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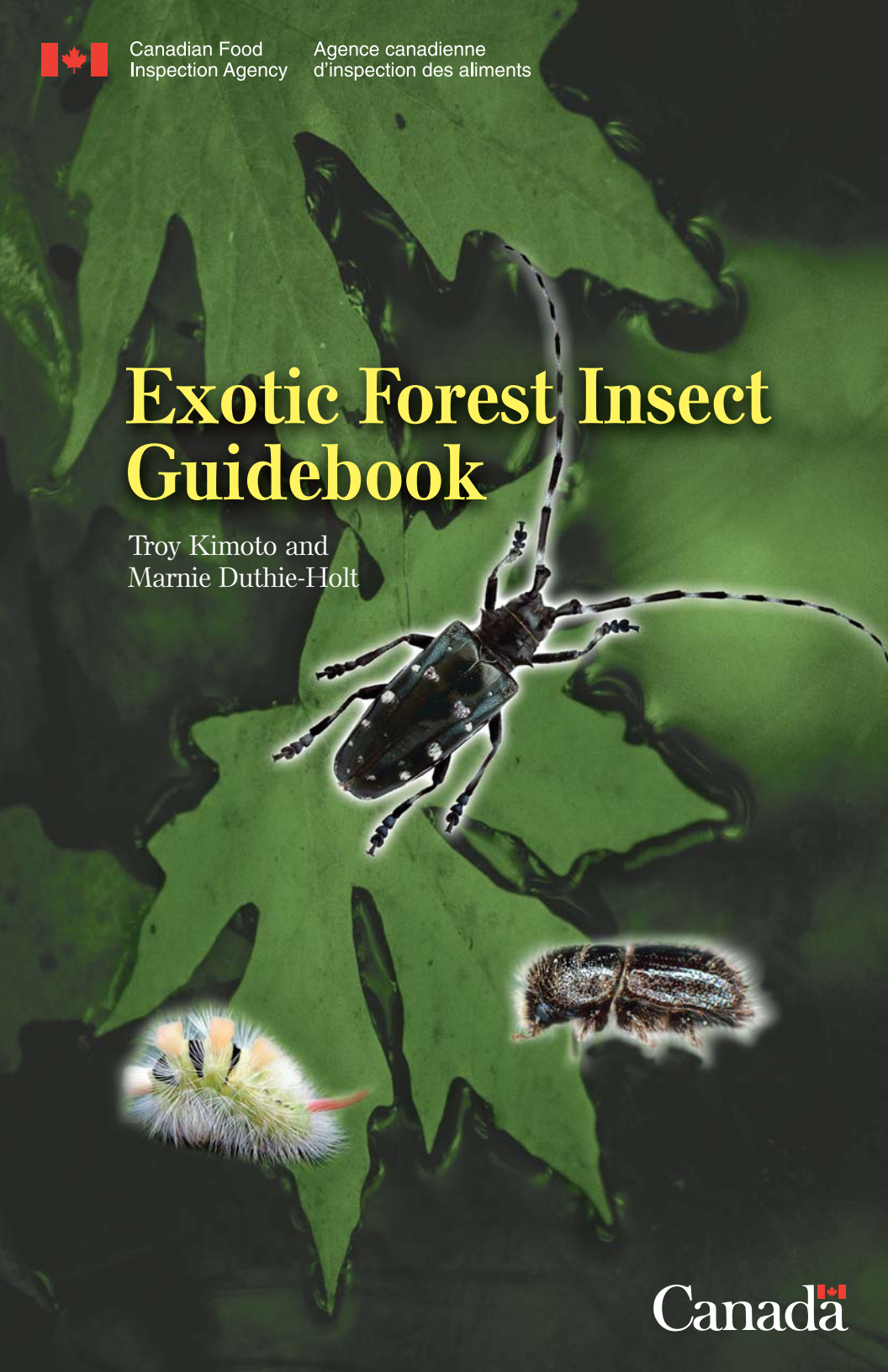
Agence canadienne d'inspection des aliments

Exotic Forest Insect Guidebook

Troy Kimoto and
Marnie Duthie-Holt



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Exotic Forest Insect Guidebook

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Prepared by:

Troy Kimoto
Plant Health Survey Unit
Canadian Food Inspection Agency

Marnie Duthie-Holt
Medi-For Forest Health Consulting

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Troy Kimoto and Marnie Duthie-Holt

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Introduction

Trees and forested areas are invaluable resources as they provide ecological, economic, spiritual and social benefits to all within Canada.

Human activities impact the surrounding environment by altering the structure and dynamics of ecosystems. The rate and extent of global trade and human migration have increased dramatically over the years. This expansion has increased the probability that organisms can be accidentally moved to and become established in areas outside of their natural range.

Most organisms fail to survive when introduced into a new environment or moved over long distances. Sometimes the conditions are suitable for an introduced organism to survive, find an appropriate food source and successfully reproduce in its new environment. Once established, their population levels may increase rapidly because the predators, parasites and diseases which attack them in their native range are not usually present in the new environment. Canadian forests have been dynamically evolving since the last ice age (~10, 000 years ago) in response to fire, climate and indigenous insects and diseases. When exotic forest pests become established, trees are abruptly exposed to a new invasive species and may not have the mechanisms to defend themselves.

In conjunction with the absence of population-limiting factors, the establishment of introduced forest pests may lead to either localized or large scale tree mortality that can impact private residences, municipalities, industries and forest ecosystems. Recently, the Emerald Ash Borer (*Agrilus planipennis*), a metallic woodborer native to China, has become established in North America where it is causing extensive mortality to green and white ash trees and threatens to severely limit the distribution of these species. However, in this insect's native range such damage has rarely been observed.

The Canadian Food Inspection Agency (CFIA) has a mandate, under the federal Plant Protection Act, to protect Canada's plant resource base against the introduction and spread of quarantine pests according to standards outlined in the International Plant Protection Convention. The CFIA does this by developing import, export and domestic regulatory policies and associated inspection, surveillance and eradication programs.

PATHWAYS OF INTRODUCTION

In terms of introduced organisms, pathways can be defined as means by which organisms are moved to new environments. Various plant health policies have identified that the greatest risks of introducing forest insects are generally associated with the importation and domestic movement of:

- Wood packaging material
- Shipping containers
- Nursery stock
- Firewood
- Raw logs with bark
- Christmas trees
- Personal effects

Wood packaging material can be one of the most important pathways for the introduction of exotic forest insects because it is often used to ship a wide variety of consignments (e.g. steel products, granite, break bulk, glass, machinery, vehicles, consumer products, etc.).

The risk posed by wood packaging varies with wood quality and degree of finishing. The higher the grade and degree of finishing, the less likely the possibility of infestation.

In the past, many exotic plant pests have been intercepted on loose wood dunnage, pallets, crating or other wood packaging made from low grade material from various origins. North America has recently agreed to begin the implementation of a new International Plant Protection Convention standard (ISPM #15) that will regulate the movement of international wood packaging.

Cities and urbanized areas have higher probabilities of receiving exotic forest pests because of the large volume of goods that are imported into those areas. Urban trees and forested areas are often exposed to poor growing conditions due to soil compaction, air pollution, mechanical damage, etc. The combination of these factors increases their vulnerability to exotic forest pests.

CFIA forest pest surveillance programs target the routes of these pathways and high risk locations (e.g. international ports or terminals, industrial zones, landfills and storage sites, nurseries, etc.). For example, high risk consignments within transport containers are inspected at major ports before they are permitted to enter Canada. However, only a small proportion of these containers are inspected upon entry and therefore, a large volume of uninspected wood packaging material is transported to urban and rural centres throughout Canada. As it is a tremendous undertaking to monitor the introduction of forest pests in a country the size of Canada, it is important to have many additional "eyes" that are on the lookout for exotic organisms.

OBJECTIVES

This book is designed for public and private sector Canadians who work in the areas of tree health and arboriculture. This book focuses more on insect descriptions, host tree preferences, damage symptoms and geographic distribution rather than insect biology in order to increase the probability of finding exotic pests during tree health assessments. A key issue in the eradication of quarantine insects is discovering and identifying populations while they are still at low and controllable levels. Hopefully this book will serve as an early detection tool.

This book is intended to help detect exotic forest insects and should be used in conjunction with indigenous pest field guides. However, the information within this book will **not** transform the reader into an expert in insect identification. Some exotic insects, especially bark beetles, may resemble indigenous or naturalized insects. Some of the damage caused by exotic and indigenous forest insects may also be very similar (e.g. red needles). Therefore, suspect specimens need to be examined by professional entomologists for conclusive identification.

Most of the insects included in this book could pose a serious threat if they became established in Canada. However, there are a few that have already become established and are being eradicated and/or regulated. The insects within this book do not represent a complete list of exotic forest insects which could invade Canada. There are a large number of non-indigenous insects throughout temperate forest regions in the world and only a very small portion of these has been included.

How to Use this Book

BOOK FORMAT

Descriptions of insects in this book are organized by guilds, which represents similarities in their biology and the part of a tree in which they breed. Bark beetles are small insects that usually feed beneath the bark on phloem. Woodborers are a diverse assemblage of round and flat-headed wood borers, wood wasps, weevils and other insects that feed within the wood. Defoliators are primarily moths, the larvae of which feed on foliage or needles. Within this guidebook, these guilds are colour coded for convenient referencing. The insects are also arranged alphabetically within each guild and each family.

For many exotic insects scientific information may be difficult to obtain. Some insects have not been extensively studied in their native range. Therefore, there is some variation in the amount of information presented for each insect.

For each insect, information is arranged into 6 categories:

- Identification
- Host trees
- Location of infestation within the tree
- Host condition
- Distribution
- Signs and symptoms

Identification briefly describes some of the key anatomical features that distinguish one insect from another.
Host trees indicates which trees, by genus, are known hosts of an insect.
Location of infestation within the tree describes the parts (roots, root collar, bole, branches, etc.) and tissues (foliage, phloem, sapwood, heartwood, etc.) that are attacked by the various life stages of the insect.
Host condition outlines the health status, age and size of trees that are attacked.
Distribution lists the countries or regions in which the insect is either native or has been introduced.

Signs and symptoms describes the characteristics that are indicative of insect attack (signs such as colour of frass, exit hole size and shape, egg gallery shape, etc.) and outlines a tree's response to attack by the insect (symptoms such as resinosis, fading foliage, thinning crown, etc.). Literature cited within the text of this book is assigned a unique number. Citations can be looked up in the Reference section at the back of the book.

Two cross-reference indexes are provided. The first index can help determine which insects will attack specific parts of a given tree. The second index indicates which tree genera are known hosts of specific insects.

Wherever possible, non-scientific language is used throughout this book to describe the insects. However, in some instances entomological terminology is used. A glossary is located at the end of the guidebook to define these terms.

DETECTING EXOTIC FOREST INSECTS

Detecting newly introduced forest insects can be very difficult because the population may be localized and still at very low densities. Furthermore, the signs and symptoms may be masked by other factors. However, there are specific clues that can be used to increase the likelihood of detection. General symptoms of decline in coniferous trees are a thin crown, stunted leader (i.e. top) and a chlorotic or reddening crown. In broad-leaved trees, epicormic shoots, wilted leaves, thin crown and pre-mature foliage colour change are common indications of decline. Although these symptoms characterize many other types of forest health stress factors (e.g. drought, root disease, hail damage, insects, mammals, salt damage, sun scald), they are also the most obvious external indicators of exotic insects.

Obtaining a "search image" for these symptoms is an initial step in locating potentially infested trees. As many exotic forest insects tend to breed in stressed trees, it is important that inspectors and surveyors check all obviously declining trees. This is particularly important in urban areas where trees often grow in sub-optimal conditions and are subjected to many stress factors.

In order to find infested trees, the surveyor must scan the entire length of a tree. Vigilance and general observation for declining trees is most beneficial. Scanning trees while walking through parks, sparsely treed industrial areas, woodlots, fencerows, riparian corridors or other wooded areas is critical in quickly locating and identifying an early attack.

General symptoms of decline should draw attention to a tree or a group of trees. The next step is to determine the causal agent. Familiarity with indigenous or naturalized biotic and abiotic forest health factors as well as local site conditions will greatly enhance the likelihood of an accurate assessment. External signs of insect activity include the presence of larvae or adults, frass (within bark cracks or crevices, on understory leaves, at the base of the tree, etc.), exit holes, entrance holes, pitch tubes along the bole, resinosis, gouting, oviposition niches, defoliation (partial or complete) and silk webbing. Internal signs such as egg and larval galleries, tunnels within twigs or branches, pupal chambers and the presence of various insect life stages can be uncovered by removing portions of the outer and inner bark with an axe or knife. Permission from the landowner is always required for more invasive investigations.

If the cause of tree decline seems suspicious, contact your local municipal or city forester, provincial ministry of natural resources entomologist/pathologist or professional arborist. Record pertinent information (street address or geographical coordinates, tree species affected, observable signs and symptoms, etc.) and if possible, collect a specimen (preferably adults) as these will assist professionals in evaluating the situation.

SAMPLE SPECIMEN SUBMISSION

This guidebook should assist in recognizing the presence of introduced forest insects but it can not replace the years of specialized training required to correctly identify insect species. There are many anatomical characteristics that require microscopic examination by specialists. The "Identification" section within the text of this guidebook only provides a general description of an insect and does not contain enough information to allow the reader to dependably identify an insect to the species level. If all other sources (e.g. local forest health specialists, native forest insect guidebooks, etc.) are unable to provide a definitive identification of a forest pest, please contact a Plant Health specialist at your local Canadian Food Inspection Agency office (http://www.inspection.gc.ca).

Troy Kimoto
Survey Biologist
Canadian Food Inspection Agency

DEFOLIATORS

- Lymantriidae
- Tortricidae
- Lasiocampidae

Lepidoptera: Lymantriidae

Calliteara pudibunda (Linnaeus)

Pale tussock moth

IDENTIFICATION

Adult: Adults are robust light gray to gray-brown moths with a wingspan of 40 to 62 mm in females and 33 to 45 mm in males.[2, 47] The front wings are light gray to gray-brown with rust-coloured spots and two dark transverse bands. The hindwings are dirty white to almost white.[2, 47] While at rest, adult moths extend their large, white and densely hairy front legs.[2, 47] Males have densely pectinate antennae.[2, 47]

Larva: Larvae are usually bright yellow-green but can appear brownish. Larvae have four erect, yellow-white, dorsal tufts on segments 4 through 7 with black transverse colouration between each tuft. Third instar larvae also have a distinguishable erect, red, hair-pencil on the 11th segment.[2, 47]

Egg: Eggs are gray-blue, oblate spheroid (pumpkin shaped) with a slight, dark depression on the top.[2, 47]

HOST TREES

Acer, Aesculus, Betula, Carpinus, Castanea, Corylus, Fagus, Juglans, Quercus, Populus, Salix, Sorbus, Tilia and *Ulmus*.[2, 47] Prefers *Fagus* and *Carpinus*[2, 47]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage within the crown.[2, 47]

HOST CONDITION

Healthy trees.[2, 47]

DISTRIBUTION

Europe, central Asia, China and Japan.[2, 47]

SIGNS AND SYMPTOMS

Eggs are usually deposited on the bark of tree trunks and on foliage, in flat masses of 50 to 300 eggs.[2, 47]

Young larvae gather on the underside of leaves. Their feeding activity punctures the leaf tissue creating holes which may contain a few uneaten veins or the holes may be completely clear.[2] Mature larvae devour the entire leaf.[2, 47] Pieces of uneaten leaves, frass and branchlets can be found on the forest floor because mature larvae are wasteful eaters.[2, 47] Severe defoliation causes thinning in the canopy (i.e. increased sunlight penetration to the forest floor).[47] Branch tip die-back, up to 30 cm, can also occur during heavy infestations.[47] Outbreaks can result in complete defoliation of the host tree by the end of summer and cause mortality in young trees.[2, 47]

A

Adult *C. pudibunda*. Note two dark transverse bands on front wings.

B

Adult *C. pudibunda* extending white, hairy front legs.

C

Pumpkin-shaped *C. pudibunda* eggs. Note black depression on the top.

D

Bright yellow-green *C. pudibunda* larva. Note red hair-pencil.

E

C. pudibunda larva. Note four erect, yellow-white, dorsal tufts.

Lepidoptera: Lymantriidae

Lymantria dispar (Linnaeus)

Gypsy moth

IDENTIFICATION

Adult: Male moths are much smaller than females and have a wing span of 35 to 40 mm.[1] Females have a wingspan of 55 to 70 mm. Males are brown whereas females are mainly white. Both sexes have a dark, crescent-shaped mark on the forewing.[1, 2, 39] Both sexes also have pectinate antennae, however the males have longer branches that give their antennae a more feathery appearance.[1]

Larva: The 1st (3 mm) and 3rd (7 mm) instars are black with long hairs; the 2nd instar (5 mm) is brown with short hairs. Instars 4, 5 and 6 are similar to each other and may be light to dark gray with flecks of yellow. They have long hairs that may be dark or golden and have 2 rows of tubercles along the back. Normally 5 pairs of blue tubercles are followed by 6 pairs of red, however variations are known to occur including all 11 pairs of tubercles being blue.[1]

Egg: Ovoid egg masses are covered with tan coloured hairs from the female's abdomen. They eventually become sun bleached with age. Egg masses are approximately 30 to 60 mm long and 20 to 30 mm wide and may contain 100 to 1000 eggs.[1, 4] Spent egg masses have pin-sized holes caused by emerging larvae.[39]

HOST TREES

Quercus (main host), *Acer, Alnus, Betula, Crataegus, Fagus, Malus, Populus, Prunus, Salix, Tilia* and many other tree and shrub species.[1, 36, 39]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage within the crown.[2]

HOST CONDITION

Healthy trees.[4]

DISTRIBUTION

Europe, northern Africa, Asia, eastern Canada and northeastern USA.[1]

SIGNS AND SYMPTOMS

Typically near their pupation sites, female moths lay egg masses on tree bark, branches and other protected places including rock piles, lawn furniture, bird houses, piles of wood, beneath logs, underneath recreational vehicles or equipment, etc.[4]

Early instar larvae excavate small holes in leaves and feed gregariously.[2] As the larvae grow they make larger holes and they also consume the leaf margin.[1] Final instar larvae will consume the entire leaf. At high populations, larvae can strip all leaves from a tree.[1] At low populations, feeding may be barely noticeable and larvae may be difficult to find since they prefer to rest in dark locations under bark flaps, stones, litter on the ground, etc.[4] Larvae seek sheltered places to pupate.[57] Pupae may be found attached by silken thread to branches, tree trunks, rocks, forest debris, buildings or fences.[57]

During outbreaks large amounts of frass may fall from defoliated trees.[4] When food is scarce, larvae will also feed on unripe tissues of annual shoots, flowers and buds.[2] One year of defoliation may not kill a healthy tree. Severe defoliation can reduce tree growth and predispose trees to attack from other insects and diseases. Four successive years of defoliation can cause mortality, especially in weakened or stressed trees.[58]

A

Larger and mainly white female (top). Smaller and mainly brown male (bottom). Note dark crescent-shaped mark on forewings.

B

Female *L. dispar* moth ovipositing an ovoid egg mass. Egg masses are covered with tan coloured hairs from the female's abdomen.

C

L. dispar larva. Note five pairs of blue tubercles are followed by six pairs of red.

D

Defoliation by early instar *L. dispar* larvae. Note small holes in the leaves.

E

Defoliation by late instar *L. dispar* larvae. Note consumed leaf margin.

F

Extensive stand defoliation caused by *L. dispar*.

Lepidoptera: Lymantriidae

Lymantria monacha (Linnaeus)

Nun moth

IDENTIFICATION

Adult: Nun moths are moderately sized, hairy and often stout-bodied with a wingspan of 45 to 55 mm (female) or 35 to 45 mm (male).[2, 4] Moths have white forewings with numerous dark, transverse, wavy lines (arches) and patches. The hind wings are gray-white or gray-brown, with minute dark patches along the outer edge.[2, 4] Female antennae are short and saw-like, whereas male antennae are feathery.[2, 4] Females have a reddish-brown abdomen with black spots, males have a gray-black abdomen.[2, 4] Melanic gray-brown and black forms are also known to occur.

Larva: Mature larvae are light to dark brown and have an orange to pale-brown head with dense black markings. Larvae are 30 to 35 mm long. Numerous short black and white hairs are present; hairs on the prothoracic and anal segments are longer. The 1st four abdominal segments have a dorsal pair of small, bluish glandular protrusions; the 6th and 7th segments have prominent mid-dorsal, orange glandular warts.[2, 4] A dark dorsal band runs from the 2nd to the 11th segment.[2, 4]

Egg: Eggs are initially orange-brown or purplish, turning dark brown over time, 1 mm in diameter, spherical and slightly concave in the centre.[4, 43, 94]

HOST TREES

Prefers *Picea, Larix, Abies, Pinus* and *Pseudotsuga*.[1, 4, 94] Will also feed on *Acer, Betula, Carpinus, Fagus, Fraxinus, Malus, Prunus, Quercus, Ulmus* and other fruit trees.[1, 4, 94]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on needles or leaves. First instars prefer newly expanded foliage or young male flowers, whereas older larvae can feed on new and old foliage.[4, 94, 95, 96]

HOST CONDITION

Healthy trees.[4]

DISTRIBUTION

China, Japan, Korea, Russia, Turkey and Europe.[1, 4]

SIGNS AND SYMPTOMS

Naked clusters of eggs may be found in bark crevices or under bark scales of trees and logs, wood packaging, forest products, sea containers and ships.[1] Egg clusters are not covered with the abdominal hair of females.[4] On coniferous trees, female nun moths preferentially oviposit on the lower bole, but during outbreaks oviposition will occur on the upper bole and in the crown.[95]

Gymnosperms

First instar larvae will only feed on the foliage of newly expanded shoots and are unable to consume older needles.[4] Second and third instar larvae are able to feed on older foliage but prefer to feed on new needles.[4, 95] Larvae can be wasteful feeders and may only consume the base of a needle, resulting in partially uneaten needles falling to the ground.[94] The crowns of defoliated trees appear thinned and have a reddish-brown colour. During outbreaks, over 50% of the foliage can be defoliated. Severe defoliation over a few years can cause tree mortality.[95]

Angiosperms

Initially, larval browsing creates holes in the leaves.[7] As feeding progresses, leaves are entirely consumed except for the middle vein.[96]

A

Adult *L. monacha*. Note white forewings and numerous dark, transverse, wavy lines and patches.

B

Thin crowns caused by *L. monacha* defoliation.

C

Mature dark brown *L. monacha* larva (30-35 mm long). Note mid-dorsal orange warts on the 6th and 7th segments.

D

Bark scale removed to reveal naked *L. monacha* egg mass.

E

L. monacha defoliation on understory host tree.

F

Extensive stand defoliation caused by *L. monacha*. Note thinning reddish-brown crowns.

