DETECTING SIGNS AND SYMPTOMS OF

ASIAN LONGHORNED BEETLE INJURY

TRAINING GUIDE

Canada

Detecting Signs and Symptoms of

Asian Longhorned Beetle Injury

Training Guide

Jozef Ric[1], Peter de Groot[2], Ben Gasman[3], Mary Orr[3],
Jason Doyle[1], Michael T Smith[4], Louise Dumouchel[3], Taylor Scarr[5], Jean J Turgeon[2]

1 Toronto Parks, Forestry and Recreation
2 Natural Resources Canada - Canadian Forest Service
3 Canadian Food Inspection Agency
4 United States Department of Agriculture - Agricultural Research Service
5 Ontario Ministry of Natural Resources

We dedicate this guide to our spouses and children for
their support while we were chasing this beetle.

Library and Archives Canada Cataloguing in Publication

Detecting Signs and Symptoms of Asian Longhorned Beetle Injury : Training / Jozef Ric, Peter de Groot, Ben Gasman, Mary Orr, Jason Doyle, Michael T Smith, Louise Dumouchel, Taylor Scarr and Jean J Turgeon

ISBN 0-662-43426-9
Cat. No. Fo124-7/2006E

1. Asian longhorned beetle. 2. Trees- -Diseases and pests- -Identification. I. Ric, Jozef II. Great Lakes Forestry Centre

QL596.C4D47 2006 634.9’67648 C2006-980139-8

Cover: Asian longhorned beetle *(Anoplophora glabripennis)* adult. Photography by William D Biggs

Additional copies of this publication are available from:

Publication Office
Natural Resources Canada Canadian Forest Service
Great Lakes Forestry Centre
1219 Queen Street East
Sault Ste. Marie, Ontario
CANADA P6A 2E5

glfcweb@nrcan.gc.ca

Plant Health Division
Canadian Food Inspection Agency
Floor 3, Room 3201 E
59 Camelot Drive
Ottawa, Ontario
CANADA K1A 0Y9

guides@inspection.gc.ca

Cette publication est aussi disponible en français sous le titre:
Détection des signes et symptômes d’attaque par le longicorne étoilé : Guide de formation.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

This guide was born out of the hard work, unwavering dedication and unparalleled experience of all those involved, either directly or peripherally, with the Asian longhorned beetle eradication programme that began in September 2003 in the Greater Toronto Area. At one point or another during this programme, the team led by the Canadian Food Inspection Agency comprised collaborators and employees from various agencies, namely: the City of Toronto, the City of Vaughan, the Toronto and Region Conservation Authority, the Region of York, the Ontario Ministry of Natural Resources, the Canadian Forest Service of Natural Resources Canada, and three branches of the United States Department of Agriculture (Animal and Plant Health Inspection Service, Agricultural Research Service and Forest Service). This guide is testimony to their collective efforts.

Most of the images contained in this guide were chosen from thousands of pictures taken in the Greater Toronto Area by various members of this team. We thank everyone who unknowingly contributed photographic images to this programme. Unless otherwise noted photo credits are those of the Canadian Food Inspection Agency. We extend our gratitude to the following individuals who kindly allowed the reproduction of their photographs: Dorothy Ambeault, Bill Biggs, Chuck Jones, and Isabelle Ochoa (Natural Resources Canada, Sault Ste Marie), Klaus Bolte (Natural Resources Canada, Ottawa), Wayne Ingram (Ontario Ministry of Natural Resources), James Solomon (USDA Forest Service, www.forestryimages.org), USDA Forest Service -Ogden Archives (USDA Forest Service, www.forestryimages.org), Minnesota Department of Natural Resources Archives (Minnesota Department of Natural Resources, www.forestryimages.org) and Bruce Gill (Canadian Food Inspection Agency, Ottawa).

Special thanks to: Troy Kimoto, Bruce Gill, and Rob Favrin (Canadian Food Inspection Agency), Jon Sweeney, Dorothy Ambeault, and Bill Biggs (Natural Resources Canada - Canadian Forest Service) and Steve Miller and Richard Burton (Toronto Parks, Forestry and Recreation) for their valuable suggestions and comments; Ron Fournier (Natural Resources Canada - Canadian Forest Service) for sorting all of the images taken during this program; Isabelle Ochoa (Natural Resources Canada - Canadian Forest Service) for making our conceptual idea of a life cycle a reality; Karen Jamieson (Natural Resources Canada - Canadian Forest Service) for editing the final version of this guide and for her assistance in finding a designer and a printer; and, Steve Matsumoto (Toronto Parks, Forestry and Recreation) for his assistance with the short paragraph on inspection safety. This work was translated by Pierre de Tonnancour (Public Works and Government Services Canada).

Funding for the design, layout, translation and printing of this guide was provided by the Canadian Food Inspection Agency. We greatly appreciate the financial assistance provided by our respective supervisors/managers for making it possible to take this project from the conceptual stage to a "fait accompli".

Jozef Ric, Peter de Groot, Ben Gasman, Mary Orr, Jason Doyle, Michael T Smith, Louise Dumouchel, Taylor Scarr, Jean J Turgeon

November 2006

INTRODUCTION

The Asian longhorned beetle, *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae) is native to China and Korea. Between 1996 and 2002, populations of this insect were found in several cities in the United States of America. In 2003, an established population of the Asian longhorned beetle was discovered in an industrial park in the Greater Toronto Area, on the border between Toronto and Vaughan, Ontario, Canada. In North America, this invasive alien insect attacks and kills a wide range of deciduous tree species, and thus poses a high-risk to the urban and natural forests of Canada.

Once an alien species is discovered, a delimiting survey needs to be carried out to quickly establish the boundaries of the infested area and to determine where and when the species first became established. This information is used to identify the most appropriate course of action (i.e., eradicate the invading species, minimize its impact or control or limit its spread) and is critical to its success. The urgent need for this information on the extent of the infestation cannot be overstated. Rapid acquisition of this information requires that inspectors[6] already qualified in host identification, be trained to recognize and detect the invading species as well as its signs and symptoms of injury. This guide, which contains descriptions of the signs and symptoms of Asian longhorned beetle injuries, is a reference tool that can be used for the basic training of inspecting crews charged with the detection of the beetle.

This guide contains colour images and brief descriptions of the life stages to aid in the recognition of this species under field conditions. A list of tree genera found in the urban forest of the Greater Toronto Area is also included. Each genus from that list has been assigned to a group based on the likelihood of it being attacked by the beetle. This guide provides images and descriptions of the signs and symptoms that can be used to recognize infested trees and describes how to distinguish these from similar

6 In this guide, an inspector is an individual examining a tree for the purpose of finding the Asian longhorned beetle or detecting the presence of signs and symptoms of injuries caused by the beetle.

(“look-alikes”) signs and symptoms that are not caused by the Asian longhorned beetle. The final section comprises step-by-step instructions detailing i) how to examine individual trees, ii) where to look for the beetle and its signs of injury in the landscape and in trees, iii) when to conduct surveys, and iv) what to do if beetles or signs of infestation are discovered. A brief description of the verification process is also included. This process, which is initiated upon the discovery of either the insect or its signs and symptoms, comprises a series of steps to ensure that quality samples of insects or signs and symptoms are collected from the field and submitted to experts for verification. The verification process is necessary because misidentification can have serious implications for Canadian trade. Thus, the discovery of a beetle specimen or of a tree with suspect signs or symptoms should never be considered an Asian longhorned beetle or a tree infested by the beetle, respectively, until it has been confirmed by an expert or specialist.

The aim of this guide is to collate the information required to increase the likelihood of finding signs of the presence of the Asian longhorned beetle in urban landscapes. It is not within the scope of this guide to provide detailed procedures to carry out large scale detection and survey methods at the landscape level.

HOW TO USE THIS GUIDE

The chapters of this guide should be read in order of presentation. Each section of this guide builds upon the previous one. Inspectors must learn first to recognize the insect. Next, it is important for inspectors to know which tree species can be attacked by the beetle and to be able to identify them. Inspectors must also become familiar with the appearance of the numerous signs of injury on these hosts and with the tree's response to these injuries. Once this knowledge has been acquired, inspectors can proceed to the final section, which contains general information on survey methods and timing as well as generalized procedures and principles to follow while searching for the beetle's presence or signs and symptoms of its presence.

RECOGNIZING THE ASIAN LONGHORNED BEETLE

INTRODUCTION

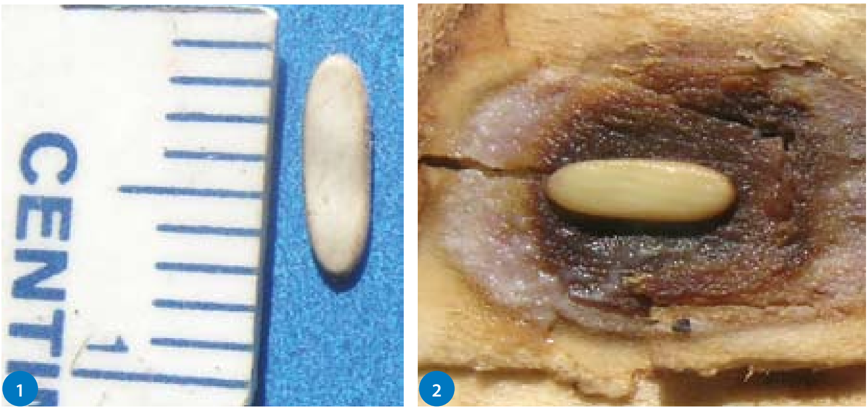
It is important to become familiar with the general appearance of the different life stages of the Asian longhorned beetle and with the time of year it can be seen. This section contains brief morphological descriptions of each life stage. These descriptions will enable inspectors to recognize this species in the field or draw their attention to specimens that should be referred to specialised staff or experts for verification. A diagram of the Asian longhorned beetle life cycle illustrates when the various life stages occur throughout the year.

DESCRIPTION OF LIFE STAGES

The Asian longhorned beetle belongs to a group of wood-boring insects known as longhorned beetles or roundheaded borers. The development of this insect goes through four stages: egg, larva, pupa and adult. Each of these stages is described below.

Egg

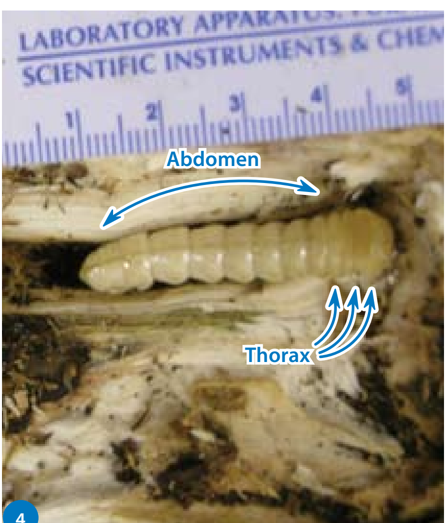
The egg is white when recently laid (Figure 1), and turns to off-white or ivory-white as it matures (Figure 2). It is 5-7 mm long and oblong. Eggs are laid singly under the bark and typically hatch in 10-15 days, if laid in the summer.

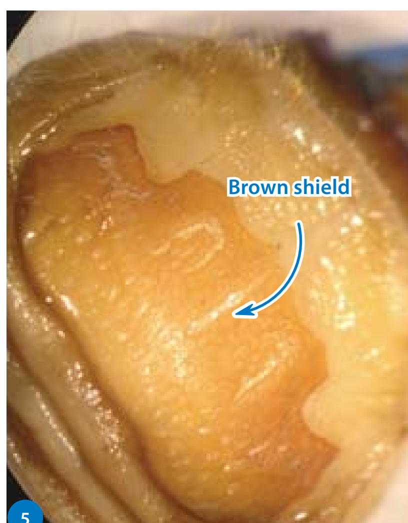


FIGURES 1-2. 1, Eggs of the Asian longhorned beetle are white when laid. **2,** Egg colour changes from white to ivory-white as it ages.

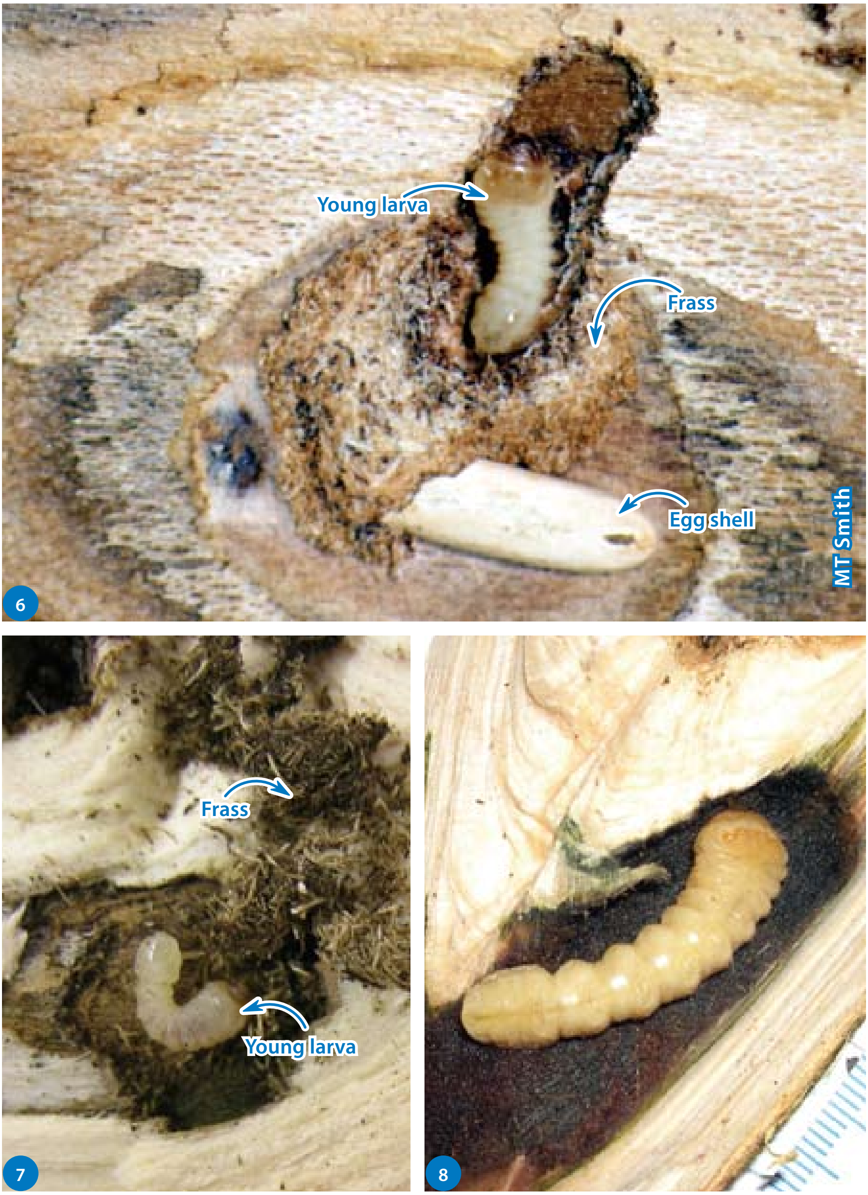
Larva

The head has dark brown mouthparts, easily seen when looking at the ventral side of the larva (Figure 3). The thoracic and abdominal segments of the larva's body are cream coloured (Figure 4). The first segment of the thorax, located behind the head, is the largest and has a brown sclerotized (i.e., hardened) shield on the dorsal side of it (Figure 5). The body tapers from that first segment towards the end of the abdomen. The young larva is between 7-20 mm in length and feeds beneath the bark on the sapwood for about 20 days (Figures 6, 7). The mature larva is 30-60 mm in length and tunnels into the wood (Figure 8).





FIGURES 3-5. 3, Close-up view of the mouthparts, as seen from the ventral side of a mature larva's head. **4,** Location of thoracic and abdominal segments on a mature larva. **5,** Close-up view of the hardened brown shield on the dorsal side of the first thoracic segment of a mature larva.



FIGURES 6-8. 6, Recently-hatched larva feeding on the sapwood. **7,** Young larva feeding on the sapwood. **8,** Mature larva feeding in the wood.

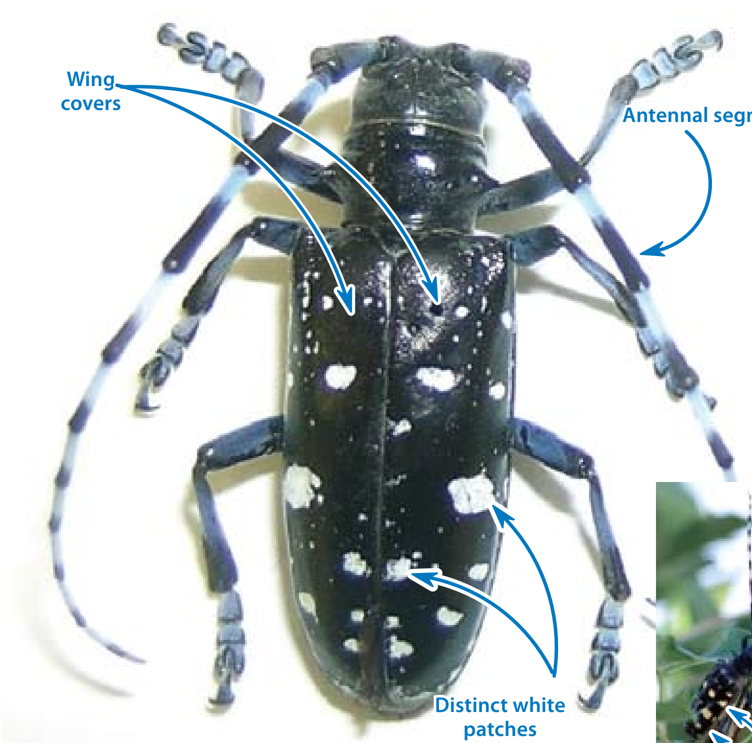
Pupa

The pupa is off-white or ivory-white, 30-37 mm by 11 mm, and is typically found in a pupal chamber located in the wood (Figure 9).

FIGURE 9. A pupa in its pupal chamber.

Adult

The body of the adult is jet-black, glossy and may have a bluish tinge. Each wing cover has about 20 white (Figure 10) or yellow patches (Figure 11). The antennae have 11 segments that alternate between blue-white and blue-black (Figure 10). The female is 22-36 mm long by 8-12 mm wide, with antennae about 1.2-1.8 times its body length (Figures 12, 13). The male is 19-32 mm long by 6.5-11 mm wide, with antennae about 1.6-2.1 times its body length (Figures 14, 15).



FIGURES 10-11. 10, Asian longhorned beetle adult with distinct white patches on the wing covers. **11,** Asian longhorned beetle adult with distinct yellow patches on the wing covers feeding on maple.

12

K Bolte

13

I Ochoa

FIGURES 12-13. 12, Asian longhorned beetle female. **NOTE** that antennae are about the same length as the body. **13,** Example of the range in size of females.

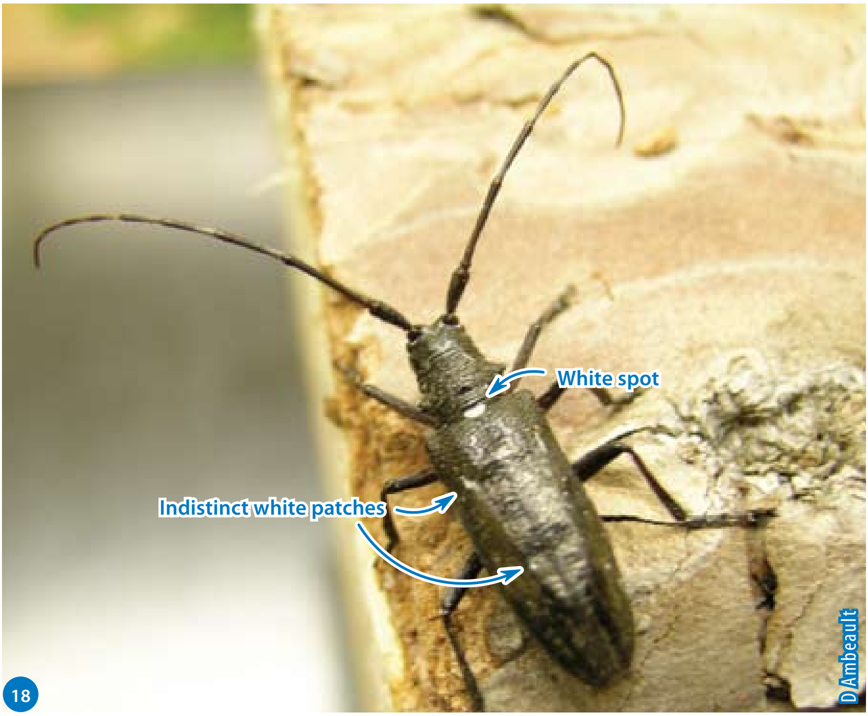
14

K Bolte

15

I Ochoa

FIGURES 14-15. 14, Asian longhorned beetle male. **NOTE** that antennae are longer than the body. **15,** Example of the range in size of males.



FIGURES 16-18. 16, Asian longhorned beetle adult. **17,** Whitespotted sawyer male. **NOTE** the single white spot between the wing covers. **18,** Whitespotted sawyer female. **NOTE** the white spot between the wing covers and many indistinct white patches on the wing covers.

"LOOK-ALIKES" [7]

In the Greater Toronto Area, the insect that has been confused most frequently with the Asian longhorned beetle is the whitespotted sawyer, which is native to North America and lays its eggs in dead or dying conifers. The process of identification is based on unique morphological features of the insect and is performed by taxonomists. The table below contains some of the features that can be used to distinguish the two species on a preliminary basis.

Name	Asian longhorned beetle	whitespotted sawyer
Hosts	Hardwoods	Conifers
Body length (without antennae)	17-39 mm	13-28 mm
Body appearance	Glossy black with a smooth surface (Figure 16).	Bronzy black, with rough dimpled surface (Figures 17, 18).
Antennae	**Male:** Distinct blue-white and blue- black bands; about twice as long as body. **Female:** Distinct blue-white and blue-black bands; slightly longer than body.	**Male:** All black; about twice as long as body. **Female:** Faint bands of white and gray; slightly longer than body.
Wing covers	Both females and males have up to 20 distinct, irregular-shaped white spots. No white spot between the tops of the wing covers.	Only females have indistinct white patches. Both females and males have one large white spot between the top of the wing covers.
Legs	Bluish white	Dark or slightly grayish black

7 Only common names of insects have been used in this guide. Information on their scientific names and the order and family to which they belong has been provided in Appendix 1.

The most effective way to use this information to make a tentative identification of a beetle you have captured or seen in a tree is to ask yourself the following series of questions:

If the beetle **HAS** a distinct white spot between the tops of the wing covers, and **HAS**:

- (i) bronzy black wing covers, (ii) completely black antennae that are about twice as long as the body, and (iii) dark legs, you likely have a MALE WHITESPOTTED SAWYER (Figure 17).
- (i) bronzy black wing covers with indistinct white patches, (ii) black antennae with faint grey bands that are just slightly longer than the body, and (iii) dark legs, you likely have a FEMALE WHITESPOTTED SAWYER (Figure 18).

If the beetle **DOES NOT HAVE** a noticeable white spot between the tops of the wing covers, but **HAS**:

- (i) glossy black and smooth wing covers with up to 20 distinct white patches (Figure 16), (ii) antennae with distinct black and white bands that are about twice as long as the body, and (iii) bluish white legs, you might have a MALE ASIAN LONGHORNED BEETLE (Figures 14,15).
- (i) glossy black and smooth wing covers with up to 20 distinct white patches, (ii) antennae with distinct black and white bands that are just slightly longer than the body, and (iii) bluish white legs, you might have a FEMALE ASIAN LONGHORNED BEETLE (Figures 12, 13).

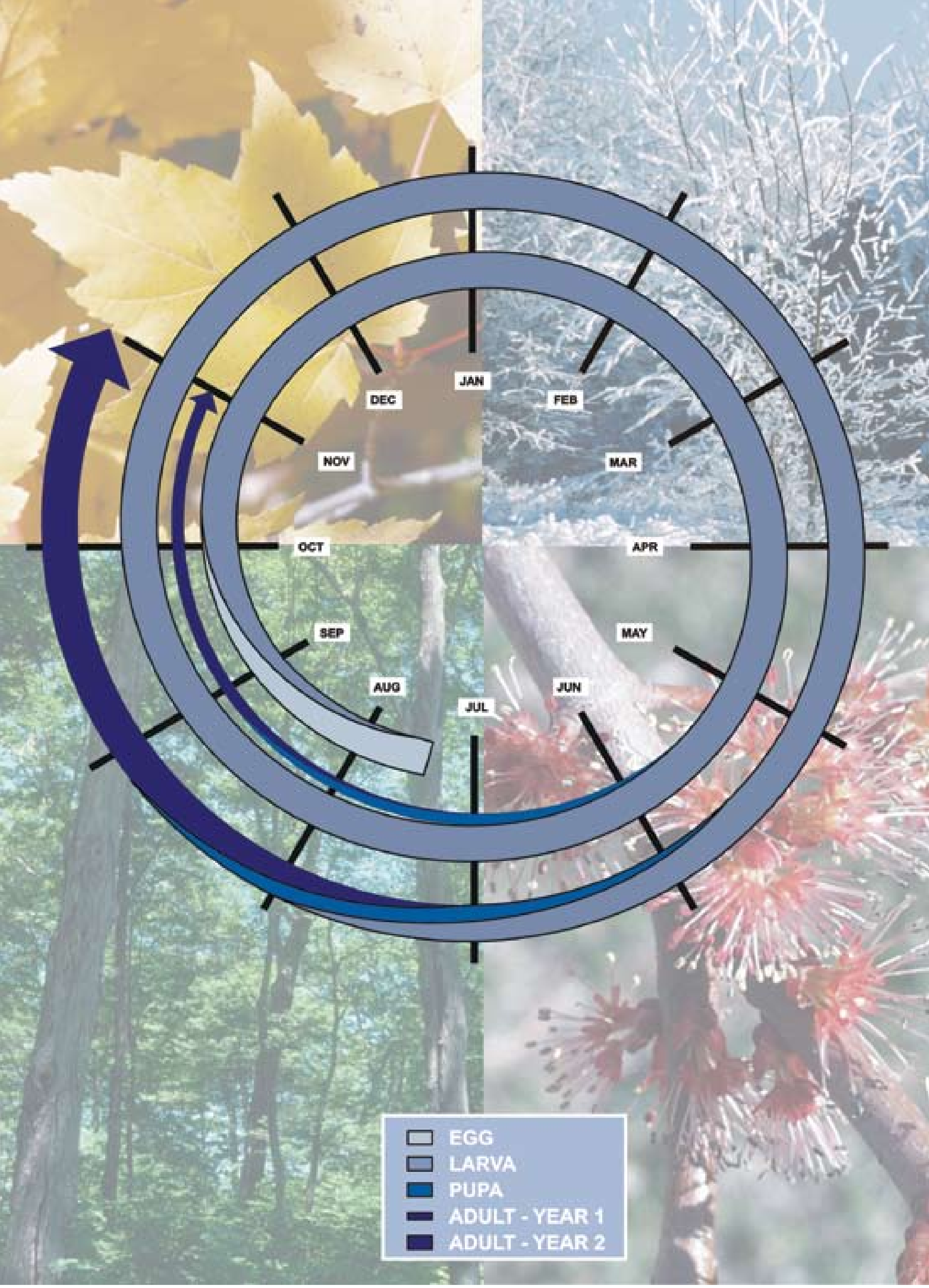
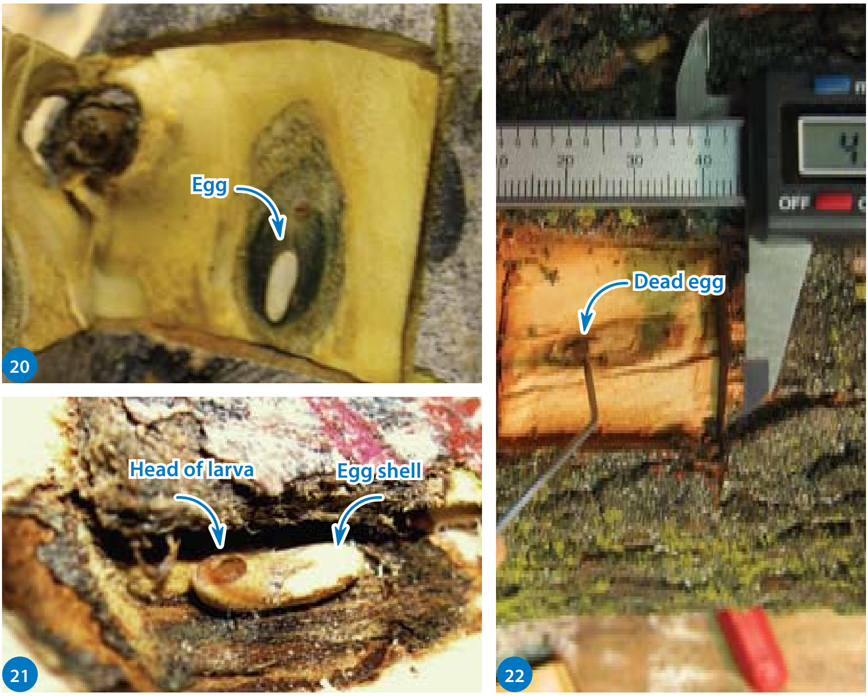


FIGURE 19. Schematic diagram illustrating the life cycle of the Asian longhorned beetle in the Greater Toronto Area.

"TYPICAL" LIFE CYCLE

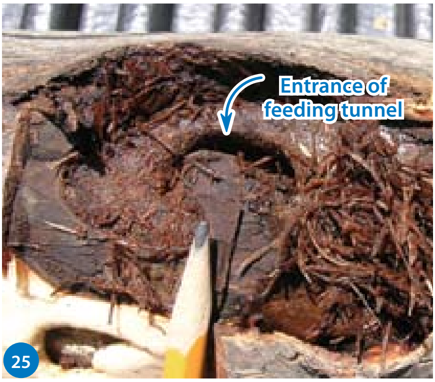
In Asia and the United States, the Asian longhorned beetle requires 1 to 2 years to complete its development from egg to adult, although most beetles take one year. In the Greater Toronto Area, because of a slightly cooler climate, most beetles need two years to complete their life cycle (Figure 19). There is evidence that some beetles require as many as three years. A description of the typical life cycle of the Asian longhorned beetle in the Greater Toronto Area follows.

