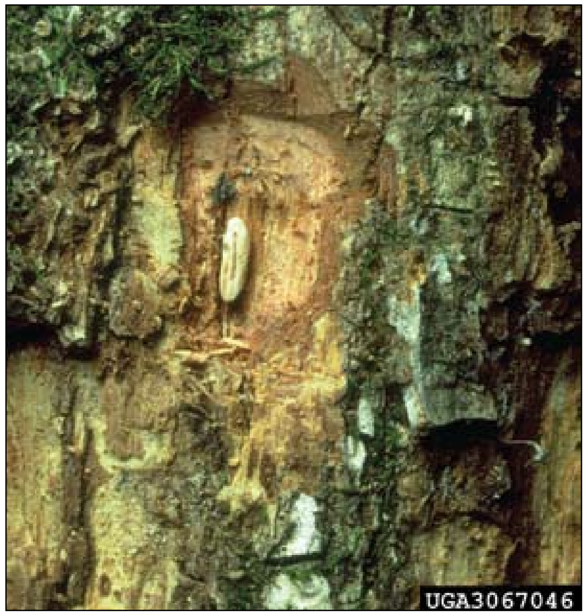


Figure 2. Egg of white oak borer, exposed by removal of bark flap. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Larva of white oak borer. (USDA Forest Service Fact Sheet)

Figure 4. Signs of of white oak borer activity: (left) frass pushed out of borer hole in tree trunk; (right) emergence holes in tree trunk. (Left: James Solomon, USDA Forest Service, Bugwood.org; right: USDA Forest Service Fact Sheet)

Important Biological Control Agents Related to this Pest Species

Natural enemies of white oak borer have not been studied.

Web Links for Information on White Oak Borer

http://www.fs.fed.us/r8/foresthealth/pubs/oakpests/p19.html; USDA Forest Service factsheet covering biology and control.

Articles

Donley, D.E. 1978. Distribution of the white oak borer *Goes tigrinus* Degeer (Coleoptera: Cerambycidae) in a mixed oak stand. In: Pope, P.E. (ed.). *Central hardwood forest Conference II*. Proceedings of a meeting held at Purdue University at West Lafayette, Indiana, November 14-16, 1978. West Lafayette, Indiana, USA. Department of Forestry and Natural Resources, Purdue University: 529-539.

Solomon, J.D. and D.E. Donley. 1983. Bionomics and control of the white oak borer. Research Paper SO-198, Southern Forest Experiment Station, USDA Forest Service.

106. Whitespotted Sawyer, *Monochamus scutellatus* (Say) (Coleoptera: Cerambycidae)

Orientation to Pest

Whitespotted sawyer, *Monochamus scutellatus* (Say), is a native North American borer that attacks dying or recently dead conifers that have dried out somewhat but have not been heavily attacked by other wood-feeding insects. There are two recognized subspecies, *M. scutellatus scutellatus* and *M. scutellatus oregonensis*. Females lay their eggs in slits chewed in the bark near branch scars or rough areas of bark. When eggs hatch, young larvae bore through the phloem into the cambium. Young larvae mine beneath the bark. Later instars tunnel toward the heartwood. Prior to pupation, the larva turns its tunnel toward the surface, where it pupates behind a chip plug. There is one generation per year in the northern part of its range and two in the southern portion. Logs left in the forest untended over a summer season are especially suitable for attack by this borer. This sawyer beetle is also able to vector the parasitic pinewood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer) Nickle, which causes pine-wilt disease in Minnesota and Wisconsin. Damage to logs can be reduced by cutting timber in fall or winter and removing logs from woods before summer. Pulpwood logs can be partially protected by piling them in the shade or covering them with slash.

Hosts Commonly Attacked

The whitespotted sawyer attacks a variety of conifers but prefers eastern white pine (*Pinus strobus* L.). This beetle will also attack jack pine (*P. banksiana* Lamb.), red pine (*P. resinosa* Ait.), balsam fir (*Abies balsamea* [L.] Mill.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.), and red spruce (*P. rubens* Sarg.). Tamarack (*Larix laricina* (DuRoi) K. Koch) occasionally serves as a host.

Distribution

Whitespotted sawyer is found in the United States, north of North Carolina and westward through the Great Lakes states, across Canada and north to Alaska.

Images of Whitespotted Sawyer

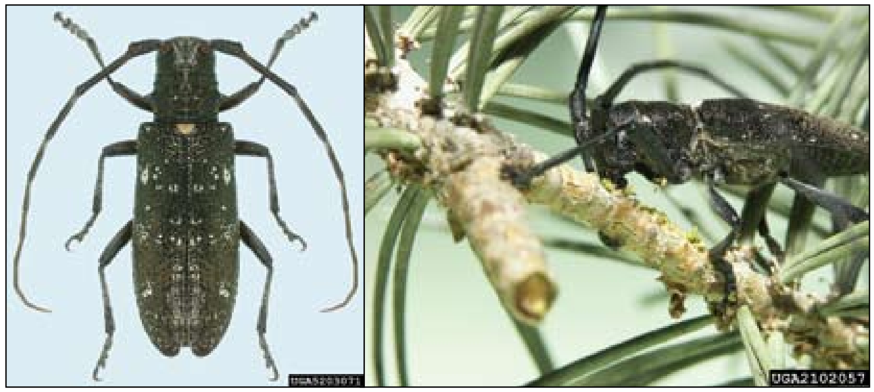


Figure 1. Adult whitespotted sawyer, *Monochamus scutellatus*; right, adult feeding on twigs. (Left: Natasha Wright, Florida Department of Agriculture and Consumer Services, Bugwood.org; right: Joseph Berger, Bugwood.org)

Figure 2. Adult emergence hole (with head of adult visible) of whitespotted sawyer. (Laura Lazarus, North Carolina Division of Forest Resources, Bugwood.org)

Figure 3. Flagging of branches killed by adult feeding of whitespotted sawyer beetles. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of whitespotted sawyer include tachinids in the genus *Eutheresia* and ichneumonids in the genera *Rhyssa* and *Dolichomitus*, but their actual influence on population levels of whitespotted sawyer is unknown.

Web Links for Information on Whitespotted Sawyer

http://wiki.bugwood.org/HPIPM:Pine_Sawyers; biology of pine sawyers; Bugwood Wiki fact sheet.

http://www.forestpests.org/vermont/whitespottedsawyer.html; forestry fact sheet from Vermont.

http://www.na.fs.fed.us/spfo/pubs/fidls/ws_sawyer/ws_sawyer.htm; USDA Forest Service fact sheet on biology and control.

Articles

Raske, A.G. 1973. Relationship between felling date and larval density of *Monochamus scutellatus*. *Bi-monthly Research Notes* 29(4): 23-24.

Wingfield, M.J. and R.A. Blanchette. 1983. The pine-wood nematode, *Bursaphelenchus xylophilus*, in Minnesota and Wisconsin: insect associates and transmission studies. *Canadian Journal of Forest Research* 13(6): 1068-1076.

107. Bagworm, *Thyridopteryx ephemeraeformis* (Haworth) (Lepidoptera: Psychidae)

Orientation to Pest

Bagworm, *Thyridopteryx ephemeraeformis* (Haworth), is native to North America, and larvae defoliate arborvitae (*Thuja occidentalis* L.), juniper (*Juniperus virginiana* L.), eastern white pine (*Pinus strobus* L.), and blue spruce (*Picea pungens* Engelm.), on which they are often abundant. Male moths have wings but females are wingless and are unable to move. Males and females emerge in the fall and males fly to females. Females never emerge from their larval shelters (the "bag"), and mate while still in their bags. Females then develop their eggs, which are laid inside the bag and these are the overwintering stage. Eggs hatch in spring and some larvae spin silk threads and are blown by the wind. Upon alighting on plants, neonate larvae accept or reject plants, and if the latter spin a new thread and repeat the dispersal process. Many larvae, however, skip this dispersal phase and settle on their natal plants. Once a larva has accepted a plant, it constructs a bag and drags it around as it feeds. Mature larvae attach their bags to the plant and pupate inside them. There is one generation per year. Bagworms can be locally dense on ornamental plantings, causing defoliation and killing trees or shrubs. Damage to forest stands is not usually important, because larvae prefer sunny sites. Some damage does, however, occur in Atlantic white cedar (*Chamaecyparis thyoides* [L.] Britton, Sterns and Poggenb.) and black locust (*Robinia pseudoacacia* L.) stands, especially in the southern United States.

Hosts Commonly Attacked

Bagworm commonly attack arborvitae (*T. occidentalis*), juniper (*J. virginiana*), eastern white pine (*P. strobes*), blue spruce (*P. pungens*), Atlantic white cedar (*C. thyoides*), and black locust (*R. pseudoacacia*). On other hosts, bagworm larvae are rare.

Distribution

Bagworm is widely distributed in the eastern United States.

Images of Bagworm

Figure 1. Adult male bagworm moth, *Thyridopteryx ephemeraeformis*. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Bagworm (continued)

Figure 2. Bagworm eggs dissected out of female inside case. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 3. Young bagworm in small case (top); older bagworm with larger, but still mobile, case (bottom). (Top: Rayanne Lehman, Pennsylvania Department of Agriculture, Bugwood.org; bottom: Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Images of Bagworm (continued)

Figure 4. Bagworm caterpillar partialy extended outside of protective bag (top), and caterpillar pulled out of bag (bottom). (Both photos: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Figure 5. Bagworm prepupa (bottom) and pupa (top) in bags cut open for viewing. (Gerald J. Lenhard, Louiana State University, Bugwood.org)

Images of Bagworm (continued)

Figure 6. Male bagworm mating with flightless female inside her larval bag. (Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org)

Figure 7. Bag of mature bagworm, fixed in place (left); many bagworm cases (right) on heavily infested plant. (Left: John H. Ghent, USDA Forest Service, Bugwood.org; right: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Bagworm (continued)

Figure 8. High densities of bagworm bags on partly defoliated conifer. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of bagworms have been frequently studied because the bags are large and stationary, inviting their examination. The ichneumonid *Itoplectis conquisitor* (Say), a generalist pupal parasitoid, is commonly found attacking bagworms and is often the most abundant species reared from this host. Many other species of parasitoids have also been reared from bagworms.

Web Links for Information on Bagworm

http://ento.psu.edu/extension/factsheets/bagworm; fact sheet of Pennsylvania State University.

http://www.uark.edu/ua/arthmuse/bagworm.html; University of Arkansas fact sheet.

http://njaes.rutgers.edu/pubs/publication.asp?pid=FS1144; fact sheet of New Jersey Rutgers NJAES Cooperative Extension.

Articles

Horn, D.J. and R.F. Sheppard. 1979. Sex ratio, pupal parasitism, and predation in two declining populations of the bagworm, *Thyridopteryx ephemeraeformis* (Haworth) (Lepidoptera: Psychidae). *Ecological Entomology* 4: 259-265.

Moore, R.G. and L.M. Hanks. 2004. Aerial dispersal and host plant selection by neonate *Thyridopteryx ephemeraeformis* (Lepidoptera: Psychidae). *Ecological Entomology* 29: 327-335.

108. Birch Casebearer, *Coleophora serratella* (L.) (Lepidoptera: Coleophoridae)

Orientation to Pest

Birch casebearer, *Coleophora serratella* (L.), is a European moth that is invasive in North America and is associated with birches (*Betula*), alders (*Alnus*), and elms (*Ulmus*). High densities sometimes defoliate birches, and this insect is considered one of the most important pests of birch in some parts of Canada such as Newfoundland. Because of misapplication of names, literature records from 1938 to 1972 under this name very likely do not refer to the true *C. serratella* as described here. The adult appears in late spring. Eggs are laid on host leaves and the larva feeds by inserting its head into small mines that it creates. The larva constructs a protective case, which it drags with it as it moves around to feed. Pupation occurs in early summer, and occurs in the larval case, which is fixed to the upper surface of a leaf in a sunny situation.

Hosts Commonly Attacked

Birch casebearer feeds on birches (*Betula*), alders (*Alnus*), and elms (*Ulmus*).

Distribution

Birch casebearer is found in the northeastern United States, eastern Canada from Newfoundland through southern Ontario into Manitoba, and in western Canada, in British Columbia.

Images of Birch Casebearer

Figure 1. Adult birch casebearer, *Coleophora serratella*. (Ian Kimber)

Figure 2. Several larvae (in cases) of birch casebearer on young white birch leaf. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Birch Casebearer (continued)

Figure 3. Larva of birch casebearer, with the case removed. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 4. White birch defoliated by birch casebearer. (Claude Monnier - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Natural enemies of birch casebearer have been studied in Quebec and Newfoundland, and as many as 38 species of parasitoids attack this invasive species there. In the native range (central Europe) 25 species are reported associated with this case bearer. Some of these species (e.g., *Campoplex borealis* [Zett.] and *Apanteles coleophorae* [Wilk.], *Apanteles mesoxanthus* Ruschka, and *Apanteles cornvinus* Reinh.) have been released in North America, but there are no records of their establishment.

Web Links for Information on Birch Casebearer

http://www.exoticpests.gc.ca/ins_details_eng.asp?pestType=ins&lang=en&geID=8229; Canadian factsheet on forest invasive alien species.

Articles

Pschorn-Walcher, H. 1980. Population fluctuations and parasitisation of the birch-alder casebearer (*Coleophora serratella* L.) in relation to habitat diversity. *Zeitschrift für Angewandte Entomologie* 89(1): 63-81. (In German).

Guevremont, H. and J. Juillet. 1975. Parasites of the birch casebearer, *Coleophora fuscedinella* [= *Coleophora serratella*] Zeller (Lepidoptera: Coleophoridae), in the Sherbrooke region, Quebec. *Phytoprotection* 56 (1): 1-17. (In French).

109. Larch Casebearer, *Coleophora laricella* (Hübner) (Lepidoptera: Coleophoridae)

Orientation to Pest

The larch casebearer, *Coleophora laricella* [Hübner]), is an invasive species from Europe that caused extensive defoliation of North American larch before it was brought under biological control. It has one generation per year. Adults emerge in late spring and deposit their eggs singly on needles in early summer. Newly hatched larva bore into needles and feed as needle miners. After larvae consume a portion of their first needle, a section of a mined-out needle is lined with silk, cut free, and carried as a case. Larvae in cases then move to other needles and continue to feed. Fed-on needles are only partly consumed. They remain attached to branches but turn brown, making damage readily visible. Cases are enlarged as larvae grow. Larvae overwinter in cases fixed to branches and resume feeding in spring on new foliage. Upon reaching maturity, larvae pupate in their cases from which moths later emerge.

Hosts Commonly Attacked

In North America, this moth attacks both eastern (*Larix laricina* [Du Roi] K. Koch) and western (*Larix occidentalis* Nuttl.) larch.

Distribution

Larch casebearer occurs in Canada from the Maritmes to western Canada and in the United States from New England to Minnesota and, separately, in Washington, Oregon, Idaho and western Montana. This distribution corresponds to that of eastern and western larch.

Images of Larch Casebearer

Figure 1. Adults of larch casebearer (*Coleophora laricella*) mating. (Roger Ryan, USFS PNW Station, Bugwood.org)

Figure 2. Young larva of larch casebearer in needle-mining phase. (Roger Ryan, USFS PNW Station, Bugwood.org)

Images of Larch Casebearer (continued)

Figure 3. Older larva of larch casebearer with case. (Roger Ryan, USFS PNW Station, Bugwood.org)

Figure 4. View of larch casebearer larva with case partially removed. (Victor Ryabincov, Bugwood.org)

Figure 5. Close view of damage to needles caused by larch casebearer larval feeding. (Ferenc Lakatos, University of West-Hungary, Bugwood.org)

Images of Larch Casebearer (continued)

Figure 6. Branch showing yellow foliage that has been partly consumed by larch casebearer. (Roger Ryan, USFS PNW Station, Bugwood.org)

Figure 7. Larch stand showing reddish-brown foliage due to feeding of larch casebearer. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 8. Cluster of overwintering larch casebearer in cases at tip of twig. (Roger Ryan, USFS PNW Station, Bugwood.org)

Images of Larch Casebearer (continued)

Figure 9. The braconid *Agathis pumila* (Ratzburg), one of two key species giving successful biological control of larch casebearer in North America. (Roger Ryan, USFS PNW Station, Bugwood.org)

Figure 10. The eulophid *Chrysocharis laricinellae* Ratzburg, showing egg-laying behavior. (Roger Ryan, USFS PNW Station, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

While a larger number of parasitoids were introduced, two species—the braconid *Agathis pumila* (Ratzburg) and the eulophid *Chrysocharis laricinellae* Ratzburg—were responsible for effective biological control of larch casebearer in North America.

Web Links for Information on Larch Casebearer

http://www.na.fs.fed.us/spfo/pubs/fidls/larch/larch.htm; USDA Forest Service Leaflet with information on biology, life history, damage, and control.

http://www.fs.fed.us/r1-r4/spf/fhp/mgt_guide/larch_casebearer/larch_casebearer.pdf; USDA Forest Service bulletin.

http://www.fs.fed.us/r1-r4/spf/fhp/field_guide/124lrchcb.htm.

http://www.dec.ny.gov/docs/lands_forests_pdf/cbearer.pdf.

http://www.oregon.gov/ODF/privateforests/docs/fh/larchcasebearer.pdf?ga=t.

Articles

Jagsch, A.1973. Population dynamics and parasite complex of the larch miner, *Coleophora laricella* Hb., in the natural distribution area of European larch, *Larix decidua* Mill. *Zeitschrift für Angewandte Entomologie* 73: 1-42.

Niwa, G.G. 1983. Environmental factors influencing the effectiveness of *Agathis pumila* Ratz. (Hymenoptera: Braconidae), an introduced parasite of the larch casebearer, *Coleophora laricella* Hbn. (Lepidoptera: Coleophoridae). *Forestry Abstracts* 44(11): 718.

Niwa, C.C., R.W. Stark, D.G. Burnell, and D.M.J. Knox. 1986. Annotated bibliography of larch casebearer (*Coleophora laricella*) parasitoids. Bulletin No. 41. Forest, Wildlife and Range Experiment Station, University of Idaho: 135 p.

Ryan, R.B. 1990. Evaluation of biological control: introduced parasites of larch casebearer (Lepidoptera: Coleophoridae) in Oregon. *Environmental Entomology* 19: 1873-1881.

Ryan, R.B. 1997. Before and after evaluation of biological control of the larch casebearer (Lepidoptera: Coleophoridae) in the Blue Mountains of Oregon and Washington, 1972-1995. *Environmental Entomology* 26: 703-715.

110. Pecan Cigar Casebearer, *Coleophora laticornella* (Clemens) (Lepidoptera: Coleophoridae)

Orientation to Pest

The pecan cigar casebearer, *Coleophora laticornella* (Clemens), is a case-bearing moth native to North America. Its hosts include pecan (*Carya illinoinensis* [Wangenh] K. Koch), walnut (*Juglans*), and several species of hickory (*Carya*). It often causes serious damage to these trees. This insect overwinters as a partially grown larva in a case about 6 mm long that is attached to a limb or twig. In the spring, the larvae resume feeding on the newly opened buds and young foliage and when mature, larvae pupate within their cases. Moths emerge and lay eggs on leaves. Young larvae feed as leafminers, but later construct cases in which they remain as they move about, feeding on leaves and, the following year, buds. After leaf drop, larvae move back onto twigs or limbs, where they attach their cases for overwintering. There may be several generations per year. The pecan cigar casebearer occurs from New England south to Florida and as far west as Texas.

Hosts Commonly Attacked

Hosts of pecan cigar casebearer include pecan (*Carya illinoinensis* [Wangenh] K. Koch), walnut (*Juglans*), and several species of hickory (*Carya*).

Distribution

This moth is found in the eastern United States, from New England south to Florida and west to Texas.

Images of Pecan Cigar Casebearer

Figure 1. Adult pecan cigar casebearer, *Coleophora laticornella*. (Mark Dreiling)

Images of Pecan Cigar Casebearer (continued)

Figure 2. Larva of pecan cigar casebearer larvae in case. (H.C. Ellis, University of Georgia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

None

Web Links for Information on Pecan Cigar Casebearer

None

Articles

None

111. Oak Skeletonizer, *Bucculatrix ainsliella* Murtfeldt (Lepidoptera: Bucculatricidae)

Orientation to Pest

The oak skeletonizer, *Bucculatrix ainsliella* Murtfeldt, is a native North American moth whose larvae skeletonize the leaves of some oaks (*Quercus*). Eggs are laid on the upper side of leaves, adjacent to a major vein. The first instar larvae are leafminers, forming a strongly contorted serpentine mine about 1 cm long. Older larvae feed externally on the lower leaf surfaces, causing "windows" in leaves or skeletonizing them. There are two generations per year. Adults are active in April and May (generation one) and again in July and August (generation two). In the southern United States fly into September. The oak skeletonizer overwinters as a pupa in a white cocoon about 3 mm in length. Occasionally outbreaks occur over large areas.

Hosts Commonly Attacked

Oak skeletonizer feeds on red (*Quercus rubra* L.) and black (*Q. velutina* Lam.) oaks. Records on chestnut oak (*Q. montana* Willdenow) and chestnut (*Castanea*) are unconfirmed.

Distribution

The moth occurs in southern Canada and in the United States from Maine to North Carolina and west to Mississippi. It has also been introduced into British Columbia and, since 2006, into western Europe.

Images of Oak Skeletonizer

Figure 1. Mine of first instar larva of oak skeletonizer, *Bucculatrix ainsliella*. (Erik J. van Nieukerken, Netherlands Centre for Biodiversity Naturalis, Bugwood.org)

Images of Oak Skeletonizer (continued)

Figure 2. Oak skeletonizer larva feeding on the underside of an oak leaf. (G. Keith Douce, University of Georgia, Bugwood.org)

Figure 3. Oak skeletonizer cocoons attached to leaf veins; see also larvae and leaf damage (brown areas). (James Solomon, USDA Forest Service, Bugwood.org)

Images of Oak Skeletonizer (continued)

Figure 4. Leaf damage from larval feeding of oak skeletonizer. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Damage to an oak tree due to larval feeding of oak skeletonizer. (Terry S. Price, Georgia Forestry Commission, Bugwood.org)

Images of Oak Skeletonizer (continued)

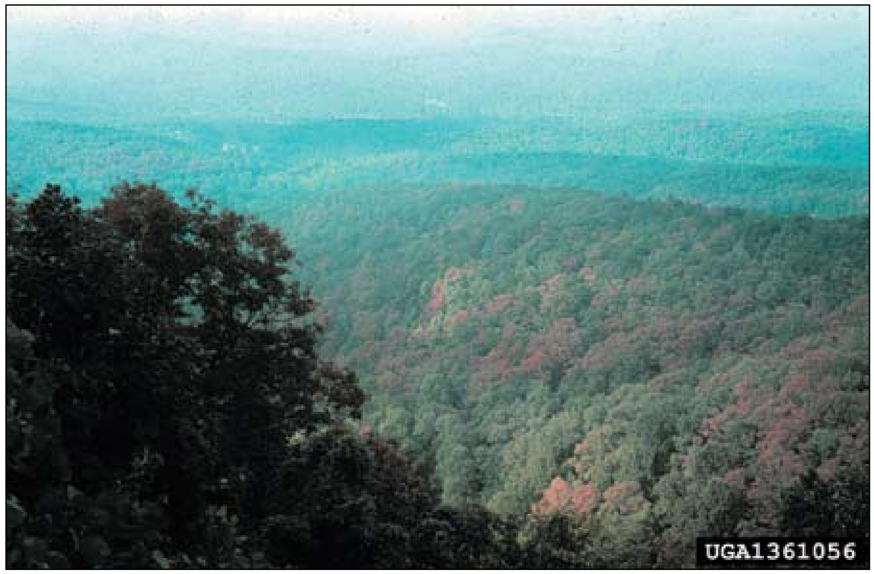


Figure 6. Damage to a stand of oak trees due to the oak skeletonizer. (Richard Jernigan, Georgia Forestry Commission, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Pupal parasitism (either by Ichneumonidae or Chalcidoidea) reached high levels (>40 percent parasitism) during the first generation of a population outbreak in British Colombia (see Gelok et al. 1998), but larval parasitism was very low.

Web Links for Information on Oak Skeletonizer

http://www.oakwilt.com/skeletonizer/index.html; website of Texas private nursery company.

http://www.forestpests.org/vermont/oakskeletonizer.html; fact sheet from Vermont Department of Forests, Parks and Recreation on lifecycle and management.

http://www.fs.fed.us/r8/foresthealth/pubs/oakpests/p13.html; USDA Forest Service fact sheet on biology and control.

http://www.microlepidoptera.nl/nieuws/art_2011.7.11.php; Microlepidoptera of the Netherlands: first report on its introduction into Europe.

Articles

Gelok, E., R. McGregor, D. Henderson, and L. Poirier. 1998. Seasonal occurrence and parasitism of *Bucculatrix ainsliella* (Lepidoptera: Lyonetiidae) on *Quercus rubra* in Burnaby, British Columbia. *Journal of the Entomological Society of British Columbia* 95: 111-116.

Gibbons, C.F. and J.W. Butcher. 1961. The oak skeletonizer, *Bucculatrix ainsliella*, in a Michigan woodlot. *Journal of Economic Entomology* 54: 681-684.

112. Palm Leaf Skeletonizer, *Homaledra sabalella* (Chambers) (Lepidoptera: Coleophoridae)

Orientation to Pest

The palm leaf skeletonizer, *Homaledra sabalella* (Chambers), is a native moth that is an important pest of many species of palms in the southern United States. It is an important pest in Florida, where it sometimes causes serious damage to palm trees. An outbreak of what appeared to be this species occurred on coconut palms (*Cocos nucifera* L.) in Florida starting in about 1995 but curiously did not affect cabbage palmetto. While identical in appearance to the cabbage palmetto-feeding moth, the coconut palm-feeding population is perhaps an invasive cryptic species. The matter is under investigation. The following notes on life history are for the traditional species (the population found on cabbage palmetto). Female moths lay batches of, on average, 36 eggs glued to the surface of older palm leaves and covered with brown, papery material. The larvae mine in groups on both the upper and lower surfaces of older leaves, under webs of silk. Excrement from the larvae is deposited on top of the silk. Pupation takes place in the larval mines. There may be up to five generations per year, and there is no diapause. Cutting and burning infested leaves is an effective method of control.

Hosts Commonly Attacked

Palm leaf skeletonizer feeds on several species of palms, including Canary Island date palm (*Phoenix canariensis* [Chabaud]) and cabbage palmetto (*Sabal palmetto* [Walter] Schultes and Schultes), the latter being an important native species in Florida. In Puerto Rico, the principal palm attacked is the Puerto Rico hat palm, *Sabal causiarum* (O.F. Cook) Becarri. This species also feeds on Latan palms (*Latania* spp.) and to a lesser extent on *Washingtonia robusta* H.Wendl.

Distribution

This insect is found across the southern United States from Florida to California, this being the northern extension of its range, which lies principally in Cuba, Puerto Rico, and Hispaniola.

Images of Palm Leaf Skeletonizer

Figure 1. Adult palm leaf skeletonizer, *Homaledra sabalella*. (Bo Zaremba)

Images of Palm Leaf Skeletonizer (continued)

Figure 2. Damage from feeding of larvae of the palm leaf skeletonizer. (Tim Borschat, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

An undescribed tachinid fly in the genus *Phytomyptera* was observed in Florida associated with the decline of serious outbreaks of this insect in the 1990s. In older records from Florida, larvae of the carabid beetle *Plochionus amandus* Newman and ants are listed as predators of this species. Also, listed are six species of hymenopterous parasitoids.

Web Links for Information on Palm Leaf Skeletonizer

http://fshs.org/Proceedings/Password%20Protected/2007%20vol.%20120/FSHS%20vol.%20120/356-359.pdf; an in-depth article on this species.

Articles

Creighton, J.T. 1937. *Homaledra sabalella* Chambers, the major pest of palms in Florida. *Journal of Economic Entomology* 30: 590-595.

Howard, F.W. and E. Abreu. 2007. The palm leaf skeletonizer, *Homaledra sabalella* (Lepidoptera: Coleophoridae): status and potential pest management options. *Proceedings of the Florida Horticultural Society* 120: 356-359.

113. Mimosa Webworm, *Homadaula anisocentra* Meyrick (Lepidoptera: Galacticidae)

Orientation to Pest

Mimosa webworm, *Homadaula anisocentra* Meyrick, is an invasive moth from China that was first recorded in North America in Washington, D.C., in 1940. Larvae feed on flowers and foliage of the introduced Asian silktree (mimosa) (*Albizia julibrissin* Durazz.) and the native North American honeylocust (*Gleditsia triacanthos* L.). Larvae web together areas on which they are feeding. This insect over-winters as pupae encased in cocoons on bark of their host tree or in the leaf litter below. Eggs of first generation moths are laid on leaves and hatch in early to mid-June. There are two generations each year and second generation moths emerge in August.

Hosts Commonly Attacked

The caterpillars of this moth feed on the introduced Asian silktree (*A. julibrissin*) and the native North American honeylocust (*G. triacanthos*).

Distribution

This insect occurs from Massachusetts and Pennsylvania, south to Florida and west to Mississippi, Kansas and Nebraska.

Images of Mimosa Webworm

Figure 1. Adult of mimosa webworm, *Homadaula anisocentra*. (Ashley Bradford, Northern Virginia, Wikipedia Commons)

Figure 2. Larva of mimosa webworm. (Stan Gilliam)

Images of Mimosa Webworm (continued)

Figure 3. A cocoon of mimosa webworm, the overwintering stage, in a bark crack. (Michael Masiuk, Bugwood.org)

Figure 4.Web produced by larvae of the mimosa webworm. (Brian Kunkel, University of Delaware, Bugwood.org)

Images of Mimosa Webworm (continued)

Figure 5. Host tree heavily damaged by mimosa webworm. (Michael Masiuk, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Some North American parasitoids attack this species, but parasitism rates are very low (2-4 percent). However, at least in Iowa one parasitoid, the eulophid *Elasmus albizziae*, attacked 39-47 percent of the pupae.

Web Links for Information on Mimosa Webworm

http://woodypests.cas.psu.edu/factsheets/insectfactsheets/html/Mimosa_Webworm.html; factsheet of Pennsylvania State University.

Articles

Heppner, J.B. and G.W. Dekle. 1975. Mimosa webworm, *Homadaula anisocentra* Meyrick (Lepidoptera: Plutellidae). Entomology Circular No. 157, Division of Plant Industry, Florida Department of Agriculture and Consumer Services.

Bastian, R.A. and E.R. Hart. 1989. First-generation parasitism of the mimosa webworm (Lepidoptera: Plutellidae) by *Elasmus albizziae* (Hymenoptera: Eulophidae) in an urban forest. *Environmental Entomology* 19: 409-414.

Sadof, C.S. and R.T. Snyder. 2005. Seasonal abundance of *Homadaula anisocentra* (Lepidoptera: Plutellidae) and two parasitoids, *Elasmus albizziae* (Hymenoptera: Elasmidae) and *Parania geniculata* (Hymenoptera: Ichneumonidae), in an urban forest. *Environmental Entomology* 34: 70-74.

114. Lodgepole Needleminer, *Coleotechnites milleri* (Busck) (Lepidoptera: Gelechiidae)

Orientation to Pest

Lodgepole needleminer, *Coleotechnites milleri* (Busck), is a native North American gelechiid moth whose larvae mine needles of lodgepole pine (*Pinus contorta* Douglas ex Loud.). Larvae of all ages mine needles. Sustained and repeated outbreaks of this species have occurred in Yosemite National Park in California, causing widespread tree mortality. The adults are active from mid-July to mid-August in odd numbered years (each generation requires two years). Eggs are laid in late summer and hatch the same year. First instars mine a single needle, near the growing tip, and overwinter inside the mined needle. The following year, larvae feed on several needles (as needle miners) and develop to the fourth instar by the end of their second growing season. Fourth instars overwinter in mined needles and in the third year, fifth instars complete their feeding in spring, pupate in mined needles, and emerge as adults by mid-summer.

Hosts Commonly Attacked

The only known host is lodgepole pine (*P. contorta*).

Distribution

This insect is found in western North American (United States and Canada) within the range of lodgepole pine.

Images of Lodgepole Needleminer

Figure 1. Adult of lodgepole needleminer, *Coleotechnites milleri*. (Kipling Will)

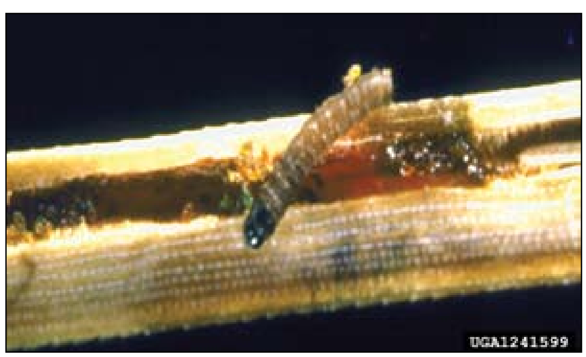


Figure 2. Larva of lodgepole needleminer. (Scott Tunnock, USDA Forest Service, Bugwood.org)

Images of Lodgepole Needleminer (continued)

Figure 3. Damage from lodgepole needleminer. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 4. Stand of lodgepole pine damaged by lodgepole needleminer. (Louisiana State University Archive, Louisiana State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many parasitoids and other natural enemies attacked this species during the declining phase of an outbreak in California (Struble, 1967). Collectively the larval and pupal parasitoids caused 28-46 percent mortality.

Web Links for Information on Lodgepole Needleminer

None

Articles on Lodgepole Needleminer

Struble, G.R. 1967. Insect enemies in the natural control of the lodgepole needle miner. *Journal of Economic Entomology* 60: 225-228.

Struble, G.R. 1973. Biology, ecology, and control of the lodgepole needle miner. Technical Bulletin, U.S. Department of Agriculture No. 1458: 38 p.

115. Banded Ash Clearwing, *Podosesia aureocincta* Purrington and Nielson, and Ash/Lilac Clearwing, *Podosesia syringae* (Harris) (Lepidoptera: Sesiidae)

Orientation to Pest

Banded ash clearwing, *Podosesia aureocincta* Purrington and Nielson, and the ash/lilac borer *Podosesia syringae* (Harris), are similar native North American clearwing moths with overlapping host ranges. *Podosesia syringae* attacks lilac (*Syringa*), ash (*Fraxinus*), privet (*Ligustrum*) and other trees and shrubs. *Podosesia aureocincta* breeds solely in ash, principally green ash (*Fraxinus pennsylvanica* Marshall) and white ash (*F. americana* L.). Before 1975, *P. aureocincta* was thought to be a subspecies or just a late brood of the ash/lilac borer emerging from September to December. Adults of *P. aureocincta* can be recognized and separated from *P. syringae* by the presence of a narrow orange-yellow partial band on the fourth abdominal segment. The larvae of *P. aureocincta* can be distinguished from those of *P. syringae* because *P. aureocincta* larvae have fewer crochets on their abdominal prolegs (12 to 16 per row vs. 16 to 20 per row for *P. syringae*). The life histories of these two species are similar. In both, females lay eggs in cracks on the bark of ash (or for *P. syringae*, various hosts). Larvae tunnel through the wood but continue to expel sawdust and frass, which accumulates around the gallery opening from which the moth will eventually emerge. The overwintering stage in both species is the partly grown larva, which becomes active in spring. Pupation occurs at the end of the larval gallery. Adults of banded ash clearwing emerge later in the year (September-December) than those of *P. syringae*. There is only one generation of *P. syringae* per year. Both species cause damage in forest trees and landscape or nursery trees. The damage caused to ash by either species, however, is negligible compared to that from the invasive emerald ash borer, *Agrilus planipennis* Fairmaire. However, *P. aureocincta* is regarded as an important timber pest in the southern United States, and in the prairie states both species are damaging to trees in shelterbelts.

Hosts Commonly Attacked

Podosesia syringae attacks lilac (*Syringa*), ash (*Fraxinus*), privet (*Ligustrum*), and other trees and shrubs, while *P. aureocincta* breeds principally in green (*F. pennsylvanica*) and white (*F. americana*) ash.

Distribution

Podosesia syringae occurs more widely than *P. aureocincta*, being found from Texas to Saskatchewan and east throughout the United States and Canada. Banded ash clearwing, *P. aureocincta*, is known just from the United States, from New York to Florida and west to Oklahoma. Populations of *P. aureocincta* are also more scattered than are those of *P. syringae*.

Images of Ash/Lilac Clearwing

Figure 1. Adult of the ash/lilac clearwing, *Podosesia syringae*; the adult of the closely related species, the banded ash clearwing, *Podosesia aureocincta* (not shown) is very similar but has a distinctive narrow yellow band around the middle of the abdomen. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 2. Larva of ash/lilac borer, *Podosesia syringae*, in green ash twig. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Death of twigs killed by larvae of ash/lilac borer; note frass in photo on right. (Both photos: James Solomon, USDA Forest Service, Bugwood.org)

Images of Ash/Lilac Clearwing (continued)

Figure 4. Pupal skins of ash/lilac borer left behind on ash trunk following moth emergence. (Both photos: Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 5. Larval galleries of the ash/lilac borer seen in cross section, in finished ash lumber. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of these clearwings have received little attention. Woodpeckers feed extensively on the immature stages. Several parasitoids have also been reared from them, but their importance has not been assessed. The ichneumonid *Phaeogenes ater* Cresson and the braconid *Macrocentrus marginator* (Nees) were reared from *P. aureocincta*, while the ichneumonid *Lissonota* sp. was reared from both *P. aureocincta* and *P. syringae*. Nematode applications can reduce borer damage in nurseries.

Web Links for Information on Ash/Lilac Borer and Banded Ash Clearwing

http://ipm.illinois.edu/landturf/insects/ash_lilac_borer/index.html; fact sheet from the University of Illinois covering both species.

http://images.bugwood.org/mediawiki/pdf.cfm?title=Archive:Ash/Podosesia_aureocincta; Bugwood fact sheet.

http://independent.academia.edu/VernonAntoineBrouJr/Papers/298747/The_Flight_Periods_of_Podosesia_Syringae_Harris_Ana_Podosesia_Aureocincta_Purrington_and_Nielsen_In_Louisiana; comparative data on flights of *P. aureocincta* and *P. syringae*.

Articles

McKnight, M.E. and S. Tunnock. 1973. The borer problem in green ash in North Dakota shelterbelts. *North Dakota Farm Research* 30(5): 8-14.

Purrington, F.F. and D.G. Nielsen. 1979. Genitalic difference between males of *Podosesia aureocincta* and *P. syringae* (Lepidoptera: Sesiidae). *Annals of the Entomological Society of America* 72: 552-555.

Solomon, J.D. 1983. Lilac borer (*Podosesia syringae*) discovered causing terminal mortality and resulting forks in young green ash trees. *Journal of the Georgia Entomological Society* 18: 320-323.

Purrington, F.F. and D.G. Nielsen. 1987. New host records of parasitic Hymenoptera in clearwing moths (Lepidoptera: Sesiidae). *Great Lakes Entomologist* 20: 141-142.

Gill, S., J. Davidson, W. MacLachlan, and W. Potts. 1994. Controlling banded ash clearwing moth borer using entomopathogenic nematodes. *Journal of Arboriculture* 20: 146-149.

116. Red Oak Clearwing Borer, *Paranthrene simulans* (Grote) (Lepidoptera: Sesiidae)

Orientation to Pest

Red oak clearwing borer, *Paranthrene simulans* (Grote), is a native North American clearwing moth that affects American chestnut (*Castanea dentata* [Marsh.] Borkh.) and some oaks. It is widespread in both eastern Canada and the eastern United States. Adult moths emerge from April to June in the southern parts of the species' range and June and July in the northern portion. Females lay eggs in bark crevices on the lower trunk. Larvae burrow in the inner bark and create ovoid chambers. As larvae grow, they extend their galleries. Larvae overwinter for two winters in their galleries. In spring, after the second winter, larvae bore to the bark surface, cap the gallery exits with a thin membrane, and then pupate. The whole life cycle requires two years. Open-grown trees are attacked most often. Bark swelling, pellet-like frass in bark cracks, and empty pupal cases on the trunk are visible signs of attack by this borer. Tunneling causes losses to nursery tree production and promotes decay in the lower butt, below the cut made for harvest. Pheromone traps are available to monitor moth flight to time pesticide applications.

Hosts Commonly Attacked

This borer attacks American chestnut (*C. dentata*) and species in both the red and white oak groups. Moth preference among hosts varies by region. In the southern United States older Nuttall (*Quercus texana* Buckl.), cherrybark (*Q. pagoda* Rafinesque), Shumard (*Q. shumardii* Buckland), and eastern black (*Q. velutina* Lamb.) oaks are the principal hosts. In the northeastern United States, injury is greatest in nursery stock and sapling red or white oak group trees.

Distribution

This borer occurs in the eastern parts of Canada and the United States, north to Minnesota and south and west to Texas.

Images of Red Oak Clearwing Borer

Figure 1. Adult red oak clearwing borers, *Paranthrene simulans*. (Top: Daniel Herms, The Ohio State University, Bugwood.org; bottom: James Solomon, USDA Forest Service, Bugwood.org)

Images of Red Oak Clearwing Borer (continued)

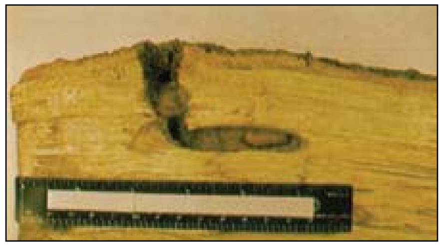


Figure 2. Larva of red oak clearwing borer in its gallery. (USDA Forest Service Fact Sheet)

Figure 3. Emergence holes of red oak clearwing borer on lower trunk of Nuttall oak. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on the natural enemies of this species.

Web Links for Information on Red Oak Clearwing Borer

http://www.fs.fed.us/r8/foresthealth/pubs/oakpests/p17.html; USDA Forest Service fact sheet.

http://images.bugwood.org/mediawiki/pdf.cfm?title=Archive:Oak/Paranthrene_simulans; Bugwood Wiki fact sheet.

Articles

McKern, J.A. and A.L. Szalanski. 2007. Molecular diagnostics of economically important clearwing moths (Lepidoptera: Sesiidae). *Florida Entomologist* 90: 475-479.