G

Defoliation by late instar *L. monacha*. Note partially eaten needles.

Lepidoptera: Tortricidae

Choristoneura murinana (Hübner)

Silver fir shoot tortricid

IDENTIFICATION

Adult: Moths have a wingspan of 17 to 25 mm.[2] Forewings are gray and yellow with variable brown markings and a characteristic broad, red-brown transverse band.[2] Hind wings are gray-brown with yellowish tips.[2]

Larva: Newly hatched larvae are green-yellow with a brown head, and are 1.5 mm long.[2] Second instar larvae are dark yellow with a yellow-brown head.[2] Mature larvae, 16 to 22 mm long, have a shiny black head and a pale gray-green body with lighter lateral and ventral segments.[2] They also have an orange anal shield.[2] Chitinized warts with black hairs occur over the entire body.[2, 13]

Egg: Eggs are 1.5 by 1.2 mm, somewhat flat, slightly green, oval and characteristically rimmed.[2]

HOST TREES

Abies (main host), *Cedrus, Juniperus, Picea, Pinus* and *Pseudotsuga*.[13]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage in the crown.[2]

HOST CONDITION

Healthy trees.[2] Prefer forests with a large percentage of *Abies*. Mature trees are preferred but larvae will also feed on young trees.[126]

DISTRIBUTION

Central and southeastern Europe.[2, 13]

SIGNS AND SYMPTOMS

Eggs are predominantly deposited in the upper crown of host trees, in two overlapping rows on the upper side of the needle.[2, 13, 126] Females oviposit approximately 10 to 30 eggs within these two rows and up to 100 eggs in total.[2]

Immediately after hatching, 1st instar larvae seek hibernation sites between the bud scales or bark cracks and spin fine white hibernacula within which they moult and pass the rest of the summer and the following winter.[126] First instar larvae do not feed.[13] In the spring, 2nd instar larvae penetrate new unopened buds, weave silk threads over the bud scales and cause the developing shoot to become characteristically bent.[2, 126] Unlike North American coniferophagous *Choristoneura* species, *C. murinana* larvae only feed on newly formed needles and will not feed on older needles, even during outbreaks.[2, 13, 126]

Early instar larvae create holes in the needles and often leave behind partially eaten stubs, while older instars consume the entire needle.[2] On rare occasions, the epidermis and inner bark of young shoots are consumed. Defoliation primarily occurs in the upper crown, but will also occur in the lower crown during outbreaks.[2] Pupation normally occurs in the foliage.[13]

Symptoms of attack include loss of newly flushed needles, decrease in annual height increment and gradual thinning and rounding of the crown.[2] Defoliated crowns may appear reddish-brown. Mortality occurs on trees experiencing two or more consecutive years of severe defoliation.[126] Cones do not develop because feeding occurs on flower buds.[2]

A

Adult *C. murinana*. Forewings are gray and yellow with brown markings.

B

C. murinana larva. Note silk threads and partially consumed needles.

C

C. murinana larva. Note black head.

D

Mature *C. murinana* larva.

E

C. murinana only feeds on new foliage. Note reddish-brown colour of damaged shoots.

F

C. murinana defoliation from the previous year.

Lepidoptera: Tortricidae

Tortrix viridana Linnaeus

European oak leafroller

IDENTIFICATION

Adult: Forewings are pale-green or yellow-green; hindwings are brownish-gray to grayish; both wings have a white, frayed outer edge.[6, 36, 42, 87] The wingspan is approximately 18 to 23 mm.[6, 42, 87] The head is yellowish and adults have a grayish, 8 mm long abdomen.[6, 42]

Larva: Younger larvae are gray coloured with dark heads.[6] Older instar larvae turn gray-green.[6] Larvae are 15 to 19 mm long and 2.5 mm wide.[42]

Egg: Eggs are round, with a diameter of about 0.7 mm.[6, 42] They are initially light yellow, later changing to brown.[6, 42]

HOST TREES

Quercus (main host), *Acer, Betula, Carpinus, Fagus* and *Populus*.[6, 42] They also feed on shrubs including *Vaccinium* and *Urtica*.

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage, with the most preferable section being the upper crown.[6]

HOST CONDITION

Drought stressed and healthy hosts. Pole-sized and older trees are preferred.[6]

DISTRIBUTION

Europe, northern Africa, Cyprus, Iran and Israel.[6, 36, 42, 83]

SIGNS AND SYMPTOMS

Each female oviposits approximately 50 to 60 eggs in pairs within a cement-like mass.[42, 76, 87] Eggs are deposited on branches, leaves, and branch forks, within the entire crown.[6] A dust and algae lining make the eggs nearly invisible.[6]

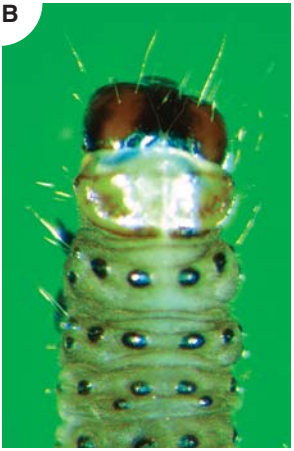
Emerging larvae bore into open buds, since closed buds cannot be penetrated.[6] Therefore, emerging larvae can only survive if the buds are in synchrony with their development.[6] As the buds flush, the larvae move to young leaves and flowers and continue feeding.[6, 42] Larvae construct shelters by rolling leaves with silk webbing.[42] Third instar larvae become more mobile and are thus more visible. Similar to other tortricids, when larvae are disturbed, they will drop on a silken thread.[34] Last instar larvae feed upon the expanded foliage as well as the bark of tender young shoots.[42, 76]

Tortrix viridana is part of a *Quercus* die-back complex that results in thinning foliage, progressive die-back, cambial necrosis, epicormic shoot development and tree mortality.[80, 81, 83] Successive defoliation can cause growth loss and can also weaken trees and predispose them to mortality by other organisms.[42]

A

Adult *T. viridana* (18-23 mm wingspan). Note pale-green forewings and frayed outer edge.

B



Gray-green *T. viridana* larva (late instar).

C

T. viridana larva (15-19 mm long).

D

Rolled leaf shelters created by *T. viridana* larvae.

E

Thinned crowns caused by *T. viridana* defoliation.

F

Rolled leaf shelters created by *T. viridana* larvae.

Lepidoptera: Lasiocampidae

Dendrolimus sibiricus Tschetverikov

Siberian coniferous silk moth

IDENTIFICATION

Adult: Moths are yellowish-brown or light gray to dark brown or almost black.[4] The front wings have two dark transverse bands and a white spot in the centre. The hind wings are the same base colour as the forewings but without any markings.[1] Males are approximately 30 mm long and have a wing span of 40 to 60 mm. Females are approximately 40 mm long and have a wing span of 60 to 80 mm.[4, 24]

Larva: Larvae are mainly black or dark brown with numerous spots and long hairs.[4, 24] Reddish setae are found on the sides of larvae, usually as red jagged bands or spots.[1] The 2nd and 3rd segments are marked with blue-black stripes. Larvae are approximately 55 to 70 mm long.[4, 24]

Egg: Eggs are 2.2 mm long and 1.9 mm wide (oval). They are initially light-green but turn creamy-white and finally darken and become spotted.[24]

HOST TREES

Abies, Larix, Picea, Pinus and *Tsuga.*[4, 24]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage in the crown.[4, 24]

HOST CONDITION

Stressed (e.g. drought) and healthy trees.[4, 24]

DISTRIBUTION

China, Mongolia, Japan, Korea, Kazakhstan and Russia.[4]

SIGNS AND SYMPTOMS

Female moths oviposit a single egg or clusters (an average of 200 to 300 eggs) of egg chains primarily on needles in the lower part of the crown. However, during outbreaks eggs are laid throughout the tree and even on the ground.[4, 24]

First instar larvae preferentially consume the edges of needles.[4, 24] Older larvae will completely consume entire needles and may sometimes eat the bark of young shoots and cones.[24] Defoliated crowns appear reddish-brown.[16]

Severe defoliation over a few years can lead to direct tree mortality or it can predispose host trees to attack by secondary insects.[4, 24] In it's native range, *D. sibiricus* outbreaks can cause severe tree mortality over very large areas.[4, 24]

Mating *D. sibiricus* moths. Note two dark transverse bands and white spot on forewing.

D. sibiricus larva (55-70 mm long).

Reddish-brown crowns of trees defoliated by *D. sibiricus*.

Oval *D. sibiricus* eggs (1.9 mm wide).

D. sibiricus larva. Note red bands on the side of the larva.

D. sibiricus larva. Note 2nd and 3rd segments with blue-black stripes.

D. sibiricus cocoon.

Lepidoptera: Lasiocampidae

Malacosoma neustria (Linnaeus)

European tent caterpillar

IDENTIFICATION

Adult: Adult moths vary greatly in colour.[2, 111] There are two common morphs, one light and one dark, with less frequent intermediates. The basic colour is brown, but can range from ochre-yellow to red-brown.[2, 111] Males have a wingspan of 30 to 40 mm, with the more robust females having a wingspan of 36 to 40 mm.[2, 111] Forewings have a brownish, narrow-edged, oblique, central transverse band.[2, 111] The fringes of the forewings are irregularly variegated and checkered.[2, 111] Male and female antennae are bipectinate, with females having shorter antennal branches and shorter antennae.

Larva: First instar larvae are black and approximately 2 mm long.[111] Mature larvae are 40 to 55 mm long, slender and are covered with numerous fine secondary setae.[2, 111] Larvae are marked with a distinct white dorsal line and blue or gray-blue, and red-yellow lateral bands separated by black edging.[2, 111]

Egg: Eggs are white or gray-brown.[111]

HOST TREES

Acer, Alnus, Amygdalus, Betula, Carpinus, Castanea, Cotoneaster, Corylus, Crataegus, Fagus, Juniperus, Larix, Malus, Morus, Populus, Prunus, Pyrus, Quercus, Rosa, Rubus, Salix, Sorbus, Syringa, Ulmus and occasionally *Tilia* and *Fraxinus*.[111]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on foliage within the crown.[111]

HOST CONDITION

Healthy trees.[111]

DISTRIBUTION

China, Europe, Iran, Japan, Korea, Mongolia, northern Africa, Siberia, Syria, Taiwan and Turkey.[111]

SIGNS AND SYMPTOMS

Eggs are deposited in masses of 150 to 400 and are cemented together by a frothy varnish-like material. Similar to other *Malacosoma* species, eggs are deposited in a band (1 cm wide) around 1 and 2 year old branch tips.[70, 111]

Newly emerged larvae immediately crawl to the crown. Larvae feed gregariously and gather at major branch forks to construct tents.[111] Although larvae feed within these tents, they also feed throughout the entire crown.[111] Larvae can completely defoliate trees during outbreaks.[111]

As larvae develop they become solitary and eventually seek sheltered locations to pupate such as bark crevices, between dried leaves on the tree stem or branches, in leaves on the ground or in the cracks of buildings.[111] Cocoons are yellowish-white and may occur in clusters.[70, 111]

Defoliation can cause growth loss and can predispose host trees to mortality by other organisms.[111] Trees may be killed after a few years of severe defoliation.[111]

A

Adult *M. neustria* (dark morph). Note central transverse band.

B

Complete defoliation of host tree during a *M. neustria* outbreak. Note silk tents.

C

M. neustria larvae. Note white, gray-blue and red-yellow bands separated by black edging.

D

M. neustria larvae on silk tent.

E

M. neustria egg mass (1 cm wide).

F

Foliage partially consumed by *M. neustria* larva.

G

Male *M. neustria* (light morph).

LARGER WOODBORERS

- Buprestidae
- Cerambycidae
- Curculionidae
- Siricidae

Coleoptera: Buprestidae

Agrilus biguttatus (Fabricius)

Two spotted oak borer

IDENTIFICATION

Adults are cylindrical, metallic beetles, 8 to 13 mm long, ranging in colour from golden-green, green, blue-green, blue to violet.[42, 129] The elytra are slender and have two white spots near the posterior end of the elytral suture.[42, 129] The frons is wide and flat, with a shallow depression.[129] The length of the pronotum is one and a half times the width.[129]

HOST TREES

Quercus (main host), *Fagus* and *Castanea*.[98, 130] *Quercus rubra* is a known host tree occurring within Canada.[98]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood along the entire bole (including stumps) and larger diameter branches.[120, 129, 130] Immature beetles maturation feed on host tree leaves.[42, 98, 120]

HOST CONDITION

Standing trees (especially if weakened by defoliation, frost damage or water stress) or recently downed trees and stumps.[98, 120, 129, 130] In it's native range, larvae will not develop in dried dead trees.[120] Healthy trees are also susceptible to attack.[98, 120] Although beetles prefer larger diameter (i.e. greater than 30 cm) and older (i.e. 50 to 120 years) trees, attacks have also been recorded on 20 year old hosts.[98, 120]

DISTRIBUTION

Europe, Middle East, Siberia and northern Africa.[42, 98, 120]

SIGNS AND SYMPTOMS

Females oviposit clusters of 5 to 6 eggs on the bark of host trees.[42, 120, 129] Larvae bore through the bark and excavate frass-filled, zig-zagging galleries which can reach lengths of 155 cm.[42, 98, 120] Early instar larvae generally make their galleries along the wood grain while older instars produce galleries in irregular twisting transverse directions.[42, 98, 120] These galleries are not as distinctly "S-shaped" as those created by the emerald ash borer, *Agrilus planipennis*. Dark cracks and discolouration of the bark and cambial tissue may occur over the galleries as the tree tries to defend itself from the invasion.[98, 120]

Larvae overwinter in 10 to 14.8 mm by 3 to 4.5 mm chambers within the inner bark.[42, 120] Woodpecker activity on living trees may indicate overwintering larvae.[120] Beetles emerge from "D-shaped" exit holes that are about 2.5 by 3.0 mm and are found from ground level up to a height of 10 m (i.e. lower portion of the crown).[42, 98, 120]

Larval galleries can girdle the host tree resulting in twig and branch die-back, changes in foliage colour from green to brown, thinning of foliage within the crown, development of epicormic shoots along the stem and tree mortality in heavily infested trees.[42, 98, 120]

Adult *A. biguttatus* (8-13 mm long). Note white spots near elytral suture.

Zig-zag shaped larval galleries (up to 155 cm long).

Branch and twig dieback caused by *A. biguttatus*.

A. biguttatus larva just prior to pupation.

Mature *A. biguttatus* larva.

D-shaped exit hole (2.5 by 3.0 mm) of *A. biguttatus*.

Early instar larval galleries. Note zig-zag shape.

Coleoptera: Buprestidae

Agrilus planipennis Fairmaire

Emerald ash borer

IDENTIFICATION

Adult beetles are metallic blue-green, narrow, hairless, elongate, 8.5 to 14.0 mm long and 3.1 to 3.4 mm wide.[86] The head is flat and the vertex is shield-shaped.[86] The eyes are bronze or black and kidney shaped.[86] The prothorax is slightly wider than the head and is transversely rectangular, but is the same width as the anterior margin of the elytra. The posterior margins of the elytra are round and obtuse with small tooth-like projections on the edge.[86]

Mature larvae are 26 to 32 mm long and creamy white.[86] The body is flat and broad shaped.[86] The posterior ends of some segments are bell-shaped. The abdomen is 10-segmented. The 1st 8 segments each have one pair of spiracles and the last segment has one pair of brownish, pincer-like appendages.[86]

HOST TREES

Fraxinus, Juglans, Pterocarya and *Ulmus*.[86] In North America, only *Fraxinus* has been found infested to date.

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood along the entire bole and larger branches (greater than 2.5 cm diameter) in the crown. In addition to mature trees, galleries can occur in young saplings. Immature beetles maturation feed on leaves.[86]

HOST CONDITION

Healthy or weakened trees.[86]

DISTRIBUTION

China, Japan, Korea, Mongolia, Russia and Taiwan. Introduced to Canada (Essex, Lambton & Elign Counties and Chatham-Kent Municipality, Ontario) and USA (Michigan, Illinois, Indiana and Ohio).[1, 86]

SIGNS AND SYMPTOMS

Immature beetles maturation feed on host tree foliage, creating irregular notches in the leaves.[86] Eggs are laid singly on the bole or branches.[86] First instar larvae bore through the bark and feed on the inner bark and the outer sapwood, eventually forming flat and wide (6 mm), "S-shaped" galleries that are filled with a fine brownish frass.[86] Galleries are 9 to 16 cm long (up to 20 to 30 cm) and increase in width from the beginning to the end.[86] Galleries can occur along the entire bole and in branches that are at least 2.5 cm in diameter.[86] Callus tissue may be produced by the tree in response to larval feeding and may cause vertical bark cracks to occur over a gallery.[86]

Pupation takes place at the end of a gallery just beneath the bark, or near the surface of the sapwood (5 to 10 mm) and even in the corky tissue of thick-barked trees.[86] Beetles emerge through "D-shaped" exit holes, 3.5 by 4.1 mm in size.[86] These holes are very difficult to find so careful inspection is required.[86] Woodpecker activity may also indicate the presence of this beetle.[86] Dying or dead trees, particularly with bark sloughing off and crown die-back can also be used as indicators of attack.[86] Other signs of attack include a thinning crown, epicormic shoots, and vertical cracks on the trunk.[86]

A

Adult *A. planipennis* (8.5-14 mm long). Metallic, green-blue body.

B

Various larval instars of *A. planipennis*.

C

S-shaped larval galleries of *A. planipennis*.

D

D-shaped exit hole (3.5 by 4.1 mm) of *A. planipennis*.

E

Epicormic shoots caused by *A. planipennis*.

F

Vertical bark cracks over larval galleries caused by callus tissue production.

G

Thinned ash crowns infested with *A. planipennis*.

Coleoptera: Cerambycidae

Anoplophora glabripennis (Motschulsky)

Asian long-horned beetle

IDENTIFICATION

Adults are large shiny black beetles, 20 to 35 mm long and 7 to 12 mm wide. There are up to 20 irregular white spots on each elytron. There is one prominent spine on each side of the black thorax. The antennae are longer than the body and consist of 11 black segments with a white or whitish-blue base. The legs are black and have a bluish tinge.[1, 4, 38, 99]

HOST TREES

Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus and *Ulmus* are host trees in North America.[1, 4, 38] The suitability of *Alnus, Crataegus, Elaeagnus, Fraxinus, Hibiscus, Malus, Morus, Prunus, Pyrus, Quercus, Robinia* and *Tilia* in North America is still in question.

LOCATION OF INFESTATION WITHIN THE TREE

Female beetles oviposit on exposed roots, along the entire bole and on branches as small as 2 to 3 cm in diameter.[4] Immature larvae feed on the inner bark and sapwood while mature larvae feed on the heartwood.[4, 38] Beetles feed on leaves, petioles, or the inner bark of twigs.[1, 38, 99]

HOST CONDITION

Healthy and weakened trees. Females do not oviposit on dead, debarked wood.[1]

DISTRIBUTION

China, Korea and Japan. Introduced and under eradication in New York, Chicago, New Jersey, Toronto, Bayern (Germany), Gien and Sainte Anne sur Brivet (France) and Braunau (Austria).[1, 4, 38]

SIGNS AND SYMPTOMS

Beetles feed on the leaves and twigs of host trees.[1, 4, 38, 99] Feeding damage on young shoots causes them to wither and die.[99]

Females chew oval oviposition niches (about 10 mm wide) and lay a single egg in the inner bark. Depending upon the tree species, the oviposition niches are initially reddish-brown but fade over time. Oviposition niches can occur from ground level up into the crown on branches that are at least 2 to 3 cm in diameter. Frothy, white sap may exude from recently created oviposition niches.[1, 4, 38] Over time, the sap ferments and stains the bark.

Young larvae feed within the inner bark and sapwood and can cause the bark to become concave.[38, 99] Mature larvae bore into the heartwood. Late instar galleries are initially perpendicular to the stem axis but gradually turn upwards and can reach lengths of 3.5 to 15 cm.[4] These winding larval galleries can eventually lead to tree mortality in heavily infested trees. Coarse, sawdust-like frass is expelled from the larval galleries and will occur in piles around the base of the tree or in branch forks.[4, 38] Adults emerge through the wood by chewing round exit holes 6 to 12 mm in diameter and expel large, coarse wood fibres on the ground.[1, 4, 99] Exit holes may be present anywhere on the larger above ground parts of the host, including branches, trunk, and exposed roots.[1, 4, 38, 99]

Leaf yellowing and wilting, pre-mature leaf drop, branch die-back and tree death are symptoms of advanced infestation.[1, 4, 99]

Adult *A. glabripennis* (20-35 mm long).
Note approximately 20 irregular white spots on each elytron.

Bark staining caused by fermented sap.

New *A. glabripennis* oviposition niches (10 mm wide).

Old (darker) and new (reddish-brown) oviposition niches of *A. glabripennis*.

Frothy, white sap exuding from recent *A. glabripennis* oviposition niches.

Circular *A. glabripennis* exit hole (6-12 mm wide).

Coarse frass expelled by larva of *A. glabripennis*.

Coleoptera: Cerambycidae

Callidiellum rufipenne (Motschulsky)

Smaller Japanese cedar longhorned beetle

IDENTIFICATION

Adult beetles are 6 to 14 mm long, 3 to 4 mm wide and have a slightly flattened body.[91] The head and thorax are brown with reddish-brown hairs.[91] The 1st antennal segment is black while the following segments are chestnut brown.[91] Male antennae are slightly longer than the body while those of the female are about two-thirds the body length.[8] Male elytra are usually black with metallic blue-violet or greenish reflections.[8, 91] Females typically have brownish-red to red elytra.[91]

HOST TREES

Chamaecyparis, Cryptomeria, Cupressus, Juniperus and *Thuja.*[1] The suitability of *Cedrus, Pinus* and *Abies* is still in question.[91] In North America, *C. rufipenne* has been found in *T. occidentalis, J. virginiana* and *J. communis*.[1, 90, 91, 92]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on inner bark and sapwood where the stem or branch diameter is at least 1 cm.[8, 90, 91]

HOST CONDITION

Preferentially attacks dying, weakened, stressed or freshly felled trees.[10, 90]

DISTRIBUTION

China, Japan, Korea and Russia (Sakhalin). Introduced into Italy, Spain and North America (Connecticut and North Carolina).[1, 20, 90, 91, 92]

SIGNS AND SYMPTOMS

Eggs are laid in bark crevices. Newly hatched larvae bore through the bark and construct shallow, flat and irregular shaped galleries (2 to 6 mm wide).[10, 91] Gentle scraping of the bark may be required to expose the frass-filled galleries.[91] These larval galleries increase in width as the larvae increase in size.[90] Mature larvae create an "L-shaped" gallery by boring straight into the sapwood, then construct 2.4 to 2.7 cm long pupation chambers parallel to the grain.[10, 91] The entrance to these pupal chambers is tightly packed with fine, powdery frass.[10] Adults emerge from elliptical exit holes that are 6 to 10 mm or more in diameter.[90]

Other signs of attack include bark depressions resulting from larval mining, light red frass on branches and the trunk, 8 to 15 mm long cracks in the bark, callus tissue (i.e. puckering) forming over the larval galleries and brittle branches that may crack and expose the larval galleries beneath.[9, 90, 91] Attacks can also hasten the death of the host tree or increase its susceptibility to pathogens or other forest insects.[91]

A

Adult *C. rufipenne*. Head and thorax are brown with reddish-brown hairs.

