United States Department of Agriculture

Animal and Plant Health Inspection Service

Cooperating State Departments of Agriculture

New Pest Response Guidelines

Exotic Wood-Boring and Bark Beetles

This document is not intended to be complete and exhaustive. It provides a foundation based upon available literature to assist in the development of appropriate and relevant regulatory activities. Some key publications were not available at the time of writing, and not all specialists and members of the research community were consulted in the preparation of this document.

References to commercial suppliers or products should not be construed as an endorsement of the company or product by the USDA.

All uses of pesticides must be registered or approved by appropriate Federal, State, and/or Tribal agencies before they can be applied. The information provided on pesticide labels may not reflect all of the actual information, including precautions and instructions for use, which you are required to follow in your specific State or locality. It is the responsibility of persons intending to use a pesticide to read and abide by the label, including labeling approved for the particular State or locality in which the chemical is to be used, and to comply with all Federal, State, Tribal, and local laws and regulations relating to the use of the pesticide. APHIS program staffs are responsible for their compliance with applicable environmental regulations.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife, if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

First edition issued 2011

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Cite the guidelines as follows: USDA–APHIS. 2011. *New Pest Response Guidelines: Exotic Wood-Boring and Bark Beetles*. USDA–APHIS–PPQ–EDP-Emergency Management, Riverdale, Maryland.

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Cover Image

***Top left*—**Gallery damage caused by *Agrilus biguttatus* Fabricius (Buprestidae) (Gyorgy Csoka, Hungary Forest Research Institute, http://www.bugwood.org)

***Top right*—**Adult of *Monochamus saltuarius* (Cyorgy Csoka, Hungary Forest Research Institute, Hungary, http://www.bugwood.org)

***Bottom right*—**Adult of *Agrilus biguttatus* (Gyorgy Csoka, Hungary Forest Research Institute, http://www.bugwood.org)

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Exotic Wood-Boring and Bark Beetles

Introduction

Contents

Purpose

Use *New Pest Response Guidelines: Exotic Wood-Boring and Bark Beetles* as a guide when designing a program to detect, monitor, control, contain, or eradicate, an infestation of exotic wood-boring or bark beetles (EWBBB) in the United States and collaborating territories. Selected species in the order Coleoptera, families Buprestidae, Cerambycidae and Curculionidae, are discussed here as these are currently of particular concern, but the information found in the guidelines may be applicable for other exotic wood-boring and bark beetles.

The United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA–APHIS–PPQ) developed the guidelines through discussion, consultation, or agreement with staff at USDA-Agricultural Research Service, and university advisors.

Any new detection may require the establishment of an Incident Command System to facilitate emergency management. This document is meant to provide the necessary information to launch a response to a detection of most exotic wood-boring and bark beetles.

If exotic wood-boring and bark beetles are detected, PPQ personnel will produce a site-specific action plan based on the guidelines. As the program develops and new information becomes available, the guidelines will be updated.

Users

The guidelines is intended as a field reference for the following users who have been assigned responsibilities for a plant health emergency for exotic wood-boring and bark beetles:

- PPQ personnel
- Emergency response coordinators
- State agriculture department personnel
- Others concerned with developing local survey or control programs

Pest Status

Exotic wood-boring and bark beetles:

- Cause damage by feeding on host shrubs and trees, lowering timber quality and yield (Evans et al., 2004)
- Transmit pathogens to host plants (Kirisits, 2004; Kobayashi et al, 1984)
- Weaken or kill host plants (Evans et al., 2004)

Contacts

When an emergency program for exotic wood-boring and bark beetles has been implemented, its success depends on the cooperation, assistance, and understanding of other involved groups. The appropriate liaison and information officers should distribute news of program progress and developments to interested groups, including the following:

- Other Federal, State, county, and municipal agricultural officials
- Grower groups such as specific commodity or industry groups
- Commercial interests
- Academic entities with agricultural interests
- Land Grant universities and Cooperative Extension Services
- State and local law enforcement officials
- Tribal governments
- Public health agencies
- Agricultural interests in other countries
- National, State and local news media
- The public

Initiating an Emergency Pest Response Program

An emergency pest response program consists of detection and delimitation, and may be followed by programs in regulation, containment, eradication and control. The New Pest Advisory Group (NPAG) will evaluate the pest. After assessing the risk to U.S. plant health, and consulting with experts and regulatory personnel, NPAG will recommend a course of action to PPQ management.

Follow this sequence when initiating an emergency pest response program:

1. A new or reintroduced pest is discovered and reported.
2. The pest is examined and pre-identified by regional or area identifier.
3. The pests identity is confirmed by a national taxonomic authority recognized by USDA–APHIS–PPQ-National Identification System.
4. Existing *New Pest Response Guidelines* are consulted or a new NPAG is assembled in order to evaluate the pest.

5. Depending on the urgency, official notifications are made to the National Plant Board, cooperators, and trading partners.
6. A delimiting survey is conducted at the site of detection.
7. An Incident Assessment Team may be sent to evaluate the site.
8. A recommendation is made, based on the assessment of surveys, other data, and recommendation of the Incident Assessment Team or an NPAG, as follows:
    - ❖ Take no action
    - ❖ Regulate the pest
    - ❖ Contain the pest
    - ❖ Suppress the pest
    - ❖ Eradicate the pest
9. State Departments of Agriculture are consulted.
10. If appropriate, a control strategy is selected.
11. A PPQ Deputy Administrator authorizes a response.
12. A command post is selected and the Incident Command System is implemented.
13. State Departments of Agriculture cooperate with parallel actions using a unified command.
14. Traceback and trace-forward investigations are conducted.
15. Field identification procedures are standardized.
16. Data reporting is standardized.
17. Regulatory actions are taken.
18. Environmental Assessments are completed as necessary.
19. Treatment is applied for required pest generational time.
20. Environmental monitoring is conducted, if appropriate.
21. Pest monitoring surveys are conducted to evaluate program success.
22. Programs are designed for eradication, containment, or long-term use.

Preventing an Infestation

Federal and State regulatory officials must conduct inspections and apply prescribed measures to ensure that this pest does **not** spread within or between properties. Federal and State regulatory officials conducting inspections should follow the sanitation guidelines in ***Preparation, Sanitization, and Clean-up*** on **page 4-2** before entering and upon leaving each property to prevent contamination.

Scope

The guidelines is divided into the following chapters:

1. *Introduction*
2. *Pest Information*
3. *Identification*
4. *Survey Procedures*
5. *Regulatory Procedures*
6. *Control Procedures*
7. *Environmental Regulations*
8. *Pathways*

The guidelines also includes appendixes, a glossary, and an index.

The Introduction contains basic information about the guidelines. This chapter includes the guideline's purpose, scope, users, and application; a list of related documents that provide the authority for the guidelines content; directions about how to use the guidelines; and the conventions (unfamiliar or unique symbols and highlighting) that appear throughout the guidelines.

What the Guidelines Does Not Cover

The guidelines does not cover the emerald ash borer (*Agrilus planipennis* (Fairmaire)), the Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)), nor the redbay ambrosia beetle (*Xyleborus glabratus* Eichhoff). For information concerning these and other exotic wood-boring and bark beetles, visit the Web site of the Federal Plant Pest Programs.

Address	USDA–APHIS–PPQ-Emergency and Domestic Programs, Plant Pest Programs http://www.aphis.usda.gov/plant_health/plant_pest_info/index.shtml

Authorities

The regulatory authority for taking the actions listed in the guidelines is contained in the following authorities:

- Plant Protection Act of 2000 (Statute 7 USC 7701-7758)
- Executive Order 13175, Consultation and Coordination with Indian and Tribal Governments
- Fish and Wildlife Coordination Act
- National Historic Preservation Act of 1966
- Endangered Species Act
- National Environmental Policy Act

Resources

The following resources are related to all programs for exotic wood-boring and bark beetles:

- ***How to Submit Bark Beetle Specimens*** on **page C-1**
- ***Taxonomic Support for Surveys*** on **page D-1**
- ***Key to Help Screen Tomicus piniperda*** on **page E-1**, Cavey et al. 1994
- ***Key for Separating Tomicus Bark Beetles*** on **page F-1**, Brodel 2005 (rev. 2009)

- ***Wasp Watcher Brochure*** on **page H-1**, WaspWatcher: How to Find the Wasp that Hunts Emerald Ash Borer
- *A Resource for Wood Boring Beetles of the World: Bark Beetle Genera of the United States*, Mercado 2011; available on the Web at http://itp.lucidcentral.org/id/wbb/bbgus/index.html

Program Safety

Safety of the public and program personnel is a priority in pre-program planning and training and throughout program operations. Safety officers and supervisors must enforce on-the-job safety procedures.

Support for Program Decisionmaking

USDA–APHIS–PPQ-Center for Plant Health, Science and Technology (CPHST) provides technical support to emergency pest response program directors concerning risk assessments, survey methods, control strategies, regulatory treatments, and other aspects of pest response programs. PPQ managers consult with State departments of agriculture in developing guidelines and policies for pest response programs.

Address	USDA–APHIS–PPQ-Center for Plant Health, Science, and Technology http://www.aphis.usda.gov/plant_health/cphst/index.shtml

How to Use the Guidelines

The guidelines is a portable electronic document that is updated periodically. Download the current version from its source, and then use Adobe Reader® to view it on your computer screen. You can print the guidelines for convenience. However, links and navigational tools are only functional when the document is viewed in Adobe Reader®. Remember that printed copies of the guidelines are obsolete once a new version has been issued.

Conventions

Conventions are established by custom and are widely recognized and accepted. Conventions used in the guidelines are listed in this section.

Advisories

Advisories are used throughout the guidelines to bring important information to your attention. Please carefully review each advisory. The definitions have been updated so that they coincide with the America National Standards Institute (ANSI) and are in the format shown below.

Address	Address indicates the person or agency to contact, along with their Web site address, email address, telephone number, or other means of contact.
Example	Example provides an example of the topic.
Source	Source indicates the location of information used for writing this section of the guidelines.
	IMPORTANT indicates helpful information.
	CAUTION indicates that people could possibly be endangered and slightly hurt.
	NOTICE indicates a possibly dangerous situation where goods might be damaged.

Boldfacing

Boldfaced type is used to highlight negative or important words. These words are: **never, not, do not, other than, prohibited**.

Lists

Bulleted lists indicate that there is no order to the information being listed. Numbered lists indicate that information will be used in a particular order.

Disclaimers

All disclaimers are located on the unnumbered page that follows the cover.

Table of Contents

Every chapter has a table of contents that lists the heading titles at the beginning to help facilitate finding information.

Control Data

Information placed at the top and bottom of each page helps users keep track of where they are in the guidelines. At the top of the page is the chapter and first-level heading. At the bottom of the page is the month, year, title, and page number. PPQ-Emergency and Domestic Programs-Emergency Programs is the unit responsible for the content of the guidelines.

Change Bar

A vertical black change bar in the left margin is used to indicate a change in the guidelines. Change bars from the previous update are deleted when the chapter or appendix is revised.

Decision Tables

Decision tables are used throughout the guidelines. The first and middle columns in each table represent conditions, and the last column represents the action to take after all conditions listed for that row are considered. Begin with the column headings and move left-to-right, and if the condition does not apply, then continue one row at a time until you find the condition that does apply.

Table 1-1 How to Use Decision Tables

If you:	And if the condition applies:	Then:
Read this column cell and row first	Continue in this cell	TAKE the action listed in this cell
Find the previous condition did not apply, then read this column cell	Continue in this cell	TAKE the action listed in this cell

Footnotes

Footnotes comment on or cite a reference to text and are referenced by number. The footnotes used in the guidelines include general text footnotes, figure footnotes, and table footnotes.

General text footnotes are located at the bottom of the page.

When space allows, figure and table footnotes are located directly below the associated figure or table. However, for multi-page tables or tables that cover the length of a page, footnote numbers and footnote text cannot be listed on the same page. If a table or figure continues beyond one page, the associated footnotes will appear on the page following the end of the figure or table.

Heading Levels

Within each chapter and section there can be four heading levels; each heading is green and is located within the middle and right side of the page. The first-level heading is indicated by a horizontal line across the page, and the heading follows directly below. The second-, third-, and fourth-level headings each have a font size smaller than the preceding heading level. The fourth-level heading runs in with the text that follows.

Hypertext Links

Figures, headings, and tables are cross-referenced in the body of the guidelines and are highlighted in boldface type. These appear in blue hypertext in the online guidelines.

Italics

The following items are italicized throughout the guidelines:

- Cross-references to headings and titles
- Names of publications
- Scientific names

Numbering Scheme

A two-level numbering scheme is used in the guidelines for pages, tables, and figures. The first number represents the chapter. The second number represented the page, table, or figure. This numbering scheme allows for identifying and updating. Dashes are used in page numbering to differentiate page numbers from decimal points.

Transmittal Number

The transmittal number contains the month, year, and a consecutively-issued number (beginning with -01 for the first edition and increasing consecutively for each update to the edition). The transmittal number is only changed when the specific chapter sections, appendixes, or glossary, tables, or index is updated. If no changes are made, then the transmittal number remains the unchanged. The transmittal number only changes for the entire guidelines when a new edition is issued or changes are made to the entire guidelines.

Acknowledgements

Writers, editors, reviewers, creators of cover images, and other contributors to the guidelines, are acknowledged in the Acknowledgements section. Names, affiliations, and Web site addresses of the creators of photographic images, illustrations, and diagrams, are acknowledged in the caption accompanying the figure.

How to Cite the Guidelines

Cite the guidelines as follows: USDA–APHIS. 2011. *New Pest Response Guidelines: Exotic Wood-Boring and Bark Beetles*. USDA–APHIS–PPQ–EDP-Emergency Management, Riverdale, Maryland.

How to Find More Information

Contact USDA–APHIS–PPQ–EDP-Emergency Management for more information about the guidelines.

Address	USDA–APHIS–PPQ–EDP-Emergency Management 4700 River Road, Unit 160 Riverdale, MD 20737-1237 Phone: 301-734-8247 FAX: 301-734-8584

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Exotic Wood-Boring and Bark Beetles

Pest Information

Contents

Introduction

Use *Chapter 2 Pest Information* to learn more about the classification, history, host range, and biology of exotic wood-boring and bark beetles (EWBBB) absent from the United States and collaborating territories. Selected species in the order Coleoptera, families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the general information found in the guidelines may be applicable for other exotic wood-boring and bark beetles.

Classification

Exotic wood-boring and bark beetles in the families Buprestidae, Cerambycidae, and Curculionidae, are organized within the phylum Arthropoda, class Insecta, subclass Pterygota, and order Coleoptera.

Species in the families Buprestidae and Cerambycidae are commonly known as wood-boring beetles and the same terminology was used in the guidelines.

Species in the family Curculionidae, subfamilies Platypodinae and Scolytinae, are commonly known as ambrosia beetles and bark beetles, respectively, and the same terminology was used in the guidelines. These subfamilies were previously classified as separate families within the order Coleoptera (Marvaldi, 1997; Kuschel et al. 2000). (Outside the scope of the guidelines, some scolytines are also known as ambrosia beetles.)

Use ***Table 2-1*** and ***Table 2-2*** **on page 2-4** as aids to the classification of exotic wood-boring and bark beetles, and the names used to describe them in the guidelines

The target species included in the guidelines were selected from the Analytic Hierarchy Process (AHP) Prioritized Pest List used by the Cooperative Agricultural Pest Survey (CAPS) program to prioritize pests. They were found to be high-risk pests based on their potential economic and environmental impact.

To avoid confusion in the guidelines, scientific names were used to refer to species of exotic wood-boring and bark beetles because many have multiple common names. Common names were used to refer to pests with established common names, such as the emerald ash borer.

Table 2-1 Families and Species of Exotic Wood-Boring and Bark Beetles

Family	Species (Subfamily)
Buprestidae	*Agrilus biguttatus* Fabricius
Cerambycidae	*Monochamus saltuarius* Gebler, *Monochamus sutor* Linnaeus, *Tetropium castaneum* Linnaeus, *Tetropium fuscum* Fabricius
Curculionidae	*Platypus quercivorus* Murayama (Platypodinae), *Tomicus destruens* Wollaston (Scolytinae)

Table 2-2 Common Names and Synonyms of Exotic Wood-Boring and Bark Beetles

Scientific Name	Common Names	Synonyms
Buprestidae	flatheaded or metallic wood borers	
Agrilus biguttatus Fabricius	oak splendour beetle, two-spotted wood borer	*Agrilus bicolor* Fleischer, *Agrilus coerulescens* Schilsky, *Agrilus octoguttatus* Fourcroy, *Agrilus morosus* Gory & Laporte, *Agrilus pannonicus* Piller & Mitterpacher, *Agrilus subfasciatus* Ménétriés, *Buprestis biguttatus* (=biguttata) Fabricius, *Buprestis pannonicus* Geoffroy in Fourcroy, *Cucujus octoguttatus* Geoffroy in Fourcroy
Cerymbicidae	longhorned beetles, roundheaded wood borers	
Monochamus saltuarius Gebler	Sakhalin pine sawyer, Sakhalin pine longicorn beetle, Japanese pine sawyer	*Monochammus saltuarius*, *Monochammus suzukii* Murase, *Monochamus sultuarius* Pic, *Monohammus saltuarius* Gebler
Monochamus sutor Linnaeus	small white-marmorated long-horned beetle, small white-marmorated longicorn, sawyer beetle	*Cerambix sutor* Linnaeus, *Cerambyx anglicus* Voet, *Cerambyx atomarius* DeGeer, *Cerambyx sutor* Linnaeus, *Lamia heinrothi* Caderhjielm, *Monohammus obscurior* Abeille de Perrin, *Monohammus sutor* Sonthonnax
Tetropium castaneum Linnaeus	black spruce beetle, European spruce longhorn beetle	*Callidium aulicum* Fabricius, *Callidium castaneum* (Linnaeus) Laicharting, *Callidium curiale* Panzer, *Callidium fulcratum* Fabricius, *Callidium impressum* Paykull, *Callidium ruficrus* Schrank, *Cerambyx castaneus* Linnaeus, *Cerambyx luridus* Linnaeus, *Criomorphus aulicus* Mulsant, *Isarthron castaneum* (Linnaeus) Dejean, *Lsarthron castaneum* Linneaus, *Tetropium aulicum* Gaudin, *Tetropium luridum* Gyllenhal
Tetropium fuscum Fabricius	brown spruce longhorned beetle	*Callidium fuscum* Fabricius, *Criomorphus fuscu* Portevin, *Criomorphus fuscus* Planet, *Isarthron fuscum* Estiot
Curculionidae	true weevils	
Platypus quercivorus Murayama (Platypodinae)	oak ambrosia beetle, Japanese oak ambrosia beetle	*Crossotarsus quercivorus* Murayama, *Crossotarsus sexfenestratus* Beeson
Tomicus destruens Wollaston (Scolytinae)	pine shoot beetle, Mediterranean pine shoot beetle	*Blastophagus destruens* Wollaston, *Blastophagus piniperda* Linneaus, *Hylurgus destruens* Wollaston, *Hylurgus piniperda*, *Myelophilus destruens* Wollaston, *Tomicus piniperda* var. destruens

Pest Status

The species included in the guidelines are just a few of the wood-boring and bark beetles that are of economic concern to the United States. Some of the species attack healthy trees and, when introduced into new environments, can cause extensive damage to healthy and previously-unrecorded host species.

For example, *Tetropium fuscum* Fabricius is a potential threat to the United States. It was introduced into Nova Scotia, Canada, around 1990 where it attacks healthy stands of red spruce (*Picea rubens*) (Smith and Hurley, 2000). *Tetropium fuscum* Fabricius was most likely introduced with the wood-staining fungus *Ophiostoma tetropii* (Jacobs et al., 2003). Although efforts have been made to eradicate *Tetropium fuscum* Fabricius from Canada, there remains the possibility that it has been introduced further afield from known introduction sites, and therefore represents a credible threat to agriculture and the environment in the United States.

Other species in the guidelines have become pests in portions of their known range, including *Agrilus biguttatus* Fabricius in the Czech Republic, France, Germany, Italy, the Netherlands, Poland, and Slovakia (Evans et al., 2004); and *Platypus quercivorus* Murayama in Japan (Davis et al., 2005b). When introduced into new environments, the exotic wood-boring and bark beetles have the potential to severely impact forest ecosystems.

Related Pests

Examples of invasive wood-boring and bark beetles outside the scope of the guidelines, and currently causing extensive damage in the United States, include the emerald ash borer (*Agrilus planipennis* (Fairmaire)), Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)), and redbay ambrosia beetle (*Xyleborus glabratus* Eichhoff). Experience with these pests illustrates the need for early responses to new species of exotic wood-boring and bark beetles, in order to prevent or reduce economic losses.

Economic Importance

In the United States, costs associated with host plant damage by exotic wood-boring and bark beetles can be extreme. The costs are the result of the destruction or degradation of host material that can be used for products such as lumber and pulpwood.

An infestation of exotic wood-boring and bark beetles could increase the cost of trade through an increase in phytosanitary regulations and trade bans. Such an introduction also generates costs to handle emergency response, management costs (if the pest cannot be eradicated) and other indirect costs such as tree replacement and loss of property values. Such costs illustrate the need for early responses to new detections so that future economic losses can potentially be prevented or reduced.

Buprestidae and Cerambycidae

Although both buprestids and cerambycids usually infest recently-cut, weakened or dead trees, some species in these families can apparently attack and kill healthy trees (Haack and Slansky, 1987; Haack, 2006). Larvae either tunnel and feed in wood or feed almost exclusively on the cambial region (Haack and Slansky, 1987; Haack, 2006).

Curculionidae

Bark beetle larvae mainly feed on the phloem of the tree while adults tunnel and breed beneath the bark; ambrosia beetles tunnel through wood, inoculating the gallery with fungi which serves as larval food (Haack, 2006). Both bark and ambrosia beetles can vector fungi and other microorganisms that can infect woody host tissues (Kühnholz et al., 2001; Kirisits, 2004).

The subfamily Platypodinae includes tropical species. Members of this subfamily excavate tunnels in the heartwood by mated adults who also inoculate the gallery with fungi which serves as larval food (Atkinson, 2008). Species present in Florida can cause economic damage to un-milled logs and standing dead timber when they bore into large branches and trunks of recently killed trees (Atkinson, 2008).

Related Pests

One of the well-known invasives in the United States, the emerald ash borer (*Agrilus planipennis* (Fairmaire)), has cost municipalities, property owners, nursery operators and forest product industries tens of millions of dollars (USDA Forest Service et al., n.d.). The USDA Forest Service found in an initial economic analysis that the borer could cost approximately $7 billion more over the next 25 years, to State and local governments and land owners, to replace dead and dying host trees in urban and suburban areas if not contained and eradicated (McPartlan et al., 2006). In the urban environment alone, the borer could threaten between 30 to 90 million trees valued at $20–$60 billion (McPartlan et al., 2006).

Current and Potential Distribution and Detections

Final risk maps and host risk maps were used in this section to describe the potential distribution of exotic wood-boring and bark beetles.

The term final risk map was used to describe a map of the combined host and climatic suitability of an area, on a scale of 1 to 10. A value of one represents a low density of susceptible hosts and a low likelihood of pest growth and survival. A value of 10 indicates a high density of susceptible hosts and a high likelihood of pest growth and survival.

The term host risk map was used to describe the relative density of susceptible hosts, on a scale of 1 to 10. For pests that are insensitive to climate, the host risk map will be the final risk map. These maps are based on National Agricultural Statistics Service (NASS) data and Forest Inventory and Analysis (FIA) data. The scale of 1 to 10 describes the proportion of total host acreage per county: for example, a rank of 1 indicates no host acreage, while a score of 10 indicates that 75–100 percent of the acres in the county contain suitable hosts for the pest.

How to Download Risk Maps from NAPPFAST

The risk maps featured in this section can be downloaded from the NAPPFAST (North Carolina State University APHIS Plant Pest Forecasting System) Web site. For further information, refer to ***Table 2-3*** **on page 2-7**.

Table 2-3 How to Download Electronic Images from NAPPFAST

If you want to download the following:	Then visit this Web site:	And select this link:
Any host or risk map, including Alaska and Hawaii	http://www.nappfast.org/caps_pests/CAPs_Top_50.htm	CAPS AHP 2011 Top 50 and Pest Matrix

Buprestidae

Agrilus biguttatus* Fabricius**—*Agrilus biguttatus* is established in parts of Asia and Europe (Table 2-4* on page 2-8**). This species has **not** been detected in the United States. Use the host risk map in ***Figure 2-1* on page 2-9** as a guide to its potential distribution.

Table 2-4 Known Distribution of *Agrilus biguttatus* Fabricius (continued)

Location	References
Algeria	Davis et al., 2006
Morocco	Davis et al., 2005a
Albania	Fauna Europaea, n.d.
Austria	Fauna Europaea, n.d.
Azerbaijan	Moraal and Hilszczanski, 2000a; Ciesla, 2003a
Belarus	Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a
Belgium	Vansteenkiste et al., 2004
Bosnia and Herzegovina	Fauna Europaea, n.d.
Bulgaria	Fauna Europaea, n.d.
Croatia	Fauna Europaea, n.d.
Czech Republic	Moraal and Hilszczanski, 2000a; Ciesla, 2003a
Denmark	Fauna Europaea, n.d.
England	Foster, 1987; Godfrey, 1987; Allen, 1988; Key, 1991; Smith, 1994; Hackett, 1995a; Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003
Estonia	Fauna Europaea, n.d.
France	Jacquiot, 1976; Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a
Germany	Hartmann and Blank, 1992; Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a
Greece	Fauna Europaea, n.d.
Hungary	Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a
Italy	Fauna Europaea, n.d.
Macedonia	Fauna Europaea, n.d.
Moldova	Fauna Europaea, n.d.
Netherlands	Moraal and Hilszczanski, 2000a; Ciesla, 2003a
Norway	Fauna Europaea, n.d.
Iran	Davis et al., 2006
Poland	Moraal and Hilszczanski, 2000a; 2000b; Hilszczanski and Kolk, 2001; Ciesla, 2003a
Portugal	Fauna Europaea, n.d.
Romania	Fauna Europaea, n.d.

Table 2-4 Known Distribution of *Agrilus biguttatus* Fabricius (continued)

Location	References
Russia	Jacquiot, 1976; Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a
Slovakia	Fauna Europaea, n.d.
Slovenia	Fauna Europaea, n.d.
Spain	Davis et al., 2005a; Davis et al., 2006
Sweden	Fauna Europaea, n.d.
Switzerland	Fauna Europaea, n.d.
Turkey	Davis et al., 2006
Ukraine	Moraal and Hilszczanski, 2000a; 2000b; Ciesla, 2003a

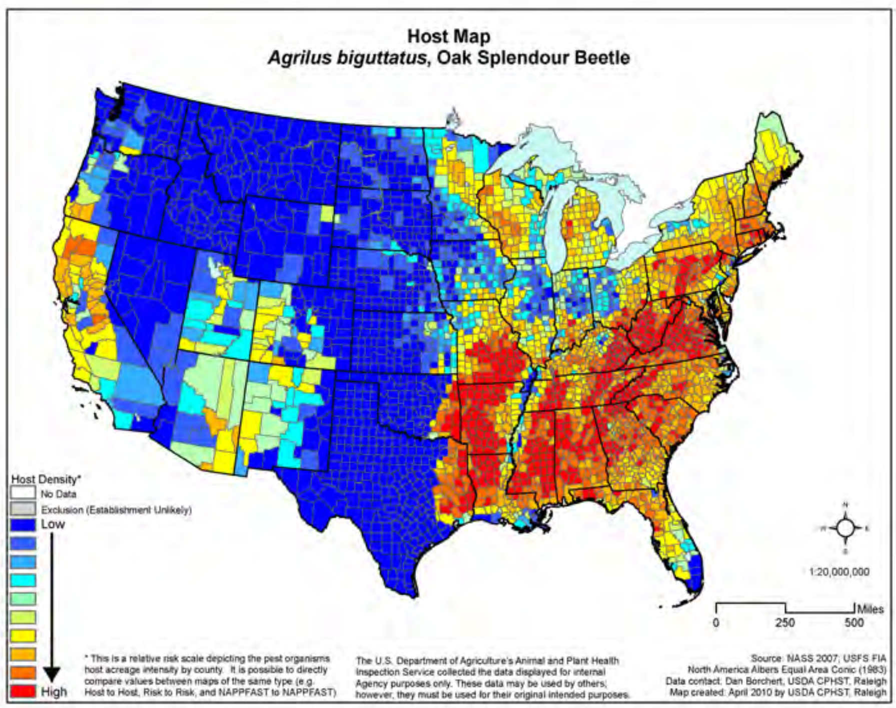

Figure 2-1 Host Risk Map for *Agrilus biguttatus* Fabricius in the Continental United States

Cerambycidae

Monochamus saltuarius* Gebleris—Monochamus saltuarius* is established in parts of Asia and Europe (***Figure 2-5* on page 2-10**). This species has **not** been intercepted in the United States. Use the final risk map in ***Figure 2-2* on page 2-11** as a guide to its potential distribution.

Table 2-5 Known distribution of *Monochamus saltuarius* Gebler

Location	References
China	Ciesla, 2001; Cesari et al., 2005; EPPO, 2007
Japan	Togashi et al., 1994; Jikumaru and Togashi, 1995; Togashi and Jikumaru, 1996; Nakayama et al., 1998; Ciesla, 2001; Cesari et al., 2005; EPPO, 2007
Korea	Cesari et al., 2005
Mongolia	CABI, 2010
Austria	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Belarus	Althoff and Danilevski, 1997; Danilevsky, 2003
Bosnia and Herzegovina	Althoff and Danilevski, 1997; Danilevsky, 2003
Croatia	Althoff and Danilevski, 1997; Danilevsky, 2003
Czech Republic	Althoff and Danilevski, 1997; Danilevsky, 2003
Estonia	
Germany	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Hungary	Althoff and Danilevski, 1997; Danilevsky, 2003
Italy	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Latvia	Danilevsky, 2003
Lithuania	EPPO, 2007
Poland	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Romania	Althoff and Danilevski, 1997; Danilevsky, 2003
Russia	Althoff and Danilevski, 1997; USDA Forest Service, 1999; Cesari et al., 2005
Slovakia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovenia	Althoff and Danilevski, 1997; Danilevsky, 2003
Switzerland	EPPO, 2007
Ukraine	Althoff and Danilevski, 1997; Danilevsky, 2003

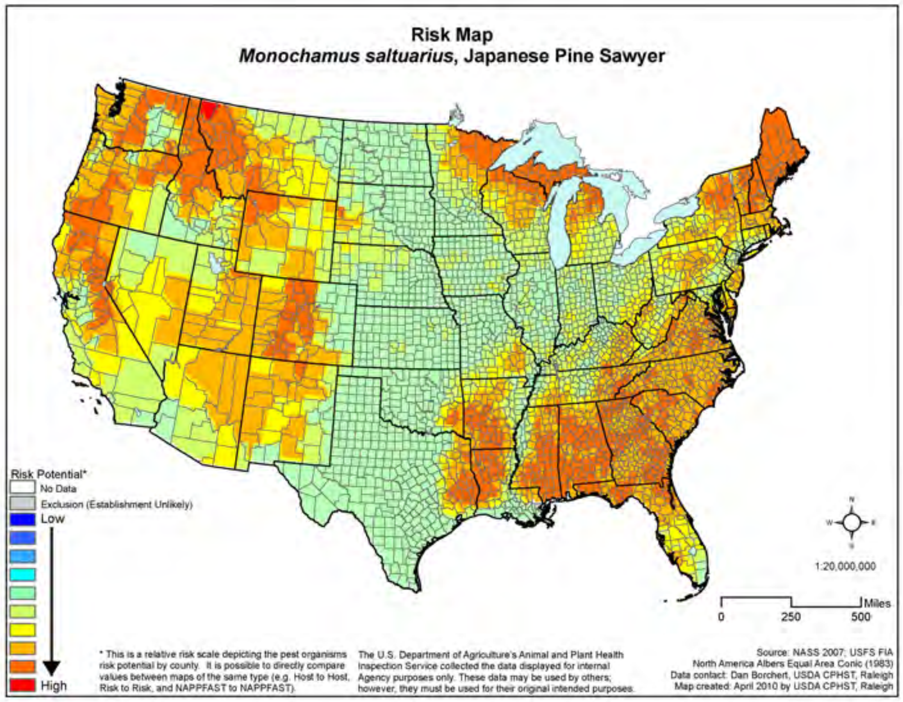

Figure 2-2 Final Risk Map for *Monochamus saltuarius* Gebler in the Continental United States

Monochamus sutor* Linnaeus**—*Monochamus sutor* is established in parts of Asia and Europe (Table 2-6* on page 2-12**). This species has **not** been intercepted in the United States. Use the host risk map in ***Figure 2-3* on page 2-13** as a guide to its potential distribution.

Table 2-6 Known Distribution of *Monochamus sutor* Linnaeus (continued)

Location	References
China	Cherepanov, 1990b; Zhang et al., 1993; Cesari et al., 2005
Japan	Cherepanov, 1990b; Cesari et al., 2005
Kazakhstan	Ciesla, 2004
Korea	Cherepanov, 1990b; Cesari et al., 2005
Mongolia	Cherepanov, 1990b; Cesari et al., 2005
Albania	Althoff and Danilevski, 1997; Danilevsky, 2003
Andorra	Fauna Europaea, n.d.
Austria	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Belarus	Althoff and Danilevski, 1997; Danilevsky, 2003
Bosnia and Herzegovina	Althoff and Danilevski, 1997; Danilevsky, 2003
Bulgaria	Althoff and Danilevski, 1997; Danilevsky, 2003; Cesari et al., 2005; EPPO, 2007
Croatia	Althoff and Danilevski, 1997; Danilevsky, 2003
Czech Republic	Althoff and Danilevski, 1997; Danilevsky, 2003
Denmark	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Estonia	Althoff and Danilevski, 1997; Danilevsky, 2003
Finland	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
France	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Georgia	Cesari et al., 2005; EPPO, 2007
Germany	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Hungary	Althoff and Danilevski, 1997; Danilevsky, 2003
Italy	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Latvia	Althoff and Danilevski, 1997; Danilevsky, 2003
Liechtenstein	Fauna Europaea, n.d.
Lithuania	Althoff and Danilevski, 1997; Danilevsky, 2003
Netherlands	Althoff and Danilevski, 1997; Danilevsky, 2003
Norway	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Poland	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Romania	Althoff and Danilevski, 1997; Danilevsky, 2003; Cesari et al., 2005; EPPO, 2007
Russia	Althoff and Danilevski, 1997; USDA Forest Service, 1991; Danilevsky, 2003; Cesari et al., 2005; EPPO, 2007

Table 2-6 Known Distribution of *Monochamus sutor* Linnaeus (continued)

Location	References
Serbia	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Slovakia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovenia	Althoff and Danilevski, 1997; Danilevsky, 2003
Spain	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Sweden	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Switzerland	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007
Ukraine	Althoff and Danilevski, 1997; Danilevsky, 2003; EPPO, 2007

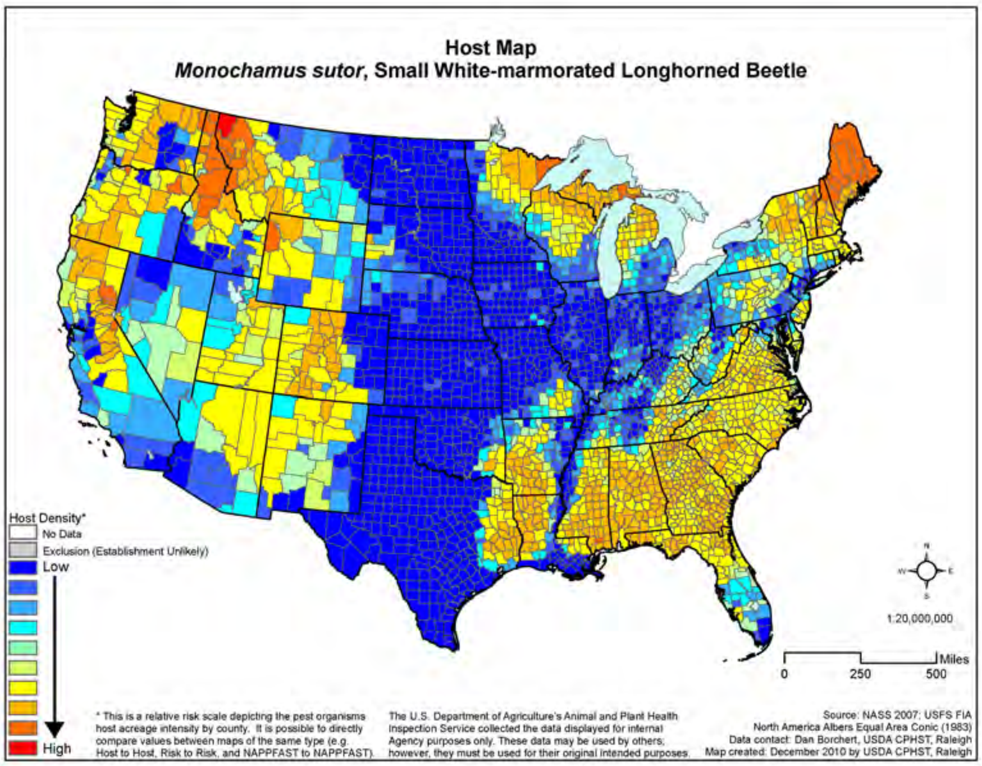

Figure 2-3 Host Risk Map for *Monochamus sutor* Linnaeus in the Continental United States

Tetropium castaneum* Linnaeus**—*Tetropium castaneum* is established in parts of Asia and Europe (Table 2-7* on page 2-14**). This species was intercepted in Oregon in 2000 but has **not** been detected since (Johnson et al., 2002). Use the host risk map in ***Figure 2-4* on page 2-15** as a guide to its potential distribution.