117. Persimmon Borer, *Sannina uroceriformis* Walker (Lepidoptera: Sesiidae)

Orientation to Pest

Persimmon borer, *Sannina uroceriformis* Walker, is a native North American clearwing moth found in the eastern United States. The larvae feed in the wood of the lower trunk and tap roots of the American persimmon tree, *Diospyros virginiana* L. Moths emerge in spring and mate. Females either lay their eggs on tree bark or drop them at the base of the host tree. After hatching, larvae move to suitable parts of the host tree and burrow into the bark. Larvae tunnel in the cambium downward, and when they are at or near the soil line, tunnel into the wood toward the center of the tap or lateral roots. Larvae overwinter in their galleries below the soil line and when ready to pupate extend their galleries upward in the roots to the ground line or just above. Trees growing in cutover areas and in hedgerows have higher infestation rates, as do young trees in nurseries. The life cycle takes 2-3 years to complete.

Hosts Commonly Attacked

This borer attacks only persimmons, particularly the native wild persimmon of the United States (*D. virginiana*).

Distribution

This borer occurs is found in the United States along the Atlantic coast from New Jersey to Florida, and west to Kansas, Texas, Missouri, Ohio, and Indiana.

Images of Persimmon Borer

Figure 1. Adult of persimmon borer, *Sannina uroceriformis*. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 2. Larva of persimmon borer. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Persimmon Borer (continued)

Figure 3. Pupation tubes of persimmon borer pushed out of larval galleries. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 4. Galleries of persimmon borer larvae in roots of host tree. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No natural enemies of this species have been recorded.

Web Links for Information on Persimmon Borer

http://edis.ifas.ufl.edu/in669; University of Florida fact sheet on biology and control.

http://images.bugwood.org/mediawiki/pdf.cfm?title=Archive:Borers/Sannina_uroceriformis; Bugwood factsheet.

Articles

Solomon, J.D. 1995. *Guide to Insect Borers in North American Broadleaf Trees and Shrubs*. Agriculture Handbook No. AH-706, see p. 56-57. USDA Forest Service, Washington, DC: 735 p.

118. Poplar Clearwing Borer, *Paranthrene dollii* (Neumoegen) (Lepidoptera: Sesiidae)

Orientation to Pest

Poplar clearwing borer, *Paranthrene dollii* (Neumoegen), is a native North American clearwing moth that occurs principally in the southern United States, where it infests the base and root-collar area of young cottonwoods (*Populus*) and black willow (*Salix nigra* Marshall). Eggs are laid in bark crevices, and larvae bore in the wood and pith, making open tunnels up to 15 cm long. Heavily infested trees are mechanically weakened and subject to wind and ice breakage. Damage is sometimes severe in cottonwood plantations and nurseries, and in the southern states losses may reach 12 percent of nursery stock. There is one generation per year.

Hosts Commonly Attacked

This borer attacks cottonwoods (*Populus*) and black willow (*S. nigra*).

Distribution

This borer occurs in the southern United States, from Florida to Texas.

Images of Poplar Clearwing Borer

Figure 1. Adult of poplar clearwing borer, *Paranthrene dollii*. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 2. Larva of poplar clearwing borer. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Poplar Clearwing Borer (continued)

Figure 3. Frass being expelled from larval tunnels of poplar clearwing borer. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 4. Enlarged entrance holes in stem of cottonwood seedling, caused by larvae of *Paranthrene dollii*. (USDA Forest Service Fact Sheet)

Important Biological Control Agents Related to this Pest Species

One braconid, *Apanteles paranthrenidis* Muesebeck, is known from this borer's larvae.

Web Links for Information on Poplar Clearwing Borer

http://www.forestpests.org/nursery/cwborers.html; USDA Forest Service bulletin on biology and control of several cottonwood borers, including *P. dollii*.

http://wiki.bugwood.org/Archive:Borers/Paranthrene_dollii; Bugwood Wiki fact sheet giving details of biology.

Articles

Eroles-Harkins, L. 1983. Biology and life history of the cottonwood clearwing borer, *Paranthrene dollii* (Neum.) (Lepidoptera: Sesiidae), in the laboratory and a cottonwood nursery in Mississippi. MS thesis. Mississippi State University. 106 p.

Nebeker, T.E. and L. Eroles-Harkins. 1988. Daily and seasonal flight of male *Paranthrene dollii* (Lepidoptera: Sessiidae), monitored by pheromone traps. *Florida Entomologist* 71(3): 376-380.

119. Carpenterworm, *Prionoxystus robiniae* (Peck.) (Lepidoptera: Cossidae)

Orientation to Pest

Carpenterworm, *Prionoxystus robiniae* (Peck.), is a native, wood-boring moth that attacks various hardwoods. Adults emerge between May and August and lay their eggs in large groups (200-1,000) on bark of hosts, often near wounds or objects on the bark such as vines or moss. Young larvae bore into the inner bark and feed there until half grown, at which time they bore into the sapwood and then the heartwood. In southern part of this species' range, immature stages may complete development in a single year, but in northern areas as many as 3 or 4 years may be required. Tunnels to the outside are kept open and enlarged as larvae grow. Tunnels are lined with silk by mature larvae and pupation occurs in the upper end of the tunnel near the exit hole. Pupae, when ready for adult emergence, wriggle to the exit where the adult emerges. The pupal case remains at the entrance of this exit hole. Carpenterworms seldom kill trees, but due to tunneling, infested trees are more likely to break in wind storms, may become more vulnerable to other pests, and the value of affected logs is reduced. No tree size preference has been noted for attack, with trees as small of 5 cm in diameter being infested. However, open grown trees, especially trees in urban landscapes and rural shelterbelts, are at greatest risk of attack.

Hosts Commonly Attacked

In the southern United States, oaks (*Quercus*), particularly members of the red oak group, are heavily damaged. In the prairies and Rocky Mountains of North America, poplar species (*Populus*) and green ash (*Fraxinus pennsylvanica* Marshall) are major hosts. In California, live oak (*Quercus agrifolia* Née) and introduced elms (*Ulmus*) are hosts. Other hosts include black locust (*Robinia pseudoacacia* L.), maple (*Acer*), and willow (*Salix*), among others.

Distribution

This borer is widely distributed in the United States and southern Canada.

Images of Carpenterworm

Figure 1. Adults of the carpenterworm, *Prionoxystus robiniae*; female (left) and male (right). (James Solomon, USDA Forest Service, Bugwood.org)

Images of Carpenterworm (continued)

Figure 2. Female carpenterworm, center, in natural position. (Gerald J. Lenhard, Louiana State Univ, Bugwood.org)

Figure 3. Larvae of carpenterworm. (Top: William H. Hoffard, USDA Forest Service, Bugwood.org; bottom: James Solomon, USDA Forest Service, Bugwood.org)

Images of Carpenterworm (continued)

Figure 4. Larval gallery of carpenterworm (top) and surface injury from lateral gallery in trunk (bottom). (Both photos: James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Staining and oozing are signs marking the point of entrance for carpenterworms. (Larry R. Barber, USDA Forest Service, Bugwood.org)

Images of Carpenterworm (continued)

Figure 6. Tunnels of carpenterworms in elm (left) and ash (right) logs at harvest. (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: Theodor D. Leininger, USDA Forest Service, Bugwood.org)

Figure 7. Defects in milled wood from carpenterworm tunnels and staining. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Little is know about the natural control of carpenterworms. Woodpeckers prey on larvae. Parasitism appears to be minimal.

Web Links for Information on Carpenterworm

http://wiki.bugwood.org/Archive:Borers/Prionoxystus_robiniae; Bugwood wiki fact sheet on biology and control.

http://entomology.unl.edu/ornamentals/pestprofiles/carpenterworm.shtml; fact sheet of the University of Nebraska.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=8249&ind=C; fact sheet of Natural Resources Canada.

http://www.entomology.ualberta.ca/searching_species_details.php?s=2294; University of Alberta insect collection species page.

Articles

McKnight, M.E. and S. Tunnock. 1973. The borer problem in green ash in North Dakota shelterbelts. Shelterbelt Laboratory, Rocky Mountain Forest & Range Experiment Station, Forest Service, USDA, Bottineau, North Dakota, USA. *North Dakota Farm Research* 30(5): 8-14.

Solomon, J.D. and C.J. Hay. 1974. Annotated bibliography of the carpenterworm, *Prionoxystus robiniae*. USDA Forest Service General Technical Report SO-4, Southern Forest Experiment Station: 13 p.

Forschler, B.T. and G.L. Nordin. 1998. Suppression of carpenterworm, *Prionoxystus robiniae* (Lepidoptera: Cossidae), with the entomophagous nematodes, *Steinernema feltiae* and *S. bibionis*. *Journal of the Kansas Entomological Society* 61: 396-400.

120. Pecan Carpenterworm, *Cossula magnifica* (Stecker) (Lepidoptera: Cossidae)

Orientation to Pest

Pecan carpenterworm, *Cossula magnifica* (Stecker), is a native wood boring moth that occurs throughout the southeastern United States, where it reproduces in pecan (*Carya illinoinensis* [Wangenh.] K. Koch), oak (*Quercus*), and hickory (*Carya*). Adults emerge in spring and lay their eggs on bark of small twigs. Young larvae bore in the pith of twigs. Larger larvae move into the branches or the trunk, where they excavate tunnels several inches in length. Frass is expelled through the larval tunnel, which is kept open and enlarged as the larva grows. Pupation occurs in the larval tunnel in the spring. There is one generation per year.

Hosts Commonly Attacked

This borer attacks pecan (*C. illinoinensis*), oak (*Quercus*), and hickory (*Carya*).

Distribution

This borer occurs in the southeastern United States.

Images of Pecan Carpenterworm

Figure 1. Adult of pecan carpenterworm, *Cossula magnifica*; right, in natural pose. (Left: James Solomon, USDA Forest Service, Bugwood.org; right: Theresa Thom, U.S. National Park Service)

Figure 2. Larva of pecan carpenterworm. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Pecan Carpenterworm (continued)

Figure 3. Entrance of pecan carpenterworm tunnel in twig. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 4. Larval tunnels of pecan carpenterworm seen in longitudinal section in pieces of milled wood. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Pecan Carpenterworm (continued)

Figure 5. Frass pellets and staining below the tunnel opening of the pecan carpenterworm. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 6. Larval tunnels of pecan carpenterworm seen in cross section in a log. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Two tachinid parasitoids—*Phorocera comstocki* Williston and *Phorocera signata* Aldrich and Webber—have been reared from this species, but not much is known of their effects on the insect's population dynamics.

Web Links for Information on Pecan Carpenterworm

http://wiki.bugwood.org/Archive:Borers/Cossula_magnifica; fact sheet of Bugwood Wiki on biology and control.

Articles

None

121. Spruce Budworm, *Choristoneura fumiferana* (Clemens) (Lepidoptera: Tortricidae)

Orientation to Pest

Spruce budworm, *Choristoneura fumiferana* (Clemens), is a native North American moth whose larvae feed on balasam fir (*Abies balsamea* [L. Mill.), white (*Picea glauca* [Moench] Voss), red (*P. rubens* Sarg.), and black spruce (*P. mariana* [Mill.] Britton, Sterns & Poggenburg), and sometimes larch (*Larix*), pine (*Pinus*), and hemlock (*Tsuga*). Adults fly in summer and deposits masses of eggs (2-60) on needles in the periphery of the host tree's crown. Eggs hatch and produce larvae that create a hibernacula in which they overwinter as second instars. Hibernaculae are found on branches and other sites on or near the host tree. In the spring of the following year, larvae emerge at or before bud break, disperse aerially, and begin to feed. Buds of staminate flowers are eaten if available, and then old needles are consumed. Larvae then feed on the new vegetative buds, and later, the new foliage. When about half grown, larvae tie several branch tips together with silk to make a nest, where mature larvae later pupate. Females deposit eggs before flying to new sites. Defoliation events from this moth occur regularly over wide areas in eastern Canada and economic losses can be great if uncontrolled. The population dynamics of this species have been the focus of extensive and intense investigation for many decades. For a general review of economic losses and population dynamics see Van Driesche et al. (1996) under articles below.

Hosts Commonly Attacked

Balsam fir (*A. balsamea* [L.] Mill.) is the preferred host of this species, but it also feeds on white (*P. glauca* [Moench] Voss), red (*P. rubens* Sarg.), and black spruce (*P. mariana* [Mill.] Britton, Sterns & Poggenburg), as well as to some degree on species of larch (*Larix*), pine (*Pinus*), and hemlock (*Tsuga*).

Distribution

This moth is found throughout the range of its main hosts (balsam fir and white spruce) from Virginia to Labrador and west to Alaska. Related budworms are found in the western part of North America that were formerly thought to be the same species but now are considered distinct species. Damage in the United States is concentrated along the northern tier of states in the eastern half of the country, from Maine to Minnesota.

Images of Spruce Budworm

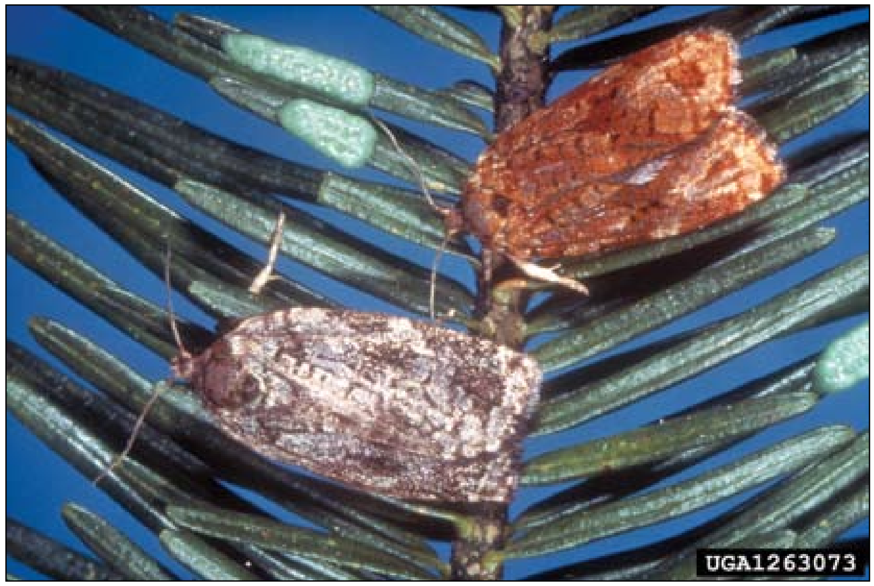


Figure 1. Adults of spruce budworm, *Choristoneura fumiferana*. (K.B. Jamieson, Canadian Forest Service, Bugwood.org)

Figure 2. Eggs of spruce budworm on needle. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Images of Spruce Budworm (continued)

Figure 3. Young larva of spruce budworm hanging from thread, preparing for dispersal by wind. (Jerald E. Dewey, USDA Forest Service, Bugwood.org)

Figure 4. Mature larva of spruce budworm. (Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Images of Spruce Budworm (continued)

Figure 5. Nests of mature spruce budworm larvae. (Top: A. Steven Munson, USDA Forest Service, Bugwood.org; bottom: Joseph O’Brien, USDA Forest Service, Bugwood.org)

Figure 6. Pupa of spruce budworm (left) and cast pupal skin (right). (Both photos: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 7. Needle mining damage caused by young larva of spruce budworm. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of Spruce Budworm (continued)

Figure 8. Needle feeding damage caused by older larvae of spruce budworm. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 9. Damage (browning) to stand of host trees by spruce budworms. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Figure 10. Aerial pesticide applications to large areas damaged by spruce budworm. (Jerald E. Dewey, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

More than 90 species of parasitoids are known to attack spruce budworm in Canada. In Van Driesche et al. (1996) there are details about some of these species and references to their life histories. In addition, some predator groups (birds) are believed to be important to the population dynamics of spruce budworm. While some 15 species of pathogens attack spruce budworm, none are important in the natural population dynamics of the pest. However, one species, *Bacillus thuringiensis* Berliner, is applied as a biopesticide for areawide control, having fewer nontarget impacts on native species than conventional pesticides. Hypotheses concerning the causes driving changes in spruce budworm numbers are discussed in Van Driesche et al. (1996). It is widely believed that one important influence is variation in spring weather that leads to different degrees of synchrony between spring larval emergence and bud break of host trees, with late bud break being unfavorable.

Web Links for Information on Spruce Budworm

http://www.na.fs.fed.us/spfo/pubs/fidls/sbw/budworm.htm; USDA Forest Service Pest and Disease leaflet covering biology and control.

http://en.wikipedia.org/wiki/Spruce_Budworm; Wikipedia article with links to other *Choristoneura* species.

http://www.sampforestpest.ento.vt.edu/defoliating/spruce-budworm/index.php; links to other documents related to sampling spruce budworm in various contexts.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=12018; fact sheet of Natural Resources Canada.

http://www.entomology.ualberta.ca/searching_species_details.php?s=5272#; contains information on taxonomy of this species.

Articles

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations.* FHTET 96-19, December 1996, USDA Forest Service, Morgantown, WV; see http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf.

122. Jack Pine Budworm, *Choristoneura pinus pinus* Freeman (Lepidoptera: Tortricidae)

Orientation to Pest

Jack pine budworm, *Choristoneura pinus pinus* Freeman, is closely related to eastern spruce budworm, *Choristoneura fumiferana* (Clemens), and is part of a complex of eight closely related species (see Lumley et al. 2010, 2011 below). Jack pine budworm is a native North American moth found in eastern Canada, westward to Alberta and in the northeastern and north central United States. Its larvae feed various pines, especially jack (*Pinus banksiana* Lamb.) and red (*P. resinosa* Sol. ex Aiton) pine. Adults fly in mid-to-late summer and lay their eggs in clusters (about 40) on needles. Eggs hatch and the young larvae, without feeding, create hibernaculae under the bark scales on tree trunks or limbs, or between needles. They then molt to second instars and overwinter. In the spring of the following year, larvae emerge near the time when staminate flower buds begin to swell. Staminate flowers are usually the larvae's first food, and thereafter most larvae move to new foliage, where they feed and develop. Needles are clipped and webbed together by older larvae, and needles are only partially consumed. Pupation occurs among the needles or webbed shoots. Feeding of jack pine budworm usually does not kill attacked trees, but may cause top killing and deform the tree, reducing quality of logs for lumber purposes. During outbreaks, younger trees may be killed outright. For further information see Van Driesche et al. (1996).

Hosts Commonly Attacked

Jack pine budworm larvae feed on various pines, but especially jack (*P. banksiana*) and red (*P. resinosa*) pine.

Distribution

This moth is found in Canada throughout the range of jack pine, from the Maritimes west to Alberta. In the United States, it is found in the northeastern and north central parts of the country, from New England to the Great Lakes states.

Images of Jack Pine Budworm

Figure 1. Adult of jack pine budworm, *Choristoneura pinus pinus*. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Images of Jack Pine Budworm (continued)

Figure 2. Hatched egg mass (shiny area on central needle) of jack pine budworm. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 3. Young larvae of jack pine budworm, feeding on male flower of host plant. (D.M. Benjamin, University of Wisconsin, Bugwood.org)

Images of Jack Pine Budworm (continued)

Figure 4. Mature larva of jack pine budworm. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 5. Pupa of jack pine budworm, in area webbed by larvae. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 6. Webbing and feeding on shoots of host by jack pine budworm larvae. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Images of Jack Pine Budworm (continued)

Figure 7. Damage (see browning) to stand of host trees by jack pine budworm larvae. (James B. Hanson, USDA Forest Service, Bugwood.org)

Figure 8. Damage to understory seedling pine by jack pine budworm. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Images of Jack Pine Budworm (continued)

Figure 9. Aerial view of area defoliated by jack pine budworm. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

From 13 to 46 parasitoid species have been recovered in studies of jack pine budworms in various locations (see Van Driesche et al. 1996 for more detail). The species of greatest importance appear to be the larval parasitoids *Apanteles fumiferanae* Viereck (Braconidae) and *Glypta fumiferana* (Viereck) (Ichneumonidae), and the pupal parasitoid *Itoplectis conquisitor* (Say) (Ichneumonidae). The abundance of male flowers in a stand is believed to be linked to outbreaks of this species (see Van Driesche et al. 1996 for a discussion of the literature on this point).

Web Links for Information on Jack Pine Budworm

http://www.na.fs.fed.us/spfo/pubs/howtos/ht_jack/ht_jack.htm; USDA Forest Service fact sheet on biology and management.

http://en.wikipedia.org/wiki/Jack_Pine; Wikipedia article on basic biology.

http://www.entomology.ualberta.ca/searching_species_print.php?s=5271&sn=; provides details on the taxonomy of this species.

Articles

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations.* FHTET 96-19, December 1996, USDA Forest Service, Morgantown, WV; see http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf.

Articles on Jack Pine Budworm (continued)

Lumley, L.M. and F.A.H. Sperling. 2010. Integrating morphology and mitochondrial DNA for species delimitation within the spruce budworm (*Choristoneura fumiferana*) cryptic species complex (Lepidoptera: Tortricidae). *Systematic Entomology* 35: 416-428.

Nealis, V.G. 1991. Parasitism in sustained and collapsing populations of the jack pine budworm, *Choristoneura pinus pinus* Free. (Lepidoptera: Tortricidae), in Ontario, 1985-1987. *The Canadian Entomologist* 123: 1065-1075.

Lumley, L.A. and F.A.H. Sperling. 2011. Utility of microsatellites and mitochondrial DNA for species delimitation in the spruce budworm (*Choristoneura fumiferana*) species complex (Lepidoptera: Tortricidae). *Molecular Phylogenetics and Evolution* 58: 232-243.

123. Large Aspen Tortrix, *Choristoneura conflictana* (Walker) (Lepidoptera: Tortricidae)

Orientation to Pest

Large aspen tortrix, *Choristoneura conflictana* (Walker), is a native North American tortricid moth found throughout the range of quaking aspen (*Populus tremuloides* Michx.) in Canada and the United States. In Canada, adults lay their eggs in June or July in flat clusters, usually on the leaves. Eggs hatch and the first instars feed together on leaves, webbing foliage together. Fed first instars then move to the trunk where they create hibernaculae and overwinter as second instars. In the spring of the following year, larvae emerge and feed by mining the swelling buds. Later, larvae feed in leaf rolls. Pupation occurs in the leaf rolls, and adults emerge in a few weeks to lay eggs of the new generation. Defoliating outbreaks have occurred in the aspen stands in Canada, Alaska, New England, New York, and Michigan. Reasons for outbreaks have not been studied, but the existence of overwintering young larvae that feed on buds the following year suggests that variation in the degree of synchrony (driven by annual weather events) between bud break and larvae resumption of feeding is likely to be a factor.

Hosts Commonly Attacked

The large aspen tortrix is mainly associated with quaking aspen (*P. tremuloides*) but also feeds on balsam poplar (*Populus* sect. *tacamahaca*), bigtooth aspen (*P. grandidentata* Michaux), paper birch (*Betula papyrifera* Marsh.), willow (*Salix*), and alder (*Alnus*).

Distribution

This moth is found throughout the range of quaking aspen in Canada and the United States.

Images of Large Aspen Tortrix

Figure 1. Adult of large aspen tortrix, *Choristoneura conflictana*. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Large Aspen Tortrix (continued)

Figure 2. Egg mass of large aspen tortrix. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 3. Young larvae of large aspen tortrix, feeding on webbed leaves. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Images of Large Aspen Tortrix (continued)

Figure 4. Mature larva of large aspen tortrix. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 5. Rolled leaf, feeding site of older larvae of large aspen tortrix. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of Large Aspen Tortrix (continued)

Figure 6. Pupa of large aspen tortrix. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 7. Quaking aspen defoliated by large aspen tortrix. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Images of Large Aspen Tortrix (continued)

Figure 8. Aerial view of area defoliated by large aspen tortrix. (USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A large number of species of parasitoids (>20) have been reared from larvae and pupae in several locations where studies have been conducted (Alberta, Canada; Alaska). Collectively, these cause significant levels of mortality, up to 50 percent in some cases. Among the more important species are *Macrocentrus iridescens* French, *Glypta inversa* Cresson, *Glypta fumiferanae* (Viereck), and *Agathis annulipes* (Cresson).

Web Links for Information on Large Aspen Tortrix

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=12016; fact sheet of Natural Resources Canada.

http://www.fs.fed.us/r10/spf/fhp/leaflets/Larasptor.htm; USDA Forest Service fact sheet.

http://www.fs.fed.us/r10/spf/fhp/leaflets/Fidl139.htm; USDA Forest Service leaflet.

http://www.entomology.ualberta.ca/searching_species_details.php?s=5251; fact sheet of the University of Alberta.

Articles

Torgersen, T.R. and R.C. Beckwith. 1974. Parasitoids associated with the large aspen tortrix, *Choristoneura conflictana* (Lepidoptera: Tortricidae), in interior Alaska. *The Canadian Entomologist* 106: 1247-1265.

Jones, B.C., J. Roland, and M.L. Evenden. 2009. Development of a combined sex pheromone-based monitoring system for *Malacosoma disstria* (Lepidoptera: Lasoicampidae) and *Choristoneura conflictana* (Lepidoptera: Tortricidae). *Environmental Entomology* 38: 459-471.

124. Sugar Pine Tortrix, *Choristoneura lambertiana* Busck (Lepidoptera: Tortricidae)

Orientation to Pest

Sugar pine tortrix, *Choristoneura lambertiana* Busck, is a tortricid moth native to western North American that feeds on various conifers, especially pines. This species includes many different races that vary in appearance or aspects of biology, some of which have been given subspecies names. This moth's life history is similar to that of other better known members of the genus. Adults fly in summer (July and August) and lay eggs on the foliage of the host plant. Young larvae overwinter in hibernaculae on the tree trunk and reemerge the following spring when they feed by mining needle sheaths and staminate cones. New foliage buds are also consumed. Several larvae (1-5) may feed together on the same shoot. Larvae web the needles into feeding shelters and pupae are formed among the webbed needles. Damaged trees are not likely to die, but tops may be killed.

Hosts Commonly Attacked

The sugar pine tortrix feeds on various pines, including sugar (*Pinus lambertiana* Douglas), lodgepole (*P. contorta* Douglas), limber (*P. flexilis* E. James), and ponderosa (*P. ponderosa* Douglas ex. C. Lawson) pines, as well as some other conifers, including Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and juniper (*Juniperus*).

Distribution

This moth is found in several western U.S. states (including California, Colorado, Idaho, Montana, Oregon, and Montana). Ranges by subspecies have been recorded as follows: *Choristoneura lambertiana lambertiana* (confirmed: Siskiyou County and Ashland, Oregon; uncertain: Alberta and British Columbia in Canada and Idaho, Montana, eastern Oregon, and Wyoming in the United States); *C. lambertiana ponderosana* (Arizona, Colorado, Nevada, New Mexico, western New England, South Dakota); *C. lambertiana subretiniana* (California and Oregon).

Images of Sugar Pine Tortrix

Figure 1. Adults (two forms with different color patterns) of the sugar pine tortrix, *Choristoneura lambertiana*. (Left: Mark McGregor, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of Sugar Pine Tortrix (continued)

Figure 2. Egg mass of the sugar pine tortrix. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of the sugar pine tortrix. (Top: Scott Tunnock, USDA Forest Service, Bugwood.org; bottom: Bernard J. Raimo, USDA Forest Service, Bugwood.org)

Images of Sugar Pine Tortrix (continued)

Figure 4. Needles that have been clipped and webbed together by sugar pine tortrix larvae. (Left: Scott Tunnock, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 5. Pupa of the sugar pine tortrix (top) and skin of emerged pupa (bottom). (Top: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; bottom: Bernard J. Raimo, USDA Forest Service, Bugwood.org)

Images of Sugar Pine Tortrix (continued)

Figure 6. Damage to tips of small pine from larvae of the sugar pine tortrix. (Dave Powell, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

As with other *Chorisoneura* species, the sugar pine tortrix is affected by a large complex of natural enemies, especially parasitoids, of which some 22 species are known from rearing. However, the effect, if any, of these species on fluctuations in density of this pest is unknown.

Web Links for Information on Sugar Pine Tortrix

http://www.ireference.ca/search/Choristoneura%20lambertiana/; discusses host plants of some of the subspecies of the sugar pine tortrix.

http://en.wikipedia.org/wiki/Choristoneura_lambertiana; Wikipedia articles includes information on ranges of subspecies.

http://www.ext.colostate.edu/pubs/insect/05567.html; factsheet of Colorado State University giving general information of subspecies associated with ponderosa pine.

Articles

Stevens, R.E., T.K. Borg, and T.O. Thatcher. 1977. Notes on a pine-feeding budworm, *Choristoneura lambertiana ponderosana* (Lepidoptera: Tortricidae), in the Colorado Rockies. *The Canadian Entomologist* 109: 1269-1274.

Powell, J.A. 1995. *Biosystematic Studies of Conifer-feeding Choristoneura (Lepidoptera: Tortricidae) in the Western United States.* University of California Publications, Entomology, Berkeley, California. (Contains range information.)

125. Western Spruce Budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae)

Orientation to Pest

Western spruce budworm, *Choristoneura occidentalis* Freeman, is a tortricid moth native to western North American that feeds on various conifers, including species of fir (*Abies*), larch (*Larix*), spruce (*Picea*), and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). The life history of this moth is similar to that of the spruce budworm (*Choristoneura fumiferana* [Clemens]). Adults fly and lay eggs in summer (July and August) on the host plant. Young larvae do not feed but rather immediately spin a hibernacula under bark scales, where they overwinter. The next spring, larvae become active and feed by mining old needles until the buds swell. Larvae then bore into the buds and feed on the expanding needles. Later in the spring, they loosely web together growing tips and feed upon the new needles, where they later pupate. There is one generation per year. This is considered one of the most damaging pests in western North American forests, and large, sustained outbreaks sometimes occur. Damaged trees may be killed entirely or just the tops may die, destroying the commercial value of the trees.

Hosts Commonly Attacked

This species feeds on various confers including *Abies concolor* (Gordon) Lindley ex Hildebrand, *A. grandis* (Douglas ex D. Don) Lindley, *A. lasiocarpa* (Hooker) Nuttall, *Larix occidentalis* Nutt., *Picea engelmannii* Parry ex Engelm., *P. glauca* (Moench) Voss, *P. pungens* Engelm., Douglas-fir, and juniper (*Juniperus*).

Distribution

This moth is found in several western U.S. states, including Colorado, Idaho, Montana, Wyoming, Colorado, Arizona, Utah, New Mexico, Oregon, and Washington, as well of British Columbia and southwest Alberta, Canada.

Figure 1. Distribution of the western spruce budworm, *Choristoneura occidentalis,* in western North America. (USDA Forest Service • Forest Insect & Disease Leaflet 53)

Images of Western Spruce Budworm

Figure 2. Adult of the western spruce budworm. (USDA Forest Service - Region 4 - Intermountain Archive, USDA Forest Service, Bugwood.org)

Figure 3. Silvery egg mass of the western spruce budworm on needle. (USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Figure 4. Very young larva of western spruce budworm feeding in bud (left) and on new foliage (right). (Both photos: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Images of Western Spruce Budworm (continued)

Figure 5. Webbed foliage, the feeding site of young larvae of the western spruce budworm. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 6. Mature larva of western spruce budworm. (Scott Tunnock, USDA Forest Service, Bugwood.org)

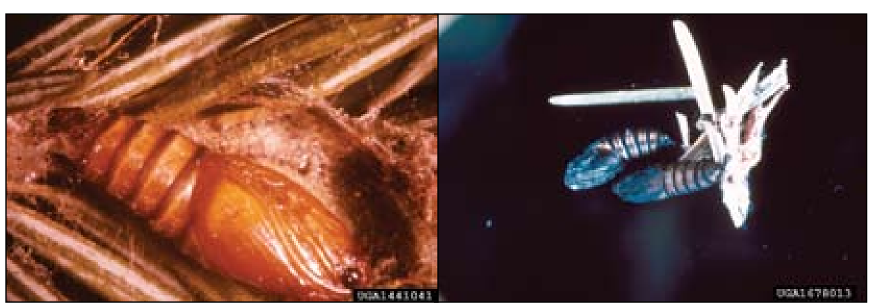


Figure 7. Pupae of the western spruce budworm. (Left: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org; right: David McComb, USDA Forest Service, Bugwood.org)

Images of Western Spruce Budworm (continued)

Figure 8. Damage caused by western spruce budworm to a grand fir. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Figure 9. Stand of grand fir in Oregon defoliated by western spruce budworm. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Images of Western Spruce Budworm (continued)

Figure 10. Stand with dead trees 10 years after a western spruce budworm outbreak in Oregon. (Dave Powell, USDA Forest Service, Bugwood.org)

Figure 11. Eggs of western spruce budworm parasitized by the egg parasitoid *Trichogramma minutum* Riley. (USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

As with other *Choristoneura* species, the western spruce budworm is affected by a large complex of natural enemies, especially parasitoids, which, along with adverse weather, partially limit the pest's density. However, population outbreaks occur when climatic and forest stand conditions are favorable. There are more than 40 species of insect parasitoids of the western spruce budworm, of which four or five species are most common. See Bellows et al. (1998) for species names.

Web Links for Information on Western Spruce Budworm

http://www.na.fs.fed.us/spfo/pubs/fidls/westbw/fidl-wbw.htm; USDA Forest Service fact sheet covering biology, control and other topics.

http://www.ext.colostate.edu/pubs/insect/05543.html; fact sheet of Colorado State University.

http://ext.nrs.wsu.edu/forestryext/foresthealth/notes/westernbudworm.htm; fact sheet of Washington State University.

http://www.oregon.gov/ODF/privateforests/docs/fh/WesternSpruceBudworm.pdf?ga=t; fact sheet of the Oregon Department of Forestry.

Articles

Schmidt, W.C. and D.C. Fellin. 1973. Western spruce budworm damage affects form and height growth of western larch. *Canadian Journal of Forest Research* 3(1): 17-26.

Jennings, D.T., F.B. Knight, S.C. Hacker, and M.E. McKnight. 1979. Spruce budworms bibliography. Misc. Rep. 213. University of Maine, School of Forest Resources, Life Science and Agricultural Experiment Station. Orono, Maine: 687 p.

Bellows, T.S., C. Meisenbacher, and R.C. Reardon. 1998. *Biological Control of Arthropod Forest Pests of the Western United States: A review and recommendations.* FHTET-96-21. USDA Forest Service, Morgantown, West Virginia, USA.

126. Spruce Bud Moth, *Zeiraphera canadensis* Mutuura and Freeman (Lepidoptera: Tortricidae)

Orientation to Pest

Spruce bud moth, *Zeiraphera canadensis* Mutuura and Freeman, is a native tortricid moth associated predominantly with spruce (*Picea*) in eastern North America. It overwinters as eggs, which hatch in the spring. There are four larval instars. First and second instar larvae mine needles of recently burst buds. Third and fourth instars feed on the stems of shoots. Pupation usually takes place in the soil. There is one generation per year. Larval feeding on shoots of the upper crown and on the leader can stunt tree growth, causing economically important damage in spruce plantations. Injury is most common on open grown spruces (before crown closure) and this species is not a pest in natural forest stands.

Hosts Commonly Attacked

This moth feeds mainly on white spruce (*Picea glauca* [Moench]), but sometimes attacks black spruce (*P. mariana* [Mill.] Britton, Sterns and Poggenburg) or balsam fir (*Abies balsamea* [L.] Mill.).

Distribution

This moth occurs throughout the range of spruce in the northern United States and eastern Canada.

Images of Spruce Bud Moth

Figure 1. Adult of spruce bud moth, *Zeiraphera canadensis* Mutuura and Freeman. (Bo Zaremba - bozaremba@comcast.net)

Images of Spruce Bud Moth (continued)

Figure 2. Parasitized egg of spruce bud moth (black) at base of shoot. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Mature larva of spruce bud moth. (Dion Manastyrski - Pacific Forestry Centre, Natural Resources Canada, Canadian Forest Service)

Figure 4. Buds damaged by spruce bud moth. (Left: Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org; right: Dion Manastyrski - Pacific Forestry Centre, Natural Resources Canada, Canadian Forest Service)

Figure 5. Buds damaged by spruce bud moth; see cap of bud held by silk threads. (Jean-François Mouton - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

In Newfoundland, Canada, the ichneumonid *Tycherus osculator* parasitizes up to 50 percent of the larvae of spruce bud moth.

Web Links for Information on Spruce Bud Moth

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=11208; fact sheet of Natural Resources Canada, including information on how to scout for this pest.

http://www.fs.fed.us/r10/spf/fhp/leaflets/Sprlarbudmot.htm; fact sheet of USDA Forest Service, Alaska on *Zeiraphera* spp. and methods for reducing their damage on spruce and larch.

Articles

Turgeon, J.J. 1985. Life cycle and behaviour of the spruce bud moth, *Zeiraphera canadensis* (Lepidoptera: Olethreutidae) in New Brunswick. *The Canadian Entomologist* 117: 1239-1247.

Turgeon, J.J. and J. Régnière. 1987. Development of sampling schemes for the spruce bud moth, *Zeiraphera canadensis* (Lepidoptera: Tortricidae). *The Canadian Entomologist* 119: 239-249.

Turgeon, J.J., N. Nelson, and E.G. Kettela. 1987. Reproductive biology of the spruce bud moth, *Zeiraphera canadensis* (Lepidoptera: Tortricidae: Olethreutinae), in New Brunswick. *The Canadian Entomologist* 119: 361-364.

Carroll, A.L. and D.T. Quiring. 1993. Influence of feeding by *Zeiraphera canadensis* (Lepidoptera: Tortricidae) on growth of white spruce: larval density - damage and damage - shoot production relationships. *Journal of Applied Ecology* 30: 629-639.

West, R.J., M. Kenis, G.W. Butt, and S.M. Bennett. 1999. Parasitoid complex of *Zeiraphera canadensis* (Lepidoptera: Tortricidae) and evaluation of *Tycherus osculator* (Hymenoptera: Ichneumonidae) as a biological control agent. *The Canadian Entomologist* 131: 465-474.

West, R.J., M. Kenis, R.S. Bourchier, S.M. Smith, and G.W. Butt. 2001. *Zeiraphera canadensis* Mutuura and Freeman, spruce bud moth (Lepidoptera: Tortricidae). In: Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000.* CABI Publishing, Wallingford, UK: 279-283.

127. Cottonwood Twig Borer, *Gypsonoma haimbachiana* (Kearfott) (Lepidoptera: Tortricidae)

Orientation to Pest

Cottonwood twig borer, *Gypsonoma haimbachiana* (Kearfott), is a native tortricid found throughout the eastern United States and parts of southern Canada. It bores in the stems of young eastern cottonwood (*Populus deltoides* Bartr.) and is considered an important pest of young cottonwoods that are grown in plantations. Winter is spent as young larvae that are found on trees in silk-lined shallow pits excavated in healed over borer entrance holes or other depressions on trees. Some older larvae overwinter in hollowed-out buds. In spring, larvae bore into tender new shoots. After pupation and adult emergence, eggs are laid singly or in small groups on the foliage. New larvae of summer generations cover themselves with silk mixed with trash, then bore into the midrib. After a few days, the larvae abandon their midrib galleries and tunnel in shoots to complete their development. In the southern United States, there may be four to five generations per year. Damaged trees are stunted, crooked, and have many limbs, reducing tree value.

Hosts Commonly Attacked

This borer attacks various poplars, especially eastern cottonwood.

Distribution

Cottonwood twig borer is found in the eastern United States, west to Texas and in Ontario, Canada. It is common in the southern United States.

Images of Cottonwood Twig Borer

Figure 1. Adults of the cottonwood twig borer, *Gypsonoma haimbachiana* (Kearfott). (Top: Jim Vargo; bottom: Steve Scott, Illinois Eastern Community College, Bugwood.org)

Images of Cottonwood Twig Borer (continued)

Figure 2. Egg of cottonwood twig borer. (R.C. Morris, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of cottonwood twig borer. (Both photos: Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Cottonwood Twig Borer (continued)

Figure 4. Cottonwood twig broken at larval tunnel of cottonwood twig borer. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 5. Frass tubes at cottonwood twig borer entrance holes are a sign of this pest's presence. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Some natural enemies of have been noted attacking cottonwood twig borer (e.g., those in Steward and Payne (1972) and Steward (1973), cited below. Also, see comments in Van Driesche et al. (1996). However, these have not been studied sufficiently to get a general understanding of their importance or distribution.

Web Links for Information on Cottonwood Twig Borer

http://wiki.bugwood.org/Archive:South/Gypsonoma_haimbachiana; Bugwood Wiki fact sheet on biology.

http://www.fs.fed.us/r8/foresthealth/idotis/insects/cwtwigbr.html; USDA Forest Service, Southern Region fact sheet.

Articles

Morris, R.C. 1967. Biology of *Gypsonoma haimbachiana* (Lepidoptera: Olethreutidae), a twig borer in eastern cottonwood. *Annals of the Entomological Society of America* 60: 423-427.

Stewart, J.W. and T.L. Payne. 1972. Parasites and predators of the cottonwood twig borer in Texas. *Environmental Entomology* 1: 669-670.

Stewart, J.W. and T.L. Payne. 1975. Seasonal abundance and impact of the cottonwood twig borer on cottonwood trees. *Journal of Economic Entomology* 68: 599-602.

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations.* FHTET 96-19, December 1996, USDA Forest Service, Morgantown, WV. (See http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

McMillin, J.D., M.J. Anderson, E.E. Butin, and E.R. Hart. 1998. Phenology and infestation patterns of the cottonwood twig borer (Lepidoptera: Tortricidae) in Iowa. *Great Lakes Entomologist* 31: 181-190.

129. Oak Leafroller, *Archips semiferanus* (Walker) (Lepidoptera: Tortricidae)

Orientation to Pest

Oak leafroller, *Archips semiferanus* (Walker), is native to North America, where it is widely distributed in the eastern half of the continent. Females lay eggs in masses of 40 to 50 eggs on branches or rough bark in July. Eggs overwinter and larvae emerge in spring and feed on buds and young leaves. Mid-to-late instar larvae roll leaves together with silk to form a nest in which they feed. Mature larvae pupate in the leaf rolls or crevices in June and adults emerge a few weeks later. Periodic outbreaks of this species have occurred in oak forests in North America since the 1960s. In Pennsylvania and Michigan, hundreds of thousands of acres have been defoliated in some years, with substantial tree mortality and economic loss.