B

Male *C. rufipenne* has black to bluish-green elytra and longer antennae. Female has red elytra and shorter antennae.

C

Adult *C. rufipenne* ready to emerge from the pupal chamber.

D

Frass plug blocking the pupal chamber entrance.

E

Frass filled *C. rufipenne* larval galleries.

F

Callus tissue surrounding *C. rufipenne* galleries.

G

Elliptical *C. rufipenne* exit hole (6-10 mm wide).

Coleoptera: Cerambycidae

Cerambyx cerdo Linnaeus

Great Capricorn beetle

IDENTIFICATION

Adult beetles are 24 to 53 mm long, with a blackish body and legs.[25] Male antennae are twice as long as the body, while those of the female extend to the elytral apex.[25] The pronotum is roughly textured and greater in width than in length. The tapered elytra are reddish-brown towards the apex.[25] The elytral apex has well developed sutural spines.[128]

HOST TREES

Quercus (main host), *Carpinus, Castanea, Ceratonia, Fagus, Fraxinus, Juglans, Pyrus, Robinia, Salix* and *Ulmus*.[25, 85, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark, sapwood and heartwood along the stem.[25, 128]

HOST CONDITION

Mature, weakened (e.g. diseased, pruned) trees, especially those growing in open and sunny locations.[25, 85, 117, 128] Occasionally young or healthy trees are attacked.[85]

DISTRIBUTION

Europe, Asia, Caucasus, Asia Minor and northern Africa.[25, 121, 128]

SIGNS AND SYMPTOMS

Females lay eggs in the bark.[117] Larvae develop in the inner bark before penetrating into the sapwood, and then into the heartwood.[25, 117, 128] Larval galleries are long, irregular and widen as the larvae increase in size.[25, 117, 128] Larval development may take up to 2 to 5 years.[25, 117]

Pupation occurs in the sapwood (approximately 80 mm deep) in a large, elongate, oval pupal cell that is partitioned from the larval gallery by a calcareous operculum secreted by the larvae.[128] Adults overwinter in the pupal cell and emerge at the end of spring, during the summer, or at the beginning of fall.[25, 117] Exit holes are more or less oval and up to 2 cm in diameter. Brown frass also accumulates at the base of infested trees.

Dark resin seeps from holes at attack sites.[117] Several generations may develop in the trunk. Re-infestation may continue year after year, highly degrading the wood and in some cases causing death of the infested tree.[117, 128]

A

Male *C. cerdo* (24-53 mm long). Antennae are twice the body length.

B

Female *C. cerdo* (24-53 mm long). Antennae extend to the elytral apex.

C

Elongate and oval *C. cerdo* pupal chamber.

D

Adult *C. cerdo*. Elytra are reddish-brown towards the apex.

E

C. cerdo larval galleries within the sapwood.

F

Long, irregular-shaped *C. cerdo* larval galleries in the inner bark. Galleries widen as the larvae increase in size.

Coleoptera: Cerambycidae

Monochamus sartor (Fabricius)

IDENTIFICATION

These shiny, black metallic beetles are 21 to 35 mm long and have sparse yellow hairs on the elytra.[2, 25, 128] Antennae are twice the body length in males but only slightly longer than the body in females.[2] Antennae of both sexes are black but the bases of the 3rd to 11th antennal segments in females are whitish-gray.[2, 25]

A distinguishing characteristic of this species is a transverse saddle-like impression found behind the pronutum.[2] The pronotum and elytra of females have a few white spots, but these are absent or indistinct on males.[25] Female elytra have parallel edges whereas the male's narrows posteriorly.[2]

HOST TREES

Picea (main host), *Abies, Larix* and *Pinus*.[2, 25]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark, sapwood and heartwood along the stem. Attacks usually occur 2 to 4 m above the ground.[2, 25, 85] Immature beetles maturation feed on needles, green cones and twigs.[2, 25, 128]

HOST CONDITION

Weakened, felled, fire scorched, or uprooted trees.[2, 25, 85, 128] Large diameter stems are preferred.[25, 85] As populations increase during an outbreak, attacks can occur on healthy trees.[2]

DISTRIBUTION

Europe.[2, 128]

SIGNS AND SYMPTOMS

Beetles emerge in spring and feed in the crown on needles, weakened twigs and green cones.[2, 85, 128] In the summer, fertilized females excavate a funnel-shaped pit in the bark, 6 to 7 mm wide and 4 to 5 mm long, and deposit a single egg in each niche.[2, 85, 128] At least 50 eggs are laid by a single female.[85]

Early instar larvae excavate large, deep, galleries (up to 50 cm long) packed with long, fibrous frass in the inner bark.[2] Through an oval entrance hole, larvae bore horizontal galleries into the sapwood that may sometimes reach the heartwood.[2, 128] Larvae then bore parallel to the grain of the wood for a few cm and expel frass through these holes.[2, 128] Last instar larvae mine "U-shaped" galleries, so that adult emergence occurs on the same side of the trunk as the entrance holes.[85, 128] Pupation chambers are plugged with wooden fibres and occur at a depth of 10 to 12 mm.[2] Adults emerge from exit holes 8 to 12 mm in diameter.[2, 128]

A

Adult *M. sartor* (21-35 mm long).

B

Male and female *M. sartor*. Male antennae are twice the body length. Female antennae are slightly longer than the body.

C

M. sartor larva and larval galleries (up to 50 cm long). Note long, fibrous frass in the larval galleries.

Coleoptera: Cerambycidae

Monochamus urussovi (Fischer)

Black fir sawyer beetle

IDENTIFICATION

Adult beetles are 18 to 37 mm long, with antennae that are 2 to 2.5 times the body length in males but only slightly longer than the body in females.[23, 25, 128]
The pronotum is as long as it is wide.[138]
The head and pronotum have sparse white or yellowish pubescence. Legs, elytra and antennae are all black with a very slight brass tinge, but female elytra also have spots of whitish-gray hairs.[25, 128, 138]

HOST TREES

Abies (most heavily damaged), *Larix, Picea* and *Pinus*.[25, 26, 137, 138] Even though this species is frequently found on *Betula*, it causes little damage to it.[26]

LOCATION OF INFESTATION WITHIN THE TREE

Immature beetles maturation feed on twigs, branches and needles within the crown.[25, 138]
Larvae breed in the inner bark and sapwood along the entire bole of standing trees. In felled trees, larvae primarily breed within the lower bole.[25, 128, 138]
Larger trees (16 to 40 cm in diameter) are preferentially attacked.[138]

HOST CONDITION

Breeding preferentially occurs in damaged (e.g. drought, fire, and windthrow), dying or recently cut trees.[25, 26, 50, 138] Outbreaks can occur in live healthy trees.[26] Beetles prefer to feed on young, thin growing shoots.[50, 138]

DISTRIBUTION

Europe, Russia, Japan, Korea, Mongolia and northern China.[25, 138]

SIGNS AND SYMPTOMS

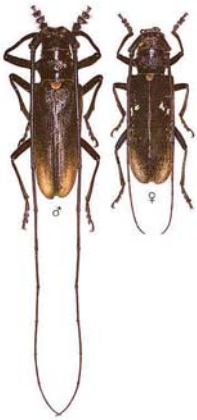
Beetles feed in the crown, removing strips of bark and infecting branches with spores of phytopathogenic *Ceratocystis* fungi.[26] The developing fungi kills branches on the periphery of the crown, weakens the tree, and reduces resin flow, thus making the tree suitable for oviposition and larval feeding.[26, 50, 138]

In the summer, fertilized females excavate oviposition niches and deposit a single egg beneath the bark.[2, 26] Larvae bore broad (2 to 2.5 cm wide), sinuous galleries beneath the bark that are filled with frass and fine chips.[2, 26, 138] Frass is expelled through ventilation holes along the gallery.[138] After overwintering, last instar larvae bore into the sapwood through an oval entrance hole that is on average 16 by 6.5 mm.[138] The excavation of these galleries is at first transverse, then longitudinal, exhibiting an almost 90 degree turn.[138] The longitudinal portion is often packed with a frass plug and ends in a pupal chamber (6.5 cm long and 2.0 cm wide).[138] Adults emerge through round exit holes that are 6 to 12 mm in diameter.[26, 138] As infested host trees die, needles fade from green to yellow and finally to red.[61]

A

Adult *M. urussovi* (18-37 mm long). Note brass tinge on elytra.

B



Male (antennae 2.0-2.5 times body length) and female (antennae slightly longer than body) *M. urussovi.*

C

Chlorotic needles on tree attacked by *M. urussovi*.

D

Circular *M. urussovi* exit hole (6-12 mm wide).

E

M. urussovi pupal chamber.

F

Broad (2-2.5 cm wide), sinuous *M. urussovi* larval galleries.

G

M. urussovi larval gallery leading to the pupal chamber.

Coleoptera: Cerambycidae

Oberea linearis (Linnaeus)

Hazelnut longhorned beetle

IDENTIFICATION

Adult beetles are 11 to 14.5 mm long and have yellow legs.[121, 128] The body is black, cylindrical and very long and narrow.[115, 121, 128] The antennae are shorter than the body.[128] The prothorax bulges slightly in the middle.[115]

HOST TREES

Corylus (main host), *Alnus, Carpinus, Juglans, Ostrya, Salix* and *Ulmus*.[25, 37, 115, 121, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae develop within one year old shoots and twigs.[25, 37, 115, 121, 128] Immature beetles maturation feed on leaves.[25, 121]

HOST CONDITION

Healthy trees.[85, 121, 128]

DISTRIBUTION

North and central Europe, Caucasus to Southern Russia, and Turkey.[37, 121, 128]

SIGNS AND SYMPTOMS

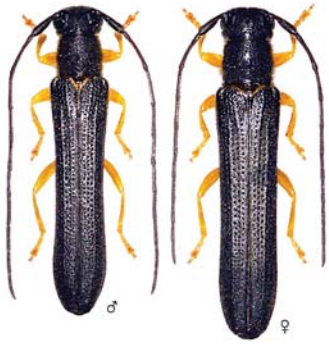
Beetles of this species feed on the lateral veins of young hazel leaves.[121]

Females chew through the bark, at the base of the previous year's branch, and deposit a single egg between the bark and sapwood.[37, 115, 128] Occasionally, adult beetles will girdle the shoot a few centimetres above the oviposition site.[37] Bark tissue around the egg becomes necrotic.[121]

Each larva bores to the central pith and mines a tunnel, 50 to 100 cm long, within the branch.[37, 115] Larval feeding causes the leaves to wilt, curl and turn brown and causes the shoot to break.[37] Crown damage is most noticeable in the fall.[37] In *Corylus*, shoot feeding also causes the bark to turn reddish.[37]

Larvae expel frass through ventilation holes along the twig so the tunnel remains hollow.[37, 115, 128] Larvae overwinter within the twig for 2 seasons.[37, 115] In the spring, last instar larvae make pupal chambers inside the base of the twig.[37, 115] The pupal cells are constructed by plugging off a section of the tunnel with two wads of fibrous frass.[128] The lower parts of pupal cells are filled with fine frass.[115] The pupal cells are 2.0 to 3.5 cm long.[115] Exit holes are oval (7.0 mm by 2.5 mm).[115]

A



Male and female *O. linearis* (11-14.5 mm long). Note yellow legs and black body.

B

O. linearis feeding on lateral vein.

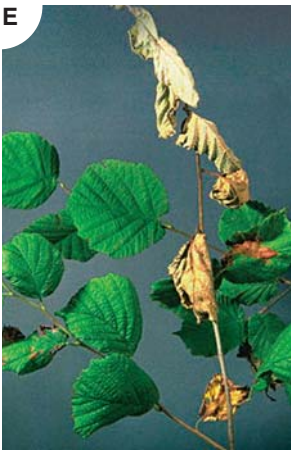
C

Maturation feeding of *O. linearis* on lateral veins of host leaf.

D

Necrotic tissue surrounding *O. linearis* oviposition niche.

E



Wilting foliage caused by *O. linearis* larva feeding within the branch.

F

O. linearis larva within larval gallery (50-100 cm long).

Coleoptera: Cerambycidae

Oberea oculata (Linnaeus)

Eyed longhorn beetle

IDENTIFICATION

Adult beetles are distinguished from other species of this genus by a comparatively large body (15 to 20 mm long), black head, elytra and antennae. The parallel elytra are covered with a fine ash-gray pubescence.[23, 25, 121, 128] The legs, pronotum, scutellum and ventral abdomen are rusty orange.[23, 25, 128] The antennae are shorter than their body and also taper from the base to the apex.[23, 128] Two (rarely 4) dark spots occur medially on the pronotum.[23, 128]

HOST TREES

Salix (main host) and *Populus*.[25, 121, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae infest living twigs, stems and branches 0.5 to 5 cm in diameter.[1, 25, 85, 121, 128, 131] Immature beetles maturation feed on leaves and young shoots.[23, 25, 128, 131]

HOST CONDITION

Healthy or recently dead hosts.[64, 85, 128]

DISTRIBUTION

Europe and Asia.[121, 128]

SIGNS AND SYMPTOMS

Immature beetles maturation feed on host leaves.[23, 128, 131] Longitudinal bite marks may be present and the leaf vein may be damaged.[23]

Females chew a small, longitudinal incision in the smooth bark of slender stems and twigs and lay a single egg.[23, 128] Bark tissue around these oviposition sites becomes callused and necrotic and the egg appears to be "enclosed in a chamber".[23]

After emerging from the eggs, larvae feed on the regenerative tissue near the oviposition site and cause dark spots to form on the bark.[23] After feeding in the callused area, larvae excavate straight longitudinal tunnels (36 to 50 cm long and 4 to 7 mm wide) in the central pith of twigs and branches.[23, 25, 85, 121, 128, 131] Ventilation holes occur at regular intervals and are used to discard frass and woodchips.[23, 131] Ejected frass accumulates on the twigs.[85]

Pupation occurs in the larval tunnels near the bark surface.[23, 85, 128, 131] Pupal cells, 4.5 cm long and 8 mm wide, are constructed by plugging off the upper and lower section of the chamber with two wads of coarse, fibrous frass.[23, 85] Shoots wither after 1 or 2 years of infestation.[23]

A

Adult *O. oculata* (15-20 mm long) with black head and antennae. Note orange pronotum, legs and abdomen.

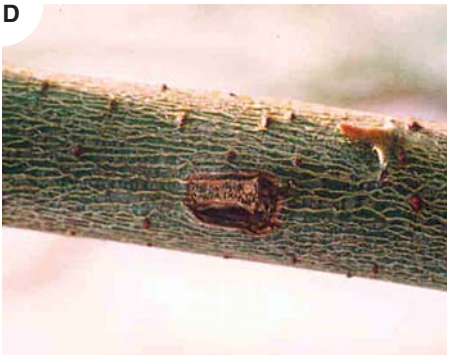
B

Ash-gray pubescence covering black elytra. Note 2 dark spots on orange pronotum.

C

O. oculata within larval gallery (36-50 cm long).

D



Callused and necrotic tissue surrounding *O. oculata* oviposition niche.

E

O. oculata larva.

Coleoptera: Cerambycidae

Plagionotus arcuatus (Linnaeus)

IDENTIFICATION

Adults are 8 to 20 mm long, with yellow-brown antennae and legs (front and middle legs have black femurs).[2, 25, 27, 128] The black pronotum is rounded laterally, has a yellow stripe on the anterior and posterior margins and has 2 oblique yellow stripes that converge near the middle.[2, 25, 27, 121] The antennae extend beyond the elytral midpoint in males and up to the midpoint in females.[27] Although colouration is variable, the elytra are typically black with yellow marks behind the scutellum and 5 to 6 transverse, thin, yellow bands.[27] The elytra are covered with dense, short brown or black hairs.[2, 27]

HOST TREES

Quercus (main host), *Acer, Carpinus, Castanea, Fagus, Prunus, Robinia, Salix* and *Tilia*.[1, 2, 25, 27, 121, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood along the entire stem or in large branches.[121, 128]

HOST CONDITION

Prefers freshly felled trees or recently cut stumps, but can attack standing trees.[2, 27, 85, 121, 128]

DISTRIBUTION

Europe, Asia Minor, Syria and northern Africa.[2, 27, 128]

SIGNS AND SYMPTOMS

Eggs are laid in bark crevices.[2, 27, 128] Larvae mine frass-filled, longitudinal galleries beneath the bark on the main stem or branches. These galleries etch the inner bark and sapwood.[27] Larval galleries are 19 to 29 cm long and 10 to 45 mm wide.[27] Mature larvae bore into the sapwood for 1 to 3 cm at a 45 to 60 degree angle, and then mine galleries parallel to the grain of the wood.[27] The entrance hole to these galleries are 8 to 10 mm in diameter.[27] A pupal cell is formed at the end of these "L-shaped" galleries.[2, 27, 131] The entrance to the pupal cell is packed with fibrous frass.[85, 128] Larvae pupate on their backs, with their heads towards the bark.[85] Adults exit through oval emergence holes.

Larval feeding weakens standing trees and causes technical damage to the wood.[6]

A

Adult *P. arcuatus* (8-20 mm long). Note two oblique yellow stripes converging near middle of the pronotum.

B

Adult *P. arcuatus*. Note yellow-brown antennae and legs.

C

P. arcuatus pupal chamber. The entrance (8-10 mm wide) is packed with fibrous frass.

D

Adult *P. arcuatus*.

Coleoptera: Cerambycidae

Saperda carcharias (Linnaeus)

Large poplar longhorned beetle

IDENTIFICATION

Adult beetles are 20 to 30 mm long, yellow-brown, gray or gray-yellow and have an acutely pointed elytra.[25] The head and pronotum have numerous small black punctures, and the elytra have larger punctures.[25] Each elytron has a faint, indistinct, light-coloured transverse band below the midpoint.[25] Antennae are yellowish or gray with black apices and extend beyond the elytral apex in males, but do not reach the apex in females.[23, 25]

HOST TREES

Populus (main host), *Betula* and *Salix*.[23, 25, 32, 85]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark, sapwood and heartwood.[2, 23, 85] They often attack the base of young trees and occasionally attack higher sections of larger stems and branches.[25] Immature beetles maturation feed on leaves and young shoots (1 to 2 mm diameter).[2, 23, 85]

HOST CONDITION

Healthy trees with a preference for hosts between 5 and 20 years old (3 to 30 cm in diameter).[23, 25, 85]

DISTRIBUTION

Europe, Korea and northern China.[2, 23, 25]

SIGNS AND SYMPTOMS

Immature beetles require supplementary feeding which mainly occurs on aspen and poplar but rarely on willow leaves.[23] Feeding usually occurs away from the leaf margin and is characterized by large oval or irregular shaped holes with serrated edges.[2, 23, 85] Usually the leaf veins and stems are consumed.[2, 85] Beetles also feed on the bark of young shoots and create pear-shaped incisions.[23]

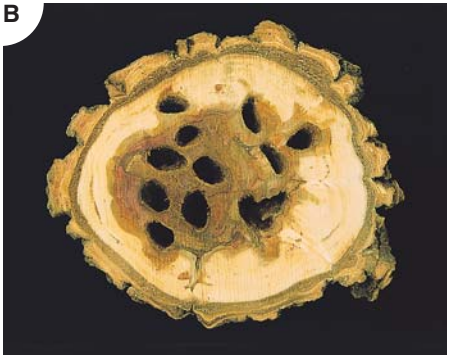
Prior to oviposition, females gnaw a vertical (occasionally oblique) incision, about 4.8 mm long, in the bark.[85] Females deposit one egg per niche, primarily on the basal part of the stem or on exposed roots.[2, 23] Each egg is covered with a sticky secretion.[85] First instar larvae excavate flat, 2.5 cm long galleries between the bark and sapwood.[2, 85] Later in the summer, older instars create "L-shaped" galleries by boring perpendicular to the sapwood and then vertically within the heartwood.[2, 85] These longitudinal galleries are 25 to 40 cm long and 12 mm wide.[23] A small ventilation hole is made in the upper part of the gallery. Coarse fibrous frass (large chips about 20 mm long) is discarded through the hole and accumulates in separate piles near the base of the tree.[2, 23]

Larvae hibernate 2 to 3 times prior to the construction of a pupal cell at the end of the "L-shaped" gallery.[23, 85] The pupal cell, 4.0 cm long and 1.5 cm wide, is isolated from the lower portion of the tunnel by a fibrous frass plug.[23] Pupae lie in cells with their heads pointing downward.[23] Severe infestations can directly cause tree mortality or predispose host trees to other mortality agents (e.g. fungi).[23]

A

Adult *S. carcharias* (20-30 mm long). Note acutely pointed elytra with numerous black punctures.

B



S. carcharias larval galleries within the heartwood.

C

Adult *S. carcharias*. Note yellow antennae with black apices.

D

Coarse fibrous frass expelled by *S. carcharias* larva.

E

Callus tissue and bark cracks caused by *S. carcharias*.

F

S. carcharias pupal chamber. Note fibrous frass plug.

G

S. carcharias larval gallery in the heartwood (25-40 cm long).

Coleoptera: Cerambycidae

Saperda perforata (Pallas)

IDENTIFICATION

Adults are yellow or grayish, slightly flattened dorsally and are 12 to 20 mm long.[23, 25, 121, 128] The pronotum typically has a single median spot as well as 8 black spots arranged into two transverse lines.[23, 25] Each elytron has a stripe of black pubescence along the shoulder, which extends towards the midpoint.[23, 25] Each elytron also has 5 black spots in a longitudinal line and a black spot on the basal quarter.[23, 25] Gray antennae have black apices.[2]

HOST TREES

Populus (main host) and *Salix*.[23, 25, 85, 121, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood of stems and branches.[23, 25] Immature beetles maturation feed on leaves and thin shoots.[23, 25]

HOST CONDITION

Weakened, dying, recently felled or stressed trees.[23, 25, 121, 128] This beetle requires a very moist breeding substrate.[121] Larger diameter trees (18 to 35 cm in diameter) are preferred.[23, 25]

DISTRIBUTION

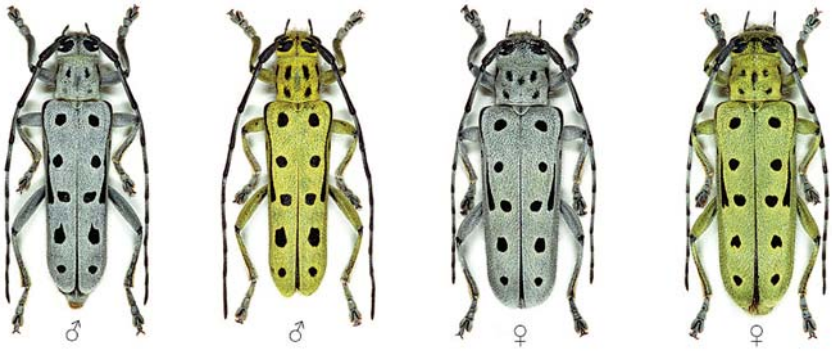
Europe and northern Asia.[2, 23, 25, 128]

SIGNS AND SYMPTOMS

Immature beetles feed on the tissues of green leaves and thin shoots.[23, 25] Prior to ovipostition, females gnaw small 3 mm incisions on the stem or branch and lay a single egg under the bark.[2, 23, 25] Larvae excavate irregular galleries in the inner bark that are packed with coarse fibrous frass.[2, 23, 25, 128]

Last instar larvae bore a 22 mm long horizontal gallery into the sapwood and then mine a longitudinal pupal chamber 21 to 27 mm long and 5 to 10 mm wide.[2, 25, 128] Larvae plug the pupal chambers with fibrous frass and pupate with their heads toward the entrance hole.[2, 25] Occasionally pupation takes place deeper in the sapwood due to desiccation of the outer sapwood.[128] Adults emerge through circular exit holes (6 mm in diameter).[2, 23]

A



Yellow and gray *S. perforata*. Note 5 black spots on each elytron.