Table 2-7 Known Distribution of *Tetropium castaneum* Linnaeus (continued)

Location	References
China	Kimoto and Duthie-Holt, 2006; Cherepanov, 1990a
Japan	Kimoto and Duthie-Holt, 2006; Kolk and Starzyk, 1996; Cherepanov, 1990
Kazakhstan	Althoff and Danilevski, 1997; Dobesberger, 2005a
Korea	Kimoto and Duthie-Holt, 2006; Kolk and Starzyk, 1996; Cherepanov, 1990a
Mongolia	Kimoto and Duthie-Holt, 2006; Kolk and Starzyk, 1996; Cherepanov, 1990a
Turkey	Dobesberger, 2005a
Albania	Althoff and Danilevski, 1997; Danilevsky, 2003
Austria	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Belarus	Althoff and Danilevski, 1997; Danilevsky, 2003
Belgium	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Bosnia and Herzegovina	Althoff and Danilevski, 1997; Danilevsky, 2003
Bulgaria	Althoff and Danilevski, 1997; Danilvesky, 2003
Croatia	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Czech Republic	Althoff and Danilevski, 1997; Danilevsky, 2003
Denmark	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Estonia	Althoff and Danilevski, 1997; Danilevsky, 2003
Finland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
France	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Germany	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Greece	Danilevsky, 2003
Hungary	Althoff and Danilevski, 1997; Danilevsky, 2003
Italy	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Latvia	Althoff and Danilevski, 1997; Danilevsky, 2003
Lithuania	Althoff and Danilevski, 1997; Danilevsky, 2003
Luxembourg	Althoff and Danilevski, 1997; Danilevsky, 2003
Moldova	Althoff and Danilevski, 1997; Danilevsky, 2003
Montenegro	Danilevsky, 2003
Netherlands	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Norway	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Poland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003

Table 2-7 Known Distribution of *Tetropium castaneum* Linnaeus (continued)

Location	References
Romania	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Russia	Althoff and Danilevski, 1997; Cherepanov, 1990a; Bense, 1995; Danilevsky, 2003
Serbia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovakia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovenia	Althoff and Danilevski, 1997; Danilevsky, 2003
Spain	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Sweden	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Switzerland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Ukraine	Althoff and Danilevski, 1997; Danilevsky, 2003
United Kingdom	Bense, 1995

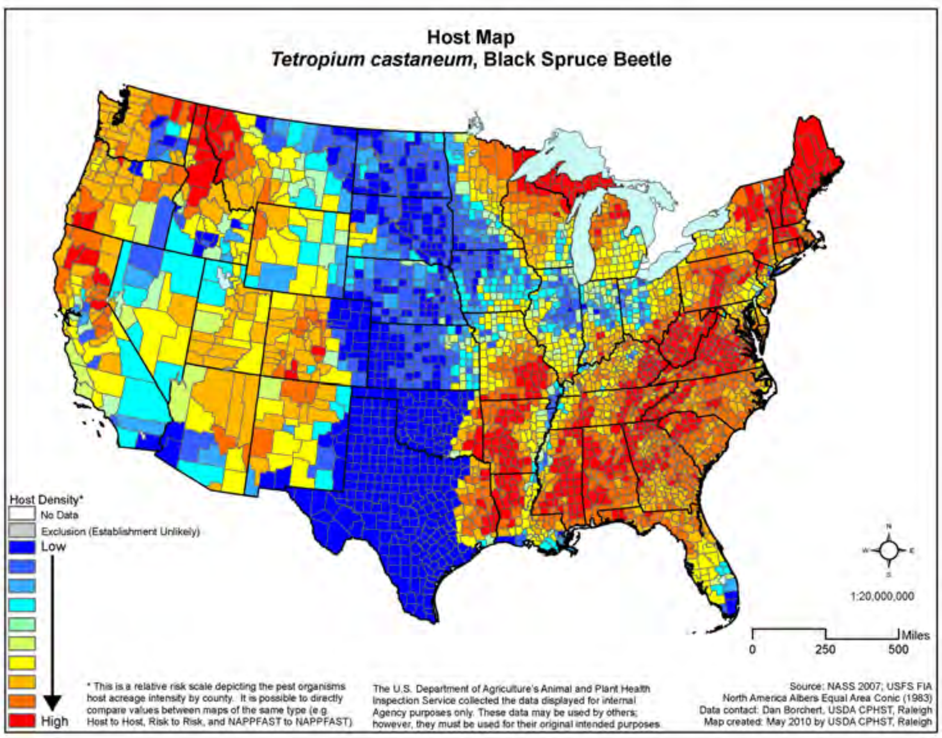

Figure 2-4 Host Risk Map for *Tetropium castaneum* Linnaeus in the Continental United States

Tetropium fuscum* Fabricius**—*Tetropium fuscum* is established in parts of Asia, Europe, and Canada (Table 2-8* on page 2-16**). This species is also found in eastern Canada in Halifax, Nova Scotia, where it was introduced around 1990 (EPPO, 2001). Use the host risk map in ***Figure 2-5* on page 2-17** as a guide to its potential distribution.

Table 2-8 Known distribution of *Tetropium fuscum* Fabricius

Location	References
Japan	Davis et al., 2008; Dobesberger, 2005b
Kazakhstan	Danilevsky, 2003
Turkey	Dobesberger, 2005b
Austria	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Belarus	Althoff and Danilevski, 1997; Danilevsky, 2003
Belgium	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Bosnia and Herzegovina	Althoff and Danilevski, 1997; Danilevsky, 2003
Bulgaria	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Croatia	Althoff and Danilevski, 1997; Danilevsky, 2003
Czech Republic	Althoff and Danilevski, 1997; Danilevsky, 2003
Denmark	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Estonia	Althoff and Danilevski, 1997; Danilevsky, 2003
Finland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
France	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Germany	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Hungary	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Italy	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Latvia	Althoff and Danilevski, 1997; Danilevsky, 2003
Lithuania	Althoff and Danilevski, 1997; Danilevsky, 2003
Moldova	Althoff and Danilevski, 1997; Danilevsky, 2003
Montenegro	Danilevsky, 2003
Netherlands	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Norway	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Poland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Romania	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Russia	Novak et al., 1976; Althoff and Danilevski, 1997; Danilevsky, 2003
Serbia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovakia	Althoff and Danilevski, 1997; Danilevsky, 2003
Slovenia	Althoff and Danilevski, 1997; Danilevsky, 2003
Sweden	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Switzerland	Bense, 1995; Althoff and Danilevski, 1997; Danilevsky, 2003
Ukraine	Althoff and Danilevski, 1997; Danilevsky, 2003
Canada	Smith and Hurley, 2000; Jacobs et al., 2003; O'Leary et al., 2003; Harrison et al., 2004; Sweeney et al., 2006

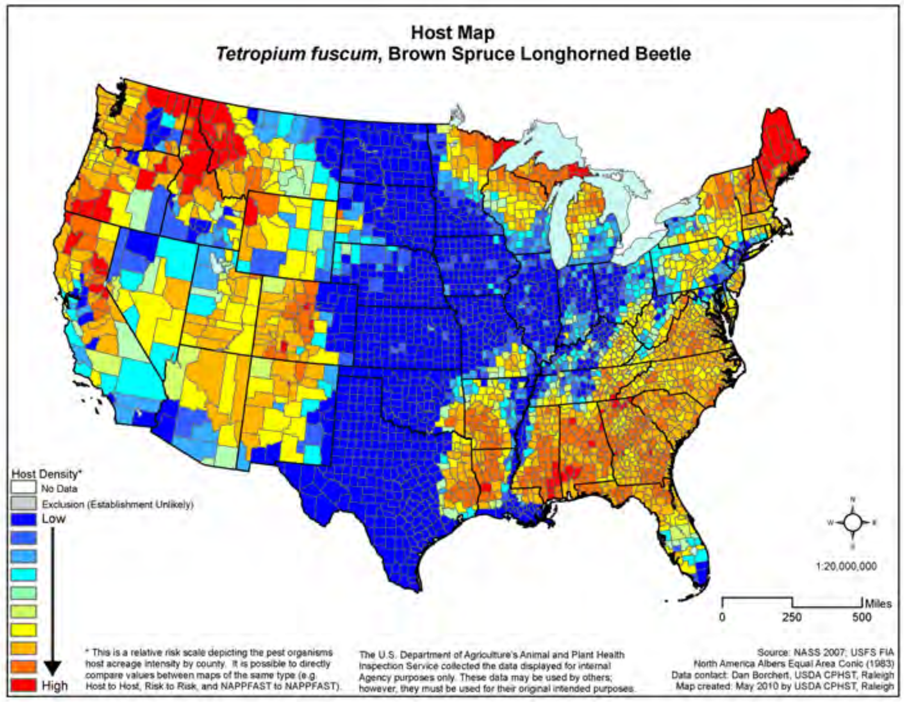

Figure 2-5 Host Risk Map for *Tetropium fuscum* Fabricius in the Continental United States

Curculionidae

Platypus quercivorus* Murayama *(Platypodinae)*—Platypus quercivorus* species has **not** been intercepted in the United States (***Table 2-17* on page 2-32**). Use the host risk map in ***Figure 2-6* on page 2-18** as a guide to its potential distribution.

Table 2-9 Known Distribution of *Platypus quercivorus* Murayama (Platypodinae)

Location	References
India	Wood and Bright, 1992; Kobayashi and Ueda, 2002; Beaver and Shih, 2003; Ciesla, 2003d; EPPO, 2007
Indonesia (Java)	Wood and Bright, 1992; Kobayashi and Ueda, 2002; Beaver and Shih, 2003;Ciesla, 2003d; EPPO, 2007
Japan	Kinuura, 1995; Beaver and Shih, 2003; Kobayashi and Ueda, 2003; Kobayashi and Ueda, 2003; Ito et al., 1998; Esaki et al., 2004; Wood and Bright, 1992; Ciesla, 2003d; EPPO, 2007
Papua New Guinea	Wood and Bright, 1992; Kobayashi and Ueda, 2002; Beaver and Shih, 2003;Ciesla, 2003d; EPPO, 2007
Taiwan	Wood and Bright, 1992; Kobayashi and Ueda, 2002; Beaver and Shih, 2003;Ciesla, 2003d; EPPO, 2007

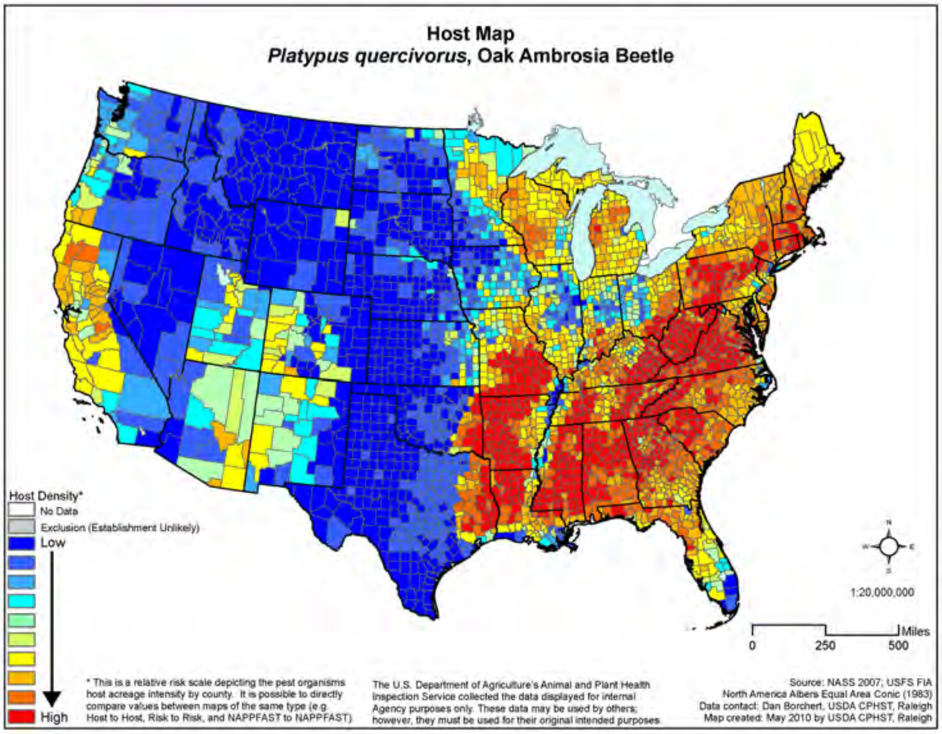

Figure 2-6 Host Risk Map for *Platypus quercivorus Murayama (Platypodinae)* in the Continental United States

Tomicus destruens* Wollaston (Scolytinae)**—*Tomicus destruens* has **not** been intercepted in the United States (Table 2-18* on page 2-33**). Use the final risk map in ***Figure 2-7* on page 2-20** as a guide to its potential distribution.

Table 2-10 Known Distribution of *Tomicus destruens* Wollaston (Scolytinae)

Location	References
Algeria	Faccoli, 2006; Horn et al., 2006
Morocco	Horn et al., 2006
Tunisia	Horn et al., 2006
Cyprus	Wood and Bright, 1992
Israel	Wood and Bright, 1992; Horn et al., 2006
Lebanon	Horn et al., 2006
Turkey	Wood and Bright, 1992; Horn et al., 2006
Croatia	Horn et al., 2006
France	Wood and Bright, 1992; Duan et al., 2004; Faccoli, 2006; Horn et al., 2006; Vasconcelos et al., 2006
Greece	Kohlmayr et al., 2002; Faccoli, 2006; Horn et al., 2006
Italy	Wood and Bright, 1992; Nanni and Tiberi, 1997; Kohlmayer et al., 2002; Peverieri and Faggi, 2005; Faccoli, 2006; Peverieri et al., 2006, Vasconcelos et al., 2006; Horn et al., 2006
Portugal	Wood and Bright, 1992; Vasconcelos et al., 2003; Horn et al., 2006; Vasconcelos et al., 2006
Spain	Wood and Bright, 1992; Kohlmayr et al., 2002; Faccoli, 2006; Horn et al., 2006; Vasconcelos et al., 2006
Madeira	Wood and Bright, 1992; Gallego and Galian, 2001

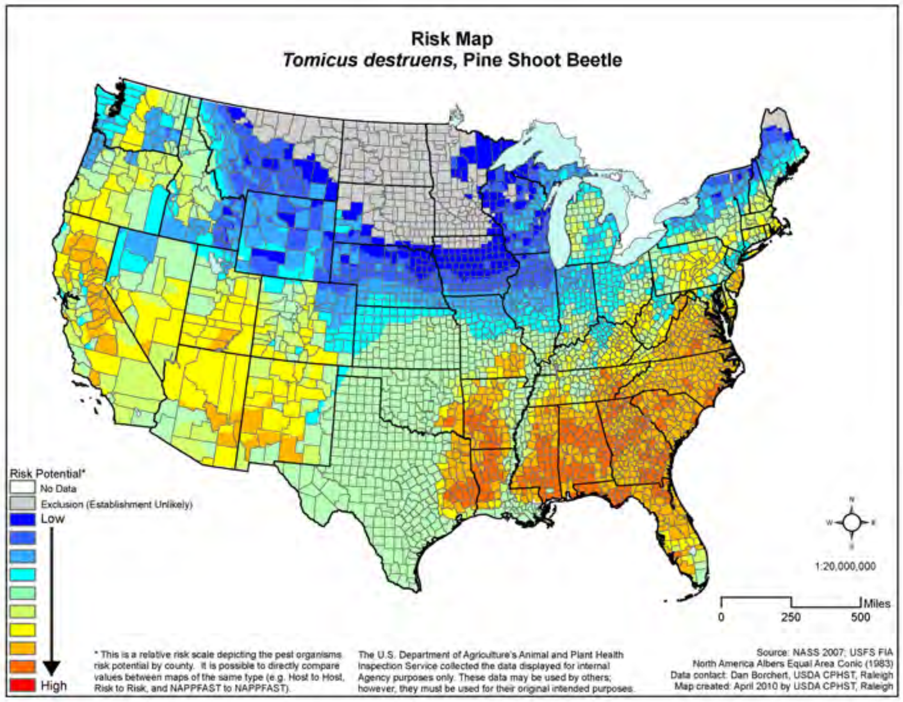

Figure 2-7 Final Risk Map for *Tomicus destruens Wollaston (Scolytinae)* in the Continental United States

Damage to Host Plants

Exotic wood-boring and bark beetles damage trees and timber by

- Attacking and potentially killing living trees by girdling or introducing pathogenic organisms that may increase decomposition/spread disease
- Tunneling throughout the tree (degrading the value of logs and lumber)
- Attacking cut timber, especially when moisture content is high
- Introducing sap-staining fungi
- Impacting the environment of host plants by affecting biodiversity, increasing runoff and erosion, etc (Brockerhoff, 2009)
- Weakening trees by feeding extensively on small branches and leaves (e.g. *Monochamus* species)

Buprestids, cerambycids, and members of the subfamily Platypodinae colonize the sapwood or heartwood of host plants (Coulson and Witter, 1984; Wood, 1982). Scolytines infest the phloem of host plants.

Buprestidae

Buprestid beetles are secondary pests that attack trees of all ages (Evans et al., 2004). Potential damage includes wounding of trees, killing shoots and branches, or killing the entire tree. Many buprestids attack hosts previously weakened by other factors (drought, repeated defoliation, etc.) (Evans et al., 2004). Economic damage is usually rated moderate (sometimes high) due to tree death, the degradation of products, and growth loss (Evans et al., 2004). Until recent experiences with the emerald ash borer (*Agrilus planipennis* (Fairmaire)), most buprestids were not considered very aggressive pests. *Agrilus biguttatus* Fabricius (Hilszczanski and Sierpinski, 2006) and *Phaenops cyanea (Fabr.)* are considered aggressive in some countries (Evans et al., 2004).

Agrilus biguttatus* Fabricius—Agrilus biguttatus* is a significant pest of oak forests in parts of Europe and Russia as well as northern Africa and the Middle East (Jacquiot 1976, Moraal and Hilszczanski 2000b, 2000a, Hilszczanski and Kolk 2001, Vansteenkiste et al., 2004). In the Voronej region of Russia, almost 50,000 acres of oak mortality has been attributed to *Agrilus biguttatus* Fabricius, and from 1945 to 1949, this pest caused considerable damage to several French regions following hot, dry summers (Jacquiot, 1976). Evans et al. (2004) stated that more vigorous trees can kill off early larval infestations through wound reactions.

Symptoms.

Galleries produced by older larvae of *Agrilus biguttatus* Fabricius can lead to partial or complete girdling of the tree while larval activity can cause twig and branch dieback, thin crowns and epicormic branching (Moraal and Hilszczanski, 2000a). Other symptoms include frass-filled galleries in the cambium layer and D-shaped adult exit holes (Ciesla, 2003a; Moraal and Hilszczanski, 2000b; 2000a). The tree will die when attacked over several successive years or when infestations are heavy (Moraal and Hilszczanski, 2000b; 2000a).

Vectored organisms.

No pathogens are known to be associated with this species. However, fungal species (e.g. *Armillaria*) can invade trees after the trees become infested with *Agrilus* species (Moraal and Hilszczanski, 2000b; 2000a). Species of this *Armillaria* can be pathogenic or saprophytic (Moraal and Hilszczanski, 2000b; 2000a). *Agrilus* spp. may transmit pathogenic fungi to healthy trees (Mihajlovi et al.; 1997).

Cerambycidae

Cerambycids are secondary pests although some are primary pests. Most cerambycids attack stressed host trees, although some such as Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)) and *Saperda* spp. can damage healthy hosts (Evans et al., 2004). Damage includes wounding and killing of branches, and in some cases the death of the host (Evans et al., 2004). An infestation of cerambycids can impact timber quality, host health, volume increment, tree shape and recreational, aesthetic and protective values (Evans et al., 2004). On occasion, mortality of pines in North America has been attributed to extensive feeding by adult species of *Monochamus* in the crowns of trees.

***Monochamus saltuarius* Gebleris—**In its native range, *Monochamus saltuarius* is a pest of *Abies* spp., *Larix* spp., *Picea* spp. and *Pinus* spp. that are either dying or recently felled (Davis et al., 2008). *Pinus densiflora* and *P. thunbergii* are main hosts in Japan (Davis et al., 2008), while *Picea abies* is the main host in Europe (Sama, 2002). This pest can reduce quantities of timber and wood product values (Ciesla, 2001).

Symptoms.

Symptoms caused by *Monochamus saltuarius* are similar to other *Monochamus* spp. Adults leave behind round emergence holes, oviposition scars on the bark, and damage on the bark of shoots, by maturation feeding (Davis et al., 2008). Galleries are packed with a mixture of frass and shredded wood. This mixture can be expelled through small slits in the bark produced by larvae (Davis et al., 2008). Oval shaped pupal chambers can be found in the xylem where they can be plugged with wood shavings (Davis et al., 2008).

Vectored organisms.

Monochamus saltuarius is the main vector of *Bursaphelenchus xylophilus*, a phytoparasitic nematode (Kobayashi et al., 1984; Ciesla, 2001). The pathogen is native to North America and does not damage native conifers (Ciesla, 2001). However, it has caused extensive mortality to several indigenous pines abroad, especially in Japan and China where it is spread by *Monochamus alternatus* (Japanese pine sawyer beetle) (Evans et al., 1996).

Monochamus species may also vector the nematodes *Bursaphelenchus mucronatus* and *B. kolymensis*. Although it is not known to cause extensive mortality on the hosts *Abies*, *Larix* and *Pinus* spp. in its native range of Siberia, it has the potential to become pathogenic to North American conifers if introduced with an exotic *Monochamus* spp. (USDA Forest Service, 1991).

***Monochamus sutor* Linnaeus—**This insect is not considered a pest of economic importance in its native range and acts as a decomposer (Ciesla, 2004). However, Evans et al. (2004) stated that *Monochamus sutor* is a pest species on *Pinus* and *Picea* in Hungary, Romania and Slovakia. Boring by larvae can reduce the structural integrity and quality of the wood (Ciesla, 2004).

Symptoms.

Symptoms caused by *Monochamus sutor* are similar to other *Monochamus* spp. Adults cause round emergence holes, oviposition scars on the bark and damage on the bark of shoots by maturation feeding (Davis et al., 2008). Galleries are packed with a mixture of frass and shredded wood. This mixture can be expelled through small slits in the bark produced by larvae (Davis et al., 2008). Oval shaped pupal chambers can be found in the xylem where they can be plugged with wood shavings (Davis et al., 2008).

Vectored organisms.

This genus is the main vector of *Bursaphelenchus xylophilus,* a phytoparasitic nematode (Kobayashi et al., 1984). This pathogen is native to North America and does not damage native conifers (Ciesla, 2004). However, it has caused extensive mortality to several indigenous pines abroad, especially in Japan where it was accidently introduced and spread by *Monochamus alternatus* (Japanese pine sawyer beetle) (Evans et al., 1996).

Monochamus species may also vector the nematodes *Bursaphelenchus mucronatus* and *B. kolymensis*. Although it is not known to cause extensive mortality on hosts (*Abies, Larix, and Pinus* spp.) in its native range of Siberia, it has the potential to become pathogenic to North American conifers if introduced with an exotic *Monochamus* species (USDA Forest Service, 1991; Ciesla, 2001).

***Tetropium castaneum* Linnaeus—** *Tetropium castaneum* is a pest on *Picea* in the Czech Republic, Estonia, Italy, Romania, Slovakia and Switzerland (Evans et al. 2004). During favorable environmental conditions, *Tetropium castaneum* can reach damaging numbers, especially when forests have been severely defoliated previously (Dobesberger, 2005a). Although this insect is considered a secondary forest pest, it can attack and kill healthy trees (Dobesberger, 2005a).

Symptoms.

Symptoms caused by *Tetropium castaneum* Linnaeus are not specific to this species, but are typical of most wood borers (Dobesberger, 2005a). These include larval feeding galleries with granular frass, oval shaped exit hoes, fading foliage of living trees and wind-snapped tree trunks due to loss of structural integrity (Dobesberger, 2005a).

Vectored organisms.

This species is not known to be associated with any pathogens. However, galleries can leave trees susceptible to secondary infection caused by fungi and other pathogens (Dobesberger, 2005a).

***Tetropium fuscum* Fabricius**—*Tetropium fuscum* is not considered a pest in its native range in Europe and Asia due to its habit of attacking trees that are already stressed or dying. However, this species is a pest on *Picea* in Estonia and Romania (Evans et al. 2004). *Tetropium fuscum* Fabricius has also shown pest potential in Nova Scotia, Canada, where this insect has become a pest of healthy red, white, and Norway spruce. Beetles from the Canadian infestation continue to re-infest a host until it dies (Cunningham, 2006).

The spread of *Tetropium fuscum* Fabricius in Canada could lead to widespread tree mortality. This could have a significant impact on forest-based industries in Canada, as red spruce is a valuable resource for pulp and lumber production (Cunningham, 2006). *Tetropium fuscum* Fabricius may lead to a significant reduction in mature red spruce stands (among other spruces); it may also lead to a decrease in biodiversity through loss of habitat and outcompeting native species (Cunningham, 2006).

If this species spreads to the United States from Canada, it may continue to attack healthy host plants and decrease biodiversity.

Symptoms.

Symptoms caused by *Tetropium fuscum* Fabricius are not specific to this species, but are typical of most wood borers. These include white resin streaks on the trunks; yellowing, brown, or reddish-brown crown; and cast needles (Smith and Humble, 2000). The oval exit holes may be plugged with sawdust. The holes are easy to see on the trunk. However, holes located at a height greater than 7 meters on the trunk are difficult to spot from the ground (Davis et al., 2008). Galleries packed with frass and wood fibers may be irregular or L-shaped (Davis et al., 2008).

Vectored organisms.

Two fungal pathogens are associated with *Tetropium fuscum* Fabricius: *Ophiostoma tetropii* and *Pesotum fragrans* (Harrison et al., 2004; Jacobs and Seifert, 2004a; 2004b). *Ophiostoma tetropii* is thought to have been introduced with the pest into Nova Scotia (Jacobs et al., 2003). This pathogen is a bluestain fungus thought to be of low virulence (Humble and Allen, 2006).

Curculionidae

Both larvae and adults of bark and ambrosia beetles damage host trees by tunneling beneath the bark or in the wood. Both groups can introduce fungi into the host tree which can cause damage and may lead to host death. This damage can also reduce product quality causing economic losses. These species may lead to infestation by other secondary pests attracted to the stressed trees.

Platypus quercivorus* Murayama *(Platypodinae)*—Platypus quercivorus* vectors the ambrosia fungus (*Raffaelea quercivora*) which is believed to be the causal agent of Japanese oak disease (or Japanese oak wilt) (Davis et al., 2006; Kubono and Ito, 2002). Since 1980, this beetle-fungus complex has killed over 200,000 fagaceous trees (annually in Japan (Ito et al., 2003; EPPO, 2003). In areas of mass attack, *Platypus quercivorus* usually bores into adjacent trees even if they are nutritionally unsuitable (Davis et al., 2008). Damage by pests may lead to invasion by secondary pests which can further damage the tree (Kozlowski et al., 1991).

Platypus quercivorus Murayama can cause slowed growth and mortality of trees. *Platypus quercivorus* and the damage caused by secondary invaders affect the quality of wood both aesthetically and structurally (Hijii et al., 1991; Kuroda and Yamada, 1996; Ito et al., 1998; Ciesla, 2003d; Ito et al., 2003a).

Symptoms.

In Asia, stands suspected of *Platypus quercivorus* Murayama infestations often have wilted canopies during summer when there is no drought and/or reddish-brown discoloration of leaves (Ciesla, 2003d; Davis et al., 2006). Formation of tyloses in the tree may be triggered by infestations of this pest (Manion, 1991). Tyloses may account for the rapid wilting of hosts, especially those found in the white oak group (Davis et al., 2006).

Vectored organisms.

Platypus quercivorus Murayama vectors the ambrosia fungus (*Raffaelea quercivora*) which may be the causal agent of Japanese oak disease (Davis et al., 2006, Kubono and Ito, 2002).

***Tomicus destruens* Wollaston *(Scolytinae)*—**In pine forests in Eurasia (Bouhot et al., 1988; Hui, 1991), Europe (Guerrero et al., 1997) and the Mediterranean region (Monleón et al., 1996; Nanni and Tiberi, 1997), *Tomicus* species are considered economically important pests.

Symptoms.

Feeding by adults can lead to dead shoots with tunnels and yellow to reddish-brown leaves; adults may also be found when examined (Ciesla, 2003c). Reddish-brown boring dust can be found on the bark surface due to breeding attacks as well as pitch tubes on the bark surface if attacked trees are healthy (Ciesla, 2003c). The egg gallery is vertical and 10–25 cm long with larval galleries branching off perpendicular to the egg gallery; larval feeding galleries are 4 to 9 cm long (Ciesla, 2003c).

Vectored organisms.

Blue stain can be found in the xylem accompanying breeding attacks (Ciesla, 2003c). Several other potentially pathogenic fungi are associated with *Tomicus destruens* Wollaston including: *Heterobasidion annosum*, *Leptographium guttulatum*, *Leptographium lundbergii*, *Leptographium serpens*, *Leptographium wingfieldii*, and *Phellinus pini* (Nanni and Tiberi, 1997; Peverieri et al., 2006). *Heterobasidion annosum* has been shown to be highly pathogenic (Viiri, 2004).

Hosts

Important

The hosts listed for each pest were reported from their current distributions, and these host species may not be present in the United States. If pests are introduced into new areas, they may attack native species that have not previously been identified as host plants. Therefore, host species should be surveyed (where applicable) and surveys should be broadened to native species within the host genera.

Buprestidae

Agrilus biguttatus* Fabricius—**The following hosts have been reported for *Agrilus biguttatus* Fabricius: European chestnut, scotchbroom, beech, European beech, oak, European turkey oak, holly oak, durmast oak, downy oak, Pyrenean oak, English oak, northern red oak, cork oak (Table 2-11* on page 2-26**).

Table 2-11 Hosts Reported for *Agrilus biguttatus* Fabricius (continued)

Host[1]	Common Name	Source
Castanea sativa	European chestnut	Key, 1991; Moraal and Hilszczanski, 2000b; 2000a, Ciesla, 2003a
Cytisus scoparius	Scotch broom	Campobasso et al., 1999
Fagus sp.	beech	Key, 1991
Fagus sylvatica	European beech	Moraal and Hilszczanski, 2000b; 2000a, Ciesla, 2003a
Quercus sp.	oak	Jacquiot, 1976; Foster, 1987; Hackett, 1995a; Moraal and Hilszczanski, 2000b, Ciesla, 2003a, Vansteenkiste et al., 2004
Quercus cerris	European turkey oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a
Quercus ilex	holly oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a

Table 2-11 Hosts Reported for *Agrilus biguttatus* Fabricius (continued)

Host[1]	Common Name	Source
Quercus petraea	Durmast oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a; Vansteenkiste et al., 2004
Quercus pubescens	downy oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a
Quercus pyrenaica	Pyrenean oak	Davis et al., 2006
Quercus robur	English oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a; Vansteenkiste et al., 2004
Quercus rubra[2]	northern red oak	Moraal and Hilszczanski, 2000b; 2000a; Ciesla, 2003a
Quercus suber	cork oak	Moraal and Hilszczanski, 2000a; Ciesla, 2003a

1 Reports of *Agrilus biguttatus* Fabricius feeding on *Populus* sp. are dubious and possibly based on a misidentification of *Agrilus ater* (Davis et al., 2006).

2 Infestations on *Quercus rubra* are considered rare (Moraal and Hilszczanski, 2000b; 2000a).

Cerambycidae

Monochamus saltuarius Gebleris*—**The following hosts have been reported for *Monochamus saltuarius* Gebleris: fir species, silver fir, Manchurian fir, Khingan fir, Siberian fir, Japanese cedar, larch, Dahurian larch, Japanese larch, Siberian larch, spruce, Norway spruce, dragon spruce, Yeddo spruce, Korean spruce, Siberian spruce, pine, jack pine, Japanese umbrella pine, Corsican pine, Japanese white pine, Siberian pine, Scots pine, Japanese black pine, Japanese hemlock (Table 2-12* on page 2-27**).

Table 2-12 Hosts Reported for *Monochamus saltuarius* Gebleris

Host	Common Name	Source
Abies spp.	fir	Ciesla, 2001
Abies alba	silver fir	Cesari et al., 2005
Abies holophylla	Manchurian fir	Ciesla, 2001; USDA Forest Service, 1991
Abies nephrolepis	Khingan fir	Ciesla, 2001; USDA Forest Service, 1991
Abies sibirica	Siberian fir	Ciesla, 2001
Cryptomeria japonica	Japanese cedar	Anonymous, 2001
Larix spp.	larch	Ciesla, 2001; Cesari et al., 2005
Larix gmelinii	Dahurian larch	Ciesla, 2001
Larix kaempferi	Japanese larch	CABI, 2004
Larix leptolepis		Ciesla, 2001

Table 2-12 Hosts Reported for *Monochamus saltuarius* Gebleris (continued)

Host	Common Name	Source
Larix sibirica	Siberian larch	Ciesla, 2001
Picea spp.	spruce	Ciesla, 2001
Picea abies	Norway spruce	Cesari et al., 2005
Picea asperata	dragon spruce	CABI 2004
Picea jezoensis	Yeddo spruce	Ciesla, 2001; USDA Forest Service, 1991
Picea koraiensis	Korean spruce	Ciesla, 2001; USDA Forest Service, 1991
Picea obovata	Siberian spruce	Ciesla, 2001
Pinus spp.	pine	Ciesla, 2001
Pinus banksiana	jack pine	CABI, 2004
Pinus densiflora	Japanese umbrella pine	Togashi et al., 1994; Jikumaru and Togashi, 1995; Nakayama et al., 1998; Ciesla 2001
Pinus nigra	Corsican pine	Cesari et al., 2005
Pinus koraiensis		USDA Forest Service, 1991
Pinus parviflora	Japanese white pine	Ciesla, 2001; CABI, 2004
Pinus parviflora var. pentaphylla		CABI, 2004
Pinus sibirica	Siberian pine	Ciesla, 2001
Pinus sylvestris	scots pine	Ciesla, 2001; Cesari et al., 2005; USDA Forest Service, 1991
Pinus thunbergii	Japanese black pine	Togashi et al., 1994; Jikumaru and Togashi, 1995; Nakayama et al., 1998
Tsuga sieboldii	Japanese hemlock	CABI, 2004

Monochamus sutor Linnaeus*—**The following hosts have been reported for *Monochamus sutor* Linnaeus: fir species, Silver fir, Manchurian fir, Khingan fir, Siberian fir, Manchurian birch, larch, Dahurian larch, Siberian larch, spruce, common spruce, Yeddo spruce, Korean spruce, Siberian spruce, pine, mugo pine, Austrian pine, Siberian stone pine, Scots pine, Mongolian pine (Table 2-13* on page 2-29**).

Table 2-13 Hosts Reported for *Monochamus sutor* Linnaeus

Host	Common Name	Source
Abies spp.	fir	Ciesla, 2004
Abies alba	silver fir	Cesari et al., 2005
Abies holophylla	Manchurian fir	USDA Forest Service, 1991
Abies nephrolepis	Khingan fir	USDA Forest Service, 1991
Abies sibirica	Siberian fir	USDA Forest Service, 1991
Betula platyphylla	Manchurian birch	Davis et al., 2006
Larix spp.	larch	Ciesla, 2004; Cesari et al., 2005
Larix gmelinii	Dahurian larch	Zhang et al., 1993; USDA Forest Service, 1991
Larix sibirica	Siberian larch	USDA Forest Service, 1991
Picea spp.	spruce	Ciesla, 2004
Picea abies	common spruce	Bakke and Kvamme, 1992; Schroeder et al., 1999; Cesari et al., 2005
Picea jezoensis	Yeddo spruce	USDA Forest Service, 1991
Picea koraiensis	Korean spruce	USDA Forest Service, 1991
Picea obovata	Siberian spruce	USDA Forest Service, 1991
Pinus spp.	pine	Ciesla, 2004
Pinus mugo	mugo pine	Cesari et al., 2005
Pinus nigra	Austrian pine	Cesari et al., 2005
Pinus sibirica	Siberian stone pine	USDA Forest Service, 1991
Pinus sylvestris	Scots pine	Bakke and Kvamme, 1992; Cesari et al., 2005
Pinus sylvestris var. mongolica	Mongolian pine	Zhang et al., 1993

Tetropium castaneum* Linnaeus**—The following hosts have been reported for *Tetropium castaneum*: fir species, silver fir, Manchurian fir, Sakhalin fir, Siberian fir, walnut, common juniper, larch, Russian larch, spruce, Norway spruce, Ajan spruce, Siberian spruce, Serbian spruce, Sitka spruce, Pine, Swiss stone pine, Austrian pine, Siberian pine, Eastern white pine, Scots pine, Douglas-fir, oak (Table 2-14* on page 2-30**).

Table 2-14 Hosts Reported for *Tetropium castaneum* Linnaeus

Host	Common Name	Source
Abies spp.	fir	Dobesberger, 2005a; Cherepanov, 1990a
Abies alba	silver fir	Dobesberger, 2005a
Abies holophylla	Manchurian fir	Dobesberger, 2005a
Abies sachalinensis	Sakhalin fir	Dobesberger, 2005a
Abies sibirica	Siberian fir	Cherepanov, 1990a
Juglans spp.[1]	walnut	Dobesberger, 2005a
Juniperus communis	common juniper	Dobesberger, 2005a
Larix spp.	larch	Cherepanov, 1990a
Larix sibirica	Russian larch	Cherepanov, 1990a
Picea spp.	Spruce	Cherepanov, 1990a
Picea abies	Norway spruce	Novak et al., 1976
Picea jezoensis	Ajan spruce	Dobesberger, 2005a
Picea obovata	Siberian spruce	Cherepanov, 1990a
Picea omorica	Serbian spruce	Dobesberger, 2005a
Picea sitchensis	Sitka spruce	Kolk and Starzyk, 1996
Pinus spp.	pine	Dobesberger, 2005a
Pinus cembra	Swiss stone pine	Dobesberger, 2005a
Pinus nigra	Austrian pine	BioLib, n.d.
Pinus sibiricus	Siberian pine	Cherepanov, 1990a
Pinus strobes	Eastern white pine	Kolk and Starzyk, 1996
Pinus sylvestris	Scots pine	Cherepanov, 1990a; Novak et al., 1976
Pseudotsuga spp.	Douglas-fir	Kolk and Starzyk, 1996
Quercus spp.[1]	oak	Dobesberger, 2005a

1 Both oak (*Quercus* spp.) and walnuts (*Juglans* spp.) can be attacked occasionally (reviewed in Duffy, 1953).

Tetropium fuscum* Fabricius—**The following hosts have been reported for *Tetropium fuscum* Fabricius in its native range: fir species, Silver fir, larch, European larch, Spruce, blue spruce, Sitka spruce, pine, Eastern white pine, Scotch pine, Douglas-fir. The following hosts were reported for this species in Canada: Norway spruce, white spruce, black spruce, red spruce (Table 2-15* on page 2-31** and ***Table 2-16* on page 2-31**).

Table 2-15 Hosts Reported for *Tetropium fuscum* Fabricius in its Native Range

Host	Common Name	Source
Abies spp.	fir	Kolk and Starzyk, 1996; Dobesberger, 2005b
Abies alba	silver fir	O'Leary et al., 2003
Larix spp. (occasional)	larch	O'Leary et al., 2003
Larix decidua	European larch	USDA, 2000
Picea spp.	spruce	Dobesberger, 2005b
Picea pungens	flue spruce	O'Leary et al., 2003
Picea sitchensis	Sitka spruce	O'Leary et al., 2003
Pinus spp.	pine	Dobesberger, 2005b
Pinus strobes	Eastern white pine	Kolk and Starzyk, 1996
Pinus sylvestris	Scotch pine	Kolk and Starzyk, 1996
Pseudotsuga spp.	Douglas-fir	Kolk and Starzyk, 1996

Table 2-16 Hosts Reported for *Tetropium fuscum* Fabricius in Canada

Host	Common Name	Source
Picea abies	Norway Spruce	O'Leary et al., 2003; Smith and Humble, 2000; Kolk and Starzyk, 1996
Picea glauca	white spruce	O'Leary et al., 2003; Smith and Humble, 2000
Picea mariana	black spruce	O'Leary et al., 2003; Smith and Humble, 2000
Picea rubens (main)	red spruce	Smith and Humble, 2000

Curculionidae

Platypus quercivorus* Murayama (Platypodinae)—**The following hosts were reported for this species: Japanese chinkapin, Sudajii, Japanese cedar, Chinese holly, spice bush, Japanese tanbark oak, Japanese oak, oak, Japanese evergreen oak, Sawtooth oak, Ichii-Gashi, Japanese blue oak, Mongolian oak, Japanese white oak, Ubame oak, Urazirogashi, Konara oak, Tsukabanegashi (Table 2-17* on page 2-32**).