Hosts Commonly Attacked

Larvae of oak leafroller feed on a range of oaks (*Quercus*), especially northern red (*Quercus rubra* L.), scarlet (*Q. coccinea* Muenchh.), chestnut (*Q. prinus* L.), and white (*Q. alba* L.) oaks. In addition, this moth sometimes feeds on species of witch hazel (*Hamamelis*) and apple (*Malus*).

Distribution

Archips semiferanus is found in southeastern Canada and the eastern United States, west to Colorado and Texas.

Images of Oak Leafroller

Figure 1. Adult of oak leafroller, *Archips semiferanus*. (Todd Gilligan, CSU, Bugwood.org)

Images of Oak Leafroller (continued)

Figure 2. Larva of oak leafroller. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this species have been studied in Pennsylvania where pupae were attacked by two ichneumonids, *Itoplectis conquistor* (Say) and *Phaeogenes gilvilabris* Allen, and larvae were attacked by various tachinids. Larval parasitism was more common than pupal parasitism.

Web Links for Information on Oak Leafroller

http://en.wikipedia.org/wiki/Archips_semiferanus; Wikipedia fact sheet on biology and taxonomy of species.

Articles

Freeman, T.N. 1958. The Archipinae of North America. *The Canadian Entomologist*, Supplement No. 7: 89 p.

Chapman, P.J. and S.E. Lienk. 1971. Tortricid fauna of apple in New York; including an account of apples' occurrence in the State, especially as a naturalized plant. New York State Agricultural Experiment Station, Special Publication, Geneva, New York: 142 p.

Wilson, L.F. 1972. Life history and outbreaks of an oak leafroller, *Archips semiferanus* (Lepidoptera: Tortricidae), in Michigan. *Great Lakes Entomologist* 5: 71-77.

Mumma, R.O. and A.S. Zettle. 1977. Larval and pupal parasites of the oak leafroller, *Archips semiferanus*. Environmental Entomology 6: 601-605.

130. Longleaf Pine Seedworm, *Cydia ingens* (Heinrich) (Lepidoptera: Tortricidae)

Orientation to Pest

Longleaf pine seedworm, *Cydia ingens* (Heinrich), is a native tortricid that is part of the *C. toreuta* complex whose members cannot be separated morphologically and whose species status is uncertain (Gilligan et al. 2008). Species are currently recognized based on host and range. *C. ingens* (in the narrow sense) has been interpreted as being restricted to Florida. This species, or closely related forms, occur in the southeastern United States where their larvae feed in immature cones of long leaf pine (*Pinus palustris* Mill.), destroying the seeds.

Hosts Commonly Attacked

There are many seed cone worms associated with various pines. In the southern United States this species, or a closely related one, feeds on long leaf pine (*P. palustris*).

Distribution

This species complex is found in the southeastern United States, with *C. ingens* (in the narrow sense) perhaps being restricted to Florida.

Image of Longleaf Pine Seedworm

Figure 1. Adult of longleaf pine seedworm, *Cydia ingens*. (Todd Gilligan, CSU, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on natural enemies of this species.

Web Links for Information on Longleaf Pine Seedworm

http://www.tortricidae.com/identificationPhoto.asp?NAV=10; website of tortricd.net, resources on the Tortricidae.

Articles on Longleaf Pine Seedworm

Abrahamson, L.P. and K.J. Kraft. 1965. A population study of the cone moth *Laspeyresia toreuta* Grote in *Pinus banksiana* stands. *Ecology* 46: 561-563.

Harbo, J.R. and K.J. Kraft. 1969. A study of *Phanerotoma toreutae,* a parasite of the pine cone moth *Laspeyresia toreuta*. *Annals of the Entomological Society of America* 62: 214-220.

Gilligan, T.M., D.J. Wright, and L.D. Gibson. 2008. *Olethreutine Moths of the Midwestern United States, An Identification Guide.* Ohio Biological Survey 16(2): 334 p.

131. European Pine Shoot Moth, *Rhyacionia buoliana* (Denis and Schiffermiiller) (Lepidoptera: Tortricidae)

Orientation to Pest

European pine shoot moth, *Rhyacionia buoliana* (Denis and Schiffermiiller), is an invasive tortricid native to Europe, the eastern Mediterranean region, and Japan. It is invasive in the United States, Canada, Chile, and Uruguay. It is a serious pest of pines, especially in pine plantations because it kills the leaders of pines, destroying their growing form. Larvae feed on pines, especially red pine (*Pinus resinosa* Sol. ex Aiton) or introduced European pines, and, in Southern Hemisphere plantations, on Monterrey pines (*P. radiata* D. Don). Buds of branches are also attacked. Moths emerge in early summer and lay their eggs on new needles. Young larvae construct webs that are coated with resin below the current year's needle sheaths and stems. Feeding initially occurs within the sheath at the base of needles. By midsummer, larvae switch and feed on buds until August. Larvae overwinter in webs at the bases of buds and in spring move to undamaged buds or new shoots, where they complete development. Pupation takes place during the second summer in the dead buds and shoots, and when adults emerge, empty pupal cases remain sticking out of the pupal chambers in the hollowed-out buds. One generation occurs each year. Death of leaders leads to deformed, bushy trees. In Chile, as much as a third of trees in Monterrey pine plantations may be infested.

Hosts Commonly Attacked

In North America, this moth attacks various native pines, especially red pine (*P. resinosa*), as well as several introduced European species, particularly Mugo (*P. mugo* Turra) and Scots (*P. sylvestris* L.) pines. The five-needle pines are relatively resistant. In the Southern Hemisphere, an important host is the North American species *P. radiata*, when grown in plantations.

Distribution

In North America, the moth occurs in southern Canada from Newfoundland to the Great Lakes and in the United States south to Maryland and Illinois. A separate infestation exists in British Columbia, Oregon, and Washington.

Images of European Pine Shoot Moth

Figure 1. Adults of European pine shoot moth, *Rhyacionia buoliana*. (Left: USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of European Pine Shoot Moth (continued)

Figure 2. Eggs (right) and first instar larva (left) of European pine shoot moth. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 3. Larva of European pine shoot moth feeding in shoot. (Fabio Stergulc, Università di Udine, Bugwood.org)

Images of European Pine Shoot Moth (continued)

Figure 4. Live pupa of European pine shoot moth in place in damaged shoot (top); pupa dissected from shoot (middle), and cast pupal skin (bottom) from damaged leader. (Top: David McComb, USDA Forest Service, Bugwood.org; middle and bottom: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of European Pine Shoot Moth (continued)

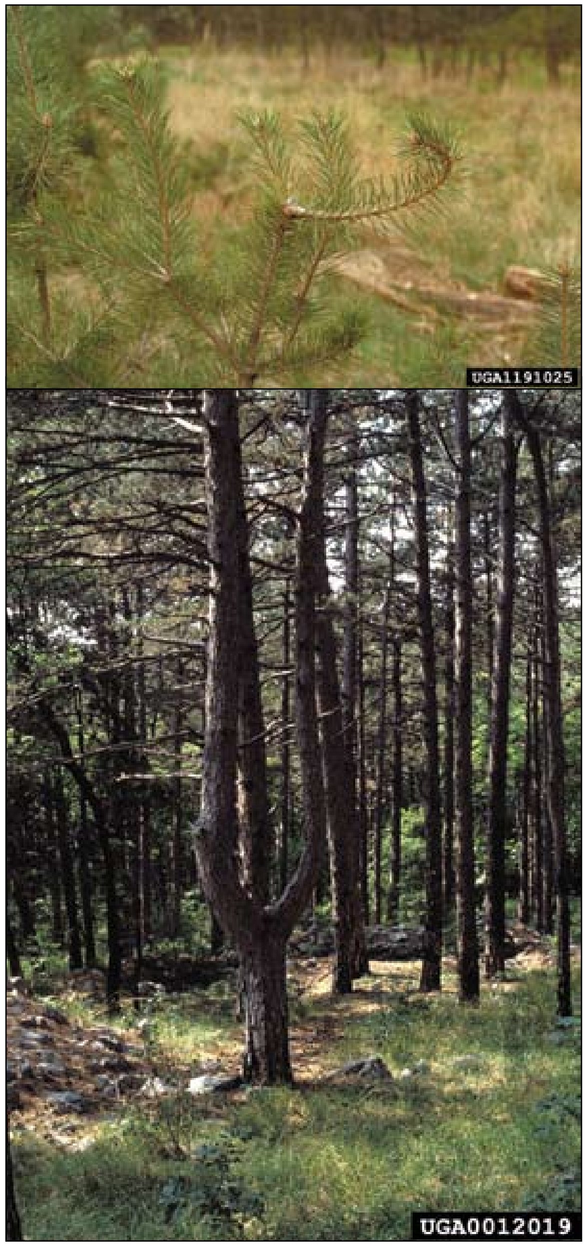


Figure 5. Deformation of shape of pine tree; top, in young tree; bottom, eventual tree shape (here, “Y”) due to leader death from feeding of European pine shoot moth. (Top: Jan Liska, Forestry and Game Management Research Institute, Bugwood.org; bottom: Fabio Stergulc, Università di Udine, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many studies have described the parasitoids that can be reared from larvae and pupae of European pine shoot moth in various countries (United States, Canada, Chile, parts of Europe) and on various tree species. More than a hundred species of parasitoids have been recorded. Studies conducted in coastal areas of Germany in the 1950s and 1960s, for example, found larval and pupal parasitism of this species to be in the 28-65 percent range in pine plantations. The most common parasitoids observed were the ichneumonid *Cremastus confluens* Grav. and the braconid *Orgilus obscurator* Nees. Similar studies have been done in various locations, with some variation in the parasitoid guild. Several European parasitoid species were released in North America for suppression of this pest, but only a few have become established. Of these, only *O. obscurator* appears to be widespread and of some importance. Releases of European parasitoids in North America have, however, had limited effect on densities of this pest in most areas. Possible explanations for this lack of control may include low vegetation diversity in North American pine plantations and a possible need to import additional species of parasitoids from Europe. Parasitoid importations against this species have also been undertaken in Chile.

Web Links for Information on European Pine Shoot Moth

http://www.forestry.ubc.ca/fetch21/FRST308/lab4/rhyacionia_buoliana/europe.html; fact sheet of the University of British Columbia.

http://wiki.bugwood.org/Archive:Northeast/Rhyacionia_buoliana; fact sheet of BugwoodWiki, covering biology.

http://www.pfc.forestry.ca/diseases/nursery/pests/europea1_e.html; Natural Resources Canada fact sheet.

http://www.cabi.org/isc/?compid=5&dsid=23641&loadmodule=datasheet&page=481&site=144; fact sheet of CABI from the UK, showing worldwide distribution.

Articles

Schultz, A., D. Häussler, K.H. Apel, and E.K. Groll. 1997. RHYA-SIM - a model illustrating the population dynamics of the pine shoot moth (*Rhyacionia buoliana*). *Beiträge für Forstwirtschaft und Landschaftsökologie* 31(2): 88-91. (In German).

Daterman, G., A. Eglitis, D. Czokajlo, C. Sack, and P. Kirsch. 2001. Attract and kill technology for management of European pine shoot moth (*Rhyacionia buoliana*) and Western pine shoot borer (*Eucosma sonomana*). In: Knízek, M., B. Forster, and W. Grodzki (eds.). Methodology of forest insect and disease survey in central Europe. Proceedings of the Fourth Workshop of the IUFRO Working Party. Prague, Czech Republic, 17-20 September 2001. *Journal of Forest Science* 47 (Special Issue 2): 66-69.

Huerta, A., F. Robredo, J. Diez, and J.A. Pajares. 2006. The parasitoid complex selection of the European pine shoot moth (*Rhyacionia buoliana* Den. et Schiff.) (Lepidoptera: Tortricidae) for the biological control in Chile. *Boletín de Sanidad Vegetal, Plagas* 32(4): 95-607. (In Spanish).

132. Nantucket Pine Tip Moth, *Rhyacionia frustrana* (Comstock) (Lepidoptera: Tortricidae)

Orientation to Pest

Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), is a native shoot-boring tortricid associated with pines in the eastern United States. There is a similar insect, found in Nebraska attacking pines in plantations, that was formerly thought to be a subspecies of *R. frustrana* but later was recognized as its own species, *R. bushnelli* Miller. Larvae of Nantucket pine tip moth bore into and kill leaders of pines, both reducing overall growth in wood volume and deforming the tree. The species is a pest of various southern pines in plantations. Some species such as shortleaf (*Pinus echinata* Miller) and loblolly (*P. taeda* L.) pines are severely affected. The proportion of tips infested by this pest decreases after trees reach 3-4 meters in height.

Hosts Commonly Attacked

In North America, Nantucket pine tip moth attacks several southern pines in plantations, especially shortleaf (*P. echinata*) and loblolly (*P. taeda*) pines. In New England, pitch pine (*P. rigida* Miller) is a favorite host in pine barrens.

Distribution

Nantucket pine tip moth occurs in the United States from eastern Texas north to Missouri, east to Florida and north to Massachusetts. There is also an isolated, invasive population in southern California.

Images of Nantucket Pine Tip Moth

Figure 1. Adult of Nantucket pine tip moth, *Rhyacionia frustrana*. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Images of Nantucket Pine Tip Moth (continued)

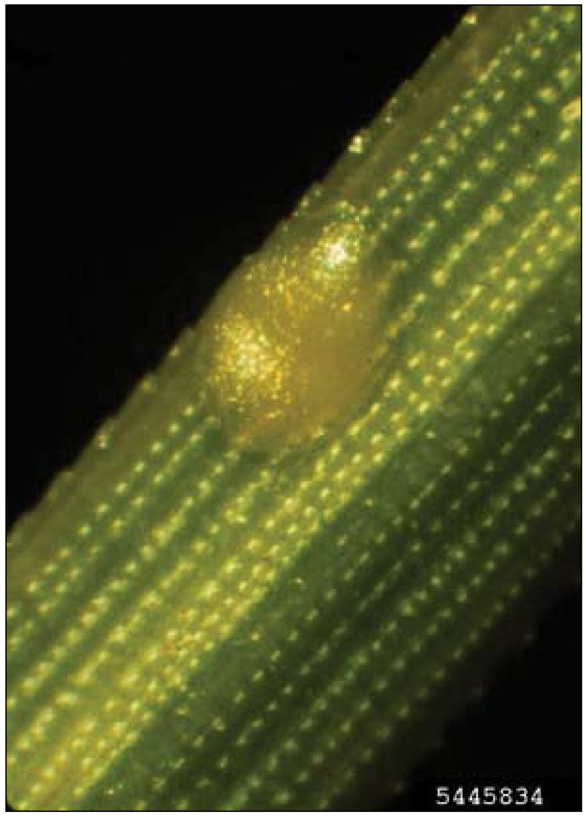


Figure 2. Egg of Nantucket pine tip moth. (Darrell Ross, Oregon State University, Bugwood.org)

Figure 3. Larva of Nantucket pine tip moth. (Darrell Ross, Oregon State University, Bugwood.org)

Images of Nantucket Pine Tip Moth (continued)

Figure 4. Pupa of Nantucket pine tip moth. (Darrell Ross, Oregon State University, Bugwood.org)

Figure 5. Dead tips caused by feeding of Nantucket pine tip moth. (Top: Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org; bottom: Darrell Ross, Oregon State University, Bugwood.org)

Images of Nantucket Pine Tip Moth (continued)

Figure 6. Stunting seedling tree due to tip death from Nantucket pine tip moth feeding. (Darrell Ross, Oregon State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many studies have described the parasitoids that can be reared from larvae and pupae of Nantucket pine tip moth. Of the various larval parasitoids noted, the species that are consistently of greatest importance in nearly all studies have been, in order of importance, the ichneumonid *Campoplex frustranae* Cushman, the tachinid *Lixophaga mediocris* Aldrich, and the eurytomid *Eurytoma pini* Bugbee (see Van Driesche et al. 1996 for details on natural enemies of this moth). Introduction of *C. frustranae* to California greatly reduced the density of the invasive population of this species found in that area.

Web Links for Information on Nantucket Pine Tip Moth

http://edis.ifas.ufl.edu/in581; a fact sheet of the University of Florida on biology and control.

http://na.fs.fed.us/spfo/pubs/fidls/nantucket/nantucket.htm; USDA Forest Service leaflet on biology and control.

Articles on Nantucket Pine Tip Moth

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations*. FHTET 96-19, December 1996, USDA Forest Service, Morgantown, WV (see http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

McCravy, K.W. and C.W. Berisford. 2001. Effects of vegetation control on parasitoids of the Nantucket pine tip moth, *Rhyacionia frustrana* (Lepidoptera: Tortricidae). *Florida Entomologist* 84: 282-287.

DeBarr, G.L., J.W. Brewer, R.S. Cameron, and C.W. Berisford. 2002. Nantucket pine tip moth, *Rhyacionia frustrana*, lures and traps: what is the optimum combination? The Nantucket pine tip moth: old problems, new research. Proceedings of an Informal Conference, The Entomological Society of America, Annual Meeting, Atlanta, Georgia, USA, 12-16 December 1999. In: Berisford, C.W. and D.M. Grosman (eds.). General Technical Report SRS-51, Southern Research Station, USDA Forest Service, Ashville, North Carolina: 56-68.

133. Pitch Pine Tip Moth, *Rhyacionia rigidana* (Fernald) (Lepidoptera: Tortricidae)

Orientation to Pest

Pitch pine tip moth, *Rhyacionia rigidana* (Fernald), is a member of a group of very similar moths, and it resembles Nantucket pine tip moth, *R. frustrana* (Fernald), in appearance and biology. But unlike *R. frustrana*, this moth can attack and kill large pitch pines (*Pinus rigida* Mill.). Besides pitch pines, this native North American tortricid attacks several other native or introduced pines. The feeding of pitch pine tip moth larvae kills branches or leaders, and may kill the entire tree. There are three generations per year in the southern United States, but only one in the north.

Hosts Commonly Attacked

In North America, this moth attacks several native or exotic pines, including pitch (*P. rigida*), Corsican (*P. nigra* J. F. Arnold), Virginia (*P. virginiana* Mill.), red (*P. resinosa* Sol. ex Aiton), Scotch (*P. sylvestris* L.), loblolly (*P. taeda* L.), and slash (*P. elliottii* Engelm.) pines.

Distribution

This moth is found from Georgia to Texas, north to Missouri, New York, and Maine.

Image of Pitch Pine Tip Moth

Figure 1. Adult of pitch pine tip moth, *Rhyacionia rigidana*. (Jim Vargo)

Important Biological Control Agents Related to this Pest Species

Little to no information is available on the natural enemies of this species, apart from some parasitoids reported from this species in Missouri (Kearby and Taylor, 1975).

Web Links for Information on Pitch Pine Tip Moth

None

Articles

Berisford, C.W. 1974. Species isolation mechanisms in *Rhyacionia frustrana* and *R. rigidana*. *Annals of the Entomological Society of America* 67: 292-294.

Kearby, W.H. and B. Taylor. 1975. Larval and pupal parasites reared from tip moths of the genus *Rhyacionia* in Missouri (Lepidoptera: Olethreutidae). *Journal of the Kansas Entomological Society* 48: 206-211.

Gargiullo, P.M. and C.W. Berisford 1983. Life tables for the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), and the pitch pine tip moth, *Rhyacionia rigidana* (Fernald) (Lepidoptera: Tortricidae). *Environmental Entomology* 12: 1391-1402.

134. Southwestern Pine Tip Moth, *Rhyacionia neomexicana* (Dyar) (Lepidoptera: Tortricidae)

Orientation to Pest

The southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar), is a native North American tip moth that distorts and kills terminals of young ponderosa pine (*Pinus ponderosa* Douglas ex Lawson) in Arizona, New Mexico, Colorado, the Dakotas, and Nebraska. Moths fly in spring laying eggs as new needles emerge. Eggs hatch in 2-3 weeks, and small larvae feed inside needles. Later, larvae feed inside needle sheaths or buds and eventually the large larvae hollow out growing shoots. Larval feeding under the bark of new shoots produces girdling wounds that cause shoots to turn brown and become crooked. Mature larvae leave the tips during summer and spin cocoons, usually in the bark crevices on the base of the tree below the litter, where they pupate and overwinter. There is one generation per year. Heavy infestation for consecutive years may retard growth, leaving trees short and bushy. Trees are affected in both plantations and natural forests. Injury is most severe where trees are planted on poor sites.

Hosts Commonly Attacked

In North America, this moth attacks ponderosa (*P. ponderosa*), Austrian (*P. nigra* J. F. Arnold), Mugo (*P. mugo* Turra), Scots *(P. sylvestris* L.), and foxtail (*P. balfouriana* Balf.) pines.

Distribution

This moth occurs in the United States in Arizona, New Mexico, Utah, Colorado, the Dakotas, Montana, and Nebraska.

Image of Southwestern Pine Tip Moth

Figure 1. Adult of southwestern pine tip moth, *Rhyacionia neomexicana*. (Jim Vargo)

Important Biological Control Agents Related to this Pest Species

Little to no information is available on the natural enemies of this species.

Web Links for Information on Southwestern Pine Tip Moth

http://wiki.bugwood.org/HPIPM:Rhyacionia_neomexicana; Bugwood Wiki fact sheet on biology and control.

http://www.ext.colostate.edu/pubs/insect/05529.html; Colorado State University fact sheet, which compares this species to related tip moths.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_026053.pdf; USDA Forest Service pest leaflet that includes a distribution map for the species.

Articles

Jennings, D.T. 1975. Life history and habits of the southwestern pine tip moth, *Rhyacionia neomexicana* (Dyar) (Lepidoptera: Olethreutidae). *Annals of the Entomological Society of America* 68: 597-606.

Stevens, R.E. and D.T. Jennings. 1977. Western pine-shoot borer: a threat to intensive management of ponderosa pine in the Rocky Mountain area and Southwest. USDA Forest Service, General Technical Report, Rocky Mountain Forest and Range Experiment Station, RM-45.

Wagner, M.R. and Z. Chen. 2004. Long-term benefits to the growth of ponderosa pines from controlling southwestern pine tip moth (Lepidoptera: Tortricidae) and weeds. *Journal of Economic Entomology* 97: 1972-1977.

135. Eastern Pine Shoot Borer, *Eucosma gloriola* Heinrich (Lepidoptera: Tortricidae)

Orientation to Pest

Eastern shoot borer, *Eucosma gloriola* Heinrich, is a tortricid moth, native to North America, whose larvae attack shoots of various native or introduced pines. Larvae tunnel in new shoots, killing them. The shape of the tree's main trunk becomes deformed when the terminal leader is killed. This moth is more common in plantations and artificially reforested areas than in native forests. In plantations, 7-41 percent of shoots and up to 10 percent of terminal leaders may be infested.

Hosts Commonly Attacked

In North America, this moth attacks various native or introduced pines, including eastern white (*Pinus strobus* L.), jack (*P. banksiana* Lamb.), red (*P. resinosa* Sol. ex Aiton), Austrian (*P. nigra* J. F. Arnold), mugo (*P. mugo* Turra), and Scots (*P. sylvestris* L.) pines.

Distribution

In North America, this moth is found from the northeastern United States west to the Great Lakes states, as well as in southern Canada.

Images of Eastern Pine Shoot Borer

Figure 1. Adult of eastern pine shoot borer, *Eucosma gloriola*. (Tom Murray)

Figure 2. Larva of eastern pine shoot borer. (Louis Wilson, USDA Forest Service)

Figure 3. Exit hole in leader of mature larvae of eastern pine shoot borer. (Louis Wilson, USDA Forest Service)

Images of Eastern Pine Shoot Borer (continued)

Figure 4. Dead leader (seen as short stub at base of top whorl of branches) caused by eastern pine shoot borer. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Figure 5. Deformity of main trunk of pine caused by eastern pine shoot borer. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Five species of natural enemies of this borer have been recorded in surveys in Pennsylvania, New York, Ontario, and Manitoba: *Glypta* sp., *Rhorus* sp. (both ichneumonids), *Bracon rhyacioniae* (Muesebeck) (Braconidae), *Elachertus cidariae* Ashmead (Eulophidae), and *Habrocytus* sp. (Pteromalidae). Of these, *Glypta* sp. (perhaps *Glypta eucosmae* Walley and Baron) may be the most important. Why this insect, which causes little damage in forests, becomes damaging in plantations is not understood.

Web Links for Information on Eastern Pine Shoot Borer

http://www.na.fs.fed.us/spfo/pubs/fidls/eps_borer/eps_borer.htm; USDA Forest Service, Forest Insect and Disease Leaflet 134, covering biology and control.

http://ento.psu.edu/extension/christmas-trees/information/pest-fact-sheets/eastern-pine-shoot-borer-eucosma-gloriola-heinric; fact sheet of Pennsylvania State University of biology and control.

Articles

Drooz, A.T. 1960. White pine shoot borer (*Eucosma gloriola* Heinrich). *Journal of Economic Entomology* 53: 248-251.

Newman, J.H. 1968. First records of the white pine shoot borer, *Eucosma gloriola* (Lepidoptera: Olethreutidae), in Michigan. *Michigan Entomologist* 1: 267-270.

Wong, H.R. and A.E. Campbell. 1967. The larval feeding habits of the eastern pine-shoot borer, *Eucosma gloriola* Heinrich (Lepidoptera: Tortricidae), in jack pine regeneration in Michigan. *Manitoba Entomologist* 1: 42-46.

DeBoo, R.F., W.L. Sippell, and H.R. Wong. 1971. The eastern pine-shoot borer, *Eucosma gloriola* (Lepidoptera: Tortricidae), in North America. *The Canadian Entomologist* 103: 1473-1486.

136. Lodgepole Cone Moth, *Eucosma rescissoriana* Heinrich (Lepidoptera: Tortricidae)

Orientation to Pest

The lodgepole cone moth, *Eucosma rescissoriana* Heinrich, is found in northwestern North America south to central California. It is highly destructive to cones and seeds of western white pine (*Pinus monticola* Douglas). In British Columbia, adults emerge in May, and oviposition occurs in early June; in Idaho, oviposition is in June. Eggs are laid under scale tips of second-year cones. Larvae burrow in cones of host plants, consuming the seeds. Pupae overwinter, presumably, in the duff. There is one generation per year. While a pest in seed orchards in North America, it is considered to be a potential biological control agent of *P. monticola* in New Zealand, where this pine is invasive outside of plantations.

Hosts Commonly Attacked

In North America, this moth attacks western white pine (*P. monticola*).

Distribution

This moth occurs in North America from British Columbia and western Alberta south as far as central California and New Mexico.

Images of Lodgepole Cone Moth

Figure 1. Adult of lodgepole cone moth, *Eucosma rescissoriana*. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 2. Eggs of lodgepole cone moth on cone scale. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Images of Lodgepole Cone Moth (continued)

Figure 3. Larvae of lodgepole cone moth hatching from eggs on cone scale. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 4. Larvae of lodgepole cone moth inside cone. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 5. Appearance of early stage of damage to cone of western white pine by lodgepole cone moth. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Images of Lodgepole Cone Moth (continued)

Figure 6. Internal feeding and damage to cone of western white pine caused by lodgepole cone moth. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Twelve species of parasitic insects were found to be associated with *E. rescissoriana* in western white pine cones in northern Idaho, of which the three most abundant species were *Pimplopterus* n. sp. (Ichneumonidae), *Chelonus petrovae* McComb (Braconidae), and *Apanteles starki* Mason (Braconidae). Total parasitism ranged from 9.4 to 40.9 percent in a seed-production area over three years.

Web Links for Information on Lodgepole Cone Moth

None

Articles

Ollieu, M.M. and J.A. Schenk. 1966. The biology of *Eucosma rescissoriana* Heinrich in western white pine in Idaho (Lepidoptera: Olethreutidae). *The Canadian Entomologist* 98: 268-274.

Goyer, R.A. and J.A. Schenk. 1969. Parasitism of the cone moth *Eucosma rescissoriana* (Lepidoptera: Olethreutidae) in northern Idaho. *The Canadian Entomologist* 101: 1063-1069.

Brockerfoff, E.G. and M. Kay. 1998. Prospects and risks of biological control of wilding *Pinus contorta* in New Zealand. Proceedings of the 51st New Zealand Plant Protection Conference: 216-223.

137. Western Pine Shoot Borer, *Eucosma sonomana* Kearfott (Lepidoptera: Tortricidae)

Orientation to Pest

The western pine shoot borer, *Eucosma sonomana* Kearfott, is a significant pest of ponderosa (*Pinus ponderosa* Douglas ex C. Lawson) and lodgepole (*P. contorta* Douglas ex Louden) pines in many parts of the western North America, and is especially damaging to young, open-grown trees. Larvae bore in terminal shoots, feeding exclusively in the pith. As a result, they stunt the growth but rarely kill the terminals. Larvae leave shoots in late spring, drop to the ground, and pupate. Repeated attacks lead to shorter trees and may cause up to a 20 percent loss in volume growth over a rotation.

Hosts Commonly Attacked

In North America, this moth attacks ponderosa (*P. ponderosa*) and lodgepole (*P. contorta*) pines.

Distribution

In North America, this moth occurs is recorded from Arizona, New Mexico, Wyoming, Colorado, Utah, South Dakota, Montana, Idaho, California, Oregon, Washington, and British Columbia (see map in Sartwell et al., 1980).

Images of Western Pine Shoot Borer

Figure 1. Adult of western pine shoot borer, *Eucosma sonomana*. (Scott Tunnock, USDA Forest Service, Bugwood.org)

Figure 2. Larva of western pine shoot borer in leader. (Darrell Ross, Oregon State University, Bugwood.org)

Images of Western Pine Shoot Borer (continued)

Figure 3. Tunnels of western pine shoot borer in lodgepole pine. (Left: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org; right: Darrell Ross, Oregon State University, Bugwood.org)

Figure 4. Terminal of pine damaged by western pine shoot moth. (Darrell Ross, Oregon State University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information was available on natural enemies of this species.

Web Links for Information on Western Pine Shoot Borer

None

Articles

Stevens, R.E. and D.T. Jennings. 1977. Western pine shoot borer: A threat to intensive management of ponderosa pine in the Rocky Mountain area and southwest. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, General Technical Report RM-45: 8 p.

Sartwell, C., G.E. Daterman, T.W. Koerber, R.E. Stevens, and L.L. Sower. 1980. Distribution and hosts of *Eucosoma sonomana* in the western United States as determined by trapping with synthetic sex attractants. *Annals of the Entomological Society of America* 73: 254-256.

138. Douglas-fir Cone Moth, *Barbara colfaxiana* (Kearfott) (Lepidoptera: Tortricidae)

Orientation to Pest

The Douglas-fir cone moth, *Barbara colfaxiana* (Kearfott), is found in western North America from California to British Columbia, east to Montana, and Colorado. Adults emerge in the spring and lay their eggs on young cones. Young larvae feed largely on cone scales, but older larvae consume developing seeds. Pupae overwinter in papery, resin-coated cocoons in center of cones. Pupae may remain in diapause for as long as 3 years. Damage occurs on Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and true firs (*Abies*) and is greatest at inland (non-coastal) sites, where summers are hotter and drier. One larva can destroy 60 percent of the seeds in a cone, while three larvae will likely destroy all of the seeds. There is one generation per year. Pheromone traps using the pheromone of *Contarinia oregonensis* Foote, can be used to monitor the pest.

Hosts Commonly Attacked

In North America, this moth attacks Douglas-fir (*P. menziesii*) and various true firs (*Abies*).

Distribution

In North America, this moth occurs is recorded from California to British Columbia, east to Montana, and Colorado.

Images of Douglas-fir Cone Moth

Figure 1. Adults of Douglas-fir cone moth, *Barbara colfaxiana*. (D. Manastyrski, Bugwood.org)

Figure 2. Larva of Douglas-fir cone moth. (Julie Brooks, Bugwood.org)

Images of Douglas-fir Cone Moth (continued)

Figure 3. Pupa of Douglas-fir cone moth. (D. Manastyrski, Bugwood.org)

Figure 4. Douglas-fir cone moth, *Barbara colfaxiana*, caught in trap baited with pheromone of *Contarinia oregonensis*. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The ichneumonid *Glypta evetriae* Cushman is reported as a parasitoid of this species.

Web Links for Information on Douglas-fir Cone Moth

http://www.forestry.ubc.ca/fetch21/FRST308/lab2/barbara_colfaxiana/conemoth.html; fact sheet of the University of British Columbia.

http://www.fgcouncil.bc.ca/PM-Factsheet08-Barbara-colfaxiana.pdf; fact sheet on control of Douglas-fir cone moth.

Articles

Clark, E.C., J.A. Schenk, and D.L. Williamson. 1963. The cone-infesting moth *Barbara colfaxiana* as a pest of Douglas-fir in northern Idaho. *Annals of the Entomological Society of America* 56: 246-250.

Hedlin, A.F. 1974. Cone and seed insects of British Columbia. Canadian Forestry Service, Pacific Forestry Research Centre, Victoria, BC. BC-X-90: 63 p.

Nebeker, T.E. 1977. A partial life table for the Douglas-fir cone moth, *Barbara colfaxiana* (Lepidoptera: Olethreutidae). *The Canadian Entomologist* 109: 943-951.

Articles on Douglas-fir Cone Moth (continued)

Sweeney, J.D. and G.E. Miller. 1989. Distribution of *Barbara colfaxiana* (Kearfott) (Lepidoptera: Tortricidae) eggs within and among Douglas-fir crowns and methods for estimating egg densities. *The Canadian Entomologist* 121: 569-578.

Koerber, T.W. and G.P. Markin. 1984. Metasystox-R® injections increase seed yield of Douglas-fir in California, Oregon, and Washington. In: Yates, H.O., III (ed.). *Proceedings of the Cone and Seed Insects Working Party Conference*. Asheville, North Carolina, Southeastern Forest Experiment Station: 137-146.

139. Pine Webworm, *Pococera robustella* (Zeller) (Lepidoptera: Pyralidae)

Orientation to Pest

Pine webworm, *Pococera robustella* (Zeller), is a native North American moth. Females lay groups of one to 10 overlapping eggs on host needles. Young larvae are pine needle miners, but older larvae feed externally, building webs around groups of needles. Larvae leave the nest to clip needles, which they bring back into the nest to consume. Mature larvae move to the ground and spin cocoons in which they pupate. Several species of pines are attacked. In southern slash pine (*Pinus elliottii* Engleman) plantations, damage occurs mainly in the first year after planting. In northern parts of the United States, damage occurs in jack (*P. banksiana* Lamb.) and red pine (*P. resinosa* Sol. ex Aiton) plantations, but is mostly of concern to Christmas tree growers due to the unsightliness of the webs. There are one (in the north) to three (in the south) generations per year.

Hosts Commonly Attacked

In North America, this moth attacks many pine species but is most common on slash (*P. elliottii*), red (*P. resinosa*) and jack (*P. banksiana*) pines.

Distribution

This moth occurs in southern Canada and throughout most of the eastern United States.

Images of Pine Webworm

Figure 1. Adult pine webworm, *Pococera robustella*. (Natasha Wright, Florida Department of Agriculture and Consumer Services, Bugwood.org

Figure 2. Larva of pine webworm. (Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Images of Pine Webworm (continued)

Figure 3. Feeding web of larvae of pine webworm. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Figure 4. Damage to a young pine seedling caused by pine webworm. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The ichneumonid *Syzeuctus elegans* (Cresson) is a common parasitoid of this species. Other natural enemies include other parasitic wasps, parasitic flies, predatory insects and birds.

Web Links for Information on Pine Webworm

http://entnemdept.ufl.edu/creatures/trees/moths/pine_webworm.htm; fact sheet of the University of Florida, covering biology and control.

http://wiki.bugwood.org/Pococera_robustella; fact sheet of Bugwood wiki covering biology and control.

http://www.freshfromflorida.com/pi/enpp/ento/entcirc/ent419.pdf; fact sheet of Florida Department of Agriculture and Consumer Services, Division of Plant Industry.

Articles

Hertel, G.D. and D.M. Benjamin. 1979. Biology of the pine webworm in Florida slash pine plantations. *Annals of the Entomological Society of America* 72: 816-819.

Wallesz, D.P. and D.M. Benjamin. 1960. The biology of the pine webworm, *Tetralopha robustella*, in Wisconsin. *Journal of Economic Entomology* 53: 587-589.

140. Zimmerman Pine Moth, *Dioryctria zimmermani* (Grote) (Lepidoptera: Pyralidae)

Orientation to Pest

Zimmerman pine moth, *Dioryctria zimmermani* (Grote), is one member of a group of closely related native North American species that have been poorly distinguished and still await further clarification in some cases. Names in the older literature may be unreliable. Adults of *D. zimmermani* emerge in mid-summer and lay their eggs in various places on the tree trunk or buds. Upon hatching, larvae immediately settle into bark crevices and overwinter in hibernacula. Larvae resume feeding the following spring by tunneling into newly formed terminals or lateral shoots, which become hooked and discolored. Larvae feed on the cambial layer and outer xylem of all common pine species. Feeding sites are distinguished by large masses of accumulated frass and pitch. When mature, larvae leave the terminals and tunnel into the whorl, girdling tips or branches. Pupation takes place in the pitch masses associated with larval feeding.

Hosts Commonly Attacked

In North America, this moth attacks most common pines, but damage is principally important in Christmas tree plantations of Scotch (*Pinus syvestris* L.), red (*P. resinosa* Sol. ex Aiton), and Austrian (*P. nigra* J. F. Arnold) pines in the north central United States and southeastern Canada.

Distribution

In North America, this moth occurs in southeastern Canada and the northeastern United States, as far west as Minnesota.

Images of Zimmerman Pine Moth

Figure 1. Adult of Zimmerman pine moth, *Dioryctria zimmermani*. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Zimmerman Pine Moth (continued)

Figure 2. Larva of Zimmerman pine moth. (Phil Pellitteri, University of Wisconsin, Entomology Dept, Bugwood.org)

Figure 3. Feeding of Zimmerman pine moth larvae results in pitch accumulations on the bark, usually near the branch nodes. (Left: Rayanne Lehman, Pennsylvania Department of Agriculture, Bugwood.org; right: Whitney Cranshaw, Colorado State University, Bugwood.org)

Figure 4. Pupal skin of Zimmerman pine moth inside pitch mass (opened). (Phil Pellitteri, University of Wisconsin, Entomology Dept, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Various parasitoids are listed in the literature as attacking this species. But many of these studies predate the clarification of species boundaries in this group and so it is unclear exactly which species these records refer to. Regardless, total parasitism in most studies did not exceed 5 percent.

Web Links for Information on Zimmerman Pine Moth

http://greenindustry.uwex.edu/problemdetails.cfm?problemid=99; fact sheet of the University of Wisconsin on recognition and control.

http://ento.psu.edu/extension/christmas-trees/information/pest-fact-sheets/zimmerman-pine-moth; fact sheet of Pennsylvania State University on biology and control.

http://extension.psu.edu/ipm/program/christmas-tree/pest-fact-sheets/stem-and-root-injury/zimmerman.pdf; fact sheet of Pennsylvania State University on biology and control.

Articles

Yonker, J.W. and D.L. Schuder. 1980. The biology of the Zimmerman pine moth (*Dioryctria zimmermani*) in Indiana landscapes with reference to its control. *Proceedings of the Indiana Academy of Science* 89: 207-208.

Mutuura, A. 1982. American species of *Dioryctria* (Lepidoptera: Pyralidae). VI. A new species of *Dioryctria* from eastern Canada and north-eastern United States. *The Canadian Entomologist* 114: 1069-1076.

141. Fall Cankerworm, *Alsophila pometaria* (Harris) (Lepidoptera: Geometridae)

Orientation to Pest

Fall cankerworm, *Alsophila pometaria* (Harris), is a native moth capable of defoliating many hardwood species. The species overwinters as eggs, which hatch in early spring to coincide with bud break. Young "inchworm" larvae skeletonize new leaves, while older larvae consume all but the larger veins or midrib. By midsummer, mature larvae crawl down or drop on silk threads to the soil where they pupate in the soil. Adults emerge in early winter (November or early December) after initial frosts to mate. The wingless females climb tree trunks and deposit their eggs in rows in a single layer on smaller branches or trunk. There is one generation per year. In some areas fall cankerworm periodically goes into outbreak, causing widespread damage. Damage results from complete or partial defoliation of forest or urban trees.

Hosts Commonly Attacked

In North America, larvae of this defoliating moth attack a wide range of hardwoods and shrubs, including elm (*Ulmus*), maple (*Acer*), ash (*Fraxinus*), oak (*Quercus*), apple (*Malus domestica* Borkh.), hickory (*Carya tomentosa* [Poir.] Nutt.), dogwood (*Cornus*), and many others.

Distribution

This moth has a wide distribution in southeastern Canada and the eastern United States, west to Alberta, Montana, and Missouri, and south to North Carolina.

Images of Fall Cankerworm

Figure 1. Adults of fall cankerworm, *Alsophila pometaria*; top, wingless female; bottom, male. (Top: James B. Hanson, USDA Forest Service, Bugwood.org; bottom: USDA Forest Service - Region 8 - Southern Archive, USDA Forest Service, Bugwood.org)

Images of Fall Cankerworm (continued)

Figure 2. Egg mass of fall cankerworm. Note straight rows of eggs in single layer. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Figure 3. Larvae of fall cankerworm; top, young larva; bottom, mature larvae. (Top: A. Steven Munson, USDA Forest Service, Bugwood.org; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Images of Fall Cankerworm (continued)

Figure 4. Feeding of fall cankerworm. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 5. Defoliation of hardwoods by fall cankerworms. (James B. Hanson, USDA Forest Service, Bugwood.org)

Figure 6. Sticky bands on shade trees to trap fall cankerworm females. (G. Keith Douce, University of Georgia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Relatively few parasitoids have been recorded attacking this species. Among these are the braconid *Meteorus autographae* Muesbeck and the scelionid egg parasitoid *Telenomus alsophilae* Viereck. The latter is believed to be the most important parasitoid affecting this species, killing 15-20 percent of the eggs. A nuclear polyhedrosis virus is also associated with this species and some strains of *Bacillus thuringiensis* Berliner are effective against it.