B

Adult *S. perforata* (yellow morph).

C

Adult *S. perforata* (gray morph).

D

S. perforata in pupal chamber. Note fibrous frass plug.

E

Adult *S. perforata* (12-20 mm long).

Coleoptera: Cerambycidae

Tetropium castaneum (Linnaeus)

European spruce longhorn beetle

IDENTIFICATION

Adults are flat, 8 to 18 mm long, with antennae that are half the body length.[2, 19, 48] Adults typically have a black body, brown elytra, and either brown or red antennae and legs.[2, 48] The shiny pronotum is rarely punctured. The eyes are separated into two halves and a conspicuous longitudinal groove exists between the antennae on the head.[2, 48, 121] The elytra are uniformly covered with very fine hairs and are densely punctured.[2, 48]

HOST TREES

Picea (main host in Europe), *Pinus* (main host in Siberia), *Abies* and *Larix*.[2, 19, 42, 48, 128]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae develop in the inner bark and outer sapwood from the roots upwards on the stem. However the lower bole is usually preferred.[2, 25, 48]

HOST CONDITION

Prefers freshly felled trees and stumps and trees weakened by drought, insects, fungi, air pollution, etc. However, healthy trees will also be attacked.[2, 19, 42, 48, 128, 131]

DISTRIBUTION

Europe and Asia (Siberia, Korea, Mongolia, China and Japan).[19, 42, 48]

SIGNS AND SYMPTOMS

Eggs are laid singly, or sometimes in clusters of up to 10 eggs, in bark crevices or under bark scales of host trees.[2, 42, 128]

Early instar larvae feed on the inner bark and outer sapwood.[128] Larvae excavate wide, irregular galleries that become densely filled with brown, granular frass.[2, 48, 128] Mature larvae bore horizontally (2 to 5 cm) into the sapwood through narrow elliptical holes.[2] Then larvae bore parallel to the grain for another 3 to 4 cm and form "L-shaped" galleries. At the end of these galleries, larvae form pupal chambers that are plugged with coarse white frass.[2, 19, 48, 128]

Pupae lie in a vertical position with their heads towards the frass plug.[48, 85, 131] In stumps, pupal cells are usually excavated in exposed roots or at the base.[128] Adults bore through the bark and emerge through oval exit holes that are 5 mm in diameter.[2, 19, 48]

Tetropium castaneum populations can build to levels where living trees are attacked and killed. The boring activity of the larvae can cause structural damage to the wood and may lead to stem breakage during windstorms. Copious resin flow occurs on attacked healthy trees.[48] The foliage of attacked trees can also fade from green to yellow and finally to reddish-brown.[42]

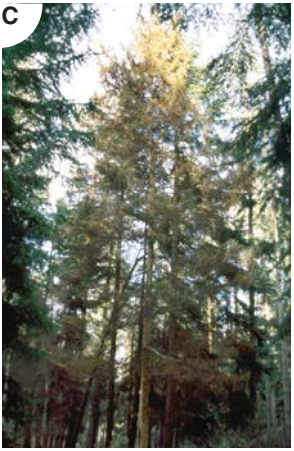
A

Adult *T. castaneum* (8-18 mm long).

B

Tree killed by *T. castaneum*. Note sloughing bark.

C



Yellowing foliage on attacked tree.

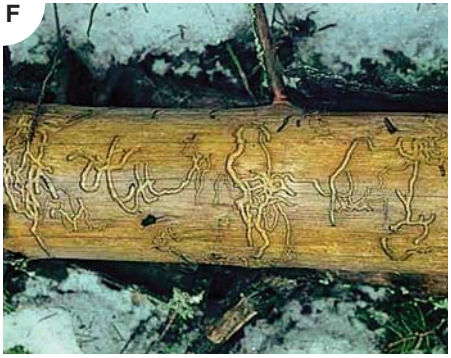
D

T. castaneum gallery filled with brown, granular frass. Note exit hole (5 mm wide).

E

T. castaneum larval galleries and exit holes (5 mm wide).

F



Irregularly shaped *T. castaneum* larval galleries.

G

Frass plug blocking pupal chamber entrance.

Coleoptera: Cerambycidae

Tetropium fuscum (Fabricius)

Brown spruce longhorn beetle

IDENTIFICATION

Adult beetles have a flattened body, 10 to 15 mm long.[1, 25, 55, 128] The head is black or dark brown, with a deep longitudinal groove between the antennae. The head is also covered with long, light-coloured hairs.[1, 25, 55] Their eyes are completely divided.[55] The slender antennae are half the length of the body and are reddish brown.[25, 55, 123, 128] The pronotum bulges laterally.[19] The elytra are tan, brown, or reddish-brown with 2 or 3 longitudinal grooves.[123] The legs are dark brown or reddish-brown.[1, 25, 55]

HOST TREES

Picea (main host), *Abies, Pinus* and *Larix*.[1, 25, 55, 128] In North America, only *Picea* has been found infested to date.[55]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood along the entire stem. However, the lower portions of the bole are the most heavily infested.[55, 123, 124]

HOST CONDITION

Stressed (e.g. drought, root disease), dying, recently felled, or healthy trees.[1, 25, 35, 55, 85] Middle aged and mature spruce trees are preferred.[124]

DISTRIBUTION

Europe and Japan. Introduced and under eradication in eastern Canada (Halifax, Nova Scotia).[1, 55]

SIGNS AND SYMPTOMS

Eggs are laid singly or in pairs in well concealed locations under bark scales or in bark crevices.[1, 55]

Larvae bore into the inner bark and excavate a network of irregular, 6 mm wide galleries, which become filled with tightly packed, fine-grained frass and short wood fibres.[1, 55] Larval galleries lightly etch the sapwood.[55] Much of the tree's inner bark can be destroyed by these wide, irregular and meandering larval galleries.[55] Mature larvae bore "L-shaped" galleries within the sapwood. Larvae first bore into the sapwood to a depth of about 2 to 4 cm, then turn parallel to the trunk for another 3 to 4 cm.[123] These galleries end in an oval-shaped pupal chamber.[1, 55]

Pupation occurs in the spring either in the bark, between the sapwood and bark or in the sapwood. Pupae lie in a vertical position with their heads pointed upward.[85] The wood may be stained from the associated *Ophiostoma* fungi.[55]

Adults exit through oval or circular exit holes that are 4 to 6 mm in diameter, which may or may not be plugged with coarse sawdust.[1, 55] Attacked trees produce excessive white resin down the length of the trunk.[55] Trees may be re-infested over subsequent years.[55] Infested tree crowns exhibit progressive yellowing, browning and loss of needles.[55] Once the tree has died, the remaining foliage changes to reddish-brown.[55]

A

Adult *T. fuscum* (10-15 mm long).

B

Resin flowing from tree attacked by *T. fuscum*.

C

Resin flowing from infested tree.

D

T. fuscum larva.

E

Irregular shaped *T. fuscum* larval galleries.

F

T. fuscum larval galleries and oval exit hole (4-6 mm wide). Note fine-grained frass in larval galleries.

G

Stand mortality caused by *T. fuscum*.

Coleoptera: Cerambycidae

Tetropium gracilicorne Reitter

Thin-antenna spruce borer

IDENTIFICATION

Adult beetles typically have a flat black body, 8 to 18 mm long, brown or red legs and relatively thin, short, brown or red antennae (half the length of body).[2, 19, 24] The 2nd through the 5th antennal segments are enlarged.[24] There are different colour morphs within this species: black body, antennae and legs with light brown elytra or completely black beetles.[19] The elytra have a broad covering of very fine hairs and are densely punctured.[2]

HOST TREES

Larix.[19]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood from root spurs to the top of the crown.[24]

HOST CONDITION

Stressed (e.g. defoliation, disease, fire, or wind), dying, and recently cut trees are preferred, but beetles also attack healthy, mature trees.[19, 24, 49] Trees of all ages are attacked.[24]

DISTRIBUTION

Asia including Russia, Kazakhstan, northern China, northern Japan and northern Mongolia.[24]

SIGNS AND SYMPTOMS

Female lays eggs, often in groups of 3 to 5 in bark crevices.[19, 24]

Larvae form irregular shaped, longitudinal galleries (10 mm wide) first in the inner bark and then later in the sapwood. Larval galleries are filled with granular frass.[19, 42] Mature larvae bore horizontally into the sapwood to a depth of 4 to 5 cm and then parallel to the wood grain for 1.6 to 2.2 cm.[19, 24] These "L-shaped" galleries end in a pupal chamber. If development occurs under thick bark, larvae may only bore beneath the bark without entering the sapwood.[24]

Before pupation, larvae make oval emergence holes that are plugged with frass.[24] Pupal chambers are lined with frass.[19, 24] Pupae develop with their heads toward the holes.[19]

Adults emerge through these oval holes.[19] External signs and symptoms include peeling bark, frass at the base of infested trees, beetles visible on the trunks, and yellowing and wilting of needles.[24] Consecutive years of attack can result in tree mortality.[42] When trees are not killed, infestations result in loss of vigor and reduced wood marketability due to bore holes.[24]

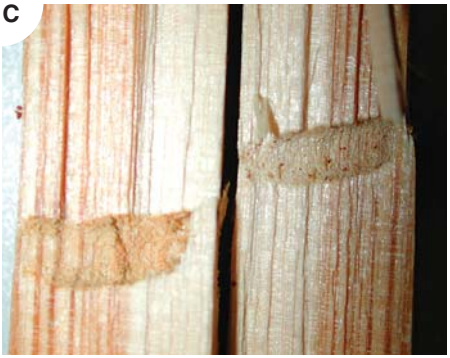
A

Adult *T. gracilicorne* (8-18 mm long). Note antennae are half the body length.

B

Close up of *T. gracilicorne* larva.

C



Start of L-shaped *T. gracilicorne* gallery in the sapwood.

Coleoptera: Cerambycidae

Xylotrechus altaicus Gebler

Altaï larch longhorn beetle

IDENTIFICATION

Adult beetles have an elongated (12 to 22 mm long), reddish-brown body.[4, 24, 27, 35] The head and thorax are black. The legs and antennae are reddish-brown.[4, 24, 27, 35] The antennae barely extend beyond the apex of the elytra.[27] The elytra are yellowish-brown and covered with dense short hairs.[4, 24, 27, 35] There are two or three barely visible, whitish bands crossing the centre of the elytra.[4, 24, 27, 35, 54]

HOST TREES

Larix.[4, 24, 35]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood over the entire length of the trunk.[4, 35, 54] Adult beetles are often found sitting on the trunks of host trees.[4, 27]

HOST CONDITION

Healthy or stressed trees are attacked. Mature trees are preferred but larch of all ages are susceptible to attack.[4] This insect is not known to attack felled (e.g. windthrow, cut logs), dying or dead trees.[4, 27, 35, 54]

DISTRIBUTION

Russia and Mongolia.[4, 24, 35]

SIGNS AND SYMPTOMS

Females usually attack hosts within 400 m of the tree in which they developed.[4] Eggs are laid singly in slit-like niches in the bark over the entire length of the trunk.[27] Oviposition usually occurs on the south-side of the trunk.[4, 35, 54]

Resin flows from wounds where young larvae have entered the bark.[4, 35] Early instar larvae feed on the inner bark.[4, 35] Larvae overwinter in the bark and in the spring they continue feeding on the inner bark, creating horizontal galleries (30 to 35 cm long and 10 to 13 mm wide) around the stem.[4, 27, 35] In the summer, larvae enter the sapwood to a depth of 1 to 10 cm and overwinter again.[27, 35]

The following spring, the larvae feed in the sapwood and gradually approach the bark surface.[4, 35] Mature larvae create pupal cells just under the bark (3 to 5 mm) and adults emerge from round exit holes, 4 to 6 mm in diameter.[4, 35] Frass is observed at the base of infested trees.[4]

Attacks can continue on the same tree for several consecutive years, ultimately causing its death.[4] Trees are eventually killed as the larvae encircle the inner bark and girdle the tree.[4] Needles of attacked trees often appear yellow or wilted.[35] When attacks on mature trees do not result in mortality, callus tissue encircles the larval galleries and the infestation causes a significant loss of vigour.[4, 27, 54]

A

Adult *X. altaicus* (12-22 mm long). Note yellowish-brown elytra, black head and thorax.

B

Adult *X. altaicus*.

Coleoptera: Cerambycidae

Xylotrechus rufilius Bates

IDENTIFICATION

The adult beetle differs from all other species in this genus by having a large, coarsely punctate, red pronotum and short elytra (length twice the total width).[27] Adults are 8 to 13 mm long.[27, 122] In males, the hind femora extend far beyond the elytral apex whereas in females the hind femora extend just beyond the apex.[27] The head and scutellum are black, while the antennae and legs are dark brown with a rusty tinge.[27]

HOST TREES

Acer, Ulmus and *Fraxinus*.[27]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood along the stem.[27]

HOST CONDITION

Dying and recently felled trees.[27]

DISTRIBUTION

Asian Russia, Japan, northeast China and Korea.[27]

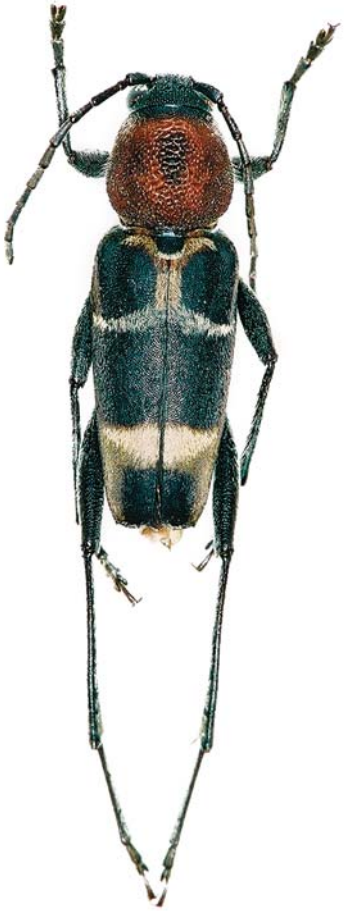
SIGNS AND SYMPTOMS

Females lay eggs singly or in batches within bark crevices.[27] Larvae bore through the bark and excavate longitudinal, meandering, frass-filled galleries.[27] Larval galleries may occasionally be transverse.[27] If eggs are laid in batches, larvae orient in different directions, leaving behind radial galleries in the inner bark.[27] The length of each larval gallery is approximately 28 cm, with an initial width of 1 mm and a terminal width of 12 mm.[27]

Some last instar larvae construct longitudinal pupal cells within the bark (a few millimetres beneath the bark surface).[27] Others bore into the wood, through 13 by 3 mm openings filled with frass, and create longitudinal pupal cells.[27] The pupal cells are 15 to 19 mm long and 5 to 7 mm wide.[27]

Larval feeding can girdle the tree causing a reduction in tree growth, crown stunting, wilting and branch mortality.[122]

A



Adult *X. rufilius*. Note large red pronotum and short elytra.

B

Adult *X. rufilius* (8-13 mm long).

Coleoptera: Curculionidae

Pissodes harcyniae (Herbst)

Spruce weevil

IDENTIFICATION

Adult weevils are black and 5 to 6 mm long.[2] Antennae are located along the middle of the adult's snout.[2] The posterior edges of the pronotum are rounded.[2] The elytra have two medial transverse yellow or white bands.[2]

HOST TREES

Picea.[2, 15]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark and sapwood on the upper part of the stem.[2, 124] Immature beetles maturation feed on the inner bark of the stem where the bark is thin and smooth.[2]

HOST CONDITION

Diseased or weakened trees ranging from 50 to 100 years old are preferentially attacked.[2, 124]

DISTRIBUTION

Central and northern Europe, Siberia.[2, 15]

SIGNS AND SYMPTOMS

Immature beetles ascend the tree and feed on the inner bark of the stem.[2] Fertilized females excavate deep narrow holes into the bark of weakened trees and lay eggs individually or in groups of 2 to 5, creating a star-like gallery.[2]

Larval galleries are irregularly shaped and are initially 3 mm wide.[2] As they enlarge, they eventually intersperse with other galleries.[2] Larval galleries penetrate the inner bark but do not etch the sapwood.[2]

At the end of the larval galleries, mature larvae bore pupal cells, 7 to 10 mm long and 3 mm wide, that penetrate deep into the sapwood.[2] The pupal cells are lined with shredded wood.[2] Attacked trees appear wilted.[2]

A

Adult *P. harcyniae* (5-6 mm long).

B

Adult *P. harcyniae*. Note two yellow medial transverse bands on elytra.

C

P. harcyniae larval galleries ending in pupal chambers.

D

Irregular shaped *P. harcyniae* larval gallery widens as larva increases in size. Note shredded wood lining the pupal chamber.

E

Resin flowing from *P. harcyniae* maturation feeding sites.

F

Debarked boles of *P. harcyniae* attacked trees.

Hymenoptera: Siricidae

Sirex noctilio Fabricius

Sirex woodwasp

IDENTIFICATION

Adult wasps have four clear yellow membranous wings.[1, 22] Both sexes also have a stout, cylindrical body measuring 9 to 36 mm and a pointed abdomen.[1, 4, 22] Males have thickened, black hind legs and orange-yellow middle segments on the abdomen.[1, 4, 22] Females have reddish-brown legs and a steel-blue body.[1, 4, 22] Females also have a spike-like projection on their abdomen, which protects the ovipositor.[1, 4, 22]

HOST TREES

Pinus (main host), *Abies* and *Picea.*[1, 4, 22, 42]

LOCATION OF INFESTATION WITHIN THE TREE

Along the lower or middle portion of the bole, larvae feed on a symbiotic fungus within the sapwood and heartwood.[22, 59, 107, 113]

HOST CONDITION

Healthy and stressed trees (e.g. logging damage, drought, fire) or dead stems.[4, 105, 116, 131]

DISTRIBUTION

Europe, northern Africa, Mongolia, Siberia and Turkey. Introduced to Australia, New Zealand, South Africa, Argentina, Brazil, Uruguay and eastern North America.[1, 4, 22, 125]

SIGNS AND SYMPTOMS

Females use their saw-like ovipositor to cut oviposition holes 12 mm into the wood of the host tree.[1, 22, 131] Up to 5 holes are drilled into the outer sapwood.[22] The spores of a symbiotic white rot fungus (*Amylostereum areolatum*), which are fed upon by the larvae, and a toxic mucus are injected into the sapwood by ovipositing females.[1, 4, 22] Up to three eggs are laid per oviposition hole.[1, 4, 22] The fungus and the mucus act together to kill the tree and create a suitable environment for developing larvae.[4, 22, 110, 118] When the bark is removed, a dark fungal stain can be seen extending vertically from each oviposition site.[4, 114]

Larval galleries, 5 to 20 cm long, are packed with chewed wood and a fine powdery frass.[1, 4, 22] These galleries occur at all depths in the sapwood and heartwood, even to the centre of large trees.[1, 4] The length of the gallery and the size of the developing wasps are dependent upon the moisture content of the wood.[4] If the wood is dry, the galleries will be short, the smaller larvae will pupate earlier and become adults at a smaller size.[4] Mature larvae pupate close to the bark surface.[4] Adults emerge through circular emergence holes 3 to 8 mm in diameter.

Symptoms of attack also include beads of resin flowing from oviposition holes.[4, 59] Needles on attacked trees wilt and turn from green to yellow and finally to reddish-brown.[4] Stem growth is drastically reduced as a result of attack.[59] Mortality occurs in heavily infested trees.[4]

Male *S. noctilio*. Note black hind legs and orange-yellow middle segments on abdomen.

Female *S. noctilio*. Note brown legs and steel-blue body.

S. noctilio larval gallery (5-20 cm long). Note chewed wood lining the gallery.

Frass-filled *S. noctilio* larval galleries.

Circular *S. noctilio* exit holes (3-8 mm wide).

Resin flowing from *S. noctilio* oviposition holes.

Reddish-brown crowns on *S. noctilio* attacked trees.