Table 2-17 Hosts Reported for *Platypus quercivorus* Murayama (Platypodinae)

Host	Common Name	Source
Castanopsis cuspidata	Japanese chinkapin	Wood and Bright, 1992
Castanopsis sieboldii	Sudajii	Kamata et al., 2002; Esaki et al., 2004
Cryptomeria japonica[1]	Japanese cedar	Wood and Bright, 1992
Ilex chinensis[1]	Chinese holly	Wood and Bright, 1992
Lindera erythrocarpa[1]	spice bush	Wood and Bright, 1992
Lithocarpus edulis	Japanese tanbark oak	Wood and Bright, 1992
Lithocarpus glaber (= Pasania edulis)	Japanese oak	Bright and Skidmore, 2002; Wood and Bright, 1992
Prunus spp.[1]		Wood and Bright, 1992
Quercus spp.	oak	Wood and Bright, 1992
Quercus acuta	Japanese evergreen oak	Kamata et al., 2002; Wood and Bright, 1992
Quercus acutissima	sawtooth oak	Wood and Bright, 1992
Quercus gilva	Ichii-Gashi	Wood and Bright, 1992
Quercus glauca	Japanese blue oak	Wood and Bright, 1992
Quercus mongolica	Mongolian oak	Kamata et al., 2002; Bright and Skidmore, 2002; Wood and Bright, 1992
Quercus myrsinaefolia	Japanese white oak	Wood and Bright, 1992
Quercus phillyraeoides	Ubame oak	Ciesla, 2003d
Quercus salicinia	Urazirogashi	Wood and Bright, 1992; Hijii et al., 1991
Quercus serrata	Konara oak	Kamata et al., 2002; Wood and Bright, 1992
Quercus sessilifolia	Tsukabanegashi	Wood and Bright, 1992

1 Some trees in the families Cupressaceae, Aquifoliaceae, Lauraceae, and Rosaceae, may be attacked but will not support reproduction (Davis et al., 2006).

Tomicus destruens* Wollaston (Scolytinae)—**The following hosts were reported for this species: Calabrian pine, Canary Island pine, Aleppo pine, Maritime pine, Italian stone pine, Radiata pine, Scots pine (Table 2-18* on page 2-33*****Table 2-18* on page 2-33**).

Table 2-18 Hosts Reported for *Tomicus destruens* Wollaston (Scolytinae)

Host	Common Name	Source
Pinus brutia	Calabrian pine	Kohlmayr et al., 2002; Faccoli, 2006; Vasconcelos et al., 2006; Horn et al., 2006
Pinus canariensis	Canary Island pine	Kohlmayr et al., 2002; Faccoli, 2006; Vasconcelos et al., 2006
Pinus halepensis	Aleppo pine	Kohlmayr et al., 2002; Nanni and Tiberi, 1997; Faccoli, 2006; Vasconcelos et al., 2006; Horn et al., 2006
Pinus pinaster	maritime pine	Kohlmayr et al., 2002; Faccoli, 2006; Vasconcelos et al., 2006; Kerdelhue et al., 2002; Horn et al., 2006
Pinus pinea	Italian stone pine	Kohlmayr et al., 2002; Nanni and Tiberi, 1997; Faccoli, 2006; Vasconcelos et al., 2006; Horn et al., 2006
Pinus radiata	radiata pine	Kerdelhue et al., 2002; Horn et al., 2006; Vasconcelos et al., 2006
Pinus sylvestris	Scots pine	Guerrero et al., 1997

Biology and Life Cycle

An understanding of the biology and life cycle of the exotic wood-boring and bark beetles can be important in determining an appropriate course of action and its timing. Fortunately, many of these species have been studied in some detail in their native range, making information available on many of these potential pests. The biology and life cycle of a particular insect should be studied before determining the course of action, to ensure that efforts are not wasted. For example, surveys should be conducted at the proper time of year.

Buprestidae

***Agrilus biguttatus* Fabricius—**

Eggs.

From May to July, *Agrilus biguttatus* Fabricius females deposit small clusters of eggs (5–6) into bark crevices (Moraal and Hilszczanski, 2000b). Eggs take 1–2 weeks to hatch (Vansteenkiste et al., 2005).

Larvae.

After hatching, larvae burrow in the bark and begin feeding on inner bark, the cambial layer, and outer sapwood (Vansteenkiste et al., 2004). Galleries are zigzagged (Moraal and Hilszczanski, 2000a) and can intercross and measure from 0.5 to 5 mm wide and up to 1.5 meters long (Vansteenkiste et al., 2004). Younger larvae make longitudinal galleries while the older larvae produce irregular twisting, transverse galleries (which may lead to girdling of the tree) (Moraal and Hilszczanski, 2000b). Successful colonization depends on larvae density and rate of callus production (Vansteenkiste et al., 2004). Hibernation occurs in the larval state and can repeat for up to two winters (Vansteenkiste et al., 2004). This occurs in Northern Germany (Moraal and Hilszczanski, 2000a). Larvae go through five instars to complete development (Moraal and Hilszczanski, 2000a; 2000b).

Pupae.

After 2–3 calendar years, pupation takes place from April to May in individual cells from 10.4 to 14.8 by 3.0 to 4.5 mm in the outer bark (Vansteenkiste et al., 2004; Moraal and Hilszczanski, 2000b).

Adults.

Adults stay under the bark for approximately two weeks before emerging (Ciesla, 2003a). Emergence occurs from May to July through characteristic D-shaped holes from 2.5 to 4 mm by 2 to 3 mm (Vansteenkiste et al., 2004; Moraal and Hilszczanski, 2000b).

Many studies have found that *Agrilus biguttatus* Fabricius will attack stressed or declining hosts (Moraal and Hilszczanski, 2000a; 2000b). Beetles prefer larger trees with a diameter at breast height (DBH) of 30–40 cm that are over 80 years old and with thick bark (Moraal and Hilszczanski, 2000b). Adults feed on both the crowns of oaks and the parenchymal tissue of leaves (Moraal and Hilszczanski, 2000a). Attacks begin in south-facing, lower stem parts moving vertically in both directions (Vansteenkiste et al., 2004).

Cerambycidae

***Monochamus saltuarius* Gebleris—**This species has a similar life history to other *Monochamus* species (Ciesla, 2001). These beetles are indigenous to temperate regions and usually attack stressed or recently killed hosts (Ciesla, 2001). This species usually has one generation per year, although it may take up to two years in some areas (Ciesla, 2001).

Eggs.

Both mating and oviposition occur at night (Davis et al., 2008). After mating occurs, eggs are laid in slits cut in the bark by females (Ciesla, 2001).

Larvae.

Larvae initially feed in the phloem but later tunnel into the sapwood and heartwood (Ciesla, 2001) and go through four instars (Davis et al., 2008). The larvae overwinter in the final instar (Davis et al., 2008; Togashi et al., 1994).

Pupae.

Pupation occurs in a pupal cell in the wood and emergence occurs when adults chew a round exit hole through the wood and bark from the pupal cell (Edmonds et al., 2000).

Adults.

Under laboratory conditions, Jikumaru et al. (1994) found that adult females survived from 3 to 80 days with an average of 47.8 days at 25°C. The mean preoviposition rate was approximately 11 days at 25°C while Nakayama et al. (1998) found it to be 16 days at 20°C. Mean ovipositions was approximately 42 days at 25°C (Jikumaru et al., 1994) and approximately 12 days at 20°C (Nakayama et al., 1998). Females produced an average of 70 eggs at 25°C with the range being 0–172 (Jikumaru et al., 1994). There was no significant difference found in the mean longevity between males and females (Nakayama et al., 1998). Adult emergence was found to take approximately 183–244 degree days above 10°C (Jikumaru and Togashi, 1995; Togashi et al., 1994).

Adults undergo maturation feeding before mating takes place, feeding on the bark of tender young shoots mainly during the day (Davis et al., 2008; Ciesla, 2001). These species maturation feed on healthy hosts although oviposition usually occurs on stressed trees (Hanks, 1999). The spread of nematodes vectored by *Monochamus saltuarius* Gebleris occurs during maturation feeding (Ciesla, 2001). Adults are strong fliers and may be aided by wind to disperse several kilometers although most do not disperse that far (Davis et al., 2008; Ciesla, 2001).

***Monochamus sutor* Linnaeus—**This species has a similar life history to other *Monochamus* species (Ciesla, 2004). In Siberia, *Monochamus sutor* Linnaeus has a two-year life cycle and is active from June to September (USDA, 1991). One generation can take 1–3 years (Kolk and Starzyk, 1996). Most of the life cycle occurs in the host tree with the exception of adult dispersal and maturation feeding (Kolk and Starzyk, 1996).

Eggs.

From mid-June to July, females deposit eggs (Novak et al., 1976). Females can lay at least 50 eggs in niches in the excavated phloem (USDA, 1991). One to six eggs per niche can be observed (USDA, 1991).

Larvae.

Once larvae hatch, they feed on the phloem and sapwood for the first year. Frass is expelled through the holes in the bark (Novak et al., 1976). Larvae overwinter primarily as second instars and resume feeding the following spring (USDA, 1991). The larvae continue to feed, boring deeper into the wood; the mature larvae then construct pupal cells (40–50 mm by 13 mm) and in Siberia, overwinter for a second time (Kolk and Starzyk, 1996; USDA, 1991). This pest has five larval instars total (USDA, 1991).

Pupae.

Pupation and emergence occurs in the spring (Davis et al., 2008; USDA, 1991). Emergence holes are oval and range from 6 to 7 mm in diameter (Kolk and Starzyk, 1996).

Adults.

Adults maturation feed primarily on the bark and phloem of twigs in the crowns of conifers (USDA, 1991). They stay in the crowns for 10–15 days coming down to deposit eggs (Novak et al., 1976). These species maturation feed on healthy hosts although oviposition usually occurs on stressed trees (Hanks, 1999). It takes 7–10 days after emergence for *Monochamus* adults to become sexually mature (USDA, 1991). Adults use volatile compounds to locate stressed, dying or recently dead host material to mate and oviposit (USDA, 1991).

Adults are strong fliers and may be aided by wind to disperse several kilometers although most do not disperse that far (Davis et al., 2008; Ciesla, 2004).

***Tetropium castaneum* Linnaeus—**Both biology and life cycles of *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius are similar and both have one generation every one to two years, depending on climate and nutritional requirements (Dobesberger, 2005a; Kolk and Starzyk, 1996). Neither species undergoes maturation feeding (Kolk and Starzyk, 1996). Copulation occurs immediately after emergence and generally lasts a few minutes (reviewed in Dobesberger, 2005a).

Eggs.

Once mating occurs, females oviposit eggs singly in bark crevices (Kolk and Starzyk, 1996). One female lays about 80–100 eggs (Novak et al., 1976). Eggs hatch 10–14 days later boring into the phloem and cambium (Kolk and Starzyk, 1996).

Larvae.

Mature larval galleries can be up to 2 cm wide and are filled with brown shredded bark and then white shredded wood (Dobesberger, 2005a; Kolk and Starzyk, 1996). The gallery depth is 2–4 cm perpendicular to the bark and then curves in a parallel direction to the stem axis where it continues for another 3–4 cm, making a hook-like tunnel (Novak et al., 1976). Larvae go through five instars (Kolk and Starzyk, 1996). Overwintering is usually carried out in the larval stage although some adults can also overwinter (Dobesberger, 2005a; Novak et al., 1976).

Pupae.

Pupation occurs in autumn in pupal chambers at the end of the hook-like tunnel (Novak et al., 1996). The chamber's entrance is plugged with frass (Novak et al., 1976). Both larval galleries and pupal chambers are similar between *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius (Kolk and Starzyk, 1996). Pupation takes approximately 14 days to complete (Novak et al., 1976).

Adults.

Emergence occurs several days after pupation through oval exit holes approximately 7 mm in diameter (Kolk and Starzyk, 1996) and occurs from May throughout the entire summer, depending on location and weather (Novak et al., 1976). This generation will produce overwintering larvae (Dobesberger, 2005a).

Flight of *Tetropium castaneum* Linnaeus occurs from May to September although a peak occurs from June to July (Kolk and Starzyk, 1996). Between 240 and 300 degree-days are needed above 5°C in 1 year to observe first flight; the peak in flight activity usually occurs around 450 degree-days above 5°C (reviewed in Dobesberger, 2005a). Adults live approximately three weeks (Novak et al., 1976).

***Tetropium fuscum* Fabricius—**Both the biology and life cycles of *Tetropium fuscum* Fabricius and *Tetropium castaneum* Linnaeus are similar and both have one generation every one to two years, depending on climate and nutritional requirements (Dobesberger, 2005a; Kolk and Starzyk, 1996). Neither species undergoes maturation feeding (Kolk and Starzyk, 1996).

Eggs.

Females lay an average of 80 eggs either singly, in pairs or groups (Davis et al., 2008). Eggs are laid in early June (NPAG, 2000) and hatch approximately two weeks later (Davis et al., 2008).

Larvae.

Larval galleries lightly etch the sapwood (Smith and Humble, 2000) and are filled with frass (Kimoto and Duthie-Holt, 2006; NPAG, 2000).The mature larvae gallery depth is 2–4 cm perpendicular to the bark and then curves in a parallel direction to the stem axis where it continues for another 3–4 cm, making a hook-like tunnel (Novak et al., 1976). Wood may be stained by associated *Ophiostoma* fungi (Smith and Humble, 2000).

Pupae.

The pupal chamber is at the end of the mature gallery (Novak et al., 1976).

Adults.

Exit holes are elliptical in shape (Novak et al., 1976) and are 4–6 mm in diameter (Kimoto and Duthie-Holt (2006). These holes may be plugged with coarse sawdust (Kimoto and Duthie-Holt, 2006).

Emergence of adults depends on location and climate. In northern Europe, *Tetropium fuscum* Fabricius emerges before May. It most frequently emerges in June, and in extreme northern regions emerges at the end of July and August (Novak et al., 1976). Adults live for approximately 3 weeks (Davis et al., 2008). During the summer, all life stages can be found in the host tree (Smith and Humble, 2000). In Canada, *Tetropium fuscum* Fabricius can complete development in a year within its host with the larval stage overwintering (Smith and Humble, 2000).

Adults prefer host trees of more than 10 cm in diameter (Cunningham, 2006). They are also attracted to damaged host trees.

Curculionidae

Platypus quercivorus Murayama (Platypodinae)—

Eggs.

Adults mate at the entrance hole (Kinuura, 2002). Once mated, females build on the horizontal gallery, branching both laterally and vertically, and lay eggs along the wall (Kinuura, 2002). As the female extends the gallery, she inoculates it with mycangial fungi (Kinuura, 2002). Males plug the entrance with their body to prevent predators and parasites from entering (Kinuura,

1995) and remove dust and frass from the gallery (Soné et al., 1998). Kinuura (1995) found the average fecundity per gallery to be 47.9 ± 8.5 SD. Eggs hatch in approximately one week (Kinuura, 1995).

Larvae.

Larvae eat the fungi from the gallery walls and when they reach the final instar, vertical cradles are formed in which the larvae pupate (Kinuura, 2002).

Reproductive potential for this species is high (Soné et al., 1998). A proportion of the brood will reach the adult stage before winter; in Japan Soné et al. (1998) found the rate to be 30–40 percent from August to October. Many new adults leave the maternal galleries to form their own, but some remain in their maternal gallery (Soné et al., 1998). Soné et al. (1998) found that these adults did not seem to lay their own eggs, suggesting that this species shows some eusocial characteristics. The larvae that do not mature overwinter at the fifth larval stage and emerge in mid-June of the following year (Soné et al., 1998).

Pupae.

Pupation can occur either before or after hibernation (Kinuura, 2002). Newly emerged adults will stay in the cradle until sclerotization takes place (Kinuura, 2002).

Adults.

The *Platypus* genus has mutualistic associations with ambrosia fungi, which are moved from old to new galleries by mycangia organs (Kinuura, 2002). *Platypus quercivorus* is usually univoltine but adults can emerge in the same year around late spring and autumn (Kinuura, 2002; Soné et al., 1998; Kinuura, 1995). In Japan, Soné et al. (1998) found that adults who emerged from their maternal gallery in autumn were not successful in reproducing in their own galleries. Emergence typically occurs from late June to early October or November (Kinuura, 2002; Soné et al., 1998).

Adults are monogamous, making only one gallery system in their life (Soné et al., 1998). Males initiate host attacks in both living and cut trees, but prefer stressed or downed trees (Soné et al., 1998). Males can attract other adults; possible plant attractants include wounded host volatiles, aggregation pheromones and sound produced by male beetles (Davis et al., 2006; Ohya and Kinuura, 2001). More than one gallery can be present on cut trees making density levels high (Soné et al., 1998).

Tomicus destruens* Wollaston (Scolytinae)—Tomicus* species are univoltine and have two dispersal phases per generation; the first is for maturation feeding on canopies of healthy pines and the other is for breeding on trunks of dying pines (Faccoli et al., 2007). Until recently, *Tomicus piniperda* and *T.*

destruens were considered synonymous. Because of this and the fact that a portion of their natural ranges overlap, the two species are sometimes confused with each other in earlier literature.

Eggs.

Females colonize the inner bark and lay eggs singly along galleries which are parallel to the wood grain (Faccoli et al., 2005b; Ciesla, 2003c). Egg galleries are 10 to 25 cm long (Ciesla, 2003c). Larvae create horizontal feeding galleries off the main gallery and range from 4 to 9 cm (Ciesla, 2003c).

Larvae.

Once larvae hatch, they begin feeding on the phloem and eventually pupate in the outer bark (Faccoli, 2007). Depending on temperature, larvae can develop within 7 to 8 weeks (Faccoli et al., 2005b).

Adults

After pupation, adults emerge in early summer and fly to healthy hosts to undergo maturation feeding and then overwinter (Faccoli et al., 2005b). Development from egg to adult takes approximately 12 weeks (Faccoli et al., 2005b). This species usually has one generation per year (Faccoli et al., 2005b) although other papers report two to three overlapping generations per year (reviewed in Ciesla, 2003c; Nanni and Tiberi, 1997). The generation could actually be multiple broods from females attacking more than one tree since the existing data does not take maturation feeding into account (Ciesla, 2003c). Re-emergence to attack other trees is common with bark and ambrosia beetles; this results in sister flights.

Adults are oligophagous and begin to emerge in the spring where they locate healthy pines to tunnel into shoots where they become sexually mature (Faccoli, 2007). In Italy, flight period is concentrated within a few weeks in spring (Faccoli et al., 2005b) with adults capable of flying at least 2 km (Ciesla, 2003c). *T. destruens* will continue to maturation feed until early autumn (Faccoli et al., 2005b). Oviposition occurs in the fall (Ciesla, 2003c). Adults then overwinter with most overwintering in the pine shoots of healthy hosts (Faccoli et al., 2005b) although all stages can overwinter (Ciesla, 2003c).

Tomicus destruens Wollaston uses volatiles to locate stressed, dying or cut trees where they can lay their eggs in autumn (Faccoli, 2007; Faccoli et al., 2005b).

Environmental Impact

In native ranges, many wood-boring and bark beetles serve beneficial roles in the forest environment. Many help open the forest canopy, help relieve tree stress by naturally thinning forests, and initiate decomposition (Goyer et al., 1998). However, some species, even within their native ranges, can cause widespread tree mortality when trees are under drought or other stresses (i.e. Southern Pine Beetle in the United States and Mountain Pine Beetle in Canada). When exotic wood-boring and bark beetles are introduced into new environments, their behavior may differ from that in their native environment. Some exotic species may cause extensive environmental damage and economic loss in their new environment because of a lack of host resistance and/or natural enemies.

Exotic wood-boring and bark beetles can:

- Damage plants by feeding on host shrubs and trees
- Lower timber quality and yield (Evans et al., 2004)
- Transmit pathogens to host plants (Kirisits, 2004; Kobayashi et al, 1984)
- Weaken or kill host plants (Evans et al., 2004)

3

Exotic Wood-Boring and Bark Beetles

Identification

Contents

Introduction

Use *Chapter 3 Identification* as a guide to recognizing exotic wood-boring and bark beetles (EWBBB) in the United States and collaborating territories. Selected species in the families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the information found in the guidelines may be applicable for other exotic wood-boring and bark beetles. Accurate identification is pivotal to assessing potential risk, developing a survey strategy, and determining the level and manner of control and/or management.

Authorities

Qualified State, County, or cooperating University, personnel may perform preliminary identification and screening of suspected wood-boring and bark beetle pests. Before survey and control activities are initiated in the United States, an authority recognized by USDA–APHIS–PPQ-National Identification Services must confirm the presence of such pests. Submit specimens to the USDA-National Identification Services (NIS).

Reporting

Forward reports of positive identifications by National specialists to PPQ-National Identification Service (NIS) in Riverdale, Maryland, according to Agency protocol. NIS will report the identification status of these tentative and confirmed records to PPQ-Emergency and Domestic Programs (EDP). EDP will report the results to all other appropriate parties.

For further information on reporting and submitting samples, refer to the following appendixes:

- ***How to Submit Bark Beetle Specimens*** on **page C-1**
- ***Taxonomic Support for Surveys*** on **page D-1**

Identifying

For further information on identification, refer to the following resources:

- ***Key to Help Screen Tomicus piniperda*** on **page E-1**, Cavey et al. 1994
- ***Key for Separating Tomicus Bark Beetles*** on **page F-1**, Brodel 2005 (rev. 2009)
- *A Resource for Wood Boring Beetles of the World: Bark Beetle Genera of the United States*, Mercado 2011; available on the Web at http://itp.lucidcentral.org/id/wbb/bbgus/index.html

Description

Use the morphological characteristics described in this section to identify adult exotic wood-boring and bark beetles. Some species may require identification or verification by expert taxonomists.

Buprestidae

The Buprestidae family is large with approximately 15,000 species worldwide. Species in this family are commonly known as either flatheaded or metallic wood borers (*Table 2-2* **on page 2-4**). Many species are metallic or brightly colored. This family is superficially similar to the click beetles (Elateridae), but lacks both the pointed posterior corners on the pronotum and a movable prothorax (Bland and Jacques, 1978).

Buprestid adults have short, vertical heads with eyes that are oval, elliptical or reniform (which may or may not project from the head) and biting mouthparts (Evans et al., 2004). The elytra completely cover the abdomen in most species and can have longitudinal grooves, rows of punctures or longitudinal keels (Evans et al., 2004). Sexual dimorphism occurs in this genus and can be very pronounced in some species (Evans et al., 2004).

The larvae usually have an expanded, flattened anterior end (Bland and Jacques, 1978). *Agrilus* species can be identified by their long, narrow bodies and first segments of the hind tarsi which are as long as the three following segments combined (Bland and Jacques, 1978).

Agrilus biguttatus **Fabricius —**No description of the eggs of *Agrilus biguttatus* is available.

Larva.

Refer to *Figure 3-1* **on page 3-6**. Larvae share the following characteristics:

- Color is cream
- Legs absent
- Body shape long and flat (Moraal and Hilszczanski, 2000a)
- Pronotum slightly wider than the rest of the body
- Tail segment with two small black-brown horns on the end (Moraal and Hilszczanski, 2000a)
- Mean length of early stage larvae approximately 10 mm
- Mean length of final larvae 25–43 mm (Moraal and Hilszczanski, 2000a)

Pupa.

Refer to ***Figure 3-2*** **on page 3-6**. No description of the pupa of *Agrilus biguttatus* Fabricius is available.

Adult female.

Refer to ***Figure 3-3*** **on page 3-7**, ***Figure 3-4*** **on page 3-7**, and ***Figure 3-5*** **on page 3-8**.

> Length 10 ½ mm; breadth (across the shoulders of the elytra) 2 ½ mm.... The front of the head flattened and with a central depression.... The elytra long and narrow, at the base slightly broader than the thorax, and the sides sharply convergent from the middle to the apices; flattened over the disc, convex along the sides, and with two incurved basal hollows between the prominent long shoulders and the flattened scutellar area; the elytral surface more shagreened than rugulose in appearance, and with two small white-haired spots adsutural and towards the apex. Abdomen with six white-haired spots ventrally. Coloration bright metallic bronze green with localised suffusion of violet. The under-surface finely and more or less closely punctate with considerable confluence of the punctures on the thoracic parts (Staig, 1940).
>
> The short head is brilliant bronze green and rugulosepunctate.... The prominent oval eyes are vertically placed and wide apart; their finely faceted corneal surfaces are dull green with darker patches and some small golden spots. The short antennae are metallic dark bronze green and are serrate, except the first three segments and the last or eleventh which are club-shaped; the first or basal segment is the largest, the second and third are about equal in size (Staig, 1940).
>
> The pronotum is transverse, its breadth (2 ¼ mm) is greater than its length, which measures 1 ½ mm; it is broadest across the middle and the base is slightly narrower than the front.... The sides of the pronotum (viewed from above) are rounded and have arcuate narrow rims (the lateral carinae); as the carinae are obliquely placed, the sides are considerably deflected in front and the sharp anterior angles are low down at the gena and at a short distance from the lower ends of the eyes.... The general appearance of the surface is that of a shagreened sculpture with slightly rugulose effect. The coloration of the pronotum is metallic bronze green suffused with violet (Staig, 1940).
>
> The prosternum, dark bronze green, is roughly triangular; its base is emarginated and sinuous and is marked off from the middle portion, by a deep transverse furrow, as a distinct gular part.... The metasternum is dark bronze green and irregularly punctate, with very short and fine

whitish hairs; but most of the punctures are confluent in broken lines. The surface is convex, except over the ante-coxal area, where it is flattened and depressed (Staig, 1940).

The scutellum is bright metallic bronze green tinged with violet; it is large and triangular, but the sides are rounded at the base and are deeply incurved towards the apex and upon the large transverse base there is a strong median transverse ridge or carina (Staig, 1940).

The elytra are bright metallic bronze green with violet along the narrowly deflected sides and upon the apices. Between the middle and the apices, and close together at the sutural margins, there are two small and irregular white spots, these being slight depressions with overlying silvery white recumbent hairs of considerable length. The length of the elytra (8 ½ mm) is more than three times the breadth (2 ½ mm across the shoulders), which is slightly greater than that of the pronotum across the middle.... The surface is punctate and more shagreened than rugulose in appearance (Staig, 1940).

The short legs are uniformly dark metallic bronze green, brighter on the tibiae, and the leg surface is finely punctulate with very short and fine whitish hairs.... The abdomen is uniformly dark metallic bronze green with a strong suffusion of violet. The proximal sternum (first and second sterna conjoined) is very long, very nearly half the length of the abdomen.... There are six white spots (slight depressions of the surface covered with moderately long overlying silvery-white hairs) on the third, fourth and fifth sterna, one pair on each and antero-lateral in position (Staig, 1940).

Adult male.

...length is 11 ½ mm. The anterior tibiae have a small sharp hook at the distal end on the inner side. The suffusion of violet on the elytra is more extensive than in the female metatype (Staig, 1940).

Figure 3-1 Final Stage Larva of *Agrilus biguttatus* Fabricius (Buprestidae) (Louis-Michel Nageleisen, Département de la Santé des Forêts, http://www.bugwood.org)

Figure 3-2 Pupae of *Agrilus biguttatus* Fabricius (Buprestidae) (Louis-Michel Nageleisen, Département de la Santé des Forêts, http://www.bugwood.org)

Figure 3-3 Dorsal View of *Agrilus biguttatus* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-4 Side View of *Agrilus biguttatus* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-5 Adult of *Agrilus biguttatus* (Andrea Battisti, Università di Padova, http://www.bugwood.org UGA1329046)

Species Similar to *Agrilus biguttatus* Fabricius—Many *Agrilus* species are similar in morphology and difficult to differentiate (Reißmann, 2010). However, *Agrilus biguttatus* Fabricius is easier to tell apart due to the pubescent white spots found on the elytra; these spots are only found on two other exotic species: *Agrilus ater* (***Figure 3-6* on page 3-9**) and *Agrilus guerini* (***Figure 3-7* on page 3-9**) (Reißmann, 2010). Other species may be pubescent, but it does not form spots like the previous three species, instead the pubescence extends over a larger area, is sparse and can look more grey than white (Reißmann, 2010).

Agrilus biguttatus Fabricius can be differentiated from both *Agrilus ater* and *Agrilus guerini* by looking at the tips of the elytra. In *Agrilus guerini*, the tips of the elytra are long, divergent and sharp; in *Agrilus ater*, the tips are divergent and sharp, but also short; in *Agrilus biguttatus*, the tips are rounded (Reißmann, 2010). Both *Agrilus ater* and *Agrilus guerini* have three white scaly patches on their elytra while *Agrilus biguttatus* only has one white scaly patch closer to the anterior part of the elytra (Reißmann, 2010).

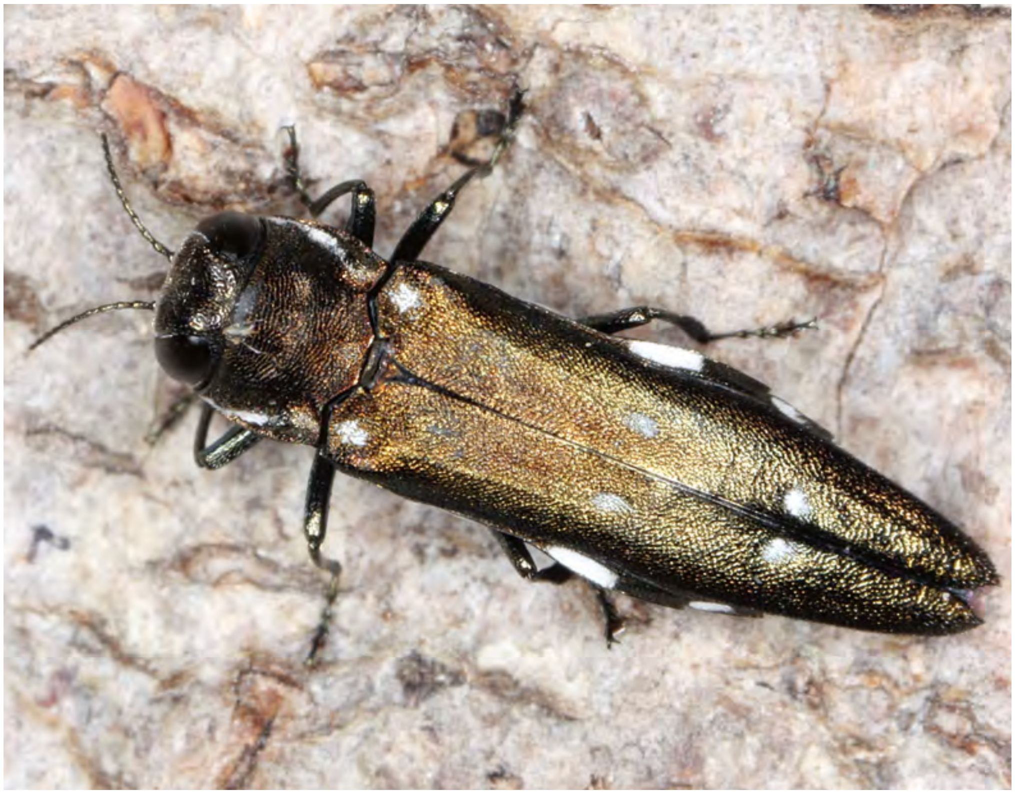

Figure 3-6 Adult of *Agrilus ater* (Christoph Benisch, http://www.kerbtier.de/)

Figure 3-7 Adult of *Agrilus guerini* (Zdenk Chalupa and Petr Horsák)

Cerambycidae

The Cerambycidae family is large with approximately 20,000 species worldwide. They are commonly known as longhorned beetles or roundheaded wood borers (*Table 2-2* **on page 2-4**). In general, beetles in this family are medium to large-sized, elongated and cylindrical; antennae are over half the length of the body, sometimes much longer (Bland and Jacques, 1978).

Larvae of this family have a rounded head-thorax area (as opposed to flatheaded Buprestidae larvae), and are whitish in color (Bland and Jacques, 1978). Cerambycid larvae have reduced or no legs (Evans et al., 2004). Phloem-residing larvae are compressed and similar to buprestids while xylem-residing larvae have cylindrical bodies (Evans et al., 2004).

***Monochamus saltuarius* Gebleris—**Use the key in Cherepanov (1990b) to differentiate adults, larvae and pupae of certain *Monochamus* spp., including *M. saltuarius* Gebleris and *M. sutor.*

Egg.

Eggs share the following characteristics:

- Color is white
- Size is 3–3.5mm long and 0.8–1.2mm wide
- Shape is either almost parallel sided or tapered slightly towards one end (Cherepanov, 1990b); ends of the eggs are rounded (Cherepanov, 1990b)

Larva.

Larvae share the following characteristics:

- Color is
- Legs are absent
- Shape cylindrical and elongate with an oval head (CABI, 2010)
- Size of final instar larvae 20–28 mm long with a head width of 3.5–4.0 mm (Cherepanov, 1990b)
- Head is flat and partially covered by the prothorax (Cherepanov, 1990b)

  Epistoma in anterior half reddish-rust, barely convex; in posterior half, bright, flat, at anterior margin laterally with three long bristles on each side of the longitudinal suture with a pair of staggered bristles (inner bristle slightly in front of lateral), near antennal socket with three bristles in transverse row, on disk with two bristles in transverse row (Cherepanov, 1990b).

> Labrum somewhat rusty, highly tapering towards the base, at anterior margin broadly rounded, in anterior half with long rusty bristles, in posterior half glabrous, medially with pair of long wide-set bristles. Mandibles black, elongate, gently sloping apically (Cherepanov, 1990b).

Diapausing larvae turn from milky white to yellowish-white, whitish-yellow or yellow (Togashi et al., 1994). The larval stages of *Monochamus saltuarius* Gebleris (Cerambycidae) and *Monochamus alternatus* (Japanese pine sawyer beetle) can be distinguished through expert examination (CABI, 2010).

Pupa.

Pupae share the following characteristics:

- Color is milky-white
- Size is 14–20 mm long and 4.5–4.8 mm wide (Cherepanov, 1990b)

> [The pupae are] characterized by a large number of spinules in the frontal region and long, large sclerotized spinule at the apex of the urogomphus. Head medially with deep longitudinal trough, lateral to it in front of antennae with numerous long setiform spinules forming broad, longitudinal field, at anterior margin near base of clypeus with six spinules forming transverse row interrupted medially, occiput glabrous, lustrous. Labrum elongate apically broadly rounded, in anterior half along margins with long acicular spinules. Upper ocular lobe with two bristles. Antennae in second half bent ventrad, here spiralled, forming two incomplete (female) or two complete loops (male) (Cherepanov, 1990b).
>
> Abdomen moderately elongate, gradually tapering towards tip. Abdominal tergites in posterior half convex in anterior half transversely depressed, medially with longitudinal groove, lateral to it in posterior half with rusty acicular spinules directed backward and forming dense transverse band divided by median longitudinal groove. Two-three rows of spinules observed in each transverse band. Tergite VII is convex, lustrous, triangular, gently rounded apically, in posterior third with solitary minute, sometimes barely perceptible, setiform spinules. Tergite VIII semi-circular, convex, lustrous, and without spinules. Urogomphus at the tip of abdomen is highly extended, terminating in long large, slightly anteriorly curved, sclerotized spinule. Ridges bordering the tip of the abdomen laterally (ventral view) with two-five minute setigerous spinules on the ventral side. Valvifers of female spherical, basally slightly wide-set, apically with small tubercle, bent towards each other (Cherepanov, 1990b).

Adult.

Refer to ***Figure 3-8*** **on page 3-12**. Adults share the following characteristics (Bense, 1995):

- Body color is predominantly black
- Size is 11–20 mm in length
- Head with sparse yellowish-grey pubescence
- Pronotum and elytra in both sexes with numerous yellowish or whitish spots
- Legs and first antennal segments partly with grey spots
- Antennal segments 3–11 in male, uniformly black; in female basal halves of these segments with whitish-grey pubescence, antennae long

> Elytra parallel-sided (male) or from base slightly enlarged posteriorly (female), apically separately rounded…. Abdominal sternite V short, apically emarginate, at posterior angles with long dense hairs forming a cluster on each side (female) or rounded, with uniform brownish bristles (males).... (Cherepanov, 1990b).

Figure 3-8 Adult of *Monochamus saltuarius* (Cyorgy Csoka, Hungary Forest Research Institute, Hungary, http://www.bugwood.org UGA1231144)

Species Similar to *Monochamus saltuarius* Gebleris—*Monochamus saltuarius* is similar to *M. carolinensis* (***Figure 3-9*** **on page 3-13**) and *M. titillator* (***Figure 3-10*** **on page 3-13** and ***Figure 3-11*** **on page 3-14**), two native North American species (Ciesla, 2001; Davis et al., 2008). It is also similar to *Monochamus alternatus* (Japanese pine sawyer beetle) (***Figure 3-12*** **on page 3-14**) which is not currently present in the United States (CABI, 2010).

The larval stage of *Monochamus saltuarius* Gebleris can only be distinguished from *Monochamus alternatus* (Japanese pine sawyer beetle) by expert examination (CABI, 2010).

Use the key in Cherepanov (1990b) to differentiate adults, larvae, and pupae, of *Monochamus* spp.

Figure 3-9 Adult of *Monochamus carolinensis* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-10 Adult *Monochamus titillator* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-11 Side View of Adult *Monochamus titillator* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-12 Adult of *Monochamus alternatus* (Pest and Diseases Image Library, http://www.bugwood.org)

***Monochamus sutor* Linnaeus—**Use the key in Cherepanov (1990b) to differentiate adults, larvae and pupae of certain *Monochamus* spp., including *M. saltuarius* Gebleris and *M. sutor.*

Egg.
Eggs share the following characteristics:

- Color is white and matte and turn brownish over time (Cherepanov, 1990b)
- Shape is elongate, slightly curved and rounded at the ends (Cherepanov, 1990b)
- Chorion with a fine, faint reticulate sculpture (Cherepanov, 1990b)
- Size is 3.8 mm by 0.8 mm (Cherepanov, 1990b)

Larva.
Larvae share the following characteristics:

- Color is white, opaque; head capsule is amber with black
- Legs absent (CABI, 2010)
- Size of mature larvae 40–50 mm in length
- Mouthparts are chewing and well developed (CABI, 2010). Body length is 40–50 mm while head width is 4.1–4.7 mm (Cherepanov, 1990b)

Pupae.
Pupae share the following characteristics:

- Color is white, opaque
- Shape is cylindrical, moderately elongate and exarate (CABI, 2010); abdomen is elongated and tapers gradually to a posterior tip (CABI, 2010)

Adult.
Refer to ***Figure 3-13* on page 3-16** and ***Figure 3-14* on page 3-17**.

The overall body length of the adult is 15–26 mm. The body is moderately elongate with head not broader than the pronotum. Head and pronotum have a deep median longitudinal groove with deep uneven punctuation and dense or sparse grey or brownish hairs. The antennae are 2.5 times the length of the body on males and less than 1.5 times the length of the body for females. The eyes are deeply faceted, broadly emarginated, with the upper ocular lobes close to each other. The distance between the ocular lobes is less than the interspace between the antennal bases. The scutellum is whitish-yellow and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold coloured markings. Females are slightly larger than males (CABI, 2010).

[Adults] are 15–24 mm long with a black body color with a metallic sheen. The scutellum is a whitish-yellow color and the prothorax has a pair of projections. The elytra have several irregular, faint, bronze or gold colored markings. The antennae are more than twice the body length on the males and about 1.5 times the body length on females. Females are slightly larger than males (Ciesla, 2004).

Species Similar to *Monochamus sutor* Linnaeus—*Monochamus sutor* is similar to *M. scutellatus* (*Figure 3-15* **on page 3-17** and *Figure 3-16* **on page 3-18**), a species native to North America (Ciesla, 2004).