Eggs are laid under the bark between early July and mid-October (Figure 20). Eggs laid in July or August hatch in about 15 days whereas those laid in September or October take much longer to hatch (Figure 21). There is evidence suggesting that some eggs can overwinter (i.e., eggs laid in October could hatch in April or May of the following season). Thus, live and dead eggs can be found under the bark throughout the year (Figure 22).

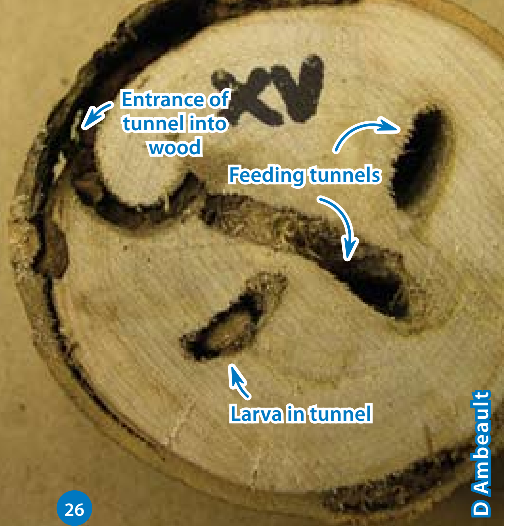


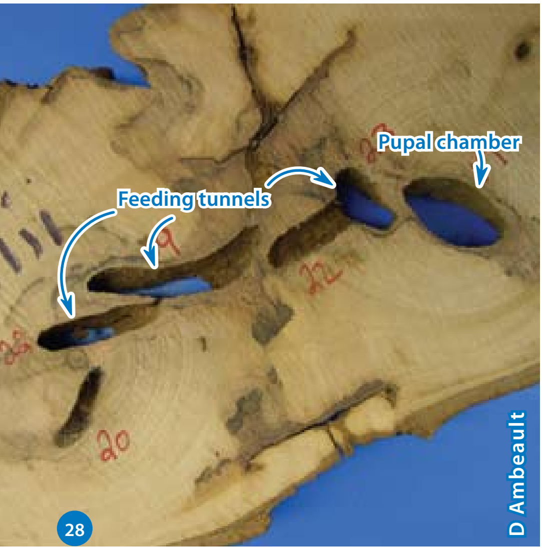
FIGURES 20-22. 20, Bark removed to expose an egg laid between the bark and the sapwood. **21,** Larva about to hatch. **22,** Bark removed to expose a dead egg.

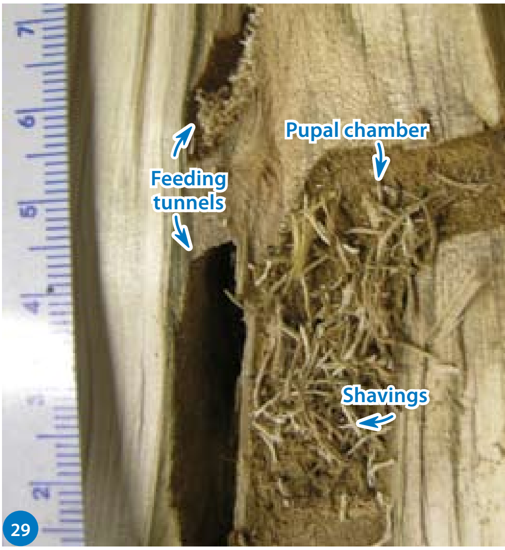
Upon hatching, larvae feed on the outer surface of the sapwood and create feeding galleries under the bark (Figures 23, 24). After feeding for several weeks or months, depending on the time of year egg hatch occurred, larvae bore a tunnel toward the heartwood (Figures 25, 26). In some instances, maturing larvae return to the entrance of the tunnel to feed on the surface of the sapwood, creating larger feeding galleries than young larvae do, just under the bark (Figure 27). Later, these larvae re-enter their tunnel and continue boring and feeding until larval development is almost complete. Each tunnel ends under the bark's surface. Upon reaching maturity, larvae create an enlarged chamber, called a pupal chamber, that is either near or in the sapwood and near the terminal end of their feeding tunnel (Figures 28-30). Larvae of all ages can be found throughout the year (Figure 19).

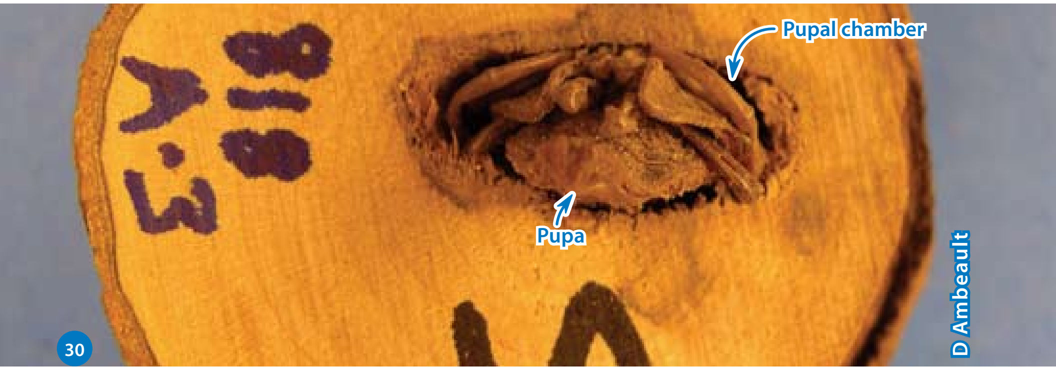


FIGURES 23-25. 23, Recently-hatched larva feeding at the surface of the sapwood. **24,** The size of a feeding gallery increases as the larva becomes older. **25,** The bark above the feeding gallery has been removed to expose the entrance of a feeding tunnel into the wood.

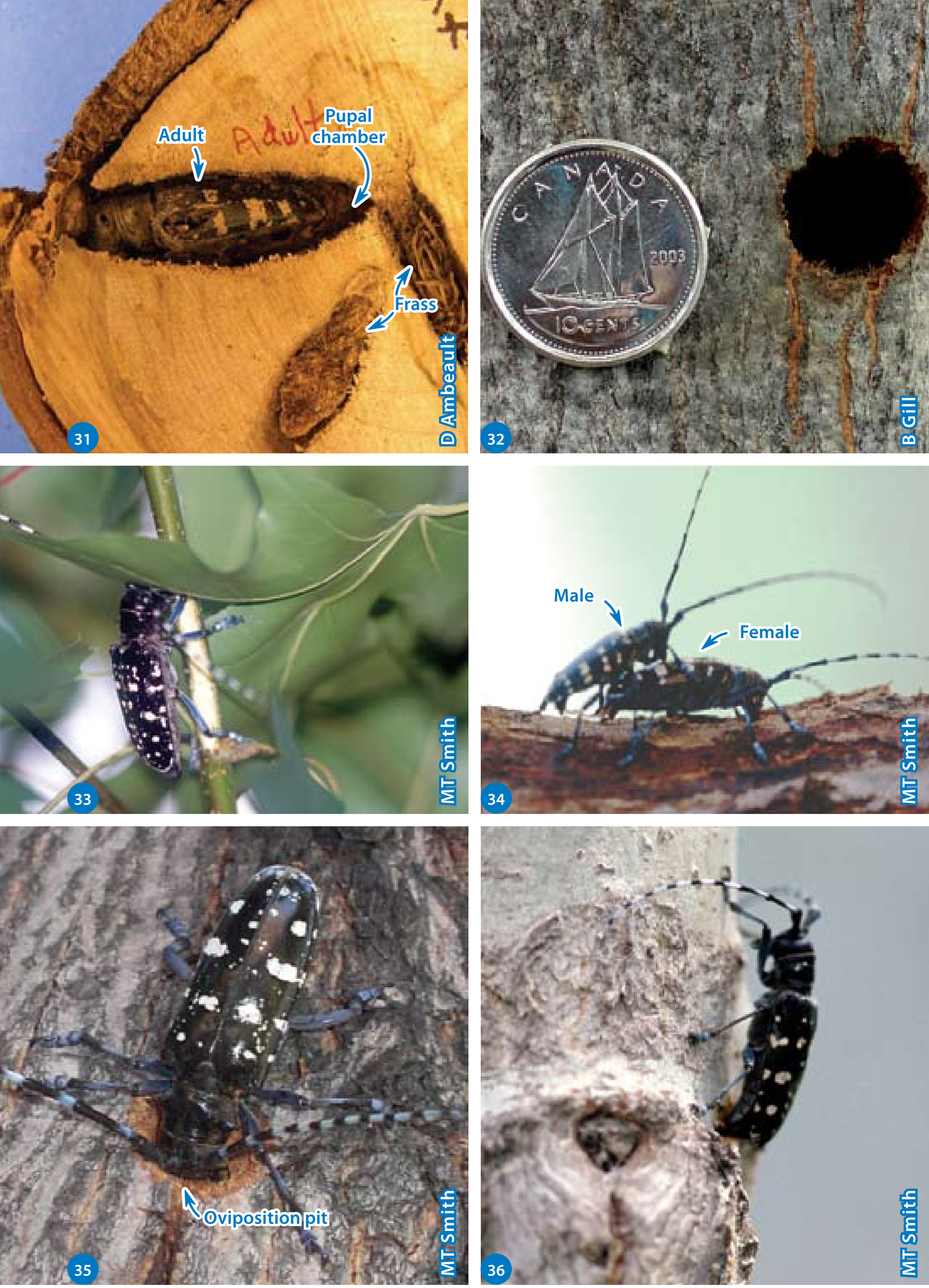








FIGURES 26-30. 26, Cross section a of tree showing the entrance of a feeding tunnel into the wood. **27,** Mature larva that has returned to the surface of the sapwood to feed. **28,** Cross section of tree showing a pupal chamber and feeding tunnels. **29,** Enlarged chamber at the end of the larval feeding tunnel near or in the sapwood. **30,** Cross section of tree showing a pupa in its pupal chamber.



FIGURES 31-36. 31, Cross section of tree showing an adult in a pupal chamber before it completes chewing an exit hole. **32,** Exit hole made by an adult beetle. **33,** Adult feeding on a twig. **34,** Mating pair. **35,** Female chewing an oviposition pit. **36,** Female laying an egg.

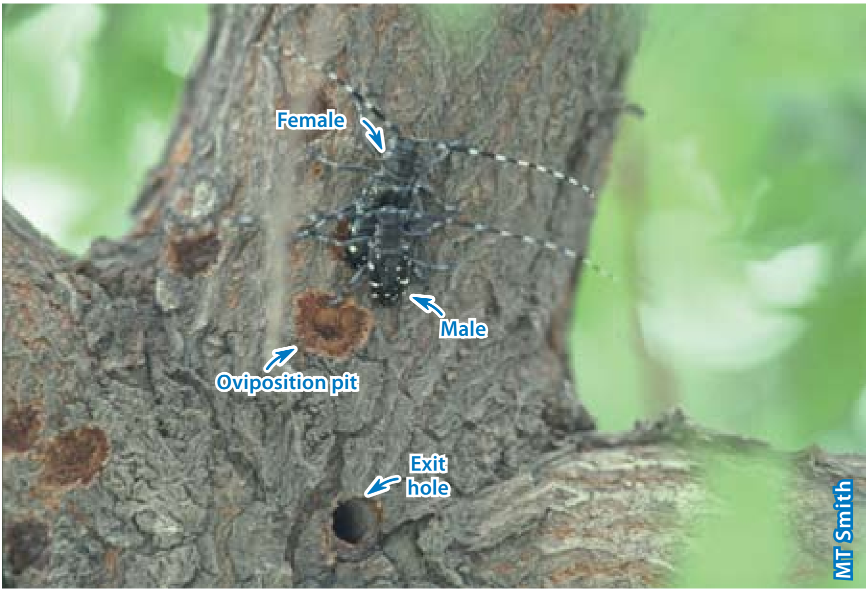


FIGURE 37. Female laying an egg. **NOTE** the male guarding the female while an egg is laid.

Pupae transform into adults within the pupal chamber (Figure 31). Pupae can be found in trees from early June until mid-August. Pupal development lasts about 20 days.

Adult beetles bore between the end of the tunnel and the tree's surface, creating a round hole through which they exit the tree (Figure 32). In the Greater Toronto Area, most adults emerge between late June and late August, but adult beetles can be found until late October. Upon exiting the tree, adult beetles undergo a maturation period lasting about 2 weeks during which they disperse, feed on leaves and the bark of twigs (Figure 33), and begin mating (Figure 34). Once mature and mated, female beetles chew irregular, oval-shaped pits into the bark (Figure 35), through which they inject an egg under the bark (Figures 36, 37).

POINTS TO REMEMBER

- Become familiar with the description of all stages of the Asian longhorned beetle because there are native insects that can be mistaken for this beetle.
- Only adults of the Asian longhorned beetle can be seen on the outside of trees - all other stages develop within the tree.
- In the Greater Toronto Area, the Asian longhorned beetle requires about two years to complete its life cycle.

TREE SPECIES AT RISK

INTRODUCTION

The Asian longhorned beetle has been reported on a wide variety of broadleaf tree species, but does not attack conifers. It is critical to know which species of hardwoods are most at risk of being attacked by the Asian longhorned beetle when conducting detection or delimitation surveys. This section contains an annotated list of the tree genera found in the Greater Toronto Area. Each genus on the list has been assigned to a category that reflects current knowledge on the likelihood of it being attacked by the beetle and indicates which genera should receive priority attention when conducting surveys.

CATEGORIES OF TREES

Not all hardwood species are equally suitable for feeding, egg laying, survival and development of the beetle. For example, some species of trees appear suitable for egg laying but not for larval development whereas others seem suitable for egg laying and development of young larvae, but not for development of mature larvae. Tree genera found in the Greater Toronto Area have been assigned to one of three groups of suitability: 1) **suitable;** 2) **questionable suitability;** and 3) **unknown suitability**. These groupings are based on knowledge of the plants attacked by the Asian longhorned beetle in its native environment, of those infested during invasions that occurred in the United States of America (i.e., New York, Chicago, Jersey City and Carteret) and Canada (i.e., Greater Toronto Area), as well as from published laboratory studies.

Trees are considered **suitable** if there is evidence (i.e., exit holes) that the beetle can complete its entire life cycle under field conditions (Table 1). Trees have a **questionable** suitability if there is evidence that either egg laying or partial larval development of the beetle is possible under field conditions, but there is no evidence that the entire life cycle can be completed under field conditions. Tree genera or species without any records of attack are classified as **unknown suitability**.

TREES TO INSPECT

In Canada, all trees belonging to genera considered **suitable** must be inspected for evidence of Asian longhorned beetle presence or injury because they are most at risk of being infested (Table 1). In many North American cities, maple is a common and valuable landscape tree. In the Greater Toronto Area, this genus has been infested more frequently than all other genera. Thus, maple should be treated as a high-risk or target genus when conducting surveys, especially in areas where the beetle density is expected to be low or is unknown. In areas where the beetle density is believed to be high, surveys must include trees belonging to all genera considered **questionable** to ensure that no infested trees remain undetected (Table 1). Trees from the **unknown suitability** category should be included in the survey as time and resources permit.

Should an infested area be discovered in another part of Canada, all tree genera not included in this list (Table 1), but present in the newly infested area would have to be included as part of the survey programme because it will be necessary to establish whether they are **suitable** trees. Not including these genera could result in missing infested trees and compromising the pest management programme. Based on current information, all trees with a stem diameter of 2.5 cm or more must be inspected.

POINTS TO REMEMBER

- Inspectors must be able to correctly identify, throughout the year, all species of trees present in the survey area.
- Surveys or tree inspections must focus on **suitable** genera, however, the other genera should be examined as well, although at a lower frequency.
- Among the **suitable** genera, maple seems to be infested the most often.
- Trees and branches with a diameter of 2.5 cm or more can be infested.
- The Asian longhorned beetle attacks both healthy and stressed trees.

Table 1. Annotated categorisation of broadleaf genera found within the infested area of the Greater Toronto Area.

back of table

Fold out

Table 1. Annotated categorisation of broadleaf genera found within the infested area of the Greater Toronto Area.

back of table

Fold out

SIGNS AND SYMPTOMS OF INJURY

INTRODUCTION

Signs and symptoms are indicators of insect attack, it is therefore important for inspectors to be able to recognize these. A **sign** is physical damage to a tree caused by an insect. Examples of signs include entrance or exit holes into the bark and wood of a tree, a feeding notch in a leaf, or a gallery underneath the bark. A **symptom** is the tree's response to insect attack. Examples of symptoms include bark cracks, dead branches, thinning crowns, and tree death. Some symptoms appear soon after attack, others take several years to become detectable.

Signs and symptoms of Asian longhorned beetle injury are much easier to find when the beetle density is high than when it is low. Experience has shown that it is impossible to rely on a single sign or symptom to detect all trees infested by the beetle, especially where beetle density is low. **Thus, inspectors should become proficient at recognizing all signs and symptoms of beetle injury.** Inspectors must also familiarize themselves with signs and symptoms that resemble those left by the Asian longhorned beetle (hereafter referred to as "look-alikes"), but, that are actually caused by other factors.

This section is an illustrated catalogue of the signs and symptoms associated with the various types of injuries caused by the Asian longhorned beetle. Signs and symptoms that resemble those made by the Asian longhorned beetle are also shown and, in some cases, described.

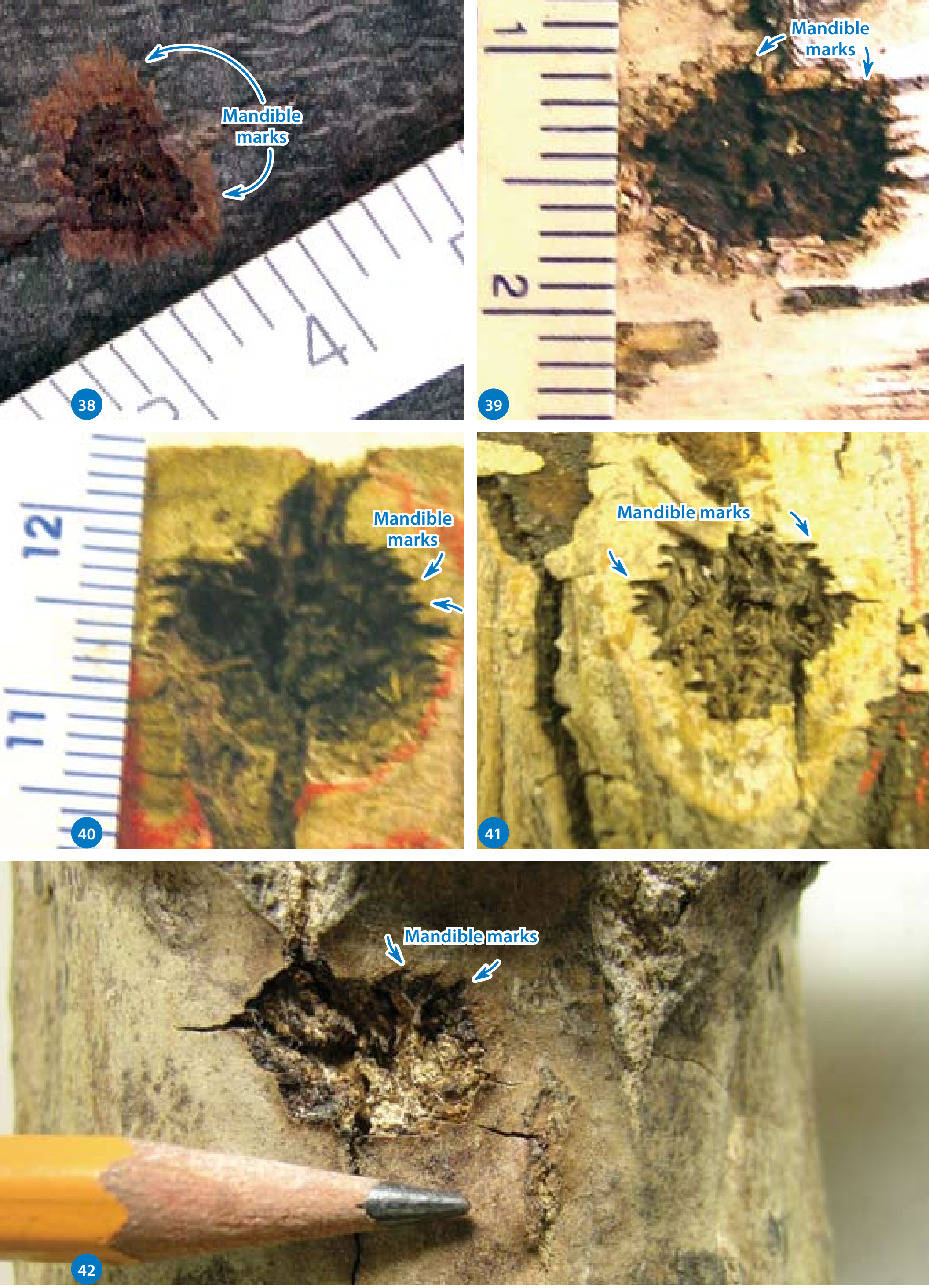
SIGNS

Signs of Asian longhorned beetle injury have been classified as 'external', when they can be seen on the outside of the bark, and 'internal', when they can only be seen after the bark is peeled off the tree or the wood has been split. Common external signs include: 1) oviposition (or egg) pits; 2) frass or shavings; 3) hollow bark; 4) exposed feeding galleries; 5) exit (or emergence) holes; and, 6) evidence of adult feeding. Among the characteristic internal signs are: 1) feeding galleries on the outer sapwood; and, 2) tunnelling through the wood.

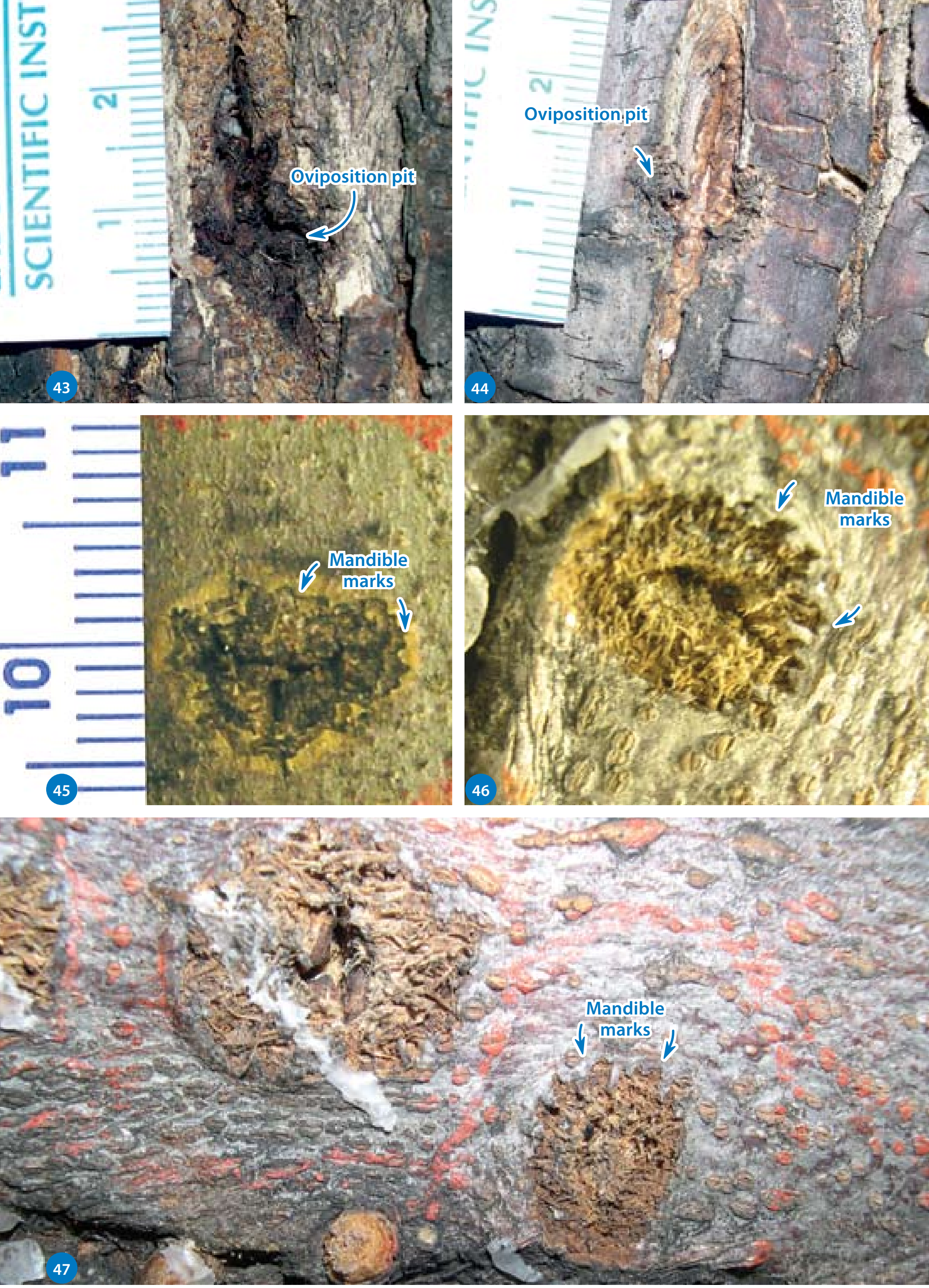
This section contains photographs showing the most typical appearance of signs resulting from adult feeding and oviposition as well as from larval feeding; however, because most signs change in appearance as they age, whenever possible images documenting these changes are also presented. Furthermore, the appearance of some signs may differ among tree species, among trees of a given species and within an individual tree. Thus, this section also provides pictures that show the variation in appearance of signs observed within trees of the same genus and, if available, among different tree genera.

External signs

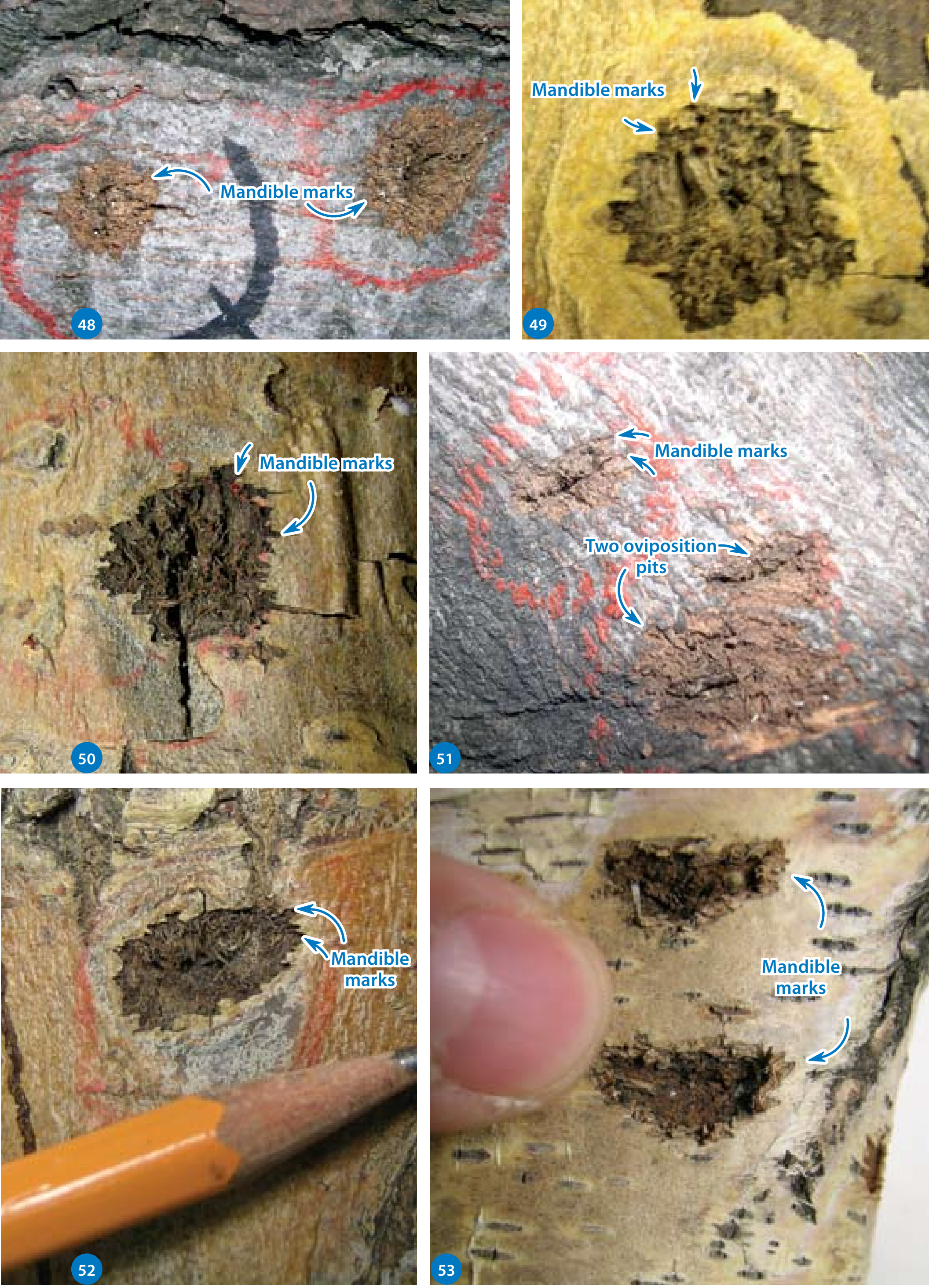
Oviposition pit: Adult females use their mouthparts or mandibles (think of them as "teeth") to chew a hole into the bark and create a cavity called an oviposition pit, through which eggs are inserted under the bark (Figures 38-47). Often, but not always, the characteristic marks made by the mandibles are visible around the outer edges of the oviposition pit. Oviposition pits vary in shape from a nearly circular pit (15 mm in diameter) to a narrow slit (about 1 mm in height) (Figures 48-56). The surface on which oviposition pits occur affects their visibility: pits on smooth bark are easier to detect than those on rough bark (Figures 57-63). The appearance of an oviposition pit changes with time. Typically, recently chewed oviposition pits (i.e., few hours to several weeks old) are reddish in colour (Figures 64-67). They become progressively darker as the season progresses because they oxidize over the season due to weathering (Figures 68-69). Oviposition pits created in previous years are dark brown to black (Figures 70-74). Oviposition pits can be seen at any time of the year on the bole, branches and exposed roots. As the tree continues to grow, the appearance of the oviposition pit changes, and may be overgrown with new tissue. In some instances, the oviposition pit may be completely grown over, making it difficult to detect. Not all oviposition pits contain an egg.