Hymenoptera: Siricidae

Sirex rufiabdominis Xiao & Wu

Red-bodied horntail

IDENTIFICATION

Adult females are 18 to 34 mm long with black, 19 to 22 segmented antennae.[63] The wings are transparent on the basal half and smoky-brown on the apical half.[63] The body is covered with yellowish-gray hairs that are particularly abundant on the head and thorax.[63] Adult males are 14 to 22 mm long and their bodies are similar in colour to females but have more hairs.[63] Wings are pale yellow.[63]

HOST TREES

Pinus.[63]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the sapwood and heartwood along the stem between the base of the tree and the main branches.[63] They are primarily found 2 m above ground level.[63]

HOST CONDITION

Weakened, stressed, or dying trees.[63] This insect prefers host trees growing in poorly sanitized or thinned forests or trees growing along the forest edge or on sunny slopes.[63]

DISTRIBUTION

China.[63, 119]

SIGNS AND SYMPTOMS

Females use their saw-like ovipositor to cut holes 1 mm into the sapwood.[63] At the time of oviposition, females first secrete a phytotoxic mucus (a colourless gel) that reduces the tree's ability to enclose the eggs.[63] One to seven eggs are laid per oviposition hole.[63] The browning and necrosis of the cambium that occurs around the phytotoxic mucus leads to wilting and tree mortality.[63]

Larvae initially bore 10 to 20 mm into the sapwood and create vertical galleries.[63] Late instar larvae then bore into the heartwood and may even reach the pith.[63] Galleries are winding (15 to 20 cm long) and filled with sawdust and small, hard frass pellets.[63] Most larvae return to the sapwood to pupate. Circular exit holes are 5 to 8 mm in diameter.[63]

A

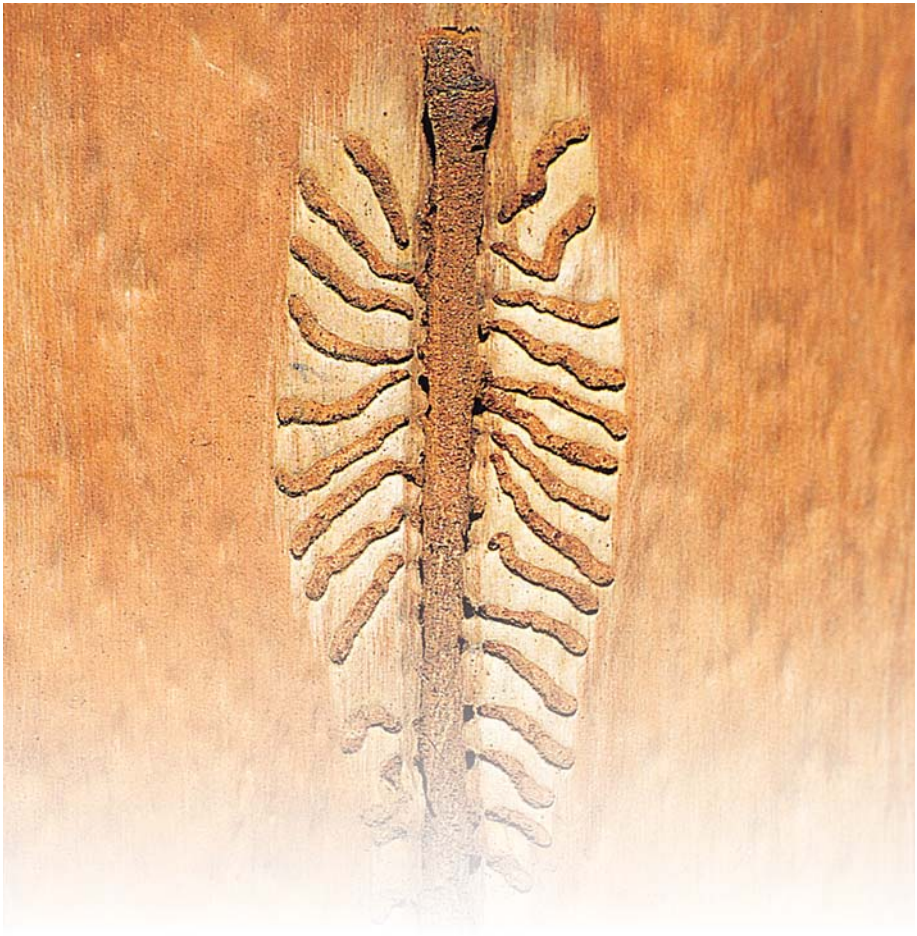
Adult *S. rufiabdominis* (18-34 mm long).

B

Frass-filled *S. rufiabdominis* larval galleries.

BARK BEETLES

- Scolytidae



Coleoptera: Scolytidae

Dendroctonus armandi Tsai & Li

Large pitch tube bark beetle

IDENTIFICATION

Adults are cylindrical beetles that are 3.5 to 6.8 mm long.[62] Newly emerged beetles are initially light-yellow but gradually become light-brown, black-brown and finally black upon maturation.[62]

HOST TREES

Pinus.[62, 101]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the lower three-quarters of the bole.[62]

HOST CONDITION

Healthy or recently felled trees, greater than 30 years old are attacked.[62] Outbreaks generally initiate in pine forests growing in nutritionally poor, steep, dry sites, with thin soil layers.[62, 69] This insect prefers to attack trees growing in sparsely stocked forests and trees growing on southern aspects.[62]

DISTRIBUTION

Central China (Gansu, Henan, Hubei, Shaanxi, Sichuan and Yunnan provinces).[62, 69, 106]

SIGNS AND SYMPTOMS

Adult females mine monoramous, longitudinal egg galleries that are 10 to 60 cm long (30 to 40 cm average).[62] Females lay eggs in niches on both sides of the egg gallery.[62] The average distance between egg niches is 8 mm.[62] Larval galleries are perpendicular to the egg gallery and are usually 2 to 3 cm long, but may reach lengths up to 5 cm.[62] Elliptical pupal chambers are formed at the end of larval galleries.[62] Maturing beetles feed within the pupal chamber, greatly enlarging it and increasing the damage to the phloem tissue.[62]

Evidence of attack includes red to gray-brown pitch tubes (10 to 20 mm in diameter), reddish frass around entrance holes on the trunk, loose frass in bark crevices and fading of the foliage from yellow to yellow-brown.[62, 65, 67] Trees girdled by larvae will eventually die.[62]

A

Adult *D. armandi* (3.5-6.8 mm long).

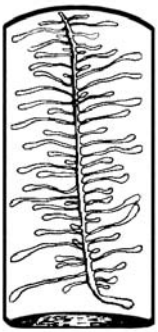
B

Pitch tubes on host tree attacked by *D. armandi*.

C

Pitch tube surrounding the entrance hole of *D. armandi*.

D



Drawing of *D. armandi* egg (10-60 cm long) and larval galleries (2-3 cm long).

Coleoptera: Scolytidae

Dendroctonus micans (Kugelann)

Great spruce bark beetle

IDENTIFICATION

Adult beetles are 5.5 to 9.0 mm long, 2.5 to 3.0 mm wide and are covered in orange hairs.[6, 60, 84] Adults are uniformly jet black or dark brown and cylindrical.[6, 84]

HOST TREES

Picea (main host), *Abies, Pinus, Larix* and *Pseudotsuga menziesii.*[4, 7, 24, 84]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark.[6, 84] Attacks usually occur on the lower part of the bole, root collars and even on underground roots. However during outbreaks, galleries can also occur on branches in the upper crown.[60, 84]

HOST CONDITION

Preferentially attacks healthy trees but will also attack stressed trees (e.g. frost, snow, wind, drought).[4, 10, 14, 84] Usually prefers older, mature trees but can also attack younger age classes.[4, 84]

DISTRIBUTION

Europe, China, Japan, Mongolia and Turkey.[4, 24, 84]

SIGNS AND SYMPTOMS

Attacking females bore through the bark and create a narrow oblique groove-like egg gallery in which a group of eggs are oviposited.[60, 84] Pitch tubes surrounding the entrance hole and dried white resin may be visible on the trunk.[6] Pitch tubes may be purple, brown, cream or white and may be present individually or in a large group.[60] Granular resin at the base of the tree is also a good indication of attack. Within the egg gallery, early instar larvae feed side by side creating a widening feeding front beneath the bark.

As a result of gregarious larval feeding that occurs until pupation, the gallery system (cavity) often appears fan-like.[10, 84] Feeding occurs along a leading edge; islands of frass and dead individuals are left behind in the rectangular cavity from which the larvae started from.[6, 60, 84] These cavities are 30 to 60 cm long and 10 to 20 cm wide.[60] Pupation occurs within individual niches in the rectangular cavity.[60]

Red, powder-like frass is expelled from emergence holes and can be found in bark crevices along the trunk.[60] Foliage can turn brown over some of the crown (e.g. top kill) or over all of the crown, depending upon the severity of the attack.[60] Entire trees can be killed as a result of the girdling caused by feeding larvae. Trees that have undergone repeated attack will also have broken, peeling (bark peels as larvae consume inner bark), and often blackened bark.[4] However, some infested trees can retain a green canopy, even with severe girdling.[84]

A

Adult *D. micans* (5.5-9.0 mm long). Note orange hairs covering body.

B

Gregarious feeding of *D. micans* larvae.

C

Pitch tube and frass at the base of an attacked tree.

D

D. micans pitch tube surrounding the entrance hole.

E

Dried resin on attacked tree.

F

Declining *Picea* caused by *D. micans* attack.

G

Top kill caused by *D. micans*.

Coleoptera: Scolytidae

Hylastes ater (Paykull)

Black pine bark beetle

IDENTIFICATION

Adults are cylindrical and shiny black or slate gray with reddish-brown antennae and elytra.[4, 18] Adults are 3.5 to 5.0 mm long and 1.4 mm wide.[4, 18] Newly emerged beetles are uniformly reddish-brown but darken as they mature.[18] When viewed from above, a small portion of the head projects beyond the pronotum.[18] The head is directed downwards and is prolonged into a short snout.[18]

HOST TREES

Pinus (main host), *Araucaria, Abies, Larix, Picea, Pseudotsuga* and *Thuja.*[4, 18]

LOCATION OF INFESTATION WITHIN THE TREE

This species breeds primarily in the inner bark of roots, fresh stumps, the base of dead and dying trees or logs in contact with the ground.[4] However, immature beetles feed on the inner bark of pine, spruce, true firs, Douglas-fir and larch seedlings.[4]

HOST CONDITION

Breeding occurs in fresh stumps, recently dead or broken host material and dying trees.[4]

DISTRIBUTION

Europe.[4] Introduced into Chile, Japan, South Africa, Australia and New Zealand.[4, 18]

SIGNS AND SYMPTOMS

Immature beetles remove patches of bark and inner bark from seedlings at ground level.[4] This feeding can cause heavy mortality.[4] Seedlings that survive attack will show resin-encrusted wounds in the major roots and on the portion of the stem below ground.[18] Injured seedlings first appear wilted and sickly, then often turn bright red, with needles becoming hard and brittle.[4] Injured seedlings tend to appear in clumps near infested stumps or logs, but may also be found at considerable distances from breeding sites.[4] In addition to the damage caused by feeding, beetles can also vector several black stain root diseases.[4]

Adults prefer moist breeding habitats especially underground roots and the underside of logs that are in contact with the ground.[4] A reddish, sawdust-like frass is expelled from entrance holes when adults bore into the bark. Brood galleries consist of a short entrance tunnel leading to an oblique nuptial chamber.[4] From this chamber the female bores a uniramous gallery (8 to 13 cm long) that is packed with frass and is usually parallel with the grain of the wood.[4] However, any males that are present will clear debris from the central egg gallery.[4] Egg galleries reach but do not engrave the surface of the sapwood, except in small diameter material.[4, 18]

About 100 eggs are laid in individual niches along the walls of the egg gallery.[18] Larval galleries initially occur at right angles to the egg gallery, but eventually become random and ultimately obliterate both the early larval galleries and those made by the parents.[4, 18] Upon maturation of the brood, groups of about 40 (up to 120) beetles may be present in broad irregularly shaped communal galleries underneath the bark.[18]

A

Adult *H. ater* (3.5-5.0 mm long).

B

Maturation feeding by *H. ater* on seedlings. Note reddish foliage.

C

Black staining of root collar associated with *H. ater* attack.

D

H. ater egg galleries (8-13 cm long). Note frass packed vertical gallery.

E

Resin-encrusted wound caused by immature *H. ater* beetles.

F

Immature beetles within communal galleries under the bark.

G

Immature beetles feeding on the inner bark of a seedling.

Coleoptera: Scolytidae

Hylesinus varius (Fabricius)

Ash bark beetle

IDENTIFICATION

Adults are black and are 2.5 to 3.0 mm long.[2] Antennae have three segments and are club shaped.[2, 112] The antennae and tarsi are both reddish.[112] The pronotum is shorter than it is wide.[2, 112] The elytra are flattened, rounded, and have irregular light and dark coloured patches.[2] Long hairs exist along the edge of the elytra.[2]

HOST TREES

Fraxinus (main host), *Acer, Ailanthus, Carpinus, Corylus, Fagus, Juglans, Olea, Pinus, Pyrus, Quercus, Robinia, Syringa, Tilia* and *Ulmus.*[2, 112]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the stem and branches.[2] Immature beetles maturation feed on the inner bark of host trees.[112]

HOST CONDITION

Freshly felled, weakened, or stressed (e.g. drought) trees.[2] This is an aggressive beetle that can also attack healthy trees.[2, 112] Prefers thin bark of young host trees.[112]

DISTRIBUTION

Europe, Turkey and northern Africa.[2, 112]

SIGNS AND SYMPTOMS

Immature beetles maturation feed on neighbouring trees (usually young trees), mining short galleries (20 mm long) in the bark.[2, 112] Gall-like swellings (callus tissue) form as a result of maturation feeding and grow larger as beetles continue to feed in the same spot.[2, 112] During outbreaks, feeding is so intense that the entire bark of a tree can be destroyed.[112]

Adults initiate attack by creating a "clamp-shaped" entrance tunnel. Adults then mine biramous, transverse egg galleries 7 to 10 cm long and 1.5 mm wide.[2, 112] The two arms of the egg galleries originate from a central nuptial chamber (connected to the entrance hole).[112] Larval galleries, 3 to 5 cm long, branch at right angles from the egg gallery and etch the sapwood.[2, 88] Larval galleries turn black over time.[112] Light coloured frass is present on the bark surface.[88] Pupation occurs at various depths in the sapwood.[2]

Growth loss (i.e. stunting) and mortality can occur, especially on young trees.[112] This beetle also vectors *Pseudomonas fraxini* and is suspected to facilitate infection by *Nectria galligena* (beech bark disease).[112]

Adult *H. varius* (2.5-3.0 mm long).

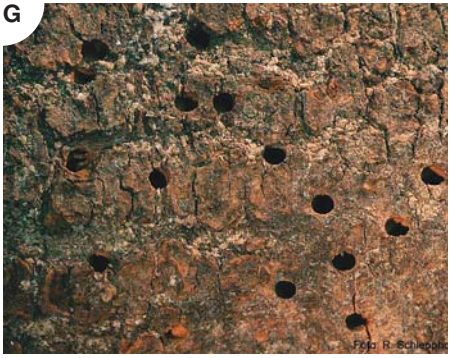
Callus tissue resulting from *H. varius* maturation feeding.

Light coloured frass from *H. varius* attack.

Callus tissue caused by maturation feeding.

H. varius egg and larval galleries.

H. varius egg and larval galleries. Note two-armed egg gallery extending from nuptial chamber.



H. varius exit holes.

Coleoptera: Scolytidae

Hylurgus ligniperda Fabricius

Red-haired pine bark beetle

IDENTIFICATION

Adults are small (4 to 6 mm long and 2 mm wide), cylindrical black-brown or golden-brown beetles.[4, 44, 93] The entire body is covered with dense yellowish or reddish hairs that are particularly noticeable on the posterior slope of the elytra and on the front of the head.[44, 93] The elytral apex is convex with a slight indentation but does not have teeth on the declivity.[82]

HOST TREES

Pinus.[44] *Pinus strobus, P. nigra* and *P. sylvestris* are known host trees occurring in Canada.[4, 93]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the stem, roots and root collar.[44] In standing trees, females oviposit near the root collar.[93] These beetles will also attack buried logs or portions of the log in contact with the ground.[4, 93] Immature beetles maturation feed on the roots and root collar of healthy and stressed seedlings and young saplings (up to 15 cm in diameter).[93]

HOST CONDITION

Stressed or recently felled trees.[44] Females oviposit on freshly cut logs, stumps, slash and even seedlings.[44, 93]

DISTRIBUTION

Europe.[44, 93] Introduced into Brazil, Chile, Uruguay, Japan, South Africa, Sri Lanka, Australia, New Zealand and North America (near Rochester, New York).[44, 93]

SIGNS AND SYMPTOMS

Each female constructs a short entrance tunnel leading to an oblique nuptial chamber in the inner bark. From this nuptial chamber the female constructs a long egg gallery that usually runs parallel or at an angle with the grain of the wood.[4, 93] The egg gallery can be up to l m long and is not always straight; it often meanders and sometimes doubles back on itself.[4, 44, 93] Galleries may occur along the stem and in the roots and root collar.

The eggs are laid in notches cut in the walls of the egg gallery and are covered with frass. Egg galleries consist of alternating, 10 to 20 cm long sections with and without eggs. As a result, the larvae tend to be found in groups with mature or nearly mature larvae near the nuptial chamber, then groups of successively smaller, even-sized larvae at intervals along the gallery. The larval galleries are initially at right angles to the egg gallery but soon become random so that they make no distinctive pattern.[4, 44, 93]

As this insect tends to attack severely stressed or recently dead host material, pitch tubes and crown symptoms are usually not evident.[75] Along with the reddish brown frass found in bark crevices of host material, the presence of small, round exit holes and dark staining caused by associated fungi are other indications of attack.[93] Upon emergence, immature beetles seek pine hosts for maturation feeding and bore spiral galleries in seedlings and young saplings.[93] Mortality can occur if larger roots or the root collar of host trees are girdled.[93]

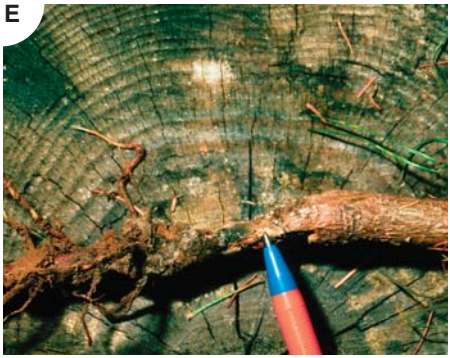
Hylurgus ligniperda has often been associated with many *Leptographium* species of varying pathogenicity. If these beetles vector a fungal pathogen, reduced height and branch growth, crown thinning, chlorosis and tree mortality may also be evident on standing infested trees.

Adult *H. ligniperda* (4-6 mm long). Note reddish hairs on the declivity and front of the head.

H. ligniperda egg gallery.

Numerous *H. ligniperda* adults under the bark.

Reddish-brown frass around stump attacked by *H. ligniperda*.



H. ligniperda maturation feeding damage on seedling.

H. ligniperda egg gallery (up to l m long) in stump.

Various life stages of *H. ligniperda*.

Coleoptera: Scolytidae

Ips hauseri Reitter

Hauser's engraver

IDENTIFICATION

Adult beetles are bright reddish-black, with an elongated body (3.5 to 5.0 mm long) and are completely covered with sparse, yellowish-brown hairs.[24] Each elytron has four spines along the declivity.[24] The 3rd spine in the male is finger-shaped and is the widest and longest, whereas in the female, the spines are all uniform.[24] The surface of the declivity is matted.[71]

HOST TREES

Picea, Larix and *Pinus.*[24]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the entire bole, including the root collar, and in larger branches (inner bark and sapwood).[24] Immature beetles maturation feed on the inner bark of brood trees.[24]

HOST CONDITION

Healthy trees. But stressed, dying and recently cut trees are preferred.[24] Mature trees are preferred, but at high populations young trees (5 to 6 cm diameter) can also be attacked.[24]

DISTRIBUTION

Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkey and China.[17, 42, 72, 73, 74]

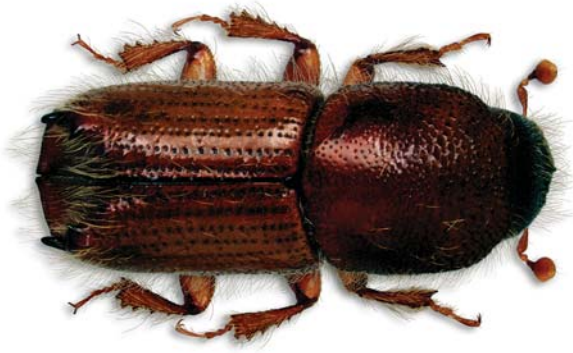
SIGNS AND SYMPTOMS

Immature beetles maturation feed under the bark of brood trees creating slightly irregular-shaped feeding galleries that are parallel to the main stem.[42] Adults emerge from small, round exit holes.[42]

One central nuptial chamber includes one male and 2 to 8 females.[24] Thus, several egg galleries can radiate downwards (most likely) or upwards from the nuptial chamber.[24] Longitudinal egg galleries are 8 to 14 cm long and 1.5 to 3.0 mm wide. These galleries are free of frass.[24] Females lay 20 to 45 eggs on both sides of the egg gallery.[42] The intervals between egg niches are shorter near the nuptial chamber than at the end of the egg gallery.[42]
The perpendicular larval galleries are short (3 to 4 cm long) and become wider as the larvae increase in size.[24, 42]

Symptoms of attack include resin flow from entrance holes, reddish-brown frass in bark crevices, pitch tubes and sparse crowns with partly dead tops and branches.[24, 42] Attack sites occur over the entire trunk from the top, down to the root collar.[24] Therefore, needles of attacked trees often show yellowing or reddening and wilting that usually begins at the top of a tree.[24]

A

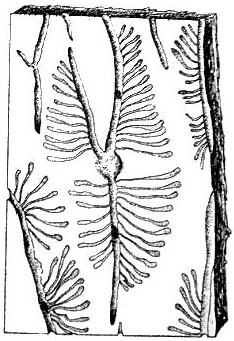


Adult *I. hauseri* (3.5-5.0 mm long).

B

Elytral declivity of male *I. hauseri*. Note size and shape of 3rd spine.

C



Drawing of *I. hauseri* egg (8-14 cm long) and larval (3-4 cm long) galleries.

Coleoptera: Scolytidae

Ips sexdentatus (Boerner)

Six-spined engraver beetle

IDENTIFICATION

Ips sexdentatus is the largest species in the genus *Ips*, measuring 5.5 to 8.2 mm in length.[4, 131] Adult beetles are dark brown and cylindrical.[4] The head is covered by a thoracic shield and the head is not visible when viewed dorsally.[4] Both sexes have six spines on each side of the declivity, of which the 4th is the largest and capitate.[24]

HOST TREES

Pinus (main host), *Abies, Larix, Picea* and *Pseudotsuga*.[4, 17]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark of the lower bole.[132] This species prefers to attack larger trees with thick bark.[4, 66]

HOST CONDITION

This insect rarely attacks healthy vigorous hosts, preferring recently cut, weakened, dying or windthrown trees.[4, 77, 78, 131]

DISTRIBUTION

Europe, Asian Russia, Mongolia, China and Thailand.[4, 17, 24]

SIGNS AND SYMPTOMS

Males initiate the attack and create a large nuptial chamber beneath the bark.[4, 131] Males are joined by 2 to 5 females that create individual egg galleries, radiating longitudinally in opposite directions from the nuptial chamber.[4, 131, 132] Egg galleries are usually 15 to 35 cm long and 4 to 5 mm wide.[4, 131, 132] Eggs are deposited in individual niches along each side of the egg gallery.[4] Larval galleries run approximately perpendicular to the egg gallery and are 8 to 10 cm long.[4, 24, 132] Larval galleries increase in size as the larvae grow.[4] Both egg and larval galleries are mainly found in the inner bark and barely etch the sapwood.[131] Large round pupal chambers are located at the end of the larval galleries.[4, 131] Round exit holes on the bole, approximately 4 mm in diameter, will be apparent once adults emerge.[4]

Breeding attacks are characterized by the presence of reddish-brown frass on the bark surface of trees, freshly cut logs, or windthrow.[4] If relatively vigorous trees are attacked, pitch tubes can be found on the bole.[4, 127] The needles of attacked trees turn from green to yellow and then reddish-brown.[4] *Ips sexdentatus* acts as a vector for a bluestain fungus, *Ophiostoma brunneo-ciliatum*, which also damages the tree and stains the wood.[4, 24, 79]

A

Star shaped *I. sexdentatus* gallery system with six egg galleries radiating from the nuptial chamber.