Web Links for Information on Fall Cankerworm

http://ento.psu.edu/extension/factsheets/fall-cankerworm; fact sheet of Pennsylvania State University on biology and control.

http://www.maine.gov/doc/mfs/fallcank.htm; fact sheet of the Maine Department of Conservation on biology and control.

http://www.umassgreeninfo.org/fact_sheets/defoliators/cankerworm.html; Extension fact sheet from the University of Massachusetts.

http://ohioline.osu.edu/hyg-fact/2000/2558.html; Extension fact sheet of the Ohio State University comparing spring and fall cankerworms.

Articles

Fedde, G.F. 1980. Spring parasitism of fall cankerworm eggs in northern Georgia by *Telenomus alsophilae* (Hymenoptera: Scelionidae). *Journal of the Georgia Entomological Society* 15: 199-206.

Miller, F., K. Malmquist, and G. Ware. 2001. Evaluation of Asian, European, and North American elm (*Ulmus* spp.) biotypes to feeding by spring and fall cankerworms. *Journal of Environmental Horticulture* 19: 216-221.

LaFrance, K.R. and A.R. Westwood. 2006. An assessment of tree banding techniques to capture cankerworm defoliators of elm and ash trees in Winnipeg, Manitoba, Canada. *Arboriculture and Urban Forestry* 32: 10-17.

142. Spring Cankerworm, *Paleacrita vernata* (Peck) (Lepidoptera: Geometridae)

Orientation to Pest

Spring cankerworm, *Paleacrita vernata* (Peck), is a native North American moth that defoliates many hardwood species and in some locations goes into periodic outbreaks. Damage is caused by young "inchworm" larvae skeletonizing new leaves and older larvae consuming all but the larger veins or midrib. This species may be confused with the very similar fall cankerworm, *Alsophila pometaria* (Harris). Adults emerge from pupal cells in the soil in early spring when the ground is thawed. Females crawl up tree trunks to lay eggs, which are deposited in loose clusters of 100 or more in bark crevices or under bark scales. Eggs hatch in early spring and larvae feed on leaves through the end of spring. Mature larvae drop to the soil on silk threads in summer. Larvae remain dormant within their soil-covered pupal cells throughout the rest of the summer and fall, pupating in late fall or early spring. There is one generation per year.

Hosts Commonly Attacked

In North America, larvae of this moth feed on many hardwood species, including elm (*Ulmus*), green ash (*Fraxinus pennsylvanica* Marsh.), maple (*Acer*), bur oak (*Quercus macrocarpa* Michx.), linden/basswood (*Tilia*), silver birch (*Betula pendula* Roth), and apple (*Malus domestica* Borkh.).

Distribution

This geometrid is found in southeastern Canada, as well as throughout the northeastern and north central United States, and west to parts of Texas, Colorado, and California.

Images of Spring Cankerworm

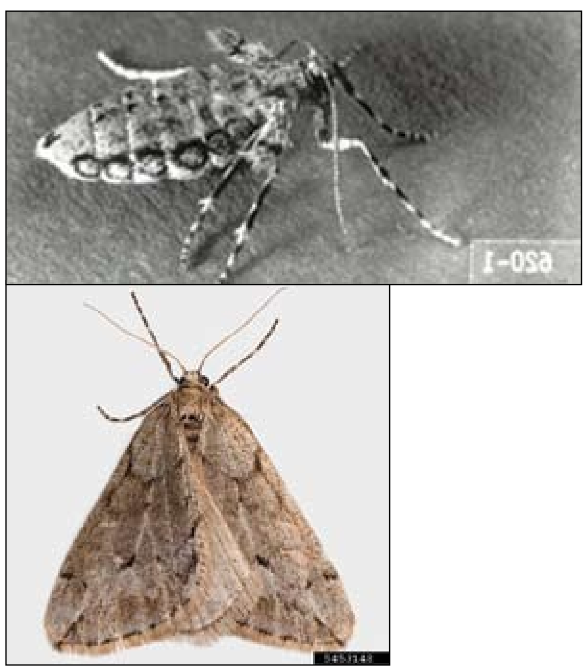


Figure 1. Adults of spring cankerworm, *Paleacrita vernata*; top, wingless female; bottom, male. (Top: Mark Ascerno, University of Minnesota, University of Minnesota • Extension; bottom: Nolie Schneider, Bugwood.org)

Images of Spring Cankerworm (continued)

Figure 2. Larvae of spring cankerworm. (Top: James B. Hanson, USDA Forest Service, Bugwood.org; bottom: USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 3. Tree trunk with band trap to catch female spring cankerworms as they crawl up trees. (William A. Carothers, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Several species of parasitoids are known from spring cankerworm, including three braconids, *Rogas geometrae* Ashmead, *Apanteles paleacritae* Riley, and *Meteorus hyphantriae* Riley. It is also attacked by the ichneumonids *Phobcampe geometrae* (Ashmead) and *Hyposoter fuscitarsis* (Vierieck). *Bacillus thuringiensis* Berliner is bacterium that has been formulated as a biopesticide that can be used to control larvae of this species.

Web Links for Information on Spring Cankerworm

http://ohioline.osu.edu/hyg-fact/2000/2558.html; Extension fact sheet of the Ohio State University comparing spring and fall cankerworms.

http://www.extension.umn.edu/distribution/horticulture/dg0876.html; fact sheet of University of Minnesota extension service comparing spring and fall cankerworms.

http://insects.tamu.edu/fieldguide/cimg293.html; fact sheet of the Texas A&M University on biology and control.

http://entomology.unl.edu/ornamentals/pestprofiles/scankerworm.shtml; fact sheet of the University of Nebraska on biology and control.

Articles

Frye, R.D., D.K. McBride, D.R. Carey, T.L. Elichuk, and R.L. Dregseth. 1977. Cankerworm control in shelterbelts. *North Dakota Farm Research* 34(6): 3-7.

LaFrance, K.R. and A.R. Westwood. 2006. An assessment of tree banding techniques to capture cankerworm defoliators of elm and ash trees in Winnipeg, Manitoba, Canada. *Arboriculture and Urban Forestry* 32: 10-17.

143. Eastern Hemlock Looper, *Lambdina fiscellaria fiscellaria* Guenée (Lepidoptera: Geometridae)

Orientation to Pest

Eastern hemlock looper, *Lambdina fiscellaria fiscellaria* Guenée, is a native North American geometrid whose larvae defoliate eastern hemlock (*Tsuga canadensis* [L.] Carrière), balsam fir (*Abies balsamea* [L.] Mill.) and white spruce (*Picea glauca* [Moench] Voss). It is found in Canada from Newfoundland to Alberta and in the United States it occurs widely within the range of eastern hemlock. Adults fly in late summer or fall and lay eggs singly or in small groups on bark, or associated moss and lichens. Winter is spent in the egg stage and larvae begin to feed in the late spring on newly opened clusters of needles. Older larvae also feed on old needles. Some attacked needles are chewed but not severed and remain attached, giving the tree a brown appearance. Pupation usually takes place on the bark. Repeated periodic outbreaks have occurred over wide areas in eastern Canada and the northeast and north central United States, especially Newfoundland, Wisconsin, and Michigan.

Hosts Commonly Attacked

This moth feeds mainly on eastern hemlock (*T. canadensis*) (especially in the more southerly parts of it range) but in the north also feeds on balsam fir (*A. balsamea*) and white spruce (*P. glauca*). During outbreaks it sometimes feeds on other conifers and even some hardwoods.

Distribution

This geometrid is found in Canada from Newfoundland to Alberta, and in the United States it occurs widely within the range of eastern hemlock.

Images of Eastern Hemlock Looper

Figure 1. Adult of eastern hemlock looper, *Lambdina fiscellaria fiscellaria*. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 2. Eggs of eastern hemlock looper. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Eastern Hemlock Looper (continued)

Figure 3. Larva of eastern hemlock looper. (Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Figure 4. Defoliation from eastern hemlock looper in Michigan. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Because outbreaks occur of this species defoliator, its natural enemies have been studied on various occasions. Before 1950, the most common parasitoid attacking it was the braconid larval parasitoid *Apanteles* sp. nr. *flavovariatus* Muesbeck. But subsequently a parasitic tachinid, *Winthemia occidentis* Reinhard, associated with another hemlock looper in western North America, was introduced and is now the dominant parasitoid of eastern hemlock looper. Pupal parasitism, while reaching up to 30 percent or more, is due to a collection of polyphagous parasitoids.

Web Links for Information on Eastern Hemlock Looper

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=8846; fact sheet of Natural Resources Canada on phenology and extent of damage in Canada.

http://www.glfc.forestry.ca/VLF/ForumPresentations/heberthemlocklooper_08e.pdf; detailed history of outbreaks in Canada.

Articles

MacLean, D.A. and E. Paul Ebe. 1999. The impact of hemlock looper (*Lambdina fiscellaria fiscellaria* [Guen.]) on balsam fir and spruce in New Brunswick, Canada. *Forest Ecology and Management* 120: 77-87

Hartling, L.K., N. Carter, and J. Proude. 1999. Spring parasitism of overwintered eggs of *Lambdina fiscellaria fiscellaria* (Lepidoptera: Geometridae) by *Telenomus* near *alsophilae* (Hymenoptera: Scelionidae). *The Canadian Entomologist* 131: 421-422.

VanFrankenhuyzen, K., R.J. West, and M. Kenis. 2001. *Lambdina fiscellaria fiscellaria* (Guenée), hemlock looper (Lepidoptera: Geometridae). In: Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000.* CABI Publishing, Wallingford, UK: 141-144.

Iqbal, J., D.A. MacLean, and J.A. Kershaw, Jr. 2011. Impacts of hemlock looper defoliation on growth and survival of balsam fir, black spruce and white birch in Newfoundland, Canada. *Forest Ecology and Management* 261: 1106-1114.

144. Western Hemlock Looper, *Lambdina fiscellaria lugubrosa* (Hulst) (Lepidoptera: Geometridae)

Orientation to Pest

Western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst), is a native North American geometrid whose larvae defoliate western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in coastal areas of Oregon, Washington, and British Columbia. Adults fly in late summer or fall and lay eggs on bark, or associated moss and lichens or even downed logs. Winter is spent in the egg stage and larvae begin to feed in the late spring. Young larvae may feed on understory vegetation of various kinds of trees or shrubs. Initial feeding on hemlock is concentrated in the buds. In summer, older larvae attack old needles, some of which are notched but not severed. These remain attached, giving the tree a brown appearance. Mature larvae spin silk threads and drop to the ground to pupate in the late summer. New moths emerge in fall to lay overwintering eggs. Repeated large outbreaks occurred over wide areas in western North America in the past, damaging large volumes of old growth hemlock. However, since old growth hemlock stands in many areas have been logged, outbreaks have become smaller.

Hosts Commonly Attacked

This moth feeds mainly on western hemlock (*T. heterophylla*), but during outbreaks other conifer species and hardwood shrubs are also attacked.

Distribution

This geometrid is found in western North America in coastal forests of Oregon, Washington, and British Columbia.

Images of Western Hemlock Looper

Figure 1. Adult of western hemlock looper, *Lambdina fiscellaria lugubrosa*. (Jerald E. Dewey, USDA Forest Service, Bugwood.org)

Images of Western Hemlock Looper (continued)

Figure 2. Larva of western hemlock looper. (Jerald E. Dewey, USDA Forest Service, Bugwood.org)

Figure 3. Defoliation of a western hemlock stand by western hemlock looper. (Bruce Hostetler, USDA Forest Service, Bugwood.org)

Images of Western Hemlock Looper (continued)

Figure 4. Defoliation of a western hemlock stand by western hemlock looper. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Pupal parasitoids reported from this species in Alaska included eight ichnuemonids: *Pimpla pedalis* Cresson, *P. aquilonia* Cresson, *P. hesperus* (Townes), *Apechthis ontario* (Cresson), *Itoplectis quadricingulatus* (Prov.), *Masttus laplantei* Mason, *Cratichneumon* sp. (probably *C. ashmeadi* [Schulz]), and *Aoplus velox occidentalis* (Harrington).

Web Links for Information on Western Hemlock Looper

http://www.fs.fed.us/r1-r4/spf/fhp/field_guide/109wsthml.htm; USDA Forest Service fact sheet on recognition and biology of pest.

http://www.fs.fed.us/r1-r4/spf/fhp/mgt_guide/hemlock_looper/page2.html; USDA Forest Service fact sheet on recognition and biology of pest.

http://www.fs.fed.us/r1-r4/spf/fhp/mgt_guide/hemlock_looper/index.html; a USDA Forest Service manual on control of western hemlock looper.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000002; a fact sheet of Natural Resources Canada on biology and phenology of pest.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5191788.pdf; a USDA Forest Service manual on control and management of western hemlock looper.

Articles

Torgersen, T.R. 1971. Parasites of the western hemlock looper, *Lambdina fiscellaria lugubrosa* (Hulst), in southeast Alaska (Lepidoptera: Geometridae). *Pan-Pacific Entomologist* 47: 215-219.

Harris, J.W.E., A.F. Dawson, and R.G. Brown. 1982. The western hemlock looper in British Columbia 1911-1980. Report BC-X-234, Pacific Forest Research Centre, Canada: 18 p.

Mills, N.J. and M. Räther. 1990. Hemlock loopers in Canada; biology, pest status and potential for biological control. *Biocontrol News and Information* 11(3): 209-222.

145. Greenstriped Forest Looper, *Melanolophia imitata* (Walker) (Lepidoptera: Geometridae)

Orientation to Pest

Greenstriped forest looper, *Melanolophia imitata* (Walker), is a native geometrid found in moist conifer forests of western North America. Adults fly in spring and lay eggs singly (up to 80 per female) on tree branches and trunks. Larvae feed on foliage of all ages, but the previous year's foliage is preferred and damage is concentrated in tree crowns. In late summer larvae drop to the ground and pupate in the litter, where they overwinter. There is one generation per year. Larvae are solitary feeders and generally are not economically damaging. However, periodic outbreaks have occurred in Canada (especially British Columbia) that were destructive to western hemlock (*Tsuga heterophylla* [Raf.] Sarg.). Outbreaks in the past have ended abruptly due to natural causes.

Hosts Commonly Attacked

This moth feeds mainly on western hemlock (*T. heterophylla*), Douglas fir (*Pseudotsuga menziesii* [Mirbel] Franco), western redcedar (*Thuja plicata* Donn ex D. Don), true firs (*Abies*), and spruce (*Picea*).

Distribution

This geometrid is found in western North America from Alaska to southern California and, in Canada, eastward to Alberta, in humid areas.

Images of Greenstriped Forest Looper

Figure 1. Adult of greenstriped forest looper, *Melanolophia imitata*. (Marius Aurelian, Bugwood.org)

Images of Greenstriped Forest Looper (continued)

Figure 2. Larva of greenstriped forest looper. (Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Past studies have shown that fungal pathogens such as species of *Cordyceps* and *Entomophthora* cause significant mortality to pupae in the soil.

Web Links for Information on Greenstriped Forest Looper

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000022; fact sheet of Natural Resources Canada on phenology and biology of insect.

http://www.for.gov.bc.ca/hfp/publications/00198/green_striped_forest_looper.htm; short fact sheet of the Ministry of Forests and Range, Province of British Columbia.

http://cfs.nrcan.gc.ca/pubwarehouse/pdfs/3317.pdf; forest pest leaflet on greenstriped forest looper by Pacific Forestry Centre of Natural Resources Canada.

Articles

Evans, D. 1962. Descriptions and life history of *Melanolophia imitata* (Walker) (Lepidoptera: Geometridae). *The Canadian Entomologist* 94: 594-605.

Humphreys, N. 1986. Green-striped forest looper in British Columbia. Canadian Forest Service, Pacific Forestry Centre, FIDS Report No. 86-9: 43 p.

146. Saddleback Looper, *Ectropis crepuscularia* (Denis and Schiffermüller) (Lepidoptera: Geometridae)

Orientation to Pest

Saddleback looper, *Ectropis crepuscularia* (Denis and Schiffermüller), is a native North American looper present across southern Canada, the adjacent tier of U.S. states, and the eastern United States. This species is a generalist, feeding more on conifers in western North American and all of Canada, but on various hardwood species in the eastern United States. Adults fly in spring, when they lay their eggs. Larvae are solitary feeders able to mimic twigs. Young larvae often begin feeding first on groundcover species and understory shrubs. Larvae later move up trees where they complete development. Mature larvae drop to the soil to pupate in the litter, where they overwinter. There at least two generations per year over much of the eastern United States. Larvae of this species are generally economically damaging. Outbreaks in British Columbia and Alaska have occurred.

Hosts Commonly Attacked

In Canada and the western United States, saddleback loopers feed mostly commonly on conifers, including hemlock (*Tsuga*), true firs (*Abies*), spruce (*Picea*), and larch (*Larix*). In the eastern United States, broadleaf trees are the main hosts, including apple (*Malus*), ash (*Fraxinus*), birch (*Betula*), dogwood (*Cornus*), maple (*Acer*), oak (*Quercus*), poplar (*Populus*), walnut (*Juglans*), and willow (*Salix*).

Distribution

This geometrid is found in a band across North America including southern Canada and the adjacent tier of U.S. states. In the eastern United States, it is also found south to Florida.

Images of Saddleback Looper

Figure 1. Adult of saddleback looper, *Ectropis crepuscularia*. (John Davis, Bugwood.org)

Images of Saddleback Looper (continued)

Figure 2. Larva of saddleback looper. (Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information on the natural enemies of this species was found.

Web Links for Information on Saddleback Looper

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=8578; fact sheet of Natural Resources Canada on biology and phenology of species.

Articles

Ferris, R.L. 1993. Saddleback looper. Forest Pest Leaflet No. 23. Pacific Forestry Centre, Canadian Forest Service: 3 p.

147. Spearmarked Black Moth, *Rheumaptera hastata* (L.) (Lepidoptera: Geometridae)

Orientation to Pest

Spearmarked black moth, *Rheumaptera hastata* (L.), is a native North American looper found from North Dakota to British Columbia and Alaska. It feeds mainly on birch (*Betula*). Adults fly in spring. In Alaska, eggs are laid singly or in clusters on tops of leaves, from mid-June to early July. Young larvae feed gregariously between two leaves webbed together to make a sandwich-type shelter. Larvae feed on both new and old-growth foliage and usually feed just on the upper side, skeletonizing leaves. Larvae mature in July and August, drop to the ground on silken threads and pupate in the leaf litter, where they overwinter. There is one generation per year. This moth is a serious defoliator of paper birch (*Betula papyrifera* Marsh.) in interior Alaska. Epidemic populations have occurred at 15- to 17-year intervals, persisted for 2 years, and then collapsed from natural causes.

Hosts Commonly Attacked

This species feeds mainly on mainly on birch (*Betula* spp.). In Alaska, paper birch (*Betula papyrifera* Marsh.) is the preferred host, but larvae also feed on species of alder (*Alnus*), willow (*Salix*), and rose (*Rosa*). In Canada, the insect also feeds on sweetgale (*Myrica*).

Distribution

This geometrid is found throughout Canada and Alaska, and the northern United States, with southerly range extensions along mountain chains (Cascades, Rockies, Appalachians).

Figure 1. North American distribution of spearmarked black moth, *Rheumaptera hastata*. (USDA Forest Service • Forest Insect & Disease Leaflet 156)

Images of Spearmarked Black Moth

Figure 2. Adult of spearmarked black moth. (S. Overby - Swedish Museum of Natural History)

Images of Spearmarked Black Moth (continued)

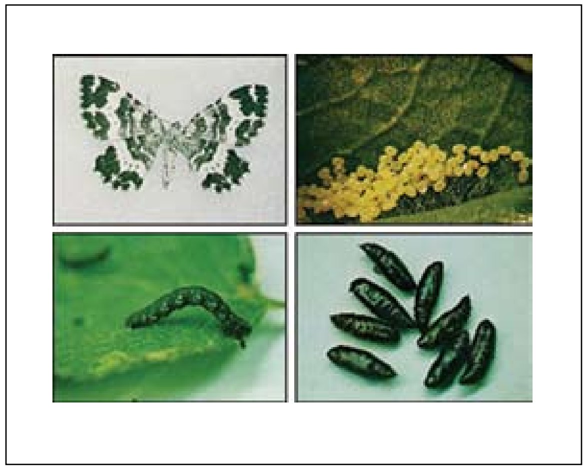


Figure 3. Life stages (adult, eggs, larva, pupae) of spearmarked black moth. (USDA Forest Service • Forest Insect & Disease Leaflet 156)

Figure 4. Larva of spearmarked black moth. (Graham Finch)

Figure 5. Tent made by larva of spearmarked black moth, where it feeds. (Graham Finch)

Figure 5. Birch defoliated by spearmarked black moth. (Peter A. Rush, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Parasitoids that have been reared from the overwintering pupae of this moth include *Aoplus ruficeps vagans* Provancher (Ichneumonidae), *Coccygomimus aquilonius* (Ichneumonidae), and *Cratichneumon* sp. (Ichneumonidae). The parasitoid *Meteorus niveitarsis* Cresson (Braconidae) has been reared from larvae.

Web Links for Information on Spearmarked Black Moth

http://www.na.fs.fed.us/spfo/pubs/fidls/spear/spear.htm; USDA Forest Service fact sheet on biology and pest status in Alaska.

Articles

McGuffin, W.C. 1973. The *Rheumaptera* of North America (Lepidoptera: Geometridae). *The Canadian Entomologist* 105: 383-389.

Werner, R.A. and B.H. Baker. 1977. Spear-marked black moth. Forest Insect & Disease Leaflet 156. Portland, OR. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. Available at http://www.ncrs.fs.fed.us/pubs/viewpub.asp?key=965.

Werner, R.A.1977. Biology and behavior of the spear-marked black moth, *Rheumaptera hastata*, in interior Alaska. *Annals of the Entomological Society of America* 70: 328-336.

148. Elm Spanworm, *Ennomos subsignarius* (Hübner) (Lepidoptera: Geometridae)

Orientation to Pest

Elm spanworm, *Ennomos subsignarius* (Hübner), is a native geometrid moth whose polyphagous larvae feed on many species of hardwood trees, especially hickory (*Carya*), oak (*Quercus*), and ash (*Fraxinus*). It is most important as a forest pest in the Appalachian Mountains, from Pennsylvania south, but an urban forest outbreak has also occurred in St. John's, Newfoundland, and Labrador. This univoltine species overwinters as eggs, which are laid in clusters on the bole and on the underside of branches. Eggs hatch in early spring and young larvae feed on the lower surfaces of leaves, producing "shot-hole" damage. Older larvae consume the whole leaf apart from the major veins. After developing through five instars, larvae pupate in loose silk cocoons formed on the partly eaten foliage and in bark crevices. Outbreaks of this species occur at irregular intervals that defoliate trees over wide areas.

Hosts Commonly Attacked

This species feeds on elm (*Ulmus*), hickory (*Carya*), oak (*Quercus*), maple (*Acer*), beech (*Fagus*), and ash (*Fraxinus*).

Distribution

This geometrid is found in hardwood forests from Newfoundland and Labrador to Saskatchewan in Canada and throughout the eastern United States, west to Michigan, Colorado, and Texas.

Images of Elm Spanworm

Figure 1. Adults of elm spanworm, *Ennomos subsignarius*, mating (left) and laying eggs (right). (Both photos: Heidi Fry, Bugwood.org)

Images of Elm Spanworm (continued)

Figure 2. Egg mass of elm spanworm. (Heidi Fry, Bugwood.org)

Figure 3. Early (left) and late (right) instar larvae of elm spanworm. (Both photos: Heidi Fry, Bugwood.org)

Figure 4. Masses of elm spanworm larvae feeding on host plant during an outbreak. (Bugwood.org)

Figure 5. Pupae of elm spanworm. (Arnold T. Drooz, USDA Forest Service, Bugwood.org)

Images of Elm Spanworm (continued)

Figure 6. Shot hole or tattered damage from feeding of elm spanworms. (Heidi Fry, Bugwood.org)

Figure 7. Trees defoliated by elm spanworm. (Heidi Fry, Bugwood.org)

Figure 8. Defoliation of a forest stand by elm spanworm. (William M. Ciesla, Forest Health Management International, Bugwood.org)

Images of Elm Spanworm (continued)

Figure 9. Adults of the egg parasitoid *Telenomus droozi* emerging from eggs of elm spanworm. (Arnold T. Drooz, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Some of the more important biological control agents affecting this species are the egg parasitoid *Telenomus droozi* Muesebeck and the predatory carabid *Calosoma scrutator* (F.), which eats larvae.

Web Links for Information on Elm Spanworm

http://ento.psu.edu/extension/factsheets/elm-spanworm; fact sheet of Pennsylvania State University on biology and control.

http://www.fs.fed.us/r8/foresthealth/idotis/insects/elmspan.html; short fact sheet of the USDA Forest Service Forest Health Protection Southern Region on biology and control.

Articles

Anderson, J.F. and K.K. Harry. 1976. Parasitoids and diseases of the elm spanworm. *Journal of the New York Entomological Society* 84: 169-177.

Drooz, A.T. 1980. A review of the biology of the elm spanworm (Lepidoptera: Geometridae). *Great Lakes Entomologist* 13: 49-53.

Fry, H.R.C., D.T. Quiring, K.L. Ryall, and P.L. Dixon. 2008. Relationships between elm spanworm, *Ennomos subsignaria*, juvenile density and defoliation on mature sycamore maple in an urban environment. *Forest Ecology and Management* 255: 2726-2732.

Fry, H.R.C., K.L. Ryall, P.L. Dixon, and D.T. Quiring. 2008. Suppression of *Ennomos subsignaria* (Lepidoptera: Geometridae) on *Acer pseudoplatanus* (Aceraceae) in an urban forest with bole-implanted acephate. *Journal of Economic Entomology* 101: 822-828.

149. Winter Moth, *Operophtera brumata* (L.) (Lepidoptera: Geometridae)

Orientation to Pest

Winter moth, *Operophtera brumata* (L.), is a European geometrid that is invasive in North America, in Nova Scotia, part of British Colombia, and, most recently, southern New England. It is a defoliator that is a generalist feeder, attacking a variety of hardwoods. Winter moths overwinter as eggs, which hatch early in spring, and young larvae feed on opening buds and developing leaves. Older larvae feed inside loose leaf rolls and, when mature, drop to the ground, where they pupate late May to early June. Adults emerge in late fall or early winter. Females, which are wingless, climb trees to lay eggs. Persistent defoliation leads to branch death, top kill, and tree death.

Hosts Commonly Attacked

This species is a generalist feeder that attacks are variety of hardwoods, but especially apple (*Malus*), red oak (*Quercus rubra* L.), American elm (*Ulmus americana* L.), red maple (*Acer rubrum* L.), American basswood (*Tilia americana* L.), and hop hornbeam (*Ostrya virginiana* [Mill.] K. Koch).

Distribution

This geometrid is native in Europe, but in North America invasive populations exist in Nova Scotia, the Pacific Northwest (Oregon to British Columbia) and the northeastern United States. Outbreak populations currently exist in eastern Massachusetts and Rhode Island. A survey with pheromone traps by Elkinton et al. (2010) recovered winter moths mainly in coastal areas from Long Island to Maine.

Images of Winter Moth

Figure 1. Adults of winter moth, *Operophtera brumata*; male (top) and wingless female (bottom). (Top: Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org; bottom: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Images of Winter Moth (continued)

Figure 2. Eggs of winter moth. (Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Figure 3. Larvae of winter moth. (Both photos: Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 4. Pupa of winter moth. (Hannes Lemme, Bugwood.org)

Images of Winter Moth (continued)

Figure 5. Feeding of larvae of winter moth. (Hannes Lemme, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

This species has well known natural enemies, having been studied in part of its native range (the UK) and been the target of successful classical biological control programs in both eastern and western Canada. Similar work is now underway in Massachusetts. The natural enemies of most importance are the tachinid parasitoid, *Cyzenis albicans* Fallén, and the ichneumonid *Argypon flaveolatum* (Gravenhorst). The tachinid is the more important.

Web Links for Information on Winter Moth

http://www.umassgreeninfo.org/fact_sheets/defoliators/wm_overview_09.pdf; University of Massachusetts fact sheet.

http://en.wikipedia.org/wiki/Winter_Moth; Wikipedia article.

http://www.youtube.com/watch?v=kVxzOl8zrUE; Youtube video on *Cyzinis albicans* releases in Massachusetts by Joe Elkinton of the University of Massachusetts.

Articles

Ring, R.A. 1988. Pest management of the European winter moth, *Operophtera brumata* (L.), in British Columbia. *Northwest Environmental Journal* 41: 329-330.

Embree, D.G. 1991.The winter moth *Operophtera brumata* in eastern Canada, 1962-1988. *Forest Ecology and Management* 39: 47-54.

Elkinton, J.S., G.H. Boettner, M. Sremac, R. Gwiazowski, R. Hunkins, J. Callahan, S.B. Schuefele, C. Donahue, A.H. Porter, A. Khrimian, B.M. Whited, and N.K. Campbell. 2010. Survey for winter moth (Lepidoptera: Geometridae) in northeastern North America with pheromone-baited traps and hybridization with the native Bruce spanworm. *Annals of the Entomological Society of America* 103: 135-145.

150. Bruce Spanworm, *Operophtera bruceata* (Hulst) (Lepidoptera: Geometridae)

Orientation to Pest

Bruce spanworm, *Operophtera bruceata* (Hulst), is a native geometrid moth in North America that closely resembles winter moth (*Operophtera brumata* [L.]). It is found from coast to coast in Canada and from New England to the Lake States in the United States. Bruce spanworm is a defoliator and a generalist feeder, attacking a variety of hardwoods. Bruce spanworm overwinters as eggs, which hatch early in spring. Larvae either feed openly or in the shelter of leaves that are loosely rolled and webbed together. When mature, larvae drop to the ground, where they pupate. Adults emerge in fall. Females, which are wingless, climb trees to lay eggs in bark crevices or under loose bark. Defoliating outbreaks have been reported.

Hosts Commonly Attacked

This species is a generalist feeder that attacks are variety of hardwoods, but especially sugar maple (*Acer saccharum* Marshall), trembling aspen (*Populus tremuloides* Michx.), willow (*Salix*), and American beech (*Fagus grandifolia* Ehrh.), among others.

Distribution

This geometrid is found from coast to coast in Canada and from New England to the Lake states in the United States.

Images of Bruce Spanworm

Figure 1. Adults of bruce spanworm, *Operophtera bruceata*; male (left) and wingless female (right). (Left: Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org; right: Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Bruce Spanworm (continued)

Figure 2. Egg of bruce spanworm. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 3. Larvae of bruce spanworm. (E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of this species are less well known than are those of the closely related winter moth.

Web Links for Information on Bruce Spanworm

http://www.maine.gov/doc/mfs/brucspan.htm; fact sheet of the state of Maine.

Articles

Elkinton, J.S., G.H. Boettner, M. Sremac, R. Gwiazdowski, R.R. Hunkins, J. Callahan, S.B. Scheufele, C.P. Donahue, A.H. Porter, A. Khrimian, B.M. Whited, and N.K. Campbell. 2010. Survey for winter moth (Lepidoptera: Geometridae) in northeastern North America with pheromone-baited traps and hybridization with the native Bruce spanworm (Lepidoptera: Geometridae). *Annals of the Entomological Society of America* 103: 135-145.

151. Forest Tent Caterpillar, *Malacosoma disstria* Hübner (Lepidoptera: Lasiocampidae)

Orientation to Pest

Forest tent caterpillar, *Malacosoma disstria* Hübner, occurs throughout Canada and the United States and is a generalist defoliator that feeds on a variety of hardwood trees. In the north and west of the United States (and southern Canada), trembling aspen (*Populus tremuloides* Michx.) is preferred. In the southern United States, various gums (*Nyssa* spp. and *Liquidambar styraciflua* L.) and oaks (*Quercus*) are the common hosts. However, during outbreaks, larvae will feed on a wide variety of hardwood species. Winter is passed as eggs, which hatch in spring. Larvae begin feeding on buds and expanding leaves. Older larvae feed on mature leaves. Young larvae feed in groups, but older larvae are dispersed. Larvae lay silk trails, which they follow, but they do not form a silken tent. Rather, they make silk mats on which larvae rest. Mature larvae wander and pupate inside a yellowish-white cocoon fixed to the host tree or other objects. Adults emerge in midsummer (north) or spring (south) and lay their eggs in clusters that encircle twigs of the host tree. Eggs are cemented together and covered with dark colored material called spumaline. There is one generation per year. A number of very large outbreaks, covering thousands of square miles and lasting for several years, have occurred in North America. Tree mortality is generally low, but loss of growth can be considerable (>70 percent) due to effects of defoliation. In the southern United States, in bottomlands, gum trees may die from defoliation. In the northeastern United States, defoliation of sugar maple stands lowers maple syrup yields and quality.

Hosts Commonly Attacked

This species is a generalist defoliator that feeds on a variety of hardwood trees. In the north and west, trembling aspen (*P. tremuloides*) is preferred. In the southern United States, gums (*Nyssa* spp. and *L. styraciflua*) and oaks (*Quercus*) are common hosts.

Distribution

Forest tent caterpillar occurs throughout Canada and the United States.

Images of Forest Tent Caterpillar

Figure 1. Adult of forest tent caterpillar, *Malacosoma disstria*. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Forest Tent Caterpillar (continued)

Figure 2. Eggs of forest tent caterpillar (top) and newly hatched caterpillars on egg mass (bottom). (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 3. Larvae of forest tent caterpillar feeding. (Gerald J. Lenhard, Louiana State University, Bugwood.org)

Images of Forest Tent Caterpillar (continued)

Figure 4. Larvae of forest tent caterpillar resting together on trunk. (Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org

Figure 5. Forest tent caterpillar cocoon (with pupa inside). (James B. Hanson, USDA Forest Service, Bugwood.org)

Images of Forest Tent Caterpillar (continued)

Figure 6. Interior view of stand defoliated by forest tent caterpillar. (Herbert A. 'Joe' Pase III, Texas Forest Service, Bugwood.org)

Figure 7. Strips of water tupelo (*Nyssa aquatica* L.) defoliated by forest tent caterpillar (green areas are strips of less favored host species). (William M. Ciesla, Forest Health Management International, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of this species are well known and include 14 species of Hymenoptera egg parasites and, attacking larvae or pupae, 52 Diptera, and 61 Hymenoptera species. In addition there are some 18 Hemiptera, nine Coleoptera, and one Dermaptera that are predators of various life stages of forest tent caterpillar. In northern areas, the tachinid *Sarcophaga aldrichi* Park is important in terminating outbreaks. In the northeastern United States, the tachinids *Zenilla protuberans* A and W and *Compsilura concinnata* Meigan are also important.

Web Links for Information on Forest Tent Caterpillar

http://facultyweb.cortland.edu/fitzgerald/ForestTentCaterpillar.html; website of T.D. Fitzgerald. “Social Caterpillars: Forest Tent Caterpillar (*Malacosoma disstria*).”

http://na.fs.fed.us/spfo/pubs/fidls/ftc/tentcat.htm; Forest and Disease Pest Leaflet No. 9 of the USDA Forest Service.

http://entnemdept.ufl.edu/creatures/trees/forest_tent_caterpillar.htm; fact sheet of the University of Florida on biology and control.

http://www.youtube.com/watch?v=x81ba8-e_O8--Youtube; video of forest tent caterpillars moving about.

Articles

Witter, J.A. and H.M. Kuhlman. 1972. A review of the parasites and predators of tent caterpillars (*Malacosoma* spp.) in North America. Minnesota Agricultural Experiment Station. Technical Bulletin 289: 48 p.

Parry, D., J.R. Spence, and W.J.A. Volney. 1997. Responses of natural enemies to experimentally increased populations of forest tent caterpillar, *Malacosoma disstria*. *Ecological Entomology* 22: 97-108.

Wood, D.M., D. Parry, R.D. Yanai, and N.E. Pitel. 2010. Forest fragmentation and duration of forest tent caterpillar (*Malacosoma disstria* Hübner) outbreaks in northern hardwood forests. *Forest Ecology and Management* 260: 1193-1197.

Wood, D., R. Yanai, D. Allen, and S. Wilmot. 2009. Sugar maple decline after defoliation by forest tent caterpillar. *Journal of Forestry* 107: 29-37.

152. Eastern Tent Caterpillar, *Malacosoma americanum* (F.) (Lepidoptera: Lasiocampidae)

Orientation to Pest

Eastern tent caterpillar, *Malacosoma americanum* (F.), occurs throughout southern Canada and the eastern United States and is a defoliator that feeds on a variety of hardwood trees, especially cherry (*Prunus*) and apple (*Malus*). Winter is passed as eggs, which hatch in spring. Larvae begin feeding on buds and expanding leaves. Older larvae feed on mature leaves. Larvae lay silk trails that they follow to foliage, where they feed in groups. When not feeding, larvae shelter in silk tents constructed low in trees in the forks of branches. Mature larvae wander and pupate inside a yellowish-white cocoon fixed to the host tree or other objects. Adults emerge in midsummer (north) or spring (south) and lay their eggs in clusters that encircle twigs of the host trees. Eggs are cemented together and covered with dark colored material called spumaline. There is one generation per year. This species is primarily a nuisance species, causing little economic loss, with the exception of black cherry (*Prunus serotina* Ehrh.) stands managed to produce veneer wood. The tents of this species are commonly seen along roadsides on young cherry or apple. Caterpillars that have fed on cherry, if then eaten by horses, can cause mares to abort, making this pest of special concern in areas dedicated to rearing race horses.

Hosts Commonly Attacked

This species is a generalist defoliator on a variety of hardwood trees, especially cherry (*Prunus*) and apple (*Malus*).

Distribution

This species occurs throughout southern Canada and the eastern United States.

Images of Eastern Tent Caterpillar

Figure 1. Adult of eastern tent caterpillar, *Malacosoma americanum*. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Eastern Tent Caterpillar (continued)

Figure 2. Egg masses of eastern tent caterpillar. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Figure 3. Young larvae of forest tent caterpillar on a small web. (A. Steven Munson, USDA Forest Service, Bugwood.org)

Images of Eastern Tent Caterpillar (continued)

Figure 4. Large larvae of eastern tent caterpillar. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Figure 5. Close up of eastern tent caterpillar larva. (Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Images of Eastern Tent Caterpillar (continued)

Figure 6. Comparison of caterpillars of eastern tent caterpillar (right) and forest tent caterpillar (left). (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 7. Close up of eastern tent caterpillar tent with mature larvae. (William H. Hoffard, USDA Forest Service, Bugwood.org)

Images of Eastern Tent Caterpillar (continued)

Figure 8. Eastern tent caterpillar cocoon (with pupa inside). (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 9. Webs of eastern tent caterpillar on defoliated trees. (Left: Robert L. Anderson, USDA Forest Service, Bugwood.org; right: G. Keith Douce, University of Georgia, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

A variety of natural enemies of this species have been recognized. See Van Driesche et al. (2002) for details. However, their importance in determining the density of this species has not been investigated.

Web Links for Information on Eastern Tent Caterpillar

http://www.ca.uky.edu/entomology/entfacts/ef423.asp; fact sheet of the University of Kentucky on biology and control.

http://ohioline.osu.edu/hyg-fact/2000/2022.html; fact sheet of Ohio State University.

http://www.ag.auburn.edu/enpl/bulletins/easterntentcaterpillar/easterntentcaterpillar.htm; fact sheet of Auburn University, Alabama.

http://www.youtube.com/watch?v=1qO6eCygcTE; a time lapse video of web construction and feeding on Youtube.

http://www.dec.ny.gov/animals/7111.html; New York Department of Conservation site comparing gypsy moths and eastern tent caterpillar.

Articles

Progar, R.A., M.J. Rinella, D. Fekedulegn, and L. Butler. 2010. Nuclear polyhedrosis virus as a biological control agent for *Malacosoma americanum* (Lepidoptera: Lasiocampidae). *Journal of Applied Entomology* 134: 641-646.

Haynes, K.F., J. McLaughlin, S. Stamper, C. Rucker, F.X. Webster, D. Czokajlo, and P. Kirsch. 2007. Pheromone trap for the eastern tent caterpillar moth. *Environmental Entomology* 36: 1199-1205.

Crump, D., R.M. Silverstein, H.J. Williams, and T.D. Fitzgerald. 1987. Identification of trail pheromone of larva of eastern tent caterpillar *Malacosoma americanum* (Lepidoptera: Lasiocampidae). *Journal of Chemical Ecology* 13: 397-402.

VanDriesche, R.G., S. Healy, and R.C. Reardon. 2002. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States. A review and recommendations*. FHTET-96-19. USDA Forest Service, Morgantown, West Virginia. (Available at http://www.fs.fed.us/foresthealth/technology/pdfs/FHTET_96_19.pdf).

153. Siberian Moth, *Dendrolimus sibiricus* TschetvericKov (Lepidoptera: Lasiocampidae)

Orientation to Pest

Siberian moth, *Dendrolimus sibiricus* TschetveriKov, is a defoliator of great importance in northern Asia, causing widespread, extensive mortality to various conifers during outbreaks. It does not occur in North American but is a species of great concern. Typically, this moth has a two-year life cycle, spread over parts of three calendar years. Adults fly and lay eggs from late June to mid-July. Eggs are laid in chains or clusters on needles or branches. In their first year, larvae feed until they reach the second or third instar and then overwinter in the forest litter. In year two, partly grown larvae continue to feed, at a slower rate, until they are in the fifth to seventh instar, at which stage they overwinter. In their third calendar year, larva feed until mature in spring and pupate inside cocoons fixed to trees. Adult moths appear in late June and July and may fly several kilometers before laying eggs. Outbreaks occur at about 10 year intervals and last 2-3 years. An outbreak can defoliate thousands of hectares and affect entire forests. Since the insect has overlapping generations and life cycles extending more than one growing season, it can defoliate stands in the spring, summer and fall, but most defoliation occurs in spring when older larvae feed.

Hosts Commonly Attacked

Larvae of *D. sibiricus* feed on the foliage of more than 20 species of conifers in northern Asia, especially on species of larch (*Larix*) and fir (*Abies*), but also on less favored hosts such as five-needle and two-needle pines (*Pinus*) and spruce (*Picea*). Injury is greatest to species of fir and certain pines (e.g., *P. koraiensis* Sieb. et Zucc. and *P. sibirica* Du Tour). Although larch species are the most favored hosts, they can re-foliate and are seldom killed. It has been shown that this polyphagous species can develop on a wide range of European and North American conifers.