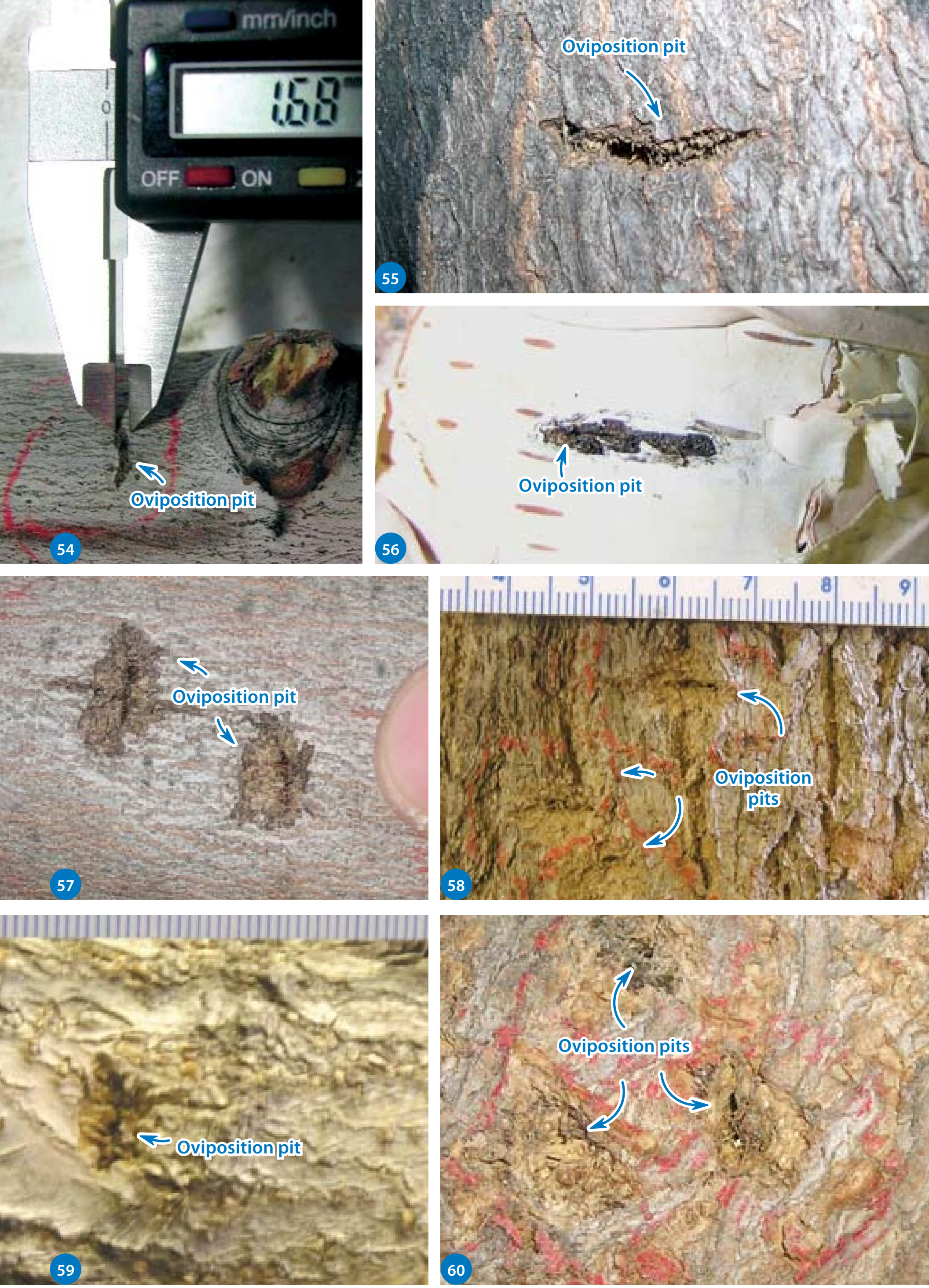
FIGURES 38-42. Typical oviposition pits on: **38,** maple; **39,** birch; **40-41,** willow; and, **42,** poplar.



FIGURES 43-47. Typical oviposition pits on: **43,** elm; **44,** elm (**NOTE** the callus tissue under the oviposition pit); **45,** ash; and, **46-47,** linden.

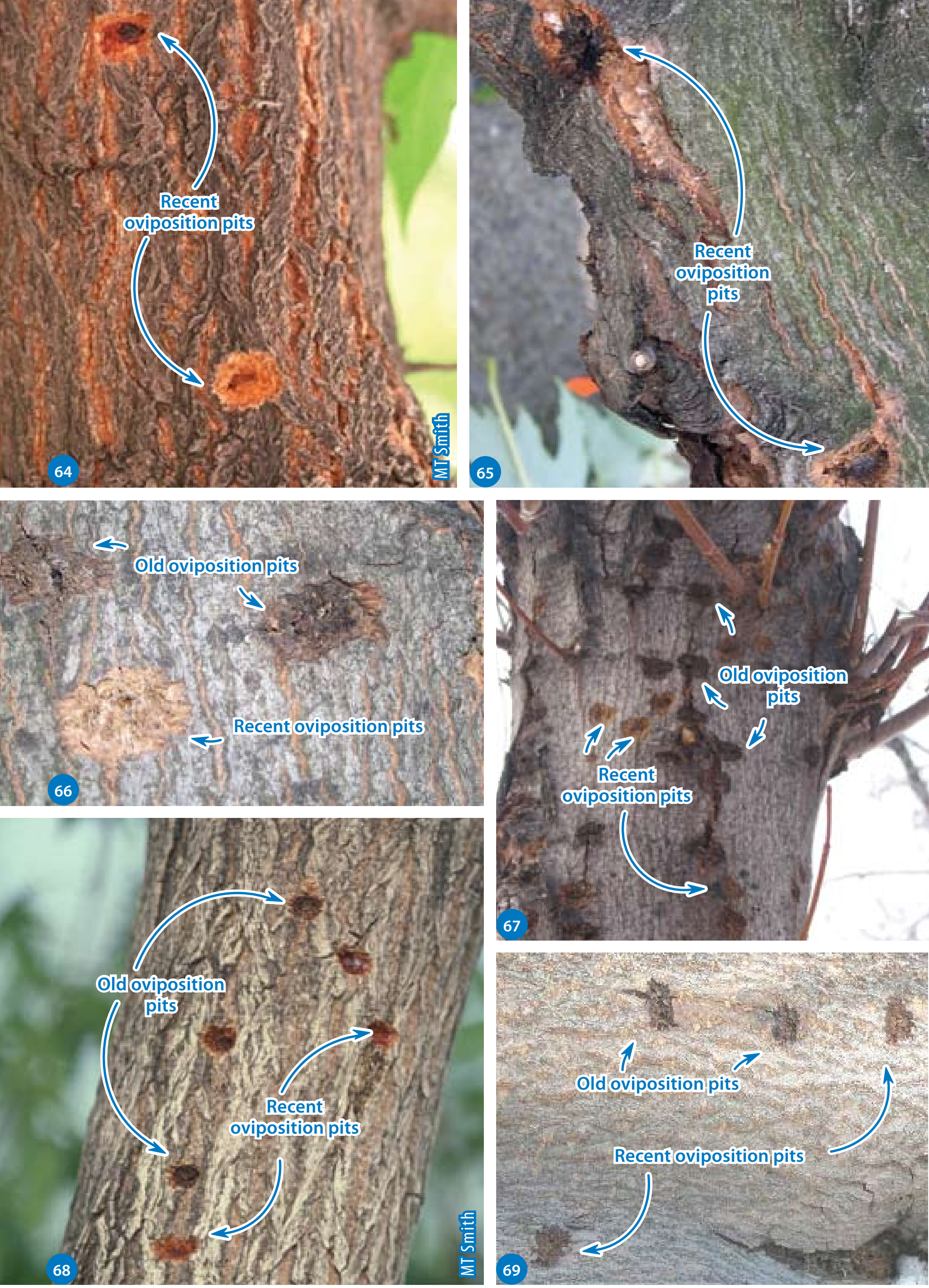


FIGURES 48-53. Circular oviposition pits on: **48,** maple; **49,** willow; and, **50,** poplar. Oblong oviposition pits on: **51,** maple; **52,** willow; and, **53,** birch.

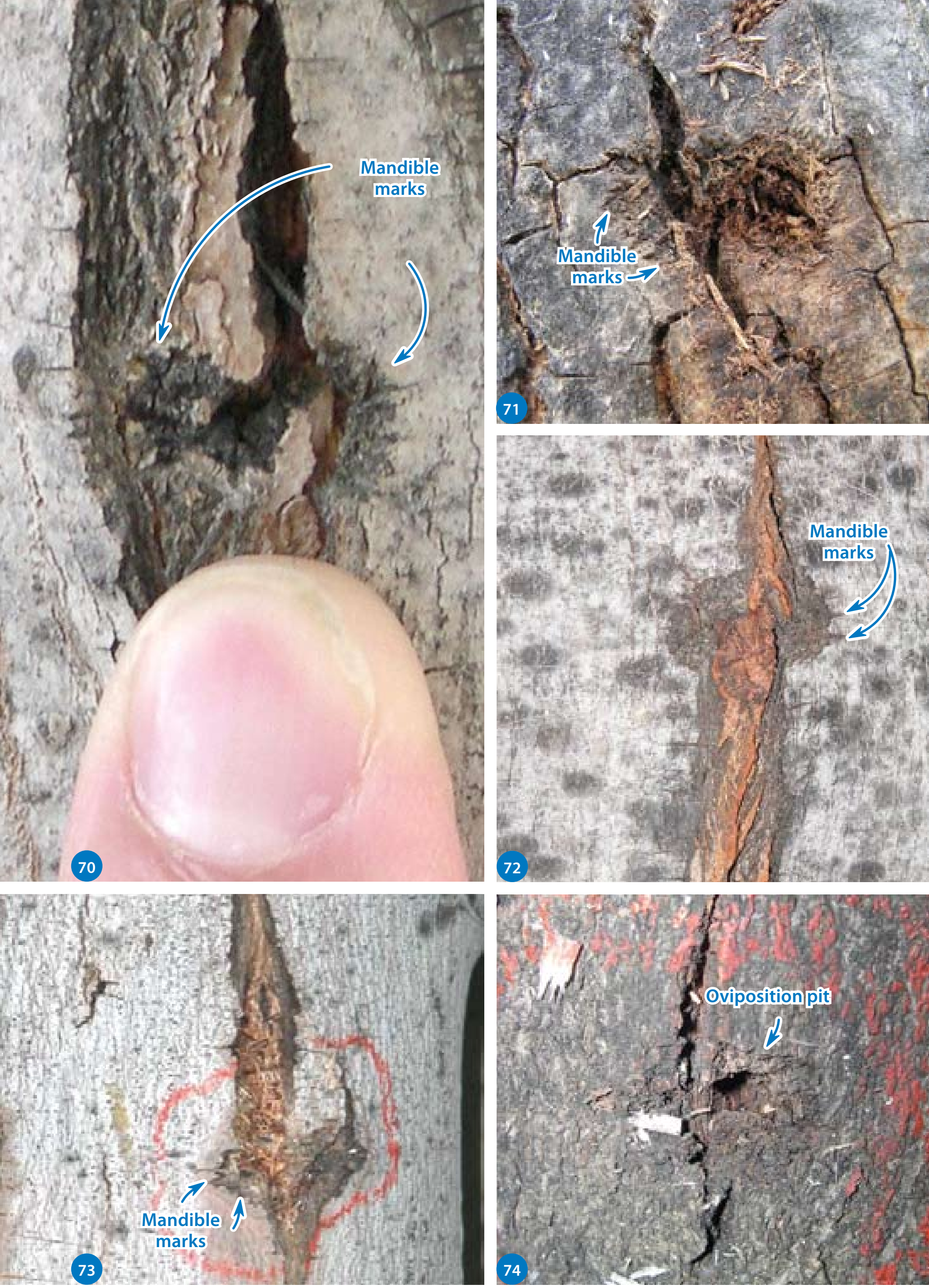


FIGURES 54-60. Narrow (slit) oviposition pits on: **54-55,** maple; and, **56,** birch. **57,** Oviposition pits on smooth bark of maple. **58,** Oviposition pits on rough bark are more difficult to detect than those on smooth bark, especially the mandible marks. **59,** Oviposition pit on rough bark of maple. **60,** Oviposition pits on rough bark of maple.

FIGURES 61-63. 61, Oviposition pits on dark bark of birch branches are difficult to see. **62,** Oviposition pit on light bark of a birch branch. **63,** Oviposition pits on light bark at the junction of birch branches.



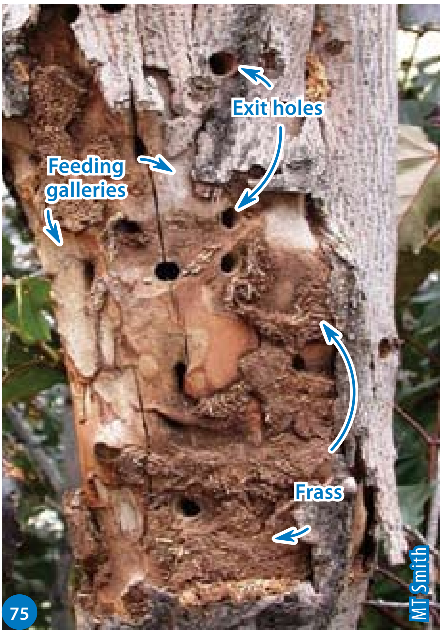
FIGURES 64-69. 64-65, Recently-chewed oviposition pits on maple. **NOTE** the presence of a dark centre. **66-69,** Examples illustrating the difference in appearance between oviposition pits chewed on maple several months ago (old) and those chewed more recently (recent). **NOTE** that in some instances the recent pits may have been made in previous years.

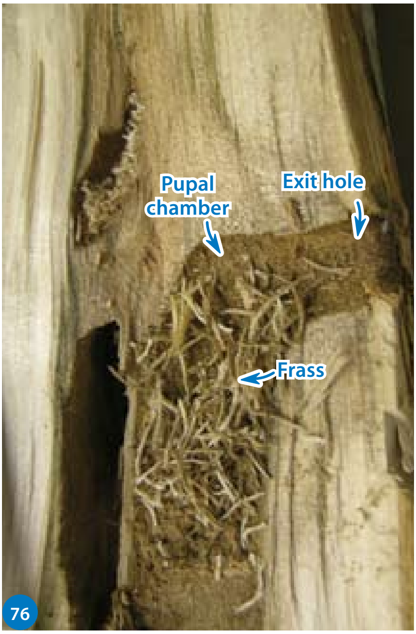


FIGURES 70-74. Examples of oviposition pits created in previous years.

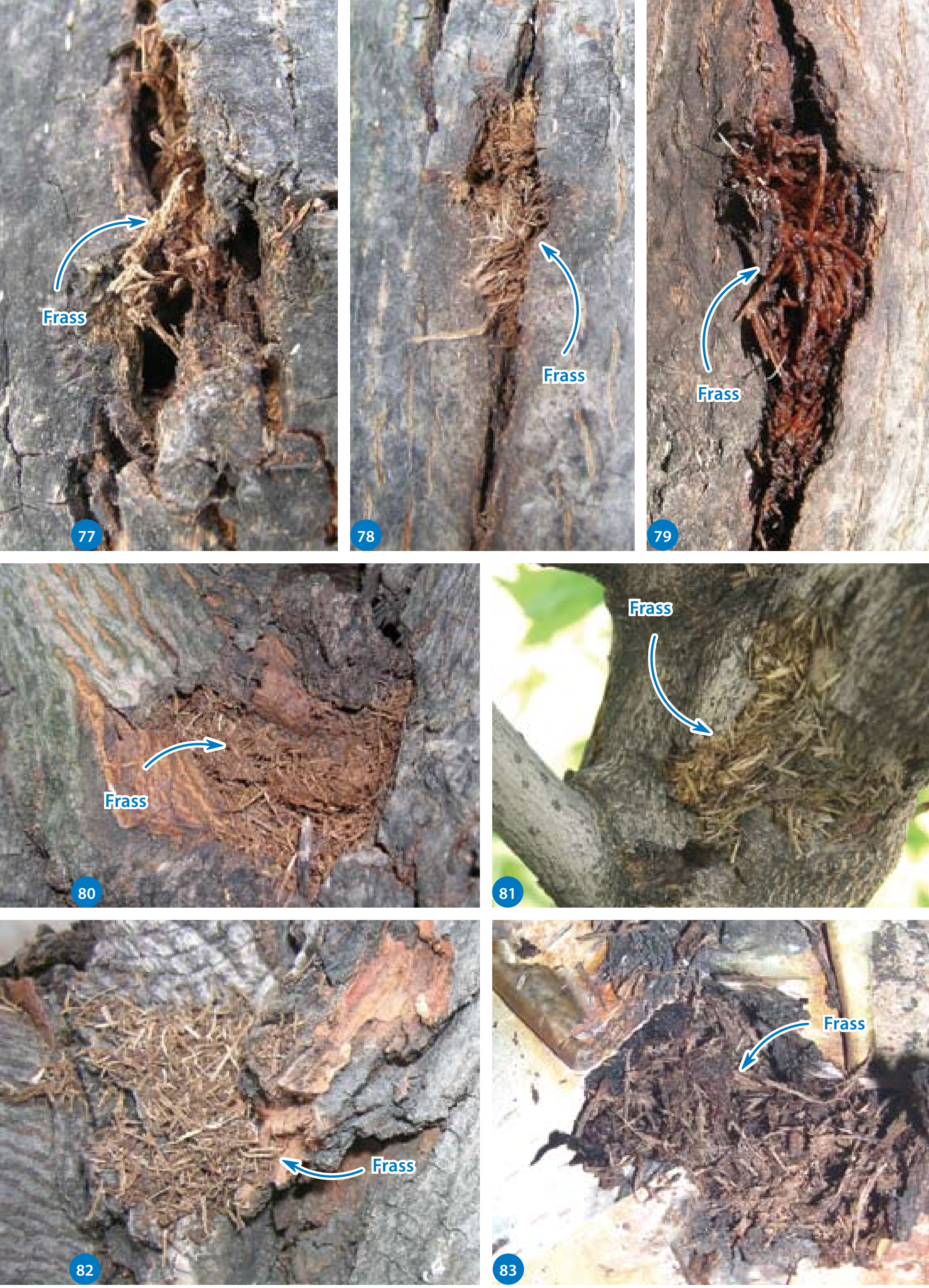
External signs

Frass: Larval feeding results in the creation of solid faecal matter or excrements that is mixed with plant fragments, in this case wood shavings, and is called frass (Figures 75, 76). The frass can be seen protruding through cracks in the bark as it is pushed out of the feeding tunnels by larvae (Figures 77-83). This material can be seen on branches, at branch junctions (Figure 84), and on the ground at the base of infested trees (Figures 85-87). The presence of massive amounts of visible frass is rare (Figure 88). In most cases, only a small amount of frass is exposed because the bark is still intact (Figure 89). Also, frass deposited on branches and on the ground around the infested tree is most visible shortly after it is extruded from the tree. Rain, snow and wind will make it difficult to detect later in the season or in subsequent years. Nonetheless, the presence of frass on the exterior surfaces of trees, such as branch junctions, has led to the discovery of infested trees.





FIGURES 75-76. 75, Bark of a maple has been removed to expose frass under the bark. **76,** Shavings found in a pupal chamber.

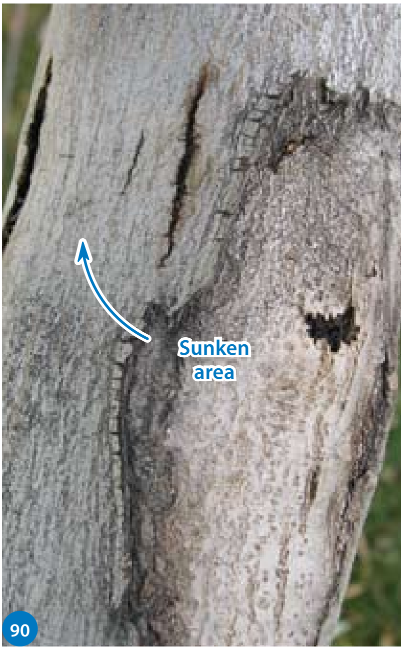


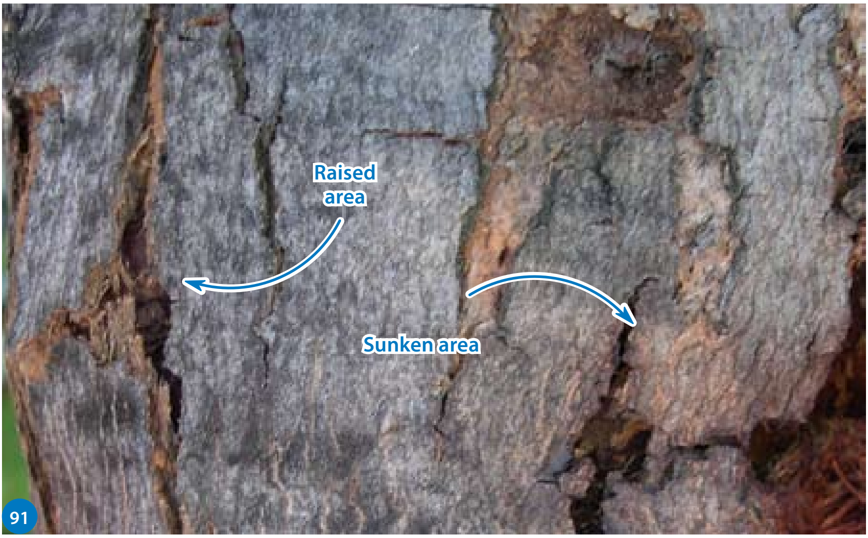
FIGURES 77-83. 77, Small amount of dry frass visible through a crack in the bark. **78,** Dry frass visible through a small crack in the bark. **79,** Wet frass visible through a small crack in the bark. **80,** Bark has been removed to expose frass visible through a crack in the bark. Frass pushed out of a feeding tunnel on: **81-82,** maple; and, **83,** birch.

FIGURES 84-89. 84, Accumulation, at a branch junction, of frass that has fallen from feeding galleries present higher in the tree. **85-87,** Frass on the ground at the base of a tree. **88,** Large amount of dry frass accumulated on the bark surface of a maple. **89,** Small accumulation of frass on the bark surface at a branch junction.

External signs

Hollow bark: Feeding by young larvae on the outer sapwood eventually leads to the separation of the bark from the sapwood and creates a hollow area under the bark. These areas may appear as sunken or raised bark (Figures 90, 91). Hollow areas can sometimes be seen through small cracks in the bark. This sign of injury can develop within the first year of attack if eggs have been laid in early summer, but in most instances it appears in the second year following the attack. Unlike frass, this sign can be visible for several years.

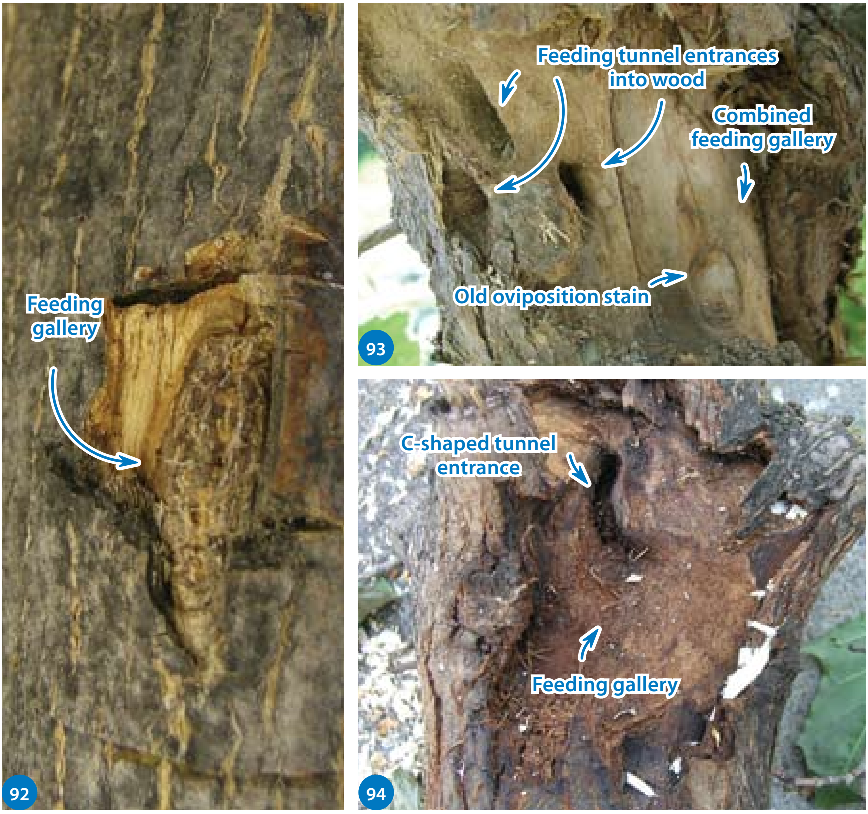




FIGURES 90-91. 90, Sunken area on maple. **91,** Raised and sunken areas on maple.

External signs

Exposed feeding gallery: Larvae feeding on the surface of the sapwood create depressed galleries of various sizes (Figures 92, 93). This sign can be seen under field conditions only when the bark above the feeding gallery has fallen off the tree. This sign always occurs underneath an oviposition pit, therefore, it is impossible to detect the oviposition pit associated with the exposed feeding gallery (Figure 94). Callus tissue can be produced around exposed feeding galleries. Typically, this sign is visible only one to several years after larval feeding has occurred.



FIGURES 92-94. 92, Small feeding gallery of a larva that did not enter the wood. **93,** Feeding gallery created by several larvae that entered the wood. **94,** Feeding gallery of larva that entered the wood.

External signs

Exit hole: An exit hole is made by an adult as it emerges from the pupal chamber located in the wood. Exit holes are circular and 6-14 mm in diameter (Figures 95-101). In the Greater Toronto Area, exit holes have been discovered throughout the year on the bole, on branches as small as 3.3 cm in diameter and on exposed roots. Most exit holes are visible for several years, however, in some instances, callus tissue is produced around the hole. The growth of callus tissue around this type of injury can start soon after adult emergence, especially if it occurs in early summer, and can eventually enclose the exit hole completely (Figures 102-105). In such cases it is impossible to detect all exit holes present on a tree.

FIGURE 95. Typical exit hole on maple.

FIGURES 96-101. Typical exit holes on: **96-97,** maple; **98,** birch; **99-100,** willow; and, **101,** poplar.

FIGURES 102-105. 102, Early stage of the growth of callus tissue around the edges of an exit hole on maple. **103,** Advanced stage of growth of callus tissue around the edges of an exit hole on maple. **104,** Callus tissue has completely covered an exit hole on maple. **105,** Bark from branch (illustrated in Figure 104) has been removed to show the exit hole under the callus tissue.

External signs

Adult feeding: Adult beetles feed on leaves, twigs, and petioles (leaf stems) (Figures 106, 107). Adults feed on leaves by removing the primary and secondary leaf veins; the presence of jagged edges along the severed leaf tissue is characteristic (Figure 108). Adult beetles feed on twigs and petioles by stripping off the outer tissue of the twigs and petioles (Figures 109-111). Signs of beetles feeding of leaves and twigs can be found during inspection of the canopy prior to leaf fall. Feeding on petioles can cause leaves to be severed from their twigs and fall to the ground prematurely; signs of feeding on leaves and petioles can also be found while inspecting the ground beneath trees for leaves that have fallen from the tree during the summer. Signs of adult feeding on twigs can be found after leaf drop in the fall and can be detected for several years after the damage was caused.

FIGURES 106-107. 106, Adult feeding on a maple twig. **107,** Adult feeding on a Russian olive.

108

109

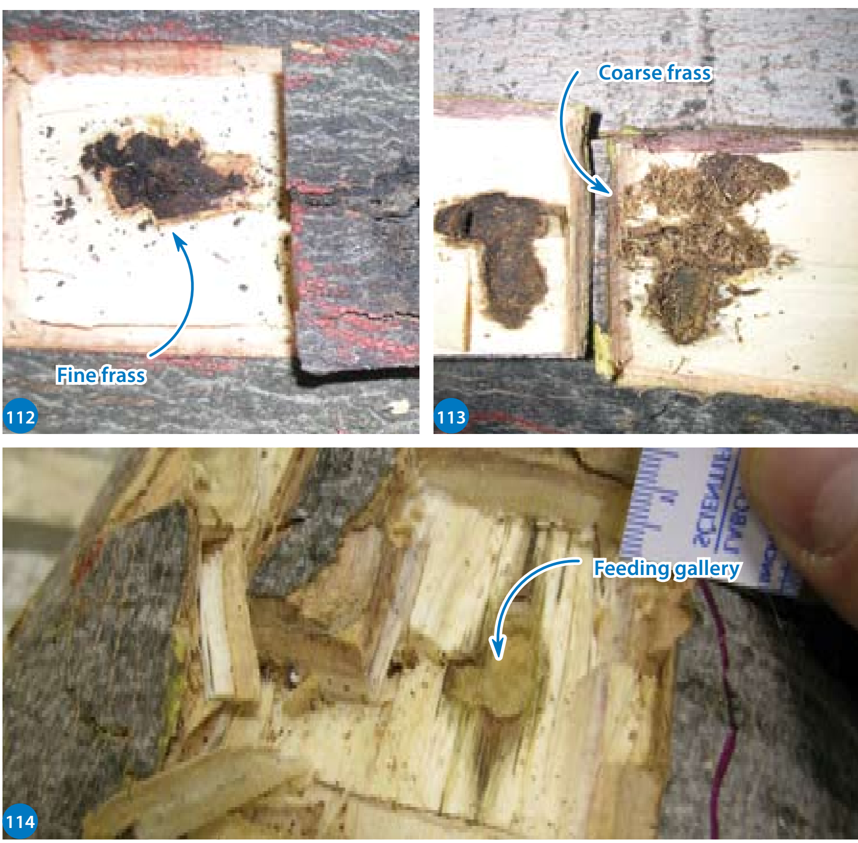
110

111

FIGURES 108-111. 108, Feeding injury by an adult on the foliage and the petiole of a maple leaf. **109,** Feeding injury by an adult on a maple twig. **110,** Feeding injury by an adult on willow twigs. **111,** Feeding injury by an adult on maple petioles.