B

Egg galleries (15-35 cm long) of *I. sexdentatus.*

C

Reddish-brown crown of *I. sexdentatus* attacked tree.

D

Immature *I. sexdentatus* beetle (5.5-8.2 mm long).

E

Pitch tube around entrance hole of *I. sexdentatus*.

F

Reddish-brown frass around the base of *I. sexdentatus* attacked tree.

G

Chlorotic foliage and woodpecker damage on *I. sexdentatus* attacked trees.

Coleoptera: Scolytidae

Ips subelongatus (Motschulsky)

Larch bark beetle

IDENTIFICATION

Adult beetles are completely brown and 4.5 to 6.0 mm long. Adults have four spines on each side of the elytral declivity.[24] The 3rd spine is the largest and is strongly capitate.[24] The surface of the elytral declivity is completely covered with long hairs.[24]

HOST TREES

Larix (main host), *Abies, Picea* and *Pinus.*[24, 26, 42]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed in the inner bark along the length of the bole.[24] Immature beetles maturation feed in the inner bark of the bole and will feed in the root collar or branches if sites on the bole are unavailable.[24]

HOST CONDITION

Healthy, dying, stressed, or cut trees. Mature trees are preferred.[24]

DISTRIBUTION

Asian Russia, northern China and Mongolia.[24, 42]

SIGNS AND SYMPTOMS

Maturation feeding usually occurs along the trunk but may also occur on the root collar, the upper bole, or on branches.[24] These maturation galleries are filled with large quantities of frass.[24, 42]

Males initiate the attack and are joined by 2 to 5 females.[42] The shape and depth of egg galleries vary depending on host health, but all galleries originate from a central nuptial chamber.[24, 42] In healthy trees, egg galleries radiate downwards and upwards from the nuptial chamber, but in stressed hosts egg galleries radiate vertically and horizontally.[24, 42] Egg galleries are usually 3.0 to 3.5 mm wide and 16 to 18 cm long, but can reach lengths up to 27 cm.[24] Larval galleries are usually perpendicular to the egg galleries.[24] Pitch tubes and reddish frass occur on the bark surface.[42] Adults emerge from small round exit holes.[24, 42]

If the initial attack density is not too high, *I. subelongatus* usually re-attacks the same host tree over several consecutive years which can lead to the death of healthy trees.[24, 26] Additional symptoms of attack include sparse crowns, partly dead tops, wilting of needles, and fading of foliage from green to yellow and finally to red.[42] Resin also flows from entrance holes.[24]

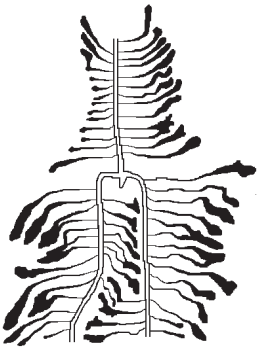
A

Adult *I. subelongatus* declivity. Note the large and capitate 3rd spine.

B

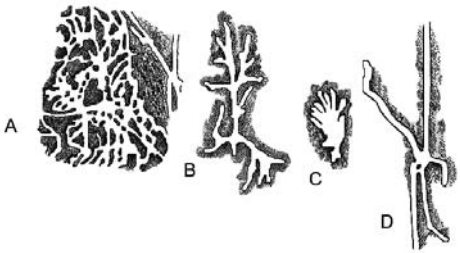
Adult *I. subelongatus* (4.5-6.0 mm long).

C



Drawing of *I. subelongatus* egg (16-18 cm long) and larval galleries on a healthy tree.

D

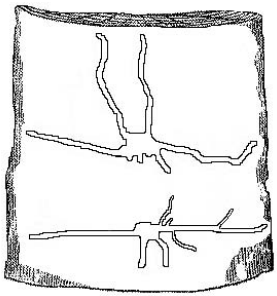


Maturation feeding galleries. In the region of larval development (A). On roots (B). Top of the trunk or on branches (C & D).

E

I. subelongatus egg and larval galleries.

F



I. subelongatus egg galleries on a stressed tree.

Coleoptera: Scolytidae

Ips typographus (Linnaeus)

European spruce bark beetle

IDENTIFICATION

Adults are 4.2 to 5.5 mm long, cylindrical and reddish or dark brown to completely black.[2, 4, 131, 136] The front of the head and the sides of the body are covered with long yellowish hairs.[1] Both sexes have four spines on each side of the elytral declivity, with the 3rd spine being the largest and capitate.[4] However, males have a larger head on the 3rd spine than do females and have fewer hairs on the pronotum.[2, 3, 97]

HOST TREES

Picea (main host), *Abies, Larix* and *Pinus.*[1, 4, 136]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed in the inner bark up to 10 m along the stem.[35, 133, 136] This species prefers thicker-barked stems with a minimum bark thickness of 2.5 mm and an optimum thickness of 5.0 mm.[131, 134]

HOST CONDITION

This beetle prefers physiologically weakened, damaged, windthrown, recently felled or overmature trees.[4, 35, 133] However, as populations increase healthy hosts may be attacked.[4, 133] Infestations are more severe in stands greater than 120 years old, with a preference for trees between 70 and 150 years old. Stands less than 40 years old sustain very little damage.[4, 5, 35, 53]

DISTRIBUTION

Europe, China, Korea, Japan and Russia.[42]

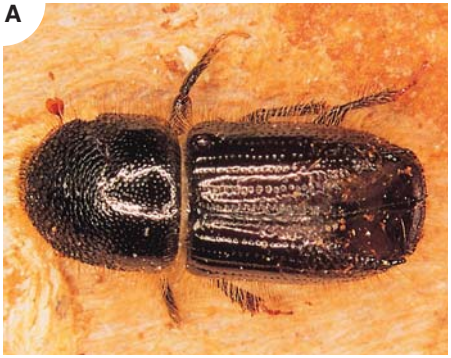
SIGNS AND SYMPTOMS

Males excavate a nuptial chamber and are joined by 1 to 4 females. Females construct egg galleries in the inner bark radiating outward from the nuptial chamber.[4] Vertical egg galleries are 10 to 20 cm long (12.5 cm average) and are usually three-armed, but can be two-armed or multi-branched.[1, 3, 88, 131] Approximately 50 eggs are laid on each side of the egg gallery.[3, 97, 136] Larval galleries radiate at right angles to the egg gallery and become wider as the larvae grow.[136]

On standing trees, needles turn yellow-green to red-brown and the foliage drops within a few weeks.[1, 136] Signs of infestation include red-brown frass in bark crevices, numerous round exit holes approximately 2 to 3 mm in diameter, and small (dime sized) tubes of resin (pitch tubes) extruding from the bark.[1, 136] Woodpecker damage may also be present.[6]

Adult beetles also carry a number of associated fungi such as *Ceratocystis polonica* (Siemaszko). This bluestain fungus is highly virulent and can kill healthy spruce trees.[4] This fungus also stains the wood with blue streaks, which reduces its commercial value.[4]

A



Adult *I. typographus* (4.2-5.5 mm long). Note yellow hairs covering head and body.

B

Brown frass around base of *I. typographus* attacked tree.

C

I. typographus egg (10-20 cm long) and larval galleries.

D

I. typographus egg and larval galleries. Galleries widen as larvae increase in size.

E

Reddish-brown crowns of trees attacked by *I. typographus*.

F

Stand mortality caused by *I. typographus*.

G

Reddish-brown frass at the base of tree attacked by *I. typographus.*

Coleoptera: Scolytidae

Pityogenes chalcographus (Linneaus)

Six-spined spruce bark beetle

IDENTIFICATION

Adult beetles are 1.6 to 2.9 mm long, and are either black or bicoloured (black head/thorax and red-brown elytra).[2, 82] The frons on males are flat, whereas the frons on females are round with a depression between the eyes.[2] Adults have a moderately excavated elytral declivity with 3 widely spaced conical teeth (per elytron) in males and 3 smaller rounded teeth in females.[2, 82]

HOST TREES

Picea, Larix, Pinus, Pseudotsuga menziesii.[28, 31] *Picea abies, Pinus sylvestris, Pinus strobus and Pseudotsuga menziesii* are known host trees occurring within Canada.

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark of stems and branches. On larger diameter trees, attacks initially occur high on the stem and subsequent attacks may occur progressively lower on the bole.[2, 97] Adults prefer to attack portions of the tree with thin bark.[29]

HOST CONDITION

Prefers stressed and recently felled trees (e.g. windthrow, uprooted trees) and logging residue (e.g. slash, stumps, broken tops). Populations can build up in these hosts and spill over into healthy trees.[28]

DISTRIBUTION

Europe, Siberia, Russia, Japan and China.[2, 15, 30]

SIGNS AND SYMPTOMS

Brownish-white frass, resulting from colonizing adult beetles can be observed in the bark crevices.[46] However, if attacks first occur high in the crown, frass will not be visible in the bark or at the base of the tree as it disperses during the fall from the canopy.[46] Streams of resin may exude from entrance holes, but these are not always readily observable within the crown.[46]

Pityogenes chalcographus galleries are stellate (star-like), usually with 3 to 6 egg galleries radiating from a central nuptial chamber. Each egg gallery is approximately 3 to 5 cm long and 1 mm wide.[2] Larval galleries are approximately 3 cm long, radiate away from the egg gallery in a more or less irregular pattern and may or may not penetrate the sapwood.[2] Larval galleries occur very close to each other and occur on both sides of the egg gallery.[2] Exit holes are small (less than 1 mm in diameter) and circular.[46]

On smaller (e.g. 2 to 4 m) trees, attacks occur along the entire length of the tree and crown symptoms (red needles) will be quite visible.[46] On larger trees, attacks initiate at the top of the crown and foliar colour change is not usually evident. In these trees the needles tend to fall to the ground, the crown appears thinned and the terminal leader will be dead.[46]

A

Adult *P. chalcographus*. Note elytral declivity with three widely spaced spines.

B

Reddish-brown crowns on *P. chalcographus* attacked saplings.

C

Egg (3-5 cm long) and larval (3 cm long) galleries of *P. chalcographus*.

D

Star shaped gallery system with egg galleries radiating from a central nuptial chamber.

E

P. chalcographus egg and larval galleries.

F

Top kill caused by *P. chalcographus*.

G

Chlorotic and thinning crown caused by *P. chalcographus*.

Coleoptera: Scolytidae

Scolytus intricatus (Ratzeburg)

European oak bark beetle

IDENTIFICATION

Adults are small brownish beetles measuring 2.4 to 4.0 mm.[4, 108, 109]

HOST TREES

Quercus (main host), *Aesculus, Betula, Carpinus, Castanea, Corylus, Fagus, Ostrya, Populus, Salix*, *Sorbus* and *Ulmus.*[4, 41, 102, 103, 104, 106, 108]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed in the inner bark on the entire stem and in branches greater than 5 cm in diameter. Immature beetles maturation feed on twigs, usually at the juncture of the current year and 1 year old shoots.[4]

HOST CONDITION

Mature, recently dead, dying or stressed trees. Recently cut (less than 18 months old) logs and branches are also attacked.[4]

DISTRIBUTION

Europe, northern Africa and Asia Minor.[4, 103, 104]

SIGNS AND SYMPTOMS

Immature beetles fly to the crown and maturation feed on twigs, then seek breeding sites in trunks and branches.[100, 104] As a result of maturation feeding, broken shoots containing small entrance holes can be found on the ground beneath host trees.[40, 46]

Either males or females will bore through the bark and initiate construction of a transverse monoramous egg gallery.[41] These egg galleries are 5 to 20 mm long (11 mm average). Eggs are laid individually in regularly spaced niches along both sides of the egg gallery.[4] Larval galleries extend parallel to the grain (perpendicular to the egg gallery) and can reach lengths of 10 to 15 cm.[100] Larvae feed on the inner bark and slightly etch the sapwood.[41] During the first two instars, larval galleries remain discreet but gradually become indistinct as the larvae mature.[41] Exit holes are round and approximately 1.5 to 2.0 mm in diameter.[46]

Infested trees exhibit general symptoms of decline that include reduced growth, crown thinning (i.e. reduced foliage cover) and mortality.[4] Leaves generally do not change colour but usually shrivel and remain on the branch.[46]

A

Adult *S. intricatus* (2.4-4.0 mm long).

B

Transverse egg gallery (5-20 mm long) and vertical larval galleries (10-15 cm long).

C

Adult *S. intricatus*.

D

S. intricatus egg (transverse) and larval (vertical) galleries.

E

S. intricatus egg (transverse) and larval (vertical) galleries.

F

S. intricatus maturation feeding damage.

Coleoptera: Scolytidae

Scolytus morawitzi (Semenov)

Morawitz's bark beetle

IDENTIFICATION

Male beetles are 2.6 to 4.2 mm long while females are 3.1 to 4.8 mm.[24, 42]
The pronotum, antennae, and legs are all reddish-brown.[24, 42] Males have a retreating forehead.[24, 42] Females have a roughly wrinkled projecting forehead, covered with hairs which are denser on the lower part of the forehead.[24, 42] The length of the pronotum is greater than its width.[24, 42]
The abdomen of adults projects slightly beyond the elytra.[24, 42] The elytra are toothed near the apex and are furrowed.[24, 42]

HOST TREES

Larix.[17, 24]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the stem and larger branches (7 mm diameter minimum) where the bark thickness does not exceed 3 to 4 cm.[24, 42] Immature beetles maturation feed on the inner bark of the stem and branches.[24, 42]

HOST CONDITION

Mature, stressed, dying or recently felled trees are preferred, but during outbreaks healthy trees of various ages are also attacked.[24] This species prefers to attack trees growing in sparse forests.[24]

DISTRIBUTION

Russia, Mongolia and northeast China.[17, 24]

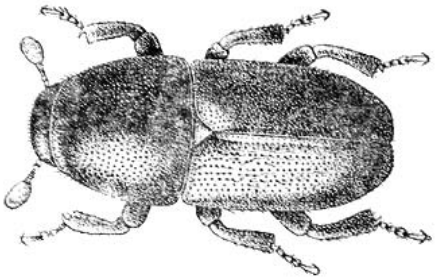
SIGNS AND SYMPTOMS

Immature beetles maturation feed at the top of the trunk and on branches.[24]
Adults bore 7 to 13 mm long galleries at these feeding sites.[24] These galleries can be distinguished from breeding sites by the absence of frass.[24]

The female adult bores under bark scales and creates a small central chamber where she initially lays 2 to 3 eggs.[24, 42]
As more eggs are laid the chamber is widened.[24] A total of 8 to 20 eggs are laid per chamber.[24, 42] Larval galleries are 15 to 17 cm long, radiate from the central chamber and may wind back and forth across other larval galleries.[24, 42] These galleries etch the sapwood and are filled with frass.[24] Larval galleries usually spiral around branches, encircling them.[24]
The ends of larval galleries are slightly enlarged to form pupal chambers.[24]
Adults emerge from small exit holes.

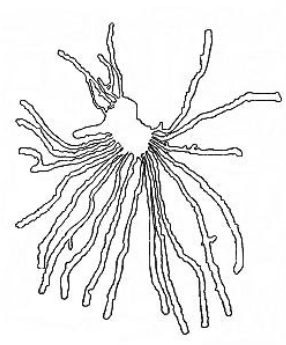
Resin and pitch tubes occur along the tree stem near the entrance holes.[24, 42]
Reddish-brown frass also occurs on the bark surface. The crowns of attacked trees are sparse with partly dead tops and branches.[24, 42] The foliage on infested trees often appears wilted and the needles usually fade from green to yellow.[24, 42]
This species usually re-attacks the same trees during several consecutive years causing their death.[24, 42]

A



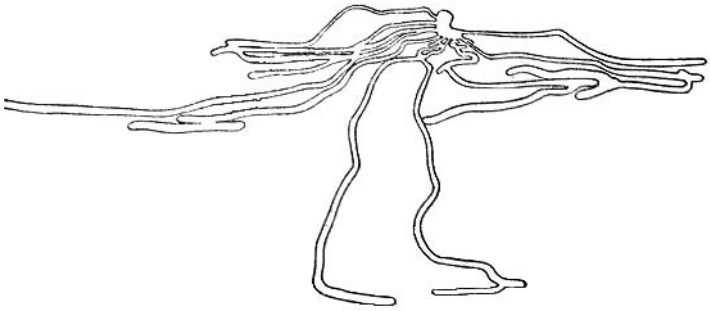
Adult *S. morawitzi* (2.6-4 mm long).

B



S. morawitzi larval galleries radiating from the nuptial chamber.

C



S. morawitzi larval galleries (15-17 mm long) radiating from the nuptial chamber.

Coleoptera: Scolytidae

Scolytus ratzeburgi Janson

Birch bark beetle

IDENTIFICATION

Adults are 4.5 to 6.5 mm, cylindrical, shiny black or brown.[2] Males have a long flat frons covered with dense hairs.[2] The pronotum is finely punctured.[2] Elytra are flat with punctured grooves and interstices, the posterior portions are smooth.[2] The legs and antennae are brown.[2]

HOST TREES

Betula and *Ulmus*.[2, 68]

LOCATION OF INFESTATION WITHIN THE TREE

Immature beetles maturation feed on bark, buds, leaves, and thin twigs in the crown.[68] Larvae usually develop beneath the thick, coarse bark of the main stem or large branches (less than 40 cm in diameter) but may occasionally develop in the smooth bark of smaller branches (5 to 7.5 cm in diameter).[68]

HOST CONDITION

Old and weakened trees. Healthy trees are attacked during outbreaks.[2]

DISTRIBUTION

Europe, Central and Eastern Russia, Mongolia and Japan.[17]

SIGNS AND SYMPTOMS

Immature beetles feed on fresh young twigs and branches of host trees.[68] They also feed on leaves but do not consume the leaf stalk.[68] Beetles bore a semi-circular gallery into the bark beneath the nodes.[68] These galleries are 1 to 2 cm long.[68] Callus tissue may occur over old maturation galleries.[68] In some cases galleries are not formed, but the bark is gnawed away in irregular patches.[68] Sometimes the maturation galleries are used as breeding sites. Otherwise, these galleries are abandoned and new ones are constructed for egg laying.[68]

Females initiate the attack. Entrance holes, shaped like the head of a golf club, are easily visible on smaller branches with thinner bark, but are difficult to find on thicker bark.[68] Females bore straight into the sapwood, then bore longitudinally along the axis of the bole. Reddish-brown frass is usually pushed out by females as they excavate the egg gallery.[68] Monoramous, longitudinal egg galleries are 0.75 to 10 cm long and etch the sapwood.[2, 68]

Eggs are laid in small niches on each side of the egg gallery and are packed with frass.[68, 131] At right angles to the egg galleries, long larval galleries (6 to 10 cm long) penetrate the sapwood as well as the bark.[2, 68, 89] As larvae grow the galleries approach the surface, with pupal chambers occurring just under the bark.[68]

Other signs of attack are the conspicuous ventilation holes in bark that are 2.5 mm in diameter.[2, 88] These holes are initially round, but become oval with use.[2] Dry crowns and die-back also occur on attacked trees.[2]

Scolytus ratzeburgi is associated with the occurrence of Dutch elm disease, facilitating the spread of this disease.[68]

A

Adult *S. ratzeburgi* (4.5-6.5 mm long).

B

S. ratzeburgi egg and larval galleries.

C

S. ratzeburgi egg (0.75-10 cm long) and larval (6-10 cm long) galleries.

D

S. ratzeburgi egg and larval galleries.

E

S. ratzeburgi ventilation holes (2.5 mm wide).

F

Dieback on *S. ratzeburgi* attacked tree.

Coleoptera: Scolytidae

Tomicus piniperda (Linnaeus)

Common pine shoot beetle

IDENTIFICATION

Adults are 3 to 5 mm long and cylindrical.[4, 131] Their head and thorax are shiny black while the elytra are reddish-brown to black.[6, 11] The head is visible from above. The elytral declivity is smooth and rounded.[4]

HOST TREES

Pinus (main host), *Abies, Larix, Picea* and *Pseudotsuga.*[4, 131]

LOCATION OF INFESTATION WITHIN THE TREE

Larvae feed on the inner bark along the bole from the root collar to the middle or lower crown. Immature beetles maturation feed and overwinter within shoots. Adults overwinter in short tunnels at the base of trees.[4, 66]

HOST CONDITION

Trees of all ages are attacked, with preference for larger standing brood trees (at least 12 cm in diameter). Dying, stressed (e.g. drought, defoliation, fire, snow) and healthy trees as well as recently cut stumps, felled trees and windthrow are preferred brood trees.[4, 66, 131] Shoot attack usually occurs above 1.8 m.[4, 12, 66]

DISTRIBUTION

Asia, northern Africa and Europe with introductions into eastern North America.[1, 4, 21, 33, 45, 51]

SIGNS AND SYMPTOMS

Breeding attacks are characterized by fine reddish-brown frass on the bark surface of trees. If relatively vigorous trees are attacked, whitish pitch tubes occur around entrance holes on the bark surface.[4] Adult beetles are associated with various species of blue stain fungi, which stain the sapwood.[4]

Females construct individual monoramous, vertical (more or less) egg galleries within the inner bark that are 10 to 25 cm long and about 2 mm wide.[4, 131] Females lay eggs singly in niches on both sides of the egg gallery.[4] This species periodically sweeps its egg galleries clean of frass.[52] Larvae construct galleries, 4 to 9 cm long, that are perpendicular to the egg gallery.[4, 131]

Immature beetles bore through the outer bark, creating round exit holes about 2 mm in diameter.[4, 51] Beetles then fly to the crowns of live, healthy pines of all ages and usually maturation feed on the current year's shoots.[4, 131] Beetles tunnel into the centre and bore outwards, hollowing out 2 to 10 cm of the shoot.[4] Shoot feeding does not kill the tree but causes reductions in height, diameter and volume.[4, 135] Damaged shoots display a round entrance hole (2 mm) and either one hollowed gallery or several short hollow galleries, which are usually surrounded by pitch.[1] Damaged shoots are disfigured, turn yellow then red, droop, become dry and brittle, and eventually break off near the entrance hole.[1, 4, 12, 131] After windstorms, branches break off and the tree appears pruned.[6]

In late October to November the adult beetles move down the tree to the base of the trunk where they bore into the bark to overwinter.[1, 131]

A

Adult *T. piniperda* (3-5 mm long) tunnelling in a shoot.

B

T. piniperda egg (10-25 cm long) and larval (4-9 cm long) galleries. Note vertical orientation of egg galleries.

C

Pitch tube surrounding entrance hole on brood tree.