Distribution

The Siberian moth does not occur in North America, but is considered a very high risk invader because of its potential for invasion and the magnitude of likely damage. Boreal and subalpine forests in North America would be at risk. Its current distribution includes Siberia (Russia), northeastern China, northern Mongolia, and part of North Korea.

Images of Siberian Moth


Figure 1. Male Siberian moth, *Dendrolimus sibericus*. (Natalia Kirichenko, Bugwood.org)


Figure 2. Egg mass of Siberian moth. (John H. Ghent, USDA Forest Service, Bugwood.org)


Figure 3. Larva of Siberian moth. (John H. Ghent, USDA Forest Service, Bugwood.org)

Images of Siberian Moth (continued)

Figure 4. Pupal cocoons of Siberian moth. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 5. Stand of Siberian larch (*Larix sibirica* Ledeb.) defoliated by Siberian moth. (John H. Ghent, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

More than 40 species of parasitoids are known to attack *D. sibiricus*, of which the most important are the egg parasites *Telenomus tetratomus* (Thomson) (Scelionidae) and *Ooencyrtus pinicola* Matsumura (Encyrtidae), the larval parasite *Rogas dendrolimi* Matsumura (Braconidae), and the larval-pupal parasites *Blepharipa schineri* (Mesnil.), *Blepharipa pratensis* Meigen, and *Lespesia frenchii* (Williston) (all Tachinidae).

Web Links for Information on Siberian Moth

http://www.aphis.usda.gov/plant_health/plant_pest_info/pest_detection/downloads/pra/dsuperanspra.pdf; a mini risk assessment of Siberian silk moth (from a North American perspective).

http://www.eppo.org/QUARANTINE/insects/Dendrolimus_sibiricus/DS_Dendrolimus_spp.pdf; an EPPO data sheet for European quarantine officials.

http://www.issg.org/database/species/ecology.asp?si=1428&fr=1&sts=&lang=EN; write up on species in Global Invasive Species Database.

ftp://ftp.fao.org/docrep/fao/011/i0640e/i0640e10h.pdf; fact sheet by United Nations FAO group.

http://spfnic.fs.fed.us/exfor/data/pestreports.cfm?pestidval=45&langdisplay=english; Exotic forest pest data sheet of the USDA Forest Service.

Articles

Kirichenko, N.I., J. Flament, Y.N. Baranchikov, and J.-C. Grégoire. 2008. Native and exotic coniferous species in Europe – possible host plants for the potentially invasive Siberian moth, *Dendrolimus sibiricus* Tschtv. (Lepidoptera, Lasiocampidae). *OEPP/EPPO Bulletin* 38: 259-263.

Kirichenko, N.I., Y.N. Baranchikov, and S. Vidal. 2009. Performance of the potentially invasive Siberian moth *Dendrolimus superans sibiricus* on coniferous species in Europe. *Agricultural and Forest Entomology* 11: 247-254.

154. Pinkstriped Oakworm, *Anisota virginiensis* (Drury) (Lepidoptera: Saturniidae)

Orientation to Pest

Pinkstriped oakworm, *Anisota virginiensis* (Drury), is a native moth that feeds on foliage of oaks (*Quercus*) and other hardwoods. It occurs throughout the eastern United States and southern Canada. Young larvae feed in groups, skeltonizing leaves. Older larvae are less gregarious and consume all but the main veins of leaves. Larvae can be found April through September depending on the climate, with one generation per year in its northern range and up to three generations per year in its southern-most range. This insect is common but not abundant and is usually considered a minor pest to landscape trees where damage to larger trees is often limited to defoliation of single branches. However, small trees can be completely defoliated.

Hosts Commonly Attacked

Pinkstriped oakworm feeds primarily on oaks (*Quercus*), but it is also reported from chestnut (*Castanea*), hazel (*Corylus*), maple (*Acer*), and birch (*Betula*).

Distribution

This species occurs in southern Canada and the eastern United States, as far west as Manitoba and Texas.

Images of Pinkstriped Oakworm

Figure 1. Adults of pinkstriped oakworm, *Anisota virginiensis*: male and female mating. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of Pinkstriped Oakworm (continued)

Figure 2. Eggs of pinkstriped oakworm. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Young larvae of pinkstriped oakworm. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Close up of pinkstriped oakworm larva. (James Solomon, USDA Forest Service, Bugwood.org)

Images of Pinkstriped Oakworm (continued)

Figure 5. Pupa of pinkstriped oakworm. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 6. A group of pinkstriped oakworm caterpillars defoliating an oak branch. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Manitoba, five species of larval or pupal parasitoids have been recorded from this species: *Houghia sternalis* (Coquillett), *Lespesia anisotae* Webber, and *Winthemia datanae* (Tns.) (all Tachinidae); and *Habronyx magniceps* (Cresson) and *Hyposoter fugitivus* (Say) (both Ichneumonidae).

Web Links for Information on Pinkstriped Oakworm

http://www.ag.auburn.edu/enpl/bulletins/pinkoakworm/pinkoakworm.htm; fact sheet of Auburn University on recognition and biology.

http://okeechobee.ifas.ufl.edu/News%20columns/Pinkstriped%20Oakworm.htm; University of Florida fact sheet on biology and control.

http://www.fs.fed.us/r8/foresthealth/idotis/insects/oakworm.html; USDA Forest Service fact sheet on two oakworm species.

Articles

Wagner, D.L., V. Giles, R.C. Reardon, and M.L. McManus. 1998. *Caterpillars of Eastern Forests*. USFS Technology Transfer Bulletin, FHTET-96-34: 113 p.

Henne, D.C. 2004. Parasitoid survey of *Anisota virginiensis* (Lepidoptera: Saturniidae) at Belair, Manitoba from 1989-1999. *Proceedings of the Entomological Society of Manitoba* 60: 5-10.

155. Orangestriped Oakworm, *Anisota senatoria* (J.E. Smith) (Lepidoptera: Saturniidae)

Orientation to Pest

Orangestriped oakworm, *Anisota senatoria* (J.E. Smith), is a native silkmoth that feeds mainly on the foliage of oaks (*Quercus*). It has as a wide distribution in eastern United States and southern Canada. Adults appear in the June or July in the northern part of its range and lay groups of eggs on the undersides of leaves of host trees. Young larvae feed in groups, skeletonizing leaves. Older larvae consume all but the main veins and are less gregarious. Mature larvae drop to the ground and wander before pupating in the soil, where they overwinter. Outbreaks occur infrequently. There is one generation per year in most parts of the range. Defoliation can be significant in some years, but little harm results unless trees are under additional stress from other factors.

Hosts Commonly Attacked

This species feeds primarily on oaks (*Quercus*).

Distribution

This species occurs in much of the eastern United States and southern Canada, west to Minnesota and Texas, although it is not common in the southeastern United States.

Images of Orangestriped Oakworm

Figure 1. Adults of orangestriped oakworm, *Anisota senatoria*. (John Wheatley, John B. Wheatley, Bugwood.org)

Images of Orangestriped Oakworm (continued)

Figure 2. Eggs of orangestriped oakworm. (John Wheatley, John B. Wheatley)

Figure 3. Young larvae of orangestriped oakworm. (Lance S. Risley, William Paterson University, Bugwood.org)

Figure 4. Close up of mature orangestriped oakworm caterpillar. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Orangestriped Oakworm (continued)

Figure 5. Defoliation by larvae of orange striped oakworm. (Erich G. Vallery, USDA Forest Service - SRS-4552, Bugwood.org

Important Biological Control Agents Related to this Pest Species

Parasitoids that have been reared in Virginia from orangestriped oakworm larvae or pupae include *Hyposoter fugitivus* (Say) (Ichneumonidae) (in larvae, 3.2 to 9.3 percent) and *Lespesia anisotae* (Webber) (Tachinidae) and *Belvosia bifasciata* (Fabricius) (Tachinidae) (in larvae at 10.7 and 0.7 percent, respectively).

Web Links for Information on Orangestriped Oakworm

http://www.ct.gov/caes/lib/caes/documents/publications/fact_sheets/entomology/orangestriped_oakworm.pdf; website of the Connecticut Agricultural Experiment Station.

http://www.ag.auburn.edu/enpl/bulletins/orangeoakworm/orangeoakworm.htm; fact sheet of Auburn University, Auburn, Alabama.

http://www.oakgov.com/msu/assets/docs/publications/e2654_oakworm.pdf; MSU Extension Bulletin-2654, fact sheet of Michigan State University.

Articles

Coffelt, M.A. and P.B. Schultz. 1993. Population biology of orangestriped oakworm (Lepidoptera: Saturniidae) in southeastern Virginia. *Journal of Entomological Science* 28: 218-229.

Coffelt, M.A. and P.B. Schultz. 1993. Larval parasitism of orangestriped oakworm (Lepidoptera: Saturniidae) in the urban shade tree environment. *Biological Control* 3: 127-134.

Coffelt, M.A. and P.B. Schultz. 1989. Development of an aesthetic injury level to decrease pesticide use against orange-striped oakworm (Lepidoptera: Saturniidae) in an urban pest management project. *Journal of Economic Entomology* 83: 2044-2049.

156. Pandora Moth, *Coloradia pandora* Blake (Lepidoptera: Saturniidae)

Orientation to Pest

Pandora moth, *Coloradia pandora* Blake, is an important defoliator of pines in the western United States. There are three recognized subspecies. Two years are needed to complete the life cycle. Adults appear in spring or early summer and eggs hatch in August. Larvae crawl up trees and young larvae feed in groups on new foliage. Immature larvae spend the winter hibernating in clusters at the base of the needles and resume feeding the following spring. In June of the second year, mature larvae crawl down trees and pupate in earthen cells in the ground. Adults may emerge the following year, or remain as pupae for up to five years. Outbreaks occur in regions with soils loose enough for larvae to bury themselves for pupation, these being chiefly pumice or decomposed granite soils. Large and economically important outbreaks have occurred in the past and these seem to reoccur at 20-30 year intervals, lasting 6 to 8 years each. Because each generation requires two years for completion and populations are synchronized, feeding is concentrated in alternate years, which allows many trees to recover and survive. In non-outbreak years, this insect is uncommon.

Hosts Commonly Attacked

This species feeds primarily on ponderosa (*Pinus ponderosa* Douglas ex C. Lawson), lodgepole (*P. contorta* Douglas) and Jeffrey (*P. jeffreyi* Balf.) pines, but other pines are also sometimes attacked.

Distribution

This species occurs in the United States west of the Rocky Mountains, except for Idaho and Washington.

Images of Pandora Moth

Figure 1. Adults of Pandora moth, *Coloradia pandora* (top, female; bottom, male). (Top: USDA Forest Service Archive, USDA Forest Service, Bugwood.org; bottom: Terry Spivey, USDA Forest Service, Bugwood.org)

Images of Pandora Moth (continued)

Figure 2. Eggs of Pandora moth. (Darrell Ross, Oregon State University, Bugwood.org)

Figure 3. Young larva of Pandora moth (top photo), and older larvae (middle and bottom photos; note: upper larvae in bottom photo is infected with a virus). (Top: Darrell Ross, Oregon State University, Bugwood.org; middle: USDA Forest Service - Region 2 - Rocky Mountain Region Archive, USDA Forest Service, Bugwood.org; bottom: Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Images of Pandora Moth (continued)

Figure 4. Pupae of Pandora moth. (Darrell Ross, Oregon State University, Bugwood.org)

Figure 5. Ponderosa pines defoliated by Pandora moth. (Bruce Hostetler, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

During epidemics, populations of Pandora moth are affected by many natural mortality factors, including a wilting virus (likely a polynucleohedrosis virus) of the mature larvae, small mammal predators of the pupae in the soil, and various parasitoids.

Web Links for Information on Pandora Moth

http://www.forestpests.org/acrobat/pandora.pdf; full text of article: Carolin, V.M., Jr., and J.A.E. Knopf. 1968. The Pandora Moth. U.S. Department of Agriculture, Forest Service, Forest Pest Leaflet 114.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_043666.pdf; USDA Forest Service leaflet on Pandora moth.

Articles

Schmid, J.M. and D.D. Bennett. 1986. The North Kaibab Pandora moth outbreak 1978-1984. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA, General Technical Report RM-153: 18 p.

Speer, J.H., T.W. Swetnam, B.E. Wickman, and A. Youngblood. 2001. Changes in Pandora moth outbreak dynamics during the past 622 years. *Ecology* 82: 679-697.

Speer, J.H. and R.L. Holmes. 2004. Effects of Pandora moth outbreaks on ponderosa pine wood volume. *Tree-Ring Research* 60: 69-76.

157. European Gypsy Moth, *Lymantria dispar* (L.) (Lepidoptera: Lymantriidae)

Orientation to Pest

European gypsy moth, *Lymantria dispar* (L.), is an invasive species in the United States that has been a major forest pest for over a century. Its damage consists of defoliation of deciduous forests and trees in spring and early summer. Efforts to control this species with introduced natural enemies began around 1900 and currently it is under good control in New England, but outbreaks still occur to the west and south, where the pest continues to invade. There is one generation a year and the species overwinters as eggs on trees or various objects. Spread occurs locally by wind-blown young caterpillars and over long distances by human movement of egg masses. Female moths cannot fly. Both adults and caterpillars are easily recognized.

Hosts Commonly Attacked

The larvae of this species feed on most species of deciduous trees, especially oaks (*Quercus*).

Distribution

Figure 1. World distribution of European gypsy moth, *Lymantria dispar*. (USDA Forest Service - Northeastern Research Station; "Gypsy Moth in North America")

Images of European Gypsy Moth

Figure 2. Female European gypsy moth (on egg mass). Note white wings with brown zigzag lines. (Steven Katovich, USDA Forest Service, Bugwood.org)

Images of European Gypsy Moth (continued)

Figure 3. Male European gypsy moth. Note brown wings and feather-like antennae. (James A. Copony, Virginia Department of Forestry, Bugwood.org)

Figure 4. Newly hatched caterpillars of European gypsy moth on egg mass, preparing to disperse by crawling or blowing in the wind on silk threads. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 5. Mature European gypsy moth caterpillar. Note series of blue or red spots on back, plus clusters of hairs on sides. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Images of European Gypsy Moth (continued)

Figure 6. Pupae of European gypsy moth in silken cradle (far left). Threads cut away to show detail. Female pupa above, male below. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 7. Defoliation from European gypsy moth. (Landesforstpräsidium Sachsen Archive, Bugwood.org)

Figure 8. Aerial view of defoliation from European gypsy moth. In the absence of effective biological control, widespread defoliation of forest stands can occur in late spring. Defoliation areas appear brown on the upper slope. (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, Bugwood.org)

Images of European Gypsy Moth (continued)

Figure 9. The nucleopolyhedrosis virus of European gypsy moth can cause epidemics in dense European gypsy moth populations but comes too late to prevent damage. Virus-killed caterpillars hang by their legs on tree, and fluids from rotting cadavers drip onto foliage, spreading virus. (William M. Ciesla, Forest Health Management International, Bugwood.org)

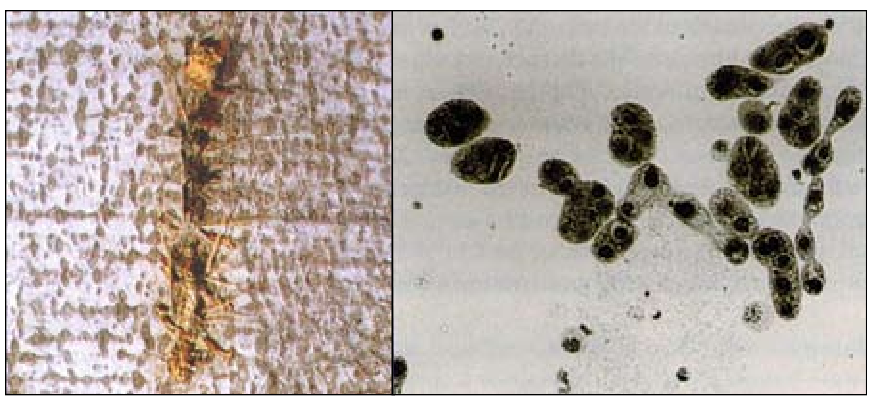


Figure 10. The fungus *Entomophthora maimaiga* has emerged as a key biological control agent of European gypsy moth in the northeastern United States (left, diseased caterpillar; right, fungal protoplasts). (Both photos: Andy Liebhold - USDA Forest Service - Northeastern Research Station; “Gypsy Moth in North America”)

Images of European Gypsy Moth (continued)

Figure 11. *Compsilura concinnata*, an important tachinid parasitoid of the European gypsy moth. (Joyce Gross, UCB, Bugwood.org)

Figure 12. *Cotesia melanoscela*, a parasitoid of European gypsy moth larvae. (James Lindsey, Ecology of Commanster)

Important Biological Control Agents Related to this Pest Species

Of some 80 species of parasitoids imported and released into the United States against this pest, 11 species became established and six are believed to have contributed to control of the European gypsy moth: (1) *Ooencyrtus kuvanae* (Howard) (Hymenoptera: Encrytidae); (2) *Cotesia melanoscela* (Ratzeburg) (Hymenoptera: Braconidae); (3) *Brachymeria intermedia* (Nees) (Hymenoptera: Chalcididae); (4) *Compsilura concinnata* (Meigen) (Diptera: Tachinidae); (5) *Parasetigena silvestris* (Robineau-Desvoidy) (Diptera: Tachinidae); and (6) *Blepharipa pratensis* (Meigen) (Diptera: Tachinidae). Effective control was achieved in the northeastern United States following the accidental introduction of the fungal pathogen *Entomophthora maimaiga* Humber, Shimazu, and Soper.

Web Links for Information on European Gypsy Moth

http://www.fs.fed.us/ne/morgantown/4557/gmoth/; a USDA Forest Service site that provide information and links to other sites on a variety of topics, including distribution, effects on forests, management, and natural enemies.

http://www.na.fs.fed.us/spfo/pubs/fidls/gypsymoth/gypsy.htm; a USDA Forest Service leaflet (Forest insect and disease leaflet No. 162) covering life cycle, hosts, effects of defoliation, population dynamics, management, use of pesticides, and silvicultural treatments.

Articles

Hajek, A.E., J.S. Elkinton, and J.J. Witcosky. 1996. Introduction and spread of the fungal pathogen *Entomophaga maimaiga* (Zygomycetes: Entomophthorales) along the leading edge of gypsy moth (Lepidoptera: Lymantriidae) spread. *Environmental Entomology* 25: 1235-1247.

Liebhold, A., J. Elkinton, D. Williams, and R.M. Muzika. 2000. What causes outbreaks of the gypsy moth in North America? *Population Ecology* 42: 257-266.

Elkinton, J.S., W.M. Healy, A.M. Liebhold, and J.P. Buonaccorsi. 2002. Gypsy moths and forest dynamics. In: McShea, W.J. and W.M. Healy. *Oak Forest Ecosystems: Ecology and Management for Wildlife*. John Hopkins University Press. Baltimore, MD, USA: 100-112.

158. Asian Pink Moth, *Lymantria mathura* Moore (Lepidoptera: Lymantriidae)

Orientation to Pest

Asian pink moth (formerly called "rosy gypsy moth"), *Lymantria mathura* Moore, is an Asian defoliator not yet present in the United States, but one that poses a high risk of invasion and potential damage. It defoliates a variety of hardwood species and outbreaks may affect large areas. During outbreaks, the pest population density may reach 1000 caterpillars per tree. The species overwinters as eggs containing fully developed larvae, ready to hatch. Larvae emerge early in spring and disperse and attack buds, then leaves. Most feeding occurs at night. Mature larvae pupate in flimsy cocoons on the host tree. Females fly at night (1:00-3:00 a.m.) and lay eggs in masses of 150-600 on bark of host tree or other objects. There is one generation per year.

Hosts Commonly Attacked

Asian pink moth attacks many species of *Betula*, *Castanea*, *Juglans*, *Malus*, *Quercus*, *Salix*, *Tilia*, *Ulmus*, and other deciduous trees. Its preferred hosts in the Russian Far East include *Juglans mandshurica* Maxim., *Quercus mongolica* Fisch. ex Turcz., and *Q. dentata* Thunb.

Distribution

Asian pink moth is native to Asia and is found in the Russian Far East, Nepal, Japan, Korea, northern India, and parts of China (Hebei, Heilongjiang, Jilin provinces, and western China).

Images of Asian Pink Moth

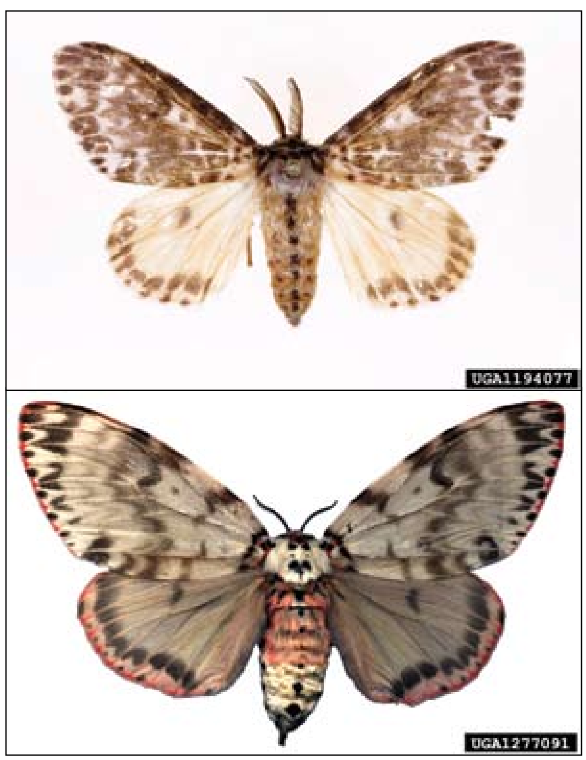


Figure 1. Adults of Asian pink moth, *Lymantria mathura* (top, male; bottom, female). (Top: DAFF Archive, Bugwood.org; bottom: David Mohn, Critters Page [Creatures Great and Small], Bugwood.org)

Images of Asian Pink Moth (continued)

Figure 2. Comparison of the female of Asian pink moth (bottom) to that of gypsy moth (*Lymantria dispar* [L.]), top. (USDA APHIS PPQ Archive, USDA APHIS PPQ, Bugwood.org)

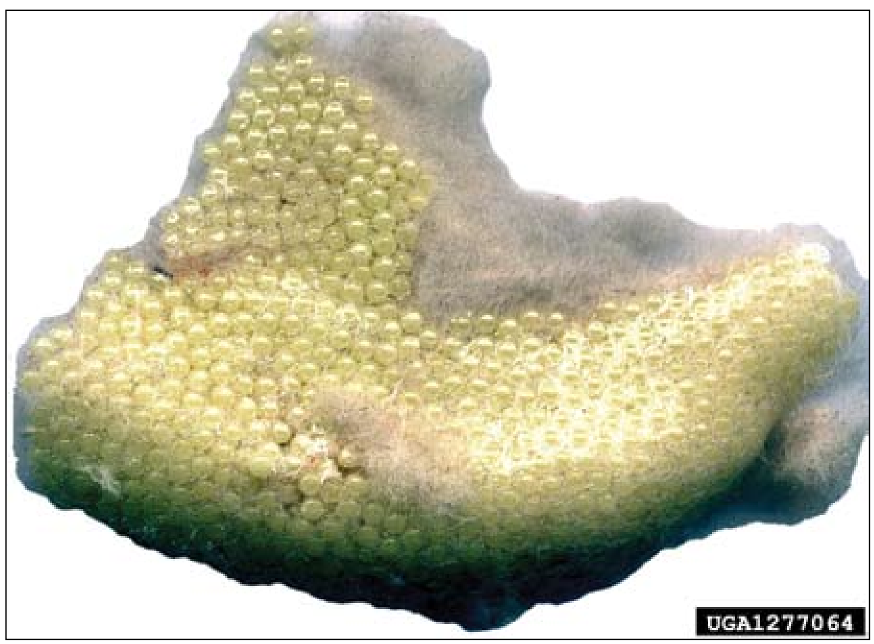


Figure 3. Egg mass of Asian pink moth. (David Mohn, Critters Page [Creatures Great and Small], Bugwood.org)

Images of Asian Pink Moth (continued)

Figure 4. Young larvae of Asian pink moth. (David Mohn, Critters Page [Creatures Great and Small], Bugwood.org)

Figure 5. Mature larvae of Asian pink moth. (USDA APHIS PPQ Archive, USDA APHIS PPQ, Bugwood.org)

Figure 6. Pupa of Asian pink moth. (David Mohn, Critters Page [Creatures Great and Small], Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Korea, natural enemies associated with Asian pink moth include *Cotesia melanoscela* (Ratzberg), the dominant larval parasitoid, and *Brachymeria lasus* (Walker), the most important pupal parasitoid.

Web Links for Information on Asian Pink Moth

http://www.eppo.org/QUARANTINE/insects/Lymantria_mathura/DS_Lymantria_mathura.pdf; detailed fact sheet of the European quarantine organization EPPO.

http://www.aphis.usda.gov/plant_health/plant_pest_info/pest_detection/downloads/pra/lmathurapra.pdf; APHIS (USDA) risk assessment for Asian pink moth to the United States.

Articles

Zlotina, M.A., V.C. Mastro, D.E. Leonard, and J.S. Elkinton. 1998. Survival and development of *Lymantria mathura* on North American, Asian, and European tree species. *Journal of Economic Entomology* 91: 1162-1166.

Anon. 2005. *Lymantria mathura*. *EPPO Bulletin* 35(3): 464-467.

159. Nun Moth, *Lymantria monacha* Moore (Lepidoptera: Lymantriidae)

Orientation to Pest

Nun moth, *Lymantria monacha* Moore, is a Eurasian species that has not yet invaded North America but is a species of high concern. Outbreaks of the nun moth are often observed in Scots pine (*Pinus sylvestris* L.) and Norway spruce stands (*Picea abies* [L.] Karst.), but many conifers and broadleaf trees are also hosts. The biology closely resembles that of the gypsy moth (*Lymantria dispar* [L.]), except that females of nun moth can fly, which they do at night. The species overwinters as eggs containing fully developed larvae, which emerge when buds on host trees are opening. Young larvae feed on buds in groups but after the first instar, larvae consume mature needles and feed alone. Pupation takes place on the host tree and by mid-summer adults are in flight. Adults lay eggs in cracks of bark on the host tree or in crevices of other objects in masses of 70 to 300 eggs. Egg masses may be moved on firewood or other material. There is one generation per year.

Hosts Commonly Attacked

Outbreaks of the nun moth are often observed in Scots pine (*P. sylvestris*) and Norway spruce (*P. abies*) stands. However, most conifers and many broad-leaved tree species may also be used as food plants.

Distribution

Nun moth is widely distributed and is found in China, Japan, Russia, and Europe.

Images of Nun Moth

Figure 1. Adults of nun moth, *Lymantria monacha*; top, male and bottom, female. (Note: this species has a wide range of color variation, which is not captured in these photos.) (Both photos: DAFF Archive, Bugwood.org)

Images of Nun Moth (continued)

Figure 2. Adult female nun moth in resting position. (Hannes Lemme, Bugwood.org)

Figure 3. Egg mass of nun moth. (Stanislaw Kinelski, Bugwood.org)

Images of Nun Moth (continued)

Figure 4. Young larvae of nun moth. (Note: like adults, larvae vary in color.) (Both photos: Stanislaw Kinelski, Bugwood.org)

Figure 5. Mature larva of nun moth. (Stanislaw Kinelski, Bugwood.org)

Images of Nun Moth (continued)

Figure 6. Pupae of nun moth. (Hannes Lemme, Bugwood.org)

Figure 7. Small conifer killed by nun moth. (Landesforstpräsidium Sachsen Archive, Bugwood.org)

Figure 8. Norway spruce stand defoliated by nun moth. (Jan Liska, Forestry and Game Management Research Institute, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many natural enemies have been recorded attacking nun moth, usually during outbreaks or in the decline phase as populations collapse. These include many species of parasitoids (mostly tachinid and sarcophagid flies and braconid wasps). See Van Driesche et al. (1996) for details. A baculovirus is also known from this species. However, there is limited experimental evidence about the role such agents play in regulation of the species or curtailment of outbreaks.

Web Links for Information on Nun Moth

http://wiki.bugwood.org/Archive:Atlas/Lymantria_monacha#Biology; short fact sheet of Bugwood Wiki.

ftp://ftp.fao.org/docrep/fao/011/i0640e/i0640e10q.pdf; fact sheet of the United Nations FAO group.

http://www.inspection.gc.ca/english/plaveg/pestrava/lymmon/tech/lymmone.shtml; fact sheet of the Canadian Food Inspection Agency.

http://www.nrs.fs.fed.us/disturbance/invasive_species/nun_moth/; contains information on the species' biology, photos, a reference list, and a pest alert.

Articles

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations.* FHTET 96-19, USDA Forest Service, Morgantown. (Available at http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

Keena, M.A., K.S. Shields, and M. Torsello. 1998. Nun moth: potential new pest. Pest Alert NA-PR-95-98. USDA Forest Service, Northeastern Area, State and Private Forestry: 2 p.

Keena, M.A. 2003. Survival and development of *Lymantria monacha* (Lepidoptera: Lymantriidae) on North American and introduced Eurasian tree species. *Journal of Economic Entomology* 96: 43-52.

Prestemon, J.P., J.A. Turner, J. Buongiorno, S.S. Zhu, and R.H. Li. 2008. Some timber product market and trade implications of an invasive defoliator: the case of Asian *Lymantria* in the United States. *Journal of Forestry* 106: 409-415.

160. Browntail Moth, *Euproctis chrysorrhoea* L. (Lepidoptera: Lymantriidae)

Orientation to Pest

Browntail moth, *Euproctis chrysorrhoea* L., is an invasive species in North America whose effects on trees is similar to that of gypsy moth (*Lymantria dispar* [L.]), being a defoliator of a wide range of deciduous broadleaf trees. Introduced into North America in the later 19th century, by 1914 it had infested a wide band of coastal and inland New England. In addition to widespread defoliation of many types of deciduous hardwood trees, including many fruit trees, the species also was a threat to public health because of the severe skin rashes from the caterpillar's hairs. These, if inhaled, could cause illness leading to death in some cases. By 1922, its range began to quickly collapse and currently the moth is found only in a few small coastal enclaves. While the cause of this decline was not understood at the time, it was subsequently proved to be caused by the action of *Compsilura concinnata* (Meigen), a polyphagous tachinid introduced against it and the gypsy moth.

Hosts Commonly Attacked

Browntail moth feeds on most species of deciduous broadleaf trees, especially species of apple (*Malus*), pear (*Pyrus*), plum (*Prunus*), oak (*Quercus*), willow (*Salix*), elm (*Ulmus*), and maple (*Acer*).

Distribution

At the height of its invasion, browntail moth was found in much of New England, but it is currently found only at the very tip of Cape Cod, Massachusetts, and on some islands in Casco Bay, near Portland, Maine.

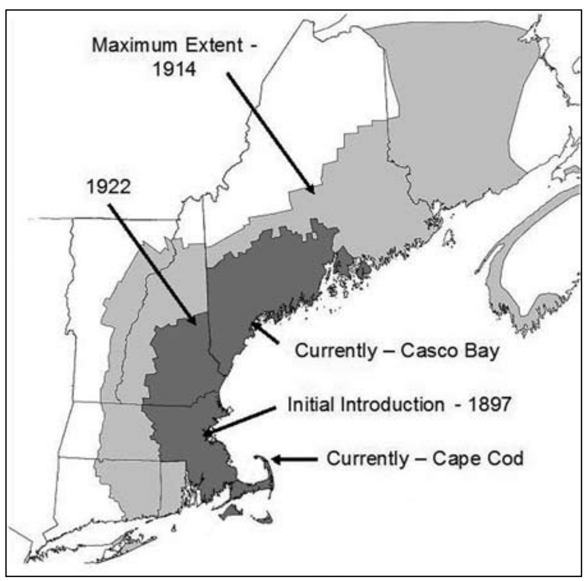


Figure 1. Historical and current distribution of browntail moth, *Euproctis chrysorrhoea*, in North America.

Images of Browntail Moth

Figure 2. Female browntail moth. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Figure 3. Egg mass of browntail moth. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Figure 4. Young browntail moth caterpillars on web. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Images of Browntail Moth (continued)

Figure 5. Mature browntail moth caterpillars. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Figure 6. Side view of browntail moth caterpillar showing prominent hairs that cause severe skin rash. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Figure 7. Skin rash from contact with browntail moth caterpillars. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Images of Browntail Moth (continued)

Figure 8. Pupae of browntail moth in web. (Jan Samanek, State Phytosanitary Administration, Bugwood.org)

Figure 9. Defoliated trees and old browntail moth webbing. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Figure 10. *Compsilura concinnata*, an important tachinid parasitoid of the European gypsy moth. (Joyce Gross, UCB, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Elkinton et al. (2006) demonstrated that *C. concinnata* (Diptera: Tachinidae) was likely the agent responsible for the extinction of browntail moth from much of its former range in North America in the early part of the 20th century. Two other tachinids, *Townsendiellomyia nidicola* and *Carcelia laxifrons*, both browntail moth specialists were also introduced and successfully established at the same time as *C. concinnata*. More recently, a nucleopolyhedrosis virus from England, specific to the moth has been released and established in Maine, but impacts on remaining populations were not yet clear as of 2010. Many browntail moth populations in Maine have been heavily affected by a naturally occurring fungal pathogen, *Entomophaga aulicae* (Reichardt in Bail) Humber.

Web Links for Information on Browntail Moth

http://www.maine.gov/doc/mfs/btm.htm; leaflet from Maine Department of Conservation that includes recommendations for chemical controls and other measures.

Articles

Elkinton, J.S., D. Parry, and G.H. Boettner. 2006. Implicating an introduced generalist parasitoid in the invasive browntail moth's enigmatic demise. *Ecology* 87: 2664-2672.

Elkinton, J.S., E. Preisser, G. Boettner, and D. Parry. 2008. Factors influencing larval survival of the invasive browntail moth (Lepidoptera: Lymantriidae) in relict North American populations. *Environmental Entomology* 37: 1429-1437. (Available at http://cels.uri.edu/preisserlab/media/publications/preisser/Env%20Ent%202008%20(37,6)%201429-1437.pdf).

161. Pine Tussock Moth, *Dasychira pinicola* (Dyar) (Lepidoptera: Lymantriidae)

Orientation to Pest

Pine tussock moth, *Dasychira pinicola* (Dyar), is a native North American tussock moth. It is known for sudden eruptions in population that quickly subside and may not occur again for many years. It is found in southeastern Canada and from the northeastern United States west to Minnesota. The larvae feed on various conifers, especially on jack pine (*Pinus banksiana* Lamb.) Outbreaks, when they do occur, can be extensive and damaging since the caterpillar stage consumes both new and old foliage, leaving host conifers completely defoliated. In the last century there have been several large outbreaks on jack pine in the Lakes States. In the Lake States, moths fly in mid-summer and eggs are laid in irregular clusters on or near the female pupal case, on the needles or the trunk. Eggs hatch later in the summer and young larvae feed on needles until they reach the second or third instar, when they go into hibernation for the winter. Larvae resume feeding in the spring, at first eating staminate flowers and young needles. Later, old-needles are also eaten. Fully grown larvae spin cocoons on needles or twigs, where they also pupate. Moths emerge shortly thereafter. There is one generation per year.

Hosts Commonly Attacked

The caterpillar stage of pine tussock moth feeds on various conifers, including jack (*P. banksiana*), red (*P. resinosa* Sol. ex Aiton), and eastern white (*P. strobus* L.) pines, spruce (*Picea*) and balsam fir (*Abies balsamea* [L.] Mill.).

Distribution

Pine tussock moth is found in southeastern Canada and from the northeastern United States west to Minnesota.

Images of Pine Tussock Moth

Figure 1. Adult of pine tussock moth, *Dasychira pinicola*. (Gordon Harrison)

Images of Pine Tussock Moth (continued)

Figure 2. Eggs of the pine tussock moth. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 3. Larva of pine tussock moth. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Figure 4. Pupa of pine tussock moth. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Images of Pine Tussock Moth (continued)

Figure 5. Jack pines damaged by pine tussock moth. (Minnesota Department of Natural Resources Archive, Minnesota Department of Natural Resources, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Natural enemies of this species have been studied during outbreaks that occurred in Wisconsin in the 1960s. Thirty-one parasitic species were reared during that study. Eight insect predators and four pathogens were also reported. Parasitism levels were significant in the egg, larval and pupal stages (see Sreenivasum et al. 1972 for details).

Web Links for Information on Pine Tussock Moth

None

Articles

Sreenivasam, D.D., D.M. Benjamin, and D.D. Walgenbach. 1972. The bionomics of the pine tussock moth. Research Bulletin No. 282. School of Natural Resources, College of Agriculture and Life Sciences, University of Wisconsin, Madison: 36 p.

162. Whitemarked Tussock Moth, *Orgyia leucostigma* (J. E. Smith) (Lepidoptera: Lymantriidae)

Orientation to Pest

Whitemarked tussock moth, *Orgyia leucostigma* (J. E. Smith), is a native North American tussock moth whose larvae feed on a variety of deciduous and coniferous trees. The species is found in most of eastern Canada and the eastern United States. This tussock moth passes the winter as eggs, which hatch in spring and thereafter young larvae often spin down on silk threads and balloon to new host plants. Young larvae skeletonize leaves of host trees, while older larvae consume whole leaves (eating all but the major veins). Cocoons are formed in bark crevices or between branches, and adults emerge in a few weeks. Females are wingless and lay eggs in masses. There are one or two generations per year depending on the region. Damage to forest trees is minor and this species is better known as a pest of shade or fruit trees in urban areas and in intensively managed plantations of Christmas trees.

Hosts Commonly Attacked

Whitemarked tussock moth exploits a broad range of plant species and has been reported to cause significant damage to many tree species, including apple (*Malus*), basswood (*Tilia*), elm (*Ulmus*), poplar (*Populus*), Norway maple (*Acer platanoides* L.), silver maple (*Acer saccharinum* L.), sycamore (*Platanus*), paper birch (*Betula papyrifera* Marsh.), yellow birch (*Betula alleghaniensis* Britt.), larch (*Larix*), and balsam fir (*Abies balsamea* [L.] Mill.).

Distribution

Whitemarked tussock moth is found throughout eastern Canada and the eastern United States.

Images of Whitemarked Tussock Moth

Figure 1. Adults of whitemarked tussock moth, *Orgyia leucostigma*: left, winged male; right, wingless female. (Left: James Solomon, USDA Forest Service, Bugwood.org; right: North Carolina Forest Service Archive, Bugwood.org)

Images of Whitemarked Tussock Moth (continued)

Figure 2. Flightless female of whitemarked tussock moth producing her egg mass. (John L. Foltz, University of Florida, Bugwood.org)

Figure 3. Larvae of whitemarked tussock moth: top, dorsal view; bottom, lateral view. (Top: John H. Ghent, USDA Forest Service, Bugwood.org; bottom: Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org)

Images of Whitemarked Tussock Moth (continued)

Figure 4. Top, pupae of whitemarked tussock moth (removed from cocoons); bottom, cocoons of whitemarked tussock moth. (Top: Robert L. Anderson, USDA Forest Service, Bugwood.org; bottom: James Solomon, USDA Forest Service, Bugwood.org)

Figure 5. Feeding damage of whitemarked tussock moth larvae. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Two strains of nucleopolyhedroviruses, one specific to whitemarked tussock moth and the other to Douglas fir tussock moth, *Orgyia pseudotsugata* (McDunnough), have been found to cause widespread mortality in populations of whitemarked tussock moth and are being developed as possible biological control agents in Christmas tree plantations (balsam fir) in eastern Canada.

Web Links for Information on Whitemarked Tussock Moth

http://www.ag.auburn.edu/enpl/bulletins/whitemarkedtussock/whitemarkedtussock.htm; fact sheet of Auburn University.

http://www.ag.auburn.edu/enpl/bulletins/whitemarkedtussock/whitemarkedtussock.htm; fact sheet of the USDA Forest Service, Forest Health Protection, Southern Region.

http://insects.tamu.edu/fieldguide/cimg313.html; fact sheet of Texas A&M University.

Articles

Thurston, G.S. 2001. *Orgyia leucostigma* (J. E. Smith), whitemarked tussock moth (Lepidoptera: Lymantriidae). In: Mason, P.G. and J.T. Huber. *Biological Control Programmes in Canada, 1981-2000*. CABI Publishing, Wallingford, UK: 201-203.

Medina, R.F. and P. Barbosa. 2002. Predation of small and large *Orgyia leucostigma* (J. E. Smith) (Lepidoptera: Lymantriidae) larvae by vertebrate and invertebrate predators. *Environmental Entomology* 31: 1097-1102.

163. Douglas-fir Tussock Moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera: Lymantriidae)

Orientation to Pest

The Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough), is a native defoliator of major importance in the interior Douglas-fir and true fir forests of western North America, where is defoliates Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) and various true firs (*Abies*). Adults emerge in late summer or early fall. The flightless females remain on their cocoons, where they mate and lay their egg mass. Eggs overwinter and hatch the following spring when new foliage has appeared. Young larvae crawl to new needles and begin feeding, but small larvae may disperse by dropping on silken threads and being blown by the wind, especially when new foliage is not available. Young larvae feed on the unfolding new needles, while older larvae feed on both new and old foliage. Foliage of heavily infested forest stands turns distinctly brownish. By late summer, mature larvae form cocoons either on the foliage when densities are low or on tree trunks and objects on the ground when densities are high. New adults emerge in a few weeks to complete the life cycle. The cocoons and egg masses are among the most conspicuous evidence of tussock moth abundance. There is one generation a year. Periodic large scale outbreaks have occurred. These outbreaks develop explosively but subside abruptly after about 3 years. Between outbreaks this insect is seldom seen.

Hosts Commonly Attacked

Douglas-fir tussock moth feeds on Douglas-fir (*P. menziesii*), and various native firs, especially grand (*Abies grandis* [Douglas ex D. Don] Lindley), white (*A. concolor* [Gordon] Lindley ex Hildebrand), and subalpine fir (*A. lasiocarpa* [Hooker] Nuttal).