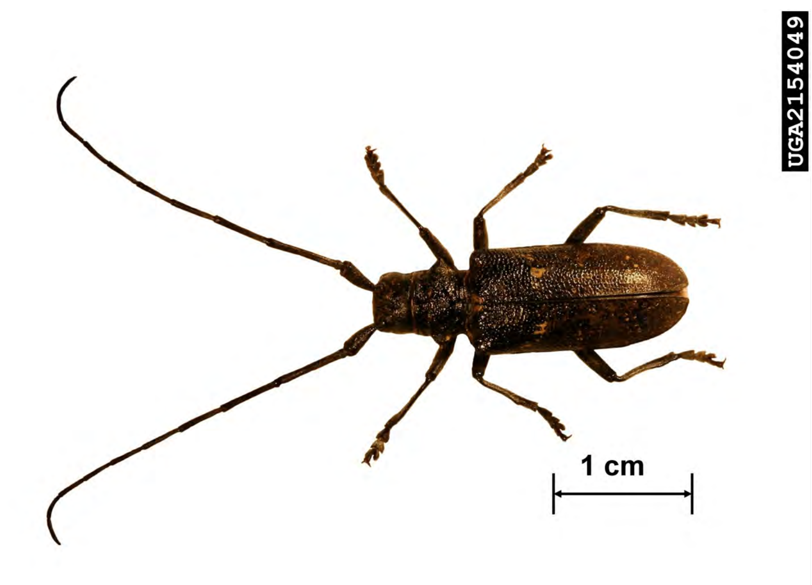

Figure 3-13 Dorsal View of Adult of *Monochamus alternatus* (Pest and Diseases Image Library, http://www.bugwood.org UGA2154049)

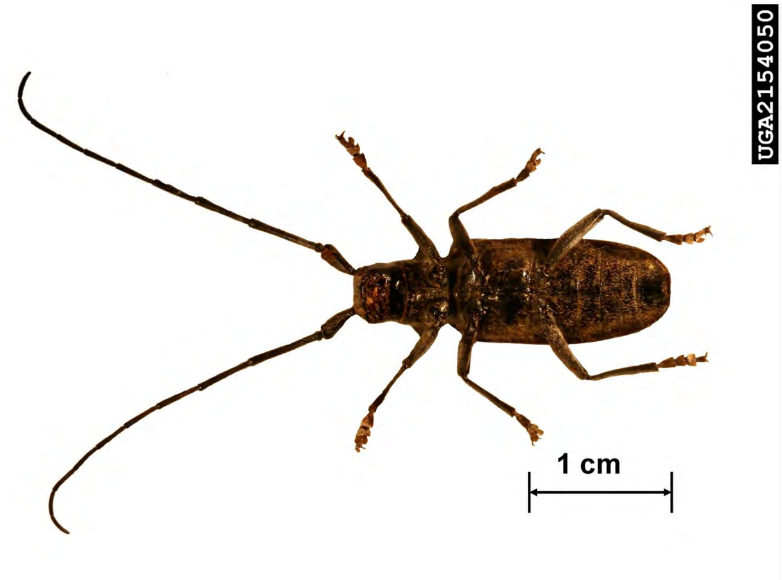

Figure 3-14 Ventral View of Adult *Monochamus sutor* (Christopher Pierce, USDA–APHIS–PPQ, http://www.bugwood.org UGA2154050)

Figure 3-15 Dorsal View of Adult *Monochamus scutellatus* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Figure 3-16 Side View of Adult *Monochamus scutellatus* (Natasha Wright, Florida Department of Agriculture and Consumer Services, http://www.bugwood.org)

Tetropium castaneum Linnaeus—

Egg.

Eggs of *Tetropium* cannot be determined to species (Dobesberger, 2005a). Eggs share the following characteristics:

- Color is white with some silver
- Shape is oblong to oval
- Size is 1.2mm by 0.5mm (Dobesberger, 2005a)
- Surface is generally smooth with a band of microsculpture that run approximately 1/5 of the length of the egg (Dobesberger, 2005a)

Larva.

Refer to ***Figure 3-17*** **on page 3-20**.

> The larva is yellow-white in color, with conspicuous legs on the thorax, the tarsi of which bear tiny spinules (Schimitschek 1929, Cherepanov 1990). Larvae range from 15 to 27 mm in length and are slightly flattened. The head measures 3.5 mm wide (Švácha and Danilevsky 1987, Cherepanov 1990). Hairs on the sides of the head are sparse and the head is rust or reddish brown, with a narrow white band laterally, typical of the genus. Long, but numerous setaceous hairs with a tubercular sclerotized base occur in the anterior half. Sclerotized and elongate spinules occur on the posterior margin of abdominal tergum IX, which look like spots and are usually not separated by a space. If they are separated by a space then the width of the space is less than the diameter of the spinule. These elongate spinules are set on their tubercular base with extensive, but indistinct sclerotization (Cherepanov 1990) (Dobesberger, 2005a).

Pupa.

Refer to ***Figure 3-18*** **on page 3-20**.

The pupa is white, about 15 mm long (range 10–20 mm) and about 4.0 mm wide (Cherepanov 1990). The mesonotum (in the region of the scutellum) is tubercularly elevated at the apex and bears highly numerous and sometimes quite large spinules. The pronotum is transversely oval, bulges moderately and occasionally bears a small transverse tubercular protuberance on the anterior margin, particularly on the male. Also fine light colored setae occur laterally and fine transverse streaks are in the middle of the disk with distinct spinules. Tergum VII is broadly rounded posteriorly and has stray minute spinules on the disk that sometimes form a transverse row. Tergite VIII is glabrous and is without spinules (Cherepanov 1990) (Dobesberger, 2005a).

Adult.

The adult varies in size and color throughout its natural range and many forms occur (Juutinen 1955, Novak et al. 1976, Cherepanov 1990). This insect has a flattened body that varies in length from 8 to 19 mm (Novak et al. 1976, Villiers 1978, Cherepanov 1990, Bense 1995). The typical form is black in color, with a shiny pronotum and brown elytra (***Figure 3-19*** **on page 3-21**) (Novak et al. 1976, Cherepanov 1990). The antennae and legs are either brown or reddish. The antennae and femora (upper legs) are markedly thick and the pronotal punctation is distinctly sparse. These characteristics of the adult distinguish it from other species of the genus. The elytra are uniformly pubescent, with two longitudinal ridges on the disk and with dense, but very fine punctuation (Cherepanov 1990). A deep groove is found on the forehead between the eyes. When viewed from the side, the pronotum has dense granulate punctation and its plate is only rarely punctured. The scutellum has parallel sides and is broadly rounded posteriorly (Dobesberger, 2005a).

Figure 3-17 Larva and Frass of *Tetropium castaneum* Linnaeus (Stanislaw Kinelski, Poland, http://www.bugwood.org UGA1258315)

Figure 3-18 Pupa of *Tetropium castaneum* Linnaeus (Stanislaw Kinelski, http://www.bugwood.org UGA1258317)

Figure 3-19 Adult of *Tetropium castaneum* (Gyorgy Csoka, Hungary Forest Research Institute, Hungary, http://www.bugwood.org UGA1231097)

Species Similar to *Tetropium castaneum* Linnaeus—Exotic *Tetropium* species are similar in appearance to indigenous species and may be difficult to distinguish (Dobesberger, 2005a). Both the larvae and pupae of *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius are similar with some differences in body structure (Kolk and Starzyk, 1996). *Tetropium castaneum* Linnaeus is also similar to *T. cinnamopterum* (***Figure 3-23* on page 3-25**) which is present in the United States.

A taxonomist with expertise in the Cerambycidae family should identify adults by examining morphological characters.

Use the key in Cherepanov (1990a) to differentiate adults, larvae and pupae of certain *Tetropium* spp. (including *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius).

Tetropium fuscum Fabricius—

Egg.

Differentiation between eggs of *Tetropium* species is not possible. Eggs of *Tetropium fuscum* Fabricius share the following characteristics:

- Color is white with a hint of green and are smooth (Dobesberger 2005b).
- Size is 1–2 mm long by 0.2–0.3 mm wide
- Shape is oval, oblong (Dobesberger 2005b)
- Surface is smooth (Dobesberger 2005b) with a band of microsculpture running about 20 percent of the egg length on the end with the developing larva’s head (Dobesberger 2005b)

Larva.

Refer to ***Figure 3-20* on page 3-23**. Larvae of *Tetropium fuscum* Fabricius are "virtually indistinguishable from other *Tetropium* species" (Smith and Humble 2000).

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

Pupa.

Refer to ***Figure 3-21* on page 3-23**.

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

Adult.

Refer to ***Figure 3-22* on page 3-24**.

> The adult is black or dark brown, with a flattened body that varies in length from 8 to 17 mm.... The elytra range in color from brown to reddish or yellow-brown or straw-yellow and bear 2 to 3 distinct longitudinal stripes.... A broad whitish to beige pubescent band is present at the base of the elytra...and the 5th sternite is distinctly truncated (flat edge). Short gray-yellow densely packed hairs cover the first quarter of the elytra. The short antennae are red-brown in color and the legs are dark brown and short. A deep groove is found on the head between the

antennae. The mat-like pronotum is almost as wide as it is long. Viewed from the side, the pronotum is angular and wide, with dense granulation. It also bears a dense, wrinkled and punctured plate that has a longitudinal hole.... The pronotum is usually black with a notable bulge and sometimes with a rusty border at the base and apex.... Fine short hairs cover the body and various diverse forms in color and size occur (Dobesberger, 2005).

Figure 3-20 Larva of *Tetropium fuscum* Fabricius (Stephanie Sopow, Natural Resources Canada, http://www.bugwood.org UGA 5331018)

Figure 3-21 Pupa of *Tetropium fuscum* Fabricius with Larval Exuvia (Stephanie Sopow, Natural Resources Canada, http://www.bugwood.org UGA5331016)

Figure 3-22 Adult of *Tetropium fuscum* Fabricius adult (Stanislaw Kinelski, Poland, http://www.bugwood.org UGA1258311)

Species Similar to *Tetropium fuscum* Fabricius—*Tetropium fuscum* Fabricius can be mistaken for other indigenous Tetropium species. This species was first found in Canada in 1999, but was initially misidentified as *Tetropium cinnamopterum* (*Figure 3-23* **on page 3-25**) (O'Leary et al., 2003). A consistent and reliable characteristic to distinguish *Tetropium fuscum* from relatives found in eastern North America is the aspirate pronotum (Smith and Hurley, 2000). *Tetropium fuscum* is also similar to *Tetropium castaneum*. The other five endemic *Tetropium* species found in North America include *T. abietis*, *T. auripilis*, *T. parallelum*, *T. schwarzianum* (*Figure 3-24* **on page 3-25**) and *T. velutinum* (Chemsak, 1996). Use the key in Chemsak (1996) to distinguish the North American *Tetropim* species.

A taxonomist with expertise in the Cerambycidae family should identify adults by examining morphological characters.

Use the key in Cherepanov (1990a) to differentiate adults, larvae and pupae of certain *Tetropium* spp. (including *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius).

Figure 3-23 Adult Male of *Tetropium cinnamopterum* (S. Sopow, Canadian Forest Service)

Figure 3-24 Adult Male of *Tetropium schwarzianum* (S. Sopow, Canadian Forest Service)

Curculionidae

Both bark beetles and ambrosia beetles are specialized groups found in the true weevil family, Curculionidae (***Table 2-2* on page 2-4**). These species are usually small, very cylindrical and dark in color.

***Platypus quercivorus* Murayama *(Platypodinae)*—**No high quality images of this species are available. A taxonomist should identify adults by examining morphological characters.

Egg.

Eggs of *Platypus quercivorus* Murayama are elongated and cylindrical (Ciesla, 2003d).

Larva.

Larvae of *Platypus quercivorus* Murayama share the following characteristics:

- Color creamy white with an amber to light brown head capsule (Ciesla, 2003d)
- Size at maturity 2–6 mm in length (Ciesla, 200
- Legs absent (Ciesla, 2003d)
- Shape of last abdominal segment is flat to slightly concavely sloped at the end

Pupa.

Pupae of *Platypus quercivorus* Murayama are creamy white with partially developed wings and appendages (Ciesla, 2003d).

Adult.

Murayama (1925) describes *Platypus quercivorus* Murayama as ferruginous brown with a darker head and elytra apex and a yellowish-brown underside. Adult females share the following characteristics:

> Front and vertex the same as in the male. Prothorax subquadrate, shining, with fine punctures and median sulcus, as in the male, on each side of the sulcus with 3–5 large round touched depressions in two rows, each depression being surrounded by a black bar.... Elytra as in the male, excepting in the more gently rounded sides and declivity.... Underside a little paler than in the male, with stronger convexity on each abdominal segment (Murayama, 1925).

Adult males share the following characteristics:

> Head with front flat, covered with an irregular rugose reticulation, a short depressed median line between the bases of the antennae; vertex rather abruptly separated from the front, with a narrow black median line, sparse rugose punctures, and long aureous hair (Murayama, 1925).
>
> Elytra elongate, with sides parallel in the anterior two thirds and gradually diminished about one third of the breadth towards the apex; upper surface with a slight declivity in the posterior third, with the apex abruptly truncated.... Underside with scanty long yellow hair and large porelike punctures, abdominal segments convex, the 7th with a large transversal shallow oval depression" (Murayama,1925).

Species Similar to *Platypus quercivorus* Murayama—*Platypus quercivorus* Murayama may be mistaken for morphologically similar wood-boring relatives. Seven *Platypus* species are found in the United States, four of which occur in southeastern United States (Atkinson, 2008; Wood, 1979) where Davis et al. (2005b) predicted *P. quercivorus* would become established if introduced. The four species are as follows:

- *Platypus quadridentatus* (***Figure 3-25* on page 3-27** and ***Figure 3-26* on page 3-27**)
- *Platypus compositus* (***Figure 3-27* on page 3-28** and ***Figure 3-28* on page 3-28**)
- *Platypus flavicornis* (***Figure 3-29* on page 3-28** and ***Figure 3-30* on page 3-29**)
- *Platypus parallelus* (***Figure 3-31* on page 3-29** and ***Figure 3-32* on page 3-30**)

Both *Platypus quadridentatus* and *P. flavicornis* attack pines and oaks while *P. compositus* and *P. parallelus* are polyphagous (Atkinson, 2008).

Figure 3-25 Side View of Adult *Platypus quadridentatus* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

Figure 3-26 Dorsal View of Adult *Platypus quadridentatus* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

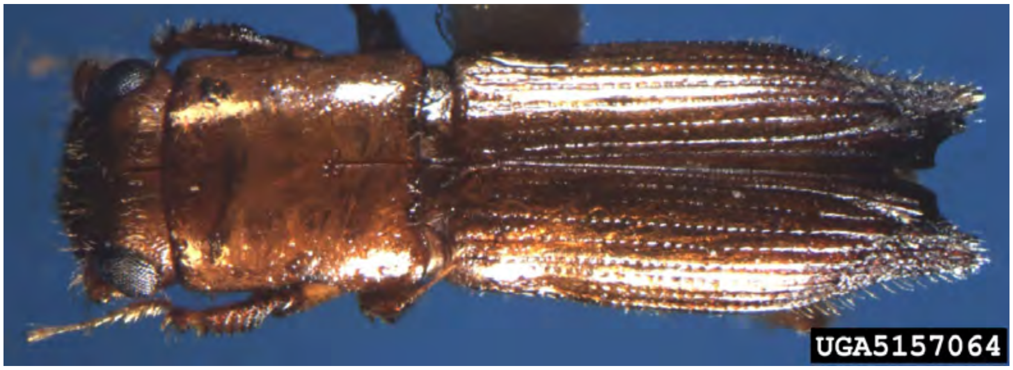

Figure 3-27 Dorsal View of Adult *Platypus compositus* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

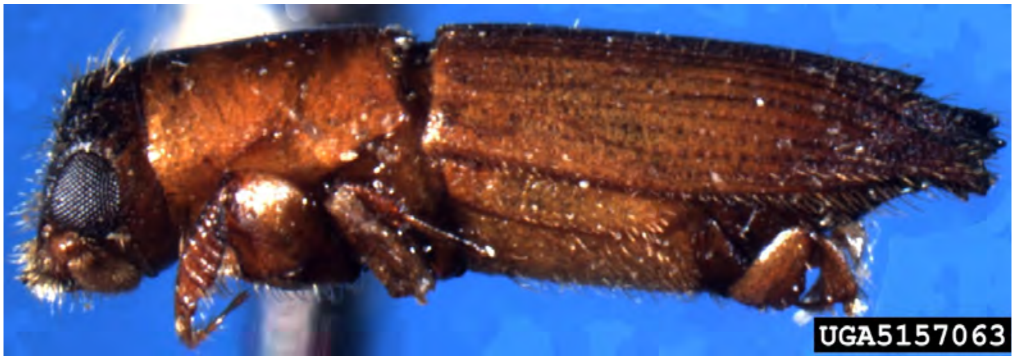

Figure 3-28 Side View of Adult *Platypus compositus* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

Figure 3-29 Dorsal View of Adult *Platypus flavicornis* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

Figure 3-30 Side View of Adult *Platypus flavicornis* (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

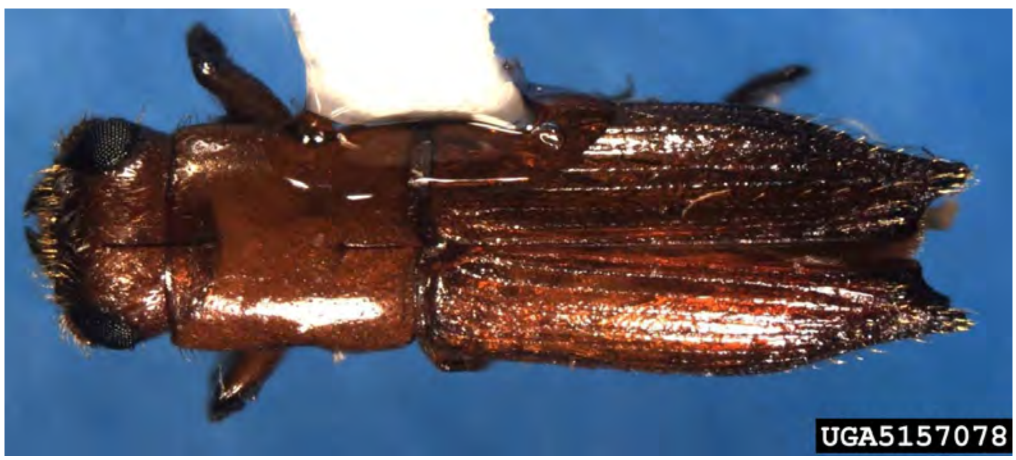

Figure 3-31 Dorsal View of Adult *Platypus parallelus* adult (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

Figure 3-32 Dorsal View of Adult *Platypus parallelus* adult (J. R. Baker and S. B. Bambara, North Carolina State University, http://www.bugwood.org)

Tomicus destruens Wollaston (Scolytinae)—

A taxonomist with expertise in the subfamily Scolytinae will identify adults examining morphological characters under magnification. To determine if the specimen is a *Tomicus* spp., use Passoa and Cavey (1994) followed by Brodel (2005, rev. 2009). To determine species of *Tomicus* (*T. destruens*, *T. minor* or *T. piniperda*) use Brodel (2005, rev. 2009) with Brodel (2000). Refer to the following Appendixes in the guidelines: ***Key to Help Screen Tomicus piniperda*** on **page E-1**, and ***Key for Separating Tomicus Bark Beetles*** on **page F-1**.

Egg.

The eggs and pupae of *T. destruens* cannot be positively identified to species due to lack of sufficient characteristics (Ciesla, 2003c).

Eggs are pearly white in color (Ciesla, 2003c).

Larva.

> Head capsule index [maximum head width ÷ head length to mandibles] 0.95. Frontal shield broad, triangulate with straight sides and distinct endocarinal line. Frontal setae five pairs of which pair 2 is the longest. Epistoma posteriorly limited by a continuous, slightly curved line which laterally bends backwards. Medially, on the anterior edge a large tubercle.
>
> Antenna short and broad without differentiation. On the flat antennal field five setae of equal length, four of which are situated laterally of the antenna. Clypeus with convex sides and gently concave anterior border. The medial of the clypeal setae about three times longer than the lateral ones. Labrum with a rounded, flattened anterior border. The lateral pair of the anteromedial setae poorly developed, bristle-like, the medial one vigorous of equal breadth.

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

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

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

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

Pupa.

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

Adult.

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

Callow adults of both species [*T. destruens* and *T. piniperda*] have a similar homogeneous yellow colour, thus for young specimens other characters must be used for identification" (Faccoli 2006). "The

> declivity.... [is] weakly, irregularly, transversely wrinkled, most easily seen on interstiae [*sic*] 2 where no setae occur, but in most *T. destruens* specimens the sculpture of the second declivital interstriae was more wrinkled than in *T. piniperda* (Faccoli, 2006).
>
> The ratio between length and width of the elytra was different between species, higher in *T. piniperda* (>1.7) than in *T. destruens* (<1.7). Also, the ratio between elytra and pronotum length was higher in *T. piniperda* (>2.35) than *T. destruens* (<2.35). Finally, the ratio between elytral length and pronotum width was higher in *T. piniperda* (>1.9) than *T. destruens* (<1.9) (Faccoli, 2006).

Species Similar to Tomicus destruens Wollaston (Scolytinae)—This species is morphologically similar to *Tomicus piniperda* and at one point was considered the same species, although molecular phylogenetic studies have since shown *T. destruens* to be a separate species (Gallego and Galián, 2001; Kerdelhué et al, 2002; Kohlmayr et al., 2002; Faccoli et al, 2005b). The adult species can be difficult to distinguish in the field (Gallego and Galián, 2001; Faccoli, 2006). Larvae and young adults can be differentiated (Lekander, 1971; Faccoli, 2006).

Tomicus piniperda is currently present in the United States and was first reported in 1992 (Haack and Kucera, 1993). *Tomicus destruens* is also similar to *T. minor* which is currently not present in the United States.

Figure 3-33 Adult of *Tomicus piniperda* (Pest and Diseases Image Library, http://www.bugwood.org UGA 5329015)

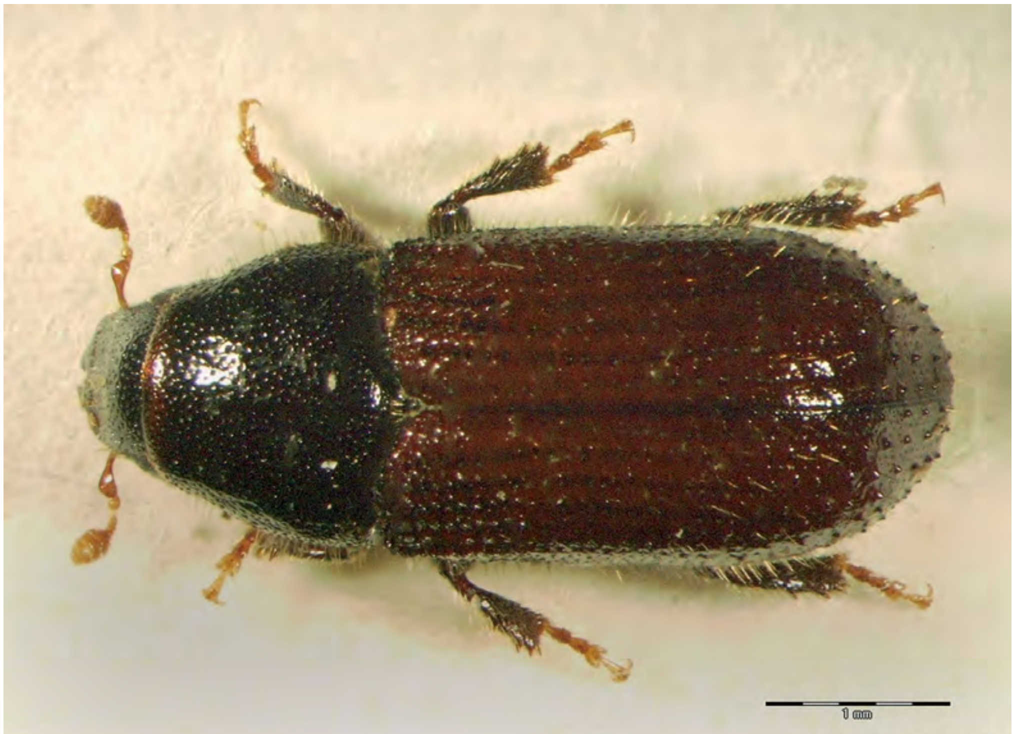

Figure 3-34 Adult of *Tomicus minor* (Maja Jurc, University of Ljubljana, http://www.bugwood.org UGA 2105036)

Taxonomists with expertise in the subfamily Scolytinae can identify adults by examining morphological characters under magnification. To determine if the specimen is a *Tomicus* spp., use Passoa and Cavey (1994) followed by Brodel (2005, rev. 2009). To determine species of *Tomicus* (*T. destruens*, *T. minor* or *T. piniperda*) use Brodel (2005, rev. 2009) with Brodel (2000). Refer to the following Appendixes in the guidelines: ***Key to Help Screen Tomicus piniperda*** on **page E-1**, and ***Key for Separating Tomicus Bark Beetles*** on **page F-1**.

4

Exotic Wood-Boring and Bark Beetles

Survey Procedures

Contents

Introduction

Use *Chapter 4 Survey Procedures* as a guide to conducting surveys for exotic wood-boring and bark beetles (EWBBB) in the United States and collaborating territories. Selected species in the families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the general information found in these guidelines may be applicable for other exotic wood-boring and bark beetles.

Preparation, Sanitization, and Clean-up

This section provides information that will help personnel to prepare to conduct a survey; procedures to follow during a survey; and instructions for proper cleaning and sanitizing of supplies and equipment after the survey is finished.

1. Obtain permission from the landowner before entering a property.
2. Determine if there have been recent pesticide applications that would make it unsafe to inspect the survey site. Contact the landowner or manager and ask if there is a re-entry interval in effect due to pesticide application. Look for posted signs indicating recent pesticide applications, particularly at agricultural sites, but including residential or industrial sites.
3. Conduct the survey at the proper time. The schedule should be on a regular time interval that coincides with weather and temperature conditions most suitable for exotic wood-boring and bark beetles. For further information, refer to ***Prediction of Insect Development*** on **page 4-8** and ***Survey Season and Timing*** on **page 4-6**.
4. Determine if quarantines for other pests are in effect for the area being surveyed. Comply with any and all quarantine requirements.
5. When visiting sites to conduct surveys or to take samples, everyone must take strict measures to prevent contamination by exotic wood-boring and bark beetles or other pests between properties during inspections.

   Before entering a new property, make certain that clothing and footwear are clean and free of pests and soil to avoid moving soilborne pests from one property to another. Wash hands with an approved antimicrobial soap. If not using an antimicrobial soap, wash hands with regular soap and warm water to remove soil and debris. Then use an alcohol-based antimicrobial lotion, with an equivalent of 63 percent ethyl alcohol. If hands are free of soil or dirt, the lotion can be applied without washing. Unlike some antimicrobial soaps, antimicrobial lotions are less likely to irritate the hands and thereby improve compliance with hand hygiene recommendations.
6. Gather together all supplies. Confirm the equipment and tools are clean. When taking plant samples, disinfest tools with bleach to avoid spreading diseases or other pests. A brief spray or immersion of the cutting portion of the tool in a 5 percent solution of sodium hypochlorite (common household liquid bleach) is an effective way to inactivate bacterial and other diseases and prevent their spread. For further information on preparing a solution of liquid bleach, refer to the PPQ *Manual for Agricultural Clearance*.

Address	PPQ Manual for Agricultural Clearance http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml

7. Mark the sampled location with flagging whenever possible, and draw a map of the immediate area and indicate reference points so that the areas can be found in the future if necessary. Do not rely totally on the flagging or other markers to re-locate a site as they may be removed. Record the GPS coordinates for each location so that the area or plant may be re-sampled if necessary.
8. Survey task forces should consist of an experienced survey specialist familiar with exotic wood-boring and bark beetles and the symptoms of their damage.

Survey Types

Plant regulatory officials conduct detection, delimiting, and monitoring surveys. Detection surveys are performed to determine if the pest is present in an area where it is not known to occur. Delimiting surveys are performed to define the extent of an infestation. Monitoring surveys are performed to determine the success of control or mitigation activities conducted against a pest.

Use the following tools and techniques when surveying for exotic wood-boring and bark beetles. The tools and techniques described in this chapter are commonly used by surveyors for many species of exotic wood-borers and bark beetles. They can be used interchangeably to suit the needs of each program:

- ***Prediction of Insect Development*** on **page 4-8**
- ***Multi-Funnel Traps*** on **page 4-11**
- ***Cross-Vane Panel Traps*** on **page 4-13**
- ***Trap Trees*** on **page 4-19**
- ***Visual Inspection*** on **page 4-22**
- ***Attractant Lures*** on **page 4-15**

Survey methods described for the exotic wood-boring and bark beetles in the guidelines are also available online from the Cooperative Agricultural Pest Survey (CAPS) program. The CAPS survey methods are the most appropriate and effective methods, and are based on scientific literature and input from subject matter experts. Refer to the CAPS Approved Methods Web site for further information.

Address	CAPS Approved Methods Web site Survey Methods for Species of Exotic Wood-Boring and Bark Beetles http://caps.ceris.purdue.edu/webfm_send/42

Detection Survey

Detection surveys are performed to ascertain the presence of a pest in an area where it is not known to occur. Detection surveys increase the chance of early detection of new pest infestations. A detection survey may be initiated after a specific risk or a pest pathway has been identified. An ideal detection survey site is a single point identified to be at high-risk for introduction of an exotic species.

Statistically, a detection survey is not a valid tool to claim that a pest does not exist in an area, even if results are negative. Negative results can be used to provide clues about mode of dispersal, temporal occurrence, or industry practices.

Procedure

Use the following tools singly or in any combination to detect exotic wood-boring and bark beetles:

1. Establish a method for recording site locations and sample numbers.
2. Choose survey sites that are at high risk. Refer to ***Targeting and Site Selection*** on **page 4-6** for further information.
3. Determine the best time of year to survey. Refer to ***Survey Season and Timing*** on **page 4-6** and ***Biology and Life Cycle*** on **page 2-33** for further information.
4. Establish regular sites to inspect along the normal surveying route. Refer to ***Sentinel Survey Sites*** on **page 4-7** for further information.
5. Use the discussion in the following sections to select, purchase, and install the traps: ***Trapping*** on **page 4-10**, ***Multi-Funnel Traps*** on **page 4-11**, ***Cross-Vane Panel Traps*** on **page 4-13**.
6. Use trap trees if appropriate. Refer to ***Trap Trees*** on **page 4-19** for further information.
7. Use lures that are attractive to the target species. Refer to ***Attractant Lures*** on **page 4-15** for further information. Refer to ***Pest-Specific Trapping and Lures*** on **page 4-20** for trapping and lure information on each species.
8. Collect, preserve, prepare, identify, and report the trapped pests. Refer to ***Collection of Trap Contents*** on **page 4-18**.
9. Check plants for pest damage. Refer to ***Visual Inspection*** on **page 4-22** for further information.

10. Update the surveying procedure as more information on survey tools becomes available.

Targeting and Site Selection

Choose sites that are at high risk when surveying for exotic wood-boring and bark beetles. High risk sites may include but are not limited to the following:

- Business sites and districts that import commodities from foreign countries (these commodities are most likely packaged in solid wood packing material)
- Warehouses near major air and sea ports of entry
- Factories
- Dunnage storage, disposal, and manufacture areas
- Wood and pallet recycling centers
- Landfills
- Distribution centers
- Landscape recycling centers
- Firewood storage areas and dealers
- Nurseries and dealers of live woody plants
- Fragmented forests near newer developments
- High traffic tourist areas
- Recreation sites such as campgrounds and parks

Survey Season and Timing

Consider the biology and ecology of the target species before deciding when to survey for a particular exotic wood-boring and bark beetle. Traps for exotic wood-boring and bark beetles are usually deployed from May to September; however, some species are in-flight much earlier in the season. For the biology and ecology of specific exotic wood-boring and bark beetles, refer to the section ***Biology and Life Cycle*** on **page 2-33**.

Sentinel Survey Sites

A sentinel survey site is a fixed location for doing survey inspections on a repeated basis. This method can be used to detect exotic wood-boring and bark beetles. If a particular area is considered at high risk for exotic wood-boring and bark beetle introduction, surveyors can use their time efficiently by establishing sentinel survey sites in that area. The best sentinel survey sites within the high risk area are chosen based on the biology and pathways of exotic wood-boring and bark beetles.

The location of the sentinel site should be recorded using GPS and a map drawn of the immediate area and reference points indicated so that the area can be found by others if necessary. Once the sentinel site is established the surveyor should re-inspect the site on a regular basis (e.g. bi-monthly or monthly) as permitted by the person's regular survey schedule. Sentinel sites should use the most effective survey method known for the targeted pest whether it is visual or trapping (i.e. pheromones, trap trees). Larvae, pupae, and adults, should be processed as described in ***Taxonomic Support for Surveys*** on **page D-1**.

Delimiting Survey

Use a delimiting survey to determine the type and extent of control measures to apply. After a new detection in the United States, or if a new area is confirmed, surveys in the area should be conducted to determine the distribution of the pest.

Procedure

Use the procedure in ***Detection Survey*** on **page 4-5** as a guide. There is no precedent set for performing delimiting surveys for wood-boring and bark beetles once discovered in a new area. The development of a specific protocol would be dependent on the species, specifically whether an attractant is available, how sensitive the species is to the attractant, whether the attractant is a pheromone or host volatile, etc.

When an exotic wood-boring and bark beetle is found, the surrounding area should be extensively surveyed through the most appropriate method available, either visual examinations or a trapping program. When mapping the delimitation area, include surrounding areas where exotic wood-boring and bark beetles may have been introduced, such as commercial or residential properties, and consider environmental and structural features that may encourage natural dispersal.

Traceback and Trace-Forward Investigations

Traceback and trace-forward investigations help surveyors determine priorities for delimiting survey activities after an initial U.S. detection. Use traceback investigations to attempt to determine the source of infection. Use trace-forward investigations to attempt to define further potential dissemination through means of natural and artificial spread (commercial or private distribution of infected plant material). Once a positive detection is confirmed, conduct investigations to determine the extent of the infestation or suspect areas in which to conduct further investigations.

Monitoring Survey

Perform a monitoring survey to determine the success of control or mitigation activities conducted against a pest.

Eradication measures should be continued until successful or until it is decided that eradication is no longer feasible. If successful, monitoring of the previously infested area should be continued for 1–2 years.

Procedure

Use the information gathered from the delimitation surveys to establish eradication and regulated zones. The infested area should be divided into separate management zones to help plan control strategies and halt the natural and human-assisted spread of the infestation. Refer to ***Regulatory Procedures*** on **page 5-1** for further information.

Prediction of Insect Development

Temperature is one of the most important factors influencing the development of all life stages of insects. To predict the development of exotic wood-boring and bark beetles, use site-specific temperature data in a tool known as the degree day value. Use degree day values for the following:

- Predicting the emergence of adults
- Determining the time to began trapping
- Monitoring the cycles of generation during a season
- Monitoring the effect of eradication or suppression measures

Degree day values are based on the developmental threshold temperature of an insect and are species typical. Threshold temperatures can represent either upper or lower limitations, and may be measurements of air or soil temperature, depending on where the insect lives.

To determine degree day values for a pest, use ***Equation 1*** on **page 4-9** or ***Equation 2*** on **page 4-9**. You can also use the online interface (***NAPPFAST*** on **page 4-9**) or utility (***University of California IPMP*** on **page 4-9**).

Refer to ***Resources*** on **page A-1** for further information on predicting insect development, and on collecting local temperature data,

Equation 1	Degree Days = [(Average Daily Temperature) – (Developmental Threshold)]
Equation 2	Degree Days = [(Maximum Temperature + Minimum Temperature)/2] – (Developmental Threshold)

NAPPFAST—In a cooperative venture, North Carolina State University (NCSU), USDA–APHIS, and the information technology company ZedX, Inc., have developed a new Web tool known as NAPPFAST (North Carolina State University APHIS Plant Pest Forecasting System). NAPPFAST uses weather, climate, and soil data, to model pest development. The models supply the predictive pest mapping needs of the Cooperative Agricultural Pest Survey (CAPS) program. In addition, the models produce potential establishment maps for exotic pests, which supports the risk assessment activities of the Pest Epidemiology Risk Assessment Laboratory (PERAL). Access the graphical user interface at the NAPPFAST Web site.

Address	NAPPFAST Web site http://www.nappfast.org/index.htm

University of California IPMP—Use the Degree-day Utility (DDU) available online from University of California, Integrated Pest Management Programs, to determine degree day values for exotic wood-boring and bark beetles as well as other pests. Access the utility at the University of California Web site.

Address	University of California Integrated Pest Management http://www.ipm.ucdavis.edu/WEATHER

Trapping

Trapping can be a very efficient way to determine if a pest is present at a location when effective attractants are available. Attractants can be added to the traps, and may include aggregation or sex pheromones and kairomones such as host volatiles. Trap trees are another viable alternative to baited traps.

Sex and aggregation pheromones should be used for trapping when available because they tend to be species-specific and can detect populations at low densities. For species that do not employ pheromones, host volatiles can also be used to detect populations at low densities. Host volatiles are generic attractants that can attract a variety of different species, making the identification process time-consuming. In addition, host volatiles must compete with volatiles being released from trees in the environment, so the range of effectiveness is reduced as well as the sensitivity to any one species.

Host volatiles are released by the host tree, usually following some injury or during drought stress. Beetles use host volatiles to locate specific tree genera or species that are suitable hosts. Ethanol is released by microorganisms in decaying woody tissue and is used by insects to locate stressed trees (Byers, 1992). The combination of ethanol and one or more monoterpenes is often found to increase attraction in some insect species.

Alpha-pinene can attract many coniferous wood-boring and bark beetles including some cerambycids, scolytines and buprestids; ethanol can attract several scolytines and curculionids (Byers, 1992; Sweeney et al., 2007; Miller and Rabaglia, 2009). Different blends of host volatiles can attract different species. Surveying with traps and lures can potentially detect new establishments before damage becomes noticeable.

Several traps are available for trapping exotic wood-boring and bark beetles. Select the best type of trap to use based on the biology of the target pest and the resources available for survey. The following traps are recommended for exotic wood-boring and bark beetles:

- Multi-funnel
- Cross-vane panel
- Trap trees

Multi-Funnel Traps

Multi-funnel traps are also known as Lindgren traps. The traps are made of black plastic funnels that are stacked and aligned vertically over each other (***Figure 4-1*** **on page 4-13**). When beetles are attracted to the lures used in conjunction with the traps, they fall through the funnels into a collection cup. Multi-funnel traps come in a variety of lengths and are referred to by the number of funnels they include (4, 8, 12, or 16). The attractants, in the form of lures, are suspended from the trap.

Number of Funnels

The number of funnels can affect the trap efficacy in some beetle species. Miller and Crowe (2009) conducted a study comparing 8-unit and 16-unit funnel traps. Out of the 7 species and 1 genus of wood-boring and bark beetles evaluated, the 16-unit trap caught higher numbers of 2 species of beetles, and the 8-unit trap caught a higher number of 1 species of beetle. The number of funnels did not affect trap catch of the other species. The type of survey (detection, delimiting, or monitoring) and available resources will dictate how many traps are placed at each site. Each trap should be baited with the appropriate lure(s) for the target species.

The Cooperative Agricultural Pest Survey program uses 8- and 12-unit funnel traps. Larger traps are more expensive and more cumbersome to use in the field (Miller and Crowe, 2009).