D

Round entrance hole (2 mm wide) on infested shoot.

E

Green flagging on shoot caused by maturation feeding.

F

Frass expelled from *T. piniperda* entrance holes.

G

Red flagging caused by maturation feeding within current year's shoot.

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Glossary

Abdomen: The region of the insect body behind the thorax. The last of the three major body divisions of an insect.

Abies: A genus of trees collectively known as true firs.

Acer: A genus of trees collectively known as maple.

Aesculus: A genus of trees collectively known as buckeye or horsechestnut.

Ailanthus: A genus of trees collectively known as Chinese-sumac or Tree-of-heaven.

Alnus: A genus of trees collectively known as alder.

Ambrosia beetle: Scolytids in which larvae feed on fungi lining larval galleries created within the wood of a tree. e.g. *Xyleborus* spp., *Xylosandrus* spp., *Trypodendron* spp.

Amygdalus: A genus of trees collectively known as almonds.

Antenna, antennae (pl.): A pair of segmented sensory organs located on the head of an insect, above the mouthparts.

Betula: A genus of trees collectively known as birch.

Bipectinate: Feathery, with branches on both sides of the main axis; applied mainly to antennae.

Biramous gallery: A system in which two egg galleries arise from the same nuptial chamber. Galleries can be longitudinal, transverse or diagonal.

Bole: The trunk or stem of a tree.

Buprestidae: A family of beetles known as flat-headed or metallic wood borers. Adults tend to be almond shaped and the larvae tend to have flattened heads.

Callus: An isolated thickening of tissue, usually developed by a plant to contain and isolate an infection or wound.

Cambium (vascular): In woody plants it is the single layer of cells between the bark and wood, from which new wood develops. Division of these cells results in diameter growth of the tree through formation of xylem and phloem.

Capitate: Abruptly enlarged and globular at the tip.

Carpinus: A genus of trees collectively known as hornbeam.

Carya: A genus of trees collectively known as hickory.

Castanea: A genus of trees collectively known as chestnut.

Cedrus: A genus of trees collectively known as true cedars.

Celtis: A genus of trees collectively known as hackberry.

Cerambycidae: A family of beetles known as longhorn beetles. Cerambycids that attack trees are also known as round headed wood borers. Adults usually have long antennae while the larvae are often cylindrical.

Chamaecyparis: A genus of trees collectively known as false cypress or yellow cedar.

Chlorosis: Abnormal condition characterized by the absence of green pigments in plants.

Coniferophagous: Organisms that feed on coniferous trees.

Coniferous tree: Commonly known as evergreen trees. Generally these trees retain their needles throughout the year, with the exception of larch. Also known as gymnosperms; woody vascular plants that produce naked seeds not enclosed in an ovary.

e.g. pines, spruces, true firs, Douglas-fir, hemlocks, cedars, junipers, cypress.

Corylus: A genus of trees collectively known as hazelnut.

Crataegus: A genus of trees collectively known as hawthorns.

Crown: The live branches and foliage at the top of a tree.

Cryptomeria: A genus of trees collectively known as Japanese-cedar or Sugi.

Cupressus: A genus of trees collectively known as cypress.

Curculionidae: A family of beetles known as weevils. Adults are snout nosed with their antennae located mid-length on the snout.

e.g. *Pissodes picea*, *Hylobius abietis*

Declivity: Posterior portion of the elytra that descends to the apex.

Deciduous tree: Commonly known as broad-leaved or hardwood trees. Generally these trees lose their leaves (except arbutus and holly) during the fall when the photoperiod decreases in intensity and duration (less light). They belong to a class of vascular plants known as angiosperms that have their ovules and seeds enclosed in an ovary.

e.g. oak, elm, ash, maple, hickory, alder, birch, arbutus, dogwood, beech, poplar, walnut.

Defoliators: Insects that feed on the needles or leaves of coniferous or deciduous trees. Major forest defoliators include budworms (Tortricids), tussock moths (Lymantriids), loopers or inchworms (Geometrids), sawflies (Diprionids), leaf beetles (Chrysomelids) and tent caterpillars (Lasiocampids).

Egg/parent gallery: The gallery produced by an adult beetle in which eggs are laid. It is from the egg or parent gallery that larval galleries will initiate.

Elaeagnus: A genus of trees collectively known as oleasters.

Elytral declivity: Posterior portion of the elytra that descends to the apex.

Elytral suture: The area on the dorsal side of a beetle where the two elytra meet.

Elytron; elytra (pl): The thickened, sclerotized forewings of insects such as beetles.

Epicormic branches: Adventitious twigs or branches that form from dormant buds along the bole or branches. These branches usually form in response to tree stress.

Epistoma: The region on an insect's face above the mouthparts and below the frons. In many beetles, the mouthparts articulate with this region.

Exit hole: A hole through the bark or wood that is created by an emerging insect.

Fagus: A genus of trees collectively known as beech.

Forewing: The first or anterior pair of insect wings.

Frass: The waste material produced by feeding insects that includes excrement and partially chewed vegetation.

Fraxinus: A genus of trees collectively known as ash.

Frons: Upper part of the insect face, between the eyes and above the epistoma.

Genus, genera (pl.): A group of evolutionarily related species, sharing one or a number of characteristics.

Hair pencil: The collection or mass of elongate hairs (i.e. setae) growing from the integument of an insect.

Head: The anterior region of an insect, which bears the mouthparts, eyes and antennae.

Heartwood: The inner core of a woody stem composed of nonliving cells and usually differentiated from the outer wood layer (sapwood) by its darker colour.

Hibernaculum; hibernacula (pl.): A shelter occupied during winter by a dormant animal.

Hindwings: The second pair of wings of an insect.

Infestation: A term generally used to define large, extensive forest insect populations. Similar in definition to an outbreak.

Inner bark: The living tissue beneath the outer bark. Also known as phloem.

Instar: The stage of an insect's life between successive molts, for example the first instar is the stage between emergence from the egg and the first molt.

Juglans: A genus of trees collectively known as walnut.

Juniperus: A genus of trees collectively known as junipers.

Large wood borers: A term used in this book to describe cerambycids, buprestids, weevils and siricids.

Larix: A genus of trees collectively known as larch.

Larva, larvae (pl.): The immature stage between the egg and pupa of insects having complete metamorphosis where the immature differs radically from the adult (e.g. caterpillars, grubs).

Larval gallery: The galleries produced by the mining action of larvae. Larval galleries initiate from egg/parent galleries.

Lasiocampidae: A family of lepidoptera known as tent caterpillars.

Lepidoptera: An order of insects that includes butterflies and moths.

Lymantriidae: A family of lepidoptera known as tussock moths.

Malus: A genus of trees collectively known as apple.

Maturation feeding: Some forest insects require supplemental feeding, before or after emerging from the host, to complete sexual maturation and sclerotization (hardening and darkening of the cuticle) or to increase energy reserves.

Monoramous (uniramous) gallery: A linear, non-branching egg gallery that can be either transverse or parallel to the wood grain.

***Morus*:** A genus of trees collectively known as mulberry.

Naturalized: An organism that has been introduced into a new environment and has become established as if it was indigenous to this area.

Necrosis: A pathological state characterized by brown or dark discoloration and disintegration (local tissue mortality) of plant tissue.

Nuptial chamber: For bark beetles and woodborers it is usually a small gallery beneath the bark in which mating occurs.

Oblate: Flattened or depressed at the poles (e.g. oblate spheroid).

Olea: A genus of trees collectively known as olives.

Order: A taxonomic subdivision that contains groups of related families or superfamilies. Order names usually end with a "-ptera" in insects.

Ostrya: A genus of trees collectively known as hop-hornbeam or ironwood.

Outbreak: A term generally used to define forest insect populations that are extensively and intensively large. Usually populations increase dramatically resulting in mortality or defoliation over a large area (> 1 ha).

Overwinter: A period of rest or hibernation by which insects survive the winter.

Oviposition: The laying or depositing of eggs.

Ovipositor: The tubular or valved egg-laying apparatus at the posterior end of a female insect.

Pathway: The way in which an organism is moved to a new environment.

Pectinate: Having branches which arise from the main axis like the teeth of a comb; usually applied to antennae.

Phloem: The tissue in the conducting system of a plant through which metabolites (products of chemical reactions in the plant, such as sugars) are transported.

Phytotoxic: Poisonous to plants.

Picea: A genus of trees collectively known as spruce.

Pinus: A genus of trees collectively known as pine.

Pitch tubes: Usually a tubular mass of resin that forms on the surface of bark at entrance holes.

Platanus: A genus of trees collectively known as sycamore.

Populus: A genus of trees collectively known as aspen, poplar or cottonwood.

Pronotum: The dorsal surface or sclerite of the 1st thoracic segment, located just behind the head of an insect.

Prunus: A genus of trees collectively known as cherry or plum.

Pseudotsuga: A genus of trees of within the pine family which is collectively known as Douglas-fir. This genus is closely related to *Larix* and is native to Canada, U.S.A., Mexico, Japan and China.

Pterocarya: A genus of trees collectively known as Asiatic nut or Chinese wingnut.

Punctate: Marked by minute depressions.

Pupa, pupae (pl.): For insects with complete metamorphosis, it is the nonfeeding stage between the larva and adult.

Pyrus: A genus of trees collectively known as pear.

Quarantine pest: A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled, (IPPC).

Quercus: A genus of trees collectively known as oak.

Root collar: The transition zone between stem and root at the ground line of a tree or seedling.

Robinia: A genus of trees collectively known as locust.

Rosa: A genus of erect or climbing shrubs collectively known as roses.

Rubus: A large genus of brambles that produce berries (e.g. blackberry, thimbleberry, raspberry, etc.).

Salix: A genus of trees collectively known as willow.

Sapwood: The wood found closest to the bark and usually distinguished from heartwood by being lighter in color. Consists of xylem (structural support, transports water, etc.).

Scolytidae: A family of beetles known as bark beetles. Includes the true bark beetles in which the larvae feed on the phloem and sapwood and ambrosia beetles that feed on fungi within the wood of a tree.

Scutellum: A more or less triangular sclerite that occurs on the dorsal surface of the thorax, behind the pronotum.

Semiochemical: A chemical produced by on organism that affects the behaviour of another organism. Semiochemicals are used to detect and monitor exotic insects.

Siricidae: A family of wood boring wasps collectively known as wood wasps or horntails.

Small wood borers: A term used to describe ambrosia beetles.

Species: A group of individuals similar in structure and capable of interbreeding and producing fertile offspring.

Sorbus: A genus of trees collectively known as mountain ash, Rowan trees or dogberries.

Stellate: Arranged like rays or radiating from a common centre (i.e. star-like).

Sternite: Ventral segments of an insect's abdomen.

Stylet: A needle-like structure.

Syringa: A genus of shrubs collectively known as lilacs or mock-orange.

Terminal leader: The apical or uppermost vertical shoot on a conifer.

Thorax: The insect body region behind the head which bears the legs and wings. The middle of the three major divisions of the insect body.

Thuja: A genus of trees collectively known as cedar.

Tilia: A genus of trees collectively known as linden or basswood.

Tortricidae: A family of lepidoptera in which species that feed on trees are generally referred to as budworms or leafrollers.

True bark beetles: Scolytidae in which the larvae feed directly beneath the bark.

e.g. *Ips typographus*, *Pityogenes chalcographus*, *Hylurgus ligniperda*, *Hylurgops palliatus*.

Tsuga: A genus of trees collectively known as hemlock.

Tubercle: Small knobby protuberance or lump on the surface of an organism.

Ulmus: A genus of trees collectively known as elm.

Uniramous (monoramous) gallery: A linear, non-branching egg gallery that can be either transverse or parallel to the wood grain.

Variegated: Having discrete markings of different colours.

Windthrow: A tree or group of trees uprooted by the wind. Also known as blowdown.

Xylem: Woody tissue in vascular plants that provides support and carries water and nutrients up from the roots.

Host–Insect Index

Host	Insect	Position within tree
Abies	*Choristoneura murinana*	Crown (foliage)
	Dendroctonus micans	Root, Root Collar, Bole, Crown (branches)
	Dendrolimus sibiricus	Crown (foliage)
	Hylastes ater	Root, Bole
	Ips sexdentatus	Bole
	Ips subelongatus	Root Collar, Bole, Crown (branches)
	Ips typographus	Bole
	Lymantria monacha	Crown (foliage)
	Monochamus sartor	Bole, Crown (branches)
	Monochamus urussovi	Bole, Crown (branches & foliage)
	Sirex noctilio	Bole
	Tetropium castaneum	Bole
	Tetropium fuscum	Bole
	Tetropium gracilicorne	Bole
	Tomicus piniperda	Bole, Crown (foliage)
Acer	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Hylesinus varius	Bole, Crown (branches)
	Lymantria dispar	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Tortrix viridana	Crown (foliage)
	Xylotrechus rufilius	Bole
Aesculus	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Scolytus intricatus	Bole, Crown (branches)
Ailanthus	*Hylesinus varius*	Bole, Crown (branches)
Albizia	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
Alnus	*Lymantria dispar*	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Oberea linearis	Crown (branches & foliage)
Amygdalus	*Malacosoma neustria*	Crown (foliage)
Araucaria	*Hylastes ater*	Root, Bole
Betula	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Lymantria dispar	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Monochamus urussovi	Bole, Crown (branches & foliage)
	Saperda carcharias	Bole, Crown (branches & foliage)
	Scolytus intricatus	*B*ole, Crown (branches)
	Scolytus ratzeburgi	Bole, Crown (branches & foliage)
	Tortrix viridana	Crown (foliage)

Host	Insect	Position within tree
Carpinus	*Calliteara pudibunda*	Crown (foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Oberea linearis	Crown (branches & foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
	Tortrix viridana	Crown (foliage)
Castanea	*Agrilus biguttatus*	Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
Cedrus	*Choristoneura murinana*	Crown (foliage)
Celtis	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
Ceratonia	*Cerambyx cerdo*	Bole
Chamaecyparis	*Callidiellum rufipenne*	Bole, Crown (branches)
Corylus	*Calliteara pudibunda*	Crown (foliage)
	Hylesinus varius	Bole, Crown (branches)
	Malacosoma neustria	Crown (foliage)
	Oberea linearis	Crown (branches & foliage)
	Scolytus intricatus	Bole, Crown (branches)
Cotoneaster	*Malacosoma neustria*	Crown (foliage)
Crataegus	*Lymantria dispar*	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
Cryptomeria	*Callidiellum rufipenne*	Bole, Crown (branches)
Cupressus	*Callidiellum rufipenne*	Bole, Crown (branches)
Fagus	*Agrilus biguttatus*	Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Lymantria dispar	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
	Tortrix viridana	Crown (foliage)
Fraxinus	*Agrilus planipennis*	Bole, Crown (branches & foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Xylotrechus rufilius	Bole

Host	Insect	Position within tree
Juglans	*Agrilus planipennis*	Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Oberea linearis	Crown (branches & foliage)
Juniperus	*Callidiellum rufipenne*	Bole, Crown (branches)
	Choristoneura murinana	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
Larix	*Dendroctonus micans*	Root, Root Collar, Bole, Crown (branches)
	Dendrolimus sibiricus	Crown (foliage)
	Hylastes ater	Root, Bole
	Ips hauseri	Root Collar, Bole, Crown (branches)
	Ips sexdentatus	Bole
	Ips subelongatus	Root Collar, Bole, Crown (branches)
	Ips typographus	Bole
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Monochamus sartor	Bole, Crown (branches)
	Monochamus urussovi	Bole, Crown (branches & foliage)
	Pityogenes chalcographus	Bole, Crown (branches)
	Scolytus morawitzi	Bole, Crown (branches)
	Sirex noctilio	Bole
	Tetropium castaneum	Bole
	Tetropium fuscum	Bole
	Tetropium gracilicorne	Bole
	Tomicus piniperda	Bole, Crown (foliage)
	Xylotrechus altaicus	Bole
Malus	*Lymantria dispar*	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
Morus	*Malacosoma neustria*	Crown (foliage)
Olea	*Hylesinus varius*	Bole, Crown (branches)
Ostrya	*Scolytus intricatus*	Bole, Crown (branches)
	Oberea linearis	Crown (branches & foliage)
Picea	*Choristoneura murinana*	Crown (foliage)
	Dendroctonus micans	Root, Root Collar, Bole, Crown (branches)
	Dendrolimus sibiricus	Crown (foliage)
	Hylastes ater	Root, Bole
	Ips hauseri	Root Collar, Bole, Crown (branches)
	Ips sexdentatus	Bole
	Ips subelongatus	Root Collar, Bole, Crown (branches)
	Ips typographus	Bole
	Lymantria monacha	Crown (foliage)
	Monochamus sartor	Bole, Crown (branches)
	Monochamus urussovi	Bole, Crown (branches & foliage)

Host	Insect	Position within tree
	Pissodes harcyniae	Bole
	Pityogenes chalcographus	Bole, Crown (branches)
	Sirex noctilio	Bole
	Tetropium castaneum	Bole
	Tetropium fuscum	Bole
	Tetropium gracilicorne	Bole
	Tomicus piniperda	Bole, Crown (foliage)
Pinus	*Choristoneura murinana*	Crown (foliage)
	Dendroctonus armandi	Bole
	Dendroctonus micans	Root, Root Collar, Bole, Crown (branches)
	Dendrolimus sibiricus	Crown (foliage)
	Hylastes ater	Root, Bole
	Hylesinus varius	Bole, Crown (branches)
	Hylurgus ligniperda	Root, Root Collar, Bole
	Ips hauseri	Root Collar, Bole, Crown (branches)
	Ips sexdentatus	Bole
	Ips subelongatus	Root Collar, Bole, Crown (branches)
	Ips typographus	Bole
	Lymantria monacha	Crown (foliage)
	Monochamus sartor	Bole, Crown (branches)
	Monochamus urussovi	Bole, Crown (branches & foliage)
	Pityogenes chalcographus	Bole, Crown (branches)
	Sirex noctilio	Bole
	Sirex rufiabdominis	Bole, Crown (branches)
	Tetropium castaneum	Bole
	Tetropium fuscum	Bole
	Tetropium gracilicorne	Bole
	Tomicus piniperda	Bole, Crown (foliage)
Platanus	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
Populus	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Lymantria dispar	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Oberea oculata	Crown (branches & foliage)
	Saperda carcharias	Bole, Crown (branches & foliage)
	Saperda perforata	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
	Tortrix viridana	Crown (foliage)
Prunus	*Lymantria dispar*	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
Pseudotsuga	*Choristoneura murinana*	Crown (foliage)
	Dendroctonus micans	Root, Root Collar, Bole, Crown (branches)
	Hylastes ater	Root, Bole

Host	Insect	Position within tree
	Ips sexdentatus	Bole
	Lymantria monacha	Crown (foliage)
	Pityogenes chalcographus	Bole, Crown (branches)
	Sirex noctilio	Bole
	Tomicus piniperda	Bole, Crown (foliage)
Pterocarya	*Agrilus planipennis*	Bole, Crown (branches & foliage)
Pyrus	*Cerambyx cerdo*	Bole
	Hylesinus varius	Bole, Crown (branches)
	Malacosoma neustria	Crown (foliage)
Quercus	*Agrilus biguttatus*	Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Lymantria dispar	Crown (foliage)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
	Tortrix viridana	Crown (foliage)
Robinia	*Cerambyx cerdo*	Bole
	Hylesinus varius	Bole, Crown (branches)
	Plagionotus arcuatus	Bole, Crown (branches)
Rosa	*Malacosoma neustria*	Crown (foliage)
Rubus	*Malacosoma neustria*	Crown (foliage)
Salix	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Lymantria dispar	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Oberea linearis	Crown (branches & foliage)
	Oberea oculata	Crown (branches & foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
	Saperda carcharias	Bole, Crown (branches & foliage)
	Saperda perforata	Bole, Crown (branches)
	Scolytus intricatus	Bole, Crown (branches)
Sorbus	*Anoplophora glabripennis*	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Scolytus intricatus	Bole, Crown (branches)
Syringa	*Hylesinus varius*	Bole, Crown (branches)
	Malacosoma neustria	Crown (foliage)
Thuja	*Callidiellum rufipenne*	Bole, Crown (branches)
	Hylastes ater	Root, Bole
	Monochamus urussovi	Bole, Crown (branches & foliage)

Host	Insect	Position within tree
Tilia	*Calliteara pudibunda*	Crown (foliage)
	Hylesinus varius	Bole, Crown (branches)
	Lymantria dispar	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Plagionotus arcuatus	Bole, Crown (branches)
Tsuga	*Dendrolimus sibiricus*	Crown (foliage)
Ulmus	*Agrilus planipennis*	Bole, Crown (branches & foliage)
	Anoplophora glabripennis	Root, Bole, Crown (branches & foliage)
	Calliteara pudibunda	Crown (foliage)
	Cerambyx cerdo	Bole
	Hylesinus varius	Bole, Crown (branches)
	Lymantria monacha	Crown (foliage)
	Malacosoma neustria	Crown (foliage)
	Oberea linearis	Crown (branches & foliage)
	Scolytus intricatus	Bole, Crown (branches)
	Scolytus ratzeburgi	Bole, Crown (branches & foliage)
	Xylotrechus rufilius	Bole

Insect–Host Index

Insect	Host	Position within tree
Agrilus biguttatus	*Castanea, Fagus, Quercus*	Bole, Crown (branches & foliage)
Agrilus planipennis	*Fraxinus, Juglans, Pterocarya, Ulmus*	Bole, Crown (branches & foliage)
Anoplophora glabripennis	*Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus, Ulmus*	Root, Bole, Crown (branches & foliage)
Callidiellum rufipenne	*Chamaecyparis, Cryptomeria, Cupressus, Juniperus, Thuja*	Bole, Crown (branches)
Calliteara pudibunda	*Acer, Aesculus, Betula, Carpinus, Castanea, Corylus, Fagus, Juglans, Quercus, Populus, Salix, Sorbus, Tilia, Ulmus*	Crown (foliage)
Cerambyx cerdo	*Carpinus, Castanea, Ceratonia, Fagus, Fraxinus, Juglans, Pyrus, Quercus, Robinia, Salix, Ulmus*	Bole
Choristoneura murinana	*Abies, Cedrus, Juniperus, Picea, Pinus, Pseudotsuga*	Crown (foliage)
Dendroctonus armandi	*Pinus*	Bole
Dendroctonus micans	*Abies, Larix, Picea, Pinus, Pseudotsuga*	Root, Root Collar, Bole, Crown (branches)
Dendrolimus sibiricus	*Abies, Larix, Picea, Pinus, Tsuga*	Crown (foliage)
Hylastes ater	*Abies, Araucaria, Larix, Picea, Pinus, Pseudotsuga, Thuja*	Root, Bole
Hylesinus varius	*Acer, Ailanthus, Carpinus, Corylus, Fagus, Fraxinus, Juglans, Olea, Pinus, Pyrus, Quercus, Robinia, Syringa, Tilia, Ulmus*	Bole, Crown (branches)
Hylurgus ligniperda	*Pinus*	Root, Root Collar, Bole
Ips hauseri	*Larix, Picea, Pinus*	Root Collar, Bole, Crown (branches)
Ips sexdentatus	*Abies, Larix, Picea, Pinus, Pseudotsuga*	Bole
Ips subelongatus	*Abies, Larix, Picea, Pinus*	Root Collar, Bole, Crown (branches)
Ips typographus	*Abies, Larix, Picea, Pinus*	Bole
Lymantria dispar	*Acer, Alnus, Betula, Crataegus, Fagus, Malus, Populus, Prunus, Quercus, Salix, Tilia*	Crown (foliage)
Lymantria monacha	*Abies, Acer, Betula, Carpinus, Fagus, Fraxinus, Larix, Malus, Picea, Pinus, Prunus, Pseudotsuga, Quercus, Ulmus*	Crown (foliage)
Malacosoma neustria	*Acer, Alnus, Amygdalus, Betula, Carpinus, Castanea, Corylus, Cotoneaster, Crataegus, Fagus, Fraxinus, Juniperus, Larix, Malus, Morus, Populus, Prunus, Pyrus, Quercus, Rosa, Rubus, Salix, Sorbus, Syringa, Tilia, Ulmus*	Crown (foliage)