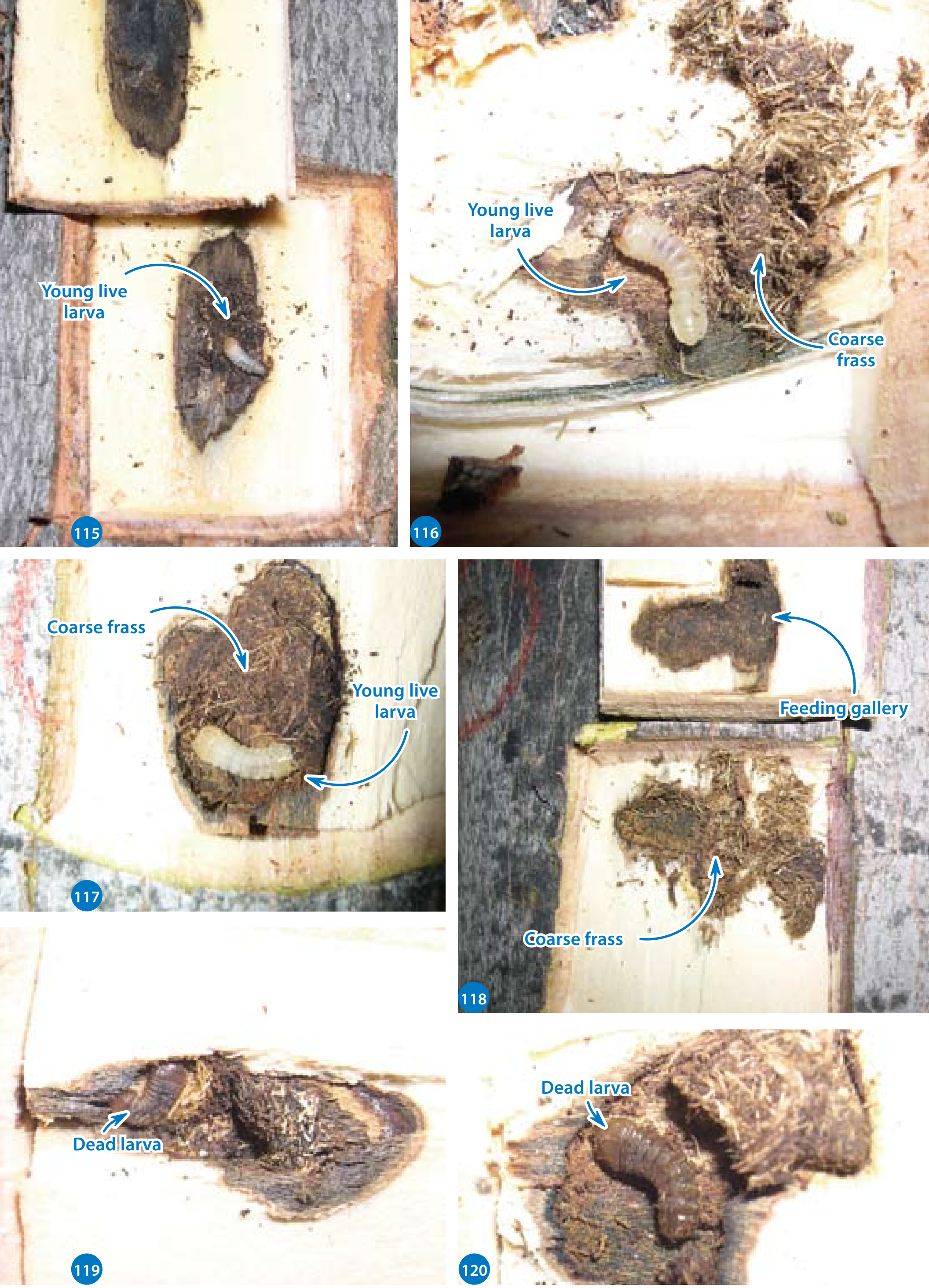
Internal signs[8]

Feeding gallery under the bark: This type of injury occurs underneath oviposition pits, begins at egg hatch and can only be revealed by carefully removing the bark. Larvae feeding on the surface of the sapwood create depressed galleries. This sign is not visible when the outer bark is still attached to the tree. Most of these galleries contain frass. The size of the frass depends on the size of the larva, with young larvae producing fine frass and older larvae producing coarser frass (Figures 112-114). Galleries can still contain live or dead larvae (Figures 115-120).



FIGURES 112-114. 112, Feeding gallery with fine frass. **113,** Feeding gallery with coarse frass. **114,** Appearance of a feeding gallery when the frass has been removed.

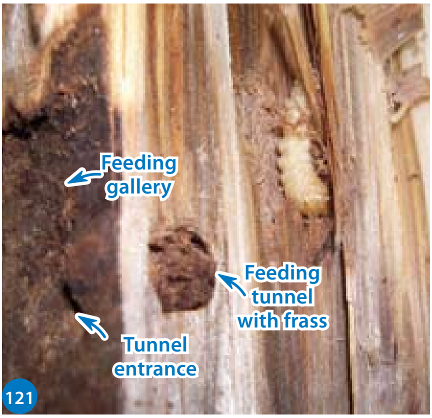
8 The examination of internal signs should be performed exclusively by specialised staff or experts under laboratory conditions.

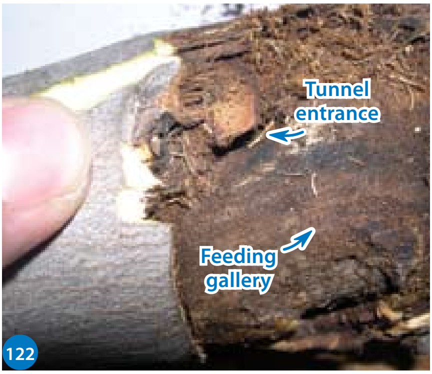


FIGURES 115-120. 115-116, Feeding gallery with a young live larva. **117,** Bark has been removed to expose a feeding gallery with a young larva. **118,** Bark has been removed to expose a feeding gallery without a larva. **119-120,** Bark has been removed to expose feeding galleries with dead larvae.

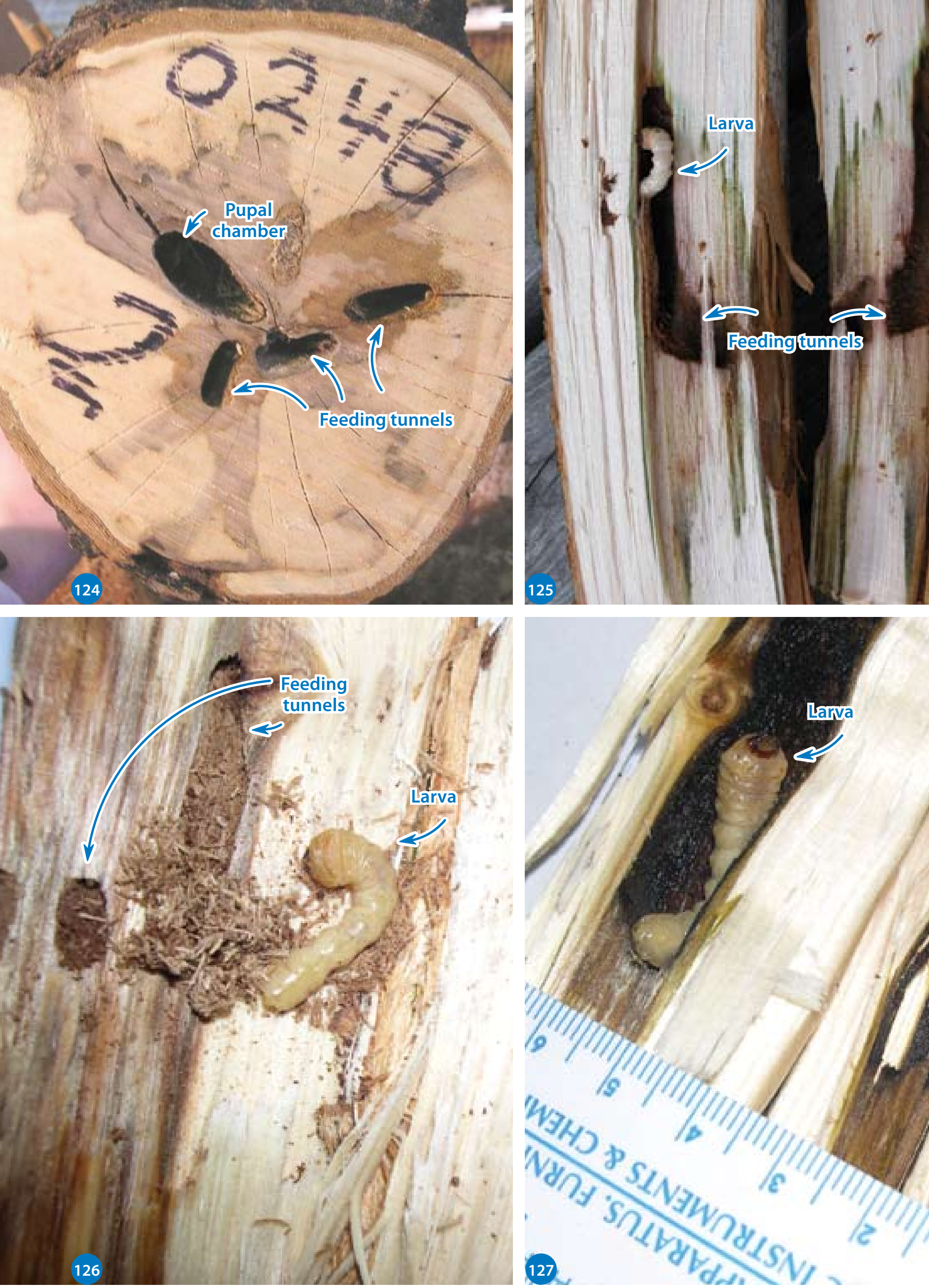
Internal signs

Tunnel into the wood: After feeding on the outer sapwood, larvae bore tunnels toward the heartwood (Figure 121). The entrance of the tunnel has a typical C-shape appearance (Figures 122-127). Some larvae die in the tunnel and eventually turn dark brown (Figures 128-130). Mature larvae can sometimes leave their tunnel and temporarily return to feed on the surface of the sapwood (Figures 131, 132). At maturity, a larva enlarges the tunnel creating a pupal chamber, where it transforms into a pupa (Figures 133, 134). Once the development is completed, the pupa transforms into an adult and bores the remainder of the exit hole tunnel (Figure 135).





FIGURES 121-123. 121, Longitudinal section of a tree showing a larval feeding tunnel. **122-123,** Characteristic C-shaped tunnel entrances into the wood.



FIGURES 124-127. 124, Cross section of a tree showing feeding tunnels. **125-127,** Longitudinal sections of branches exposing larval feeding tunnels.

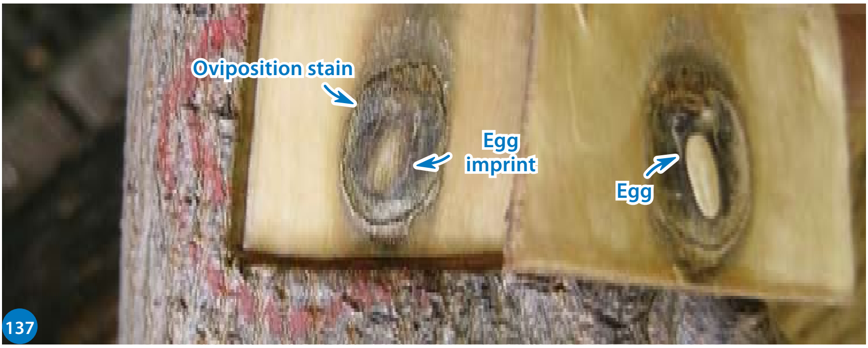
FIGURES 128-130. Longitudinal sections of infested branches showing larval feeding tunnels with a dead larva.

FIGURES 131-135. 131, Gallery made by a mature larva that had exited the feeding tunnel prior to transforming into a pupa. **132,** Mature larva that has left its tunnel and is feeding at the surface of the sapwood. **133,** Larval feeding tunnel that was being enlarged to become a pupal chamber. **134,** Cross section of a pupal chamber with a pupa. **135,** Adult found in a pupal chamber.

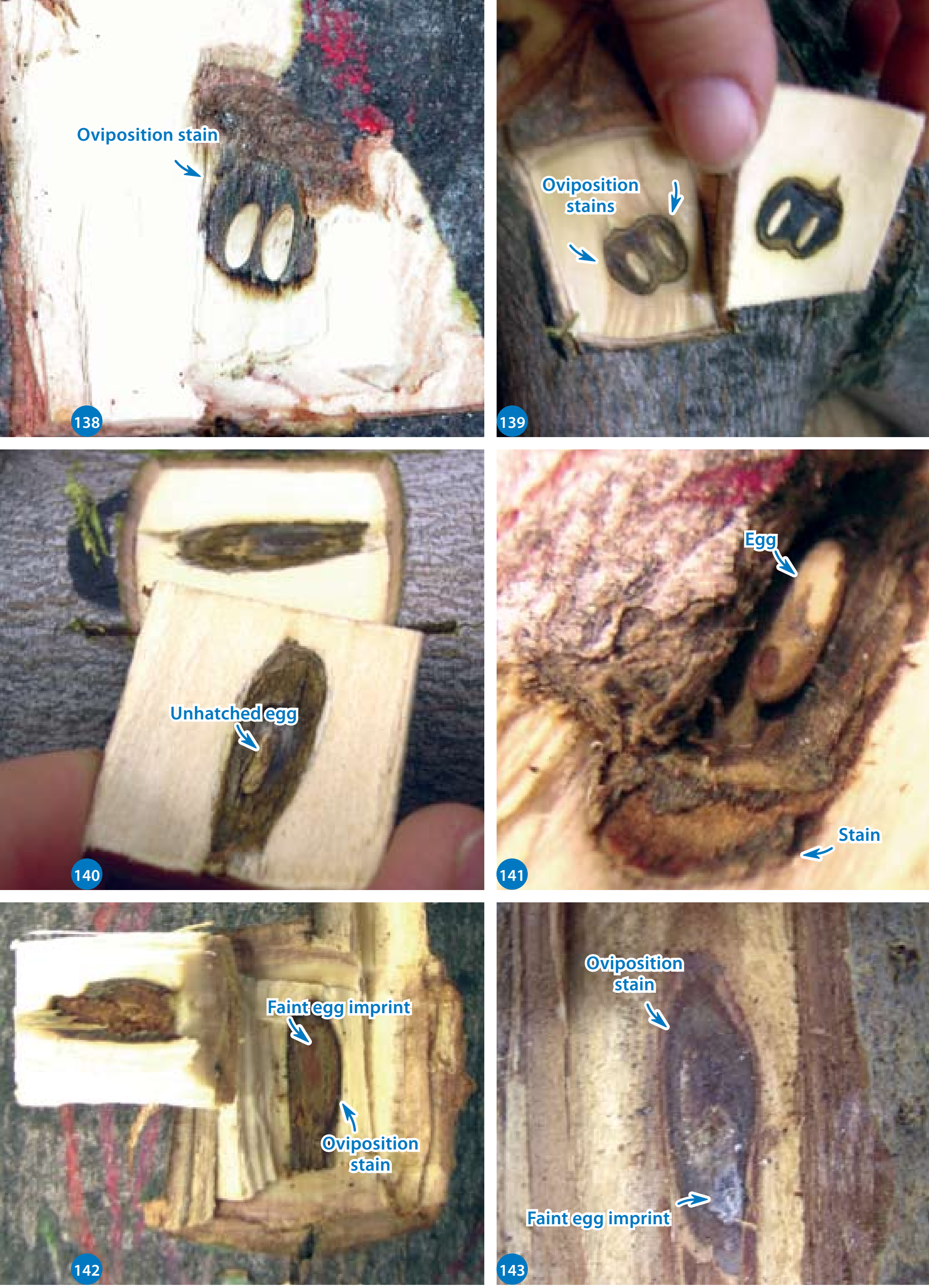
SYMPTOMS

The most typical appearance of each symptom is presented.

Oviposition stain: This symptom appears when an adult female either lays, or attempts to lay, an egg under the bark through an oviposition pit. This symptom will appear as an oval-shaped bronze to brown stained area under the bark, beneath the oviposition pit (Figure 136). The amount of time required for this stain to appear on the inner bark is unknown. The stain will typically turn black after a period of time (Figures 137-141). Eggs are not always present with the oviposition stain (Figure 142), however, in some instances, a mark or imprint left by the egg is visible on the oviposition stain (Figure 143).



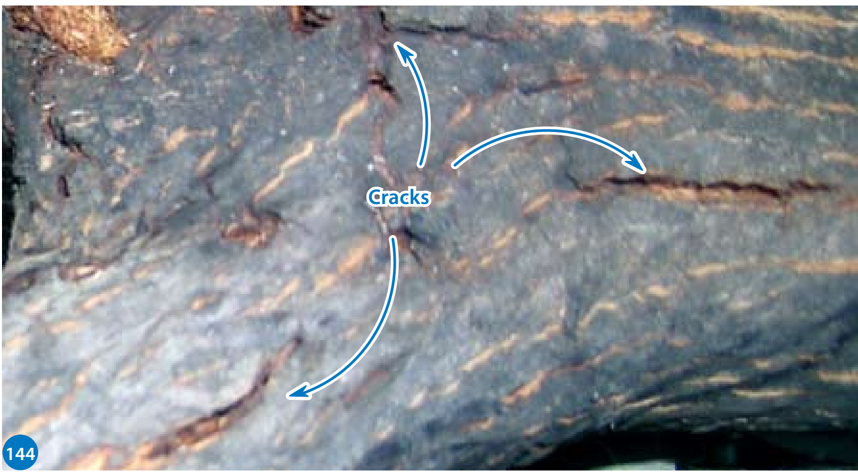
FIGURES 136-137. 136, Bark surrounding an oviposition pit has been removed to expose an egg and a characteristic oviposition stain underneath the pit. **137,** Bark has been removed to expose a live egg and a characteristic oviposition stain. **NOTE** the imprint of the egg on the stain located on the surface of the sapwood.

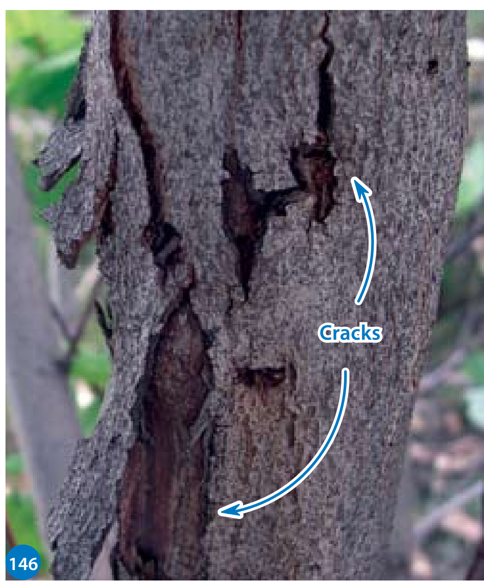


FIGURES 138-143. Most oviposition pits contain a single egg. **138,** This pit contained two eggs and a single oviposition stain. **139,**This pit contained two eggs and two oviposition stains. **140,** Oviposition stain with an egg that did not hatch. **141,** Oviposition stain with a larva that was about to hatch from the egg shell. **142 - 143,** Oviposition stains without an egg. **NOTE** the egg imprint on the oviposition stain.

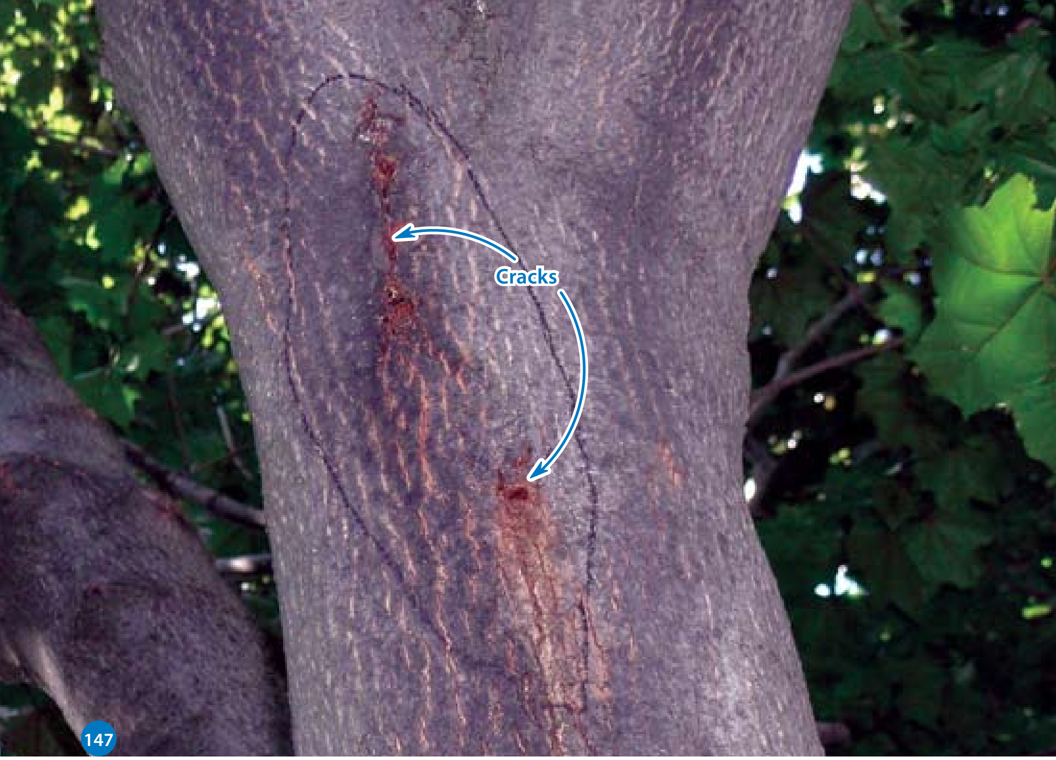
SYMPTOMS

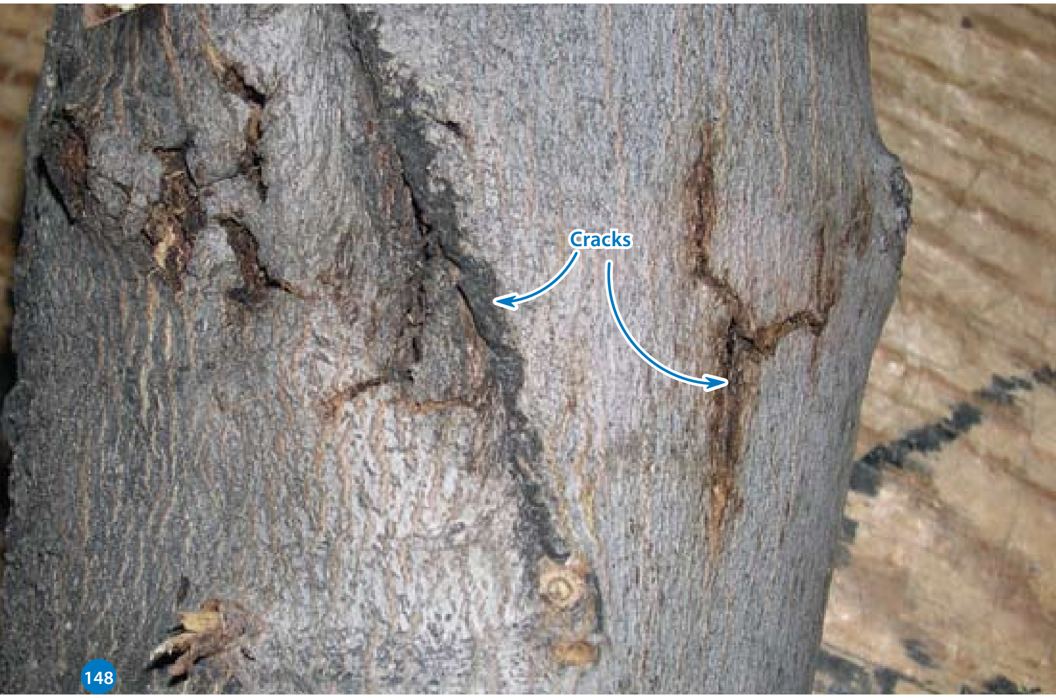
Crack in the bark: This symptom is a response to larval feeding on the surface of the sapwood, under the bark (Figures 144-148).





FIGURES 144-146. Examples of cracks in the bark caused by Asian longhorned beetle attacks.

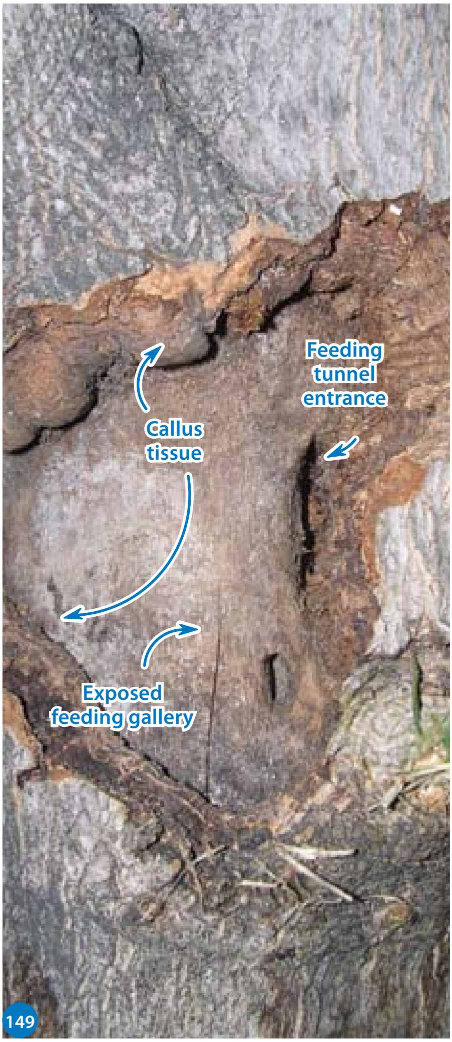




FIGURES 147-148. Examples of cracks in the bark caused by Asian longhorned beetle attacks.

SYMPTOMS

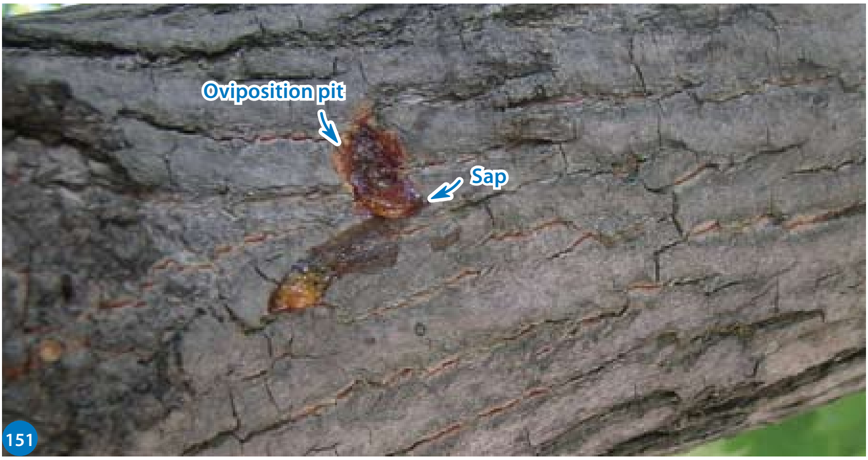
Missing bark: This symptom is a response to larval feeding under the bark and appears more than one year after larval feeding has begun (Figures 149, 150).

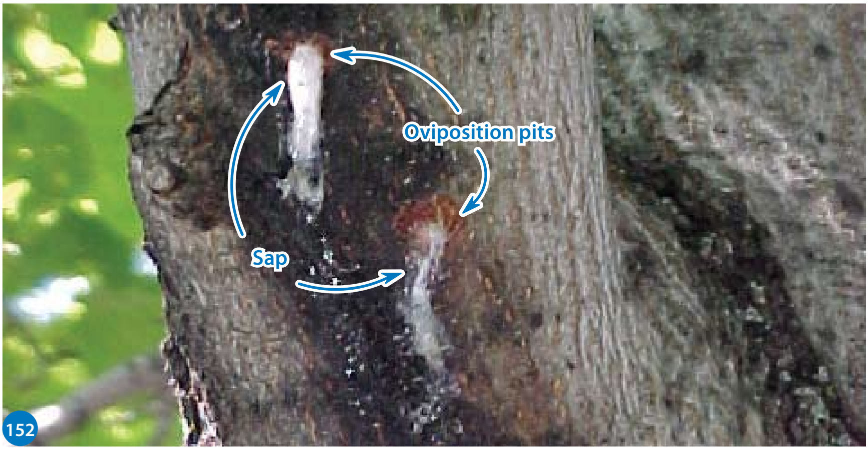


FIGURES 149-150. Examples of missing bark and exposed feeding galleries.