Wet vs. Dry Collection

Captures of *Monochamus* and weevils can be reduced by up to 80 percent with the dry collection option. Wet collection traps are more effective than dry collection traps (Miller and Duerr, 2008). The antifreeze kills the target insects as well as non-target predators that may consume or damage the target insects. In addition, the dilute antifreeze preserves the target specimens which aids in the identification process.

Procedure

1. Use 8-funnel traps in order to save resources while deploying a greater number of traps. Follow the manufacturer’s instructions to assemble the traps.
2. Determine the appropriate trapping period. Place multi-funnel traps in the field as soon as adult activity periods begins and leave them throughout the active period. The trapping period will be throughout the approximate adult activity. Actual trapping times may vary by location and target species.

3. Select the best lure for the target species. Refer to ***Attractant Lures*** on **page 4-15** and ***Pest-Specific Trapping and Lures*** on **page 4-20** for further information.
4. Determine the appropriate trapping density and placement. The type of survey (detection, delimiting, or monitoring) and available resources will dictate how many traps are placed at each site. Refer to ***Trap Placement and Density*** on **page 4-17** for further information.
5. Choose either dry or wet collection. If the survey site is in an environmentally-sensitive area, use the dry collection method. Otherwise, use the wet collection method.

Important

All treatments listed in the guidelines should only be used as a reference to assist in the regulatory decision making process. It is the National Program Manager's responsibility to verify that treatments are appropriate and legal for use. Upon detection and when a chemical treatment is selected, the National Program Manager should consult with PPQs FIFRA Coordinator to ensure that the chemical is approved by EPA for use in the United States prior to application.

If:	Then:
Wet collection	1. Attach a collection cup without a drain hole. 2. If a rubber stopper is used to seal the cup, make sure the stopper is secure inside the bottom of the collecting cup with the large end of the stopper on the inside of the cup to prevent it from falling out. 3. Fill the collection cup with about 150 ml of solution low-toxicity anti-freeze (propylene glycol) or soapy water. Avoid those that contain ethanol. 4. Attach the filled cup to the trap. 5. Make sure that all the flanges on the bottom funnel and collecting cup engage properly.
Dry collection	1. Attach an empty collection cup with a drain hole in bottom. 2. Install the insecticidal strip, Hercon® Vaportape™II (or a similar product) inside the trap to kill trapped insects. Suspend the strip with a wire inside the trap from the second to the last bottom funnel such that it is suspended in the trap and eliminates the risk of handling the strip directly. 3. Change insecticidal strips every two months. 4. Insert a small screen at the bottom of the cup to allow rainwater to drain. 5. Refer to ***Resources*** on **page A-1** for further information concerning the insecticidal strip.

6. Use ***Collection of Trap Contents*** on **page 4-18** as a guide to collect specimens and prepare them for identification.

Figure 4-1 Multi-Funnel Trap (Fengyou Jia, Division of Forest Pest Management, DCNR, PA, http://www.bugwood.org UGA 5022063)

Cross-Vane Panel Traps

Use the cross-vane panel trap in conjunction with lure dispensers to attract bark beetles, ambrosia beetles, longhorn beetles and wood borers (Czokajlo et al., 2001). The trap simulates a tree of large diameter and provides a large surface area to maximize trapping (Czokajlo et al., 2001). The trap is made from light-weight, corrugated plastic and is water- and weather-resistant. The trap consists of two intersecting panels and a top and bottom made of corrugated plastic board (***Figure 4-2*** **on page 4-14** and ***Figure 4-3*** **on page 4-15**).

Some research has suggested that cross-vane panel traps may be better at catching larger wood borers than multi-funnel traps (McIntosh et al., 2001; Morewood et al., 2002; Dodds et al., 2010 in press). Some large wood borers are able to escape from the funnel trap's collection cup due to large size, long legs and relative agility (Morewood et al., 2002). Cross-vane panel traps are the recommended traps for the cerambycid species *Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius (Sweeney et al., 2006).

Procedure

1. Follow the manufacturer's instructions to assemble the traps.
2. Determine the appropriate trapping season. The trapping season will be the period of expected flight activity of adult beetles. Traps should be placed in the field as soon as adult flight activity periods begin and remain throughout the active period. Actual trapping times may vary by location and target species. Refer to
3. Select the best lure for the target species. Refer to ***Attractant Lures*** on **page 4-15** and ***Pest-Specific Trapping and Lures*** on **page 4-20** for further information.
4. Determine the appropriate trapping density and placement. The type of survey (detection, delimiting, or monitoring) and available resources will dictate how many traps are placed at each site. Refer to ***Trap Placement and Density*** on **page 4-17** for further information.
5. Use ***Collection of Trap Contents*** on **page 4-18** as a guide to collect specimens and prepare them for identification.

Figure 4-2 Example of Cross-vane Panel Trap

Figure 4-3 Example of Collection Cup of Cross-vane Panel Trap

Attractant Lures

Number to Order

Order 10 percent more lures than are needed, because a small percentage of the lures may leak in transit from manufacturer. Inspect the lures upon receiving from manufacturers; notify manufacturers of any lures that are damaged or leaking, request replacement lures from manufacturers.

Storage

Store the lures as directed by the manufacturer until they are used. Most lures should be frozen during storage. In ultra high release (UHR) ethanol lures, water vapor pressure that is unable to pass through the lure's plastic membrane can build up inside the lure and cause the lure to eventually leak or explode. To reduce the vapor pressure, when placing lures into a trap puncture the black plastic of the ethanol UHR lures with a pin just below the top seal.

Replacement

Replace the lures as often as directed by the manufacturer. The length of effectiveness is usually reported by lure manufacturers assuming temperatures of 30°C [86°F] during the day and 20°C [68°F] at night for a daily average of 25°C [77°F]. Release rates of many exotic wood-boring and bark beetles lures are highly temperature-dependent. For example, lures will last twice as long in climates with an average daily temperature of 20°C [68°F]. Lures will last half as long in climates with an average daily temperature of 30°C [86°F]. In addition, many lure dispensers do not release the lure at a constant rate; initial rates are high and then drop off significantly over the life of the dispenser. The lure is still attractive at the lower emission rate (if the above temperature parameters are followed). Surveyors should be aware of this and not be alarmed by a sharp decline in the amount of lure visible in the dispenser. The amount of attractant remaining in the lures should be monitored biweekly when the traps are checked. Direct sunlight reduces lure lifespan and may make traps less attractive to target species.

Procedure

1. Keep a record of the change date for each lure on the trap card. This will provide information on the longevity of the attractants.
2. Transport and store lures separately in a large sealable plastic container to prevent breakage and contain leaks.

Trap Placement and Density

The criteria are listed in their approximate order of importance:

1. Place traps within 100 meters of potential host trees.
2. Set traps with different lure types at least 30 meters apart.
3. Place traps out of direct sunlight, or in partial shade (e.g., at the margin of a stand of host trees).
4. If necessary, traps may be placed near injured or fallen potential hosts. There may be some competition between the host plant and trap and lure, but both should attract potential pests to the surrounding area. Both trap and lure and host plant should be checked.
5. Place traps upwind (based upon prevailing winds) of potential sources of target species.
6. Place traps in line-of-sight from potential sources of target species (e.g. piles of SWPM, possible host trees etc.).
7. Make sure traps are not obscured by vegetation. Clip or remove any such vegetation.

Trap Setup

Procedure

1. Use a trap card to record trap site data.
2. Wear disposable latex gloves and change them between lure types to prevent cross-contamination.
3. Traps can be set up on stands or hung from rope.
4. Hang traps 25–50 m away from trees because non-host trees may interrupt attraction.
5. In all cases, traps should be hung so that the collecting container is from 20 to 50 cm above the ground and any ground cover or other vegetation.
6. Attach lures using nylon cable ties or the hangers provided.

Collection of Trap Contents

Procedure

1. Check traps every two weeks or more frequently if rain is expected.
2. Examine traps for damage.
3. Remove any debris blocking funnels, including leaves, twigs, and spider webs.
4. Ensure that all lures are still in place and still have fluid in them. Vapor pressure may make empty UHR ethanol and UHR alpha-pinene pouches appear full. These UHR lures are particularly prone to leaking. The fluid levels in the transparent bubble caps are visible.
5.

If:	Then:
Wet collection	1. Wear disposable latex gloves. 2. Strain the antifreeze into a wide mouth container (e.g., a quart-size yogurt or cottage cheese container or Whirl-Pak® bags). 3. Refill the collection cup with antifreeze as described previously. 4. In the lab, empty the contents of the bags into sorting pans. 5. Flush out all remaining debris and small insects into the sorting pan by squirting the bag with water. 6. Remove insects of interest with soft forceps or a fine-tipped paint brush. 7. Prepare the specimens for identification and shipping. Refer to ***How to Submit Bark Beetle Specimens*** on **page C-1** for further information.
Dry collection	1. Remove the collection cup from the bottom of the trap and remove all debris (leaves, twigs etc.) with a pair of long forceps. 2. Use a small, soft-bristled brush to carefully brush all insect specimens into a large re-sealable plastic bag. 3. Re-attach the collection cup. 4. Transport the plastic bags with insect specimens in a cooler with ice packs back to the lab. 5. In the lab, empty the contents of the bags into sorting pans. 6. Flush out all remaining debris and small insects into the sorting pan by squirting the bag with water. 7. Remove insects of interest with soft forceps or a fine-tipped paint brush. 8. Prepare the specimens for identification and shipping. Refer to ***How to Submit Bark Beetle Specimens*** on **page C-1** for further informaiton.

Trap Trees

Trap trees can be either intentionally damaged through girdling or other means, or else parts of a cut tree (*Figure 4-4* **on page 4-19**). These traps release attractants naturally that can be used to survey for certain types of wood-boring and bark beetles. Trap trees are left in the survey area during the breeding season and are then brought to a closed facility before emergence or cut and stripped in the field so samples can be collected.

Procedure

1. Select the location.
2. Select the tree or parts of a tree.
3. Strip the bark and leave the trap tree at the location during the breeding season of the pest.
4. Collect the pests as they emerge from the tree.

Figure 4-4 Girdled Trap Tree (Pennsylvania Department of Conservation and Natural Resources, Forestry Archive, http://www.bugwood.org UGA 5022080)

Pest-Specific Trapping and Lures

Buprestidae

Agrilus biguttatus* Fabricius—Agrilus biguttatus* does not currently have a trap and lure available. However, large sticky purple prism traps may work for *Agrilus* species other than emerald ash borer (*Agrilus planipennis* (Fairmaire)(Buprestidae)), but it is not confirmed for this species. More research needs to be completed to determine if a trap and lure combination would be effective at trapping this species.

Cerambycidae

Monochamus saltuarius*—Monochamus saltuarius* Gebleris does not have a trap and lure available. Although it has been shown that *Monochamus alternatus* (Japanese pine sawyer beetle) is attracted to pine monoterpenes, plant volatiles have not yet been shown to be attractive to *Monochamus saltuarius*. According to preliminary work by Kobayashi et al. (2003), a sex pheromone may be present on the cuticle of females and virgin males. More research needs to be completed to determine if a trap and lure combination would be effective at trapping this species. Attractants for *Monochamus alternatus* may be useful in surveying for this pest, but more research should be done to determine efficacy.

Monochamus sutor*—Monochamus sutor* Linnaeus does not have a trap and lure available. However, it has been shown that *Monochamus sutor* is attracted to pine monoterpenes. More research needs to be completed to determine if a trap and lure combination would be effective at trapping this species. Attractants for *Monochamus alternatus* (Japanese pine sawyer beetle) may be useful in surveying for this pest, but more research should be done to determine efficacy.

***Tetropium castaneum* Linnaeus—**The most effective trap and lure combination for *Tetropium castaneum* is a cross-vane panel trap with a three lure combination. The first lure is a spruce blend lure, containing the following: alpha-pinene (44 percent), (-)-beta-pinene (19 percent), (+)-3-carene (10 percent), (+)-limonene (18 percent) and alpha-terpinolene (9 percent). The second lure is geranyl acetol (fuscol/fuscomol). The third lure is ultra-high release ethanol. The geranyl acetol lure is the male-produced sex pheromone emitted by *Tetropium fuscum* Fabricius and *Tetropium cinnamopterum* (Kirby) (eastern larch borer) (Silk and Sweeney, 2007; Silk et al., 2007) and is a powerful attractant to *Tetropium castaneum*. Every effort should be made to include this lure in trapping; however, if it is not available, use the other two lures.

Trap trees are used for *Tetropium castaneum* when population densities are high. Install 1–3 trap trees per ha around mid-May and checked in June or July; trees should be debarked before larvae bore into the wood around late July (Kolk and Starzyk, 1996).

***Tetropium fuscum*—**The most effective trap and lure combination for *Tetropium fuscum* Fabricius is a cross-vane panel trap with a three lure combination. The first lure is a spruce blend lure containing the following: alpha-pinene (44 percent), (-)-beta-pinene (19 percent), (+)-3-carene (10 percent), (+)-limonene (18 percent) and alpha-terpinolene (9 percent). The second lure is geranyl acetol (fuscol/fuscomol). The third lure isultra-high release ethanol.

The geranyl acetol lure is the male-produced sex pheromone emitted by *Tetropium fuscum* and *Tetropium cinnamopterum* (Kirby) (eastern larch borer) (Silk and Sweeney, 2007; Silk et al., 2007) and is a powerful attractant to *Tetropium fuscum*. Every effort should be made to include this lure in trapping; however, if it is not available, use the other two lures.

Curculionidae

***Platypus quercivorus* Murayama *(Platypodinae)*—**The CAPS-approved survey method for *Platypus quercivorus* Murayama is the synthetic aggregation pheromone for this species in a multi-funnel trap. The pheromone is (1S,4R)-4-isopropyl-1-methyl-2-cyclohexen-1-ol and abbreviated as (-)-IMCH (Kamata et al., 2008; Mori, 2006).

The same pheromone is also referred to as (1S,4R)-p-Menth-2-en-1-ol or quercivorol (Kashiwagi et al., 2006; Tokuro et al., 2007). (1S,4R)-4-isopropyl-1-methyl-2-cyclohexen-1-ol is the International Union of Pure and Applied Chemistry (IUPAC) name; IUPAC chemical names are regarded as the standard in chemical nomenclature. The CAPS program is investigating the availability of this lure.

***Tomicus destruens Wollaston (Scolytinae)*—**The most effective survey method for *Tomicus destruens* Wollaston is a multi-funnel trap with a two lure combination including ultra high release alpha-pinene and ultra-high release ethanol.

Visual Inspection

This section provides information that will help surveyors find exotic wood-boring and bark beetles in the field. Use visual inspection to locate exotic wood-boring and bark beetles that would not be detected by other survey methods. Visual inspection is inexpensive and easy to perform; however, it is labor and time intensive, and its efficiency will vary with the habitat.

Although ground and aerial surveys may be the only viable option for some exotic wood-boring and bark beetles due to the lack of known attractants, these methods may not lead to the discovery of early infestations (Brockerhoff, 2009). Many species exhibit long periods of time between the establishment and build up of population levels to levels that are detectable (Brockerhoff, 2009). This is why survey efforts should be focused on areas at high risk, such as ports of entry where surveys can be more intensive and involve closer examination of host plants. These measures are difficult to carry out in forest settings (Brockerhoff, 2009).

When surveying for specific species, make sure to survey the correct host genera for each pest. For example, visually inspect oaks when surveying for *Agrilus biguttatus* Fabricius. For further information on plant hosts, refer to ***Reported Hosts*** on **page D-1**.

The hosts listed for each pest were reported from their current distributions, and these host species may not be present in the United States. If pests are introduced into new areas, they may attack native species that have not previously been identified as host plants. Therefore, host species should be surveyed (where applicable) and surveys should be broadened to native species within the host genera.

Procedure

1. Use the host lists in the appendix ***Reported Hosts*** on **page D-1** to select which trees to observe.
2. Examine the selected host plants, following the instructions provided in the section ***Pest-Specific Visual Inspection*** on **page 4-23**.

Pest-Specific Visual Inspection

Buprestidae

***Agrilus biguttatus* Fabricius—**Surveying for *Agrilus biguttatus* is difficult because there are no attractants or traps known for this pest. More research is needed to improve survey techniques for this species. Beat and sweep sampling are not effective at catching adults (Foster, 1987, Allen, 1988). Visual survey is currently the only viable option. Signs to look for when visually inspecting hosts include the following:

- Characteristic D-shaped exit holes (***Figure 4-7* on page 4-26**)
- Galleries that begin longitudinally, but become twisted and transverse as larvae age (Moraal and Hilszczanski, 2000b) (***Figure 4-5* on page 4-24**)
- Subcortical necrosis and longitudinal bark cracking due to early larval stages feeding (Vansteenkiske et al., 2004)
- Infested trees can also show symptoms of thin crowns, epicormic shoots, dieback or tree death at later stages of infestation (Moraal and Hilszczanski, 2000a, 2000b) (***Figure 4-6* on page 4-25** and ***Figure 4-8* on page 4-27**)

All of the signs may not be present. According to anecdotal evidence, *Agrilus biguttatus* is most active in sunlight (Godfrey, 1987; Allen, 1988; Smith, 1994).

Sites should be oak plantings or natural settings with oaks present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources. This pest is most closely associated with the following biomes (Davis et al., 2006):

- Desert and xeric shrublands
- Mediterranean scrub
- Temperate broadleaf and mixed forests
- Temperate coniferous forests.

These biomes make up approximately 68 percent of the continental United States (Davis et al., 2006).

Agrilus biguttatus emerges between May and August, but peaks from June to July (reviewed in Davis et al., 2006). In general, Buprestidae adults usually emerge in spring (around May or June in temperate, northern hemisphere areas) (Evans et al., 2004).

Some evidence suggests that *Agrilus biguttatus* may be attracted to stressed trees (Moraal and Hilszczanski, 2000b, reviewed in Vansteenkiste et al., 2004). If correct, trap trees may be a viable alternative to visual surveying but additional research is needed to support this. When using trap trees for Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)(Cerambycidae)) the tree is girdled to create stress while Tanglefoot® is spread above the girdle in order to trap incoming adults (reviewed in Davis et al., 2006). Trees are cut and debarked at the end of the season to determine if larvae are present (reviewed in Davis et al., 2006).

Large sticky purple prism traps may be an effective trap for *Agrilus* species other than emerald ash borer (*Agrilus planipennis* (Fairmaire)); however, the trap has not been evaluated for use with emerald ash borer.

Solitary Ground-Nesting Wasp.

An additional tool that may be of use in detecting, delimiting, and monitoring surveys for *Agrilus biguttatus* is the solitary ground-nesting wasp *Cerceris fumipennis*. The female wasp stocks her nest with buprestid beetles. The wasp has been recorded to collect over 30 *Agrilus* species (Careless et al., 2009). Surveyors in Canada and the United States are currently monitoring *Cerceris fumipennis* nests to detect new populations of the emerald ash borer. Collecting beetles that the wasps bring back to their nests has proven to be the most effective means of surveying for emerald ash borer (Careless et al., 2009). It is not known if the wasp collects *Agrilus biguttatus*. Refer to ***Wasp Watcher Brochure*** on **page H-1** for further information.

Figure 4-5 Gallery Damage caused by *Agrilus biguttatus* Fabricius (Buprestidae) (Gyorgy Csoka, Hungary Forest Research Institute, http://www.bugwood.org UGA 1231054)

Figure 4-6 Thin crown caused by *Agrilus biguttatus* Fabricius (Buprestidae) (Louis-Michel Nageleisen, Département de la Santé des Forêts, http://www.bugwood.org)

Figure 4-7 Characteristic D-shaped exit hole of Emerald Ash Borer (*Agrilus planipennis* (Fairmaire)(Buprestidae)) (David Cappaert, Michigan State University, http://www.bugwood.org UGA 5110034)

Figure 4-8 Epicormic Shoots Caused by Emerald Ash Borer Damage (*Agrilus planipennis* (Fairmaire)(Buprestidae)) (Pennsylvania Department of Conservation and Natural Resources - Forestry Archive, http://www.bugwood.org UGA 5022037)

Cerambycidae

Monochamus saltuarius* Gebleris—**Surveying for *Monochamus saltuarius* is difficult because there are no attractants or traps known for this pest. Visual survey is currently the only viable option. Signs to look for when visually inspecting hosts include the following (Figure 4-9* on page 4-29**):

- Oviposition scars
- Round to oval exit holes
- Dead or damaged shoots due to maturation feeding (may have reddish-brown foliage)
- Larval galleries packed with frass and wood shreds
- U-shaped pupal chambers (reviewed in Ciesla, 2001)

Signs that an Asian *Bursaphelenchus* spp. has been introduced with *Monochamus saltuarius* Gebleris include the following (***Figure 4-10* on page 4-30** and ***Figure 4-11* on page 4-31**):

- Chlorosis of tree
- Wilting of needles
- Decreased resin production (reviewed in Ciesla, 2001)

Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of this pest.

Site Selection.

Sites selected should be plantings or natural settings with Abies, Larix, Picea and/or Pinus species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources.

Davis et al. (2008) believe that this pest is most closely associated with temperate coniferous forests, and temperate broadleaf and mixed forests. These biomes make up approximately 47 percent of the continental United States, particularly east of the Mississippi River, the Pacific Northwest, Sierra-Nevada Mountains, and scattered throughout the intermountain West (Davis et al., 2008).

When to Survey.

Depending on climate, adults emerge from spring to early summer (reviewed in CABI, 2010).

Other Methods.

An effective attractant has not yet been identified for *Monochamus saltuarius*. According to preliminary work by Kobayashi et al. (2003), a sex pheromone may be present on the cuticle of females and virgin males.

Other cerambycids and *Monochamus* species have been shown to respond to bark beetle pheromones (Miller and Asaro 2005) and/or pine monoterpenes; however, different species respond to different combinations of host volatiles and bark beetle pheromones. Ipsenol and ipsdienol, two pheromones used by the bark beetle genus Ips, have been shown to attract *Monochamus* species (Miller and Asaro 2005; Miller and Borden 1990; Allison et al. 2001, 2003). Ibeas et al. (2006) found the combination of ipsenol, alpha-pinene and methylbutenol to be an effective lure for *Monochamus galloprincialis*. For *Monochamus alternatus*, the combination of alpha-pinene, beta-pinene, and 3-carene is used (Fan et al., 2007).

For *Monochamus saltuarius* surveys, in the absence of an identified, effective attractant, the combination of alpha-pinene, beta-pinene, and 3-carene could be used as a generic *Monochamus* lure. It is assumed that *M. saltuarius*, a species of Euroasian origin, would behave similarly to the Asian species, *M. alternatus*; however, this combination has not yet been evaluated for *M. saltuarius*. More research is needed to improve survey techniques for this species.

Figure 4-9 Damage Caused by *Monochamus saltuarius* Gebleris (Cerambycidae) (Gyorgy Csoka, Hungary Forest Research Institute, http://www.bugwood.org UGA 1231143)

Figure 4-10 Wilting of Needles of Austrian Pine caused by *Bursaphelenchus xylophilus* (USDA Forest Service-North Central Research Station Archive, USDA Forest Service, http://www.bugwood.org UGA 1406272)

Figure 4-11 Chlorosis of Needles caused by *Bursaphelenchus xylophilus* (A. Steven Munson, USDA Forest Service, http://www.bugwood.org UGA 1470133)

Monochamus sutor* Linnaeus—**Surveying for this pest is difficult because there are no attractants or traps known for this pest. Visual survey is currently the only viable option. Signs to look for when visually inspecting hosts (Figure 4-12* on page 4-32** and ***Figure 4-13* on page 4-33**):

- Oviposition scars
- Round to oval exit holes
- Dead or damaged shoots due to maturation feeding (may have reddish-brown foliage)
- Larval galleries packed with frass and wood shreds
- U-shaped pupal chambers (reviewed in Ciesla, 2004)

Figure 4-12 Larva Entrance Hole (right) and Adult Exit Hole (left) for *Monochamus sutor* Linnaeus (Cerambycidae) (Stanislaw Kinelski, http://www.bugwood.org UGA 1258226)

Figure 4-13 Larval Gallery of *Monochamus sutor* Linnaeus (Cerambycidae) on Spruce (Stanislaw Kinelski, http://www.bugwood.org UGA 1258225)

Signs that an Asian *Bursaphelenchus* spp. has been introduced with *M. sutor* include the following:

- Chlorosis of tree
- Wilting of needles
- Decreased resin production (reviewed in Ciesla, 2004)

Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of this pest.

Site Selection.

Sites selected should be plantings or natural settings with Abies, Larix, Picea and/or Pinus species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources. This pest is most closely associated with the following biomes (Davis et al. 2008):

- Temperate coniferous forests
- Temperate broadleaf and mixed forests

These biomes make up approximately 47 percent of the continental United States, particularly east of the Mississippi River, the Pacific Northwest, Sierra-Nevada Mountains and scattered throughout the Intermountain West (Davis et al., 2008).

When to Survey.

In Europe, adults fly from mid June to September (Kolk and Starzyk, 1996).

Other Methods.

An effective attractant has not yet been identified for M. sutor. Other cerambycids and *Monochamus* species have been shown to respond to bark beetle pheromones (Miller and Asaro, 2005) and/or pine monoterpenes; however, different species respond to different combinations of host volatiles and bark beetle pheromones. Ipsenol and ipsdienol, two pheromones used by the bark beetle genus Ips, have been shown to attract *Monochamus* species (Miller and Asaro, 2005; Miller and Borden, 1990; Allison et al., 2001, 2003). Ibeas et al. (2006) found the combination of ipsenol, alpha-pinene and methylbutenol to be an effective lure for *Monochamus galloprincialis*. For *Monochamus alternatus*, the combination of alpha-pinene, beta-pinene, and 3-carene is used (Fan et al., 2007).

For *M. sutor* surveys, in the absence of an identified, effective attractant, the combination of ipsenol, alpha-pinene and methylbutenol could be used as a generic *Monochamus* lure. It is assumed that *M. sutor*, a species of European origin, would behave similarly to the European species, *M. alternatus*; however, these combinations have not yet been evaluated for *M. sutor.* More research is needed to improve survey techniques for this species.

Tetropium castaneum* Linnaeus—**A trap and lure combination is available for *Tetropium castaneum*. Visual inspection can be used as a supplement to trapping, but should not be the main survey strategy employed. Signs to look for when visually inspecting hosts (Figure 4-14* on page 4-35**):

- Oval shaped exit holes
- Larval feeding galleries filled with granular frass
- Wind snapped tree trunks
- Fading foliage of live trees (reviewed in Dobesberger, 2005a)

Figure 4-14 Gallery of *Tetropium castaneum* Linnaeus (Cerambycidae) (Gyorgy Csoka, Hungary Forest Research Institute, http://www.bugwood.org)

These symptoms are not specific to *Tetropium castaneum* but are typical of many wood borers (reviewed in Dobesberger, 2005a). Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of this pest.

Site Selection.

Sites selected should be plantings or natural settings with *Abies*, *Picea* and/or *Pinus* species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources.

When to Survey.

Depending on weather conditions and geographical location, *Tetropium castaneum* usually emerges beginning in May and continues throughout the summer (Novak et al., 1976).

Other Methods.

An effective trap and lure combination has been identified for *Tetropium castaneum*. For further information refer to ***Pest-Specific Trapping and Lures*** on **page 4-20**.

Tetropium fuscum* Fabricius—**A trap and lure combination is available for *Tetropium fuscum*. For further information, refer to ***Pest-Specific Trapping and Lures on **page 4-20**. Visual inspection can be used as a supplement to trapping, but should not be the main survey strategy employed. Signs to look for when visually inspecting hosts (***Figure 4-15*** **on page 4-36**):

- Copious resin flows
- Yellowing of the crown
- Loss of needles
- Oval shaped exit holes
- Irregular feeding tunnels up to 6 mm across, packed with frass and wood fibers in the cambium layer (reviewed in Dobesberger, 2005b)
- Larval tunnels and pupal chambers extending up to 4 cm into the cambium layer (Jacobs et al., 2003)

Figure 4-15 Resinosis on Red Spruce Trunk caused by *Tetropium fuscum* Fabricius (Cerambycidae) (Jon Sweeney, Natural Resources Canada, http://www.bugwood.org UGA 5331008)

Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of this pest.

Site Selection.

Sites selected should be plantings or natural settings with Picea and/or Pinus species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources. This pest is most closely associated with the following biomes (Davis et al. 2008):

- Temperate coniferous forests
- Temperate broadleaf and mixed forests

These biomes make up approximately 47 percent of the continental United States, particularly east of the Mississippi River, the Pacific Northwest, Sierra-Nevada Mountains and scattered throughout the Intermountain West (Davis et al., 2008).

When to Survey.

In Europe, adults fly from May to September (Kolk and Starzyk, 1996).

Other Methods.

An effective trap and lure has been identified for *Tetropium fuscum*. For further information refer to ***Pest-Specific Trapping and Lures*** on **page 4-20**.

Curculionidae

Platypus quercivorus **Murayama *(Platypodinae)*—**An attractant was recently approved by the CAPS program for *Platypus quercivorus*. As of June, 2010, the CAPS program is investigating the availability of this lure. Currently, visual inspections are used in declining or suspect stands. Stands are considered suspect if wilted canopies are observed in summer without drought and/or leaves have a reddish-brown discoloration (Ciesla, 2003d).

Signs to look for when visually inspecting hosts:

- Splinter-like wood shavings at the base of trees
- Wilted canopies in summer when no drought is present
- Reddish-brown discoloration of leaves (reviewed in Ciesla, 2003d)
- Entrance holes caused by adult males (reviewed in Davis et al., 2006)

Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of this pest.

Site Selection.

Sites selected should be plantings or natural settings with Fagaceae species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources. Only a select few known hosts of this pest occur in the United States, including *Quercus mongolica* (Mongolian oak), *Quercus acutissima* (sawtooth oak) and *Castanea crenata* (Japanese chestnut). Survey efforts should be focused on areas where these hosts are present.

This pest is most closely associated with the following biomes (Davis et al. 2006):

- Temperate broadleaf and mixed forests
- Tropical and subtropical moist broadleaf forests

These biomes make up approximately 29 percent of the continental United States (Davis et al., 2006).

When to Survey.

Interception traps should be placed at the beginning of the flight period for P. quercivorus. In Japan this occurs in June or July (Davis et al., 2006; Ueda and Kobayashi, 2001). Traps should be placed at the edge of a stand, where the increase in light attracts adults, (Igeta et al., 2003) and checked weekly (Davis et al., 2006).

Other Methods.

"Bait logs have also been proposed as a monitoring tool. Logs should be >1 m

[~3 ¼ ft] long with a moisture content >60 percent; trap logs should be placed away from direct sunlight (Kobayashi and Ueda 2003, Kobayashi et al. 2004). Autoclaving logs extended their attractiveness (Ueda and Kobayashi 2004). This method cannot yet be recommended for use in the United States because *Quercus crispula*, the species used for bait logs in Japan, is not widely available. Other tree species have not been tested" (Davis et al., 2006).

Japanese researchers recommend using interception traps as a compliment to visual surveys (Kinuura, 1995, Esaki et al., 2002). It should be noted that these are non-selective at catching flying insects. Interception traps are described in Davis et al. (2006).

More research is needed to improve survey techniques for P. quercivorus.

Tomicus destruens Wollaston (Scolytinae)—A trap and lure combination is available for *Tomicus destruens* Wollaston. For further information refer to *Pest-Specific Trapping and Lures* on **page 4-20**. Visual inspection can be used as a supplement to trapping, but should not be the main survey strategy employed.

Signs to look for when visually inspecting hosts (***Figure 4-16* on page 4-39**):

- Feeding damage on young shoots
- Reddish-brown boring dust
- Small, round exit holes
- Maternal and larval galleries under bark
- Discolored blue-stain fungi in the xylem (reviewed in Ciesla, 2003c).

Figure 4-16 Damage caused by *Tomicus destruens* Wollaston (Scolytinae) (William M. Ciesla, Forest Health Management International, http://www.bugwood.org UGA 2500015)

Not all symptoms or signs may be present; symptoms or signs should not be relied on exclusively for detecting the presence of *Tomicus destruens*.

Site Selection.

Sites selected should be plantings or natural settings with Pinus species present, preferably near warehouses or other businesses that receive wood crating, pallets and dunnage from foreign sources.

This pest is most closely associated with the following biomes (Davis et al. 2008):

- Temperate coniferous forests
- Temperate broadleaf and mixed forests
- Mediterranean scrub

These biomes make up approximately 48 percent of the continental United States, particularly east of the Mississippi River, the Pacific Coast, Pacific Northwest, Sierra-Nevada Mountains and scattered throughout the Intermountain West (Davis et al., 2008).

When to Survey.

Visual surveys should be done in autumn during *Tomicus destruens* flight period (Gallego and Galián, 2001).

Other Methods.

Tomicus destruens has a trap and lure identified. Refer to ***Pest-Specific Trapping and Lures*** on **page 4-20** for further information.

Survey Records

Maintain records for each survey site. Negative survey data must be recorded even if no beetles are found or no samples are collected at a surveyed site. Survey records and data-recording formats should be consistent, to allow for standardized collection of information. If automated collection devices are used, such as the Integrated Survey Information System (ISIS), ensure that all surveyors are trained in the technology before beginning a survey. Use the appropriate ISIS templates for the survey type. To reduce the burden on data collectors in the field, pre-enter any known contact or address information into the database and hand-held data recorders. At the end of the survey, all survey data should be entered into a designated State or National pest database. For specific directions on how to access the ISIS template for exotic wood-boring and bark beetles, contact ISIS Customer Support.

Address	USDA–APHIS-Integrated Survey Information System http://ppqcoop.aphis.usda.gov/web/ Default.aspx?alias=ppqcoop.aphis.usda.gov/web/isis

5 Regulatory Procedures

Exotic Wood-Boring and Bark Beetles

Contents

Introduction

Use *Chapter 5 Regulatory Procedures* as a guide to the procedures that must be followed by regulatory personnel when conducting pest survey and control programs against the exotic wood-boring and bark beetles (EWBBB) absent from the United States and collaborating territories. Selected species in the order Coleoptera, families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the general information found in the guidelines may be applicable for other exotic wood-boring and bark beetles.

Instructions to Officials

Agricultural officials must follow instructions for regulatory treatments or other procedures when authorizing the movement of regulated articles. Understanding the instructions and procedures is essential when explaining procedures to persons interested in moving articles affected by the quarantine and regulations. Only authorized treatments can be used in accordance with labeling restrictions. During all field visits, please ensure that proper sanitation procedures are followed as outlined in ***Preparation, Sanitization, and Clean-up*** on **page 4-2**.

Regulatory Actions and Authorities

After an initial suspect positive detection, an Emergency Action Notification may be issued to hold articles or facilities, pending positive identification by a USDA–APHIS–PPQ-recognized authority and/or further instruction from the PPQ Deputy Administrator. If necessary, the Deputy Administrator will issue a letter directing PPQ field offices to initiate specific emergency action under the Plant Protection Act until emergency regulations can be published in the *Federal Register.*

The Plant Protection Act of 2000 (Statute 7 USC 7701-7758) provides for authority for emergency quarantine action. This provision is for interstate regulatory action only; intrastate regulatory action is provided under State authority. State departments of agriculture normally work in conjunction with Federal actions by issuing their own parallel hold orders and quarantines for intrastate movement. However, if the U.S. Secretary of Agriculture determines that an extraordinary emergency exists and that the States measures are inadequate, USDA can take intrastate regulatory action provided that the governor of the State has been consulted and a notice has been published in the *Federal Register.* If intrastate action cannot or will not be taken by a State, PPQ may find it necessary to quarantine an entire State.

PPQ works in conjunction with State departments of agriculture to conduct surveys, enforce regulations, and take control actions. PPQ employees must have permission of the property owner before entering private property. Under certain situations during a declared extraordinary emergency or if a warrant is obtained, PPQ can enter private property in the absence of owner permission. PPQ prefers to work with the State to facilitate access when permission is denied, however each State government has varying authorities regarding entering private property. A General Memorandum of Understanding (MOU) exists between PPQ and each State that specifies various areas where PPQ and the State department of agriculture cooperate. For clarification, check with your State Plant Health Director (SPHD) or State Plant Regulatory Official (SPRO) in the affected State.

Tribal Governments

USDA–APHIS–PPQ also works with federally-recognized Indian Tribes to conduct surveys, enforce regulations and take control actions. Each Tribe stands as a separate governmental entity (sovereign nation) with powers and authorities similar to State governments. Permission is required to enter and access Tribal lands.

Executive Order 13175, Consultation and Coordination with Indian and Tribal Governments, states that agencies must consult with Indian Tribal governments about actions that may have substantial direct effects on Tribes. Whether an action is substantial and direct is determined by the Tribes. Effects are not limited to current Tribal land boundaries (reservations) and may include effects on off-reservation land or resources which Tribes customarily use or even effects on historic or sacred sites in States where Tribes no longer exist.

Consultation is a specialized form of communication and coordination between the Federal and Tribal governments. Consultation must be conducted early in the development of a regulatory action to ensure that Tribes have opportunity to identify resources which may be affected by the action and to recommend the best ways to take actions on Tribal lands or affecting Tribal resources. Communication with Tribal leadership follows special communication protocols. For additional information, contact PPQ's Tribal Liaison.

Address	National Program Manager for Native American Program Delivery and Tribal Liaison USDA–APHIS–PPQ 14082 S. Poston Place Tucson, AZ 85736 Telephone: (520) 822-5440

To determine if there are federally-recognized Tribes in a State, contact the State Plant Health Director (SPHD). To determine if there are sacred or historic sites in an area, contact the State Historic Preservation Officer (SHPO). For clarification, check with your SPHD or State Plant Regulatory Official (SPRO) in the affected State.

Overview of Regulatory Program After Detection

Once an initial U.S. detection is confirmed, holds will be placed on the property by the issuance of an Emergency Action Notification. (See ***Example of PPQ 523 Emergency Action Notification*** on **page B-7**.) Immediately place a hold on the property to prevent the removal of any host plants of exotic wood-boring and bark beetles.

Traceback and trace-forward investigations from the property will determine the need for subsequent holds for testing and/or further regulatory actions. Further delimiting surveys and testing will identify positive properties requiring holds and regulatory measures prescribed.

Record-Keeping

Record-keeping and documentation are important for any holds and subsequent actions taken. Rely on receipts, shipping records and information provided by the owners, researchers or manager for information on destination of shipped plant material, movement of plant material within the facility, and any management (cultural or sanitation) practices employed.

Keep a detailed account of the numbers and types of plants held, destroyed, and/or requiring treatments in control actions. Consult a master list of properties, distributed with the lists of suspect nurseries based on traceback and trace-forward investigations, or nurseries within a quarantine area. Draw maps of the facility layout to located suspect plants, and/or other potentially infected areas. When appropriate, take photographs of the symptoms, property layout, and document plant propagation methods, labeling, and any other information that may be useful for further investigations and analysis.

Keep all written records filed with the Emergency Action Notification copies, including copies of sample submission forms, documentation of control activities, and related State issued documents if available.

Issuing an Emergency Action Notification

Issue an Emergency Action Notification to hold all host plant material at facilities that have the suspected plant material directly or indirectly connected to positive confirmations. Once an investigation determines the plant material is **not** infested, or testing determines there is **no** risk, the material may be released and the release documented on the EAN.

Regulated Area Requirements Under Regulatory Control

Depending upon decisions made by Federal and State regulatory officials in consultation with a Technical Working Group, quarantine areas may have certain other requirements for commercial or research fields in that area, such as plant removal and destruction, weevil cultural control measures, or plant waste material disposal.