Insect	Host	Position within tree
Monochamus sartor	*Abies, Larix, Picea, Pinus*	Bole, Crown (branches)
Monochamus urussovi	*Abies, Betula, Larix, Picea, Pinus, Thuja*	Bole, Crown (branches & foliage)
Oberea linearis	*Alnus, Carpinus, Corylus, Juglans, Ostrya, Salix, Ulmus*	Crown (branches & foliage)
Oberea oculata	*Populus, Salix*	Crown (branches & foliage)
Pissodes harcyniae	*Picea*	Bole
Pityogenes chalcographus	*Larix, Picea, Pinus, Pseudotsuga*	Bole, Crown (branches)
Plagionotus arcuatus	*Acer, Carpinus, Castanea, Fagus, Prunus, Quercus, Robinia, Salix, Tilia*	Bole, Crown (branches)
Saperda carcharias	*Betula, Populus, Salix*	Bole, Crown (branches & foliage)
Saperda perforata	*Populus, Salix*	Bole, Crown (branches)
Scolytus intricatus	*Aesculus, Betula, Carpinus, Castanea, Corylus, Fagus, Ostrya, Populus, Quercus, Salix, Sorbus, Ulmus*	Bole, Crown (branches)
Scolytus morawitzi	*Larix*	Bole, Crown (branches)
Scolytus ratzeburgi	*Betula, Ulmus*	Bole, Crown (branches & foliage)
Sirex noctilio	*Abies, Larix, Picea, Pinus, Pseudotsuga*	Bole
Sirex rufiabdominis	*Pinus*	Bole, Crown (branches)
Tetropium castaneum	*Abies, Larix, Picea, Pinus*	Bole
Tetropium fuscum	*Abies, Larix, Picea, Pinus*	Bole
Tetropium gracilicorne	*Abies, Larix, Picea, Pinus*	Bole
Tomicus piniperda	*Abies, Larix, Picea, Pinus, Pseudotsuga*	Bole, Crown (foliage)
Tortrix viridana	*Acer, Betula, Carpinus, Fagus, Populus, Quercus, Urtica, Vaccinium*	Crown (foliage)
Xylotrechus altaicus	*Larix*	Bole
Xylotrechus rufilius	*Acer, Fraxinus, Ulmus*	Bole

Photo Credits

Insect	Sequence	Photo Credit
Agrilus biguttatus	A	Leen G. Moraal, Alterra, Researchinstituut voor de Groene Ruimte
	B	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515035, www.invasive.org, Feb. 5, 2004
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Agrilus planipennis	A	David Cappaert, Michigan State University, Image 9000019, www.invasive.org, Feb. 5, 2004
	B	David Cappaert, Michigan State University, Image 1460072, www.invasive.org, Mar. 6, 2003
	C	David Cappaert, Michigan State University, Image 1460075, www.invasive.org, April 1, 2004
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	F	Jerry Dowding, Canadian Food Inspection Agency
	G	Jerry Dowding, Canadian Food Inspection Agency
Anoplophora glabripennis	A	Bruce Gill, Canadian Food Inspection Agency
	B	Bruce Gill, Canadian Food Inspection Agency
	C	Bruce Gill, Canadian Food Inspection Agency
	D	Bruce Gill, Canadian Food Inspection Agency
	E	Rob Favrin, Canadian Food Inspection Agency
	F	Bruce Gill, Canadian Food Inspection Agency
	G	Bruce Gill, Canadian Food Inspection Agency
Callidiellum rufipenne	A	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	B	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047055, www.invasive.org, Feb. 5, 2004
	C	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047052, www.invasive.org, Feb. 5, 2004
	D	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047053, www.invasive.org, Feb. 5, 2004
	E	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047057, www.invasive.org, Feb. 5, 2004
	F	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047056, www.invasive.org, Feb. 5, 2004
	G	Connecticut Agricultural Experiment Station Archives, Connecticut Agricultural Experiment Station, Image 3047062, www.invasive.org, Feb. 5, 2004

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Calliteara pudibunda	A	Berks, www.bioimages.org.uk
	B	Malcolm Storey, www.bioimages.org.uk
	C	Malcolm Storey, www.bioimages.org.uk
	D	M. Wilts, www.bioimages.org.uk
	E	Volker Ahrens
Cerambyx cerdo	A	Zoological Institute, Russian Academy of Sciences
	B	Zoological Institute, Russian Academy of Sciences
	C	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231104, forestryimages.org, Feb. 4, 2003
	D	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231106, forestryimages.org, Feb. 4, 2003
	E	Karl-Heinz Apel, Landesforstanstalt Eberswalde, Abteilung Waldschutz
	F	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231105, forestryimages.org, Feb. 4, 2003
Choristoneura murinana	A	Daniel Adam, Office National des Forêts, France, Image 2515007, www.insectimages.org, Feb. 4, 2004
	B	J.P. Fabre, INRA, France
	C	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515004, www.insectimages.org, Feb. 5, 2004
	D	Jean-François Abergall, Centre d'étude du machinisme agricole du génie rural, des eaux et forêts, France, Image 2515002, www.insectimages.org, Feb. 5, 2004
	E	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515003, www.insectimages.org, Feb. 5, 2003
	F	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515006, www.insectimages.org, Feb. 5, 2003
Dendroctonus armandi	A	Klaus Bolte, Natural Resources Canada, Canadian Forest Service
	B	Zhang Zheng, Research Institute of Forest Protection, Chinese Academy of Forestry
	C	Zhang Zheng, Research Institute of Forest Protection, Chinese Academy of Forestry
	D	Drawing from Li, K. and J. Zhou. 1980, Forest Insects in China, Chinese Forestry Press
Dendroctonus micans	A	Norwegian Forest Research Institute, www.skogforsk.no
	B	Fabio Stergulc, University of Udin, Image 1433022, www.invasive.org, Feb. 5, 2004
	C	Forestry Commission, Great Britain
	D	Fabio Stergulc, University of Udin
	E	Forestry Commission, Great Britain
	F	Fabio Stergulc, University of Udin
	G	Forestry Commission, Great Britain

Insect	Sequence	Photo Credit
Dendrolimus sibiricus	A	Yuri Baranchikov, Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Russia
	B	John H. Ghent, USDA Forest Service, Image 1241016, www.invasive.org, Feb. 5, 2004
	C	Yuri Baranchikov, Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Russia
	D	John H. Ghent, USDA Forest Service, Image 1241015, www.invasive.org, Feb. 5, 2004
	E	Yuri Baranchikov, Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Russia
	F	Yuri Baranchikov, Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Russia
	G	Yuri Baranchikov, Russian Academy of Sciences, V.N. Sukachev Institute of Forest, Russia
Hylastes ater	A	Daniel Adam, Office National des Forêts, France, Image 2515012, www.invasive.org, Feb. 23, 2004
	B	William M. Ciesla, Forest Health Management International, Image 1428130, www.invasive.org, Nov. 19, 2003
	C	William M. Ciesla, Forest Health Management International, Image 1428133, www.invasive.org, Feb. 23, 2004
	D	Forest Research, New Zealand
	E	Forest Research, New Zealand
	F	Forest Research, New Zealand
	G	Forest Research, New Zealand
Hylesinus varius	A	Daniel Adam, Office National des Forêts, France, Image 2515021, www.forestryimages.org, April 5, 2004
	B	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231200, www.forestryimages.org, April 4, 2004
	C	Lehrstuhl für Tierökologie, München, www.faunistik.net
	D	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515022, www.forestryimages.org, April 5, 2004
	E	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231199, www.forestryimages.org, April 5, 2004
	F	Daniel Adam, Office National des Forêts, France, Image 2515020, www.forestryimages.org, April 6, 2004
	G	R. Schlepphorst, Landesforstanstalt Eberswalde, Abteilung Waldschutz
Hylurgus ligniperda	A	Steve Passoa, USDA APHIS PPQ, Image 1669028, www.forestryimages.org, April 5, 2004
	B	Forest Research, New Zealand
	C	William M. Ciesla, Forest Health Management International, Image 1428147, www.invasive.org, Feb. 5, 2004
	D	William M. Ciesla, Forest Health Management International, Image 1428034, www.invasive.org, Feb. 5, 2004
	E	William M. Ciesla, Forest Health Management International, Image 1428140, www.invasive.org, Feb. 5, 2004
	F	William M. Ciesla, Forest Health Management International, Image 1428033, www.invasive.org, Feb. 5, 2004
	G	William M. Ciesla, Forest Health Management International, Image 1428032, www.invasive.org, Feb. 5, 2004

Insect	Sequence	Photo Credit
Ips hauseri	A	Klaus Bolte, Natural Resources Canada, Canadian Forest Service
	B	Drawing from Li, K. and J. Zhou. 1980, Forest Insects in China, Chinese Forestry Press
	C	Drawing from Li, K. and J. Zhou. 1980, Forest Insects in China, Chinese Forestry Press
Ips sexdentatus	A	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190017, www.invasive.org, Feb. 5, 2004
	B	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190019, www.invasive.org, Feb. 5, 2004
	C	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190018, www.invasive.org, Feb. 5, 2004
	D	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231218, www.invasive.org, Feb. 5, 2004
	E	Fabio Stergulc, University of Udin, Image 1433026, www.invasive.org, Feb. 5, 2004
	F	Fabio Stergulc, University of Udin, Image 1433028, www.invasive.org, Feb. 5, 2004
	G	Fabio Stergulc, University of Udin, Image 1433027, www.invasive.org, Feb. 5, 2004
Ips subelongatus	A	Yulin An, Jiangsu Entry & Exit Quarantine and Inspection Bureau of the People's Republic of China
	B	Yulin An, Jiangsu Entry & Exit Quarantine and Inspection Bureau of the People's Republic of China
	C	Drawing from Shamaev, A. V. 1994, Guide on identification of pests of forest trees trunks, on which the importers of Russian wood have phytosanitary requirement, Syktyvkar
	D	Drawing from Issaev, A. S. 1966, Borer pests of *Larix dahurica*. Moscow, Nauka
	E	Jun-Bao Wen, Beijing Forest University
	F	Drawing from Issaev, A. S. 1966, Borer pests of *Larix dahurica*. Moscow, Nauka
Ips typographus	A	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231225, www.invasive.org, Jan. 5, 2004
	B	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190030, www.invasive.org, Feb. 5, 2004
	C	Milos Knizek, Forestry and Game Management Research Institute, Czechia, Image 1191005, www.invasive.org, Feb. 5, 2004
	D	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190027, www.invasive.org, Feb. 5, 2004
	E	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 1190031, www.invasive.org, Feb. 5, 2004
	F	Petr Kapitola, Forestry and Game Management Research Institute, Czechia, Image 1191001, www.invasive.org, Feb. 5, 2004
	G	Norwegian Forest Research Institute, www.skogforsk.no
Lymantria dispar	A	Tim Tigner, Virginia Department of Forestry, Image 0886001, www.invasive.org, Feb. 5, 2004
	B	Kenneth H. Knauer, USDA Forest Service, Image 1510057, www.invasive.org, Feb. 5, 2004
	C	David Holden, Canadian Food Inspection Agency
	D	USDA APHIS PPQ Archives, Image 2652051, www.invasive.org, Feb. 5, 2004
	E	Tim Tigner, Virginia Department of Forestry, Image 0886003, www.invasive.org, Feb. 5, 2004
	F	Mark Robinson, USDA Forest Service, Image 2912081, www.invasive.org, Feb. 5, 2004

Insect	Sequence	Photo Credit
Lymantria monacha	A	Paul Schaefer, Beneficial Insects Introduction Research Unit, USDA Agricultural Research Service
	B	Landesforstpräsidium Sachsen Archives, Image 1259120, www.forestryimages.org, May 23, 2004
	C	Daniel Adam, Office National des Forêts, France, Image 2515023, www.invasive.org, Feb. 5, 2004
	D	William M. Ciesla, Forest Health Management International, Image 0017003, www.invasive.org, Feb. 5, 2004
	E	William M. Ciesla, Forest Health Management International, Image 0017006, www.invasive.org, Feb. 5, 2004
	F	Jan Liska, Forestry and Game Management Research Institute, Czechia, Image 1191019, www.invasive.org, Feb. 5, 2004
	G	Petr Kapitola, Forestry and Game Management Research Institute Czechia, Image 1191018, www.invasive.org, Feb. 5, 2004
Malacosoma neustria	A	Antoine Guyonnet, www.ibs-t.net/lepidoptera
	B	András Koltay, Hungary Forest Research Institute
	C	N. Devon, www.bioimages.org.uk
	D	N. Devon, www.bioimages.org.uk
	E	Gyorgy Csoka, Hungary Forest Research Institute
	F	András Koltay, Hungary Forest Research Institute
	G	Antoine Guyonnet, www.ibs-t.net/lepidoptera
Monochamus sartor	A	Marcel and Alain Galant
	B	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	C	Fabio Stergulc, University of Udin, Image 1433012, www.forestryimages.org, Feb. 5, 2004
Monochamus urussovi	A	Hiroshi Makihara, Forestry and Forest Products Research Institute. Agriculture, Forestry and Fisheries Research Council, Japan
	B	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	C	Stanislaw Kinelski, Image1258335, www.forestryimages.org, Aug. 30, 2004
	D	Stanislaw Kinelski, Image 1258054, www.forestryimages.org, Aug. 30, 2004
	E	Michail Mandelshtam, Institute for Experimental Medicine, St. Petersburg, Russia
	F	Michail Mandelshtam, Institute for Experimental Medicine, St. Petersburg, Russia
	G	Jun-Bao Wen, Beijing Forest University
Oberea linearis	A	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	B	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	C	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	D	Remi Coutin, OPIE
	E	Remi Coutin, OPIE
	F	Remi Coutin, OPIE

Insect	Sequence	Photo Credit
Oberea oculata	A	Frank Koehler. Bornheim, Germany
	B	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231168, www. forestryimages.org, Feb. 5, 2004
	C	Stanislav Krejcik, www.meloidae.com
	D	Adrian Colston, Wicken Fen National Nature Reserve, England.
	E	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231167, www.forestryimages.org, May 23, 2004
Pissodes harcyniae	A	University of Natural Resources & Applied Life Sciences (BOKU), Austria
	B	Wojciech Grodzki, Forest Research Institute, Krakow, Poland
	C	Stanislaw Kinelski, Image 1258263, www.forestryimages.org, Aug. 31, 2004
	D	Wojciech Grodzki, Forest Research Institute, Krakow, Poland
	E	Stanislaw Kinelski, Image 1258261, www.forestryimages.org, Aug. 31, 2004
	F	Stanislaw Kinelski, Image 1258260, www.forestryimages.org, Aug. 31, 2004
Pityogenes chalcographus	A	Landesforstpräsidium Sachsen Archives, Image 1259017, www.forestryimages.org, Sept. 24, 2004
	B	Jan Liska, Forestry and Game Management Research Institute, Czechia, Image 1191006, www.invasive.org, Feb. 5, 2004
	C	University of Natural Resources & Applied Life Sciences (BOKU), Austria
	D	University of Natural Resources & Applied Life Sciences (BOKU), Austria
	E	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231212, www.invasive.org, Feb. 5, 2004
	F	Landesforstpräsidium Sachsen Archives, Image 1259172, www.forestryimages.org, Sept. 24, 2004
	G	Landesforstpräsidium Sachsen Archives, Image 1259166, www.forestryimages.org, Sept. 24, 2004
Plagionotus arcuatus	A	Marcel and Alain Galant
	B	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231134, www.insectimages.org, Mar. 25, 2004
	C	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231133, www.insectimages.org, Mar. 25, 2004
	D	Denis Germanovich, Zoological Institute of Russian Academy of Sciences
Saperda carcharias	A	Jean Pinon, Institut National de la Recherche Agronomique, France, Image 2515061, www.invasive.org, Feb. 5, 2004
	B	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231156, www.invasive.org, Feb. 5, 2004
	C	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231157, www.invasive.org, Feb. 5, 2004
	D	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231155, www.invasive.org, Feb 5, 2004
	E	Louis-Michel Nageleisen, Département de la Santé des Forêts, France, Image 2515057, www.invasive.org, Feb. 5, 2004
	F	Petr Kapitola, Forestry and Game Management Research Institute, Czechia, Image 1191014, www.invasive.org, Feb. 5, 2004
	G	Norwegian Forest Research Institute, www.skogforsk.no

Insect	Sequence	Photo Credit
Saperda perforata	A	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	B	Marcel and Alain Galant
	C	Marcel and Alain Galant
	D	Till Tolasch, www.koleopterologie.de
	E	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
Scolytus intricatus	A	Rune Axelsson, Sweden
	B	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231187, www.invasive.org, Feb. 5, 2004
	C	Frank Koehler. Bornheim, Germany
	D	University of Natural Resources & Applied Life Sciences (BOKU), Austria
	E	Rune Axelsson, Sweden
	F	University of Natural Resources & Applied Life Sciences (BOKU), Austria
Scolytus morawitzi	A	Drawing from Li, K. and J. Zhou. 1980, Forest Insects in China, Chinese Forestry Press
	B	Drawing from Issaev, A. S. 1966, Borer pests of *Larix dahurica*. Moscow, Nauka
	C	Drawing from Li, K. and J. Zhou. 1980, Forest Insects in China, Chinese Forestry Press
Scolytus ratzeburgi	A	A.G. Kirejtshuk, Zoological Institute of Russian Academy of Sciences
	B	Karl-Heinz Apel, Landesforstanstalt Eberswalde, Abteilung Waldschutz
	C	Erkki Annila, Finnish Forest Research Institute, www.metla.fi
	D	Erkki Annila, Finnish Forest Research Institute, www.metla.fi
	E	Till Tolasch, www.koleopterologie.de
	F	Erkki Annila, Finnish Forest Research Institute, www.metla.fi
Sirex noctilio	A	Forestry and Agricultural Biotechnology Institute, University of Pretoria, South Africa
	B	Forestry and Agricultural Biotechnology Institute, University of Pretoria, South Africa
	C	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231228, www.invasive.org, Feb. 5, 2004
	D	Forests New South Wales, Department of Primary Industries, Australia
	E	Forestry and Agricultural Biotechnology Institute, University of Pretoria, South Africa
	F	Forest Research, New Zealand
	G	Forest Research, New Zealand
Sirex rufiabdominis	A	Klaus Bolte, Natural Resources Canada, Canadian Forest Service
	B	Dave Holden, Canadian Food Inspection Agency

Insect	Sequence	Photo Credit
Tetropium castaneum	A	Michael Hoskovec, Institute of Organic Chemistry and Biochemistry, Academy of Sciences of the Czech Republic
	B	Fabio Stergulc, University of Udin
	C	Stanislaw Kinelski, Image 1258308, www.forestryimages.org, July 4, 2004
	D	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231096, www.invasive.org, Feb. 4, 2004
	E	University of Natural Resources & Applied Life Sciences (BOKU), Austria
	F	Norwegian Forest Research Institute, www.skogforsk.no
	G	Stanislaw Kinelski, Image 1258317, www.forestryimages.org, July 4, 2004
Tetropium fuscum	A	Klaus Bolte, Natural Resources Canada, Canadian Forest Service
	B	Canadian Food Inspection Agency, Dartmouth
	C	Bob Guscott, Nova Scotia Department of Natural Resources
	D	Stephanie Sopow, Natural Resources Canada, Canadian Forest Service
	E	Ken Harrison, Natural Resources Canada, Canadian Forest Service
	F	Tom Prest, Canadian Food Inspection Agency
	G	Bob Guscott, Nova Scotia Department of Natural Resources
Tetropium gracilicorne	A	Hiroshi Makihara, Forestry and Forest Products Research Institute. Agriculture, Forestry and Fisheries Research Council, Japan
	B	Institut für Forstschutz, Österreichischer Pflanzenschutzdienst Holz
	C	Institut für Forstschutz, Österreichischer Pflanzenschutzdienst Holz
Tomicus piniperda	A	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231204, www.invasive.org, April 4, 2004
	B	William M. Ciesla, Forest Health Management International, Image 0017008, www.invasive.org, March 14, 2004
	C	Stanislaw Kinelski, Image 1258125, www.forestryimages.org, May 22, 2004
	D	Gyorgy Csoka, Hungary Forest Research Institute, Image 1231203, www.invasive.org, April 6, 2004
	E	Bruce Smith, USDA APHIS PPQ, Image 0805094, www.invasive.org, April 5, 2004
	F	Stanislaw Kinelski, Image 1258126, www.forestryimages.org, May 22, 2004
	G	Robert A. Haack, USDA Forest Service, Image 3225083, www.invasive.org, April 4, 2004
Tortrix viridana	A	Berks, www.bioimages.org.uk
	B	Hannes Lemme, Sächsische Landesanstalt für Forsten, Image 1220075, www.forestryimages.org, March 5, 2004
	C	Gyorgy Csoka, Hungary Forest Research Institute
	D	Stephen Dalton, NHPA, Image SDA000721A, www.nhpa.co.uk
	E	Hannes Lemme, Sächsische Landesanstalt für Forsten, Image 1260040, www.forestryimages.org, June 5, 2004
	F	Gyorgy Csoka, Hungary Forest Research Institute
Xylotrechus altaicus	A	Hiroshi Makihara, Forestry and Forest Products Research Institute. Agriculture, Forestry and Fisheries Research Council, Japan
	B	Institut für Forstschutz, Österreichischer Pflanzenschutzdienst Holz
Xylotrechus rufilius	A	Hiroshi Makihara, Forestry and Forest Products Research Institute. Agriculture, Forestry and Fisheries Research Council, Japan
	B	www.beetleskorea.com