Distribution

Douglas-fir tussock moth is found from southern British Columbia through the eastern half of the Pacific coast states. It is also found in the Rocky Mountain States, south to Arizona and New Mexico.

Images of Douglas-fir Tussock Moth

Figure 1. Adults of Douglas-fir tussock moth, *Orgyia pseudotsugata*: left, male; right, wingless female on her cocoon. (Both photos: Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Images of Douglas-fir Tussock Moth (continued)

Figure 2. Egg masses (top) of Douglas-fir tussock moth and egg mass (bottom) with newly hatched larvae. (Top: Kenneth E. Gibson, USDA Forest Service, Bugwood.org; bottom: USDA Forest Service - Region 4 - Intermountain Archive, USDA Forest Service, Bugwood.org)

Figure 3. Mature larvae of Douglas-fir tussock moth. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 4. Cocoons of Douglas-fir tussock moth (left), and close up (right). (Left: William M. Ciesla, Forest Health Management International, Bugwood.org; right: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of Douglas-fir Tussock Moth (continued)

Figure 5. Feeding damage of Douglas-fir tussock moth on Douglas-fir trees. (Dave Powell, USDA Forest Service, Bugwood.org)

Figure 6. Defoliation and tree mortality caused by Douglas-fir tussock moth. (David McComb, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The Douglas-fir tussock moth has many natural enemies including a nucleopolyhedrosis virus that is capable of dramatically reducing populations, but which usually appears after trees have been seriously defoliated. Many parasitoids are known to attack this species, including a *Telonomus* sp. egg parasitoid, and the larval parasitoids *Phobocampe pallipes* (Provancher) (Ichneumonidae) and *Carcelia yalensis* Sellers (Tachinidae). Parasitoids sometimes hasten the decline of an outbreak.

Web Links for Information on Douglas-fir Tussock Moth

http://insects.ippc.orst.edu/pdf/reb130.pdf.

http://www.forestry.ubc.ca/fetch21/DFTM/dftmtot.html; fact sheet of the University of British Columbia.

http://ext.nrs.wsu.edu/forestryext/foresthealth/notes/douglasmoth.htm; fact sheet of Washington State University.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-86.pdf; USDA Forest Service Forest Insect and Disease Leaflet.

Articles

Mills, N.J. and F. Schoenberg. 1985. Possibilities for the biological control of the Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lymantriidae), in Canada, using natural enemies from Europe. *Biocontrol News and Information* 6(1): 7-18.

Dahlsten, D.L., D.L. Rowney, and W.A. Copper. 1992. Comparison of artificial pupation shelters and other monitoring methods for endemic populations of Douglas-fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera: Lymantriidae). *The Canadian Entomologist* 124: 359-369.

Otvos, I.S., R.F. Shepherd, and J.C. Cunningham. 2001. *Orgyia pseudotsugata* (McDunnough), Douglas-fir tussock moth (Lepidoptera: Lymantriidae). In: Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000*. CABI Publishing, Wallingford, UK: 204-212.

Otvos, I.S. and R.F. Shepherd. 1991. Integration of early virus treatment with a pheromone detection system to control Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae), populations at pre-outbreak levels. *Forest Ecology and Management* 39: 143-151.

164. Poplar Tentmaker, *Clostera inclusa* (Hübner) (Lepidoptera: Notodontidae)

Orientation to Pest

Poplar tentmaker, *Clostera inclusa* (Hübner), is a native notodontid moth that feeds on poplar (*Populus*) and willow (*Salix*) and is found from southern Canada to Georgia, and west to Colorado. Adults fly from March to July in the southern United States and from July to August in the northern part of its U.S. range. Eggs are laid in clusters on the undersides of leaves. Larvae are gregarious and live in tents, which they construct by webbing together the edges of several leaves. The larvae feed through the growing season and move to the ground in late fall, where they pupate in loose cocoons and spend the winter. There are one or two generations per year, depending on the location. Small groups of open-grown trees may be defoliated.

Hosts Commonly Attacked

This caterpillar feeds on poplar (*Populus*) and willow (*Salix*).

Distribution

Poplar tentmaker is found from southern Canada to Georgia, west to Colorado.

Images of Poplar Tentmaker

Figure 1. Adult of poplar tentmaker, *Clostera inclusa*. (Marvin Smith, Bugwood.org)

Images of Poplar Tentmaker (continued)

Figure 2. Egg mass of poplar tentmaker. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 3. Mature larvae of poplar tentmaker. (Robert L. Anderson, USDA Forest Service, Bugwood.org)

Figure 4. Cocoon of poplar tentmaker. (William A. Carothers, USDA Forest Service, Bugwood.org)

Images of Poplar Tentmaker (continued)

Figure 5. Poplars defoliated by poplar tentmaker. (James Solomon, USDA Forest Service, Bugwood.org)

Figure 6. Stand of eastern cottonwood (*Populus deltoides* ssp. *deltoides* Bartram ex Marsh.) defoliated by poplar tentmaker. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Ladybird beetles may consume the eggs of this species.

Web Links for Information on Poplar Tentmaker

http://www.ag.auburn.edu/enpl//bulletins/poplartentmaker/poplartentmaker.htm; fact sheet of Auburn University on biology and control.

http://www.entomology.umn.edu/cues/Web/190PoplarTentmaker.pdf; fact sheet from the University of Minnesota.

Articles

Solomon, J.D. and F.L. Oliveria. 1993. Evaluation of poplar tentmaker defoliation on growth and survival of older cottonwood plantations. Research Paper - Southern Forest Experiment Station, USDA Forest Service (SO-271): 6 p.

165. Saddled Prominent, *Heterocampa guttivitta* (Walker) (Lepidoptera: Notodontidae)

Orientation to Pest

Saddled prominent, *Heterocampa guttivitta* (Walker), is a native North American notodontid that occurs in southeastern Canada and throughout the eastern United States, feeding on beech (*Fagus grandifolia* Ehrh.), paper birch (*Betula papyrifera* Marshall), sugar maple (*Acer saccharum* Marshall) and many other hardwoods. Adults fly in spring and lay up to 500 eggs singly on the host's leaves. Young larvae skeletonize leaves, while older ones consume all but the larger veins. During outbreaks, larvae may move from tree to tree. In mid-summer, larvae move into the leaf litter, where they pupate and then pass the winter. There is one generation per year in the northern part of the insect's range. Periodic outbreaks have occurred, especially in the northeastern United States, and these may defoliate, and sometimes kill or top-kill affected trees.

Hosts Commonly Attacked

This caterpillar feeds most commonly on American beech (*F. grandifolia*), paper birch (*B. papyrifera*), and sugar maple (*A. saccharum*).

Distribution

The saddled prominent occurs in southeastern Canada and throughout the eastern United States.

Images of Saddled Prominent

Figure 1. Adult of saddled prominent, *Heterocampa guttivitta*. (Mark Dreiling, Bugwood.org)

Images of Saddled Prominent (continued)

Figure 2. Eggs of saddled prominent. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Young larvae of saddle prominent have structures near head that resemble horns. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Mature larva of saddled prominent. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 5. Pupal cell (left) and pupa (right, removed from cell) of saddled prominent. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Saddled Prominent (continued)

Figure 6. Appearance of saddle prominent feeding on maple. (USDA Forest Service, Forest Insect & Disease Leaflet 167)

Important Biological Control Agents Related to this Pest Species

The parasitoids recorded from various life stages of the saddled prominent include the scelionid egg parasitoid *Telenomus coelodasidis* Ashmead and the larval parasitoids *Phobocampe pallida* (Cushman) (Ichneumonidae) and *Eulophus anomocerus* (J.C. Crawford) (Eulophidae), both of which were uncommon (<1 percent parasitism). Another ichneumonid, *Cratichneumon sublatus* (Cresson), is the main pupal parasitoid, attacking 1-17 percent under outbreak conditions and 32-57 percent in the year following the collapse of its host's population.

Web Links for Information on Saddled Prominent

http://www.na.fs.fed.us/spfo/pubs/fidls/saddled/fidl-sp.htm; USDA Forest Service Pest and Disease Leaflet No. 167 on biology and control.

http://wiki.bugwood.org/Heterocampa_guttivitta; Bugwood Wiki fact sheet on biology and distribution.

Articles

Fisher, G.T. 1970. Parasites and predators of the species of a saddled prominent complex at Groton, Vermont. *Journal of Economic Entomology* 63: 1613-1614.

Allen, D.C. 1972. Insect parasites of the saddled prominent, *Heterocampa guttivitta* (Lepidoptera: Notodontidae) in the northeastern United States. *The Canadian Entomologist* 104: 1609-1622.

Allen, D.C. 1973. Fecundity of the saddled prominent, *Heterocampa guttivitta*. *Annals of the Entomological Society of America* 66: 1181-1183.

Grimble, D.G. and R.G. Newell. 1973. Damage to sugar maple in New York State from saddled prominent defoliation. Applied Forestry Research Institute Note No. 7. Syracuse, NY, Syracuse University: 4 p.

Spear-O'Mara, J. and D.C. Allen. 2007. Monitoring populations of saddled prominent (Lepidoptera: Notodontidae) with pheromone-baited traps. *Journal of Economic Entomology* 100: 335-342.

166. Walnut Caterpillar, *Datana integerrima* Grote and Robinson (Lepidoptera: Notodontidae)

Orientation to Pest

Walnut caterpillar, *Datana integerrima* Grote and Robinson, is a native North American notodontid whose larvae feed on walnut (*Juglans*), butternut (*J. cinerea* L.), pecan (*Carya illinoinensis* [Wangenh.] K. Koch), and hickory (*C. tomentosa* [Poir.] Nutt.). It is found in southern Ontario (Canada) and throughout the eastern United States. Adults fly in spring and summer and lay their eggs in masses on the undersides of the leaves of the host plants. The larvae feed gregariously until almost mature and are often seen in masses on the trunk and larger limbs, where they congregate to molt. Mature larvae drop to the ground and wander before pupating in the soil. There are one or two generations per year, depending on the location.

Hosts Commonly Attacked

This caterpillar feeds on walnut (*Juglans*), butternut (*J. cinerea*), pecan (*C. illinoinensis*), and hickory (*C. tomentosa*).

Distribution

The walnut caterpillar is found in southern Ontario (Canada) and throughout the eastern United States.

Images of Walnut Caterpillar

Figure 1. Adult of walnut caterpillar, *Datana integerrima*. (Jerry Armstrong, Bugwood.org)

Images of Walnut Caterpillar (continued)

Figure 2. Eggs of walnut caterpillar. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 3. Larvae (middle instars) of walnut caterpillar. (Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 4. Larvae of walnut caterpillar feed in groups. (Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org)

Images of Walnut Caterpillar (continued)

Figure 5. Walnut caterpillars aggregating on branch for molting. (Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org)

Figure 6. Leaf skeletonizing by young larvae of walnut caterpillar. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Walnut Caterpillar (continued)

Figure 7. Complete defoliation of small tree by walnut caterpillar. (Lacy L. Hyche, Auburn University, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Known parasitoids of the walnut caterpillar include *Telenomus ichthyurae* Ashmead and *Tetrastichus* sp. in Texas.

Web Links for Information on Walnut Caterpillar

http://www.na.fs.fed.us/spfo/pubs/fidls/walnutcat/walnutfidl.htm; USDA Forest Service, Pest and Disease Leaflet No. 41

http://www.ento.okstate.edu/ddd/insects/walnutdatana.htm; fact sheet of Oklahoma State University on biology and life cycle.

http://www.ag.auburn.edu/enpl//bulletins/walnutcaterpillar/walnutcaterpillar.htm; fact sheet of Auburn University (Alabama, USA) on biology and control.

http://repository.tamu.edu/bitstream/handle/1969.1/87115/pdf_1558.pdf?sequence=1; fact sheet of the Texas A&M University on biology and control.

Articles on Walnut Caterpillar

Tedders, W.L. and H.C. Ellis. 1977. Aerial application of *Bacillus thuringiensis* var. *kurstaki* (HD-1) to shade and ornamental pecan trees against *Hyphantria cunea* and *Datana integerrima*. *Journal of the Georgia Entomological Society* 12: 248-250.

Farris, M.E. 1978. Bionomics of the walnut caterpillar, *Datana integerrima* G. & R. Urbana, Il: University of Illinois, Dissertation. 106 p.

Farris, M.E. and J.E. Appleby. 1979. The walnut caterpillar, *Datana integerrima* G. & R. In: Anon. Walnut insects and diseases, workshop proceedings. General Technical Report NC-52. U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN: 22-28.

167. Variable Oak Leaf Caterpillar, *Lochmaeus manteo* (Doubleday) (Lepidoptera: Notodontidae)

Orientation to Pest

Variable oak leaf caterpillar, *Lochmaeus manteo* (Doubleday), is a native North American moth whose larvae feed on a wide variety of deciduous trees, especially oaks. The species is found across much of eastern North America. It overwinters as a prepupa in the soil and pupation occurs in early spring, with adult emergence following in May or June. Eggs are laid singly on the leaves of the host plant. The color pattern of larvae is variable. Young larvae skeletonize leaves, but older larvae eat entire leaves apart from the larger veins. There are two generations per year in the southern United States and one in the north. Outbreaks sometimes occur that defoliate large areas; however, tree mortality is usually very low.

Hosts Commonly Attacked

All species of oaks are attacked, but white oak (*Quercus alba* L.) is preferred. Other hosts include American beech (*Fagus grandifolia* Ehrh.), American basswood (*Tilia americana* L.), paper birch (*Betula papyrifera* Marshall), American elm (*Ulmus americana* L.), walnut (*Juglans*), boxelder (*Acer negundo* L.), persimmon (*Diospyros* sp.), and apple (*Malus*).

Distribution

The variable oak leaf caterpillar is found in a wide area in eastern North America, east of a line from western Ontario to eastern Texas.

Images of Variable Oak Leaf Caterpillar

Figure 1. Adult of variable oak leaf caterpillar, *Lochmaeus manteo*. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Images of Variable Oak Leaf Caterpillar (continued)

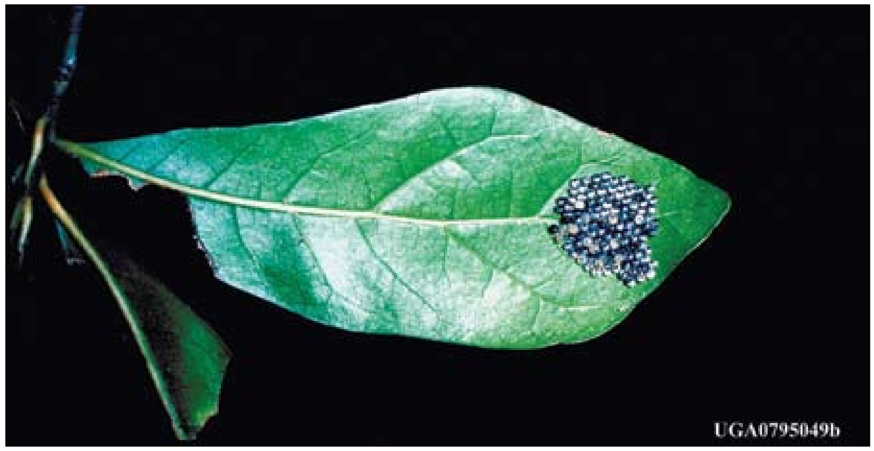


Figure 2. Eggs of variable oak leaf caterpillar. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 3. Young larvae of variable oak leaf caterpillar. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Figure 4. Mature larvae of the variable oak leaf caterpillar (color patterns vary). (Left: Gerald J. Lenhard, Lousiana State University, Bugwood.org; right: Scott Tunnock, USDA Forest Service, Bugwood.org)

Images of Variable Oak Leaf Caterpillar (continued)

Figure 5. Pupae of variable oak leaf caterpillar. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

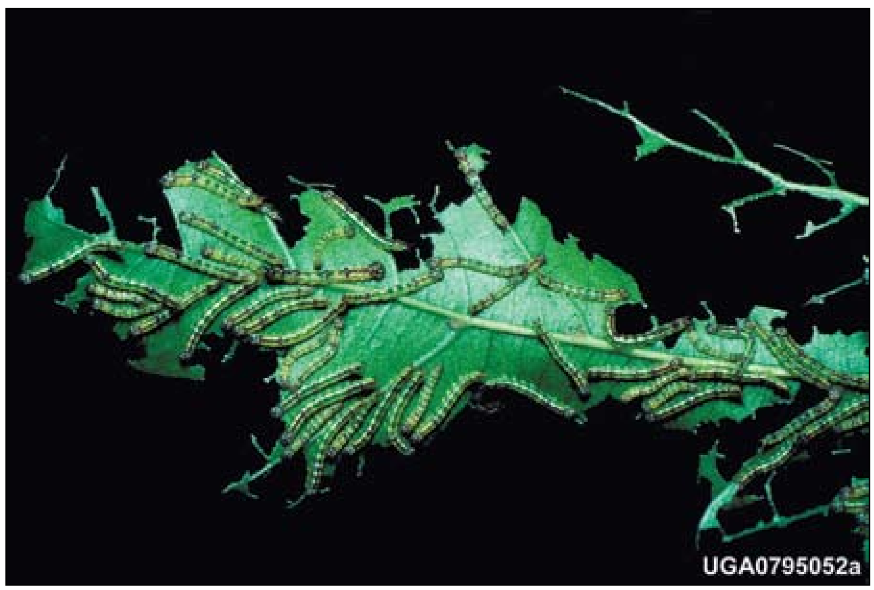


Figure 6. Feeding damage of variable oak leaf caterpillar. (Ronald F. Billings, Texas Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Among the nature enemies of this insect are egg parasitoids in the genera *Trichogramma* and *Telenomus*, which may kill 90 percent of the eggs. Nearly all egg masses have some parasitized eggs; only the eggs concealed within a cluster escape. This high level of parasitism and the failure of many prepupae to pupate in the spring, appear to be the major factors affecting population density. At least seven species of larval parasites attack variable oakleaf caterpillar larvae. The most important species are *Diradops bethunei* Cresson (Ichneumonidae), *Protomicroplitus schizurae* (Braconidae), and *Lespesia schizurae* Sabrosky (Tachinidae), which collectively may kill up to 90 percent of the larvae.

Web Links for Information on Variable Oak Leaf Caterpillar

http://www.fs.fed.us/r8/foresthealth/pubs/oakpests/p5.html; USDA Forest Service Southern Region fact sheet on biology and control.

http://www.maine.gov/doc/mfs/VariableOakLeafCaterpillar_new.htm; fact sheet of the Maine Forest Service on biology and control.

http://na.fs.fed.us/spfo/pubs/fidls/variableOLC/voc.htm; USDA Forest Service Forest Pest and Disease Leaflet No. 67.

Articles

Surgeoner, G.A. and W.E. Wallner. 1978. Foliage consumption by the variable oak leaf caterpillar, *Heterocampa manteo* (Lepidoptera: Notodontidae), its use in defoliation predictions. *The Canadian Entomologist* 110: 241-244.

168. Fall Webworm, *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae)

Orientation to Pest

Fall webworm, *Hyphantria cunea* (Drury), is a native North American tiger moth, the larvae of which feed on the leaves of more than 100 species of forest and shade trees. It is found in southern Canada and throughout the United States. Adults usually fly in late spring or early summer and lay masses of eggs on the undersides of leaves. In the southern United States, adults may be present from early spring through late summer. Larvae web foliage together and feed in groups inside a web, which is expanded as the larvae grow. Young larvae are upper surface skeletonizers, but older larvae consume the entire leaf except for the larger veins. Nearly mature larvae may feed alone outside the web. Larvae move to the ground when ready to pupate, where they spin a thin cocoon in the duff. Regional color variation exists in both adults and larvae. There are one to four generations per year, with multiple generations occurring at more southern latitudes. In its native range this insect has little impact on tree health as defoliation occurs late in the year, when most nutrients are in the roots. It is invasive in Eurasia, and there the level of damage appears to be greater.

Hosts Commonly Attacked

Fall webworm feeds on a more than 100 species of deciduous forest or shade trees. Commonly defoliated plants include hickory (*Carya tomentosa* [Poir.] Nutt.), pecan (*C. illinoinensis* [Wangenh.] K. Koch), walnut (*Juglans*), elm (*Ulmus*), alder (*Alnus*), willow (*Salix*), mulberry (*Morus*), oak (*Quercus*), American sweetgum (*Liquidambar styraciflua* L.), poplar (*Populus*) and numerous species of Rosaceae, e.g., cherry (*Prunus*), apple (*Malus*), and hawthorn (*Crataegus*).

Distribution

Fall webworm is found in southern Canada and throughout the United States.

Images of Fall Webworm

Figure 1. Adults of fall webworm, *Hyphantria cunea*, may be pure white or bear black spots. (Left: Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org; right: Gerald J. Lenhard, Louiana State University, Bugwood.org)

Images of Fall Webworm (continued)

Figure 2. Top, eggs of fall webworm near adult female; bottom, eggs with newly hatched larvae. (Top: Lacy L. Hyche, Auburn University, Bugwood.org; bottom: Ministry of Agriculture and Regional Development Archive, Ministry of Agriculture and Regional Development, Bugwood.org)

Figure 3. Left, young larvae of fall webworm; right, group of young larvae feeding. (Left: Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org; right: Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Fall Webworm (continued)

Figure 4. Top, mature larvae of fall webworm; bottom, larva of orange race. (Top: James B. Hanson, USDA Forest Service, Bugwood.org; bottom: Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 5. Pupa of fall webworm. (Ministry of Agriculture and Regional Development Archive, Ministry of Agriculture and Regional Development, Bugwood.org)

Figure 6. Close up of feeding of fall webworm. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Images of Fall Webworm (continued)

Figure 7. Feeding and webs of fall webworm. (Top: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org; bottom: Steven Katovich, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Many different species of parasitoids are associated with the larvae and pupae of this species in different locations.

Web Links for Information on Fall Webworm

http://ohioline.osu.edu/hyg-fact/2000/2026.html; fact sheet of Ohio State University on biology and control.

http://ento.psu.edu/extension/factsheets/fall-webworm; fact sheet of Pennsylvania State University.

http://www.ag.auburn.edu/enpl/bulletins/fallwebworm/fallwebworm.htm; fact sheet of Auburn University (Alabama, USA).

http://www.umassgreeninfo.org/fact_sheets/defoliators/fall_webworm.html; fact sheet of the University of Massachusetts.

http://www.oregon.gov/ODF/privateforests/docs/fh/FallWebworm.pdf?ga=t; fact sheet of the Oregon Department of Forestry.

http://edis.ifas.ufl.edu/in878; extension publication of the University of Florida.

Articles

Morris, R.F. 1963. Synonymy and color variation in the fall webworm, *Hyphantria cunea* Drury (Lepidoptera: Arctiidae). *The Canadian Entomologist* 95: 1217-1223.

Oliver, A.D. 1964. Studies on the biological control of the fall webworm, *Hyphantria cunea*, in Louisiana. *Journal of Economic Entomology* 57: 314-318.

Warren, L.O. and M. Tadic. 1970. The fall webworm, *Hyphantria cunea* (Drury). Arkansas Agricultural Experiment Station Bulletin No. 759: 106 p.

Yang, Z.Q., J.R. Wei, and X.Y. Wang. 2006. Mass rearing and augmentative releases of the native parasitoid *Chouioia cunea* for biological control of the introduced fall webworm *Hyphantria cunea* in China. *BioControl* 51: 401-418.

Wang, Y., F.Q. Goo, Z. Xu, X. Chen, K. Li, Y.F. Xiao, S.H. Sun, and J.Y. Qi. 2010. Parasitoids and mortality of the overwintering pupal stage of *Hyphantria cunea* (Drury). *Journal of Shenyang Agricultural University* 41(6): 686-689.

169. Arborvitae Leafminer, *Argyresthia thuiella* (Packard) (Lepidoptera: Argresthiidae)

Orientation to Pest

The arborvitae leafminer, *Argyresthia thuiella* (Packard), is a native North American moth that forms mines in foliage of eastern arborvitae (northern white cedar) trees (*Thuja occidentalis* L.) in forests and landscapes. This moth is found in eastern Canada and in the United States, south to Maryland and west to Missouri. It is also invasive in Europe. Adults fly in spring to early summer and adults lay eggs in the axils of branchlets or along the edges of leaves. Newly emerged larvae bore into the leaves and feed the rest of the year there as leafminers. Winter is passed as larvae in mines and pupation occurs in the mine. Adults emerge the following spring. Outbreaks in Maine have severely damaged arborvitae. Damage can also occur in nurseries or on landscape arborvitae.

Hosts Commonly Attacked

This caterpillar feeds on eastern arborvitae (northern white cedar) trees (*T. occidentalis*).

Distribution

The moth is found in eastern Canada and in the United States, south to Maryland and west to Missouri.

Images of Arborvitae Leafminer

Figure 1. Adult of arborvitae leafminer, *Argyresthia thuiella* (moth wingspan is 8 mm); bottom, moth in natural pose. (Top: Petr Kapitola, State Phytosanitary Administration, Bugwood.org; bottom: Tom Murray)

Images of Arborvitae Leafminer (continued)

Figure 2. Mature larvae of arborvitae leafminer, removed from mine. (John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 3. Top, mined (brown) arborvitae foliage; bottom, view of larvae in mine (cut away). (Top: Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org; bottom: Robert Childs, University of Massachusetts, Bugwood.org)

Images of Arborvitae Leafminer (continued)

Figure 4. Arborvitae leafminer pupa. (John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org)

Figure 5. View of damage on landscape arborvitae; top, close up; bottom, general view of damaged plant. (Both photos: Robert Childs, University of Massachusetts, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Canada, natural control of arborvitae leafminers is provided by the widespread parasitoid *Pentacnemus bucculatricis* Howard and also by *Apanteles bedelliae* Viereck. Some 26 species of parasitoids are known to attack this leafminer.

Web Links for Information on Arborvitae Leafminer

http://www.umassgreeninfo.org/fact_sheets/leaf_miners/arborvitae_leafminer.html; fact sheet of the University of Massachusetts on biology and control.

http://www.entomology.umn.edu/cues/Web/064ArborvitaeLeafminer.pdf; fact sheet of the University of Minnesota on biology and control.

http://ccesuffolk.org/assets/Horticulture-Leaflets/Arborvitae-Leafminer.pdf; fact sheet of Cornell Extension.

Articles

Kurir, A. 1983. On the dispersal and biology of the North American arborvitae leafminer, *Argyresthia thuiella* Packard (Lep., Argyresthiidae) in Austria. *Anzeiger für Schädlingskunde Pflanzenschutz Umweltschutz* 56(7): 125-128. (In German).

Anon. 1983. Cedar leafminers. *Argyresthia* spp. Insect Identification Sheet, Agriculture Canada (74): 2 p.

170. Pine Needle Sheathminer, *Zelleria haimbachi* Busck (Lepidoptera: Yponomeutidae)

Orientation to Pest

Pine needle sheathminer, *Zelleria haimbachi* Busck, is a native North American moth that feeds on needles of jack pine (*Pinus banksiana* Lamb.) in Ontario (Canada) and the Great Lakes region of the United States, and on ponderosa (*P. ponderosa* P. & C. Lawson) and lodgepole (*P. contorta* Douglas) in western North America north of Mexico. Larvae create loose silken tunnels next to the bark of first-year shoots, from where they bore through the sheaths and eat the needle bases. Needles die and turn tan, and are loosely held in the sheath. Dead needles easily slip out of the sheaths with a gentle pull. Larvae escape disturbance by wriggling backwards and falling off the shoot, to hang suspended by a strand of silk.

Hosts Commonly Attacked

This caterpillar feeds on jack (*P. banksiana*), lodgepole (*P. contorta*), and ponderosa pine (*P. ponderosa*).

Distribution

The moth is found in Ontario (Canada), the Great Lakes region of the United States, California, and other parts of the western United States.

Images of Pine Needle Sheathminer

Figure 1. Adult of pine needle sheathminer, *Zelleria haimbachi*. (Chris Grinter)

Figure 2. Oviposition scar in needles where eggs have been deposited. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Images of Pine Needle Sheathminer (continued)

Figure 3. Young larvae of pine needle sheathminer, in its sheath feeding stage. (Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Figure 4. Mature larvae of pine needle sheathminer. (Left: Connecticut Agricultural Experiment Station Archive, Connecticut Agricultural Experiment Station, Bugwood.org; right: Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org)

Figure 5. Pupae of pine needle sheathminer (left), also showing close up of webbing and frass associated with feeding; feeding damage seen from a distance (right) on ponderosa pine. (Left: Scott Tunnock, USDA Forest Service, Bugwood.org; right: Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information on natural enemies of this species was found.

Web Links for Information on Pine Needle Sheathminer

None

Articles

Stevens, H.E. 1959. Biology and control of the pine needle-sheath miner, *Zelleria haimbachi* Busck (Lepidoptera; Hyponomeutidae). Pacific Southwest Forest and Range Experiment Station: 20 p.

171. Pine Butterfly, *Neophasia menapia* (Felder and Felder) (Lepidoptera: Pieridae)

Orientation to Pest

The pine butterfly, *Neophasia menapia* (Felder and Felder), is a native North American butterfly that is an important pest of ponderosa pine (*Pinus ponderosa* P. & C. Lawson) in the western United States, where large outbreaks have occurred. Adults fly in late summer and fall, and eggs are laid in rows in groups of 5-20 on current year needles. Eggs overwinter and hatch the following June, or about the time that new needles begin to appear on ponderosa pine. Young larvae eat the old needles first, but new needles are eaten later by older larvae. Larvae attach themselves to needles, twigs, bark, or other objects before pupating. In 2 to 3 weeks, adults emerge and complete the cycle. There is one generation per year. Older trees are more susceptible to injury than younger thriftier trees. Outbreaks usually last 3 or 4 years; most cause little mortality, although intense and widespread outbreaks may result in reduction in tree growth. A few outbreaks have killed extensive stands of older trees when aided by bark beetles.

Hosts Commonly Attacked

In most areas, this caterpillar feeds mainly on ponderosa pine (*P. ponderosa*), but during outbreaks other conifers may also be attacked if intermixed with ponderosa pine, such as lodgepole (*P. contorta* Douglas) and western white (*P. monticola* Douglas ex D. Don) pines, Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.), and western larch (*Larix occidentalis* Nutt.). In the coastal area of northwestern Washington and on Vancouver Island, British Columbia, Canada, outbreaks have occurred in Douglas-fir stands.

Distribution

The butterfly is found throughout the western United States; but outbreaks have occurred primarily in Oregon, Washington, Idaho, Montana, and British Columbia.

Images of Pine Butterfly

Figure 1. Adult female (left) and male (right) of pine butterfly, *Neophasia menapia*. (Left: Ladd Livingston, Idaho Department of Lands, Bugwood.org; right: Terry Spivey, USDA Forest Service, Bugwood.org)

Images of Pine Butterfly (continued)

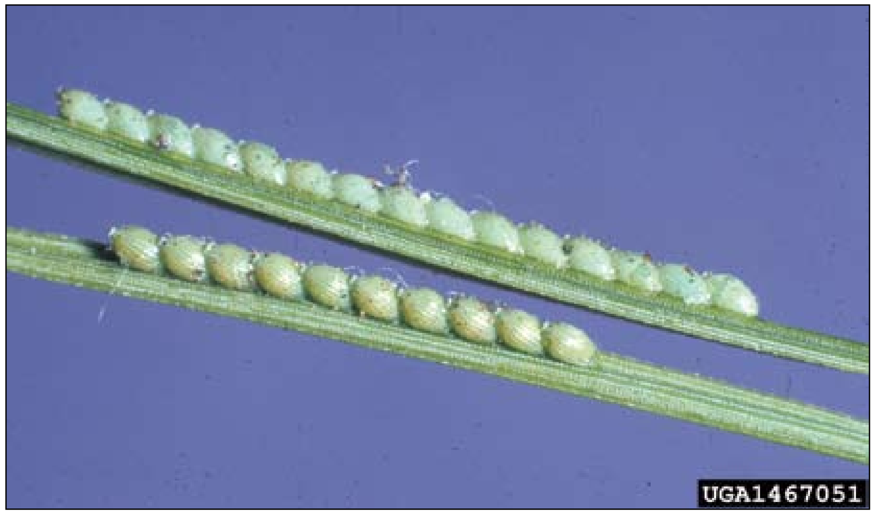


Figure 2. Eggs of pine butterfly. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Figure 3. Young larvae of pine butterfly. (Left: Scott Tunnock, USDA Forest Service, Bugwood.org; right: USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Images of Pine Butterfly (continued)

Figure 4. Mature larva of pine butterfly. (Ladd Livingston, Idaho Department of Lands, Bugwood.org)

Figure 5. Pupa of pine butterfly. (Jerald E. Dewey, USDA Forest Service, Bugwood.org)

Images of Pine Butterfly (continued)

Figure 6. Feeding damage of pine butterfly on ponderosa pines. (USDA Forest Service - Ogden Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Several insects, including hemipterans (*Podisus* spp. and *Apoecilus* spp.), snakeflies (*Raphidia* spp.), sarcophagid flies (*Agria* spp.), and wasps (Ichneumonidae) have been reported preying on different stages of pine butterfly. Decline of the 1922-23 outbreak of this butterfly was attributed to mortality from some of these natural enemies, especially a native ichneumon parasite, *Theronia atalantae* (Poda).

Web Links for Information on Pine Butterfly

http://butterfly.ucdavis.edu/butterfly/Neophasia/menapia; website on this insect from a natural history point of view.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000029&ind=P; fact sheet of Natural Resource Canada on biology and phenology.

http://extension.oregonstate.edu/mwm/w10fhmbutterfly; extension note of Oregon State University.

Articles

Evenden, J.C. 1926. The pine butterfly, *Neophasia menapia* Felder. *Journal of Agricultural Research* 33(4): 339-344.

Evenden, J.C. 1940. Effects of defoliation by the pine butterfly upon ponderosa pine. *Journal of Forestry* 38(12): 949-955.

Cole, W.E. 1966. Effect of pine butterfly defoliation on ponderosa pine in southern Idaho. *Research Note INT-46*. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 7 p.

Young, R.M. 1986. Mass emergences of the pine white, *Neophasia menapia menapia* (Felder & Felder), in Colorado (Pieridae). *Journal of the Lepidopterists' Society* 40 (4): 314.

172. Balsam Gall Midge, *Paradiplosis tumifex* Gagné (Diptera: Cecidomyiidae)

Orientation to Pest

Balsam gall midge, *Paradiplosis tumifex* Gagné, is a native North American cecidomyiid fly that galls needles of balsam (*Abies balsamea* [L.] Miller) and Fraser fir (*A. fraseri* [Pursh] Poir.). In older literature, these galls were mistakenly attributed to another species, *Dasineura balsamicola* (Lintner), which is an inquiline that invades the galls of *P. tumifex*, killing it and feeding on the gall tissue. *Paradiplosis tumifex* has a wide distribution, being found throughout the ranges of its two main hosts. The gall midge overwinters as a larva in the soil under an infested host tree. Pupation takes place in spring, and adult emergence occurs shortly thereafter. Eggs are laid in developing needles, and larval feeding causes quick development of gall tissue in immature needles. In late fall, larvae leave the galls and drop to the ground for the winter. There is one generation per year. Galling is of concern only in Christmas tree plantations, not forests.

Hosts Commonly Attacked

This gall midge attacks needles of balsam fir (*A. balsamea*) and Fraser fir (*A. fraseri*).

Distribution

This species is found throughout the ranges of balsam and Fraser firs, being much of southeastern Canada and adjacent areas of the northeastern United States (range of balsam fir), plus the sky islands of the southern Appalachian Mountains (range of Fraser fir).

Images of Balsam Gall Midge

Figure 1. Adult balsam gall midge, *Paradiplosis tumifex*. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Images of Balsam Gall Midge (continued)

Figure 2. Balsam gall midge galls on balsam fir. (Ronald S. Kelley, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 3. Larvae of the balsam gall midge exposed by opening the gall. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Parasitoids of this gall maker include the encyrtids *Pseudoencyrtus borealis* MacGown, *Tetrastichus cecidivorus* MacGowan, *Tetrastichus marcovitchi* (Crawford), *Tetrastichus whitmani* (Firault), and the platygasterids *Platygaster abicollis* MacGown and Osgood and *Playtgaster mainensis* MacGown and Osgood.

Web Links for Information on Balsam Gall Midge

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=3708; fact sheet of Natural Resources Canada on biology and phenology.

http://www.maine.gov/doc/mfs/balsgalmid.htm; fact sheet of the state of Maine.

http://extension.unh.edu/resources/files/Resource000986_Rep2348.pdf; highly detailed power point presentation on biology and control of this gall maker.

Articles

Osgood, E.A. and R.J. Gagné. 1978. Biology and taxonomy of two gall midges (Diptera : Cecidomyiidae) found in galls on balsam fir needles with description of a new species of *Paradiplosis*. *Annals of the Entomological Society of America* 71: 85-91.

West, R.J. and J.D. Shorthouse. 1982. Morphology of the balsam fir needle gall induced by the midge *Paradiplosis tumifex* (Diptera: Cecidomyiidae). *Canadian Journal of Botany* 60: 131-140.

Räther, M. and N.J. Mills. 1989. Possibilities for the biological control of the Christmas tree pests, the balsam gall midge, *Paradiplosis tumifex* Gagné (Diptera: Cecidomyiidae) and the balsam twig aphid, *Mindarus abietinus* Koch (Homoptera: Mindaridae), using exotic enemies from Europe. *Biocontrol News and Information* 10(2): 119-129.

Osgood, E.A., R.L. Bradbury, and F.A. Drummond. 1992. The balsam gall midge - an economic pest of balsam fir Christmas trees. Maine Agricultural Experiment Station Technical Bulletin No. 151: 30 p. (Available at http://library.umaine.edu/maineaes/technicalbulletin/tb151.pdf).

173. Poplar Leafcurl Midge, *Prodiplosis morrisi* Gagné (Diptera: Cecidomyiidae)

Orientation to Pest

The poplar leafcurl midge, *Prodiplosis morrisi* Gagné, is a native North American cecidomyiid fly that lays its eggs on developing cottonwood terminals. The larvae feed on surfaces of expanding leaves, causing them to curl into elongated, largely cylindrical shapes. Leaves may stay green with only curled edges turning brown, or leaf may be killed. With sufficient feeding, terminal shoots may become stunted or killed. Trees of all sizes may be attacked. There may be up to five or more generations per year. Each generation damages 1 to 2 whorls of leaves, and because there is a short period between generations, normal leaves alternate with damaged leaves. The many larvae that develop in each curled leaf drop to the soil beneath the tree to pupate. Larvae of the last generation overwinter in the soil.

Hosts Commonly Attacked

This midge attacks various species of *Populus*, including eastern cottonwood (*P. deltoides* W. Bartram ex Humphry Marshall), quaking aspen (*P. tremuloides* Michx.), and *Populus* hybrids.

Distribution

This species is of greatest importance in the southern United States, in cottonwood plantations.

Images of Poplar Leafcurl Midge

Figure 1. Injury to cottonwood seedling from poplar leafcurl midge, *Prodiplosis morrisi*. (James Solomon, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on natural enemies of this species.

Web Links for Information on Poplar Leafcurl Midge

http://wiki.bugwood.org/Archive:Poplar/Prodiplosis_morrisi; Bugwood Wiki fact sheet on biology.

Articles

Gagné, R.J. 1966. A new species of *Prodiplosis* (Diptera: Cecidomyiidae) found in leaf curls on *Populus deltoides*. *Annals of the Entomological Society of America* 59: 1154-1157.

Gagné, R.J. 1989. *The Plant-feeding Gall Midges of North America*. Cornell University Press. Ithaca, New York: 340 p.

Ostry, M.E., L.F. Wilson, H.S. McNabb, Jr., and L.M. Moore. 1988. *A Guide to Insect, Disease, and Animal Pests of Poplars*. Agricultural Handbook No. 677. U.S. Department of Agriculture, Washington, DC: 118 p.

Skuhravý, V., M. Skuhravá and J.W. Brewer. 1997. Gall midges (Dipt., Cecidomyiidae) associated with *Populus tremula*, *P. tremuloides* and their hybrid (Salicaceae). *Journal of Applied Entomology* 121: 315-320.

174. Douglas-fir Needle Midge, *Contarinia pseudotsugae* Condrashoff (Diptera: Cecidomyiidae)

Orientation to Pest

Douglas-fir needle midge, *Contarinia pseudotsugae* Condrashoff, is one of three species in this genus of native North American cecidomyiid flies that lay their eggs in developing needles of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco). This is the most abundant of the three. It is a significant pest of Douglas-fir when it is grown as Christmas trees, particularly in the dry-belt of open-grown interior forests in the Pacific northwestern United States in California, Oregon, Washington, Idaho, Montana, and in British Columbia, Canada. Adults emerge from the soil in spring and lay eggs on needles. The larvae bore into needles to feed, causing their growth to be deformed. In the fall, mature larvae drop back into the soil to pupate and overwinter. Damaged needles bear small galls and heavily galled Christmas trees have lower market value. There is one generation of this fly per year.

Hosts Commonly Attacked

The only known host of this insect is Douglas-fir (*P. menziesii*).

Distribution

This species is of concern in the Pacific northwestern United States (California, Oregon, Washington, Idaho, and Montana) and British Columbia, Canada, but is also found in Pennsylvania.

Images of Douglas-fir Needle Midge

Figure 1. Adult of Douglas-fir needle midge, *Contarinia pseudotsugae*. (USDA Forest Service Archive, USDA Forest Service, Bugwood.org)

Images of Douglas-fir Needle Midge (continued)

Figure 2. Larva of Douglas-fir needle midge inside its gall, which has been cut open. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 3. Douglas-fir needles (top) showing injury due to Douglas-fir needle midge; and, bottom, damage in an earlier stage. (Top: Elizabeth Willhite, USDA Forest Service, Bugwood.org; bottom: Rayanne Lehman, Pennsylvania Department of Agriculture, Bugwood.org)

Figure 4. Damage to Douglas-fir from Douglas-fir needle midge. (Left: USDA Forest Service Archive, USDA Forest Service, Bugwood.org; right: Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information is available on natural enemies of this species.