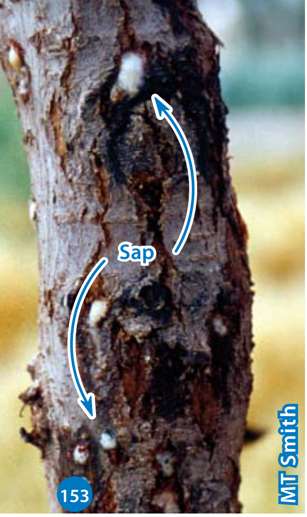
SYMPTOMS

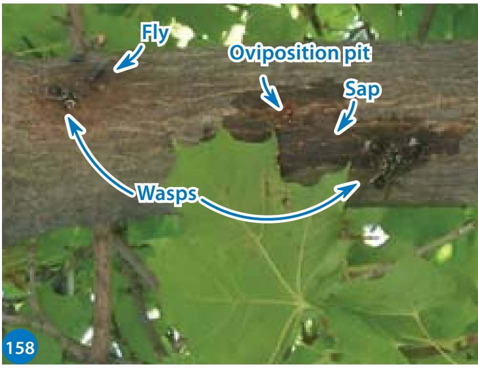
Foamy or frothy sap: This external symptom can appear shortly after adults chew oviposition pits in the bark (Figures 151-154). This sap often attracts insects such as ants (Figures 155, 156), wasps and flies (Figures 157, 158). In other infested areas (e.g., U.S.A.), butterflies, flies and scarab beetles have also been observed on or around frothy sap (Figures 159-161).



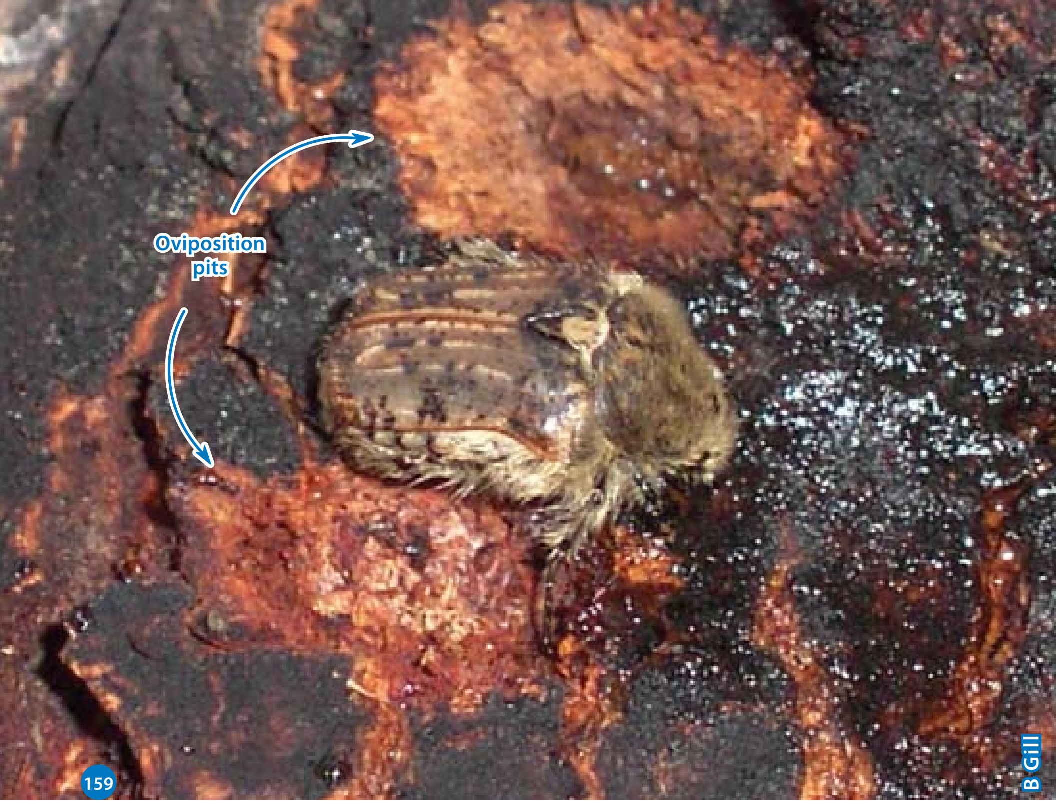


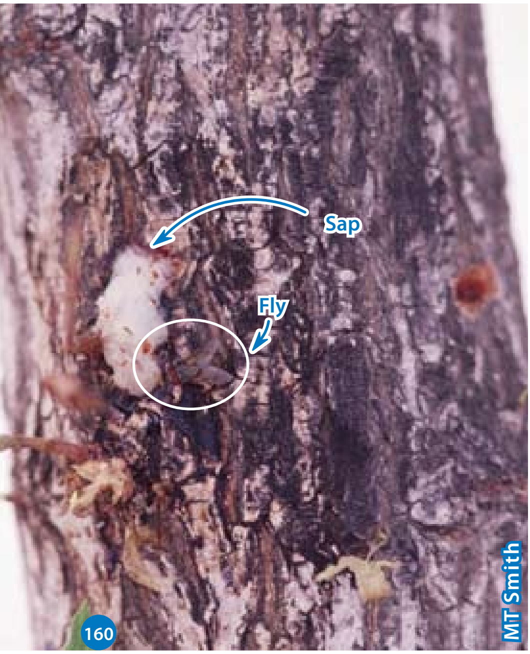
FIGURES 151-152. 151, Sap flowing from an oviposition pit on a maple branch. **152,** Foamy sap flowing from several oviposition pits on a maple branch.

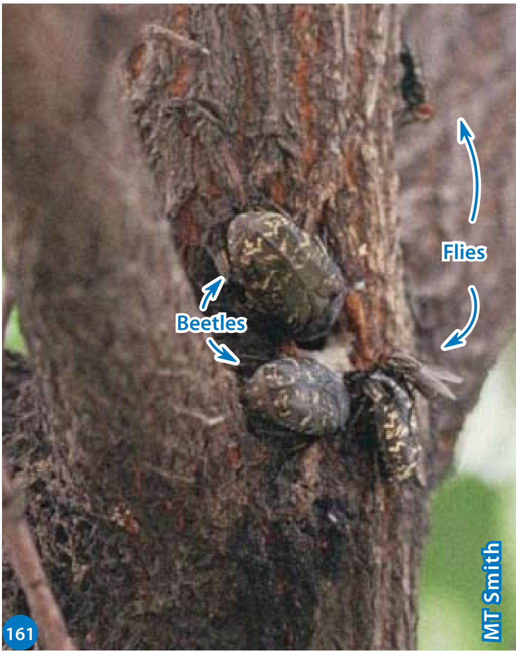




FIGURES 153-158. 153, Foamy sap flowing from oviposition pits on the main stem of a small elm. **154,** Black sap flowing from oviposition pits on the branches of a Russian olive. **155,** Sap flowing from an oviposition pit can attract ants. **156,** Single ant attracted by the sap oozing from an oviposition pit. **157,** Wasp attracted by the sap oozing from an oviposition pit. **158,** Sap flowing from oviposition pits can attract wasps and flies.



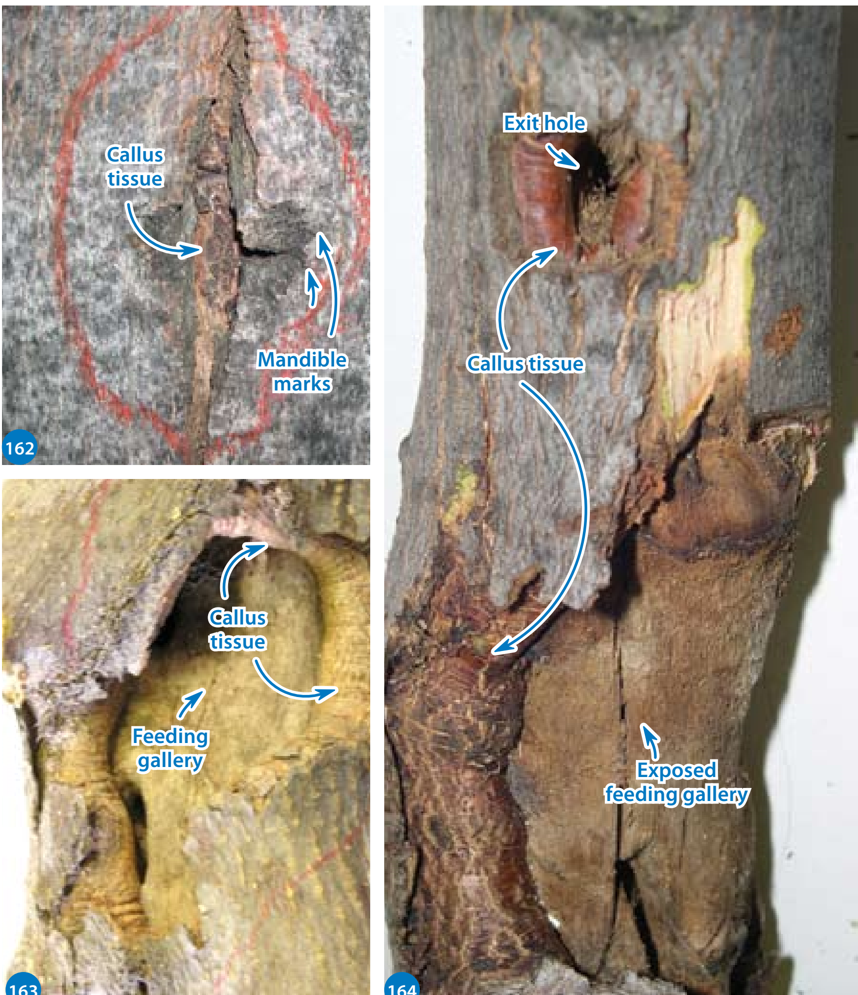




FIGURES 159-161. 159, Bumble flower beetle attracted by the sap oozing from oviposition pits. **160,** Unidentified fly attracted by the sap oozing from an oviposition pit. **161,** Scarab beetles and tachinid flies attracted by the sap oozing from an oviposition pit.

SYMPTOMS

Callus tissue around injuries: This symptom appears around oviposition pits (Figure 162), feeding galleries (Figure 163), and exit holes (Figure 164) several months after the injury has occurred.



FIGURES 162-164. 162, Callus tissue under oviposition pit. **163,** Callus tissue around a feeding gallery. **164,** Callus tissue around an exit hole and a feeding gallery.

SYMPTOMS

Branch dieback: When the Asian longhorned beetle attacks live trees, branches and trees die from the top down (Figures 165-168). This symptom becomes apparent when beetle densities are high or trees have been attacked repeatedly over many years. At that time, the main stem and large limbs become either girdled because of the surface feeding on the sapwood or weakened because of the presence of numerous tunnels into the wood (Figures 169, 170). Such trees are susceptible to wind breakage.

FIGURE 165. Early stage of top dieback on a heavily-infested maple.

FIGURES 166-167. 166, Example of advanced top dieback on infested maples. **NOTE** the presence of green hardwood trees in the background. **167,** Example of top dieback on poplars infested by the Asian longhorned beetle.

FIGURES 168-170. 168, Example of branch dieback on infested willows. **169,** Maple stem and limb girdled by larval feeding. **170,** Maple stem riddled with Asian longhorned beetle feeding tunnels are weakened and susceptible to wind breakage.

SYMPTOMS

Tree death: This symptom becomes apparent when beetle densities are high and trees have been attacked for many years (Figure 171).

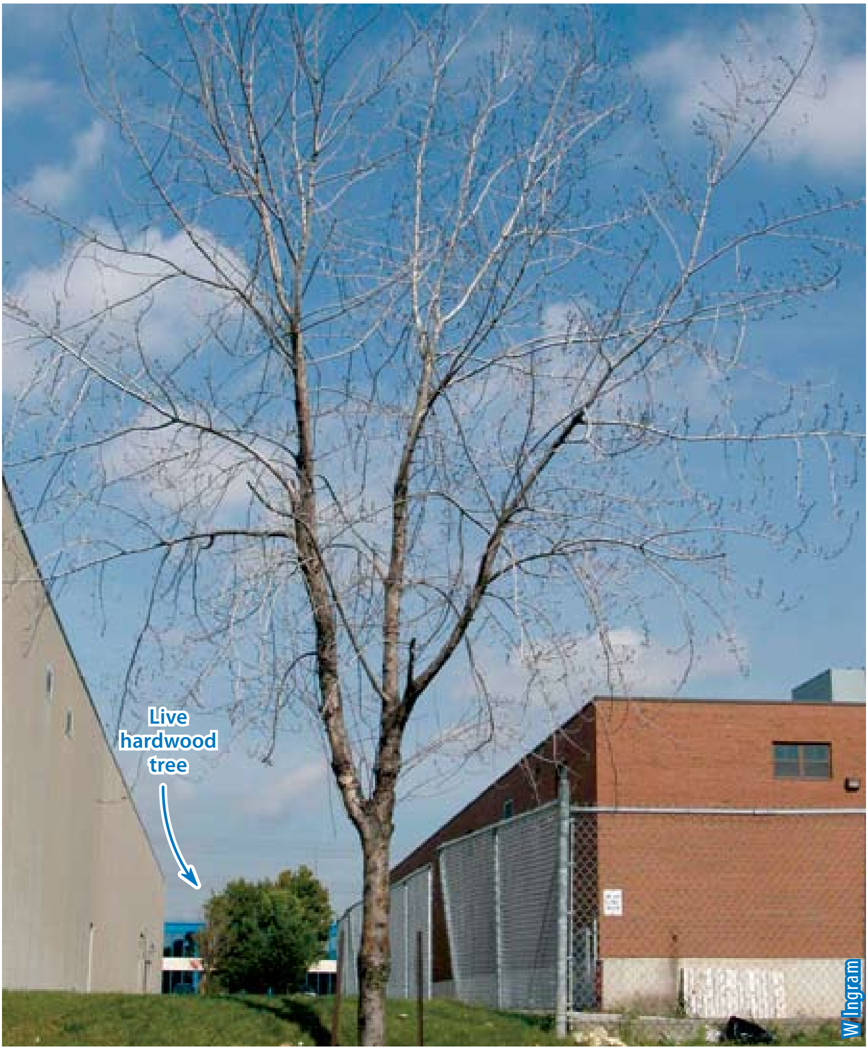


FIGURE 171. Maple tree killed by repeated attacks of the Asian longhorned beetle. **NOTE** the presence of green hardwood trees in the background.

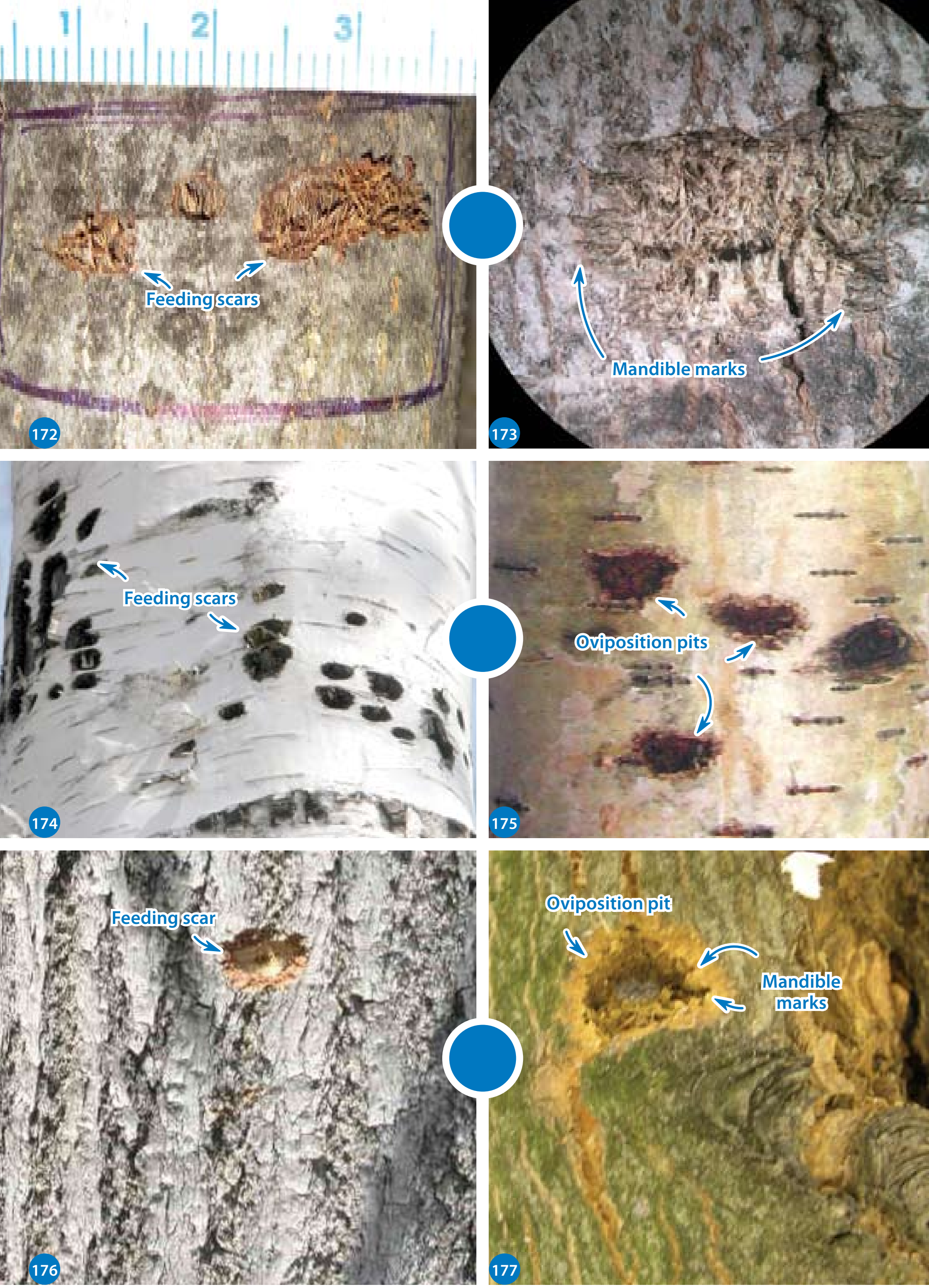
"LOOK-ALIKES"

Several injuries caused by animals, tree diseases, weather conditions or other agents can look like the signs or symptoms caused by an Asian longhorned beetle injury and lead to confusion. Often, the only way to distinguish "look-alikes" from real signs is to search for additional signs (i.e., oviposition stain, feeding gallery, etc,). This search should be performed by specialists under laboratory conditions to ensure that it is fully documented for future reference. Therefore, inspectors should report all suspect injuries or signs to specialists. Reporting these suspect injuries or signs will also ensure that these "look-alikes" can be used for training purposes and provide all survey staff and specialists with a more comprehensive basis on which to make the correct identification.

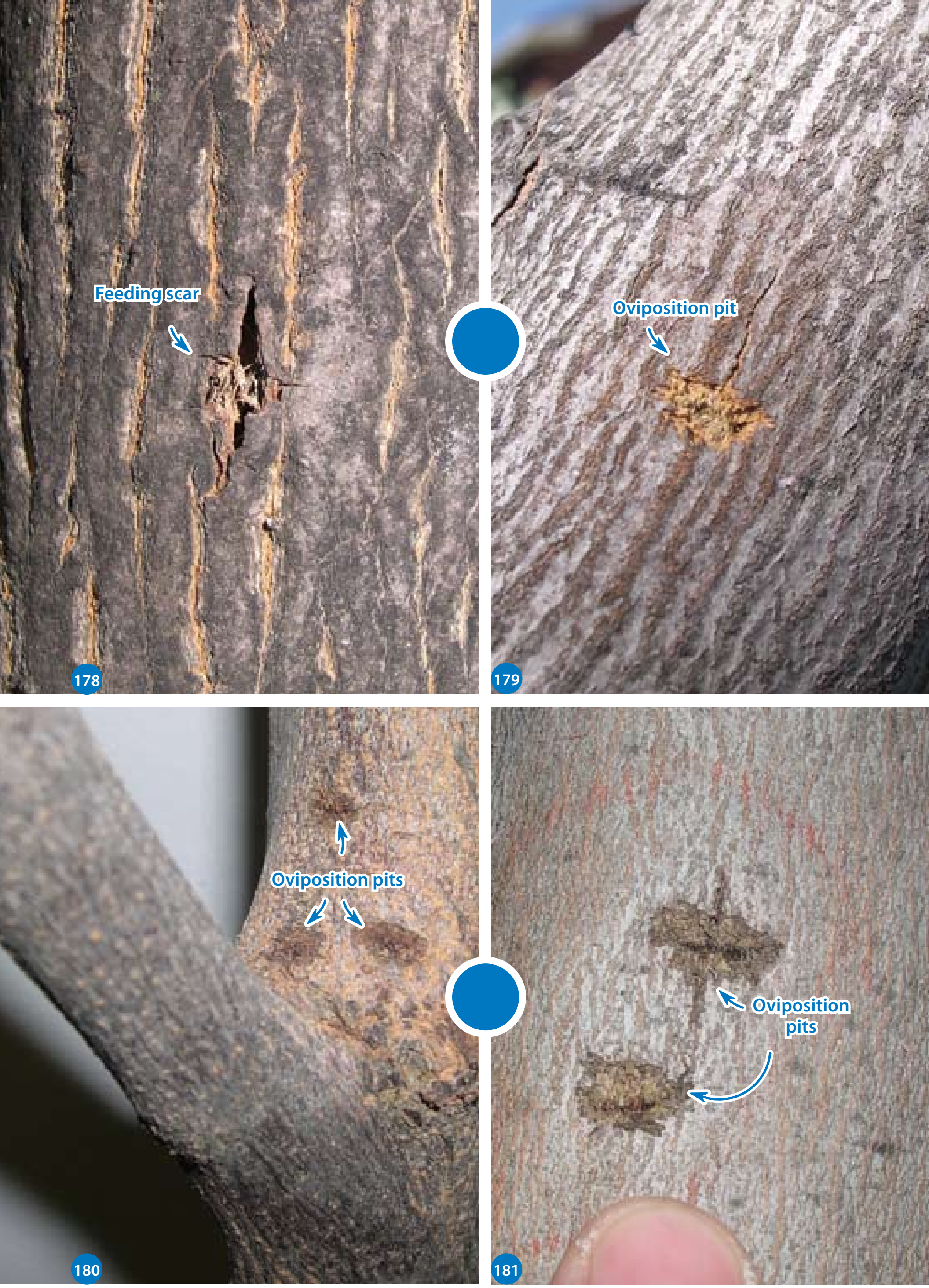
In this section, several of these known "look-alikes" injuries are shown and paired with an image of the damage caused by the Asian longhorned beetle. Each pair is connected by a blue dot. The first image is always that of the look-alike whereas the second one is that of the Asian longhorned beetle. These "look-alikes" have been grouped under the type of Asian longhorned beetle sign they resemble.

Oviposition pit: Old feeding pits made by animals such as squirrels (Figures 172, 173), sapsuckers (Figures 174-177), and woodpeckers (Figures 178, 179) can resemble Asian longhorned beetle oviposition pits. Injuries caused by other insects such as the hickory borer (Figures 180-183), and the poplar-and-willow borer (Figures 184, 185) can also resemble those of the beetle. Some of the cankers observed on poplars have been confused with oviposition pits (Figures 186, 187). On occasion, natural folds, cracks or injuries on the bark can be confused with oviposition pits of the Asian longhorned beetle (Figures 188-195).

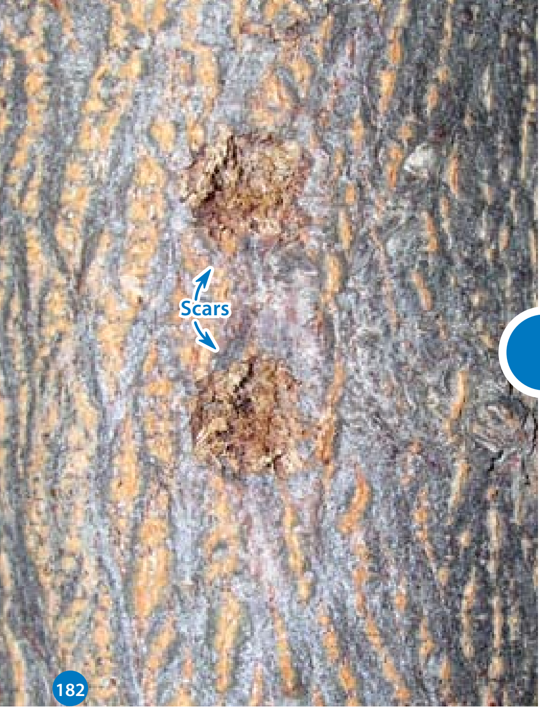
There are some mechanical injuries that resemble oviposition pits (Figures 196-199). In some instances, the sap flowing from mechanical injuries can also be confused with the symptom resulting from the injury response of the tree to a female beetle chewing the bark and laying an egg (Figures 200, 201). Among the most common mechanical injuries are those resulting from lawn trimmers and from tree climbing activities (Figures 202, 203).

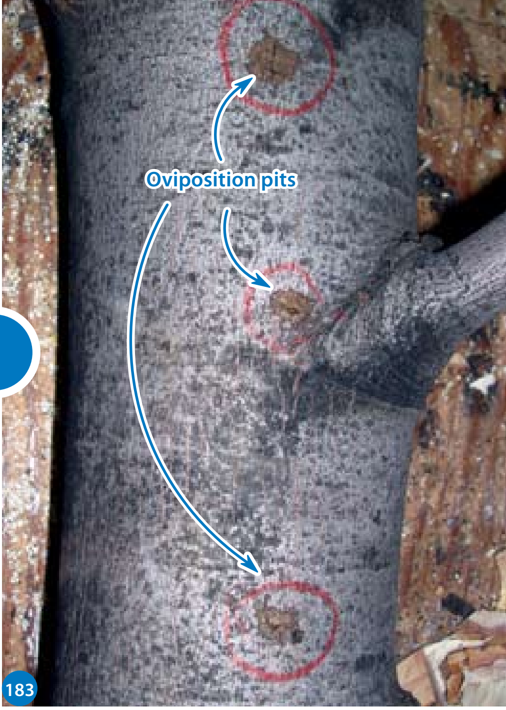


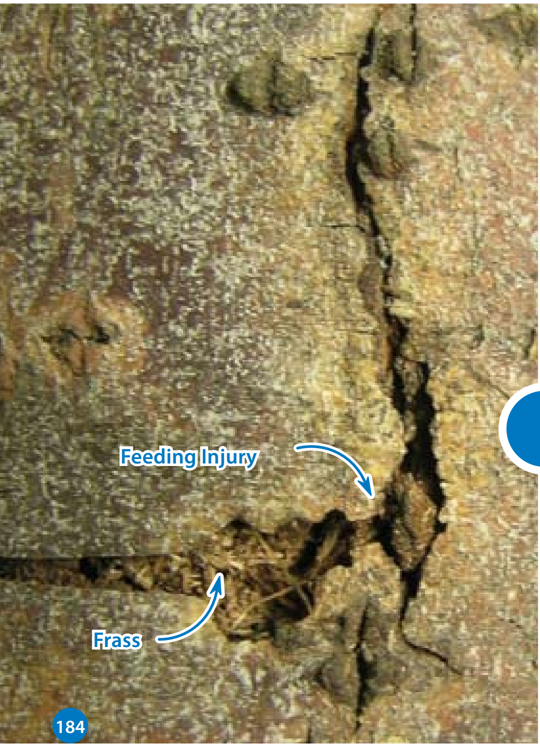
FIGURES 172-177. 172, Squirrel feeding scars on maple. **NOTE** the absence of mandible marks. **173,** Oviposition pit. **174,** Sapsucker feeding scars on birch. **NOTE** that holes are deep and there are no mandible marks. **175,** Oviposition pits. **176,** Sapsucker feeding scar on maple. **NOTE** that the wood is visible and white. **177,** Oviposition pit. **NOTE** that the centre is black.

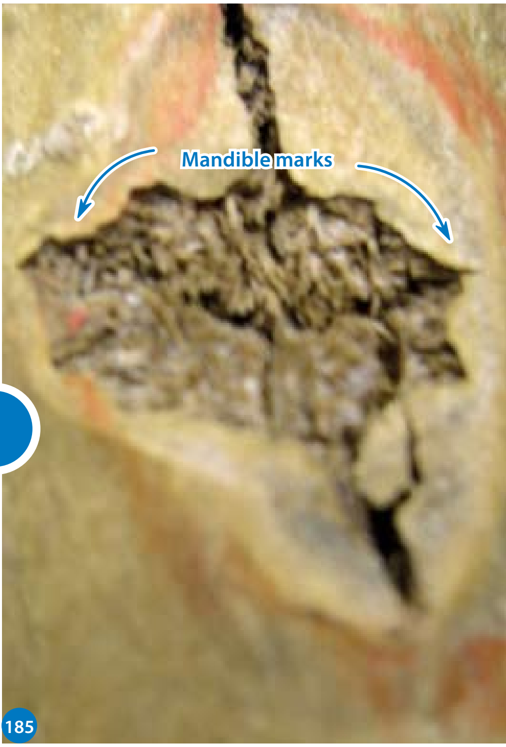


FIGURES 178-181. 178, Woodpecker feeding scar on maple. **NOTE** the absence of mandible marks. **179,** Oviposition pit on maple. **180,** Slanted oviposition pits made by the hickory borer on hickory. **NOTE** that hickory is not a suitable tree genus for the Asian longhorned beetle. **181,** Oviposition pits on maple.