Any regulatory treatments used to control exotic wood-boring and bark beetles or herbicides used to treat plants will be labeled for that use or exemptions will be in place to allow the use of other materials.

Establishing a Federal Regulatory Area or Action

Regulatory actions undertaken using Emergency Action Notifications continue to be in effect until the prescribed action is carried out and documented by regulatory officials. These may be short-term destruction or disinfestation orders or longer term requirements for growers that include prohibiting the planting of host crops for a period of time. Over the long term, producers, shippers, and processors may be placed under compliance agreements and permits issued to move regulated articles out of a quarantine area or property under an EAN.

Results analyzed from investigations, testing, and risk assessment will determine the area to be designated for a Federal and parallel State regulatory action. Risk factors will take into account positive testing, positive associated, and potentially infested exposed plants. Boundaries drawn may include a buffer area determined based on risk factors and epidemiology.

Regulatory Records

Maintain standardized regulatory records and database(s) in sufficient detail to carry out an effective, efficient, and responsible regulatory program.

Use of Chemicals

The PPQ *Treatment Manual* and the guidelines identify the authorized chemicals, and describe the methods and rates of application, and any special application instructions. For further information refer to **Control Procedures** on **page 6-1**. Concurrence by PPQ is necessary before using any chemical or procedure for regulatory purposes. No chemical can be recommended that is not specifically labeled for exotic wood-boring and bark beetles.

6

Exotic Wood-Boring and Bark Beetles

Control Procedures

Contents

Introduction

Use *Chapter 6 Control* to learn more about controlling an infestation of wood-boring and bark beetles (EWBBB) in the United States and collaborating territories. Selected species in the families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the general information found in these guidelines may be applicable for other exotic wood-boring and bark beetles.

Successful control of EWBBB species depends on discovering the pests soon after introduction.

Overview of Emergency Programs

APHIS-PPQ develops and makes control measures available to involved States. Environmental Protection Agency-approved treatments will be recommended when available. If selected treatments are not labeled for use against the organism or in a particular environment, PPQs FIFRA Coordinator is available to explore the appropriateness in developing an Emergency Exemption under Section 18, or a State Special Local Need under section 24(c) of FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act), as amended. The PPQ FIFRA Coordinator is also available upon request to work with EPA to expedite approval of a product that may not be registered in the United States or to obtain labeling for a new use-site. The PPQ FIFRA Coordinator is available for guidance pertaining to pesticide use and registration. For contact information, refer to ***Resources*** on **page A-1**.

Treatment Options

Consider the treatment options described within this chapter when taking action to eradicate or control exotic wood-boring and bark beetles.

Treatments may include the following:

- *Chemical Controls* on **page 6-5**
- *EPA Registered Insecticides* on **page 6-8**
- *Cultural Controls* on **page 6-10**
- *Pest-Specific Cultural Controls* on **page 6-11**
- *Biological Controls* on **page 6-13**
- *Other Control Methods* on **page 6-14**

Environmental Documentation and Monitoring

Obtain all required environmental documentation before beginning. Contact Environmental Services Staff for the most recent documentation. For further information, refer to ***Environmental Compliance*** on **page 7-1**.

Efficacy of Treatment

Eradication measures should be continued for several years to ensure that populations of exotic wood-boring and bark beetles have been eliminated. Once the pest has been eradicated, monitoring of the site should be continued for 1 to 2 years. For more information, refer to ***Monitoring Survey*** on **page 4-8**.

Site Assessment

Site Visit

When visiting a site keep a log of observations, flag the infested areas, and record the coordinates. Also, record the name of the property owner. Some of this information may have been recorded during the survey (see ***Preparation, Sanitization, and Clean-up*** on **page 4-2**). Communicate frequently with the person responsible for the site.

Classification

Information on the type of property needs to be recorded to help develop a control plan. Site access, security, containment, and ownership type may dictate a particular direction in eradication options. Prepare a concise overview of the infested area. Record information about the infested property, including the following:

- Location
- Type of property ownership (government, private, tribal, commercial, residential or agricultural)
- Current and past property uses
- Distribution of exotic wood-boring and bark beetles
- Status of security and containment
- Modes of artificial movement

Safeguarding Against Artificial Movement

The most likely way that exotic wood-boring and bark beetles would be moved artificially would be through host material. Types of commonly moved host material include wood packing material, host logs, and host nursery stock. The biggest risk is likely from movement of firewood.

When exotic wood-boring and bark beetles are found in an area, care should be taken to carefully check host material moving out of the immediate area. If necessary, quarantines may be put into place to help prevent the spread of the target pest to uninfested areas. For further information, refer to ***Issuing an Emergency Action Notification*** on **page 5-5.**

Chemical Controls

Many wood-boring and bark beetles are cryptic in nature, spending most of their time beneath the bark. This behavior protects a majority of the life cycle from many of the commonly used insecticides. This makes treatments with chemicals very difficult. The most effective treatments will be systemic insecticides which are injected into the trunk or soil and travel through the vascular transport system of the tree. These types of chemical control may be labor intensive and expensive due to the necessity of repeated treatments.

Many current programs such as those for Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky) (Cerambycidae) or emerald ash borer (*Agrilus planipennis* (Fairmaire) (Buprestidae)) do not use insecticides as a major component of their control measures. Treatments most likely will not kill the entire target pest population, but through annual treatment it may protect valuable shade trees (Cappaert et al., 2005).

Application

At the initiation of an eradication program, evaluate the available insecticides for their use in program operations. Select an insecticide after considering local conditions along with survey results.

Labeling

While the proposed formulation is approved for an effective eradication program, it may not be labeled, at the time of pest detection, for the specific use-site where treatment is required. If a formulation is not labeled for the needed use, it may be possible to request a Federal Crisis or Quarantine Exemption from the U.S. Environmental Protection Agency (EPA) under Section 18 of the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). For further information refer to ***Regulatory Procedures*** on **page 5-1**.

The prescribed formulation must be labeled for use on the site where it is to be applied and must be registered for use in the State where the eradication program is occurring. All applicable label directions must be followed, including requirements for personal protection equipment, maximum treatment rates, storage and disposal.

Refer to ***Table 6-1*** **on page 6-9** for a list of EPA-registered insecticides for the control of exotic wood-boring and bark beetles.

Pest-Specific Chemical Controls

Important

All treatments listed in the guidelines should only be used as a reference to assist in the regulatory decision making process. It is the National Program Manager's responsibility to verify that treatments are appropriate and legal for use. Upon detection and when a chemical treatment is selected, the National Program Manager should consult with PPQ's FIFRA Coordinator to ensure that the chemical is approved by EPA for use in the United States prior to application.

Buprestidae

Agrilus biguttatus **Fabricius—**In Europe, chemical controls are rarely used for *Agrilus* species (Evans et al., 2004). In a few cases, insecticides may be applied to cut trees (Evans et al., 2004).

Cerambycidae

Monochamus saltuarius **Gebleris and** ***Monochamus sutor*** **Linnaeus—** Chemical control for these pests is actually aimed at controlling the nematode *Bursaphelenchus xylophilus*, the causal agent of pine wilt disease. Apply fenitrothion, carbaryl, fenthion and diazinon to the crown of trees to prevent adult feeding of *Monochamus alternatus* (Japanese pine sawyer beetle) on pine twig bark (Kobayashi, 1988). Inject mesulfenfos, morantel tartrate and levamisole hydrochloride into healthy tree trunks in winter to prevent the disease development; this effect lasts 1–2 years depending on dosage and tree size (Kobayashi, 1988).

Tetropium castaneum **Linnaeus—**Regarding *Tetropium* species, Evans et al. (2004) states that there are a few cases where insecticides are applied to felled trees to reduce infestations. Because this species is not usually considered a primary pest in native areas, there are no specific insecticides mentioned in the literature used to control the pest.

Tetropium fuscum **Fabricius—**A few chemical controls have been tested on *Tetropium fuscum* including neem seed extracts (which contain azadirachtin), imidacloprid and emamectin benzoate all injected in trees as systemics (Canadian Forest Service, 2006). Of the three, imidacloprid was the most promising, although uptake in the phloem of insecticides was slow and variable (Canadian Forest Service, 2006). Kreutzweiser et al. (2007) stated that recent studies have indicated it is effective against *T. fuscum* in eastern Canada while Gous and Richardson (2008) states that imidacloprid is successful at controlling *T. fuscum* on *Picea* species.

Curculionidae

***Platypus quercivorus* Murayama (Platypodinae)—**Contact insecticides sprayed on host tree bark and systemic insecticides applied to the soil or host tree bark can be used on high value trees (Ciesla, 2003d). Both *Platypus quercivorus* and its associated fungus, *Ophiostoma longicollum,* can be controlled by NCS (metam-ammonium) injections into holes bored in the oak stems (Weng et al., 2000).

***Tomicus destruens* Wollaston (Scolytinae)—**Breeding attacks by *Tomicus destruens* can be prevented by spraying synthetic pyrethroid insecticides (reviewed in Ciesla, 2003c). It has also been shown that *T. destruens* can be repelled by non-host compounds (Guerrero et al., 1997). The compound tested, benzyl alcohol, can serve as an alternative anti-aggregation pheromone that is cheap, photostable and readily available (Guerrero et al., 1997).

Similar Species

Emerald ash borer (*Agrilus planipennis* (Fairmaire)(Buprestidae))— Systemic insecticides used to control emerald ash borer (EAB) can be applied in three ways: soil injections or drenches; trunk injections; or, lower trunk sprays (Herms et al., 2009). Protective cover sprays can be applied to the trunk, main branches, and foliage (Herms et al., 2009).

Several studies have found that emamectin benzoate (a trunk injected systemic insecticide) is effective at controlling emerald ash borer for at least 2 years with a single application; it provided a higher level of control than other products when tested side-by-side (Herms et al., 2009).

Other soil drenches and injections are most effective when injected at the base of the trunk (Herms et al., 2009). Imidacloprid treatments in spring or fall are effective at controlling emerald ash borer (Herms et al., 2009). Cappaert et al. (2006) found that imidacloprid-based products substantially reduced larval densities of *Agrilus planipennis* versus untreated trees.

Basal trunk spray insecticide studies have found that applications of bifenthrin, cyfluthrin, and carbaryl were effective at controlling emerald ash borer while acephate sprays and *Beauvaria bassiana* were less effective (Herms et al., 2009).

Studies on effectiveness of insecticide use on larger trees (> 25 inches d.b.h.) have been inconsistent (Herms et al., 2009). It may be necessary to combine two treatment strategies when trees are large and under high pest pressure (Herms et al., 2009).

EPA Registered Insecticides

The registration of these insecticides with the U.S. Environmental Protection Agency was based on a search of the National Pesticide Information Retrieval System (NPIRS) database in April, 2010. Users must verify the EPA registration of these insecticides. Contact the PPQ Pesticide Coordinator for their current status.

Table 6-1 EPA-Registered Insecticides Used to Control Beetles Similar to Wood-boring and Bark Beetles in the United States (NPIRS Public, 2010)

Active Ingredient	Application Method	Similar Species[1]	Crops[2]	Registrant
Bidrin® (Dicrotophos)	trunk injection	bronze birch borer, emerald ash borer	trees	J.J. Mauget Company, 2007
Bifenthrin	preventive bark and foliage cover sprays	twigborers	trees	FMC Corporation, 2007
Carbaryl	preventive bark and foliage cover sprays, trunk drench	emerald ash borer, elm bark beetle, Ips engraver beetle, mountain pine beetle, roundheaded pine beetle, spruce beetle, Western pine beetle	trees	Prokoz, Inc., 2005
Chlorpyrifos	preventive and remedial trunk and limb sprays	longhorn beetles (cottonwood, locust, red oak), metallic wood borers (bronze birch, flatheaded apple tree, two-lined chesnut)	trees	Dow AgroSciences, 2008
Cyfluthrin	preventive bark and foliage cover sprays	emerald ash borer	trees	Bayer Environmental Science, 2006
Diazinon	foliage cover spray	twig borers	fruit and nut trees	MANA, Makhteshim Agan of North America, Inc., n.d.
Dinotefuran	systemic bark spray	flatheaded borers, roundheaded borers including Asian longhorned beetle	ornamentals and trees	Valent USA. Corporation, 2007
Emamectin benzoate	trunk injection	flathead borers, emerald ash borer, bronze birch borer, two-lined chestnut borer, longhorn borers, roundhead borers, eucalyptus borer, pine sawyer, bark beetles, Ips engraver beetles, mountain pine beetle, southern pine beetle, spruce beetle, western pine beetle	ash trees	Syngenta Crop Protection, 2009.
Imadacloprid	soil injection or drench, trunk injection	emerald ash borer, flatheaded borers, bronze birch borer, alder borer	trees	Bayer Environmental Science, 2007.
Permethrin	preventive bark and foliage cover sprays	bark beetles, *Dendroctonus* spp., *Ips* spp., elm bark beetles, mountain pine beetles, pine engravers, turpentine beetles, western pine beetles, coleopteran borers, bronze birch borer, flatheaded apple tree borer	ornamental and fruit trees	FMC Corporation, 2004.

1 Pest species that are similar to exotic wood-boring and bark beetles and are listed on the label of the pesticide.

2 Crops for which EPA has registered the application of this pesticide.

Cultural Controls

Rely on a combination of cultural and biological control methods in non-emergency situations. Cultural control may be subject to obtaining environmental documentation under the National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA). Check with the program manager to make sure such documentation is in order.

Sanitation and Silviculture

Sanitation involves several measures used to help ensure that suitable host material is removed before pest levels become a problem, including silvicultural measures such as thinning and timely removal of cut or infested material. Silvicultural practices include the following:

- Thinning stands
- Pruning
- Cleaning

There are several different types of thinning techniques that may be used, including low thinning, crown thinning, selection thinning, and mechanical thinning. Thinning stands can help prevent host stress and reduce competition between hosts for water and other nutrients. Thinning can lead to a change in microclimate (temperature, humidity) which may be unsuitable for beetle survival and development (Amman et al., 1988). Sanitation harvests can also be used to remove unhealthy or stressed trees.

Cleaning methods include prescribed burning, cuttings, chipping, basal spraying, and foliage spraying.

Heterogeneity in both tree species represented and age of the stand should also be pursued as a long term management option in forested landscapes. Mixed stands make it more difficult for beetles to detect and find species. Some tree species may also protect surround trees by producing beetle-repelling pheromones (Goyer et al., 1998).

Carry out sanitation in nurseries, farms, and other establishments where hosts are present within the core and buffer areas. Depending on the circumstances and equipment available, use the following techniques:

- Sanitation should be conducted at least at weekly intervals
- During sanitation, obviously infested trees should be removed
- Inspect and clean vehicles. Inspect vehicles, trucks, wagons, and other vehicles used in host areas or used to transport host material to avoid accidental movement of host material with exotic wood-boring and bark beetles eggs, larvae, pupae, or adults.

Salvage

This method is used to help prevent the spread of infestations through prompt removal when large volumes of wood are present.

Pile and Burn

Piling and burning infested material can be used to kill all life stages of wood-boring and bark beetles. This method may work for small infestations in rural areas and is described in detail in Swain and Remion (1983). Chipping and fumigating infested material may also be used. Use the following methods to destroy all host material completely.

Burning, disking, and burying—Collect, pile and burn host material, including debris, if local ordinances permit. Disk residue under the soil or bury in an approved landfill. Bury the insects under 0.5–1 meters of soil, and then firmly pack the soil.

Chipping—Chip logs that are infested with exotic wood-boring and bark beetles.

Pest-Specific Cultural Controls

Buprestidae

***Agrilus biguttatus* Fabricius—**The most common strategy employed in Europe to control *Agrilus* species (specifically Poland and Germany) is silvicultural (Evans et al., 2004). Occasional preventive burning and insecticide application to cut trees are used in a few cases (Evans et al., 2004).

For management of *Agrilus biguttatus*, Moraal and Hilszczanski (2000b) suggest removing stems that are heavily infested with larvae as a means to reduce beetle populations. Dead trees do not need to be removed. For long term management, it is suggested that age structure of trees be increased, susceptibility of trees to insect infestation should be decreased and shrub and underwood layers should be increased to provide shade to stems (Moraal and Hilszczanski, 2000b).

Cerambycidae

***Monochamus saltuarius* Gebleris and *Monochamus sutor* Linnaeus—** When cut, dead trees can be burned, chipped or fumigated to kill *Monochamus alternatus* (Kobayashi, 1988). This method should also be effective at killing other *Monochamus* spp. Other cultural controls include avoiding storage of recently cut sawtimber and pulpwood in forests during the egg laying period, prompt salvage and utilization of damaged or killed trees and storing logs under water sprays at sawmills (USDA, 1991; Furniss and Carolin, 1977).

Pine wilt resistant clones of *Pinus densiflora* and *P. thunbergii* are being planted in Japan and could be used as a long term control of *Monochamus alternatus* if it were to become established in the United States (Kobayashi, 1988).

Controls for *Monochamus alternatus* may be applicable for other *Monochamus* species. Many control studies for this species have focused on integrating biological control with sanitation and removal of infested trees (Evans et al., 2004). Many studies have shown promise with the fungus *Beauveria bassiana* (Shimazu et al., 1995).

***Tetropium castaneum* Linnaeus and *Tetropium fuscum* Fabricius—** Strategies to control *Tetropium* species focus on prevention (Evans et al., 2004). To control *Tetropium* species, debark cut trees and cover them to ensure that populations cannot effectively reproduce; cut trees may also be processed or burned (Evans et al., 2004). Silvicultural strategies are also employed, including clear felling, selective thinning and forest sanitation (Evans et al., 2004).

Curculiondae

***Platypus quercivorus* Murayama *(Platypodinae)* and *Tomicus destruens* Wollaston (Scolytinae)—**Infestations of bark and ambrosia beetles can be controlled by removing and harvesting trees in a timely manner as well as rapid debarking or processing once logs are transported to a sawmill (reviewed in Ciesla, 2003d).

Because logs are left in the forest for extended amounts of time in Europe, control measures include debarking logs and exposing logs to solar radiation (Ciesla, 2003c).

Biological Controls

If the pest population was discovered too late for eradication measures to be effective, then rely on containment or management options.

Containment means keeping the target population confined to a specific area, and perhaps later developing tools to eradicate it. Using this approach requires strong regulatory procedures. A variation of containment is known as Slow the Spread (USDA–APHIS–PPQ, 2003). In Slow the Spread, the spread of the pest population is slowed as much as possible, resources permitting. Slow the Spread is usually reserved for high-impact pests such as the gypsy moth.

In contrast, management is used when the population of the pest is so large or widely spread that resources are better directed at limiting the impacts caused by the infestation.

The following control options are best suited for both containment programs and long term management. They could be used in an eradication program if the intent is to bring population numbers down to better achieve this goal.

Biological control agents are useful for suppressing pest populations, but do not eradicate them. Biological control can be useful if rigorous screening on non-target organisms is tested. Obtain the proper permits from PPQ-Plant, Organism, and Soil Permits, prior to testing.

Address	PPQ Plant, Organism and Soil Permits http://www.aphis.usda.gov/plant_health/permits/index.shtml

Biological control agents are characterized as predators, parasites, parasitoids, or pathogens. Successful biological control agents usually have the following characteristics:

- Living on or in another organism and ultimately killing it
- Producing several broods each year
- Feeding on only one kind of food

Unfortunately, little is known about the biology, host range, and mass rearing methods of the natural enemies of exotic wood-boring and bark beetles in this manual. As with the evaluation of any new biological control agent, extensive tests should be completed to determine the efficacy of suppressing exotic wood-boring and bark beetles and the susceptibility of non-target organisms.

Some of the natural enemies of exotic wood-boring and bark beetles have been compiled in ***Natural Enemies*** on **page G-1**. *Platypus quercivorus* Murayama (Platypodinae) is absent from the Appendix because natural enemies have not been reported for this pest.

Entomopathogenic Fungi—Research trials with *Beauveria bassiana* found that *Tetropium fuscum* Fabricius (brown spruce longhorn beetle) adults were susceptible to infection in both the laboratory and the field. Polyester quilt batting bands impregnated with *Beauveria bassiana* conidia and wrapped around the trunks of spruce trees resulted in 66 percent infection rate of *Tetropium fuscum* adults, but infected beetles likely died too slowly to significantly reduce their rate of reproduction. These research trials have not yet resulted in a viable registered pest control product (J. Sweeney, pers. comm.)

For further information, contact the CPHST Biological Control Coordinator.

Address	USDA–APHIS-CPHST Biological Control Coordinator http://www.aphis.usda.gov/plant_health/cphst/projects/arthropod-pests.shtml

Other Control Methods

Mating Disruption

Mating disruption is the use of a synthesized sex pheromone to disrupt reproduction in the target pest. This method is effective when population densities are low to moderate, and is both environmentally friendly and species-specific.

Tetropium fuscum Fabricius (Cerambycidae) males emit a pheromone that synergizes the attraction of both sexes when combined with commercially available host volatile attractants. The attractants are a blend of monoterpenes (spruce blend) andethanol lure. Traps baited with the pheromone + spruce blend + ethanol are useful for survey and early detection and may prove useful in control strategies, such as mass trapping or mating disruption. However, research to determine the feasibility of mating disruption in *T. fuscum* has only recently been initiated (Silk et al., 2007).

Currently no sex pheromones have been identified for the exotic wood-boring and bark beetles discussed in the guidelines.

Sterile Insect Technique

Sterile insect technique has not been developed for any exotic wood-boring and bark beetles. Many of these species only spend a small portion of their life cycle outside of the host plant and thus release of their sterilized counterparts would have to be timed accordingly to be successful.

7

Exotic Wood-Boring and Bark Beetles

Environmental Compliance

Content

Introduction

Use *Chapter 7 Environmental Compliance* as a guide to environmental regulations when conducting a program against exotic wood-boring and bark beetles (EWBBB) absent from the United States and collaborating territories. Selected species in the order Coleoptera, families Buprestidae, Cerambycidae, and Curculionidae, are discussed here as these are currently of particular concern, but the general information found in the guidelines may be applicable for other exotic wood-boring and bark beetles.

Overview

A key element in designing a program or an emergency response is consultation with Environmental Services (ES), a unit of APHIS' Policy and Program Development Staff (PPD). ES prepares environmental documentation such as Environmental Impact Statements (EIS) and Environmental Assessments (EA) to aid in program operational decisions, as well as endangered species consultation. ES also coordinates pesticide registration and approvals for APHIS pest control and eradication programs, ensuring that registrations and approvals meet program needs and conform to pesticide use requirements.

National Environmental Policy Act

Agencies should prepare an Environmental Assessment (EA) or Environmental Impact Statement (EIS) concurrently and integrated with environmental impact analyses, surveys, and studies required by the Fish and Wildlife Coordination Act, National Historic Preservation Act of 1966, Endangered Species Act, and other laws and executive orders. Environmental documents prepared to comply with other Acts also may be incorporated into National Environmental Policy Act (NEPA) documents as part of the NEPA process.

Categorical Exclusion

Categorical Exclusions (CE) are categories of actions that do not have a significant effect on the quality of the human environment and for which neither an Environmental Assessment (EA) nor an Environmental Impact Statement (EIS) is generally required.

USDA–APHIS managers are encouraged to use categorical exclusions where appropriate to reduce paperwork and speed up decision making. Proposed actions are subject to sufficient environmental review to determine whether they fall within the broadly defined categories. Each time a specific categorical exclusion is used, the required review must be done. An EA may be prepared for proposed actions otherwise excluded when the manager determines that the action may have potential to significantly affect the environment or an EA would be helpful in planning or decision-making.

Environmental Impact Statement

An Environmental Impact Statement (EIS) is a detailed statement that must be included in every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The primary purpose of an EIS is to serve as an action-forcing device to ensure that the policies and goals defined in the National Environmental Policy Act (NEPA) are infused into the ongoing programs and actions of the Federal government. Generally, EISs are prepared when Federal agencies recognize that their actions have the potential for significant environmental effects (adverse or beneficial), or when an Environmental Assessment leads to a finding of potentially significant impact.

APHIS prepares EISs for administrative proceedings that establish broad scale significant impact-generating strategies, methods, or techniques such as large-scale aerial pesticide applications. This can include contingency or emergency strategies that are comprehensive in scope or long-range plans with potential for significant environmental impact. APHIS also prepares programmatic EISs to examine strategies and options for dealing with issues with important implications for the maintenance and enhancement of environmental quality.

Environmental Assessment

An Environmental Assessment (EA) is a concise public document that briefly provides sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement (EIS) or a Finding of No Significant Impact (FONSI). An EA aids an agency's compliance with the National Environmental Policy Act (NEPA) when no EIS is necessary and facilitates the preparation of an EIS when necessary. Generally, an EA leads to a FONSI or an EIS, but it could also lead to abandonment of a proposed action.

The content of an EA must include brief discussions of the need, alternatives, and potential environmental impacts of the proposal, and a list of agencies and persons consulted.

Environmental Monitoring

APHIS–PPQ requests assistance from Environmental Services (ES) before PPQ personnel or funding are used for control operations. Additionally, program staff should consult with PPQ–EDP- Environmental Monitoring staff to determine if an environmental monitoring plan is required for the operation. State, regional, and national program managers determine counties where treatments may be needed.

Program personnel should evaluate the need for and success of biological control agents and herbicide treatments used in eradication or suppression of the target foreign noxious weed or host weeds and avoid damage to non-target plants.

Biological Assessment

A biological assessment is an analysis of the effects that a Federal agency action may have on listed or proposed endangered or threatened species and designated critical habitat. The Endangered Species Act (ESA) requires this analysis if the proposed action may affect a listed species. In such a case, consultation with the U.S. Fish and Wildlife Service (FWS) or the National Marine Fisheries Service (NMFS) is required. Federal agencies are required to insure that any action authorized, funded, or carried out is not likely to jeopardize listed species or result in adverse modification of designated critical habitat.

8

Exotic Wood-Boring and Bark Beetles

Pathways

Contents

Introduction

Use *Chapter 8 Pathways* to learn more about interceptions of wood-boring and bark beetles in the United States and collaborating territories. Selected species in the families Buprestidae, Cerambycidae and Curculionidae are discussed here as these are currently of particular concern, but the general information found in these guidelines may be applicable for other exotic wood-boring and bark beetles (EWBBB). Discussion in this chapter was restricted to the genus level and includes *Agrilus, Monochamus, Tetropium, Platypus,* and *Tomicus*. Many EWBBBs are identified to genus only when intercepted, making it difficult to determine patterns when potential interceptions are excluded.

Interceptions

Previous interception rates are inaccurate at illustrating the frequency at which these wood-boring and bark beetles enter the United States. One reason is that many larvae may be difficult to detect due to size and/or cryptic nature.

Before 2000, *Tetropium fuscum* Fabricius (Cerambycidae) and other *Tetropium* spp. were not listed as pests of quarantine significance because they were widely distributed throughout Europe and western Siberia, and were apparently unable to damage healthy hosts (NPAG, 2000). However, after

Tetropium fuscum was introduced into Canada, causing death in healthy spruce trees, the genus was reclassified as reportable by the PPQ National Identification Service (AQAS, 2010).

Travel

Travel is not an important means of dispersal because the five genera have not been intercepted from passenger baggage (AQAS, 2010) (***Table 8-1* on page 8-3**).

Natural

Natural spread of any of the five genera to the United States is not expected unless they become established elsewhere on the North American continent and spread from their initial introduction site.

Tetropium fuscum Fabricius (Cerambycidae) is currently present in Nova Scotia and could spread naturally. According to Jacobs et al. (2003), *T. fuscum* was introduced into Canada through shipment of wood or wood packing material from Europe.

Commerce

Approximately 89 percent of interceptions of the five genera were via maritime. This number suggests that sea travel is a significant pathway. This is not surprising considering that host materials for these genera are used extensively in shipping goods and other materials around the world. Other pathways include airport (5 percent); land border (5 percent); and foreign, inland inspection, inspection station, PPQ, and rail, which collectively make up 1 percent.

Specific products that may lead to the introduction of the five genera include sawn timber in international trade; imported furniture with wooden components; wooden souvenirs moved by tourists; and imports of live plants. For example, the citrus longhorned beetle (*Anoplophora chinensis* (Forster) Cerambycidae) was introduced into the United States on live plants (Haack, 2003).

Table 8-1 Interceptions of Select Wood-boring and Bark Beetle Genera at U.S. Ports of Entry during the period 1990–2009 (AQAS, 2010)

	Interceptions		Countries of Origin		Destinations	
Species[1]	Number	Top Ranked[2]	Number	Top Ranked	Number	Top Ranked
Agrilus	21	W, P, O	12	Belgium, Israel	11	CA, FL, TN
Monochamus	594	W	36	China, Russia, Italy	41	CA, NY, TX
Platypus	51	P, W	13	Mexico, Costa Rica	17	FL, CA
Tetropium	479	W, O	24	Italy, China, Germany	33	FL, TX, CA
Tomicus	119	W	19	Italy, Turkey, France	18	FL, GA, IL

1 All species within the genus.

2 W = Wood packing material; P = Plant; O = Other.

Countries of Origin

From 1990 to 2009, these five genera originated from at least 53 different countries (AQAS, 2010). When totaled, Italy and China made up over 50 percent of interceptions. Interceptions from European countries totaled 60 percent. From the Italy interceptions, over 75 percent were on tile, stone, quarry, and related products, most found in the wood packing material used to ship the commodities (AQAS, 2010). The China interceptions were found mainly on wood packing material used for a variety of commodities (AQAS, 2010) (***Table 8-2* on page 8-4**).

Table 8-2 Top 10 Countries of Origin of EWBBBs[1] Intercepted 1990-2009[2]

Country	Number of Interceptions	Approximate Percent Total
Italy	395	31
China	288	23
Russia	107	9
Unknown	53	4
Turkey	49	4
Spain	39	3
France	36	3
Mexico	33	3
Germany	29	2
Poland	25	2

1 *Agrilus, Monochamus, Tetropium, Platypus,* and *Tomicus.*

2 AQAS, 2010.

Destinations

From 1990 to 2009, the final destinations of the 5 intercepted genera included at least 41 states and 1 territory (AQAS, 2010). The top three destination states were Florida, California and Texas (*Table 8-3* **on page 8-4**).

Table 8-3 Top 10 Destinations of EWBBBs[1] Intercepted 1990-2009[2]

Country	Number of Interceptions	Approximate Percent Total
Florida	198	16
California	182	14
Texas	148	12
Illinois	75	6
New York	65	5
Georgia	52	4
Washington	45	4
New Jersey	39	3
Indiana	35	3
Oregon	34	3

1 *Agrilus, Monochamus, Tetropium, Platypus,* and *Tomicus.*

2 AQAS, 2010.

Risk

Many of these species are native to areas that have climates and host plants similar to environments in the United States and thus pose a considerable establishment and environmental risk:

- Many have either shown pest potential or are closely related to other known pest species
- Many can either inoculate living hosts with harmful pathogens or provide opportunities for secondary pests and/or pathogens to be introduced
- All are associated with several important genera of plants, including *Pinus, Picea, Larix,* and *Quercus,* and could potentially change the species composition of forests
- Introduction of any may have an effect on the community ecology of native species of wood-boring and bark beetles
- Newly established populations may go undetected for many years due to their cryptic nature, concealed activity, slow development of damage symptoms, or misdiagnosis

Solid Wood Packing Material

Many exotic wood-boring and bark beetle larvae can survive and develop in cut wood, meaning that a majority of wooden materials, including lumber, crating, pallets, and dunnage used in international trade, can potentially serve as a pathway for exotic wood-boring and bark beetles. Several of the introduced EWBBBs are thought to have been introduced by untreated wood packing material, including Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)(Cerambycidae)) and emerald ash borer (*Agrilus planipennis* (Fairmaire)(Buprestidae)). These high profile introductions have raised attention and concern over this pathway on an international level.

Due to the known importance of the maritime pathway, measures have been enacted by the International Plant Protection Convention (IPPC) to help lessen the risk associated with wood packing material, specifically ISPM 15. ISPM 15 is an International Phytosanitary Measure that requires wood packing material (dunnage, pallets, crates, etc.) to be either heat treated or fumigated with methyl bromide if material is greater than 6mm.

Once treated, the material is stamped with a seal of compliance. This seal includes the International Plant Protection Convention (IPPC) symbol, the ISO two-letter country code with a unique number assigned to the producer of the wood packing material responsible for treatment that follows (this is assigned by the National Plant Board in the United States) and the treatment abbreviation (HT for heat treatment or MB for methyl bromide). Refer to the IPPC Web site for more information.

Address	International Plant Protection Convention https://www.ippc.int/

Although wood packing material has been recognized as a significant pathway and measures have been taken to decrease the risk, it cannot be eliminated completely. Illustrating this point, a study by Zahid et al. (2008) in Australia found that approximately a tenth of materials stamped with the ISPM 15 decal were non-compliant. Of the 9 percent of non-compliant wood, 8.5 had bark, 5.9 percent had fungi and live insects, frass and soil made up 3.2 percent, 2.8 percent and 1.7 percent respectively. Trade increase over time and increase in wood packing material usage may also have offset some gains achieved by such phytosanitary measures (Brockerhoff, 2009).

Because of the extensive damage these pests have caused, it is imperative that this pathway continue to be monitored efficiently and effectively.

Exotic Wood-Boring and Bark Beetles

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Use the *References* section to learn more about the publications, Web sites, and other resources, that were consulted during the production of the guidelines.

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Exotic Wood-Boring and Bark Beetles

Glossary

Use the *Glossary* to find the meaning of specialized words, abbreviations, acronyms, and terms used by USDA–APHIS–PPQ–Emergency and Domestic Programs.

ambrosia beetle. beetles within the order Coleoptera, family Curculionidae, subfamily Platypodinae as well as some Scolytinae
APHIS. Animal and Plant Health Inspection Service
AQAS. Agricultural Quarantine Activity System, a Web database accessible from any USDA–APHIS computer
backtracking. tracing the possible movement of infested materials to determine the extent of the infestation
bark beetle. beetles within the order Coleoptera, family Curculionidae, subfamily Scolytinae
barrier. natural or artificial obstacle to movement
bluestain fungus. fungus that uses the wood without causing decay, causing a bluish to grayish discoloration of sapwood
boring dust. brownish, dry, crumbly decay of wood caused by fungi decomposing cellulose and leaving the lignin in a modified state
BSLB. brown spruce longhorn beetle (*Tetropium fuscum* Fabricius (Cerambycidae))
breeding attack. occurs when an insect attacks a host plant in order to successfully breed
buffer area. survey area 1–2 miles from the perimeter of a regulated area, or 50 miles from the core of a regulated area in an extended survey
callow. condition of the adult shortly after eclosion when its cuticle is not fully sclerotized or fully mature in color
cambium. meristematic tissue in woody plants that exists between the wood (xylem) and the inner most bark (phloem)
cast needles. premature drop of needles from tree
CFR. Code of Federal Regulations
confirmed detection. positive identification of a submitted specimen
containment. application of phytosanitary measures in and around an infested area to prevent spread of a pest
control. suppression, containment or eradication of a pest population
CPHST. Center for Plant Health Science and Technology
crown, brown or red. leaves discolored brown or red in the area of the tree above the trunk
day degree. measure of physiological time using the accumulation of heat units (degrees) above an insects developmental threshold for a 24-hour period
d.b.h. diameter at breast height
delimiting survey. survey to determine the extent of the infestation in an area

after the target species has been detected
detection. collection of any life stage of the target pest
destructive sampling. method of observing signs and symptoms of the presence or absence of a pest by destruction of the living sample unit; for example, removal of bark to look for larvae
detection survey. survey conducted in a susceptible area not known to be infested with the target pest
developmental thresholds. minimum and/or maximum temperatures that support physiological development of a species
DHB. diameter at breast height
dispersal, active. spread of an organism by its own method of locomotion (e.g., walking, flight, etc.)
dispersal, passive. spread of an organism aided by other than its own method of locomotion (e.g., wind, water, man, etc.)
diurnal. active during the day
eclosion. escape of the adult insect from the cuticle of the pupa, the cocoon, or the puparium
EAB. emerald ash borer
EAN. Emergency Action Notification
elytron. leathery forewing of beetles (Coleoptera), serving as a covering for the hind wings, commonly meeting opposite elytron in a straight line down the middle of the dorsum in repose (*plural elytra*)
EPA. United States Environmental Protection Agency
epistoma. oral margin or sclerite directly behind the labrum
eradication. application of phytosanitary measures to eliminate a pest from an area before it becomes too large in area or numbers for current technology
entomopathogen. pathogen that induces illness in insects
eusocial.
Exotic Species. organism of pest species not native to or historically resident in North America.
F1 sterility. inherited sterility
fagaceous. belonging to the Fagaceae, a family of trees, including beech, oak, and chestnut
ferruginous brown. color of iron rust or reddish-brown
FONSI. Finding of No Significant Impact
fumigation. application of an approved fumigant, such as methyl bromide, as a treatment
funicle. part of the flagellum of the antenna proximal to the club
generation. period of time for the pest to complete all stages of development predicated on the basis of biological information
GPS. global positioning system
ground spray. using ground spray equipment to apply pesticide to the ground, selected resting places, or host vegetation in a target infested area
hibernaculum. larval overwintering refuge constructed with silk
host. plant species, substrate, debris, or other food reproduction of the target

pest
host collecting. collection and retention of infested host material for the purposes of determining characteristics of a pest's use of the host; also known as holding
host volatiles. generic attractants that can attract a variety of different species
indigenous. native
ISIS. Integrated Survey Information System
infestation. collection of one or more target pests from an area
km. kilometer
labrum. upper lip, abutting the clypeus in front of the mouth
management. application of selected phytosanitary measures in and around an infested area to keep an invading population in check when other means of eradication of the population would fail
maturation feeding. feeding required by an individual organism before it can reproduce successfully
mesonotum. notum of mesothorax
mesothorax. second or middle thoracic segment bearing the meddle legs and the forewings
monitoring. using interdependent visual or trapping surveys in an area where treatment has been applied to evaluate the effectiveness of the application; also known as evaluation survey
monophagous. biological control agent feeding on only one kind of food
multivoltine. biological control agent producing several broods each year
mycangial fungi.
mycangia organs.
NAPIS. National Agricultural Pest Information System
NAPPFAST. North Carolina State University APHIS Plant Pest Forecasting System
natural enemies. living organisms found in a natural community that kill, weaken or inhibit the biological potential of a pest species
n.d. no date
nonmigratory. species in which the individuals typically do not move far from the area of their birthplace
parasites. organism living on the host at one or multiple life stages; may kill or debilitate the host
parasitoid. organism living on the host when immature and killing host; free-living as adults; host-specific; obligate on certain hosts; find hosts effectively even when host population numbers are not particularly dense
pathogen. agent, usually microbial, that induces illness
pathway. means by which plant pests are introduced
PestID. database containing all the information recorded from the PPQ Form 309 Pest Interception Record
pitch tubes. tubular mass of resin mixed with bark, wood borings, and insect excrement that form on the surface of the bark at beetle entrance holes
phenology. timing of recurrent biological events

PPQ. Plant Protection and Quarantine
predator. free-living organisms that consume substantial numbers of prey
pronotum. upper and dorsal part of the prothorax
prosternum. sternum of the prothorax
protective value. similar to recreational and aesthetic values; worth of the tree as protection
prothorax. first thoracic ring or segment, bearing the anterior legs but no wings
pubescent. downy; clothed with soft, short, fine, loosely set hair
regulated articles. all known or suspected hosts of a confirmed infestation of an exotic species including soil and any other suspected product or article
regulatory inspection. visual examination of host material, containers, and transport
sclerite. any plate of the body wall bounded by membrane or sutures
sclerotization. hardening of the cuticle involving the development of crosslinks between protein chains
scutellum. in adult Coleoptera, the triangular piece at the base and between the elytra
SD. standard deviation
seta. sclerotized hairlike projection of cuticula arising from a single trichogen cell and surrounded at the base by a small cuticular ring (*plural setae*)
sex pheromone. chemical substance that is secreted by an insect to attract or advertise reproductive competence to the opposite sex of the same species
soil treatment. application of an approved insecticide to the soil of nursery or within the drip line of host plants
SPHD. State Plant Health Director
spinule. small spine
SPRO. State Plant Regulatory Official
sternum. entire ventral division of any segment
suppression. application of phytosanitary measures in an infected area to reduce pest populations
sweep net. survey method in which a mesh net suspended around a hoop is swept through the air or around vegetation to collect insects
tergum. upper or dorsal surface of any body segment of an insect, whether consisting of one or more than one sclerite
thorax. middle portion of the body between the head and abdomen, consisting of three segments (prothorax, mesothorax, and metathorax) each of which usually bear a pair of articulated legs
trap survey. determining the presence or absence of a pest by the use of traps placed in a predetermined pattern and serviced on a given schedule
tyloses. bladder-like outgrowth from certain cells in woody tissue that extends into and blocks adjacent conducting xylem cells
univoltine.
urban area. noncommercial crop production area containing multiple or single-family dwellings; also known as residential area

USDA. United States Department of Agriculture

visual survey. examining hosts, substrate, or hiding places for eggs, larvae, adults, or visible damage; in the field, in regulated establishments, or in monitoring the movement of regulated articles

volume increment. marketable wood product

white oak group. any of a number of oaks having leaves with rounded lobes, acorns that mature in one season, whitish or grayish bark, and hard, impervious wood

white resin streaks. viscous substance that is produced by the plant when attacked by a number of species

A

Exotic Wood-Boring and Bark Beetles

Resources

Use *Appendix A Resources* to find the contacts and products mentioned in the guidelines. To locate where in the guidelines a product is mentioned, refer to the index.