Web Links for Information on Douglas-fir Needle Midge

http://extension.psu.edu/ipm/program/christmas-tree/pest-fact-sheets/needle-discoloration-and-injury/Douglas-fir.pdf; fact sheet of Pennsylvania State University on biology and control.

http://oregonstate.edu/dept/nurserystartup/onnpdf/onn060108.pdf; fact sheet of Oregon State University, helpful in determining a spray schedule for this pest.

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5187407.pdf; fact sheet of the USDA FS Forest Health Protection unit on recognition and biology.

Articles

Condrashoff, S.F. 1961. Three new species of *Contarinia* (Diptera: Cecidomyiidae) in Douglas-fir needles. *The Canadian Entomologist* 93(2): 123-130.

Condrashoff, S.F. 1962. Bionomics of three closely related species of *Contarinia* Cond. (Diptera: Cecidomyiidae) from Douglas-fir needles. *The Canadian Entomologist* 94: 376-394.

175. Pine False Webworm, *Acantholyda erythrocephala* (L.) (Hymenoptera: Pamphiliidae)

Orientation to Pest

Pine false webworm, *Acantholyda erythrocephala* (L.), is an introduced pamphiliid sawfly of European origin that is now present in several parts of eastern North America and Canada. It feeds on several pines. Winter is passed as prepupae, which pupate in the spring. Adults emerge soon after and lay eggs in short rows of 3 to 10 eggs in small slits cut into last year's needles. Young larvae spin loose webs in which they feed gregariously on old needles, which they cut off and then pull into the web to eat. Older larvae are solitary and feed from silken tubes bound to twigs. Frass and bits of needles stick to these silk tubes. When mature, larvae drop to the ground, build earthen cells, and overwinter as prepupae. Heavy infestations can defoliate hosts and cause tree mortality.

Hosts Commonly Attacked

This sawfly feeds especially on eastern white (*Pinus strobus* L.) and red (*P. resinosa* Sol. ex Aiton), but also Scotch (*P. sylvestris* L.), Austrian (*P. nigra* J. F. Arnold), and Japanese red (*P. densiflora* Siebold & Zucc.) pines.

Distribution

This sawfly is found in New England, New York, New Jersey, Pennsylvania, Wisconsin, Minnesota, Newfoundland, Alberta, Quebec, and Ontario.

Images of Pine False Webworm

Figure 1. Top, adult male (right) and female (left) of pine false webworm, *Acantholyda erythrocephala*, in copula; and, bottom, adult female ovipositing on red pine foliage. (Both photos: Barry Lyons, Canadian Forest Service, Bugwood.org)

Images of Pine False Webworm (continued)

Figure 2. Eggs of pine false webworm on red pine foliage. (Barry Lyons, Canadian Forest Service, Bugwood.org)

Figure 3. Top, neonate larva of pine false webworm emerging from the egg; and bottom, ultimate instar larva climbing on silk strands outside the web. (Both photos: Barry Lyons, Canadian Forest Service, Bugwood.org)

Images of Pine False Webworm (continued)

Figure 4. Damage (shoots with clipped off needles) by pine false webworm on young plantation-grown red pine. (Barry Lyons, Canadian Forest Service, Bugwood.org)

Figure 5. Defoliation in pine plantations in Simcoe Co., Ontario, due to pine false webworm. (Barry Lyons, Canadian Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Since this is an invasive species in North America, the parasitoids from its native range in Europe have been investigated for introduction. The most important such species is the tachinid *Myxexoristops hertingi* Mesnil, which has been released in Ontario, Canada.

Web Links for Information on Pine False Webworm

http://bugs.osu.edu/bugdoc/Shetlar/factsheet/christmasstree/pine_false_webworm.htm; fact sheet of Ohio State University on biology and control of pine false webworm for Christmas tree growers.

http://www.dec.ny.gov/docs/lands_forests_pdf/pfw.pdf; article concerning importance of pine false webworm in New York.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000130; fact sheet of Natural Resources Canada.

Articles

Lyons, D.B. 1995. Pine false webworm, *Acantholyda erythrocephala*. In: Armstrong, J.A. and W.G.H. Ives (eds.). *Forest Insect Pests in Canada*. Natural Resources Canada, Canadian Forest Service, Ottawa: 245-251.

Kessel, C. 1998. The impact of the pine false webworm on the Ontario Christmas tree industry. In: Lyons, D.B., G.C. Jones, and T.A. Scarr (eds.). *Proceedings of a workshop on the pine false webworm, Acantholyda erythrocephala (Hymenoptera: Pamphiliidae)*. University of Toronto, Toronto, Ontario, Canada, 16 February 1998.

Asaro, C. and D.C. Allen. 2001. History of a pine false webworm (Hymenoptera: Pamphiliidae) outbreak in northern New York. *Canadian Journal of Forest Research* 31: 181-185.

Kenis, M. and K. Kloosterman. 2001. European parasitoids of the pine false webworm (*Acantholyda erythrocephala* [L.]) and their potential for biological control in North America. In: Liebhold, A.M., M.L. McManus, I.S. Otvos, S.L.C. Fosbroke (eds.). Proceedings of a conference entitled "Integrated management and dynamics of forest defoliating insects" held 1999 August 15-19, Victoria, British Columbia, and published as General Technical Report NE-277. U.S. Department of Agriculture, Forest Service, Northeastern Research Station, Newtown Square, Pennsylvania, USA: 65-73. (Available at http://iufro-archive.boku.ac.at/wu70307/victoria/kenis.pdf).

Lyons, D.B., M. Kenis, and R.S. Bourchier. 2002. *Acantholyda erythrocephala* (L.), pine false webworm (Hymenoptera: Pamphiliidae). In: Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000*. CABI, Wallingford, UK: 22-28.

176. Redheaded Pine Sawfly, *Neodiprion lecontei* (Fitch) (Hymenoptera: Diprionidae)

Orientation to Pest

Redheaded pine sawfly, *Neodiprion lecontei* (Fitch), is a native North American sawfly that defoliates various pines. Conifers in other genera may also be fed on when they grow intermixed with preferred species. This sawfly is found in southeastern Canada and throughout the eastern United States. It overwinters as a prepupa in the soil. Pupation occurs in spring and adults emerge soon after. Eggs are inserted in needles of either the current or previous year's growth. A single female may lay up to 150 eggs. The larvae feed gregariously on either old or new needles, or even bark of tender twigs. Young larvae partially consume needles and cause them to dry out and curl, giving a straw-like appearance. Older larvae may consume entire needles. In some cases, trees may be completely defoliated. To prepare for winter, mature larvae drop from the foliage to the ground, where they spin a cocoon and molt to the pre-pupal stage. There are three generations per year in the southern United States but only one in the northern part of the United States and in Canada. This is one of the most damaging sawflies in North America. Trees at greatest risk are stressed trees growing on shallow soils, very wet or dry sites, or ones where trees are experiencing severe competition from other vegetation. Reducing vegetative competition, avoiding planting on poor sites, and using tight spacing to encourage early canopy closure are recommended to reduce damage from this sawfly to pines grown in plantations.

Hosts Commonly Attacked

The main hosts of redheaded pine sawfly are jack (*Pinus banksiana* Lambert), red (*P. resinosa* Sol. ex Aiton), shortleaf (*P. echinata* Mill.), loblolly (*P. taeda* L.), slash (*P. elliottii* Engelm.), longleaf (*P. palustris* Mill.), and pitch (*P. rigida* Mill.) pines.

Distribution

This sawfly is found in southeastern Canada and throughout the eastern United States.

Images of Redheaded Pine Sawfly

Figure 1. Adult redheaded pine sawfly, *Neodiprion leconte*. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Redheaded Pine Sawfly (continued)

Figure 2. Eggs of redheaded pine sawfly being laid (top) and, bottom, close up of eggs in pine needle. (Top: James McGraw, North Carolina State University, Bugwood.org; bottom: Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 3. Larvae of redheaded pine sawfly; left, close up of two, and right, a large aggregation of feeding larvae. (Left: Gerald J. Lenhard, Louisiana State University, Bugwood.org; right: Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org)

Figure 4. Cocoons of redheaded pine sawfly. (Lacy L. Hyche, Auburn University, Bugwood.org)

Images of Redheaded Pine Sawfly (continued)

Figure 5. Characteristic "straw" damage caused by redheaded pine sawfly larvae. (G. Keith Douce, University of Georgia, Bugwood.org)

Figure 6. Damage (branches with clipped off needles) to longleaf pines by redheaded pine sawfly. (Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Important natural enemies of this sawfly include a nuclear polyhedrosis virus that has been developed in Canada as a biopesticide, the egg parasitoid *Closterocerus cinctipennis* Ashmead, and tachinid larval parasitoids in the genus *Spathimeigenia*.

Web Links for Information on Redheaded Pine Sawfly

http://www.forestpests.org/vermont/redheadsawfly.html; fact sheet of the Vermont Department of Forests, Parks, and Recreation on biology and control.

http://edis.ifas.ufl.edu/in882; fact sheet of the University of Florida on biology and control.

http://pubs.ext.vt.edu/3006/3006-1453/3006-1453_pdf.pdf; fact sheet of the Virginia Tech extension on biology and control.

http://ohioline.osu.edu/hyg-fact/2000/2554.html; fact sheet of Ohio State University extension on biology and control.

Articles

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Drooz, A.T., R.C. Wilkinson, and V.H. Fedde. 1977. Larval and cocoon parasites of three Neodiprion sawflies in Florida. *Environmental Entomology* 6: 60-62.

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Hyche, L.L. 1992.The redheaded pine sawfly (*Neodiprion lecontei*): a guide to recognition and habits. Bulletin No. 617 of the Alabama Agricultural Experiment Station. Auburn University, Auburn, Alabama: 11 p.

Wilson, L.F., R.C. Wilkinson, Jr., and R.C. Averill. 1992. Redheaded pine sawfly - its ecology and management. USDA Forest Service Handbook No. 694: 54 p.

177. Swaine Jack Pine Sawfly, *Neodiprion swainei* (Middleton) (Hymenoptera: Diprionidae)

Orientation to Pest

Swaine jack pine sawfly, *Neodiprion swainei* (Middleton), is a native North American sawfly. It is considered to be the most important sawfly pest of pines in eastern Canada. Its preferred host is jack pine (*Pinus banksiana* Lambert), but other species of pines will also be defoliated if they grow near an outbreak of this sawfly on jack pine. This sawfly is found in the Great Lakes states of the United States and throughout most of the range of jack pine in Canada (from Nova Scotia west to Alberta). Outbreaks, though, have only been recorded in Ontario and Quebec. Swaine jack pine sawfly overwinters as a prepupa in cocoons in the litter or topsoil. Pupation occurs in spring and adults emerge soon after. In June or July, females lay one to three eggs per needle in the current year's growth. The larvae feed gregariously on old needles, usually on trees in exposed locations. Mature larvae drop from foliage to the ground, where they spin a cocoon in the duff and molt to the prepupa, the overwintering stage. There is one generation per year. Many outbreaks of this sawfly occurred in Ontario and Quebec up until the 1960s, usually at about 8 year intervals, on poor sites (for jack pine) on outwash plains. The last significant defoliation (in Canada) occurred over 440 ha in Quebec in 1994. In stands of mature trees, most trees may either be killed or, if they survive, will be stag-headed (killed on top). In the Great Lakes states (in the United States), outbreaks have occurred mainly in plantations or windbreaks. A nuclear polyhedrosis virus that is specific to this sawfly was discovered in the 1960s and developed as a potential biopesticide. It provided effective control but was never developed as a commercial pesticide.

Hosts Commonly Attacked

The main host of the Swaine jack pine sawfly is jack pine (*P. banksiana* Lambert), but other pines that may be defoliated if near an outbreak of this sawfly include red (*P. resinosa* Sol. ex Aiton), eastern white (*P. strobus* L.), and Scotch (*P. sylvestris* L.) pines.

Distribution

This sawfly is found in Canada from Nova Scotia west to Alberta and in the Great Lakes states of the United States.

Images of Swaine Jack Pine Sawfly

Figure 1. Adult Swaine jack pine sawfly, *Neodiprion swainei*. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Swaine Jack Pine Sawfly (continued)

Figure 2. Eggs of Swaine jack pine sawfly. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Larvae of Swaine jack pine sawfly. (Both photos: Catherine Linnen, University of Kentucky, Bugwood.org)

Figure 4. Damage to jack pine by Swaine jack pine sawfly. (Claude Monnier - Natural Resources Canada, Canadian Forest Service)

Images of Swaine Jack Pine Sawfly (continued)

Figure 5. Jack pines defoliated by Swaine jack pine sawfly. (Robert Gagnon - Natural Resources Canada, Canadian Forest Service)

Important Biological Control Agents Related to this Pest Species

Important natural enemies of this sawfly include a nuclear polyhedrosis virus and various larval parasitoids. Red wood ants (Formicidae) were also introduced from Manitoba and Italy into Quebec as pupal predators.

Web Links for Information on Swaine Jack Pine Sawfly

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=6585; fact sheet of Natural Resources Canada on biology and control.

Articles

Smirnoff, W.A. 1961. Predators of larvae of *Neodiprion swainei* Midd. (Hymenoptera: Tenthredinidae). *The Canadian Entomologist* 93: 272-275.

Smirnoff, W.A., J.J. Fettes, and W. Haliburton. 1962. A virus disease of Swaine's jack pine sawfly, *Neodiprion swainei* Midd., sprayed from an aircraft. *The Canadian Entomologist* 94: 477-486.

McLeod, J.M. 1970. The epidemiology of the Swaine jack-pine sawfly, *Neodiprion swainei* Midd. The Forestry Chronicle April issue: 126-130. (Available at http://pubs.cif-ifc.org/doi/pdf/10.5558/tfc46126-2; provides details of timing and stand location where outbreaks have occurred in Quebec).

Price, P.W. and H.A. Tripp. 1972. Activity patterns of parasitoids on the Swaine jack pine sawfly, *Neodiprion swainei* (Hymenoptera: Diprionidae), and parasitoid impact on the host. *The Canadian Entomologist* 104: 1003-1016.

Price, P.W., R.H. MacArthur, and E.O. Wilson. 1973. Parasitoid strategies and community organization. *Environmental Entomology* 2: 623-626.

Finnegan, R.J. and W.A. Smirnoff. 1984. *Neodiprion swainei* (Middleton), Swaine jack pine sawfly (Hymenoptera: Diprionidae). In: Kelleher, J.S. and M.A. Hulme (eds.). *Biological Control Programmes against Insects and Weeds in Canada 1969-1980*. Commonwealth Agricultural Bureaux, Slough, United Kingdom: 341-348.

178. European Pine Sawfly, *Neodiprion sertifer* (Geoffroy) (Hymenoptera: Diprionidae)

Orientation to Pest

European pine sawfly, *Neodiprion sertifer* (Geoffroy), is a European species that is invasive in North America. It feeds on many species of pines. This sawfly occurs across Canada and widely in the eastern United States. The winter is passed as eggs, which hatch in early spring. Larvae feed gregariously on old needles. New foliage is never eaten. Larvae move from tree to tree as necessary for food. Mature larvae drop from foliage to the ground, where they spin a cocoon in the duff and pupate. Adults emerge in late summer and lay 6 to 8 eggs per needle in new foliage. There is one generation per year. Trees attacked by this sawfly are never killed because new foliage is not eaten. Damage consists of reduced tree growth in forests or loss of quality in Christmas tree plantations.

Hosts Commonly Attacked

European pine sawfly feeds on many species of pines, but especially on Scots (*Pinus sylvestris* L.), red (*P. resinosa* Sol. ex Aiton), jack (*P. banksiana* Lambert), Japanese red (*P. densiflora* Siebold & Zucc.), and Table mountain pines (*P. pungens* Lamb.). Other species of pines will also be defoliated if they grow near an outbreak of this sawfly.

Distribution

This sawfly is found in Newfoundland, Nova Scotia, New Brunswick, Ontario, Quebec, and British Columbia in Canada, and in the eastern United States from New England west to North Dakota, and south to Missouri.

Images of European Pine Sawfly

Figure 1. Adults of European pine sawfly, *Neodiprion sertifer*; top, female; bottom, male (note enlarged antennae). (Both photos: Louis-Michel Nageleisen, Département de la Santé des Forêts, Bugwood.org)

Images of European Pine Sawfly (continued)

Figure 2. Egg scars of European pine sawfly in needles of Scots pine. (Andrea Battisti, Universita di Padova, Bugwood.org)

Figure 3. Larvae of European pine sawfly. (Top: Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org; bottom: Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 4. Pupal cocoons of European pine sawfly. (Jim Occi, BugPics, Bugwood.org)

Images of European Pine Sawfly (continued)

Figure 5. Damage to red pine by European pine sawfly larvae; note that only old needles are eaten. (Both photos: Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 6. Larvae of European pine sawfly killed by a virus (note the characteristic position, hanging head down). (John D. Kegg, New Jersey Department of Agriculture, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Important natural enemies of this sawfly include an imported European nuclear polyhedrosis virus that is used effectively as a biopesticide, and several European larval parasitoids, which have not provided control of this pest.

Web Links for Information on European Pine Sawfly

http://ohioline.osu.edu/hyg-fact/2000/2555.html; fact sheet of Ohio State University on biology and control.

http://ento.psu.edu/extension/factsheets/european-pine-sawfly; fact sheet of Pennsylvania State University on biology and control.

http://www.forestpests.org/vermont/europeansawfly.html; fact sheet of Vermont Department of Forests, Parks, and Recreation.

http://www.exoticpests.gc.ca/ins_details_eng.asp?pestType=ins&lang=lt&geID=6583; website of Forest Invasive Alien Species (Government of Canada).

Articles

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Entwistle, P.F., H.F. Evans, K.A. Harrap, and J.S. Robertson. 1978. Field trials on the control of the pine sawfly, *Neodiprion sertifer*, using purified nuclear polyhedrosis virus. Technical Report, Unit of Invertebrate Virology, Natural Environment Research Council (UK): 62 p.

Gur'yanova, T.M. 1979. Significance of the diapause of the parasite *Exenterus abruptorius* (Ichneumonidae) in the dynamics of numbers of the red pine sawfly (*Neodiprion sertifer*). *Zoologicheskii Zhurnal* 58 (9): 1339-1349.

179. Virginia Pine Sawfly, *Neodiprion pratti pratti* (Dyar) (Hymenoptera: Diprionidae)

Orientation to Pest

Virginia pine sawfly, *Neodiprion pratti pratti* (Dyar), is a native North American sawfly that feeds on Virginia (*Pinus virginiana* Mill.) and shortleaf (*P. echinata* Mill.) pines. It is found from New Jersey south to North Carolina and west to Illinois. The winter is passed as eggs, which hatch in early spring. Larvae feed gregariously on old needles. Mature larvae drop from foliage to the ground, where they spin cocoons in the duff and pupate. Adults emerge in late summer and lay eggs individually in needles. There is one generation per year. Trees attacked by this sawfly are not killed, but tree growth in forests is reduced. A large outbreak of this species (5.6 million acres) occurred in the 1950s in Maryland, Virginia, and North Carolina. Note, this species should not be confused with *Neodiprion pratti* (Dyar), a species associated with sand pine (*P. clausa* [Chapm. ex Engelm.] Sarg.).

Hosts Commonly Attacked

Virginia pine sawfly feeds on Virginia (*P. virginiana* Mill.) and shortleaf (*P. echinata* Mill.) pines.

Distribution

Virginia pine sawfly is found from New Jersey south to North Carolina and west to Illinois.

Images of Virginia Pine Sawfly

Figure 1. Adult male of Virginia pine sawfly, *Neodiprion pratti pratti*. (USDA Forest Service - Region 8 - Southern Archive, USDA Forest Service, Bugwood.org)

Images of Virginia Pine Sawfly (continued)

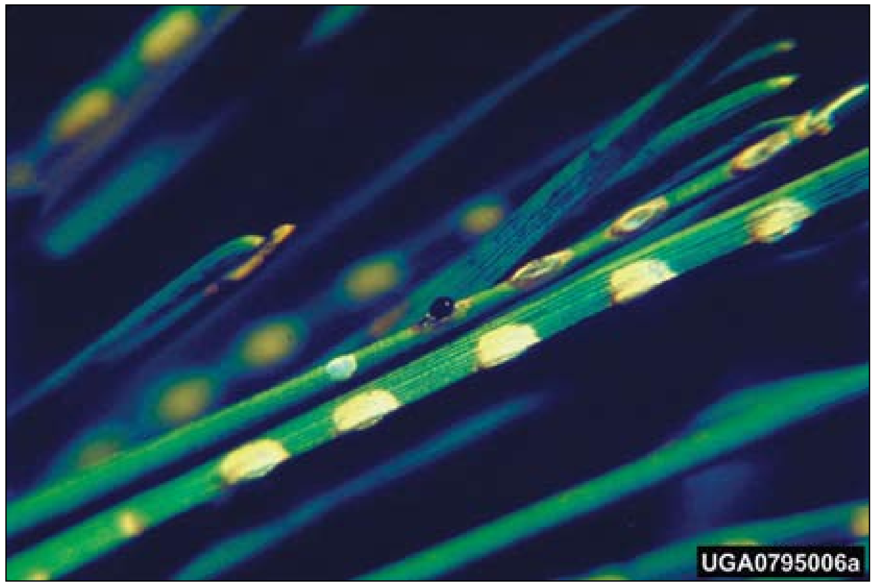

Figure 2. Egg scars of Virginia pine sawfly on pine needles. (Caleb L. Morris, Virginia Department of Forestry, Bugwood.org)

Figure 3. Larvae of Virginia pine sawfly. (USDA Forest Service - Forest Health Protection, Southern Region)

Figure 4. Feeding damage of Virginia pine sawfly. (USDA Forest Service - Ashville Archive, USDA Forest Service, Bugwood.org)

Images of Virginia Pine Sawfly (continued)

Figure 5. Pine stand defoliated by Virginia pine sawfly. (Caleb L. Morris, Virginia Department of Forestry, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

No information was found on the natural enemies of this species.

Web Links for Information on Virginia Pine Sawfly

http://www.fs.fed.us/r8/foresthealth/idotis/insects/vapinesf.html; USDA Forest Service fact sheet on biology and control.

http://pubs.ext.vt.edu/2911/2911-1424/2911-1424.html; Virginia Extension Service fact sheet on biology and control.

http://entnemdept.ufl.edu/creatures/trees/sawfly/pine_sawflies.htm; fact sheet of the University of Florida; compares some details among a number of sawfly species that feed on pine, including Virginia pine sawfly.

http://www.forestpests.org/acrobat/not%20linked/gfc-01.pdf; fact sheet of the Georgia Forestry Commission; provides drawings that compare body markings of larvae of various sawflies that feed on pines.

Articles

None

180. Hemlock Sawfly, *Neodiprion tsugae* Middleton (Hymenoptera: Diprionidae)

Orientation to Pest

The hemlock sawfly, *Neodiprion tsugae* Middleton, is an important native defoliator of western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in western North America. This sawfly overwinters as eggs, which are laid in the fall in needles of the current year's growth, usually one egg per needle. Eggs hatch in spring and the larvae feed into early summer. Young larvae usually feed gregariously, but change to feeding singly as they mature. The larvae eat the old needles, reducing growth but rarely killing trees. Mature larvae drop to the duff where they spin cocoons. Usually there is one generation a year, but some larvae take more than one year to complete their life cycle. Extensive outbreaks on western hemlock have been recorded in natural forests in Oregon, British Columbia, and Alaska, often in association with outbreaks of blackheaded budworm (*Acleris gloverana* Walsingham). In coastal Alaska, defoliation can be concentrated on large trees on southern and western slopes near waterways. In British Columbia when hemlock sawfly is associated with blackheaded budworm, thinned stands have been reported to suffer heavier defoliation than unthinned stands.

Hosts Commonly Attacked

The main host is western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), but in addition, mountain hemlock (*T. mertensiana* [Bong.] Carr). and Pacific silver fir (*Abies amabilis* Douglas ex J. Forbes) are sometimes attacked as well.

Distribution

This sawfly is found in coastal forests of western North America in Oregon, Washington, British Columbia, and Alaska. It also occurs in interior forests of British Columbia, Idaho, and Montana.

Figure 1. North American distribution of hemlock sawfly, *Neodiprion tsugae*. (USDA Forest Service • Forest Insect and Disease Leaflet 31)

Images of Hemlock Sawfly

Figure 2. Adult of hemlock sawfly. (Edward H. Holsten, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of hemlock sawfly. (Top: USDA Forest Service - Region 10 - Alaska Archive, USDA Forest Service, Bugwood.org; bottom: Dion Manastyrski - Natural Resources Canada, Canadian Forest Service)

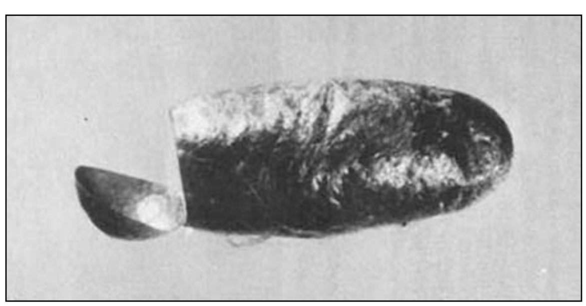

Figure 4. Cocoon of hemlock sawfly, from which the adult has emerged. (USDA Forest Service Insect and Disease Leaflet 31)

Images of Hemlock Sawfly (continued)

Figure 5. Feeding damage (thin foliage) of hemlock sawfly on western hemlock. (David L. Overhulser, Oregon Department of Forestry, Bugwood.org)

Figure 6. Stand of hemlock showing extensive damage during outbreak of hemlock sawfly. (USDA Forest Service - Region 10 - Alaska Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Parasitoids attacking hemlock sawfly include the ichneumonids *Delomerista japonica diprionis* Cushman, *Oresbius tsugae tsugae* (Cushman), and *Itoplectis quadricingulatus* (Provancher). A fungus (*Entomopthora sphaerosperma* Fres.) was the most effective control observed in studies in Alaska, particularly in wet years.

Web Links for Information on Hemlock Sawfly

http://www.fs.fed.us/r10/spf/fhp/leaflets/Fidl31.htm; USDA Forest Service Insect and Disease Leaflet 31 on biology and control of hemlock sawfly.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000010; fact sheet on this insect by Natural Resources Canada.

Articles

Furniss, R. L. and P.B. Dowden. 1941. Western hemlock sawfly, *Neodiprion tsugae* Middleton, and its parasites in Oregon. *Journal of Economic Entomology* 34: 46-52.

Hard, J.S. 1976. Natural control of hemlock sawfly, *Neodiprion tsugae* Middleton (Hymenoptera: Diprionidae), populations in southeast Alaska. *The Canadian Entomologist* 108: 485-498.

Hard, J.S. and D.C. Schmiege. 1968. The hemlock sawfly in southeast Alaska. USDA Forest Service Research Paper No. PNW-65. Pacific Northwest Forestry and Range Exp. Station, Portland, Oregon: 11 p.

Torgersen, T.R. 1968. Parasites of the hemlock sawfly, *Neodiprion tsugae*, in coastal Alaska. *Annals of the Entomological Society of America* 61(5): 1155-1158.

181. Introduced Pine Sawfly, *Diprion similis* (Hartig) (Hymenoptera: Diprionidae)

Orientation to Pest

Introduced pine sawfly, *Diprion similis* (Hartig), is an invasive species in North America of Eurasia origin that defoliates eastern white pine (*Pinus strobus* L.) and some other pines. It occurs widely in eastern Canada and the United States. Winter is spent in the prepupal stage in a cocoon on the tree or in the duff. Insects pupate in early spring and adults emerge by May to mid-June. Females lay eggs in rows of up to 10 in slits cut in needles of hosts. Young larvae feed in groups, but older larvae feed alone. Larvae of the first generation feed on old needles only, but larvae of the second generation eat both old and new needles. Normally there are two generations per year, but in favorable areas, there may be a partial third generation. Infested trees may be defoliated and trees may be killed.

Hosts Commonly Attacked

This species feeds on pines, especially eastern white pine (*P. strobus*). Scotch (*P. sylvestris* L.), red (*P. resinosa* Sol. ex Aiton), jack (*P. banksiana* Lamb.), and mugo (*P. mugo* Turra) pines are also attacked.

Distribution

In the United States, this sawfly is found from Maine west to Minnesota and south to North Carolina, Tennessee, and Virginia. In Canada, it is present in Newfoundland, Nova Scotia, New Brunswick, Prince Edward Island, Quebec, Ontario, and Manitoba.

Images of Introduced Pine Sawfly

Figure 1. Adult of introduced pine sawfly, *Diprion simili*. (John H. Ghent, USDA Forest Service, Bugwood.org)

Images of Introduced Pine Sawfly (continued)

Figure 2. Eggs of introduced pine sawfly inserted into a pine needle. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 3. Larvae of introduced pine sawfly. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 4. Cocoon (emerged) of introduced pine sawfly. (Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org)

Images of Introduced Pine Sawfly (continued)

Figure 5. Defoliation of eastern white pines due to introduced pine sawfly larvae. (John H. Ghent, USDA Forest Service, Bugwood.org)

Figure 6. Emergence of the ichneumonid parasitoid *Exenterus amictorius* (Panzer) from a cocoon of introduced pine sawfly. (John H. Ghent, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

In Europe, many species of parasitoids have been reared from D. similis, including most commonly *Aptesis subguttatus* (Grav.), *A. basizonia* (Grav.), *Exenterus amictorius* (Panzer), *E. adspersus* Hartig., *Palexorista inconspicua* (Meigen), *Hypsantyx impressus* (Grav.), and *Monodontomerus dentipes* (Dalman). *Palexorista inconspicua* is believed by some to be the most important tachinid parasitoid of *D. similis* in Europe. In North America, *D. similis* is attacked by several European parasitoids that were introduced against other closely related invasive sawflies. In Connecticut, nearly 50 percent of *D. similis* larvae were parasitized by a complex of eight parasitoid species, especially *M. dentipes*, which was also one of the most important parasitoids in Pennsylvania and New Jersey. In Minnesota, the most common parasitoids were *E. amictorius*, *M. dentipes*, and *Delomerista japonica* Cushman. *Diprion similis* did not invade the southern United States until the 1970s, and, in that region, few parasitoid species were found attacking the pest. *Monodontomerus dentipes* was introduced to the region, where it became abundant and was credited with controlling the pest in North Carolina.

Web Links for Information on Introduced Pine Sawfly

http://www.exoticpests.gc.ca/ins_details_eng.asp?pestType=ins&lang=lt&geID=6552; fact sheet of Environment Canada on biology of species.

http://www.forestpests.org/vermont/introducedsawfly.html; fact sheet of the Vermont Department of Forests, Parks and Recreation on biology and control.

http://na.fs.fed.us/spfo/pubs/fidls/intro_sawfly/intro_sawfly.htm; USDA Forest Service Forest Insect and Disease Leaflet.

Articles

Monroe, H.A.U. 1935. Observations on the habits of an introduced pine sawfly *Diprion simile* Htg. *The Canadian Entomologist* 67: 137-140.

Tsao, C.H. and A.C. Hodson. 1956. The effect of different host species on the oviposition and survival of the introduced pine sawfly. *Journal of Economic Entomology* 49: 400-401.

Coppel, H.C., J.W. Mertins, and J.W.E. Harris. 1974. The introduced pine sawfly, *Diprion similis* (Hartig) (Hymenoptera: Diprionidae): A review with emphasis on studies in Wisconsin. *University of Wisconsin-Madison Research Bulletin* R 2393: 74 p.

Drooz, A.T.; J.H. Ghent, and C.M. Huber. 1985. Insect parasites associated with the introduced pine sawfly, *Diprion similis* (Hartig) (Hymenoptera: Diprionidae), in North Carolina. *Environmental Entomology* 14: 401-403.

182. European Spruce Sawfly, *Gilpinia hercyniae* (Hartig) (Hymenoptera: Diprionidae)

Orientation to Pest

The European spruce sawfly, *Gilpinia hercyniae* (Hartig), is an introduced sawfly from Europe that feeds on spruce (*Picea*). Currently, this sawfly is found in Canada from the Maritimes west to Manitoba, and on the island of Newfoundland. In the United States, it is present from the northeast to the Great Lake states. White spruce (*Picea glauca* [Moench] Voss) and other species in the genus are attacked. Adults emerge in spring and lay eggs in slits cut in needles of host trees. Larvae of all ages feed singly; old needles are preferred, but both old and new needles are consumed. Mature larvae spin cocoons in which they pupate. For the overwintering generation, cocoons are formed in the duff below host trees, while non-overwintering cocoons are attached to foliage or twigs. Depending on the location, there may be one to three generations per year. About a decade or so after the detection of this species in North America, outbreaks became widespread and continuous in eastern Canada. In the 1940s, biological control of this species was achieved by introducing a series of European parasitoids and, accidentally, a nuclear polyhedrosis virus. Outbreaks of this species no longer occur in North America due to the combined action of these natural enemies.

Hosts Commonly Attacked

White spruce (*P. glauca* [Moench] Voss) is the preferred host, but red (*P. rubens* Sarg.), black (*P. mariana* [Mill.] Britton, Sterns & Poggenburg), and Norway (*P. abies* [L.] H. Karst.) spruce are attacked.

Distribution

This sawfly is found from the Maritimes west to Manitoba, and on the island of Newfoundland. In the United States, it is present in the northeastern States, west to the Great Lakes region.

Images of European Spruce Sawfly

Figure 1. Adult of the European spruce sawfly, *Gilpinia hercyniae*. (Gerhard Elsner, Biologische Bundesanstalt für Land und Forstwirtschaft, Bugwood.org)

Images of European Spruce Sawfly (continued)

Figure 2. Eggs (seen as swollen areas, see arrow) inside spruce needles. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Larvae of the European spruce sawfly. (Gerhard Elsner, Biologische Bundesanstalt für Land und Forstwirtschaft, Bugwood.org)

Figure 4. Cocoons of a non-diapausing generation of the European spruce sawfly. (Gerhard Elsner, Biologische Bundesanstalt für Land und Forstwirtschaft, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Importations of parasitoids from Europe against the European spruce sawfly were begun after detection of a large outbreak in the Gaspé region of Quebec, and natural enemy introductions were carried out on a massive scale. Millions of sawfly cocoons and eggs were collected in Europe and shipped to Canada where their parasitoids were reared and released. Eventually a rearing program was established in Canada that produced over 800 million parasitoids between 1932 and 1958. Overall some 30 species of parasitoids were identified from Europe and Japan and introduced into North America. At least seven species established, of which the first was *Dahlbominus fuscipennis* Zett. in Quebec, followed by several species of *Exenterus*. Biological control was eventually achieved not by parasitoids but by the accidental introduction of a nucleopolyhydrosis virus (*Borrelinavirus hercyniae*) sometime before 1938. By 1943, *G. hercyniae* populations were in marked decline with *B. hercyniae* identified as the most important cause. This virus, together with the introduced parasitoids, caused a widespread reduction of *G. hercyniae* of 90-95 percent by 1945. Once outbreaks had ceased *G. hercyinae* populations were regulated by the combination of *B. hercyniae* and two introduced parasitoids *Drino bohemica* (Mesn.) and *Exenterus vellicatus* Cush. Minor outbreaks continued to occur for some years, on the edge of the species' range and in forests that had been sprayed with DDT to control populations of the spruce budworm (*Choristoneura fumiferana* Clem.); areas where the pest had temporarily outpaced the expansion of the ranges of the introduced natural enemies or where natural enemies had been killed by pesticide use.

Web Links for Information on European Spruce Sawfly

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=6555; fact sheet of Natural Resources Canada.

Articles

Clark, R.C., L.J. Clarke, and K.E. Pardy. 1973. Biological control of the European spruce sawfly in Newfoundland. *Bi-monthly Research Notes* 29(1): 2-3.

Adams, P.H.W. and P.F. Entwistle. 1981. An annotated bibliography of *Gilpinia hercyniae* (Hartig), European spruce sawfly. *Occasional Papers* No. 11. Commonwealth Forestry Institute: 58 p.

McCugan, B.M. and H.C. Coppell. 1962. A review of biological control attempts against insects and weeds in Canada. Part II. Biological control of forest insects, 1910-1958. Technical Communication No. 2, Commonwealth Institute of Biological Control, Trinidad. Commonwealth Agriculture Bureaux, Farnahm Royal, Bucks, England: 35-177.

183. Larch Sawfly, *Pristiphora erichsonii* (Hartig) (Hymenoptera: Tenthridinidae)

Orientation to Pest

Larch sawfly, *Pristiphora erichsonii* (Hartig), was historically a serious pest of larch (*Larix*) in North America. It is present throughout Canada, Alaska, and most of the northern tier of US states. Distinct strains of the species have been recognized, with different geographical origins. A debate has existed over whether strains of this species found in North American before 1920 were native to North America or were invasive from Europe at an earlier date. Further complicating matters is the accidental introduction of additional strains, definitely from Europe, that occurred during a biological control program (1910-1930) against the species that released cocoons (both parasitized and unparasitized) collected in Europe in the field in Canada. This sawfly overwinters as prepupae in cocoons in the duff. Adults emerge in spring and lay eggs in new shoots, causing curling. All larch sawfly adults are females. Newly hatched larvae feed in groups, mainly on the needle clusters of older twigs. Dense populations can defoliate whole trees. Mature larvae drop to the ground to spin cocoons. There is one generation per year in most locations, but some individuals may remain in their cocoons for two or three winters before emerging. Damaging outbreaks have occurred periodically. During outbreaks, trees are not commonly killed, but wood growth is reduced. Weakened surviving trees may also be at increased risk of bark beetle attack.

Hosts Commonly Attacked

Larch sawfly feeds on eastern larch (*Larix laricina* [Du Roi] K. Koch), western larch (*L. occidentalis* Nutthal), and alpine larch (*L. lyallii* Parl.).

Distribution

Larch sawfly occurs in all Canadian provinces, Alaska, all the northern tier of U.S. states, as well as Maryland, North Carolina, and West Virginia.

Images of Larch Sawfly

Figure 1. Adult of larch sawfly, *Pristiphora erichsonii*. (Natural Resources Canada, Canadian Forest Service)

Images of Larch Sawfly (continued)

Figure 2. Larvae of larch sawfly. (Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 3. Cocoons of larch sawfly, showing adult emergence holes. (Arnold T. Drooz, USDA Forest Service, Bugwood.org)

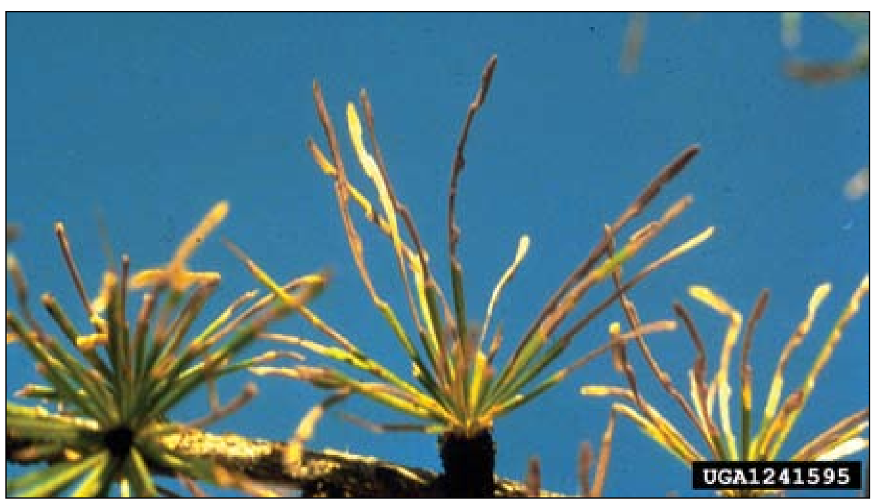

Figure 4. Larch needles showing feeding by larch sawfly larvae. (Dayle D. Bennett, Bugwood.org)

Images of Larch Sawfly (continued)

Figure 5. A larch stand in Minnesota showing partial (50 percent) defoliation caused by larch sawfly. (Arnold T. Drooz, USDA Forest Service, Bugwood.org)

Figure 6. Landscape level defoliation of larch in Minnesota in 1953 caused by larch sawfly. (Arnold T. Drooz, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The history of biological control efforts against larch sawfly in North America is complex. See Van Driesche et al. (1996) for a detailed history. Natural enemies in North America that are important to the population dynamics of larch sawfly include a tachinid (*Bessa harveyi* [Townsend]), a guild of native small mammals, and two introduced ichneumonid parasitoids, *Mesoleius tenthredinis* Morely and *Olesicampe benefactor* Hinz. An important factor mediating outcomes in early stages of the biological control program was variation in the ability of the several sawfly strains to encapsulate the eggs of the parasitoid *M. tenthredinis*. This was subsequently resolved by introduction of a second strain that was able to resist encapsulation.

Web Links for Information on Larch Sawfly

http://www.forestry.ubc.ca/fetch21/FRST308/lab5/pristiphora_erichsonii/sawfly.html; fact sheet of the University of British Columbia on biology.

Articles

Turnock, W.J. 1960. Ecological life-history of the larch sawfly, *Pristiphora erichsonii* (Htg.) (Hymenoptera: Tenthredinidae), in Manitoba and Saskatchewan. *The Canadian Entomologist* 92: 500-516.

Hu, F. 1964. Population dynamics of the larch sawfly. *The Canadian Entomologist* 96: 160-161.

Turnock, W.J. 1972. Geographical and historical variability in population patterns and life systems of the larch sawfly (Hymenoptera: Tenthredinidae). *The Canadian Entomologist* 104: 1883-1900.

Wong, H.R. 1974. The identification and origin of the strains of the larch sawfly, *Pristiphora erichsonii* (Hymenoptera: Tenthredinidae), in North America. *The Canadian Entomologist* 106: 1121-1131.

Maltais, P.P., J.J. Juillet, and D.D. de Oliveira. 1980. Ecology and population dynamics of the larch sawfly, *Pristiphora erichsonii* (Htg.) in Kouchibouguac National Park, New Brunswick. *Annals of the Entomological Society of Quebec* 25: 141-162.

Krause, S.L. and K.F. Raffa. 1996. Defoliation tolerance affects the spatial and temporal distributions of larch sawfly and natural enemy populations. *Ecological Entomology* 21: 101-111.