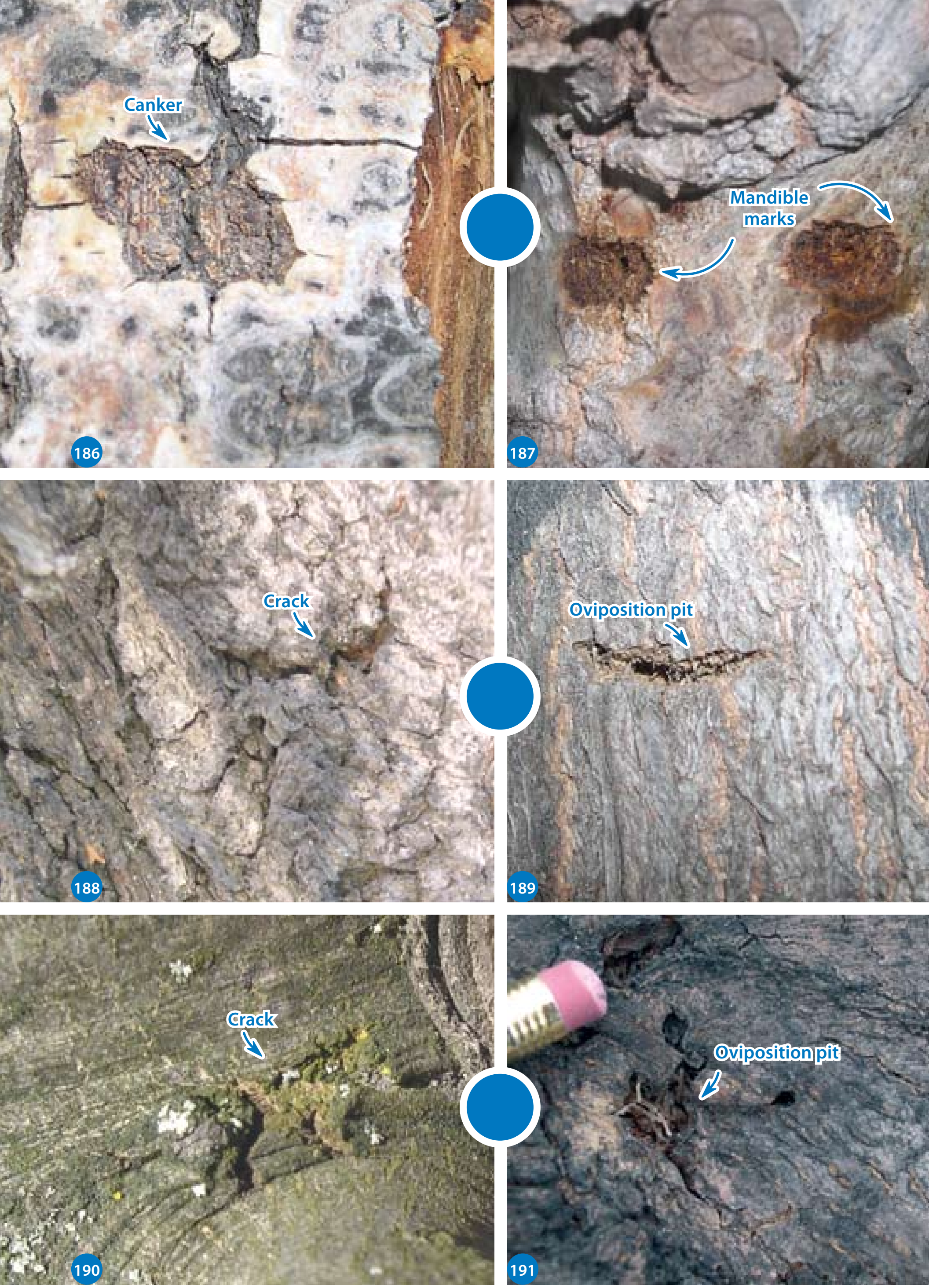




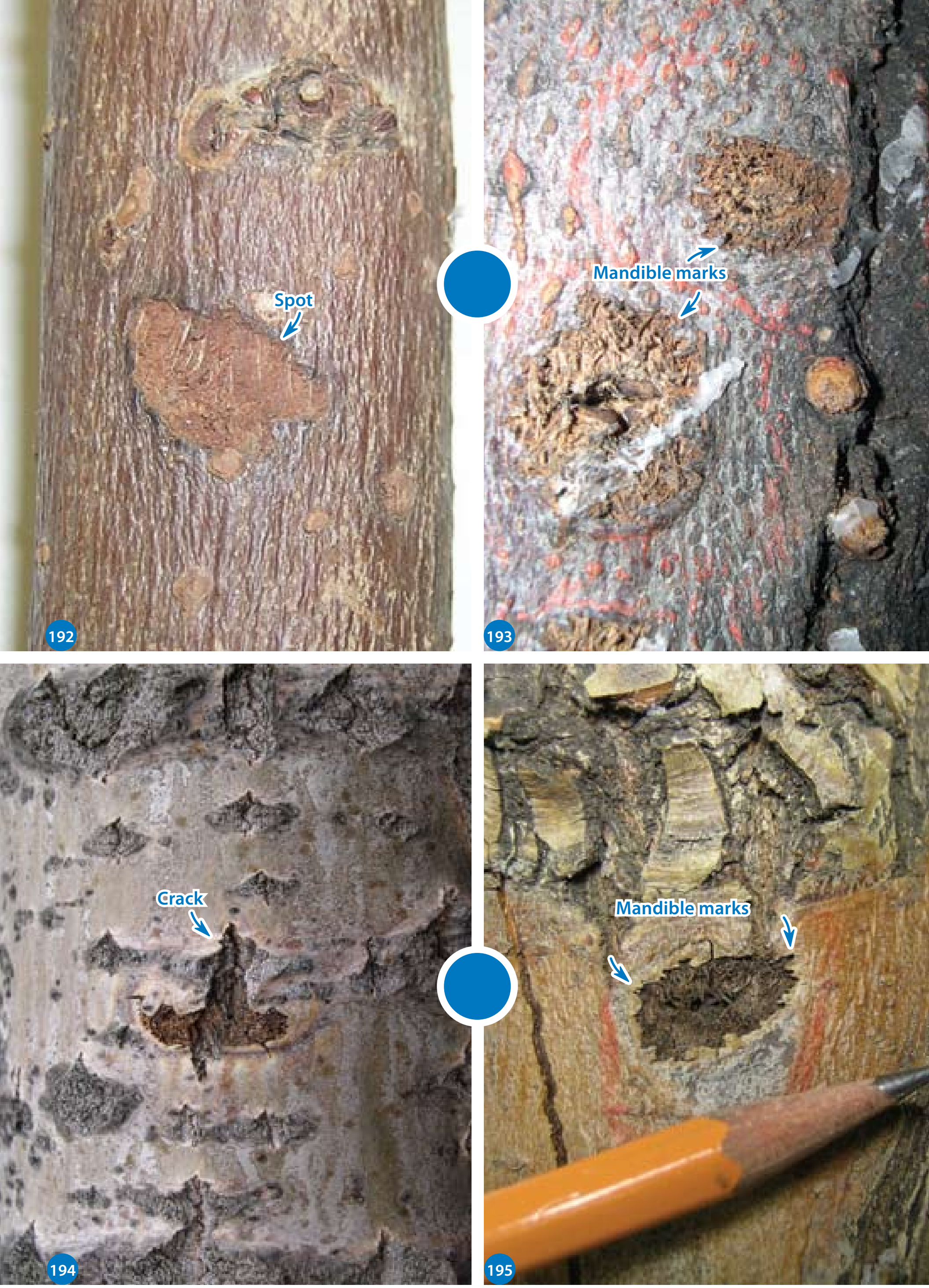




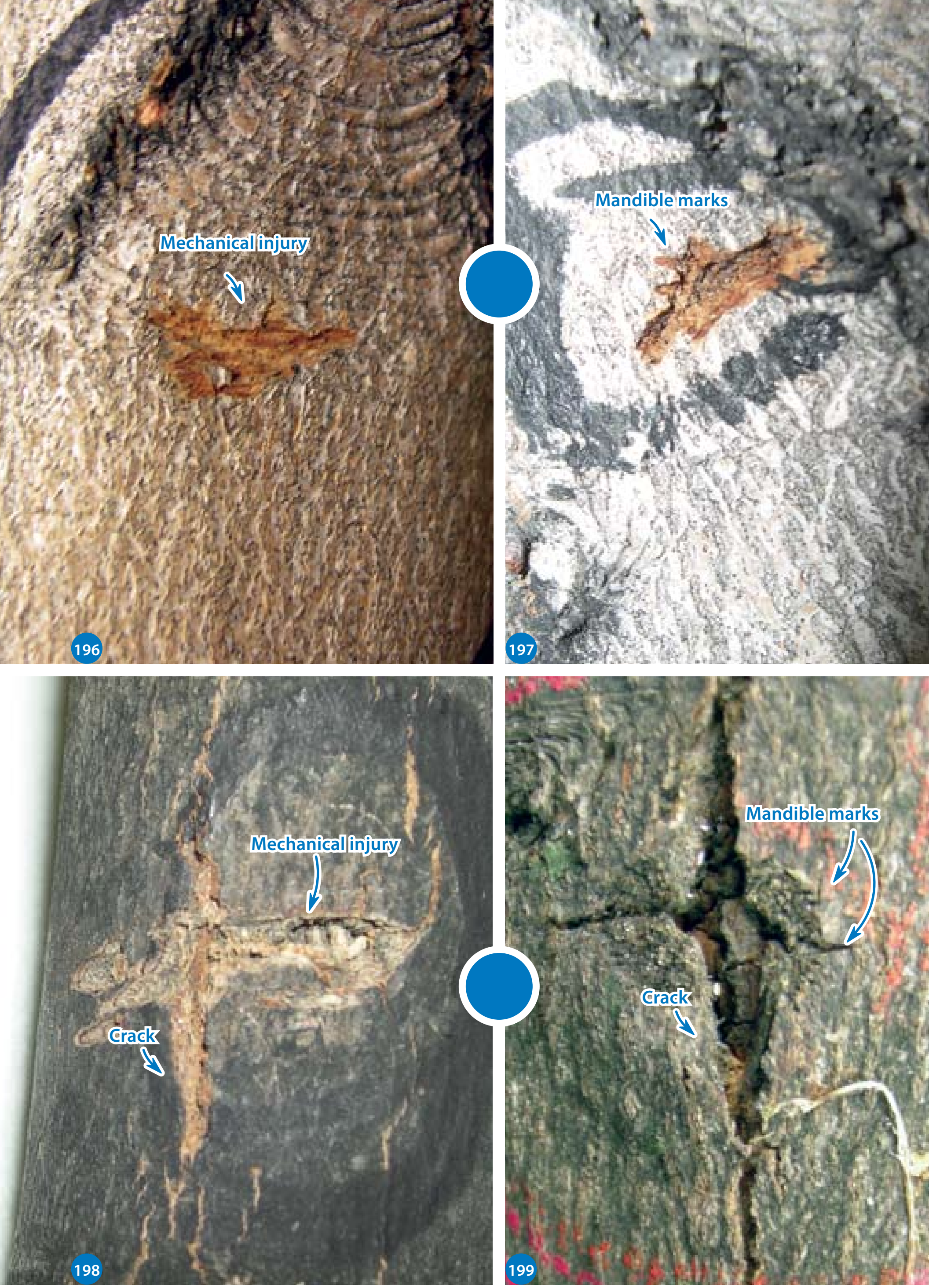
FIGURES 182-185. 182, Round oviposition pits made by the hickory borer on hickory. **NOTE** that hickory is not a suitable tree genus for the Asian longhorned beetle. **183,** Oviposition pits on maple. **184,** Feeding injury by the poplar-and-willow borer. **NOTE** the absence of mandible marks. The presence of frass makes it difficult to differentiate under field conditions. **185,** Oviposition pits on willow.



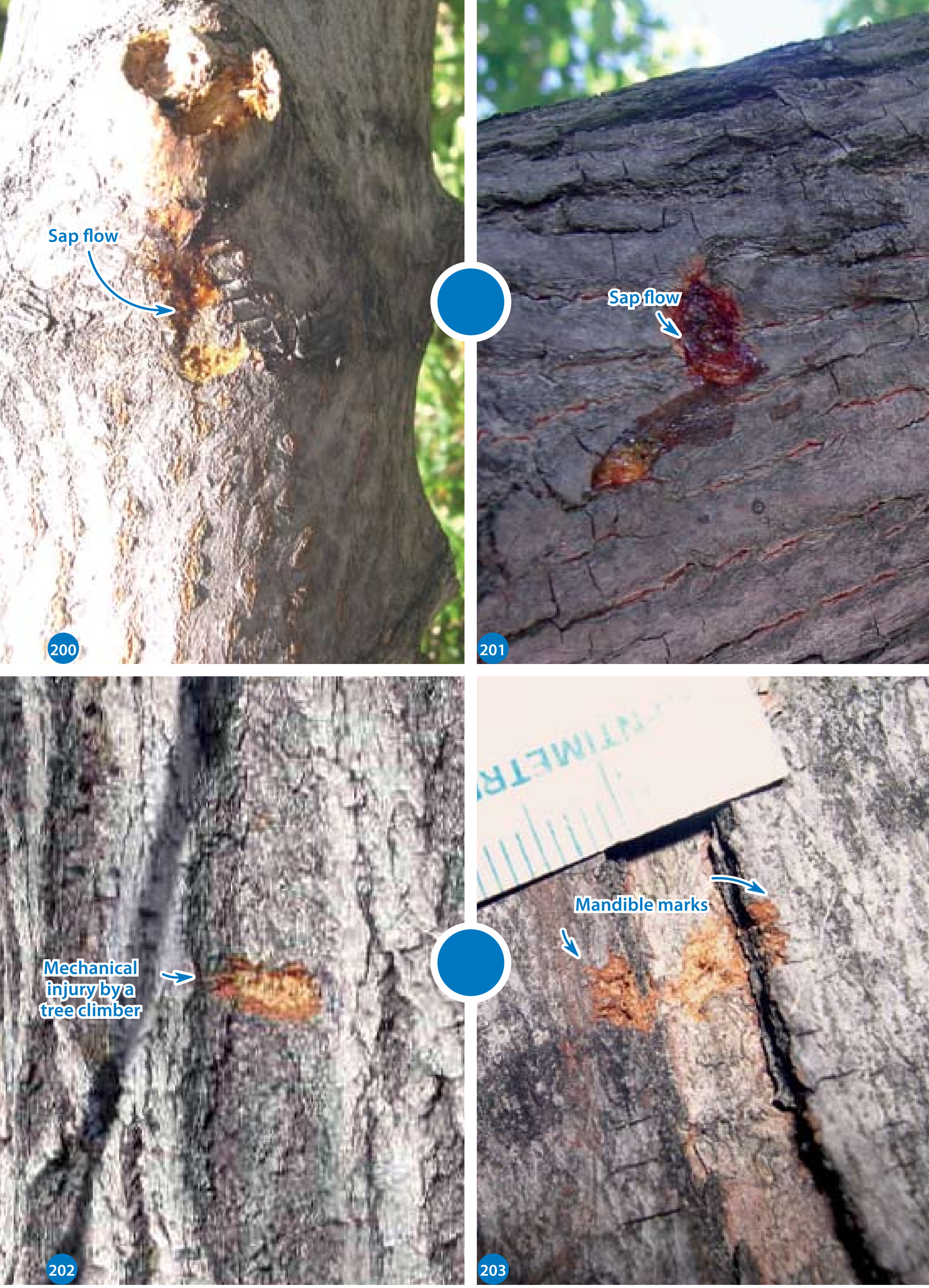
FIGURES 186-191. 186, Canker on poplar. **NOTE** the absence of mandible marks. **187,** Oviposition pit on poplar. **188,** Crack in the bark of maple. **189,** Oviposition pit. **190,** Crack in the bark of maple at a branch junction. **NOTE** that such cracks will have to be dissected by a specialist under laboratory conditions. **191,** Old oviposition pit with frass at a branch junction.



FIGURES 192-195. 192, Spot in the bark of linden. **NOTE** the irregular shape of the spot, the clearly delineated edge, and the absence of mandible marks. **193,** Oviposition pits on linden. **194,** Crack in the bark of poplar. **NOTE** the absence of mandible marks. **195,** Oviposition pit on poplar.



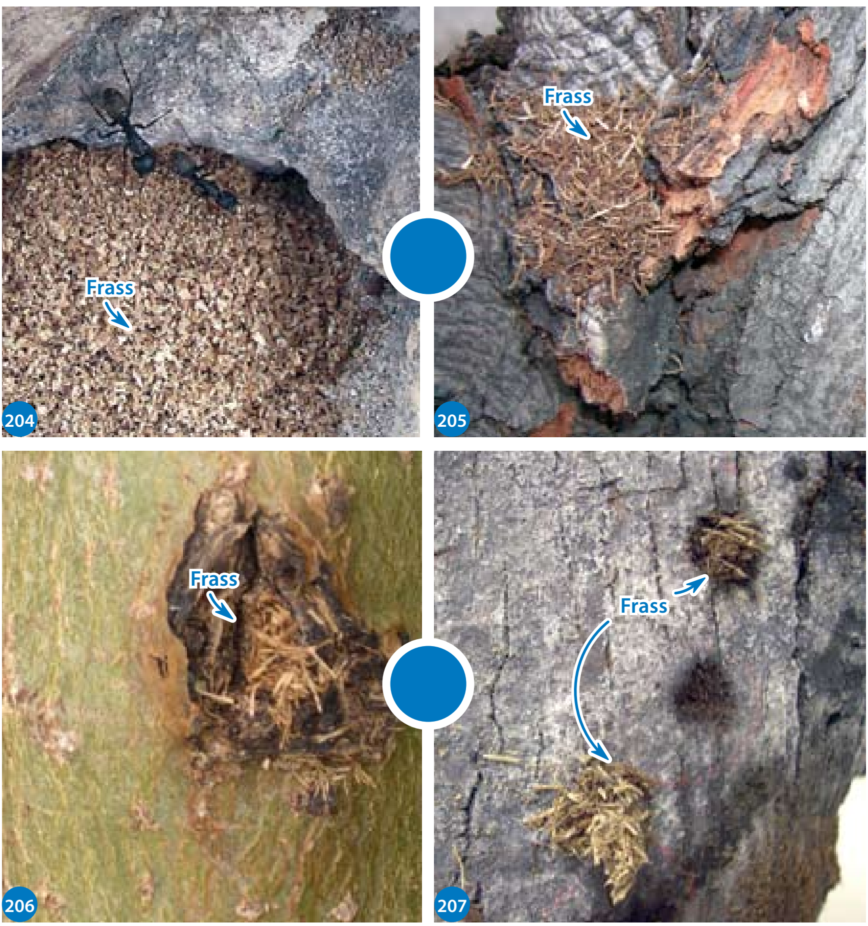
FIGURES 196-199. 196, Mechanical damage on maple. **197,** Oviposition pit on maple. **198,** Mechanical damage across a crack in the bark of a maple. **199,** Old oviposition pit on maple.



FIGURES 200-203. 200, Mechanical damage with sap flow on maple. **201,** Oviposition pit with sap flow. **202,** Mechanical injury caused by a tree climber on a maple. **203,** Oviposition pit.

"LOOK-ALIKES"

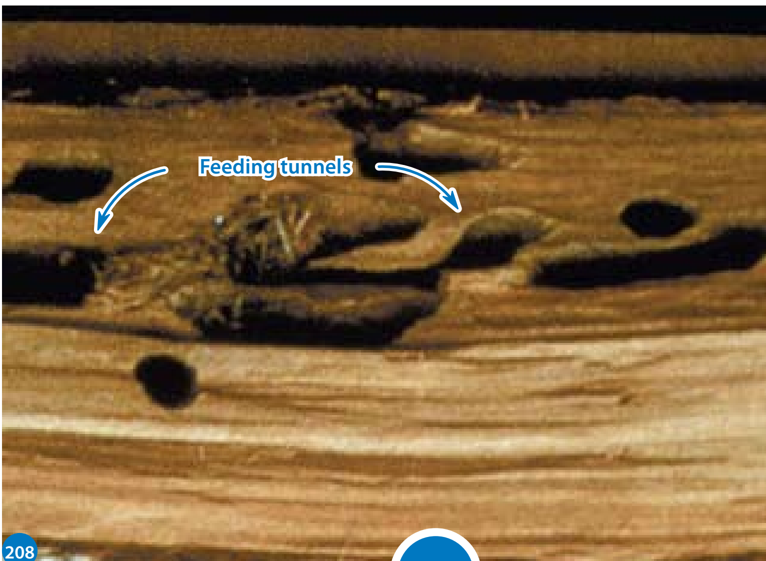
Frass: Frass made by insects such as the carpenter ants (Figures 204, 205) and the poplar-and-willow borer (Figures 206, 207) can be confused with that left by the Asian longhorned beetle. Maple callus borers have been found in large callus surrounding the feeding galleries created by Asian longhorned beetle larvae. Frass from these two species of insects was mixed and could not be distinguished.



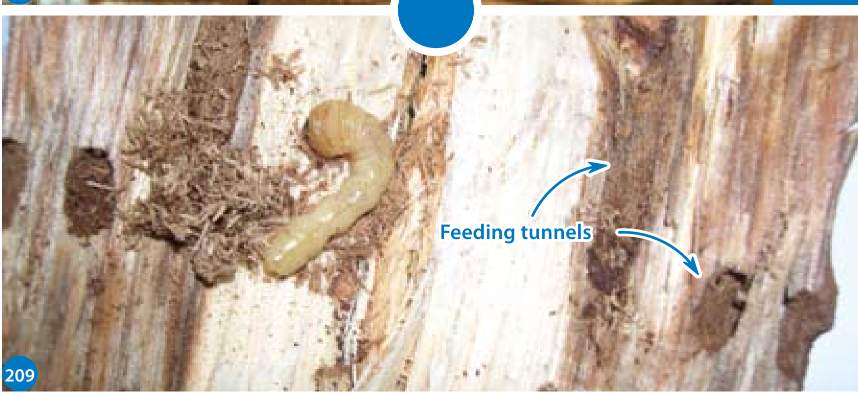
FIGURES 204-207. 204, Frass from carpenter ants. **NOTE** the pellet shape of the frass. **205,** Frass from Asian longhorned beetle. **NOTE** the presence of shavings held together with frass. **206,** Frass from the poplar-and-willow borer. **207,** Frass from Asian longhorned beetle.

"LOOK-ALIKES"

Tunnel into the wood: The feeding gallery, the tunnel entrances and tunnels into the wood of poplar borer larvae (Figures 208, 209), carpenterworms (Figures 210, 211) and some unidentified borers (Figures 212-215) resemble those of the Asian longhorned beetle.

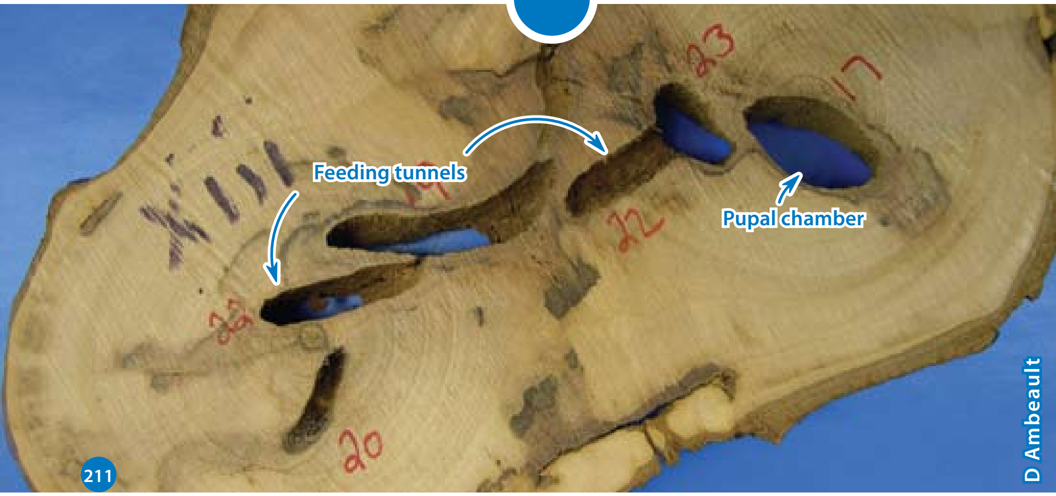


Minnesota Department of Natural Resources Archives, Minnesota Department of Natural Resources, www.forestryimages.org

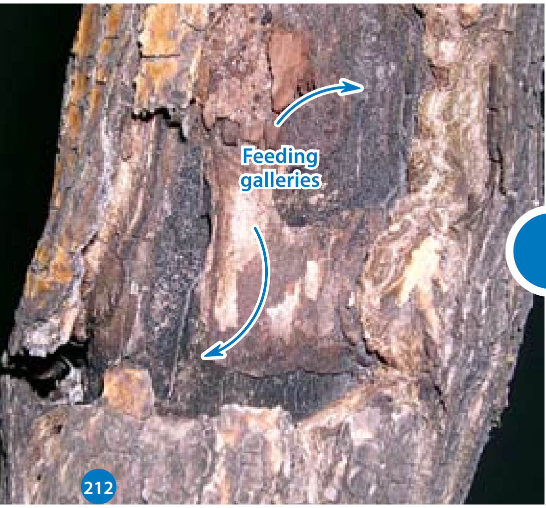


FIGURES 208-209. 208, Tunnelling by poplar borer larvae. **209,** Asian longhorned beetle feeding tunnel.

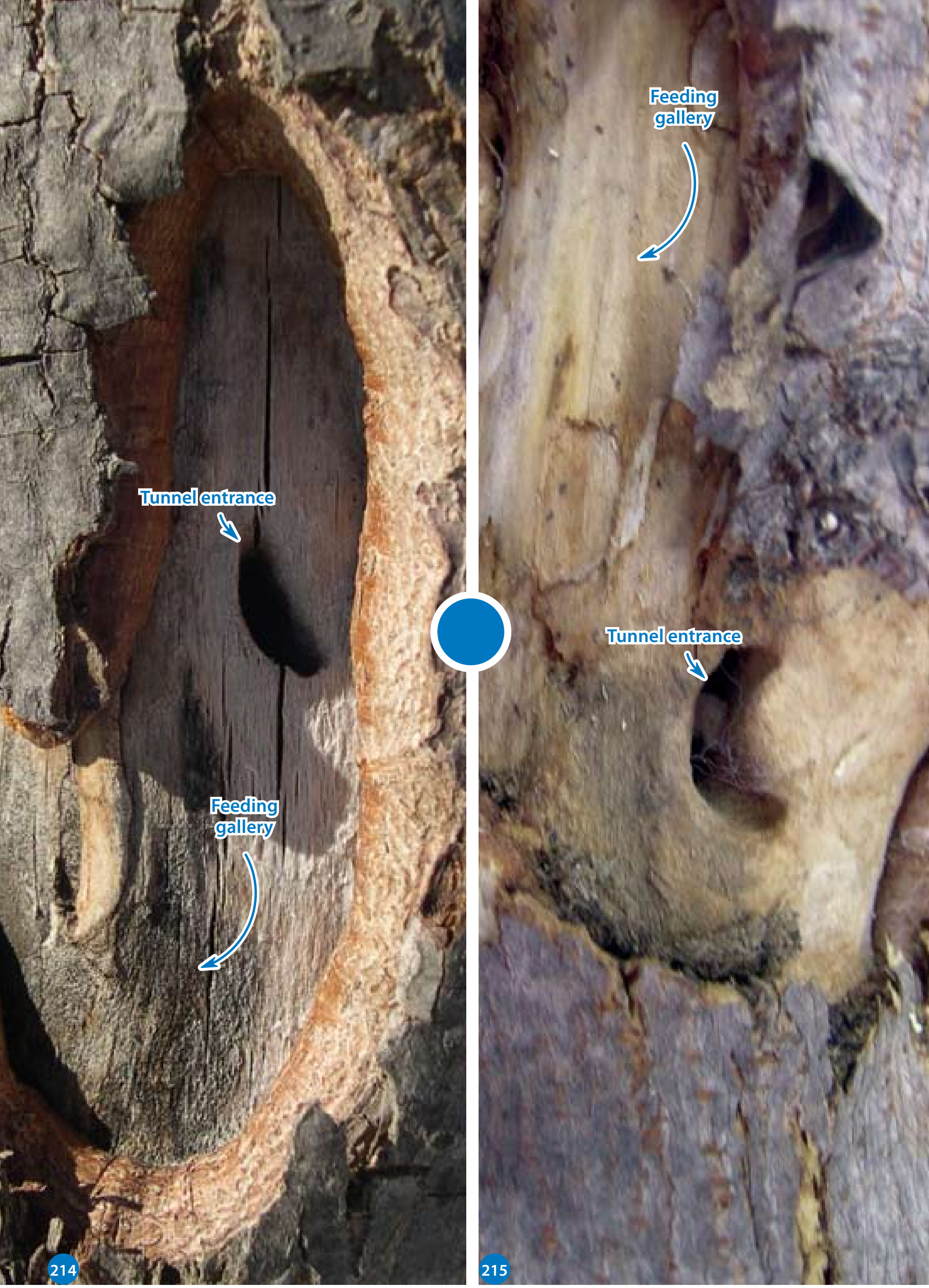
USDA Forest Service - Ogden Archives, USDA Forest Service, www.forestryimages.org



D Ambeault



FIGURES 210-213. 210, Tunnelling by carpenterworm larvae. **NOTE** the circular shape of the tunnels. **211,** Asian longhorned beetle feeding tunnel. **NOTE** the flattened shape of the tunnels. **212,** Feeding galleries by the ash borer on the stem of an ash tree. **NOTE** that ash is not a suitable genus for the Asian longhorned beetle. **213,** Asian longhorned beetle feeding gallery.



FIGURES 214-215. 214, Feeding gallery and tunnel entrance by a buprestid (i.e., flat-headed borer) larva on maple. **215,** Asian longhorned beetle feeding gallery and characteristic c-shaped tunnel entrance in the wood.