Table A-1 Exotic Wood-Boring and Bark Beetles Resources

Resource	Contact Information
USDA–APHIS–PPQ-Center for Plant Health, Science, and Technology	http://www.aphis.usda.gov/plant_health/cphst/index.shtml
USDA–APHIS–PPQ-Emergency and Domestic Programs, Plant Pest Programs	http://www.aphis.usda.gov/plant_health/plant_pest_info/index.shtml
CAPS Approved Methods Web site, Survey Methods for Species of Exotic Wood-Boring and Bark Beetles	http://caps.ceris.purdue.edu/webfm_send/42
NAPPFAST	http://www.nappfast.org/index.htm
University of California Integrated Pest Management	http://www.ipm.ucdavis.edu/WEATHER
PPQ Manual for Agricultural Clearance	http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml
Host or risk maps	http://www.nappfast.org/caps_pests/CAPs_Top_50.htm
USDA–APHIS-Integrated Survey Information System	http://ppqcoop.aphis.usda.gov/web/Default.aspx?alias=ppqcoop.aphis.usda.gov/web/isis
PPQ Plant, Organism and Soil Permits	http://www.aphis.usda.gov/plant_health/permits/index.shtml
National Program Manager for Native American Program Delivery and Tribal Liaison, USDA–APHIS–PPQ	14082 S. Poston Place Tucson, AZ 85736 Telephone: (520) 822-544
USDA–APHIS-CPHST Biological Control Coordinator	http://www.aphis.usda.gov/plant_health/cphst/projects/arthropod-pests.shtml
PPQ-FIFRA Coordinator, PPQ-Emergency and Domestic Programs	4700 River Road Riverdale, MD 20737 Telephone: (301) 734-5861
Environmental Compliance Coordinator, PPQ-Emergency and Domestic Programs	4700 River Road Riverdale, MD 20737 Telephone: (301) 734-7175
A Resource for Wood Boring Beetles of the World: Bark Beetle Genera of the United States	http://itp.lucidcentral.org/id/wbb/bbgus/index.html
International Plant Protection Convention	https://www.ippc.int/

B

Exotic Wood-Boring and Bark Beetles

Forms

Contents

PPQ 391 Specimens For Determination

This report is authorized by law (7 U.S.C. 147a). While you are not required to respond your cooperation is needed to make an accurate record of plant pest conditions. *See reverse for additional OMB information.*

FORM APPROVED
OMB NO. 0579-0010

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE

SPECIMENS FOR DETERMINATION

Instructions: Type or print information requested. Press hard and print legibly when handwritten. Item 1 - assign number for each collection beginning with year, followed by collector's initials and collector's number. Example (collector, John J. Dingle): 83-JJD-001.
Pest Data Section – Complete Items 14, 15 and 16 or 19 or 20 and 21 as applicable. Complete Items 17 and 18 if a trap was used.

FOR IIBIII USE
LOT NO.
PRIORITY

1. COLLECTION NUMBER
2. DATE: MO | DA | YR
3. SUBMITTING AGENCY: ☐ State Cooperator ☐ PPQ ☐ Other ____

SENDER AND ORIGIN / INTERCEPTION SITE

4. NAME OF SENDER
5. TYPE OF PROPERTY *(Farm, Feedmill, Nursery, etc.)*
6. ADDRESS OF SENDER
ZIP
7. NAME AND ADDRESS OF PROPERTY OR OWNER
COUNTRY/ COUNTY

PURPOSE

8. REASON FOR IDENTIFICATION *("x" ALL Applicable Items)*

A. ☐ Biological Control (Target Pest Name)
B. ☐ Damaging Crops/Plants
C. ☐ Suspected Pest of Regulatory Concern *(Explain in* REMARKS*)*
D. ☐ Stored Product Pest
E. ☐ Livestock, Domestic Animal Pest
F. ☐ Possible Immigrant *(Explain in* REMARKS*)*
G. ☐ Survey *(Explain in* REMARKS*)*
H. ☐ Other *(Explain in* REMARKS*)*

9. IF PROMPT OR URGENT IDENTIFICATION IS REQUESTED, PLEASE PROVIDE A BRIEF EXPLANATION UNDER "REMARKS".

HOST DATA

10. HOST INFORMATION
NAME OF HOST *(Scientific name when possible)*

11. QUANTITY OF HOST
NUMBER OF ACRES/PLANTS
PLANTS AFFECTED *(Insert figure and indicate* ☐ Number ☐ Percent*):*

12. PLANT DISTRIBUTION
☐ LIMITED
☐ SCATTERED
☐ WIDESPREAD

13. PLANT PARTS AFFECTED
☐ Leaves, Upper Surface ☐ Leaves, Lower Surface ☐ Petiole ☐ Stem
☐ Trunk/Bark ☐ Branches ☐ Growing Tips ☐ Roots
☐ Bulbs, Tubers, Corms ☐ Buds ☐ Flowers ☐ Fruits or Nuts
☐ Seeds

PEST DATA

14. PEST DISTRIBUTION
☐ FEW
☐ COMMON
☐ ABUNDANT
☐ EXTREME

15. ☐ INSECTS ☐ NEMATODES ☐ MOLLUSKS

NUMBER SUBMITTED	LARVAE	PUPAE	ADULTS	CAST SKINS	EGGS	NYMPHS	JUVS.	CYSTS
ALIVE								
DEAD								

16. SAMPLING METHOD
17. TYPE OF TRAP AND LURE
18. TRAP NUMBER

19. PLANT PATHOLOGY – PLANT SYMPTOMS *("X" one and describe symptoms)*
☐ ISOLATED ☐ GENERAL

20. WEED DENSITY
☐ FEW ☐ SPOTTY ☐ GENERAL

21. WEED GROWTH STAGE
☐ SEEDLING ☐ VEGETATIVE ☐ FLOWERING/FRUITING ☐ MATURE

22. REMARKS

23. TENTATIVE DETERMINATION

24. DETERMINATION AND NOTES *(Not for Field Use)*

SIGNATURE ____ DATE ____

FOR IIBIII USE
DATE RECEIVED
NO.
LABEL
SORTED
PREPARED
DATE ACCEPTED
RR

PPQ FORM 391 *Previous editions are obsolete.*
(AUG 02)

This is a 6-Part form. Copies must be disseminated as follows:
☐ PART 1 – PPQ ☐ PART 2 – RETURN TO SUBMITTER AFTER IDENTIFICATION ☐ PART 3 – IIBIII OR FINAL IDENTIFIER
☐ PART 4 – INTERMEDIATE IDENTIFIER ☐ PART 5 – INTERMEDIATE IDENTIFIER ☐ PART 6 – RETAINED BY SUBMITTER

Figure B-1 Example of PPQ 391 Specimens For Determination, side 1

OMB Information
According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this information collection is 0579-0010. The time required to complete this information collection is estimated to average .25 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information.

Instructions
Use PPQ Form 391, Specimens for Determination, for domestic collections (warehouse inspections, local and individual collecting, special survey programs, export certification).

BLOCK	INSTRUCTIONS
1	1. Assign a number for each collection beginning the year, followed by the collector's initials and collector's number **EXAMPLE** In 2001, Brian K. Long collected his first specimen for determination of the year. His first collection number is 01-BLK-001 2. Enter the collection number
2	Enter date
3	Check block to indicate Agency submitting specimens for identification
4	Enter name of sender
5	Enter type of property specimen obtained from (farm, nursery, feedmill, etc.)
6	Enter address
7	Enter name and address of property owner
8A-8L	Check all appropriate blocks
9	Leave Blank
10	Enter scientific name of host, if possible
11	Enter quantity of host and plants affected
12	Check block to indicate distribution of plant
13	Check appropriate blocks to indicate plant parts affected
14	Check block to indicate pest distribution
15	• Check appropriate block to indicate type of specimen • Enter number specimens submitted under appropriate column
16	Enter sampling method
17	Enter type of trap and lure
18	Enter trap number
19	Enter X in block to indicate isolated or general plant symptoms
20	Enter X in appropriate block for weed density
21	Enter X in appropriate block for weed growth stage
22	Provide a brief explanation if Prompt or URGENT identification is requested
23	Enter a tentative determination if you made one
24	Leave blank

Distribution of PPQ Form 391
Distribute PPQ Form 391 as follows:
1. Send Original along with the sample to your Area Identifier.
2. Retain and file a copy for your records.

Figure B-2 Example Of PPQ 391 Specimens For Determination, side 2

Purpose

Submit PPQ Form 391, Specimens for Determination, along with specimens sent for positive or negative identification.

Instructions

Follow the instructions in ***Table B-1*** **on page B-5**. Inspectors must provide all relevant collection information with samples. This information should be communicated within a State and with the regional office program contact. If a sample tracking database is available at the time of the detection, please enter collection information in the system as soon as possible.

Address	Fillable PPQ Form 391 http://www.aphis.usda.gov/library/forms/pdf/PPQ_Form_391.pdf

Distribution

Distribute PPQ Form 391 as follows:

1. Send the original along with the sample to your area identifier.
2. Retain and file a copy for your records.

Table B-1 Instructions for Completing PPQ Form 391, Specimens for Determination

Block		Instructions
1	COLLECTION NUMBER	1. ASSIGN a collection number for each collection as follows: 2-letter State code–5-digit sample number (Survey Identification Number in Parentheses) Example: PA-1234 (04202010001) 2. CONTINUE consecutive numbering for each subsequent collection 3. ENTER the collection number
2	DATE	ENTER the date of the collection
3	SUBMITTING AGENCY	PLACE an X in the PPQ block
4	NAME OF SENDER	ENTER the sender's or collector's name
5	TYPE OF PROPERTY	ENTER the type of property where the specimen was collected (farm, feed mill, nursery, etc.)
6	ADDRESS OF SENDER	ENTER the sender's or collector's address
7	NAME AND ADDRESS OF PROPERTY OR OWNER	ENTER the name and address of the property where the specimen was collected
8A-8H	REASONS FOR IDENTIFICATION	PLACE an X in the correct block
9	IF PROMPT OR URGENT IDENTIFICATION IS REQUESTED, PLEASE PROVIDE A BRIEF EXPLANATION UNDER "REMARKS"	LEAVE blank; ENTER remarks in *Block 22*
10	HOST INFORMATION NAME OF HOST	If known, ENTER the scientific name of the host
11	QUANTITY OF HOST	If applicable, ENTER the number of acres planted with the host
12	PLANT DISTRIBUTION	PLACE an X in the applicable box
13	PLANT PARTS AFFECTED	PLACE an X in the applicable box
14	PEST DISTRIBUTION FEW/COMMON/ ABUNDANT/EXTREME	PLACE an X in the appropriate block
15	INSECTS/NEMATODES/ MOLLUSKS	PLACE an X in the applicable box to indicate type of specimen
	NUMBER SUBMITTED	ENTER the number of specimens submitted as ALIVE or DEAD under the appropriate stage
16	SAMPLING METHOD	ENTER the type of sample
17	TYPE OF TRAP AND LURE	ENTER the type of sample
18	TRAP NUMBER	ENTER the sample numbers
19	PLANT PATHOLOGY-PLANT SYMPTOMS	If applicable, check the appropriate box; otherwise LEAVE blank
20	WEED DENSITY	If applicable, check the appropriate box; otherwise LEAVE blank

Table B-1 Instructions for Completing PPQ Form 391, Specimens for Determination (continued)

Block		Instructions
21	WEED GROWTH STAGE	If applicable, check the appropriate box; otherwise LEAVE blank
22	REMARKS	ENTER the name of the office or diagnostic laboratory forwarding the sample; include a contact name, email address, phone number of the contact; also include the date forwarded to the State diagnostic laboratory or USDA–APHIS–NIS
23	TENTATIVE DETERMINATION	ENTER the preliminary diagnosis
24	DETERMINATION AND NOTES (**Not** for Field Use)	LEAVE blank; will be completed by the official identifier

PPQ 523 Emergency Action Notification

FORM APPROVED - OMB NO. 0579-0102

U.S. DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

EMERGENCY ACTION NOTIFICATION

	SERIAL NO.	
	1. PPQ LOCATION	2. DATE ISSUED
3. NAME AND QUANTITY OF ARTICLE(S)	4. LOCATION OF ARTICLES	
	5. DESTINATION OF ARTICLES	
6. SHIPPER	7. NAME OF CARRIER	
	8. SHIPMENT ID NO.(S)	
9. OWNER/CONSIGNEE OF ARTICLES	10. PORT OF LADING	11. DATE OF ARRIVAL
Name:	12. ID OF PEST(S), NOXIOUS WEEDS, OR ARTICLE(S)	
Address:	12a. PEST ID NO.	12b. DATE INTERCEPTED
	13. COUNTRY OF ORIGIN	14. GROWER NO.
PHONE NO. / FAX NO.	15. FOREIGN CERTIFICATE NO.	
SS NO. / TAX ID NO.	15a. PLACE ISSUED	15b. DATE

Under Sections 411, 412, and 414 of the Plant Protection Act (7 USC 7711, 7712, and 7714) and Sections 10404 through 10407 of the Animal Health Protection Act (7 USC 8303 through 8306), you are hereby notified, as owner or agent of the owner of said carrier, premises, and/or articles, to apply remedial measures for the pest(s), noxious weeds, and or article(s) specified in Item 12, in a manner satisfactory to and under the supervision of an Agriculture Officer. Remedial measures shall be in accordance with the action specified in Item 16 and shall be completed within the time specified in Item 17.

AFTER RECEIPT OF THIS NOTIFICATION, ARTICLES AND/OR CARRIERS HEREIN DESIGNATED MUST NOT BE MOVED EXCEPT AS DIRECTED BY AN AGRICULTURE OFFICER. THE LOCAL OFFICER MAY BE CONTACTED AT:

16. ACTION REQUIRED

☐ TREATMENT:

☐ RE-EXPORTATION:

☐ DESTRUCTION:

☐ OTHER:

Should the owner or owner's agent fail to comply with this order within the time specified below, USDA is authorized to recover from the owner or agent cost of any care, handling, application of remedial measures, disposal, or other action incurred in connection with the remedial action, destruction, or removal.

17. AFTER RECEIPT OF THIS NOTIFICATION COMPLETE SPECIFIED ACTION WITHIN (Specify No. Hours or No. Days):	18. SIGNATURE OF OFFICER:

ACKNOWLEDGMENT OF RECEIPT OF EMERGENCY ACTION NOTIFICATION

I hereby acknowledge receipt of the foregoing notification.

SIGNATURE AND TITLE:	DATE AND TIME:

19. REVOCATION OF NOTIFICATION

ACTION TAKEN:

SIGNATURE OF OFFICER:	DATE:

PPQ FORM 523 (JULY 2002) Previous editions are obsolete.

Figure B-3 Example of PPQ 523 Emergency Action Notification

Purpose

Issue a PPQ 523, Emergency Action Notification (EAN), to hold all host plant material at facilities that have the suspected plant material directly or indirectly connected to positive confirmations. Once an investigation determines the plant material is not infested, or testing determines there is no risk, the material may be released and the release documented on the EAN.

The EAN may also be issued to hold plant material in fields pending positive identification of suspect samples. When a decision to destroy plants is made, or in the case of submitted samples, once positive confirmation is received, the same EAN which placed plants on hold also is used to document any actions taken, such as destruction and disinfection. Additional action may be warranted in the case of other fields or greenhouses testing positive for red palm weevil.

Instructions

If plant lots or shipments are held as separate units, issue separate EANs for each unit of suspected plant material and associated material held. EANs are issued under the authority of the Plant Protection Act of 2000 (statute 7 USC 7701-7758). States are advised to issue their own hold orders parallel to the EAN to ensure that plant material cannot move intrastate.

When using EANs to hold articles, it is most important that the EAN language clearly specify actions to be taken. An EAN issued for positive testing and positive-associated plant material must clearly state that the material must be disposed of, or destroyed, and areas disinfected. Include language that these actions will take place at the owner's expense and will be supervised by a regulatory official. If the EAN is used to issue a hold order for further investigations and testing of potentially infested material, then document on the same EAN, any disposal, destruction, and disinfection orders resulting from investigations or testing.

Follow the instructions in ***Table B-2* on page B-9** when completing PPQ 523 for the red palm weevil. Find additional instructions for completing, using, and distributing the form in the PPQ *Manual for Agricultural Clearance*.

Address	PPQ *Manual for Agricultural Clearance* http://www.aphis.usda.gov/import_export/plants/manuals/online_manuals.shtml

Table B-2 Instructions for Completing PPQ Form 523, Emergency Action Notification

Block		Instructions
1	COLLECTION NUMBER	ENTER the name and location of the nearest PPQ office
2	DATE	ENTER the date of the collection
3	PPQ LOCATION	ENTER the host scientific name and cultivar
4	LOCATION OF ARTICLES	ENTER the location of the article (premise location, pier, dock, container yard, hold space, etc.)
6	SHIPPER	ENTER the plant material source if known
7	NAME OF CARRIER	LEAVE blank unless that information is known
8	SHIPMENT ID NO.	LEAVE blank unless that information is known
12	ID OF PEST	To place plant material on a property on “Hold”, enter “suspect red palm weevil, *Rhynchophorus ferrugineus*”; the authority under which actions are taken is The Plant Protection Act of 2000, Statute 7 USC 7701-7758
16	ACTION REQUIRED	ENTER the following text: “All host plants of the red palm weevil, *Rhynchophorus ferrugineus*, are prohibited from movement from the property pending further notification by USDA–APHIS–PPQ and/or the State department of agriculture. No other plant material may leave the property until further evaluations can be made. After further investigations are conducted on the listed plants and other host material, if a positive detection is confirmed on the property, plant material will be treated/destroyed under supervision, with approved methods in accordance with USDA and State policies. Any additional hosts of red palm weevil on the property are subject to Federal and State quarantine requirements prior to movement from the property.”

C

Exotic Wood-Boring and Bark Beetles

How to Submit Bark Beetle Specimens

A. INSECTS and MITES:
Taxonomic support for insect surveys requires that samples be competently and consistently sorted, stored, screened in most cases, and submitted to the identifier.
Submission requirements for insects are:
1. ***Sorting trap samples***: Trapping initiative is most commonly associated with a pest survey program, such as Wood Boring and Bark Beetles (WBBB), see Bark Beetle Submission Protocol from the PPQ CAPS program for detailed procedures. As such, it is important to sort out the debris and non-target insect orders from the trap material. The taxonomic level of sorting will depend on the expertise available on hand and can be confirmed with the identifier.

2. ***Screening trap samples***: Consult the screening aids on the CAPS website for screening aids for particular groups. The use of these aids should be coupled with training from identifiers and/or experienced screeners before their use. These can be found at:
http://pest.ceris.purdue.edu/caps/screening.php

3. ***Storing samples***: Where appropriate, samples can be stored indefinitely in alcohol, however samples of dried insects such as those in sticky traps may decompose over time if not kept in a cool location such as a refrigerator or freezer. If insect samples have decomposed, do not submit them for identification.

4. ***Packaging and Shipping:*** Ensure specimens are dead prior to shipping. This can be accomplished by placing them in a vial of alcohol or place the dry specimens in the freezer for at least 1day. The following are a few tips on sorting, packaging and shipping liquids, sticky traps and dry samples:

Liquids: Factors such as arthropod group, their life-stage and the means they were collected determine the way the specimens are handled, preserved and shipped to the identifier. In general mites, insect larvae, soft-bodied and hard-bodied adult insects can be transferred to vials of 75-90% Ethanol (ETOH), or an equivalent such as isopropyl alcohol. At times, Lingren funnel trap samples may have rainwater in them. To prevent later decay, drain off all the liquid and replace with alcohol. Vials used to ship samples should contain samples from a single trap and a printed or hand-written label with the associated collection number that is also found in the top right corner of form 391. Please make sure to use a writing utensil that isn't alcohol soluble, such as a micron pen or a pencil. It is very important not to mix samples from multiple traps in a single vial so as to preserve the locality association data. Vials can be returned to field personnel upon request.

If sending specimens in alcohol is an issue with the mail or freight forwarder, the majority of liquid can be decanted off from the vial and then sealed tightly in the container just prior to shipping. Notify the identifier that the vials will need to have alcohol added back to them as soon as they are received. During the brief time of shipping, the specimens should not dry out if the vial is properly sealed.

Sticky trap samples: Adult Lepidoptera, because of their fragile appendages, scales on wings, etc. require special handling and shipping techniques. Lepidoptera specimens in traps should not be

Figure C-1 Procedures for Submitting Survey Samples to Domestic and Other Identifiers, page 1

manipulated or removed for preliminary screening unless expertise is available. Traps can be folded, with stickum-glue on the inside, but only without the sticky surfaces touching, and secured loosely with a rubber band for shipping. Inserting a few styrofoam peanuts on trap surfaces without insects will cushion and prevent the two sticky surfaces from sticking during shipment to taxonomists. Also DO NOT simply fold traps flat or cover traps with transparent wrap (or other material), as this will guarantee specimens will be seriously damaged or pulled apart – making identification difficult or impossible.

An alternative to this method is to cut out the area of the trap with the suspect pest and pin it securely to the foam bottom of a tray with a lid. Make sure there is some room around the specimen for pinning and future manipulation. For larger numbers of traps, placing several foam peanuts between sticky surfaces (arranged around suspect specimens) can prevent sticky surfaces from making contact when packing multiple folded-traps for shipment. DO NOT simply fold traps flat or cover traps with transparent wrap (or other material), as this will guarantee specimens will be seriously damaged or pulled apart – making identification difficult or impossible.

Dry specimens: Some collecting methods produce dry material that is very fragile. Dry samples can be shipped in vials or glassine envelopes, such as the ones that can be purchased here: http://www.bioquip.com/Search/default.asp. As with the alcohol samples, make sure the collection label is associated with the sample at all times. This method is usually used for larger insects and its downside is the higher chance of breakage during shipping. Additionally, dry samples are often covered in debris and sometimes difficult to identify.

Be sure that the samples are adequately packed for shipment to ensure safe transit to the identifier. If a soft envelope is used, it should be wrapped in shipping bubble sheets; if a rigid cardboard box is used, pack it in such a way that the samples are restricted from moving in the container. Please include the accompanying documentation and notify the identifier prior to shipping. Remember to inform the identifier that samples are on the way, giving the approximate number and to include your contact information.

Documentation: Each trap sample/vial should have accompanying documentation along with it in the form of a completed PPQ form 391, *Specimens for Determination.* The form is fillable electronically and can be found here:
http://cals-cf.calsnet.arizona.edu/azpdn/labs/submission/PPQ_Form_391.pdf

It is good practice to keep a partially filled electronic copy of this form on your computer with your address and other information filled out in the interest of saving time. Indicate the name of the person making any tentative identifications prior to sending to an identifier. Please make sure all fields that apply are filled out and the bottom field (block 24: Determination and Notes) is left blank to be completed by the identifier. Include the trap type, lure used, and trap number on the form. Also, include the phone number and/or e-mail address of the submitter. Other documentation in the form of notes, images, etc. can be sent along with this if it useful to the determination. It is important that there be a way to cross-reference the sample/vial with the accompanying form. This can be done with a label with the "Collection Number" in the vial or written on the envelope, etc.

Figure C-1 Procedures for Submitting Survey Samples to Domestic and Other Identifiers, page 2

Guidelines for Submitting Wood Borer and Bark Beetle (WBBB) Specimens for identification

USDA-APHIS-PPQ
CAPS Program

PEST DETECTION
Cooperative Agricultural Pest Survey

The purpose of this document is to outline the proper procedures for preserving, packaging and shipping WBBB specimens collected in Lindgren funnel traps as part of the USDA-APHIS-PPQ CAPS (Cooperative Agricultural Pest Survey) Program. The quality of specimens and the associated data is paramount in survey effectiveness. As such, this document will focus on the techniques and practices that ensure this high quality.

ATTENTION: **Submit preserved samples only, do NOT send decayed specimens**
Make sure the PPQ form 391 is clearly associated with each sample

General Procedures:

1. Service the traps
2. Take the samples to the lab and sort to order
3. Prepare samples for shipment

1. **Service the traps**

Lindgren trap samples are collected at the bottom of the trap in a container with a wet killing agent. For CAPS surveys, the collection container should be filled with a preservative, such as soapy water (a few drops of dish soap) or a 50% concentration of the non-toxic antifreeze (propylene glycol). Make sure to replace the solvent every time the trap is serviced.

Disposable paint filters. Photo by K. Metz, 2010

Traps should be serviced every 10-12 days or after a bad weather event which can disturb the sample, like rain, strong winds or snow. Leaving samples out for too long may damage them beyond recovery. Prior to going out in the field pack the following items: water and preservative mix to refill the trap, replacement bait (if needed), a pencil, adhesive label paper, disposable paint filters, a cooler with ice, and zippered bags each containing a paper towel wetted with 70% alcohol. At the site, strain the sample through the paint filter and place it in the zippered bag. A single sample, in this context, includes all contents of the collecting container. Use a pencil to write the label and stick it to the sample bag. It is good practice to double-label: a label inside the bag and an adhesive label on the outside. This minimizes error and ensures data preservation. If a sample is large, sub-divide it to several clearly labeled bags rather than overfilling. Make sure samples sit on top of the ice and are not crushed.

Lindgren trap. Photo by Bud Mayfield, 2004

Figure C-1 USDA–APHIS–PPQ–CAPS "Guidelines for Submitting Wood Borer and Bark Beetle Specimens for Identification", page 1

2. **Take the samples to the lab and sort to order**

Once the samples are in the lab, place them in the freezer for 24hrs or until ready to process. Rinse the samples off the filter over a sorting tray. Then, using soft tweezers and a magnifying glass or a dissecting microscope, pick out all beetles (order Coleoptera) and wood wasps, such as *Sirex noctilio* (order Hymenoptera, family Siricidae).. The beetle or wood wasp sample is then placed into a glass vial filled with 70-80% ethanol with a label and packaged with form 391 to be sent to an identifier. Make sure the alcohol label contains the collection number matching the associated entry in the 391 data form. Similarly to the field practice, one vial is usually used per sample, but if the sample is too big it should be sub-divided among several vials and labeled.

3. **Prepare samples for shipment**

Vial packaging. Photo by K. Metz 2010

Mailing tube. Photo by J. Brambila 2005

Each sample is packaged with form 391: "Specimens for Determination." Fully capturing the collection data is critical to a successful survey so the data form must be filled out thoroughly. There is no such thing as too much data. Section 22 is reserved for survey description, in this case WBBB. Section 24 should be left blank to be used by the identifier.

When packaging samples for shipment, there are several ways of ensuring the form remains with the sample. A paper envelope or a zippered bag work well to contain the sample vial with the data form stapled to the bag. Alternatively, rubber bands can be used to secure the form – a method that works better if there are multiple vials per sample. When securing multiple vials in one shipment, make sure to wrap each one in a paper towel and tape so as to contain the sample in case of breakage.

The vials should then be packed in a cardboard box or mailing tube large enough to have space for packing material on all sides. Packing material prevents the vials from being shaken or broken. Styrofoam peanuts, plastic foam, bubble wrap or crumpled newspapers are examples of packing materials. The vials can also be sent in padded envelopes sealed with tape, not staples.

SURVEY MATERIALS AND SUPPLIES

Alcohol	Isopropyl alcohol, also known as "rubbing alcohol" or 70% Ethyl alcohol (ethanol) to rinse and preserve specimens.
Alcohol bottles	Neoprene plastic bottles with spouts to dispense alcohol. Make sure the bottles are clearly labeled with the chemical they contain.

Figure C-1 USDA–APHIS–PPQ–CAPS "Guidelines for Submitting Wood Borer and Bark Beetle Specimens for Identification", page 2

Propylene glycol	Non-toxic antifreeze. Used as a preservative in Lindgren funnel trap collecting containers. Diluted to 50% concentration with water. An alternative is a few drops of dish soap in water.
Specimen bags	Large zippered bags. Used to hold freshly-collected specimens and specimen vials. Paper envelopes can also be used to hold contain vials during shipment.
Filters	Disposable cone paint filters are ideal for straining the preservative while catching the smallest of bark beetles.
Vials	Clean glass screw-top vials, new or recycled. A variety of vial sizes should be available to accommodate samples of various size.
Pipettes	Plastic or glass droppers or pipettes to transfer alcohol.
Tweezers	Fine tweezers to move specimens. Soft tweezers should be used to prevent specimen damage.
Sorting trays	Used to rinse and sort specimens in the lab.
Brushes	Fine paint brushes can be used to transfer small specimens.
Rubber bands	Assorted sizes, to tie vials together.
Writing utensils	Both standard ink and Sharpie marker inks are somewhat water soluble and run in alcohol. Micron pens have alcohol-proof ink and can be used alongside pencils. These pens come in a variety of tip widths, with very fine tips being preferable for writing and drawing. A sharp pencil is a good alternative to ink.

Authorship & Acknowledgements:

This document was prepared by Julieta Brambila (2005) and modified by Kira Metz (2010). Charles Brodel, Amanda Hodges, Joseph Beckwith, Robert Brown and James LaBonte reviewed this work.

Figure C-1 USDA–APHIS–PPQ–CAPS "Guidelines for Submitting Wood Borer and Bark Beetle Specimens for Identification", page 3

D

Exotic Wood-Boring and Bark Beetles

Taxonomic Support for Surveys

Background

The National Identification Services (NIS) coordinates the identification of plant pests in support of USDAs regulatory programs. Accurate and timely identifications provide the foundation for quarantine action decisions and are essential in the effort to safeguard the nation's agricultural and natural resources.

NIS employs and collaborates with scientists who specialize in various plant pest groups, including weeds, insects, mites, mollusks and plant diseases. These scientists are stationed at a variety of institutions around the country, including federal research laboratories, plant inspection stations, land-grant universities, and natural history museums. Additionally, the NIS Molecular Diagnostics Laboratory is responsible for providing biochemical testing services in support of the agency's pest monitoring programs.

On June 13, 2007, the PPQ Deputy Administrator issued PPQ Policy No. PPQ-DA-2007-02 which established the role of PPQ NIS as the point of contact for all domestically- detected, introduced plant pest confirmations and communications. A Domestic Diagnostics Coordinator (DDS) position was established to administer the policy and coordinate domestic diagnostic needs for NIS. This position was filled in October of 2007 by Joel Floyd (USDA, APHIS, PPQ-PSPI,NIS 4700 River Rd., Unit 52, Riverdale, MD 20737, phone (301) 734-4396, fax (301) 734-5276, e-mail: joel.p.floyd@aphis.usda.gov).

Taxonomic Support and Survey Activity

Taxonomic support for pest surveillance is basic to conducting quality surveys. A misidentification or incorrectly screened target pest can mean a missed opportunity for early detection when control strategies would be more viable and cost effective. The importance of good sorting, screening, and identifications in our domestic survey activity cannot be overemphasized.

Fortunately most states have, or have access to, good taxonomic support within their states. Taxonomic support should be accounted for in cooperative agreements as another cost of conducting surveys. Taxonomists and laboratories within the state often may require supplies, develop training materials, or need to hire technicians to meet the needs of screening and identification. Moreover, when considering whether to survey for a particular pest a given year, it is advisable to consider the challenges of taxonomic support as a factor in choosing that as a survey target in the first place.

Sorting and Screening

For survey activity, samples that are properly sorted and screened prior to being examined by an identifier will result in quicker turn around times for identification.

Sorting

is the first level of activity that assures samples submitted are of the correct target group of pests being surveyed, i.e., after removal of debris, ensure that the correct order, or in some cases family, of insects is submitted; or for plant disease survey samples, select those that are symptomatic if appropriate. There should be a minimum level of sorting expected of surveyors depending on the target group, training, experience, or demonstrated ability.

Screening

is a higher level of discrimination of samples such that the suspect target pests are separated from the known non-target, or native species of similar taxa. For example, only the suspect target species or those that appear similar to the target species are forwarded to an identifier for confirmation. There can be first level screening and second level depending on the difficulty and complexity of the group. Again, the degree of screening appropriate is dependent on the target group, training, experience, and demonstrated ability of the screener.

Check individual survey protocols to determine if samples should be sorted, screened or sent entire (raw) before submitting for identification. If not specified in the protocol, assume that samples should be sorted at some level.

Resources for Sorting, Screening, and Identification

Sorting, screening, and identification resources and aids useful to CAPS and PPQ surveys are best developed by taxonomists who are knowledgeable of the taxa that includes the target pests and the established or native organisms in the same group that are likely to be in samples and can be confused with the target. Many times these aids can be regionally based. They can be in the form of dichotomous keys, picture guides, or reference collections. NIS encourages the development of these resources, and when aids are complete, post them in the CAPS website so others can benefit. If local screening aids are developed, please notify Joel Floyd, the Domestic Diagnostics Coordinator, as to their availability. Please see the following for some screening aids currently available: http://pest.ceris.purdue.edu/caps/screening.php

Other Entities for Taxonomic Assistance in Surveys

When taxonomic support within a state is not adequate for a particular survey, in some cases other entities may assist including PPQ identifiers, universities and state departments of agriculture in other states, and independent institutions. Check with the PPQ regional CAPS coordinators about the availability of taxonomic assistance.

Universities and State Departments of Agriculture:

Depending on the taxonomic group, there are a few cases where these two entities are interested in receiving samples from other states. Arrangements for payment, if required for these taxonomic services, can be made through cooperative agreements. The National Plant Diagnostic Network (NPDN) also has five hubs that can provide service identifications of plant diseases in their respective regions.

Independent Institutions: the Eastern Region PPQ office has set up multi-state arrangements for Carnegie Museum of Natural History to identify insects from trap samples. They prefer to receive unscreened material and work on a fee basis per sample.

PPQ Port Identifiers: There are over 70 identifiers in PPQ that are stationed at ports of entry who primarily identify pests encountered in international commerce including conveyances, imported cargo, passenger baggage, and propagative material. In some cases, these identifiers process survey samples generated in PPQ conducted surveys, and occasionally from CAPS surveys. They can also enter into our Pest ID database the PPQ form 391 for suspect CAPS target or other suspect new pests, prior to being forwarded for confirmation by an NIS recognized authority.

PPQ Domestic Identifiers: PPQ also has a limited number of domestic identifiers (three entomologists and two plant pathologists) normally stationed at universities who are primarily responsible for survey samples. Domestic identifiers can be used to handle unscreened, or partially screened samples, with prior arrangement through the PPQ regional survey coordinator. They can also as an intermediary alternative to sending an unknown suspect to, for example, the ARS Systematic Entomology Lab (SEL), depending on their specialty and area of coverage. They can also enter into our Pest ID database the PPQ form 391 for suspect CAPS target or other suspect new pests, prior to being forwarded for confirmation by an NIS recognized authority.

PPQ Domestic Identifiers
Bobby Brown
Domestic Entomology Identifier
Specialty:forest pests (coleopteran, hymenoptera)
Area of coverage:primarily Eastern Region

USDA, APHIS, PPQ
901 W. State Street
Smith Hall, Purdue University
Lafayette, IN 47907-2089
Phone: 765-496-9673
Fax: 765-494-0420
e-mail: robert.c.brown@aphis.usda.gov

Julieta Brambila
Domestic Entomology Identifier
Specialty:adult Lepidoptera, Hemiptera
Area of Coverage: primarily Eastern Region
USDA APHIS PPQ
P.O. Box 147100
Gainesville, FL 32614-7100
Office phone: 352- 372-3505 ext. 438, 182
Fax: 352-334-1729
e-mail: julieta.bramila@aphis.usda.gov

Kira Zhaurova
Domestic Entomology Identifier
Specialty: to be determine
Area of Coverage: primarily Western Region
USDA, APHIS, PPQ
Minnie Belle Heep 216D
2475 TAMU
College Station, TX 77843
Phone: 979-450-5492
e-mail: kira.zhaurova@aphis.usda.gov

Grace O'Keefe
Domestic Plant Pathology Identifier
Specialty: Molecular diagnostics (citrus greening, P. ramorum, bacteriology, cyst nematode screening)
Area of Coverage: primarily Eastern Region
USDA, APHIS, PPQ
105 Buckhout Lab
Penn State University
University Park, PA 16802
Lab: 814 - 865 - 9896
Cell: 814 – 450- 7186
Fax: 814 - 863 – 8265
e-mail: grace.okeefe@aphis.usda.gov

Craig A. Webb, Ph.D.
Domestic Plant Pathology Identifier
Specialty: Molecular diagnostics (citrus greening, P. ramorum, cyst nematode screening)
Area of Coverage: primarily Western Region
USDA, APHIS, PPQ
Department of Plant Pathology
Kansas State University
4024 Throckmorton Plant Sciences
Manhattan, KS 66506-5502
Cell (785) 633-9117
Office (785) 532-1349
Fax: 785-532-5692
e-mail: craig.a.webb@aphis.usda.gov

Final Confirmations

If identifiers or laboratories at the state, university, or institution level suspect they have detected a CAPS target, a plant pest new to the United States, or a quarantine pest of limited distribution in a new state, the specimens should be forwarded to an NIS recognized taxonomic authority for final confirmation. State cooperator and university taxonomists can go through a PPQ area identifier or the appropriate domestic identifier that covers their area to get the specimen in the PPQ system (for those identifiers, see table G-1-1 in the Agriculture Clearance Manual, Appendix G link below). They will then send it to the NIS recognized authority for that taxonomic group.

State level taxonomists, who are reasonably sure they have a new United States. record, CAPS target, or new federal quarantine pest, can send the specimen directly to the NIS recognized authority, but must notify their State Survey Coordinator (SSC), PPQ Pest Survey Specialist (PSS), State Plant Health Director (SPHD), and State Plant Regulatory Official (SPRO).