Van Driesche, R.G., S. Healy, and R.C. Reardon. 1996. *Biological Control of Arthropod Pests of the Northeastern and North Central Forests in the United States: A review and recommendations*. FHTET 96-19, December 1996, USDA Forest Service, Morgantown, WV. (See http://www.forestpestbiocontrol.info/fact_sheets/documents/arthropodpestsnortheastern_northcentral.pdf).

184. Mountain Ash Sawfly, *Pristiphora geniculata* (Hartig) (Hymenoptera: Tenthridinidae)

Orientation to Pest

Mountain ash sawfly, *Pristiphora geniculata* (Hartig), is a European tenthredinid sawfly that is invasive in North America. In North America, it feeds on species of *Sorbus*. Mountain ash sawfly occurs in Canada east of central Ontario and in the northeastern United States. The winter is passed as a prepupa in a cocoon in the soil or leaf litter. Pupation occurs in the spring and adults emerge soon after. Eggs are deposited in slits cut in the edges of the leaves of the host trees. Newly hatched larvae feed on the leaf edges. When disturbed, larvae raise their bodies in an "s" position. Young larvae feed gregariously, but older larvae feed individually. Larvae eat entire leaves except for the midribs. Mature larvae of the overwintering generation drop to the soil and spin their cocoons. Mountain ash sawfly is primarily a pest of ornamentals and in the wild has largely been suppressed by the introduced parasitoid *Olesicampe geniculatae* Quednau and Lim. In all but the northern part of its range in North America, there are two generations per year.

Hosts Commonly Attacked

This species feeds on American mountain ash (*Sorbus americana* Marshall) and European mountain ash (*S. aucuparia* L.).

Distribution

Mountain ash sawfly occurs in Canada east of central Ontario and in the northeastern United States, including New York, New Jersey, and Michigan.

Images of Mountain Ash Sawfly

Figure 1. Adult of mountain ash sawfly, *Pristiphora geniculata*. (James Lindsey, Bugwood.org)

Figure 2. Eggs of mountain ash sawfly, inserted into edges of leaves of the host plant. (L.J. Lipovsky, Maine Forest Service)

Images of Mountain Ash Sawfly (continued)

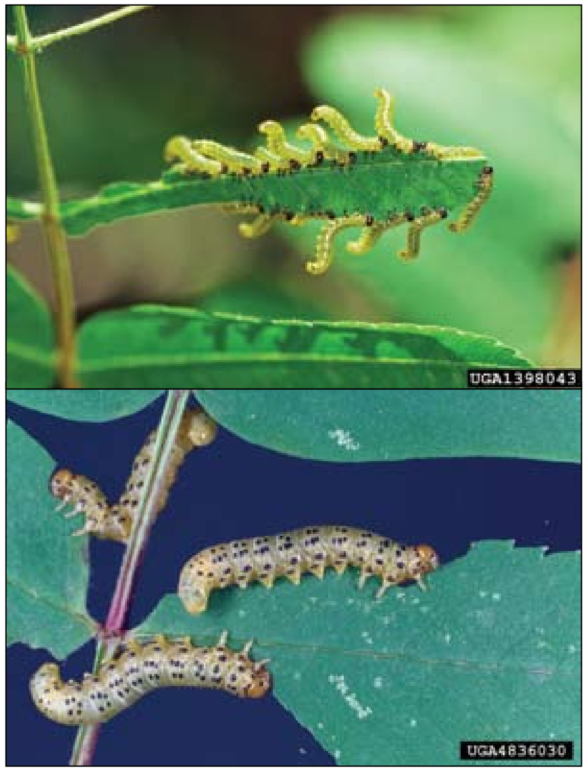

Figure 3. Larvae of mountain ash sawfly; young larvae feeding in a group (top) and older larvae feeding alone (bottom). (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 4. Foliage of mountain ash stripped of all but mid ribs by mountain ash sawfly larvae. (Joseph O'Brien, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

This introduced sawfly has been controlled by releases of the parasitoid *Olesicampe geniculatae*.

Web Links for Information on Mountain Ash Sawfly

http://www.forestpests.org/vermont/mountainashsawfly.html; fact sheet of the Bugwood network.

http://maine.gov/doc/mfs/mtnash.htm; fact sheet of the Maine Department of Conservation on biology and control of insect.

http://www.fs.fed.us/r6/nr/fid/invasives/mtn-ash-sawfly.shtml; fact sheet of USDA Forest Service Forest Health Protection Pacific Northwest Region—biology and control.

Articles

Forbes, R.S. and L. Daviault.1964. The biology of the mountain ash sawfly, *Pristiphora geniculata* (Htg.) (Hymenoptera: Tenthredinidae), in eastern Canada. *The Canadian Entomologist* 98: 1117-1133.

Quednau, F.W. 1990. Introduction, permanent establishment, and dispersal in eastern Canada of *Olesicampe geniculatae* Quednau and Lim (Hymenoptera: Ichneumonidae), an important biological control agent of the mountain ash sawfly, *Pristiphora geniculata* (Hartig) (Hymenopttera: Tenthredinidae). *The Canadian Entomologist* 122: 921-934.

West, R.J., P.L. Dixon, F.W. Quednau, K.P. Lim, and K. Hiscock. 1994. Establishment of *Olesicampe geniculatae* Quednau and Lim (Hymenoptera: Ichneumonidae) to control the mountain ash sawfly, *Pristiphora geniculata* (Hartig) (Hymenopttera: Tenthredinidae) in Newfoundland. *The Canadian Entomologist* 126: 7-11.

West, R.J., P.L. Dixon, F.W. Quednau, and K.P. Lim. 2001. *Pristiphora geniculata* (Hartig), mountain ash sawfly (Hymenoptera: Tenthredinidae). In: Mason, P.G. and J.T. Huber (eds.). *Biological Control Programmes in Canada, 1981-2000*. CABI Publishing, Wallingford, UK: 228-230.

185. Yellowheaded Spruce Sawfly, *Pikonema alaskensis* (Rohwer) (Hymenoptera: Tenthredinidae)

Orientation to Pest

The yellowheaded spruce sawfly, *Pikonema alaskensis* (Rohwer), is a native sawfly found throughout northeastern and northwestern North America that feeds on all species of native and introduced spruce (*Picea*). It overwinters as prepupae in the duff and adults emerge in spring. Eggs are laid in the current season's needles just as buds begin to flush in the spring. Larvae feed on the new needles primarily, but may exploit old needles if new needles become scarce. In summer, fully developed larvae drop to the ground and spin cocoons (in which they molt to the prepupal stage) in the duff or topsoil. Damage occurs mainly in the upper crown of young, open-grown spruce, especially on trees in ornamental and shelterbelt plantings; mature trees are rarely attacked. Several years of heavy feeding may kill the leader and upper crown branches of trees. There is one generation per year.

Hosts Commonly Attacked

Hosts of yellowheaded spruce sawfly include all native spruces in North America: Engelmann (*Picea engelmannii* Parry ex Engelm.), white (*P. glauca* [Moench] Voss), black (*P. mariana* [Mill.] Britton, Sterns & Poggenburg), Sitka (*P. sitchensis* [Bong.] Carr.), and Colorado blue (*P. pungens* Engelm.), and the introduced Norway spruce (*P. abies* [L.] Karst.).

Distribution

This sawfly occurs in throughout the range of spruce in North America, and can be found from Alaska to Maine.

Images of Yellowheaded Spruce Sawfly

Figure 1. Adult of yellowheaded spruce sawfly, *Pikonema alaskensis*. (D.K.B. Cheung)

Images of Yellowheaded Spruce Sawfly (continued)

Figure 2. Ovipostion cuts in needles made by yellowheaded spruce sawfly. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Larvae of yellowheaded spruce sawfly; top, young larvae and bottom, mature larvae. (Top: Thérèse Arcand - Natural Resources Canada, Canadian Forest Service; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 4. Prepupa of yellowheaded spruce sawfly in cocoon (opened). (D.K.B. Cheung)

Images of Yellowheaded Spruce Sawfly (continued)

Figure 5. Damage (top) to white spruce from yellowheaded spruce sawfly; close up (bottom) of larvae feeding on spruce. (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 6. Stand of spruce showing injury from yellowheaded spruce sawfly. (USDA Forest Service - Northeastern Area Archive, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

The natural enemies of this species have been studied in Minnesota, Maine and Nova Scotia. A monitoring trap has been developed for one parasitoid, the ichneumonid *Syndipnus rubiginosus* Walley.

Web Links for Information on Yellowheaded Spruce Sawfly

http://www.na.fs.fed.us/spfo/pubs/gtr/sprucesawfly/biology.htm; a very detailed fact sheet of the USDA Forest Service on biology of this species.

http://www.fs.fed.us/r10/spf/fhp/leaflets/yellowhd_spruce_sawfly.pdf; fact sheet of the USDA Forest Service on biology and control.

http://gardenline.usask.ca/pests/yellow.html; fact sheet of the University of Saskatchewan on biology and control.

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=7875; fact sheet of the Natural Resources Canada on biology and phenology.

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/opp3005; fact sheet of the Alberta Department of Agriculture, on biology and control.

http://www.entomology.umn.edu/cues/Web/225YellowheadedSpruceSawfly.pdf; fact sheet of the University of Minnesota on biology and control.

http://www.maine.gov/doc/mfs/yhss.htm; fact sheet of the Maine Department of Conservation on biology and control.

http://www.forestpests.org/vermont/yellowheadsawfly.html; fact sheet of the Vermont Department of Forests, Parks, and Recreation.

http://www.fs.fed.us/r6/nr/fid/fidls/fidl-69.pdf; USDA Forest Service Forest Pest Leaflet No. 69.

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186. Birch Leafminer, *Fenusa pumila* (Leach) (Hymenoptera: Tenthridinidae)

Orientation to Pest

The birch leafminer, *Fenusa pumila* (Leach) (formerly known as *Fenusa pusilla* [Lepeletier]), is a European sawfly that was mines the leaves of several species of birch (*Betula*) in North America, where it invaded just prior to the 1920s. It is found principally in southeastern Canada and the northeastern United States, in the range of its main hosts, gray (*Betula populifolia* Marshal) and paper birch (*B. papyrifera* Marshal). This sawfly overwinters as prepupae in earthen cells in the soil. Pupation occurs in spring and adults emerge near bud break. Eggs are laid singly in unfolding leaves, and larvae create leafmines where they feed. Mines are blotch shaped and enlarge and eventually merge as larvae grow. In New England, there is only one full generation per year, but a small fraction of the first and second generations develop to adults without diapause and emerge to produce a partial second and third generations. Before the 1980s, birch leafminer densities were high enough so that most leaves of white and gray birches in landscapes or road edges were mined; mined leaves being completely browned. This created an aesthetic problem on landscape trees and likely reduced the vigor of forest trees. In the period of 1970-2000, birch leafminer was subjected to biological control through introduction of its specialized parasitoids from Europe and densities in the northeastern United States have now declined to low pest levels (<5 percent leaves mined).

Hosts Commonly Attacked

The principal birch species used as hosts are gray (*B. populifolia*) and paper (*B. papyrifera*) birch. Yellow (*B. alleghaniensis* Britton) and black (=sweet) (*B. lenta* L.) birch are not attacked. Several introduced European birches are also attacked in landscape plantings.

Distribution

This sawfly occurs from Newfoundland (Canada) south to Maryland and west to Minnesota and Iowa, with isolated populations also in Oregon, Washington, and Alaska, especially on introduced birches planted as ornamentals.

Images of Birch Leafminer

Figure 1. Adults of birch leafminer, *Fenusa pumila*; left, adult on young birch leaf; right, close up. (Left: Steven Katovich, USDA Forest Service, Bugwood.org; right: Cheryl Moorehead, individual, Bugwood.org)

Images of Birch Leafminer (continued)

Figure 2. Eggs of birch leafminer (points), surrounded by yellow halos of tissue. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

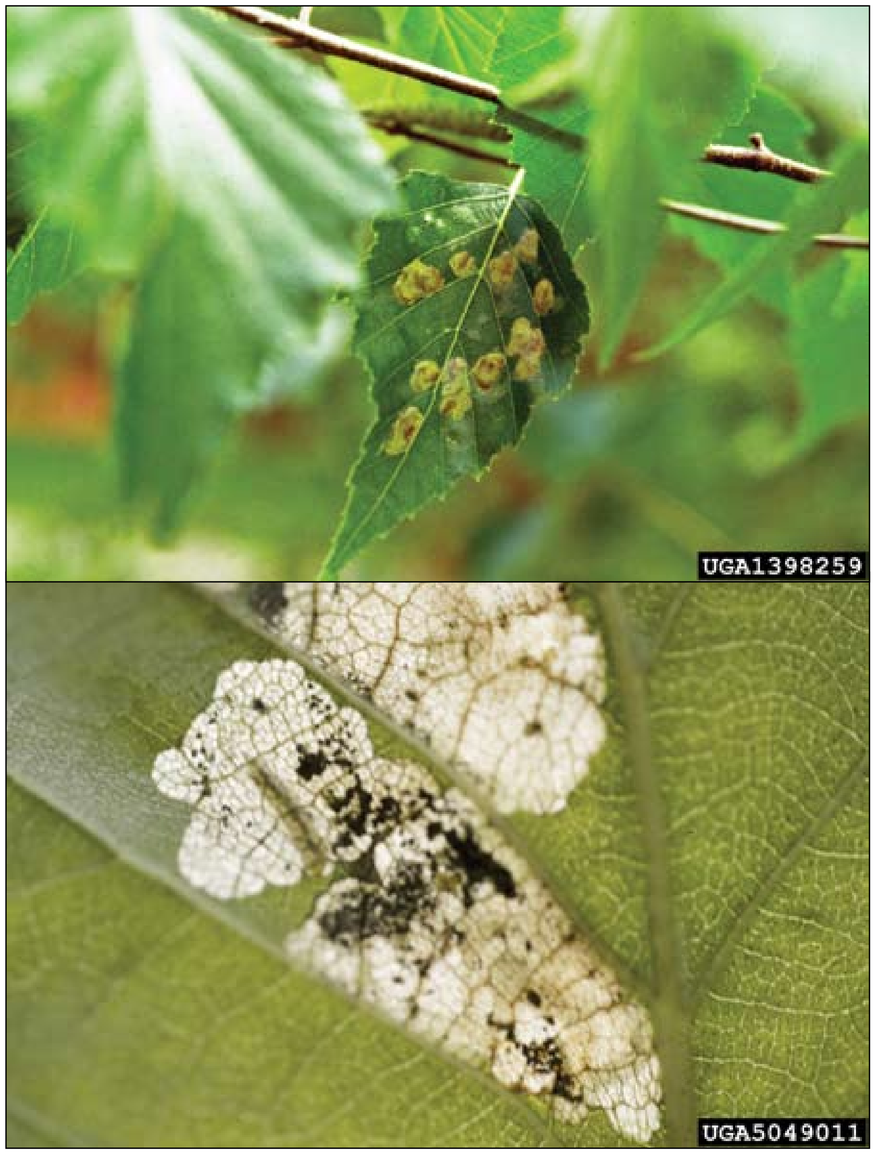

Figure 3. Small mines of birch leafminer, showing young larvae feeding in separate mines (top); bottom, close up on a single mine, with larva visible. (Top: Steven Katovich, USDA Forest Service, Bugwood.org; bottom: Joseph O'Brien, USDA Forest Service, Bugwood.org)

Images of Birch Leafminer (continued)

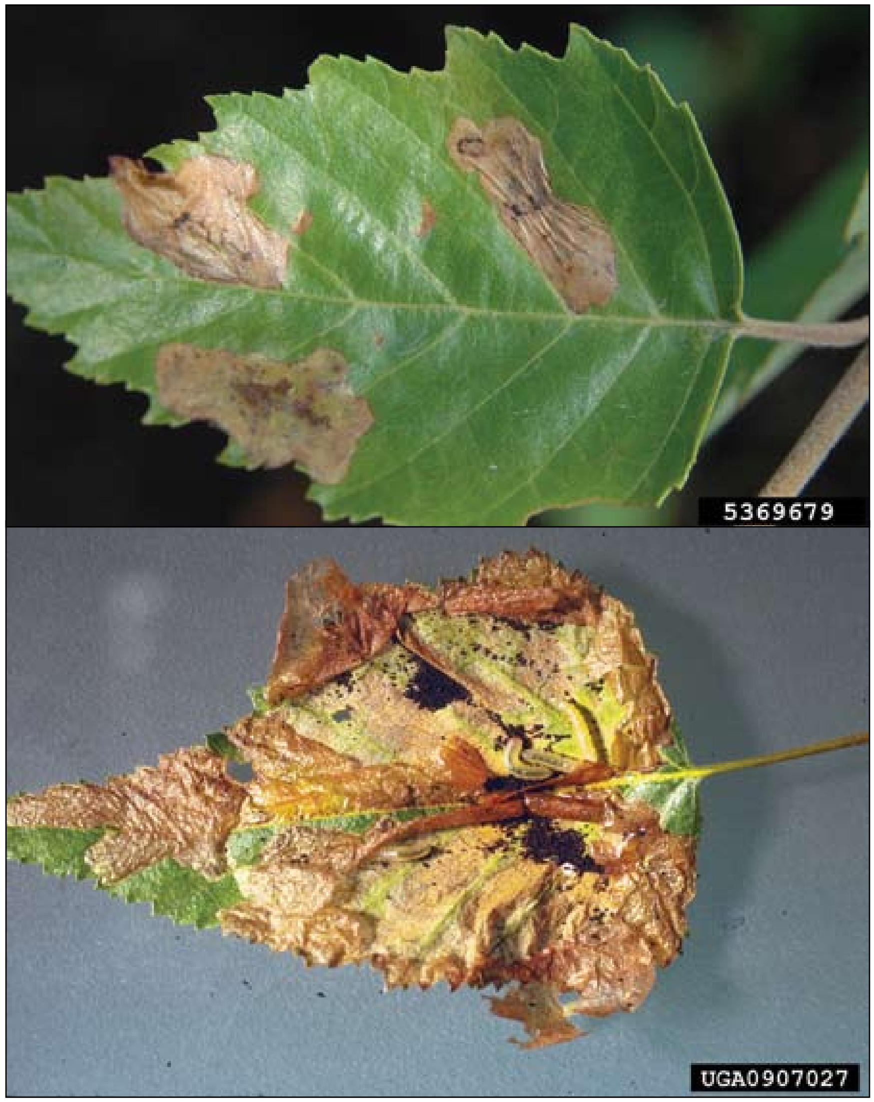

Figure 4. Middle-age (top) and older (bottom) larvae of birch leafminer, showing fusion of mines as larvae increase in size. (Top: Brian Kunkel, University of Delaware, Bugwood.org; bottom: E. Bradford Walker, Vermont Department of Forests, Parks and Recreation, Bugwood.org)

Figure 5. Close up of damage on branch heavily mined by birch leafminer. (Whitney Cranshaw, Colorado State University, Bugwood.org)

Images of Birch Leafminer (continued)

Figure 6. High density of mining by birch leafminer. (Steven Katovich, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Two European ichneumonids (*Lathrolestes nigricollis* [Thompson] and *Grypocentrus albipes* Ruthe) and one eulophid (*Chrysocharis nitetis* [Wilkinson]) were introduced into North America for biological control of the birch leafminer. *Lathrolestes nigricollis* is the only species to have become widely established. At the level of individual release sites, *L. nigricollis* has lowered pest density from 50 to <5 percent of first generation leaves being mined. At the landscape level, this parasitoid has suppressed this leafminer to insignificant levels throughout the northeastern United States, with the exception of southern New Jersey.

Web Links for Information on Birch Leafminer

http://njaes.rutgers.edu/pubs/publication.asp?pid=FS1164; fact sheet of Rutgers University (New Jersey) on biology and control.

http://www.extension.umn.edu/distribution/horticulture/DG6134.html; fact sheet of University of Minnesota Extension on biology and control.

http://www.invasiveforestinsectandweedbiocontrol.info/target_pests/insects_mites/Birchleafminer.htm; fact sheet of the University of Massachusetts on biological control of birch leafminer.

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Casagrande, R., R.G. Van Driesche, M. Mayer, R. Fuester, D. Gilrein, L. Tewksbury, and H. Faubert. 2009. Biological control of *Fenusa pusilla* (Hymenoptera: Tenthredinidae) in the northeastern United States: a thirty-four year perspective on efficacy. *Florida Entomologist* 92: 243-247. (Available at http://www.fcla.edu/FlaEnt/fe92p243.pdf).

187. Ambermarked Birch Leafminer, *Profenusa thomsoni* (Konow) (Hymenoptera: Tenthridinidae)

Orientation to Pest

The ambermarked birch leafminer, *Profenusa thomsoni* (Konow), is a European sawfly that feeds inside the leaves of several species of birch (*Betula*). It invaded North America at the beginning of the 20th century but was first reported in Canada in 1959. It is found both in the northeastern United States (New England through the Great Lakes region) and in eastern Canada from the Maritimes to Manitoba, where it is not considered a pest because of its low densities. It also occurs in western Canada and Alaska, where it reached high densities in Alberta (1990s) and Alaska (2000-2008), especially in urban areas, before being brought under biological control with an introduced parasitoid and two native species. This sawfly overwinters as prepupae in earthen cells in the soil. Pupation occurs in the spring, and adults emerge in early summer. Eggs are inserted singly into tissue of mature leaves, and larvae create leafmines where they feed. The blotch-shaped mines of this species increase in size and several mines may merge as larvae grow. In Alaska there is one generation per year; however, there are two in Massachusetts.

Hosts Commonly Attacked

The principal birch species used as hosts by ambermarked birch leafminer are gray (*Betula populifolia* Marshal) and paper (*B. papyrifera* Marshal) birch, but yellow birch (*B. alleghaniensis* Britt.) is also reported as a host. Several introduced European birches are also attacked in landscape plantings.

Distribution

This sawfly occurs from the northeastern United States (New England to the Great Lake States), eastern Canada from the Maritimes to Manitoba, in western Canada (Alberta, Northwest Territories), and Alaska. Small urban populations are found in additional locations (e.g., Bozeman, Montana) and many of these may be unrecognized, being taken for mines of *Fenusa pumila* Leach.

Images of Ambermarked Birch Leafminer

Figure 1. Adult of ambermarked birch leafminer, *Profenusa thomsoni*. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Images of Ambermarked Birch Leafminer (continued)

Figure 2. Eggs of ambermarked birch leafminer. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 3. Mine of nearly mature larva of ambermarked birch leafminer. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 4. Older instar of ambermarked birch leafminer, with mine opened to reveal larva. (Thérèse Arcand - Natural Resources Canada, Canadian Forest Service)

Figure 5. Close up of branch with mines of ambermarked birch leafminer. (René Pâquet - Natural Resources Canada, Canadian Forest Service)

Images of Ambermarked Birch Leafminer (continued)

Figure 6. Birch trees (brown) in Alaska heavily mined by ambermarked birch leafminer. (Chris MacQuarrie, University of Alberta)

Figure 7. Important parasitoids of ambermarked birch leafminer in Alaska: *Aptesis segnis* (top), *Lathrolestes soperi* (middle), and *Lathrolestes thomsoni* (bottom). (All three photos: Anna Soper, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Three ichneumonids (*Lathrolestes soperi* Reshchikov, *L. thompsoni* Reshchikov, and *Aptesis segnis* [Provancher]) are important biological control agents of this leafminer. The two *Lathrolestes* species attack the host larva in the mine. *Lathrolestes soperi* is known from Anchorage, Alaska and is of unknown origin. This species is particularly common in forested habitats. *Lathrolestes thompsoni* is a species that was observed to provide control of this leafminer in Edmonton, Alberta, and was moved to Anchorage, Alaska, where it was established to provide biological control. *Aptesis segnis* is a facultative hyperparasitoid that attacks the host (or parasitoid) in the host's pupal cells in the soil.

Web Links for Information on Ambermarked Birch Leafminer

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=7926; fact sheet of the Natural Resouces Canada, on biology and phenology.

Articles

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Reshchikov, A.V., A. Soper and R.G. Van Driesche. 2010. Revision of the Nearctic species of *Lathrolestes* (Hymenoptera: Ichneumonidae), with special reference to species attacking *Betula* leaf mining Tenthredinidae (Hymenoptera). *Zootaxa* 2614: 1-17.

188. Sirex Woodwasp, *Sirex noctilio* (Fabricius) (Hymenoptera: Siricidae)

Orientation to Pest

Sirex woodwasp, *Sirex noctilio* (Fabricius), is a European woodwasp that is widely invasive in the Southern Hemisphere. More recently it has also become established in the United States and Canada, with the initial discovery in New York in 2004. This species is a major threat to pines. In contrast to native North American woodwasps that attack only dead and dying trees, Sirex woodwasp can attack and kill living pines. At low population densities, the wasp selects suppressed, stressed, or injured trees for egg laying. Foliage of infested trees initially wilts and turns red in 3-6 months following attack. Infested trees often have pearly resin beads exuding from the drill holes where eggs were laid. Larval galleries are tightly packed with fine white sawdust and adults chew round exit holes that vary from 3 to 9 mm in diameter. *Sirex noctilio* is expected to complete one generation per year throughout most of the United States. Adult emergence occurs from July through September, with peak emergence during August. When eggs are laid, the female wasp also injects into the tree both a toxic mucus and a symbiotic fungus (*Amylostereum areolatum* [Fr.] Boidin). The toxic mucus shuts down the water transport, allowing the fungus to grow rapidly and kill the tree. The fungus also provides nutrition for the developing woodwasp larvae. Females can produce 25 to 450 eggs in their lifetime, depending upon their size. The larval stage generally takes 10-11 months.

Hosts Commonly Attacked

In addition to its preferred pine hosts (*Pinus*), *S. noctilio* can occasionally use spruce (*Picea*), fir (*Abies*), larch (*Larix*), and Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco).

Distribution

Sirex noctilio is native to Eurasia and North Africa, but it has invaded the Southern Hemisphere (New Zealand, Australia, Argentina, Chile, Brazil, Uruguay, and South Africa). Most recently, it has also been introduced to the United States (Michigan, New York, Ohio, Pennsylvania, and Vermont) and Canada.

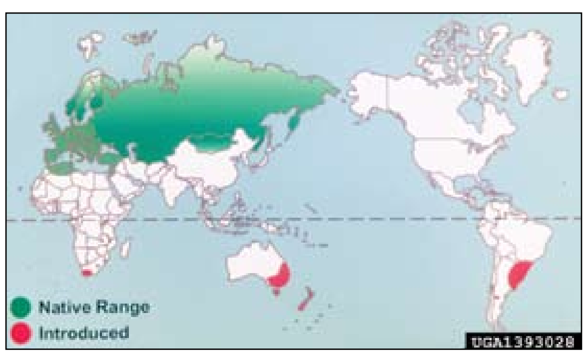

Figure 1. Worldwide distribution of *Sirex noctilio*, before its invasion in North America. (Dennis Haugen, Bugwood.org)

Images of Sirex Woodwasp

Figure 2. Mating pair of Sirex woodwasps (top: female left, male right) and mounted adult male (bottom). (Top: Vicky Klasmer, Instituto Nacional de Tecnologia Agropecuaria, Bugwood.org; bottom: Pest and Diseases Image Library, Bugwood.org)

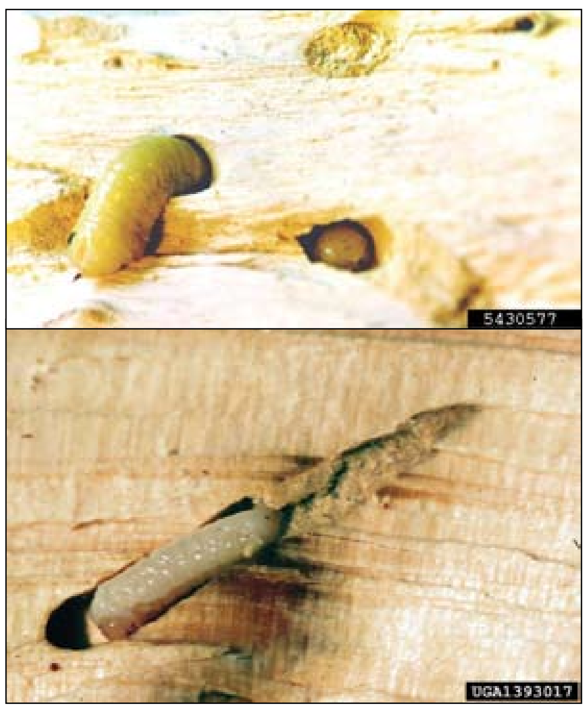

Figure 3. Larvae of *Sirex noctilio* in galleries inside wood. (Top: Vicky Klasmer, Instituto Nacional de Tecnologia Agropecuaria, Bugwood.org; bottom: Dennis Haugen, Bugwood.org)

Images of Sirex Woodwasp (continued)

Figure 4. Wood sawn from a tree damaged by *Sirex noctilio*. (Dennis Haugen, Bugwood.org)

Figure 5. Cambial staining caused by the symbiotic fungus (*Amylostereum areolatum*) that is transmitted by *Sirex noctilio*. White plugs are larval galleries packed with excrement (frass). (Vicky Klasmer, Instituto Nacional de Tecnologia Agropecuaria, Bugwood.org)

Images of Sirex Woodwasp (continued)

Figure 6. Emergence holes of *Sirex noctilio*. The round exit holes vary from 3 to 9 mm in diameter. (Dennis Haugen, Bugwood.org)

Figure 7. Resin beads from *Sirex noctilio* oviposition drills in red pine. (David Williams, USDA APHIS, Bugwood.org)

Images of Sirex Woodwasp (continued)

Figure 8. Tree mortality (80-90 percent) from a *Sirex noctilio* outbreak in a 15-year-old plantation in South Australia in 1989. (Dennis Haugen, Bugwood.org)

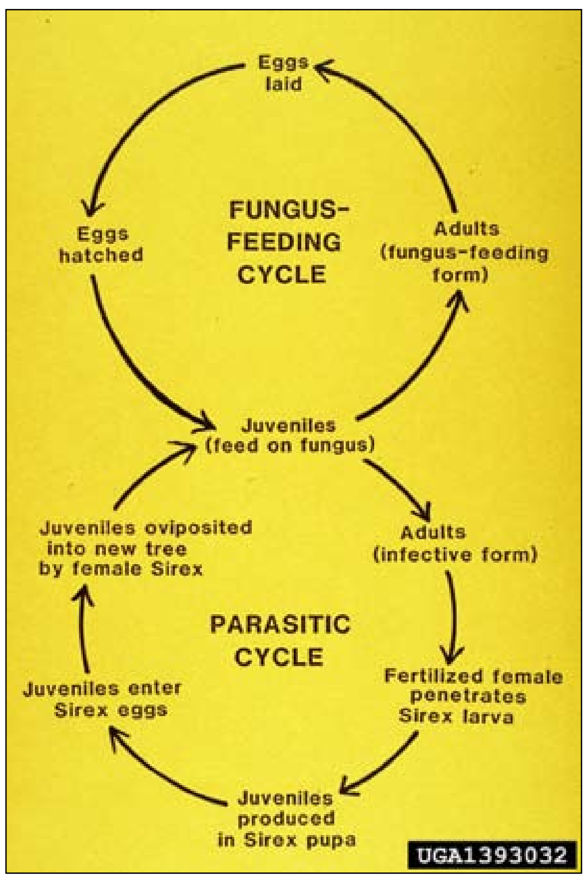

Figure 9. Life cycles of the two forms of the nematode *Beddingia siricidicola*. (Dennis Haugen, Bugwood.org)

Images of Sirex Woodwasp (continued)

Figure 10. Applying nematodes to a *Sirex noctilio*-infested tree for biological control. Inoculation holes are made with a special punch hammer. (Dennis Haugen, Bugwood.org)

Figure 11. *Sirex noctilio* parasitoids, *Rhyssa persuasoria* (left) and *Rhyssa lineolata* (right). (Kevin Dodds, USDA Forest Service, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

Several parasitoids have been introduced from Europe and North America into New Zealand and Australia for biological control of Sirex woodwasps in pine plantations. The most effective species were *Rhyssa persuasoria* (L.), *Megarhyssa nortoni* (Cresson), and *Ibalia leucospoides* Hochenwald. However, the highest level of control was ultimately provided in Australia by a parasitic nematode (*Beddingia siricidicola* [Bedding]). This nematode invades the eggs of female woodwasps and is transported by them to new egg laying sites. The growing nematode can develop into either of two very different forms: one is a fungus-eating form that lives on the symbiotic fungus transmitted by the woodwasp and the other is a parasite that develops inside woodwasp larvae and adults. Infected woodwasp larvae are not killed, but rather, the nematode reproduces inside the larval stages and infects the eggs of the adult female before she emerges from a tree. The nematode is effective in controlling Sirex woodwasp because it sterilizes the female but does not affect her flying ability, thus allowing her to disperse nematodes widely.

Web Links for Information on Sirex Woodwasp

http://na.fs.fed.us/spfo/pubs/pest_al/sirex_woodwasp/sirex_woodwasp.htm; a pest alert fact sheet of the USDA Forest Service on identification and biology.

http://www.invasivespeciesinfo.gov/animals/sirexwasp.shtml; a list of websites about *Sirex noctilio*.

http://www.massnrc.org/pests/pestFAQsheets/european%20woodwasp.htm; a fact sheet of the University of Massachusetts, including links to key sites for further information.

http://www.aphis.usda.gov/plant_health/plant_pest_info/sirex/downloads/sirexfungus.pdf; a fact sheet on *Amylostereum areolatum*.

Articles

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189. Asian Chestnut Gall Wasp, *Drycosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae)

Orientation to Pest

The Asian chestnut gall wasp, *Drycosmus kuriphilus* Yasumatsu, is a gall making cynipid that is specific to chestnut (*Castanea* spp.). The gall wasp is native to China but invasive in many countries around the world, including parts of the United States. Galling disrupts shoot and twig growth, impedes normal flowering, and weakens infested trees. Adult females (there are no males) emerge from galls in early to mid summer and lay several eggs in each chestnut bud they attack. Eggs hatch in mid to late summer, and young larvae feed a little and then overwinter in the infested buds. When buds begin to grow in spring, galls are formed. Galls have one to several chambers, each with a developing gall wasp larva. Larvae eat the tissue within the galls and pupate there. New gall wasps emerge soon after. After adults emerge, galls turn brown and woody and may remain on the tree for several years and are a clear sign of infestation. In China, pest outbreaks occur about every 10 years and last 2-3 years. There is one generation per year.

Hosts Commonly Attacked

This species is specific to species of chestnuts (*Castanea*).

Distribution

Asian chestnut gall wasp is native to China, but is also present in Korea, Japan, Nepal, Europe (Italy, France, Slovenia, Hungary, Switzerland, and Croatia) and the United States as an invasive pest.

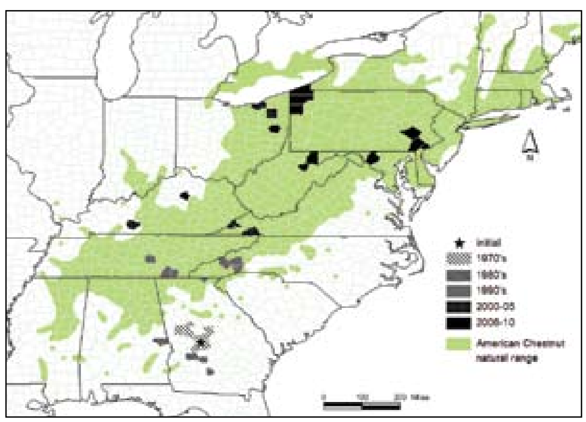

Figure 1. Distribution of the chestnut gall wasp, *Drycosmus kuriphilus*, in the United States. (Ignazio Graziosi)

Images of Chestnut Gall Wasp

Figure 2. Adult of Asian chestnut gall wasp. (Lynne Rieske)

Images of Chestnut Gall Wasp (continued)

Figure 3. Young gall of Asian chestnut gall wasp in spring (top) and old gall after wasp emergence (bottom), which may remain on trees for several years. (Both photos: Lynne Rieske)

Figure 4. Interior view of gall in cross section, showing multiple chambers and one gall wasp pupa. (Melanie Sprinkle, Bugwood.org)

Figure 5.View of old galls on leafless chestnut tree in winter. (Lynne Rieske)

Important Biological Control Agents Related to this Pest Species

Classical biological control programs focusing on the parasitoid *Torymus sinensis* Kamijo (Hymenoptera: Torymidae) have been implemented in several countries, including Japan and the United States. Several native species also utilize the gall wasp as a host.

Web Links for Information on Chestnut Gall Wasp

http://www.eppo.org/QUARANTINE/insects/Dryocosmus_kuriphilus/DS_Dryocosmus_kuriphilus.pdf; extensive document of EPPO (European quarantine organization) on many aspects of the species' biology.

http://www.agroscope.admin.ch/data/publikationen/1304403002_Aebi_A_Paper_Dryocosmus_Kuriphilus_01-2011.pdf; an extensive document on this species and its biological control in Switzerland.

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190. Spruce Spider Mite, *Oligonychus ununguis* (Jacobi) (Acari: Tetranychidae)

Orientation to Pest

Spruce spider mite, *Oligonychus ununguis* (Jacobi), is a cosmopolitan spider mite of uncertain origin associated with spruce (*Picea*) and other conifers. All life stages (egg, immature stages, adult) occur together on the host foliage, which is webbed over as infestation grows. Winter is passed in the egg stage. Multiple generations occur per year. Outbreaks are often induced by the use of pesticides but may occur naturally in dry years. Outbreaks are more common on young trees, on which mites prefer older foliage in the interior of the tree.

Hosts Commonly Attacked

This mite feeds on Colorado (*Picea pungens* Engelm.) and white (*P. glauca* [Moench] Voss) spruce, Douglas-fir (*Pseudotsuga menzeseii* Mirb.), thuja (*Thuja*), jack (*Pinus banksiana* Lamb.) and some other pines, eastern hemlock (*Tsuga canadensis* [L.] Carrière), and larch (*Larix*).

Distribution

Spruce spider mite is found in many countries around the world, and its origin in unknown. Its occurrence on introduced plants in countries lacking native conifers suggests that at least part of this distribution is from invasion, likely due to movement of infested woody nursery stock.

Images of Spruce Spider Mite

Figure 1. Adult of spruce spider mite, *Oligonychus ununguis*. (Ward Strong, BC Ministry of Forests, Bugwood.org)

Figure 2. Eggs of spruce spider mite. (Both photos: Ward Strong, BC Ministry of Forests, Bugwood.org)

Images of Spruce Spider Mite (continued)

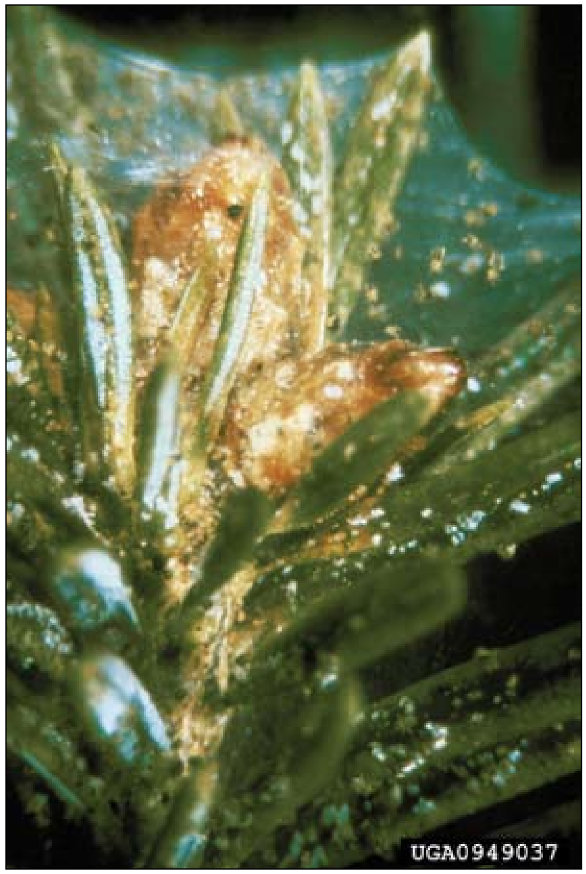

Figure 3. Colony, with webbing, of spruce spider mite. (USDA Forest Service - Region 4 - Intermountain Archive, USDA Forest Service, Bugwood.org)

Figure 4. Close up of chlorotic spotting causing by spruce spider mite feeding. (John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org)

Images of Spruce Spider Mite (continued)

Figure 5. Damage on white spruce (top) from spruce spider mite and close up (bottom) of webbing from mite. (Both photos: Ward Strong, BC Ministry of Forests, Bugwood.org)

Important Biological Control Agents Related to this Pest Species

As with most spider mites, control agents are various species of predatory mites (Phytoseiidae), predatory gall midges (Cecidomyiidae, genus *Feltiella*), and ladybird beetles (Coccinellidae), which vary by region. Destruction of such natural enemies through widespread use of pesticides for control of other forest pests can induce outbreaks of *O. ununguis*. This occurred in Montana in the 1950s, for example, when DDT was applied over a large area for control of western spruce budworm (*Choristoneura occidentalis* Freeman). Such problems are most likely in plantations, seed orchards, or Christmas tree farms that are regularly treated for various insect pests.

Web Links for Information on Spruce Spider Mite

http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=136; fact sheet of Natural Resources Canada.

http://wiki.bugwood.org/Oligonychus_ununguis; Bugwood Wiki factsheet on biology and control.

http://ento.psu.edu/extension/christmas-trees/information/pest-fact-sheets/Spspidermiteent069.pdf/view; Pennsylvania Department of Agriculture circular on control of spruce spider mite.

Articles

Löyttyniemi, K. and K. Heliövaara. 1991. Effect of forest fertilization on the spruce spider mite *Oligonychus ununguis* (Jacobi) (Acarina, Tetranychidae). *Acarologia* 32: 139-143.

Shrewsbury, P.M. and M.R. Hardin. 2003. Evaluation of predatory mite (Acari: Phytoseiidae) releases to suppress spruce spider mites, *Oligonychus ununguis* (Acari: Tetranychidae), on juniper. *Journal of Economic Entomology* 96: 1675-1684.