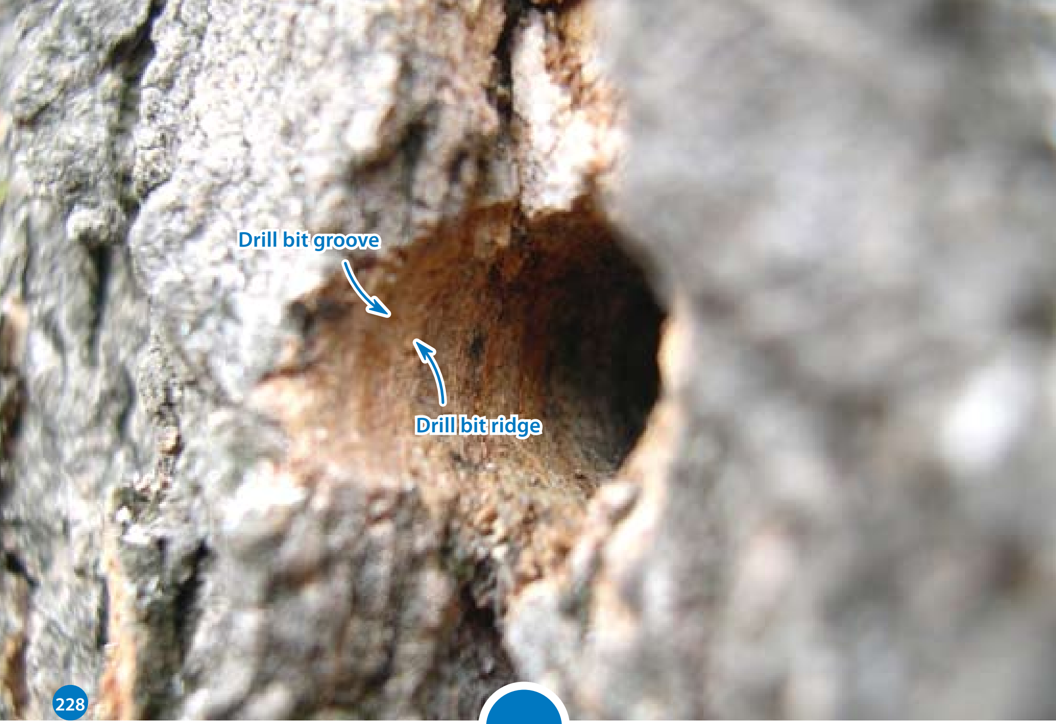
"LOOK-ALIKES"

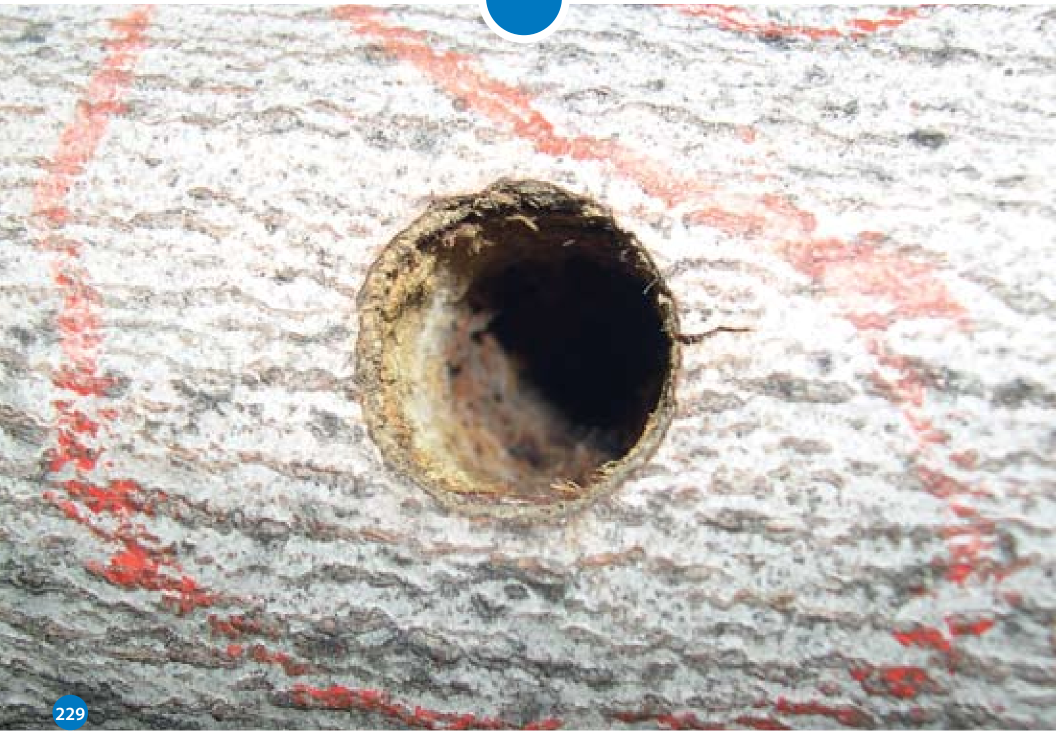
Exit hole: Some holes made by insects such as the carpenter bee (Figures 216-219), the hickory borer (Figures 220, 221), the lilac borer (Figures 222, 223), the gallmaking maple borer (Figures 224, 225), and the maple callus borer (Figures 226, 227) can resemble exit holes made by the Asian longhorned beetle. Sometimes people drill holes into trees that are of the same size and shape as that of an exit hole (Figures 228, 229).

FIGURES 216-219. 216, Entrance hole of a carpenter bee. **217,** Cross section of the branch in Figure 216 showing the circular shape of tunnels made by the carpenter bee. **218,** Asian longhorned beetle exit hole on a dead branch. **219,** Cross section of the branch in Figure 218 showing the flattened shape of the tunnels made by the Asian longhorned beetle.

FIGURES 220-223. 220, Exit hole by the hickory borer. **NOTE** that hickory is not a suitable tree species for the Asian longhorned beetle. **221,** Exit hole on maple. **222,** Exit hole by the ash borer on a stem of ash. **NOTE** that ash is not a suitable tree species for the Asian longhorned beetle and that these holes are typically 4-5 mm in diameter. **223,** Exit hole on maple. **NOTE** that that these holes are typically 6-14 mm in diameter.

FIGURES 224-227. 224, Exit hole by the gallmaking maple borer on maple. **NOTE** that these holes are 4-5 mm in diameter. **225,** Exit hole on maple. **226,** Exit hole made by the maple callus borer. **NOTE** that these holes are 3-4 mm in diameter and that pupal skins often protrude partly out of the trunk. **227,** Exit holes on maple. **NOTE** the absence of pupal skins and that these holes are 6-14 mm in diameter.





FIGURES 228-229. 228, Sugar maple tapping hole drilled by humans. **NOTE** the presence of grooves and ridges left by the drill bit. **229,** Exit hole made by the Asian longhorned beetle on maple.

POINTS TO REMEMBER

- There are several types of signs and symptoms of injury caused by the Asian longhorned beetle.
- External signs are oviposition pits, frass or shavings, hollow bark, exposed feeding galleries, exit holes, and adult feeding.
- Internal signs are feeding galleries under the bark and tunnels into the wood.
- Symptoms include oviposition stains, cracks in the bark, missing bark, foamy or frothy sap, callus tissues around injuries, branch dieback and tree death.
- The appearance of signs and symptoms changes with time, and is influenced by bark thickness and texture, tree species, and weather conditions.
- Examine leaves that have fallen prematurely for the presence of adult feeding signs.
- Most of the damage to the trees is caused by larvae feeding at the sapwood-bark interface and by larvae tunnelling into the wood.
- Beware of the "look-alikes" and report them to qualified staff or experts.

SEARCHING FOR THE ASIAN LONGHORNED BEETLE

INTRODUCTION

In this section, the inspection methods currently used to detect the presence of the Asian longhorned beetle are briefly reviewed and a flowchart depicting the suggested steps or actions of inspecting a tree is presented. General information is provided on where to look in the landscape and within a tree, and when to look for live stages or signs and symptoms. Also included are instructions on what inspectors should do upon finding suspect insects or signs and symptoms of the Asian longhorned beetle.

INSPECTION METHODS

Examination of trees for the presence of signs and symptoms can be done either from the ground or from within the tree (hereafter referred to as within-crown). It is generally accepted that within-crown methods are more effective than ground inspections. The selection of the most appropriate method to examine a tree should be based on the objective of the survey (e.g., delimitation, detection), the type of survey being conducted, (e.g., suitable tree genera only, questionable tree genera), the size of the trees to be surveyed and the severity of the infestation.

There are federal, provincial and municipal safety regulations governing arboricultural work and tree survey in Canada. Tree inspections must be performed by "competent and qualified" personnel trained in the code of rules, techniques and procedures approved by these Regulating Authorities.

Ground inspection

This is the most rapid method of tree inspection (Figure 230). This method is effective when surveying heavily infested areas. It is also appropriate for the inspection of small diameter trees and shrubs and the lower branches of large trees. The use of high contrast binoculars (Figure 231) greatly increases the area of the tree that can be surveyed, especially in winter. The main stem(s) and the main lower branches should **ALWAYS** be examined from the ground to ensure there is no readily apparent sign of attack prior to proceeding with a within-crown inspection method.

FIGURE 230. Inspector performing ground survey.

FIGURE 231. Inspector using binoculars to examine the bole and branches of a tree for signs or symptoms of injury.

Within-crown inspection

This method allows examination of all parts of the tree, especially those sections not visible from the ground or when leaves are present. Three approaches are currently used to conduct within-crown inspection: ladders, bucket trucks, and tree climbers. **Ladders** can be a useful complement to ground inspection when examination of the entire bole and upper branch junctions of trees too small to climb safely is difficult to accomplish solely from the ground (Figure 232). Inspection with **bucket trucks** is much slower than ground examination, but it provides inspectors with the ability to examine large trees, or parts of large trees such as branch junctions, that cannot be examined completely from the ground (Figures 233, 234). Also, it is the most effective method to detect evidence of maturation feeding by adults in the foliage of the crown. The amount of time required to set-up for each tree is high, thus, it is preferable to limit the use of bucket trucks for within-crown inspection to the leading edge of an infested area. Inspection by **tree climbers** is also slower

FIGURE 232. Inspector using a ladder to perform a within-crown inspection on a small tree.

than by ground (Figures 235-237). This approach is without a doubt the most thorough and effective for detecting signs and symptoms of Asian longhorned beetle injury on the bole and branches of large trees. It is the method of choice, especially at the leading edge or in areas where beetle densities are low. It is also the only practical method of inspecting trees in woodlots.


233


234

FIGURES 233-234. 233, Bucket truck fully set up to perform a within-crown inspection of a tree. **234,** Within-crown inspection of a tree using a bucket truck.

FIGURES 235-237. 235, Tree climber performing a within-crown inspection of a tree at the leading edge of the infestation during the summer months. **236,** Tree climber performing a within-crown inspection in a residential neighbourhood during the winter months. **237,** Tree climber performing a within-crown inspection in a woodlot.

RECOMMENDED PROCESS

A step-by-step process to detect signs and symptoms of Asian longhorned beetle attack has been developed (Figure 238). The process is applicable irrespective of the inspection method. Inspection by several inspectors may be required either because the tree is too large to be completely surveyed from the ground, the tree has foliage and portions of the bole and branches cannot be examined from the ground or because the inspector does not have the tools (i.e., a ladder) or the training required to perform a complete within-crown inspection (i.e., bucket truck operation or tree-climbing certification). The emphasis of this flowchart is on the identification of the necessary steps that must be taken while inspecting a single tree, not on the specific requirements of the programme or project. For example, training requirements and health and safety procedures are not presented here, because these would be specific to the organization(s) in charge of the survey and to their respective protocols.

To keep survey procedures simple and easy to remember, the entire process has been divided into five parts or steps. A short paragraph describing each of these steps follows. The starting point of any inspection is a tree in an area targeted for survey, either intensively or extensively.

STEP 1. Determine if this is an initial inspection. If **IT IS**, proceed to Step 2. If **IT IS NOT** an initial inspection, (i.e., it is either a second, third etc. visit to this tree or it is a follow-up inspection because the previous inspector could not examine the tree completely), proceed to Step 3.

STEP 2. Identify the tree genus using foliage or twigs (depending on the season), and determine whether it is on the list of **suitable** genera. If **IT IS** a suitable genus, record the exact location of the tree (i.e., UTM coordinates from GPS units set to a common datum (e.g., NAD 83) and street address, etc,) and any other tree measurement considered essential by the organization in charge of the survey, and proceed to Step 3. If **IT IS NOT** a suitable species, locate the next tree to be examined and repeat Step 1.

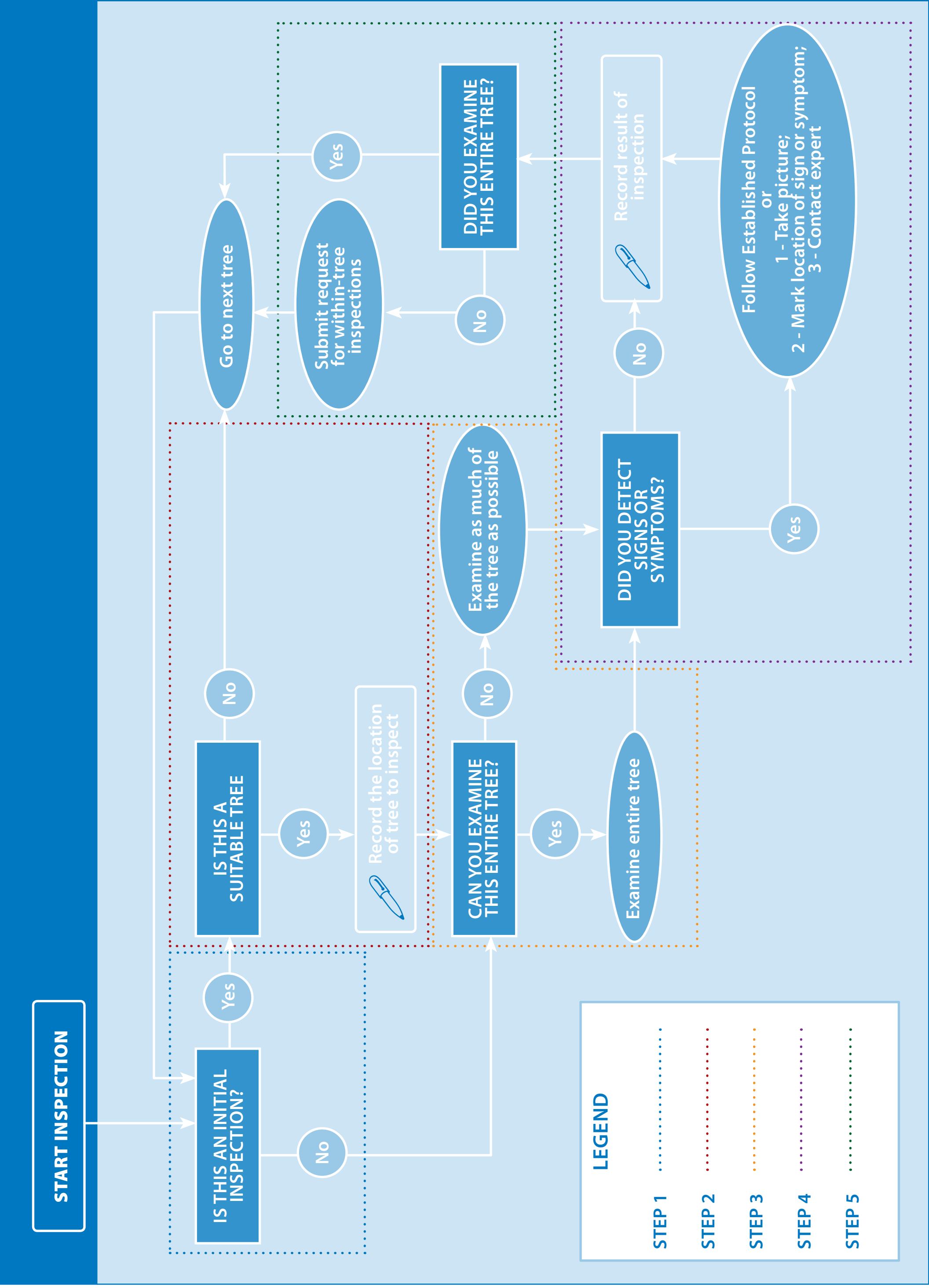


FIGURE 238. Recommended process for detecting signs and symptoms of Asian longhorned beetle injuries.

This step could be adapted to a survey of genera of questionable or unknown suitability by substituting the word "suitable" with the word "questionable" or "unknown", depending on the objective of the survey.

STEP 3. Determine whether the entire tree can be examined. If the answer is **YES**, examine the entire tree thoroughly, give special attention to branches that are about 2.5 cm in diameter or greater (See section below "Where to look for beetles, signs and symptoms"), and proceed to Step 4. If the answer is **NO,** examine thoroughly as much of the tree as possible and proceed to Step 4.

STEP 4. Examine the tree to determine whether signs or symptoms are present. If **SUSPECT BEETLES, SIGNS OR SYMPTOMS** are detected, follow the procedures established by the organization in charge of the survey or follow the recommendations given in the section "What to do when...". When the inspection is complete, record the results on the appropriate form designed by the organization in charge and proceed to Step 5. If **NO BEETLE, SIGN OR SYMPTOM** is detected, record the results of the inspection on the appropriate form and proceed to Step 5.

STEP 5. Specify whether the entire tree was inspected. If **IT WAS**, go to the next tree to examine and repeat Step 1. If the tree **WAS NOT** completely examined, fill out a request for a follow-up inspection (i.e., within-crown) and submit it to the appropriate staff. Locate the next tree and repeat Step 1.

At the end of the day, make sure all of the pictures and forms, or personal data devices used, detailing the results of the inspections are submitted to the appropriate staff (Appendix 2). Pictures and the information on the forms or the personal data devices will be downloaded onto a computer and backed-up for future reference.

WHERE TO LOOK FOR BEETLES, SIGNS AND SYMPTOMS

In the landscape

Populations of the Asian longhorned beetle have been discovered in several urban landscapes of North America. Industrial parks are probably the most common point of establishment of these populations because they are the final destination of infested material such as solid wood palettes or packaging material (Figures 239-241). In these areas, infestations of invasive species often remain undetected for long periods of time simply because tree maintenance is not a priority. During that time, population density increases and once it reaches a certain level, adults begin to spread. Beetles can spread actively by flying along natural corridors such as railway and power lines, highway corridors, and fence lines. Alternatively, adult beetles can spread passively into other landscapes by hitch-hiking on vehicles. Larvae can also be dispersed when infested trees or parts of infested trees are transported elsewhere for use as firewood or for disposal following tree maintenance work.

FIGURE 239. Wood pallets left in garbage bins.

240

241

FIGURES 240-241. 240, Wood pallets stacked behind a factory in an industrial park. **241,** Pile of wood pallets dumped at a disposal site.

In the Greater Toronto Area, signs and symptoms of the Asian longhorned beetle have been found on trees located in industrial parks (Figure 242), along railways (Figure 243), under electrical power lines (Figure 244), along fences overgrown with trees (Figures 245-246), on edges of woodlots (Figure 247), along boulevards in commercial areas (Figure 248), on residential properties (Figures 249-251), in parks (Figure 252), open or green spaces, a cemetery, and in an enclosed courtyard.

FIGURES 242-243. Infested trees have been found: **242,** along boulevards in industrial parks; and, **243,** along railway lines.

FIGURES 244-247. Infested trees have been found: **244,** under electrical power lines; **245 -246;** along fences; and, **247,** on the edges of woodlots.

FIGURES 248-249. Infested trees have been found: **248,** along streets and parking areas of commercial centres; and, **249,** along boulevards in residential neighbourhoods.

FIGURES 250-251. Infested trees have been found: **250,** in the front yards; and, **251,** in the backyards of residential neighbourhoods.

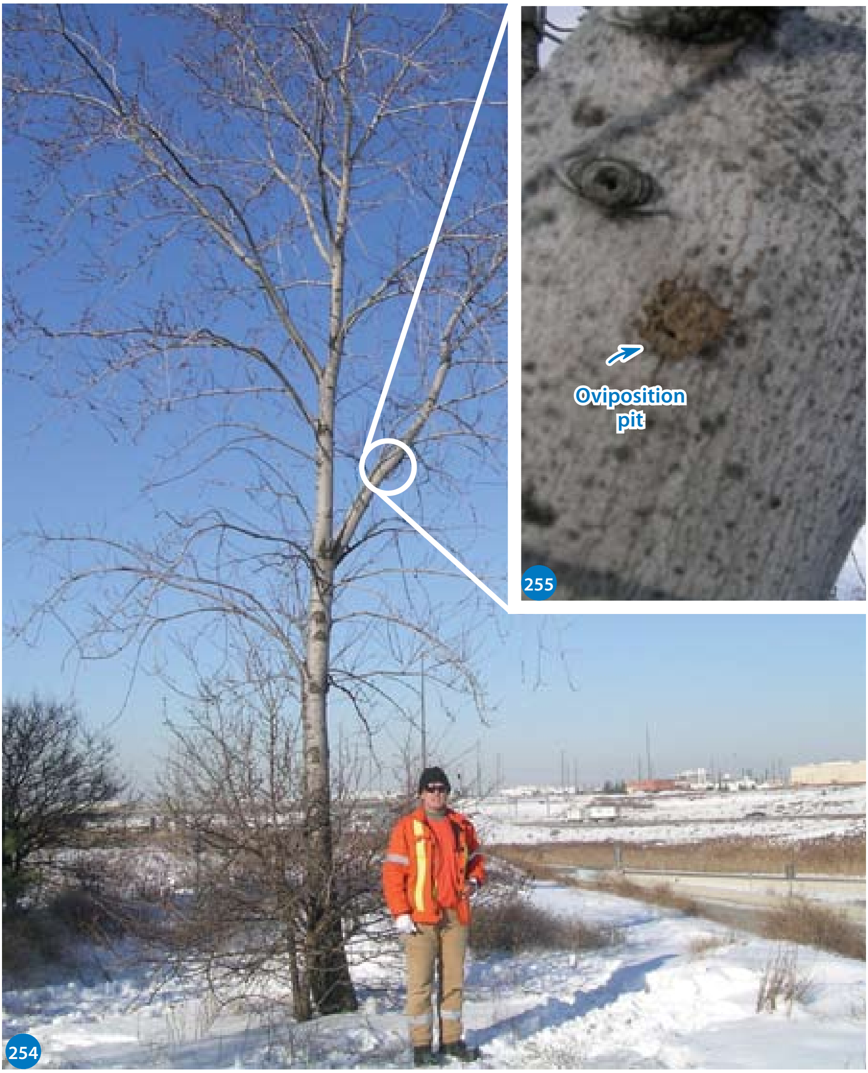
FIGURE 252. Infested trees have been found in parks.

In the tree

Beetles: Upon emergence, adult beetles move to the top of trees and feed on shoots, petioles or leaves for one to two weeks. After that period, beetles can be seen anywhere on branches, trunks or large roots of trees. Male beetles either rest or wander in search of female beetles (Figure 253). Female beetles rest, chew egg pits and lay eggs. Both males and females continue to feed throughout their adult life.

FIGURE 253. Adult beetle resting on a branch.

Signs and symptoms: The location of specific signs and symptoms, which is given in the previous section, depends not only on tree size, but is also related to the number of times a tree has been attacked. On large trees attacked for the first time, egg pits are found predominantly on branches of the upper canopy (Figures 254, 255). In small trees (less than 16 cm diameter at breast height), egg pits are found lower on the trunk (Figures 256, 257). On trees attacked repeatedly for several years, egg pits are found lower on the trunk because the preferred sites to lay eggs, located higher in the tree, were used up in previous years. (Figures 258, 259). Also, trees that have been attacked for several years will have many exit holes in the upper crown.



FIGURES 254-255. 254, Location of egg pits on tall trees infested for the first time. **255,** Oviposition pit.

FIGURES 256-257. 256, Location of egg pits on short trees infested for the first time. **257,** Oviposition pit.

FIGURES 258-259. 258, Distribution of signs on trees attacked for the first time. **259,** Signs of attack are found lower and lower on the trunk as the number of years of attack and the level of infestation increases. **NOTE** the aluminum tag is at 1.4 m above ground.

WHEN TO CONDUCT INSPECTIONS

Time of year

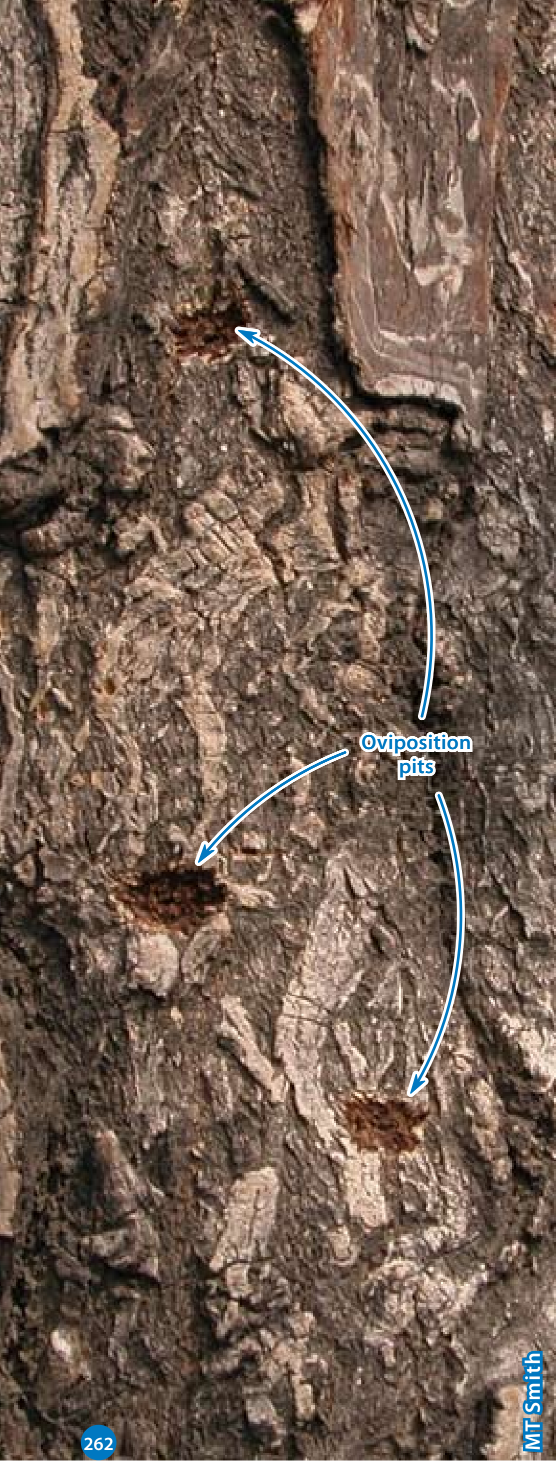
Inspections are easier and more effective during winter months because of the absence of leaves on trees, but can take place throughout the year. Inspections conducted during the winter months can take advantage of greater visibility of the bole and branches, where most signs are located (Figure 260).

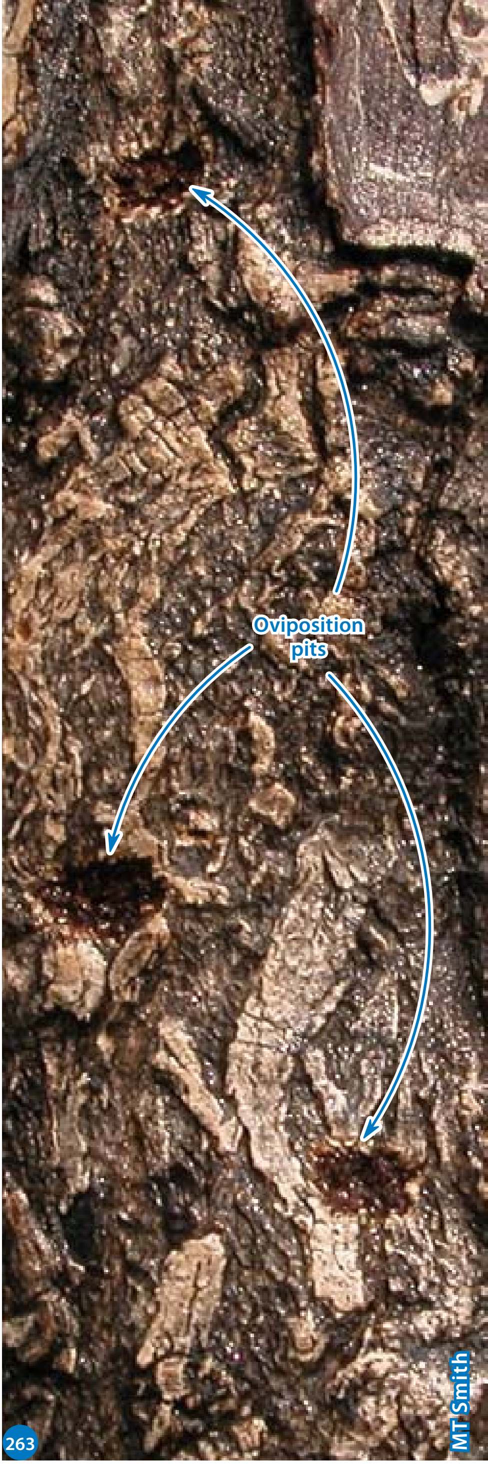
FIGURE 260. Signs of attack are easier to detect in the absence of foliage.

Weather conditions

Ideally, trees should be inspected under dry weather conditions. Snow and rain can obscure the natural appearance of the signs on the bole, especially old oviposition pits (Figures 261-263). Similarly, very bright or dark overcast days can reduce the visual contrast between the signs of injury and the bark.

FIGURE 261. Tree bole covered by snow preventing the detection of signs.





FIGURES 262-263. 262, Appearance of fresh oviposition pits on dry bark. **263,** Appearance of fresh oviposition pits on wet bark.

WHAT TO DO WHEN ...

... you find a specimen

When an inspector finds an adult specimen suspected of being the Asian longhorned beetle, he/she should take the following steps, if it is possible to capture the adult:

1. Capture the adult either by placing a container over the beetle and gently easing it inside, or by picking up the beetle by the sides of the body and placing it inside the container and securing the lid tightly (use only containers that can be sealed properly);

2. Contact the specialised staff, inform them of your find and request the staff to come and pick up your specimen;

3. Record, with a pencil on a piece of paper, the date of collection (e.g., 11 Oct 2005), the exact location the specimen was collected from (i.e., UTM coordinates from GPS units set to a common datum (e.g., NAD 83) and street address), the tree genus or species on which the specimen was found on or collected from, and your name;

4. Place this label inside the container; and,

5. Upon their arrival, give the container with the adult and label to the specialised staff, which will ensure that the verification process is initiated and completed.