Before forwarding these suspect specimens to identifiers or for confirmation by the NIS recognized authority, please complete a PPQ form 391 with the tentative determination. Also fax a copy of the completed PPQ Form 391 to “Attention: Domestic Diagnostics Coordinator” at 301-734-5276, or send a PDF file in an e-mail to mailto:nis.urgents@aphis.usda.govwith the overnight carrier tracking number.

The addresses of NIS recognized authorities of where suspect specimens are to be sent can be found in The Agriculture Clearance Manual, Appendix G, tables G-1-4 and G-1-5: http://www.aphis.usda.gov/import_export/plants/manuals/ports/downloads/mac_pdf/g_app_identifiers.pdf

Only use Table G-1-4, the “Urgent” listings, for suspected new United States records, or state record of a significant pest, and Table G-1-5, the “Prompt” listings, for all others.

When the specimen is being forwarded to a specialist for NIS confirmation, use an overnight carrier, insure it is properly and securely packaged, and include the hard copy of the PPQ form 391 marked “Urgent” if it is a suspect new pest, or “Prompt” as above.

Please contact Joel Floyd, the Domestic Diagnostics Coordinator if you have questions about a particular sample routing, at phone number: 301-734-5276, or e-mail: joel.p.floyd@aphis.usda.gov

Digital Images for Confirmation of Domestic Detections

For the above confirmations, do not send digital images for confirmation. Send specimens in these instances. For entry into NAPIS, digital imaging confirmations can be used for new county records for widespread pests by state taxonomists or identifiers if they approve it first. They always have the prerogative to request the specimens be sent.

Communications of Results

If no suspect CAPS target, program pests, or new detections are found, communication of these identification results can be made by domestic identifiers or taxonomists at other institutions directly back to the submitter. They can be in spread sheet form, on hard copy PPQ form 391’s, or other informal means with the species found, or “no CAPS target or new

suspect pest species found”. Good record keeping by the intermediate taxonomists performing these identifications is essential.

All confirmations received from NIS recognized authorities, positive or negative, are communicated by NIS to the PPQ Emergency and Domestic Programs (EDP) staff in PPQ headquarters. EDP then notifies the appropriate PPQ program managers and the SPHD and SPRO simultaneously. One of these contacts should forward the results to the originating laboratory, diagnostician, or identifier.

Data Entry

Cooperative Agricultural Pest Survey (CAPS)

For survey data entered into NAPIS, new country and state records should be confirmed by an NIS recognized authority, while for others that are more widespread, use the identifications from PPQ identifiers or state taxonomists.

E

Exotic Wood-Boring and Bark Beetles

Key to Help Screen *Tomicus piniperda*

Key to help screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera)

NA-TP-06-93

The following key was designed so that entomologists with little taxonomic experience in bark beetles (Scolytidae) could recognize *T. piniperda*. Help notes and a glossary follow the key. Although this will produce accurate identifications, it should be emphasized that all *T. piniperda* determinations need to be confirmed by a specialist. Such caution is important because the ever changing Nearctic scolytid fauna may someday include genera which resemble *T. piniperda*.

1. Basal margin of elytra armed (Figure 1) ______ 2
1'. Basal margin of elytra unarmed ______ **NOT** *T. piniperda*

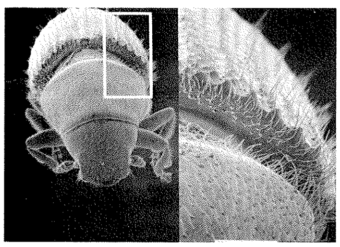

Figure 1.

2. Eyes not divided or emarginate (Figure 2) ______ 3
2'. Eyes divided or emarginate ______ **NOT** *T. piniperda*

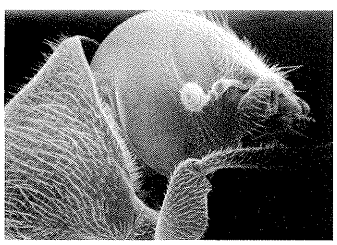

Figure 2.

3. Anterior lateral portions of pronotum with setiferous puntures (Figure 3) ______ 4
3'. Anterior lateral portions of pronotum asperate ______ **NOT** *T. piniperda*

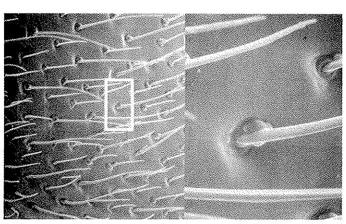

Figure 3.

Figure E-1 Key to Help Screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera) (Cavey, J., S. Passoa, and D. Kucera. 1994), page 1

4. Funicle with 6 segments (Figures 4 and 5; numbered in Figure 5; **S** = scape, **C** = club) 5
4'. Funicle with 5 or 7 segments ______ **NOT** *T. piniperda*

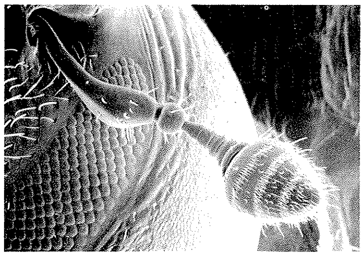

Figure 4.

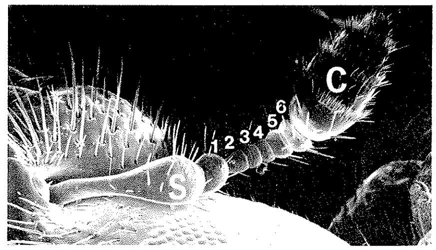

Figure 5.

5. Second row of setae continues uninterrupted through the declivity __ **NOT** *T. piniperda*
5'. Second row of setae sparse or absent on the declivity (Figures 6, 7) ______ *T. piniperda*

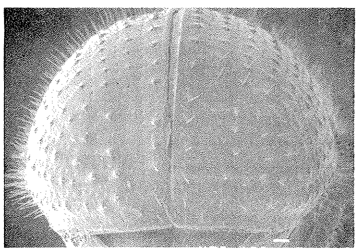

Figure 6.

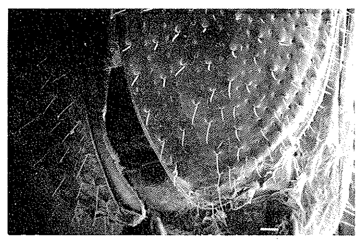

Figure 7.

Key prepared by

Steven Passoa	USDA/APHIS/PPQ, Northeastern Region
Joe Cavey	USDA/APHIS/PPQ, Northeastern Region

Figure E-2 Key to Help Screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera) (Cavey, J., S. Passoa, and D. Kucera. 1994), page 2

Help notes to *Tomicus piniperda* key

Couplet 1:

It is easier to see armed elytra when the beetle is viewed "head on." Common scolytids with unarmed elytra are *Ips*, *Orthotomicus*, *Scolytus*, and *Xyleborus*.

Couplet 3:

For an example of an asperate pronotum, see Wood 1982; page 698, *Ips calligraphus*, figure 169-1.

Couplet 4:

Don't count the scape or the club. Only the number of segments in the funicle is important. A common genus of scolytids with a 5-segmented funicle is *Dendroctonus* while *Hylurgopinus* has a 7-segmented funicle.

Couplet 5:

Some scolytids have a row of setae on the elytra between rows of punctures or striae. On *T. piniperda*, the second row of setae from the midline (suture) usually does not continue onto the declivity or is represented on the declivity by only a few scattered hairs. Do not confuse short hairs on the declivity of *T. piniperda* with major setae. When the taxonomic literature describes the second interval as bare, it ignores any short hairs which may be present. Unlike major setae, the short hairs are not in rows (see Figure 6). The best way to examine the declivity is with oblique lighting. It is usually necessary to rotate the specimen in order to search for the smooth area. Evaluating the declivity is a difficult character for the non-specialist; it may be necessary to examine a reference specimen of *T. piniperda* first for practice.

Important notes:

Some females of *T. piniperda* (5-10%) have a more continuous second row of setae on the declivity and might consequently key incorrectly in couplet 5 (S.L. Wood, pers. comm.). Any scolytids that key past couplet 4 in this key should be considered as suspect exotic species.

Description of *T. piniperda* adult:

Size 3.5 to 4.8 mm

Color light brown to black depending on maturity. A bicolored form exists where the elytra are reddish brown while the head and thorax are black (Berg, unpublished PPQ notes and specimens in APHIS Port Collection, Baltimore, Maryland).

Figure E-3 Key to Help Screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera) (Cavey, J., S. Passoa, and D. Kucera. 1994), page 3

Glossary

Armed elytra
elytra that have a series of raised semicircular projections (Figure 1).

Asperate pronotum
a pronotum roughened with blunt or pointed grainlike elevations.

Club
enlarged apical segments of the antenna (segments 8-11 on T. piniperda.

Declivity
the portion of the elytra that slopes downward at the rear end of the beetle above the anus.

Elytra
the hardened front wing covers of beetles.

Funicle
that portion of the antenna between the scape and the club (segments 2-7 in *T. piniperda*).

Scape
the elongate first segment of the antenna.

Setiferous punctures
a pit in the cuticle (skin) with a hair in the center.

Non-target information which may help future survey efforts.

1. Other scolytids found in pine shoots in the northeastern USA with *T. piniperda* include:
   Pityophthorus spp. (3 species)
   Orthotomicus caelatus

2. Other insects found in pine shoots during the *T. piniperda* survey in the Northeastern USA;
   Dioryctria sp. (Lepidoptera: Pyralidae)
   Pissodes spp. (Coleoptera: Curculionidae)

3. Native scolytids that resemble *T. piniperda* include:
   Hylastes salebrosus
   Hylurgops spp. (various species)

4. Scolytids which do not yet occur in the USA that resemble *T. piniperda* are:
   Tomicus spp., for example *T. minor*
   Hylurgus ligniperda

Figure E-4 Key to Help Screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera) (Cavey, J., S. Passoa, and D. Kucera. 1994), page 4

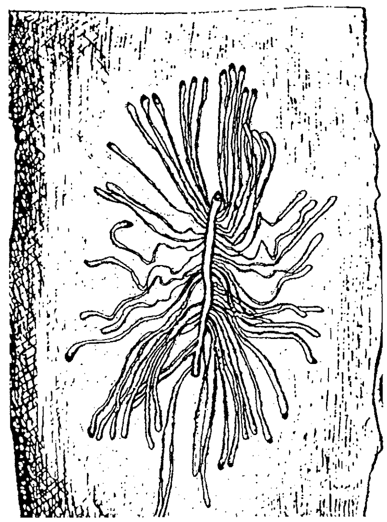

Figure 8

Typical bark beetle gallery of *T. piniperda* showing a vertical egg gallery constructed by a pair of adult beetles along with radiating larval galleries (USDA Coop. Econ. Ins. Rpt., 1972).

Acknowledgements

We thank the following people for their advice in constructing this technical note.

Don Anderson and **Natalia Vandenberg**	USDA/ARS/SEL
Stephen L. Wood	Brigham Young University
Russ Stewart	USDA/APHIS/BATS staff
Robert A. Haack	USDA Forest Service, NCFES
Daniel R. Kucera	USDA Forest Service, NA

The support of the USDA/APHIS/PPQ Northeastern Region and use of the scanning electron microscope and insect collection at Ohio State University is also appreciated.

Photo Credits:

John Mitchell	Ohio State University
Steven Passoa	USDA/APHIS/PPQ
Sara Donahue	USDA/ARS/SEL
Natalia Vandenberg	USDA/ARS/SEL

Figure E-5 Key to Help Screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera) (Cavey, J., S. Passoa, and D. Kucera. 1994), page 5

F

Exotic Wood-Boring and Bark Beetles

Key for Separating *Tomicus* Bark Beetles

Use Appendix F *Key for Separating* Tomicus *Bark Beetles* as a key to the identification of several *Tomicus* species (Brodel 2005, rev. 2009).

Tomicus Bark Beetles: A Key for Separating Program Species *piniperda* from European Exotics *destruens* and *minor*

This key pertains to three species of *Tomicus*, all of European origin. One of them, *T. piniperda* (L.), successfully established in the U.S. and was first detected in Ohio in 1992. It is commonly known as the pine shoot beetle. As of 2009, the National Agricultural Pest Information System indicates that this pest has been found in at least 17 states in the Northeast and Midwest.

The other two species, *T. destruens* (Wollaston) and *T. minor* (Hartig), are distributed in different parts of Europe. *Tomicus destruens* was for many years thought to be a subspecies or ecotype of *T. piniperda*. Geographic distributions of the two overlapped in several areas of Europe. Both seemed to attack various kinds of pine trees and effect the same type of damage. Then, after Wood and Bright (1992) listed it as a separate species, several authors (Gallego and Galián 2001; Kerdelhué *et al.* 2002; Kohlmayr *et al.* 2002) successfully demonstrated via genetic polymerase chain reaction studies and behavioral and morphological studies that *piniperda* and *destruens* are distinct species.

CAPS survey specialists and identifiers need to be able to distinguish all of these species from each other. In certain states where it is already established, *T. piniperda* will be 'background static', so to speak, unless it is detected in a previously uninfested county. In those states, specialists will need to be able to distinguish *T. piniperda* from the other two exotics. In states where none of the species exist, specialists will need to separate specimens of *Tomicus* from those of other scolytid genera before sending them forward for more specific identification.

To accomplish initial separation of *Tomicus* from other scolytids, including *Ips*, *Orthotomicus*, *Scolytus*, and *Xyleborus*, and to separate among species of *Tomicus*, the following reference materials are recommended as an interfacing group:

- Passoa, S. and J. Cavey. 1993. Key to help screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera). USDA, APHIS, PPQ. NA-TP-06-93. 5 pp.
- Brodel, C. 2000. Distinguishing *Tomicus minor* from *T. piniperda*. USDA, APHIS, PPQ. 1 p.
- Brodel, C. 2009. *Tomicus* bark beetles: a key for separating program species *piniperda* from European exotics *destruens* and *minor*. USDA, APHIS, PPQ. 4 pp.

Good Lighting Technique Required

To adequately view antennal setae referred to by Brodel (2009), one must have a lateral view of the antennal club. Direct light from one gooseneck lamp at the tip of the antenna, but in a plane just above the tip. Another gooseneck lamp should be held above the plane of the antenna, with its light shining parallel to the length dimension of the antennal club, but in the opposite direction of the first gooseneck. This orientation of lights relative to the antenna will, figuratively, make each seta "glow" and thus stand out from the background color of the antennal cuticle, even if that color is light yellowish or reddish brown. Using this technique, one will notice that, in *piniperda*, the area between sutures 2 and 3 looks very similar at first glance to the shiny areas

Figure F-1 *Tomicus* Bark Beetles: A Key for Separating Program Species *piniperda* from European Exotics *destruens* and *minot* (Brodel 2005, rev. 2009), page 1

between the base of the club and suture 1 and between sutures 1 and 2. In contrast, with *destruens*, the area between sutures 2 and 3 seems to be covered with setae, whereas segments 1 and 2 appear mostly shiny with sparse setae.

Bibliography

Brodel, C. 2000. Distinguishing between *Tomicus minor* and *T. piniperda*. USDA, APHIS, PPQ. 1 pg.

Brodel, C. 2009. *Tomicus* bark beetles: a key for separating program species *piniperda* from European exotics *destruens* and *minor*. USDA-APHIS-PPQ. 4 pp.

Gallego, G. and J. Galián. 2001. The internal transcribed spacers (ITS1 and ITS2) of the rDNA diferenciate (sic) the bark beetle forest pests *Tomicus destruens* and *T. piniperda*. Insect Molecular Biology 10: 415-420.

Kerdelhué, C., G.Roux-Morabito, J. Forichon, J. Chambon, A. Robert, and F. Lieutier. 2002. Population genetic structure of *Tomicus piniperda* L. (Curculionidae: Scolytinae) on different pine species and validation of *T. destruens* (Woll.). Molecular Ecology 11: 483-495.

Kohlmayr, B., M. Riegler, R. Wegensteiner, and C. Stauffer. 2002. Morphological and genetic identification of the three pine pests of the genus *Tomicus* (Coleoptera, Scolytidae) in Europe. Agricultural and Forest Entomology 4: 151-157.

Passoa, S. and J. Cavey. 1993. Key to help screen *Tomicus piniperda* (L.) from other North American Scolytidae (Coleoptera). USDA, APHIS, PPQ. NA-TP-06-93.

Wood, S. L. and D. E. Bright, Jr. 1992. A catalog of Scolytidae and Platypodidae (Coleoptera), Part 2: Taxonomic index. Vol. A. Great Basin Naturalist Memoirs, no. 13. Brigham Young University, Provo, Utah. 833 pp.

Charles F. Brodel
National Coleoptera Specialist
USDA, APHIS, PPQ
Miami, Florida
November, 2005
(revised August, 2009)

Figure F-2 *Tomicus* Bark Beetles: A Key for Separating Program Species *piniperda* from European Exotics *destruens* and *minot* (Brodel 2005, rev. 2009), page 2

A Key for Separating Program Species *piniperda* from European Exotics *destruens* and *minor*

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National Coleoptera Specialist
USDA APHIS PPQ
Miami, Florida
November, 2005
(revised August, 2009)

Use the key by Passoa and Cavey (1993) up to couplet 5 and then transfer to this key. Their key and couplets a through c in this key enable one to separate specimens of *Tomicus*, both program species *piniperda* and invasive European species, from other scolytid beetles likely to be intercepted in domestic traps. These include *Orthotomicus*, *Ips*, *Scolytus*, and *Xyleborus*. If a specimen keys to *Tomicus*, then proceed to couplet 1 of the key below. Couplet 1 refers to figures in Passoa and Cavey and the job aid "Distinguishing *Tomicus minor* from *T. piniperda*" by Brodel (2000).

a. Couplet 5 not reached .... not *Tomicus*
a'. Couplet 5 reached .... b

b. Scutellum not visible and/or scales or scale-like setae present .... not *Tomicus*
b'. Scutellum visible and no scales or scale-like setae present c

c. Elytral declivity with setae not arranged in rows ....
....*Tomicus puellus* OR not *Tomicus*
[NOTE: *T. brevipilosus* (Eggers), *T. puellus* (Reitter), and *T. pilifer* (Spessivtsev) are Asian species]
c'. Elytral declivity with setae arranged in rows from base to apex .... *Tomicus* 1

* * * * *

1. Second row of setae from elytral suture continues uninterrupted to apex of elytral declivity (NOTE: 5-10% of *T. piniperda* females have a more continuous, but not necessarily complete, second row of setae-- S. L. Wood); antennal club with very few, scattered setae between sutures 2 and 3 .... *T. minor* (Hartig)
1'. Second row of setae from elytral suture absent or sparse on elytral declivity (see Figs. 6 and 7 in key by Passoa and Cavey and drawing of *T. piniperda* in job aid by Brodel); antennal club with more numerous setae between sutures 2 and 3 (Figs. 1 and 2) 2

2. Antennal club with one row of setae, usually in a zigzag line, between the second and third sutures (Fig. 1) (NOTE: this line might sometimes be straight and be seen to originate

3

Figure F-3 ***Tomicus*** **Bark Beetles: A Key for Separating Program Species** ***piniperda*** **from European Exotics** ***destruens*** **and** ***minot*** **(Brodel 2005, rev. 2009), page 3** near the 2nd suture); density of setae on antennal segment 3 appearing about the same as on segments 1 and 2 (Fig.1)…………………..……..……......... *T. piniperda* (L.)

2'. Antennal club with three rather indistinct rows of setae, sometimes seen as two, between the second and third sutures (Fig. 2); density of setae on segment 3 appearing much greater than on segments 1 and 2 (Fig. 2) ……………………….. ………………………………………………………… *T. destruens* (Wollaston)

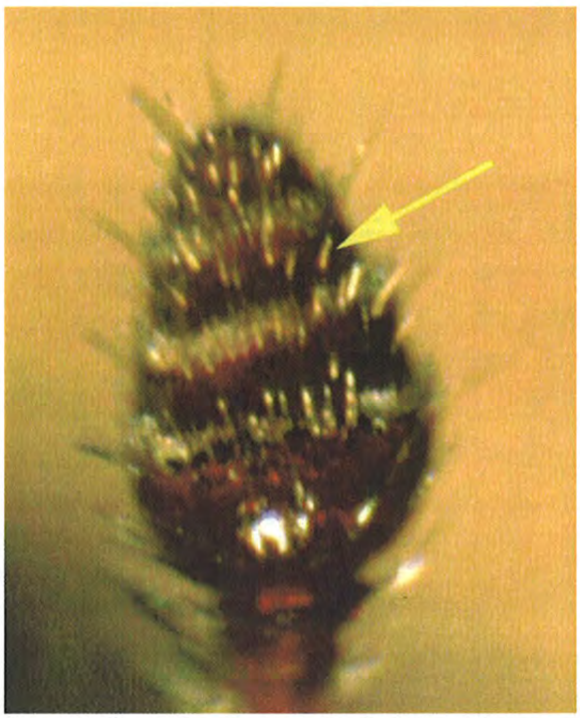


Fig. 1. *T. piniperda*: antennal club with one row of setae (arrow), usually in a zigzag line, between the 2nd and 3rd sutures

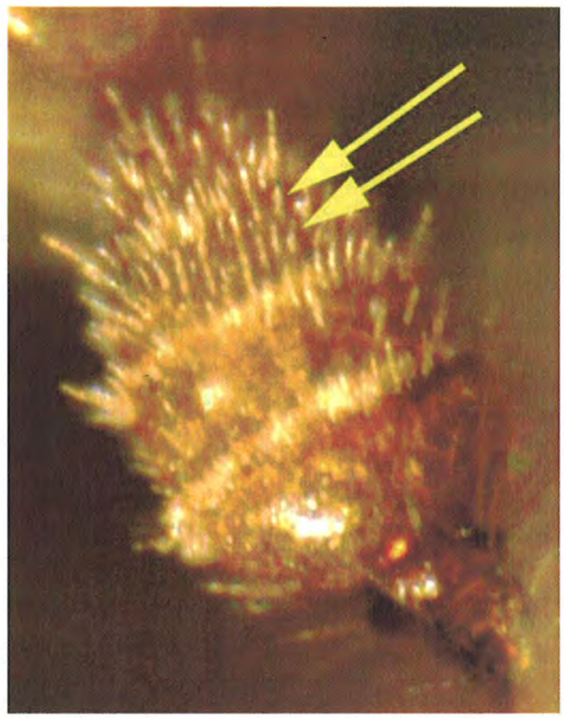
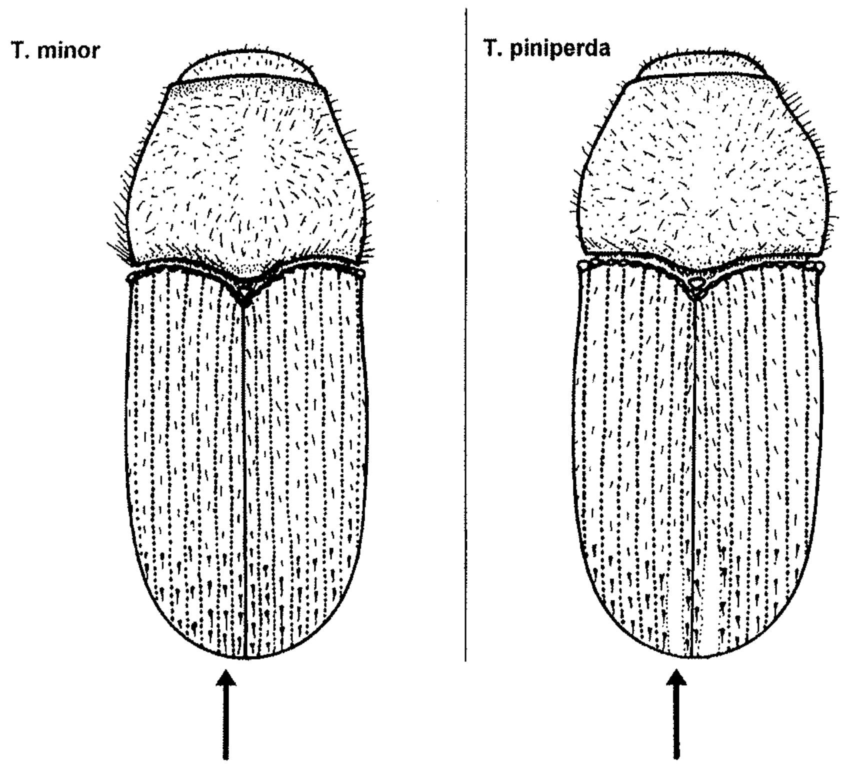


Fig. 2. *T. destruens*: antennal club with two or three rows of setae (arrows) between the 2nd and 3rd sutures

Figure F-4 *Tomicus* Bark Beetles: A Key for Separating Program Species *piniperda* from European Exotics *destruens* and *minot* (Brodel 2005, rev. 2009), page 4

Distinguishing ***Tomicus minor*** from ***T. piniperda***

Tomicus minor and ***T. piniperda*** can be separated taxonomically by examining the setae on the elytral declivity. The drawings below (Grune 1979) depict both species. In ***T. minor***, the second row of setae to the right or left of the elytral suture is complete or almost complete. In most specimens of *T.* ***piniperda***, there are no setae in this row. In 5 to 10 percent of females, however, this row has at least a few setae. For this reason, it is desirable to obtain as many specimens as possible from the same infested host.



The literature provides at least two other taxonomic characters for separating these species, but their reliability is doubtful. Firstly, the frons of ***T. minor*** is said to be "sparsely punctured", whereas that of ***T. piniperda*** is "densely punctured" (Grune 1979). Secondly, the row indicated by the arrows above is said to be "slightly depressed" in *T.* ***piniperda***, but not in *T.* ***minor*** (Pfeffer 1995).

Sources:

Grune, von Sabine. 1979. Brief illustrated key to European bark beetles. Verlag M. & H. Schaper, Hannover. 179 pp.

Pfeffer, A. 1995. Zentral- und westpalaarktische Borken- und Kernkafer (Coleoptera: Scolytidae, Platypodidae). Naturhistorisches Museum Basel. 310 pp.

Prepared by: Charles Brodel, Entomologist
USDA, APHIS, PPQ - Miami

Figure F-5 Distinguishing *Tomicus minor* from *T. piniperda* (Brodel, 2000)

G

Exotic Wood-Boring and Bark Beetles

Natural Enemies

Contents

Table G-1 Parasitoids of *Agrilus biguttatus* Fabricius (Buprestidae)

Species	Family	References
Atanycolus nessi	Braconidae	Moraal and Hilszczanski, 2000a; Kenis and Hilszczanski, 2004
Atanycolus sculpturatus	Braconidae	Kenis and Hilszczanski, 2004
Baryscapus agrilorum	Eulophidae	Kenis and Hilszczanski, 2004
Deuteroxorides elevator	Ichneumonidae	Kenis and Hilszczanski, 2004
Dolichomitus imperator[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Doryctes mutilator[1]	Braconidae	Kenis and Hilszczanski, 2004
Spathius curvicaudus	Braconidae	Moraal and Hilszczanski, 2000a; Kenis and Hilszczanski, 2004
Spathius curvicaudis	Braconidae	Moraal and van Achterberg, 2001
Spathius ligniarius	Braconidae	Moraal and Hilszczanski, 2000a; Kenis and Hilszczanski, 2004
Spathius radzayanus	Braconidae	Moraal and Hilszczanski, 2000a; Kenis and Hilszczanski, 2004
Spathius rubidus	Braconidae	Kenis and Hilszczanski, 2004

1 The identification of the parasitoid or insect host was doubtful or unknown.

Table G-2 Natural enemies of *Monochamus saltuarius* Gebleris (Cerambycidae)

Species		References
Cleonymus serrulatus[1,2]	Pteromalidae	Natural History Museum, 2007
Spathius spp.[1]	Braconidae	CABI, 2010
Stenagostus umbratilis[3]	Elateridae	CABI, 2010

1 Parasite

2 Parasitoid

3 Predator

Table G-3 Parasitoids of *Monochamus sutor* Linnaeus (Cerambycidae)

Species	Family	References
Atanycolus genalis	Braconidae	Kenis and Hilszczanski, 2004
Dolichomitus mesocentrus	Ichneumonidae	Kenis and Hilszczanski, 2004
Dolichomitus tuberculatus	Ichneumonidae	Kenis and Hilszczanski, 2004
Helconidea dentator	Braconidae	Kenis and Hilszczanski, 2004
Iphiaulax impostor	Braconidae	Kenis and Hilszczanski, 2004
Rhimphoctona megacephalus[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona teredo	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhyssa amoena[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhyssa persuasoria[1]	Ichneumonidae	Kenis and Hilszczanski, 2004

1 The identification of the parasitoid or insect host was doubtful or unknown.

Table G-4 Natural Enemies of *Tetropium castaneum* Linnaeus (Cerambycidae) (continued)

Species	Family	References
Atanycolus denigrator	Braconidae	Kenis and Hilszczanski, 2004
Atanycolus genalis	Braconidae	Kenis and Hilszczanski, 2004
Atanycolus initiator	Braconidae	Kenis and Hilszczanski, 2004
Baeacis dissimilis	Braconidae	Dobesberger, 2005a
Billaea triangulifera	Tachinidae	Kenis and Hilszczanski, 2004
Coleocentrus caligatus	Ichneumonidae	Kenis and Hilszczanski, 2004
Dolichomites dux	Ichneumonidae	Dobesberger, 2005a
Dolichomitus mesocentrus	Ichneumonidae	Kenis and Hilszczanski, 2004
Dolichomitus tuberculatus[1]	Ichnemonidae	Kenis and Hilszczanski, 2004
Doryctes leucogaster	Braconidae	Kenis and Hilszczanski, 2004
Doryctes mutilator (=obliterates)	Braconidae	Kenis and Hilszczanski, 2004

Table G-4 Natural Enemies of *Tetropium castaneum* Linnaeus (Cerambycidae) (continued)

Species	Family	References
Doryctes undulatus	Braconidae	Kenis and Hilszczanski, 2004
Helcon tardator[2]	Braconidae	Kenis and Hilszczanski, 2004
Helconidea dentator	Braconidae	Kenis and Hilszczanski, 2004
Helcostizus restaurator[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Laphria (=Choerades gilva)	Asilidae	CABI, 2010
Lissonota buccator[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Neoxorides collaris	Ichneumonidae	Kenis and Hilszczanski, 2004
Neeoxorides nitens	Ichneumonidae	Kenis and Hilszczanski, 2004
Odontocolon dentipes[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Odontocolon spinipes	Ichneumonidae	Kenis and Hilszczanski, 2004
Ontsira antica	Braconidae	Kenis and Hilszczanski, 2004
Ontsira imperator	Braconidae	Kenis and Hilszczanski, 2004
Podoschistus scutellaris[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Poemenia hectica[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Poemenia notata[2]	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona megacephalus	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona pectoralis	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona teredo (=xoridoidea)	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona xoridiformis	Ichneumonidae	Kenis and Hilszczanski, 2004
Townesia tenuiventris[2]	Ichneumonidae	Kenis and Hilszczanski, 2004
Wroughtonia dentator	Braconidae	Dobesberger, 2005a
Wroughtonia tardator	Braconidae	Dobesberger, 2005a
Xorides ater[2]	Ichneumonidae	Kenis and Hilszczanski, 2004
Xorides brachylabris	Ichneumonidae	Kenis and Hilszczanski, 2004
Xorides irrigator	Ichneumonidae	Kenis and Hilszczanski, 2004
Xorides niger	Ichneumonidae	Dobesberger, 2005a
Xorides praecatorius	Ichneumonidae	Kenis and Hilszczanski, 2004
Xorides propinquus	Ichneumonidae	Kenis and Hilszczanski, 2004

1 Collected from *Tetropium* spp.

2 The identification of the parasitoid or insect host was doubtful or unknown.

Table G-5 Natural Enemies of *Tetropium fuscum* Fabricius (Cerambycidae)

Species	Family	References
Atanycolus denigrator	Braconidae	Kenis and Hilazczanski, 2004
Atanycolus genalis (=initiator)	Braconidae	Dobesberger, 2005b; Kenis and Hilazczanski, 2004
Atanycolus neesi	Braconidae	Dobesberger, 2005b; Kenis and Hilazczanski, 2004
Atanycolus sculpturatus	Braconidae	Dobesberger, 2005b
Athous subfuscus	Elateridae	Dobesberger, 2005b
Billaea adelpha	Tachinidae	Kenis and Hilszczanski, 2004
Billaea triangulifera	Tachinidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Deuteroxorides elevator[1]	Ichneumonidae	Kenis and Hilszczanski, 2004
Dolichomitus dux	Ichnemonidae	Dobesberger, 2005b; Kenis and Hilazczanski, 2004
Dolichomitus terebrans	Ichnemonidae	Dobesberger, 2005b
Dolichomitus mesocentrus	Ichnemonidae	Kenis and Hilszczanski, 2004
Dolichomitus sericeus	Ichnemonidae	Kenis and Hilszczanski, 2004
Dolichomitus tuberculatus[2]	Ichnemonidae	Kenis and Hilszczanski, 2004
Doryctes mutilator (=obliterates)	Braconidae	Dobesberger, 2005b; Kenis and Hilazczanski, 2004
Doryctes obliterates	Braconidae	Dobesberger, 2005b
Helcon angustator	Braconidae	Kenis and Hilazczanski, 2004
Helconidea dentator	Braconidae	Kenis and Hilazczanski, 2004
Helcostizus restaurator[2]	Ichneumonidae	Kenis and Hilszczanski, 2004
Inocellia crassicornis	Inocellidae	Dobesberger, 2005b
Laphria gilva	Asilidae	Dobesberger, 2005b
Neoxorides collaris	Ichnemonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Odontocolon dentipes	Ichnemonidae	Dobesberger, 2005b
Odontocolon spinipes	Ichnemonidae	Dobesberger, 2005b
Ontsira antica	Braconidae	Kenis and Hilszczanski, 2004
Ontsira imperator	Braconidae	Kenis and Hilszczanski, 2004
Palloptera usta	Pallopteridae	Dobesberger, 2005b
Phaeostigma notata	Raphidiidae	Dobesberger, 2005b
Poemenia hectica[2]	Ichneumonidae	Kenis and Hilszczanski, 2004
Raphidia spp.	Raphidiidae	Dobesberger, 2005b
Rhimphoctona megacephalus	Ichnemonidae	Dobesberger, 2005b

Table G-5 Natural Enemies of *Tetropium fuscum* Fabricius (Cerambycidae)

Species	Family	References
Rhimphoctona megacephalus	Ichnemonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Rhimphoctona macrocephala[1]	Ichnemonidae	Dobesberger, 2005b
Rhimphoctona obscuripes	Ichneumonidae	Kenis and Hilszczanski, 2004
Rhimphoctona teredo	Ichnemonidae	Kenis and Hilszczanski, 2004
Rhimphoctona xoridiformis	Ichnemonidae	Kenis and Hilszczanski, 2004
Rhyssa lineolata[1]	Ichnemonidae	Dobesberger, 2005b
Thanasimus spp.	Cleridae	Dobesberger, 2005b
Townesia tenuiventris	Ichneumonidae	Dobesberger, 2005b
Wroughtonia dentator	Braconidae	Dobesberger, 2005b
Xorides ater[1]	Ichneumonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Xorides brachylabris	Ichneumonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Xorides irrigator	Ichneumonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004
Xorides praecatorius	Ichneumonidae	Dobesberger, 2005b; Kenis and Hilszczanski, 2004

1 The identification of the parasitoid or insect host was doubtful or unknown.

2 Collected from *Tetropium* spp.

Table G-6 Parasitoids of *Tomicus destruens* Wollaston (Curculionidae, Scolytinae)

Species	Family	References
Eurytoma morio	Eurytomidae	CABI, 2010
Heydenia pretiosa	Pteromalidae	Natural History Museum, 2007
Metacolus unifasciatus	Pteromalidae	Natural History Museum, 2007
Roptrocerus xylophagorum	Pteromalidae	Natural History Museum, 2007

H

Exotic Wood-Boring and Bark Beetles

Wasp Watcher Brochure

Use this 2-page brochure as a guide to finding *Cerceris fumipennis*, a solitary ground-nesting wasp. The wasp stocks her nest with native buprestid beetles, as well as the emerald ash borer if available (Anonymous. n.d.).

Identifying Markings

- ½ - ¾ inch long
- Dark smoky brown wings
- One cream/yellow band on second segment of abdomen (near "waist")
- Three large cream/yellow spots on face


Markings of Female *Cerceris fumipennis*
(photos by P. Careless)

Cerceris is active in eastern North America during
July and August

(Cerceris is pronounced: 'ser-ser-iss)

How to Identify Nests

- Round hole the diameter of a pencil
- Holes go straight down (not angled into the ground)
- Surrounded by a circle of excavated soil (not all to one side like a dog would dig)
- Often tucked beside or partially under a clump of grass
- Nests may be clustered together in a colony. Colonies may contain 5-500 nests.


Cerceris Nests
(photos by P. Careless)

To be suitable for EAB monitoring, a colony should be within 1000 yards (1000 m) of ash trees

Biosurveillance

- Visit your colony mid-day, 3-4 sunny days during July and select as many nests as you can keep an eye on.
- At each nest, pin the 'collar' to the ground with golf tee, placing the second hole over the nest entrance.
- Wasps without prey can come and go easily through the hole (A). A wasp carrying prey will not fit through the hole (B).
- For 1-3 hours, watch as wasps return to nests. Wasps with prey can be netted in flight or caught as they try to pass through the collar. Take prey and release wasp.
- Collect a total of 50 beetles over 3-4 visits. Place beetles from each day in a baggie labeled with place and date. Beetles found on the ground may be included. Place in freezer and mail to us at end of summer.

A - Wasp Entering Nest Through Collar

B - Wasp Unable to Enter With Prey
(photos by P. Careless & M. Bohne)

Figure H-1 Guide to Finding *Cerceris fumipennis,* side 1

Promising Nest Sites

- Hard packed sandy soil
- Areas of human disturbance (**baseball diamonds,** old sand pits, trail and road edges, informal parking lots, fire-pits, etc.)
- Full sunshine
- Sparse vegetation (about 50% hard-packed soil and 50% short vegetation)
- Near a wooded area, about 200 yards (200m) or less

Typical *Cerceris* Colony Sites
(photos by P. Careless & C. Teerling)

What is Emerald Ash Borer?

- Small metallic green beetle (1/2" long, 1/8" wide)
- An exotic beetle from Asia
- Larva tunnels under the bark
- Attacks and kills **all** species of ash
- First found in Michigan in 2002
- Spreading VERY rapidly across the USA and Canada (primarily in firewood)
- Early detection is difficult. This wasp and WaspWatchers can help.

Emerald Ash Borer

For more information, visit our website at
www.cerceris.info

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In Canada, Philip Careless
pcareles@uoguelph.ca

Thanks to…

WaspWatcher

How to find the wasp that hunts **emerald ash borer**

This native wasp is **not known to sting humans**, even when handled.

Female *Cerceris fumipennis*
with Emerald Ash Borer

Cerceris fumipennis is a solitary ground-nesting wasp. The female stocks her nest with buprestid beetles, including emerald ash borer (EAB) when present.

Biosurveillance (observing colonies of these native wasps and collecting some of the prey they bring back) is currently the most promising way to monitor for EAB. Researchers in the United States and Canada are looking for colonies of these wasps throughout the state, and could use your help.

Figure H-1 Guide to Finding *Cerceris fumipennis,* side 2

Exotic Wood-Boring and Bark Beetles

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