If it is not possible to capture the adult, record the location, the time of sighting, the location and genus or species of the tree, the signs you observed, and report your discovery immediately to the specialised staff. The specialised staff will provide specific instructions on how to proceed.

... you find a tree with signs or symptoms

When an inspector finds a sign or symptom suspected of being from an Asian longhorned beetle injury, the following steps should be taken:

1. Take several pictures of the suspect sign(s) or symptom(s) immediately upon discovery [Note: The purpose of taking photographs is to maintain permanent records of the signs and symptoms seen by the inspector under field conditions. Often such images constitute the only evidence that an injury was discovered on a tree. Such images are also extremely valuable for training new inspectors];

2. Preserve the suspect sign or symptom in its original state - DO NOT CUT INTO THE SIGN OR SYMPTOM and WAIT UNTIL IT CAN BE EXAMINED BY THE SPECIALISED STAFF;

3. Mark and secure the suspect sign or symptom by placing a piece of flagging tape above and below it (Figure 264) [Note: The purpose of this action is to make it easier, for you or the specialised staff, to find again at a later time during that day or on another day];

4. Contact specialised staff and request verification of a suspect sign or symptom;

5. When the specialized staff arrives, direct them to the clearly-marked injury [Note: If there is a need to collect additional evidence (e.g., frass), the designated staff will determine whether it is preferable to cut the entire branch or limb and take it back to a laboratory for a more controlled examination of the evidence. This will be done in a manner that documents the original state of the sign]; and,

6. Infested trees are often found in small groups - begin inspection of nearby trees to determine whether surrounding trees are infested.

FIGURE 264. Example of how to mark the location of a suspect sign.

PROCESS OF VERIFICATION

A report by an inspector of the discovery of either adult specimens or signs and symptoms sets in motion a mandatory process of verification by specialists. These discoveries could be look-alikes and thus, must be treated as suspects until the verification process has been completed.

Beetle specimens collected during inspections are placed in alcohol together with the completed data label (see section "What to do when.... you find a specimen"). They are given a unique collection number (creating a permanent record), and are sent to a qualified insect identification specialist for examination and authentication of the initial field identification. The identification expert submits an official report detailing the result of the examination to the appropriate supervisor for follow-up action.

Upon discovery of trees that have only signs or symptoms characteristic of Asian longhorned beetle, a portion of the tree (i.e., limb or branch) or the entire tree may be removed following government regulations and taken back to a laboratory for a more extensive examination. This examination will be done in a manner that documents the state of the signs or symptoms. If egg, larval or pupal specimens are retrieved during this examination of the suspect tree or limb, they will be sent to an expert in insect identification for verification. A report detailing the results of this examination will be submitted to the appropriate supervisor for follow-up action.

POINTS TO REMEMBER

- Learn and remember the detection process of your organisation: if unsure, ask questions.
- When conducting surveys, ALWAYS examine as much of the tree as you can with your binoculars and, if necessary, request a follow-up inspection to ensure the tree has been completely examined.
- Do not destroy or alter signs or symptoms discovered in the field: take pictures and ensure that the image is in focus.
- Within an infested area, all urban landscapes with trees should be surveyed.
- Surveys can be conducted at any time during the year, but a greater proportion of the bole and branches can be examined from the ground on clear winter days.
- Infested trees are often found in groups.
- Remember what to do when you find either an adult beetle you suspect is the Asian longhorned beetle or signs and symptoms of its injury.
- The discovery of adult specimens or of signs and symptoms suspected of being Asian longhorned beetle-related sets in motion a mandatory process of verification by specialists.

REFERENCES

USEFUL WEB SITES

AGENCY	WEBSITES[§]
Canadian Food Inspection Agency	http://www.inspection.gc.ca
Natural Resources Canada, Canadian Forest Service	http://www.pfc.forestry.ca/news/asian_longhorn_e.html
Ontario Ministry of Natural Resources	http://ontariosforests.mnr.gov.on.ca/foresthealthoverview.cfm
Toronto and Region Conservation	http://www.trca.on.ca
City of Toronto, Urban Forestry Services	http://www.toronto.ca/trees
Regional Municipality of York, Forestry Division	http://www.region.york.on.ca/Services/Forestry/Forest_Asian.htm
City of Vaughan, Parks and Forestry Department	http:// www.vaughan.ca
U.S.D.A. - Animal and Plant Health Inspection Service	http://www.aphis.usda.gov/ppq/ep/alb/ http://www.aphis.usda.gov/newsroom/hot_issues/alb/alb.shtml
U.S.D.A. - Beneficial Insects Introduction Research	http://www.ars.usda.gov/main/site_main.htm?modecode=19-26-00-00
U.S. Forest Service, Northeastern Area, St. Paul Field Office	http://www.na.fs.fed.us/spfo/alb
University of Vermont, Entomology Research Laboratory	http://www.uvm.edu/albeetle/

§ Most of these sites are linked to other useful sites.

REFERENCES

SELECTED REFERENCES

Anonymous. 2004. *Trees Under Threat: The Asian Longhorned Beetle in Greater Toronto.* Toronto: Ontario Ministry of Natural Resources

Auclair AND, Fowler G, Hennessey MK, Hogue AT, Keena M, Lance DR, Mcdowell RM, Oryang DO, Sawyer AJ. 2005. Assessment of the Risk of Introduction of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in Municipal Solid Waste from the Quarantine Area of New York City to Landfills Outside of the Quarantine Area: A Pathway Analysis of the Risk of Spread and Establishment. Journal of *Economic Entomology* **98**: 47-60

Breuning S. 1946. Nouveaux coléoptères paléarctiques (Col.) (3e note) (1). *Miscellanea Entomologica, Revue Entomologique Internationale* **43**: 21-24

Bancroft JS, Smith MT. 2005. Dispersal and influences on movement for *Anoplophora glabripennis* calculated from individual mark-recapture. *Entomologia Experimentalis et Applicata* **116**: 83-92

Bancroft JS, Smith MT, Chaput EK, Tropp J. 2002. Rapid test of the suitability of host-trees and the effects of larval history on *Anoplophora glabripennis* (Coleoptera: Cerambycidae). *Journal of the Kansas Entomological Society* **75**: 308-316

D'Amico V, Podgwaite JD, Duke S. 2004. Biological activity of *Bacillus thuringiensis* and associated toxins against the Asian longhorned beetle (Coleoptera: Cerambycidae). *Journal of Entomological Science* **39**: 318-324

Dubois T, Hajek AE, Hu JF, Li ZH. 2004. Evaluating the efficiency of entomopathogenic fungi against the Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae), by using cages in the field. *Environmental Entomology* **33**: 62-74

Dubois T, Hajek AE, Smith SM. 2002. Methods for rearing the Asian longhorned beetle (Coleoptera: Cerambycidae) on artificial diet. *Annals of the Entomological Society of America* **95**: 223-230

Dubois T, Li ZZ, Hu JF, Hajek AE. 2004. Efficacy of fiber bands impregnated with *Beauveria brongniartii* cultures against the Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae). *Biological Control* **31**: 320-328

Fallon DJ, Solter LF, Keena M, McManus M, Cate JR, Hanks LM. 2004. Susceptibility of Asian longhorned beetle, *Anoplophora glabripennis* (Motchulsky) (Coleoptera: Cerambycidae) to entomopathogenic nematodes. *Biological Control* **30**: 430-438

Farrar JL. 1995. *Trees in Canada*. Markham, Ontario: Fitzhenry & Whiteside Limited, Canadian Forest Service - Natural Resources Canada, Canada Communication Group - Publishing, Supply and Services Canada

Fleming MR, Bhardwaj MC, Janowiak J, Shield JE, Roy R, et al. 2005. Noncontact ultrasound detection of exotic insects in wood packing materials. *Forest Products Journal* **55**: 33-37

Haack RA. 2003. Research on *Anoplophora glabripennis* in the United States. In *Nachrichtenbl. Deut. Pflanzonschutzd*., pp. 68-70. Stuttgart: Eugen Ulmer GmbH & Co.

Haack RA, Law KR, Mastro VC, Ossenbruggen HS, Raimo BJ. 1997. New York's Battle with the Asian Long-Horned Beetle. *Journal of Forestry* **95**: 11-15

Hajek AE, Curtiss RT, Liebherr JK. 2004. Characters differentiating male from female *Anoplophora glabripennis* (Motschulsky) (Coleoptera: Cerambycidae). *Proceedings of the Entomological Society of Washington* **106**: 928-931

Hoebeke ER. Asian longhorned beetle or Whitespotted sawyer? USDA - Forest Service NA-PR-01-98. *http://www.na.fs.fed.us/fhp/alb/pubs/alb_wss/alb_wss.htm*

Humphreys N, Allen E, Humble L. 1998. An Asian Long-horned Beetle. NRCan - CFS - Pacific Forestry Centre: Victoria, B.C. *http://warehouse.pfc.forestry.ca/pfc/5059.pdf*

Keena MA. 2002. *Anoplophora glabripennis* (Coleoptera: Cerambycidae) fecundity and longevity under laboratory conditions: comparison of populations from New York and Illinois on *Acer saccharum*. *Environmental Entomology* **31**: 490-498

Keena MA. 2005. Pourable artificial diet for rearing *Anoplophora glabripennis* (Coleoptera: Cerambycidae) and methods to optimize larval survival and synchronize development. *Annals of the Entomological Society of America* **98**: 536-547

Kethidi DR, Roden DB, Ladd TR, Krell PJ, Retnakaran A, Feng Q. 2003. Development of SCAR markers for the DNA-based detection of the Asian long-horned beetle, *Anoplophora glabripennis* (Motschulsky). *Archives of Insect Biochemistry and Physiology* **52**: 193-204

Lingafelter SW, Hoebeke ER. 2002. *Revision of Anoplophora (Coleoptera: Cerambycidae)*. Washington, D.C.: Entomological Society of Washington.

MacLeod A, Evans HF, Baker RHA. 2002. An analysis of pest risk from an Asian longhorn beetle *(Anoplophora glabripennis)* to hardwood trees in the European community. *Crop Protection* **21**: 635-645

Morewood WD, Hoover K, Neiner PR, McNeil JR, Sellmer JC. 2004. Host tree resistance against the polyphagous wood-boring beetle *Anoplophora glabripennis*. *Entomologia Experimentalis et Applicata* **110**: 79-86

Morewood WD, Hoover K, Neiner PR, Sellmer JC. 2005. Complete development of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in northern red oak trees. *The Canadian Entomologist* **137**: 376-379

Morewood WD, Hoover K, Sellmer JC. 2003. Predation by Achaearanea tepidariorum (Araneae : Theridiidae) on *Anoplophora glabripennis* (Coleoptera: Cerambycidae). *The Great Lakes Entomologist* **36**: 31-34

Morewood WD, Neiner PR, McNeil JR, Sellmer JC, Hoover K. 2003. Oviposition preference and larval performance of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in four eastern North American hardwood tree species. *Environmental Entomology* **32**: 1028-1034

Morewood WD, Neiner PR, Sellmer JC, Hoover K. 2004. Behavior of adult *Anoplophora glabripennis* on different tree species under greenhouse conditions. *Journal of Insect Behavior* **17**: 215-226

Motschulsky V. 1853. Diagnoses de Coléoptères nouveaux trouvés par M.M. Tatarinoff et Gaschkewitsch aux environs de Pékin. *Études Entomologiques* **2**: 44-51

Nowak D, Pasek JE, Sequeira RA, Crane DE, Mastro VC. 2001. Potential effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on urban trees in the United States. *Journal of Economic Entomology* **94**: 116-122

Peterson AT, Scachetti-Pereira R, Hargrove WW. 2004. Potential geographic distribution of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in North America. *American Midland Naturalist* **151**: 170-178

Smith MT, Bancroft J, Li G, Gao R, Teale S. 2001. Dispersal of Anoplophora glabripennis (Cerambycidae). Environmental Entomology **30**: 1036-1040

Smith MT, Bancroft J, Tropp J. 2002. Age-specific fecundity of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on three tree species infested in the United States. *Environmental Entomology* **31**: 76-83

Smith MT, Tobin PC, Bancroft J, Li GH, Gao RT. 2004. Dispersal and spatiotemporal dynamics of Asian longhorned beetle (Coleoptera: Cerambycidae) in China. *Environmental Entomology* **33**: 435-442

Solter LF, Keena M, Cate JR, McManus ML, Hanks LM. 2001. Infectivity of four species of nematodes (Rhabditoidea: Steinernematidae, Heterorhabditidae) to the Asian longhorn beetle, *Anoplophora glabripennis* (Motchulsky) (Coleoptera: Cerambycidae). *Biocontrol Science and Technology* **11**: 547-552

Wang BD, Mastro VC, McLane WH. 2000. Impacts of chipping on surrogates for the longhorned beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in logs. *Journal of Economic Entomology* **93**: 1832-1836

Williams D, Li G, Gao R. 2004. Tracking movements of individual *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adults: Application of harmonic radar. *Environmental Entomology* **33**: 644-649

Williams DW, Lee HP, Kim IK. 2004. Distribution and abundance of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in natural Acer stands in South Korea. *Environmental Entomology* **33**: 540-545

Xiao Gangrou (editor). 1991. Forest insects of China (2nd Edition). Beijing: China Forestry Publishing House.

Zhang AJ, Oliver JE, Chauhan K, Zhao BG, Xia LQ, Xu ZC. 2003. Evidence for contact sex recognition pheromone of the Asian longhorned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae). *Naturwissenschaften* **90**: 410-413

APPENDIX 1

COMMON AND SCIENTIFIC NAMES OF INSECTS

COMMON NAME	SCIENTIFIC NAME	ORDER	FAMILY
Ash borer	*Podosesia syringae* (Harris)	Lepidoptera	Sesiidae
Bumble flower beetle	*Euphoria inda* (Linné)	Coleoptera	Scarabaeidae
Carpenterworm	*Prionoxystus robiniae* (Peck)	Lepidoptera	Cossidae
Gallmaking maple borer	*Xylotrechus aceris Fisher*	Coleoptera	Cerambycidae
Hickory borer	*Goes pulcher* (Haldeman)	Coleoptera	Cerambycidae
Large carpenter bees	*Xylocopa spp*	Hymenoptera	Apidae
Maple callus borer	*Synanthedon acerni* (Clemens)	Lepidoptera	Sesiidae
Poplar-and-willow borer	*Cryptorhynchus lapathi* (L.)	Coleoptera	Curculionidae
Poplar borer	*Saperda calcarata Say*	Coleoptera	Cerambycidae
Sugar maple borer	*Glycobius speciosus* (Say)	Coleoptera	Cerambycidae
Whitespotted sawyer	*Monochamus s. scutellatus* (Say)	Coleoptera	Cerambycidae

APPENDIX 2

Form used in the Greater Toronto Area to record the results of tree inspections

Tear Out

APPENDIX 2

Form used in the Greater Toronto Area to record the results of tree inspections

Tear Out

PARTNERS

THE ASIAN LONGHORNED BEETLE EMERGENCY RESPONSE TEAM IN THE GREATER TORONTO AREA:

Canadian Food Inspection Agency | Agence canadienne d'inspection des aliments

TORONTO

TORONTO AND REGION Conservation for The Living City

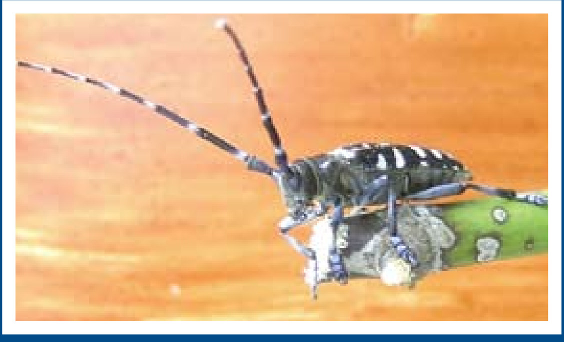
City of Vaughan
The City Above Toronto

York Region

Ontario
Ministry of Natural Resources

USDA
UNITED STATES DEPARTMENT OF AGRICULTURE

Natural Resources Canada | Ressources naturelles Canada



APPENDIX 2 - Form used in the Greater Toronto Area to record the results of tree inspections

ASIAN LONGHORNED BEETLE GROUND SURVEY FORM

1. **Survey date** (i.e., 23 jun 2006):

2. **Survey grid:**

3. **Survey Team number:**

4. **Number of team members:**

5. **Survey team leader:**

6. **Property type:**
Residence ☐ Industry ☐ Parkland ☐
Forested area ☐ Railway ☐ Commercial ☐ School ☐
Highway 407 ☐ Boulevard ☐ Place of worship ☐
MTO ☐ Hydro ☐ Other : ______

7. Zone UTM

8. UTM Easting

9. UTM Northing

10. **City:** Toronto ☐ Vaughan ☐ Other: ______

11. **Address:**
______ Number
______ Street name (no abbreviation)
______ Property name

12. **Tree tag number**

14. **UTM East** (If tagged)

15. **UTM North** (If tagged)

13. **Tree genus:** ______ Dead tree ☐

Species (If known): ______ No suitable tree species present ☐

Genera to tag and inventory:
Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus, Ulmus

16. **DBH (cm):**

17. **Picture taken:** Yes ☐ No ☐

Genera to inventory only: *Ailanthus, Alnus, Amelanchier, Carpinus, Carya, Cercis, Cornus, Crataegus, Elaeagnus, Fagus, Fraxinus, Gleditsia, Gymnocladus, Hamamelis, Hibiscus, Juglans, Liriodendron, Malus, Melia, Morus, Ostrya, Prunus, Pyrus, Rhamnus, Quercus, Robinia, Sambucus, Sassafras, Tilia*

18. **Tree is suspect:** Yes ☐ No ☐
(Suspect sheet)

19. **Climber required:** Yes ☐ No ☐
(Climber sheet)

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**

14. **UTM East** (If tagged)

15. **UTM North** (If tagged)

13. **Tree genus:** ______ Dead tree ☐

Species (If known): ______ No suitable tree species present ☐

Genera to tag and inventory:
Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus, Ulmus

16. **DBH (cm):**

17. **Picture taken:** Yes ☐ No ☐

Genera to inventory only: *Ailanthus, Alnus, Amelanchier, Carpinus, Carya, Cercis, Cornus, Crataegus, Elaeagnus, Fagus, Fraxinus, Gleditsia, Gymnocladus, Hamamelis, Hibiscus, Juglans, Liriodendron, Malus, Melia, Morus, Ostrya, Prunus, Pyrus, Rhamnus, Quercus, Robinia, Sambucus, Sassafras, Tilia*

18. **Tree is suspect:** Yes ☐ No ☐
(Suspect sheet)

19. **Climber required:** Yes ☐ No ☐
(Climber sheet)

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**

14. **UTM East** (If tagged)

15. **UTM North** (If tagged)

13. **Tree genus:** ______ Dead tree ☐

Species (If known): ______ No suitable tree species present ☐

Genera to tag and inventory:
Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus, Ulmus

16. **DBH (cm):**

17. **Picture taken:** Yes ☐ No ☐

Genera to inventory only: *Ailanthus, Alnus, Amelanchier, Carpinus, Carya, Cercis, Cornus, Crataegus, Elaeagnus, Fagus, Fraxinus, Gleditsia, Gymnocladus, Hamamelis, Hibiscus, Juglans, Liriodendron, Malus, Melia, Morus, Ostrya, Prunus, Pyrus, Rhamnus, Quercus, Robinia, Sambucus, Sassafras, Tilia*

18. **Tree is suspect:** Yes ☐ No ☐
(Suspect sheet)

19. **Climber required:** Yes ☐ No ☐
(Climber sheet)

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**

14. **UTM East** (If tagged)

15. **UTM North** (If tagged)

13. **Tree genus:** ______ Dead tree ☐

Species (If known): ______ No suitable tree species present ☐

Genera to tag and inventory:
Acer, Aesculus, Albizia, Betula, Celtis, Platanus, Populus, Salix, Sorbus, Ulmus

16. **DBH (cm):**

17. **Picture taken:** Yes ☐ No ☐

Genera to inventory only: *Ailanthus, Alnus, Amelanchier, Carpinus, Carya, Cercis, Cornus, Crataegus, Elaeagnus, Fagus, Fraxinus, Gleditsia, Gymnocladus, Hamamelis, Hibiscus, Juglans, Liriodendron, Malus, Melia, Morus, Ostrya, Prunus, Pyrus, Rhamnus, Quercus, Robinia, Sambucus, Sassafras, Tilia*

18. **Tree is suspect:** Yes ☐ No ☐
(Suspect sheet)

19. **Climber required:** Yes ☐ No ☐
(Climber sheet)

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**	
14. **UTM East** **(If tagged)**	
15. **UTM North** **(If tagged)**	
16. **DBH (cm):**	17. **Picture taken:** Yes ☐ No ☐
18. **Tree is suspect:** Yes ☐ No ☐ (Suspect sheet)	19. **Climber required:** Yes ☐ No ☐ (Climber sheet)

13. **Tree genus:** ____________________ Dead tree ☐

Species (If known)**:** ____________ No suitable tree species present ☐

Genera to tag and inventory:
Acer, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus*, *Ulmus*

Genera to inventory only: *Ailanthus*, *Alnus*, *Amelanchier*, *Carpinus*, *Carya*, *Cercis*, *Cornus*, *Crataegus*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Gleditsia*, *Gymnocladus*, *Hamamelis*, *Hibiscus*, *Juglans*, *Liriodendron*, *Malus*, *Melia*, *Morus*, *Ostrya*, *Prunus*, *Pyrus*, *Rhamnus, Quercus*, *Robinia*, *Sambucus*, *Sassafras, Tilia*

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**	
14. **UTM East** **(If tagged)**	
15. **UTM North** **(If tagged)**	
16. **DBH (cm):**	17. **Picture taken:** Yes ☐ No ☐
18. **Tree is suspect:** Yes ☐ No ☐ (Suspect sheet)	19. **Climber required:** Yes ☐ No ☐ (Climber sheet)

13. **Tree genus:** ____________________ Dead tree ☐

Species (If known)**:** ____________ No suitable tree species present ☐

Genera to tag and inventory:
Acer, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus*, *Ulmus*

Genera to inventory only: *Ailanthus*, *Alnus*, *Amelanchier*, *Carpinus*, *Carya*, *Cercis*, *Cornus*, *Crataegus*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Gleditsia*, *Gymnocladus*, *Hamamelis*, *Hibiscus*, *Juglans*, *Liriodendron*, *Malus*, *Melia*, *Morus*, *Ostrya*, *Prunus*, *Pyrus*, *Rhamnus, Quercus*, *Robinia*, *Sambucus*, *Sassafras, Tilia*

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**	
14. **UTM East** **(If tagged)**	
15. **UTM North** **(If tagged)**	
16. **DBH (cm):**	17. **Picture taken:** Yes ☐ No ☐
18. **Tree is suspect:** Yes ☐ No ☐ (Suspect sheet)	19. **Climber required:** Yes ☐ No ☐ (Climber sheet)

13. **Tree genus:** ____________________ Dead tree ☐

Species (If known)**:** ____________ No suitable tree species present ☐

Genera to tag and inventory:
Acer, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus*, *Ulmus*

Genera to inventory only: *Ailanthus*, *Alnus*, *Amelanchier*, *Carpinus*, *Carya*, *Cercis*, *Cornus*, *Crataegus*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Gleditsia*, *Gymnocladus*, *Hamamelis*, *Hibiscus*, *Juglans*, *Liriodendron*, *Malus*, *Melia*, *Morus*, *Ostrya*, *Prunus*, *Pyrus*, *Rhamnus, Quercus*, *Robinia*, *Sambucus*, *Sassafras, Tilia*

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**	
14. **UTM East** **(If tagged)**	
15. **UTM North** **(If tagged)**	
16. **DBH (cm):**	17. **Picture taken:** Yes ☐ No ☐
18. **Tree is suspect:** Yes ☐ No ☐ (Suspect sheet)	19. **Climber required:** Yes ☐ No ☐ (Climber sheet)

13. **Tree genus:** ____________________ Dead tree ☐

Species (If known)**:** ____________ No suitable tree species present ☐

Genera to tag and inventory:
Acer, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus*, *Ulmus*

Genera to inventory only: *Ailanthus*, *Alnus*, *Amelanchier*, *Carpinus*, *Carya*, *Cercis*, *Cornus*, *Crataegus*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Gleditsia*, *Gymnocladus*, *Hamamelis*, *Hibiscus*, *Juglans*, *Liriodendron*, *Malus*, *Melia*, *Morus*, *Ostrya*, *Prunus*, *Pyrus*, *Rhamnus, Quercus*, *Robinia*, *Sambucus*, *Sassafras, Tilia*

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

12. **Tree tag number**	
14. **UTM East** **(If tagged)**	
15. **UTM North** **(If tagged)**	
16. **DBH (cm):**	17. **Picture taken:** Yes ☐ No ☐
18. **Tree is suspect:** Yes ☐ No ☐ (Suspect sheet)	19. **Climber required:** Yes ☐ No ☐ (Climber sheet)

13. **Tree genus:** ____________________ Dead tree ☐

Species (If known)**:** ____________ No suitable tree species present ☐

Genera to tag and inventory:
Acer, *Aesculus*, *Albizia*, *Betula*, *Celtis*, *Platanus*, *Populus*, *Salix*, *Sorbus*, *Ulmus*

Genera to inventory only: *Ailanthus*, *Alnus*, *Amelanchier*, *Carpinus*, *Carya*, *Cercis*, *Cornus*, *Crataegus*, *Elaeagnus*, *Fagus*, *Fraxinus*, *Gleditsia*, *Gymnocladus*, *Hamamelis*, *Hibiscus*, *Juglans*, *Liriodendron*, *Malus*, *Melia*, *Morus*, *Ostrya*, *Prunus*, *Pyrus*, *Rhamnus, Quercus*, *Robinia*, *Sambucus*, *Sassafras, Tilia*

19. **Tree location:** Front ☐ Side ☐ Back ☐ City street ☐

20. **Notes:** (number of trees, if applicable)

Table 1. Annotated categorisation of broadleaf genera found within the infested area of the Greater Toronto Area.

Category of Suitability	Genus§	Common name	Presence of infested trees in Canada as of March 2006¥	Tree population within infested area of Ontario (%)	Comment ¶
Suitable	*Acer*	Maple	Yes (with exit holes) - several species	47.43	Reported to be "very good hosts" in USA and hosts in China
	Aesculus	Horsechestnut	None	0.21	Reported to be "very good hosts" in USA
	Albizia	Silk-Tree	None	<0.01	Reported to be "occasional hosts" in USA
	Betula	Birch	Yes (with exit holes)	2.40	Reported to be "good hosts" in USA
	Celtis	Hackberry	None	0.08	Reported to be "occasional hosts" in USA
	Platanus	Plane-Tree	None	0.03	Reported to be "good hosts" in USA
	Populus	Poplar	Yes (with exit holes)	3.79	Reported to be "occasional hosts" in USA
	Salix	Willow	Yes (with exit holes)	4.91	Reported to be "very good hosts" in USA and hosts in China
	Sorbus	Mountain-Ash	None	0.72	Reported to be "occasional hosts" in USA
	Ulmus	Elm	Yes (NO exit hole)	7.83	Reported to be "very good hosts" in USA and hosts in China
Questionable	*Alnus*	Alder	None	0.06	Reported to be hosts (i.e., exit hole) in China
	Crataegus	Hawthorn	None	0.98	
	Elaeagnus	Silverberry, Russian-Olive	None	0.58	Reported to be hosts in Asia
	Fraxinus	Ash	Yes (one tree with a dead egg and larva - NO exit hole)	4.18	Reported to be "occasional hosts" in USA and Asia
	Hibiscus	Hibiscus	None	1.57	Reported to be "questionable hosts" in USA
	Malus	Apple	None	2.72	Reported to be "questionable hosts" in USA
	Melia		None	<0.01	Reported to be hosts in China‡
	Morus	Mulberry	None	1.99	Reported to be "questionable hosts" in USA and hosts in Asia
	Prunus	Cherry, Plum	None	9.42	Reported to be "questionable hosts" in USA and hosts in Asia
	Pyrus	Pear	None	1.85	Reported to be "questionable hosts" in USA and hosts in Asia
	Quercus	Oak	None	1.09	Reported to be "questionable hosts" in USA
	Robinia	Locust	None	0.47	Reported to be "questionable hosts" in USA and hosts in Asia
	Tilia	Linden	Yes (one tree with dead larvae - NO exit hole)	2.01	Reported to be "questionable hosts" in USA and hosts in Asia
Unknown	*Ailanthus*	Tree-of-heaven	None	0.11	Reported NOT to be a host in Asia
	Amelanchier	Serviceberry	None	0.28	
	Carpinus	Blue-Beech	None	0.08	
	Carya	Hickory	None	0.06	
	Cercis	Redbud	None	0.01	
	Cornus	Dogwood	None	1.09	
	Corylus	Hazel	None	0.01	
	Euonymus	Euonymus	None	<0.01	
	Fagus	Beech	None	0.18	
	Gleditsia	Honey-Locust	None	0.99	
	Gymnocladus	Kentucky Coffetree	None	0.02	
	Hamamelis	Witch-Hazel	None	0.02	
	Juglans	Walnut, Butternut	None	0.70	
	Liriodendron	Tulip-Tree	None	0.01	
	Magnolia	Magnolia	None	<0.01	
	Ostrya	Ironwood	None	0.21	
	Rhamnus	Buckthorn	None	1.83	
	Sambucus	Elder	None	0.04	
	Syringa	Common Lilac	None	0.02	
	Viburnum	Viburnum	None	0.01	

§ Listed alphabetically within each category of suitability.

¥ An infested tree is defined as a one with signs of injury by the Asian longhorned beetle.

¶ As compiled by A. Sawyer (USDA, APHIS-PPQ, Otis) and reported at http://www.uvm.edu/albeetle/hosts.htm but modified by the authors.

‡ Lingafelter and Hoebeke 2002