



INVASIVE FOREST

# PESTS

AND DISEASES

A QUICK REFERENCE GUIDE





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## INTRODUCTION

Invasive species are plants, animals, and micro-organisms that, when introduced outside of their natural environment, out-compete native species (Government of Canada, 2016). Invasive species can have harmful consequences for the natural environment, economy, and society, including human health.

Invasive forest pests affect Ontario ecosystems significantly. Quality of wood can become greatly decreased, impacting the lumber and wood industries. A loss of trees, immature and mature alike, relates directly to a loss of habitat for wildlife, including species at risk. Changes in forest composition change the way we use natural areas as well. For instance, dead-standing trees pose risk of injury, and a lack of biodiversity might reduce recreational engagement. Forest pests are generally associated with the import and export of wood packaging materials, shipping containers and the movement of firewood.

Forest diseases have been on the rise given the increase in international trade and exchange of plant material. Forest diseases can be caused by different organisms that affect the whole tree, causing defoliation, root decay and stem cankers that reduce the distribution of nutrients throughout the tree, eventually leading to tree mortality.

There are federal regulatory measures in place underneath the authority of the Plant Protection Act (CFIA, 2017) to reduce artificial spread of forests pests and diseases. Regulations vary based on species; however, they often prohibit the movement of specific materials from infested areas to areas with no known infestation, or prescribe additional steps such as phytosanitary requirements (CFIA, 2017). For more information please visit:

[www.inspection.gc.ca/plants/](http://www.inspection.gc.ca/plants/)

## HOW DO INVASIVE FOREST PESTS AND DISEASES ARRIVE AND SPREAD?

Invasive forest pests and diseases arrive through a number of natural and anthropogenic-influenced pathways. Natural pathways may include wind and water, for example, or even hitch-hiking on other organisms (ie. sap-feeding beetles transport the invasive fungus causing oak wilt to new host trees).

Examples of anthropogenic (human) oriented pathways include international trade (ie. packaging materials), the movement of firewood and top soil, and the transfer of insects or spores from one area to another when people do not properly clean hiking boots or recreational equipment before moving to a new location.

## WHAT CAN I DO ABOUT INVASIVE FOREST PESTS AND DISEASES?

- » Learn to identify invasive forest pest and pathogen species that are a threat to Ontario.
- » Play, clean, go: REMOVE plants, animals & mud from boots, gear, pets, and vehicle.
- » CLEAN your gear before entering and leaving the recreation site.
- » STAY on designated roads and trails.
- » USE CERTIFIED or local firewood and hay.
- » If you see an invasive forest pest, pathogen, or symptom thereof, please contact the toll-free **Invading Species Hotline** at **1-800-563-7711** or report a sighting online at [EDDMapS.org/Ontario](http://EDDMapS.org/Ontario)

## TEMPLATE FOR REPORTING A SIGHTING

When submitting a report through the Invading Species Hotline or online at [EDDMapS.org/Ontario](http://EDDMapS.org/Ontario), it is best to have the following information on-hand to submit a complete report:

### What?

What species do you suspect you encountered?  
Are there native lookalikes that you may not have considered?

### Picture?

In order to confirm reports, a picture is required. However, with some high-priority species, it is best to always report!

### When and where?

Be sure to note the date and geographical location where you encountered the invasive forest pest or pathogen (latitude and longitude).

### Specimen?

Do you have the organism on hand? If so, call **1-800-563-7711** and ISAP staff will direct you on your next steps.

## HOW TO REPORT INVASIVE SPECIES

- » **Call:** 1-800-563-7711
- » **Email:** [info@invadingspecies.com](mailto:info@invadingspecies.com)
- » **Create a profile:** on [EDDMapS.org/Ontario](http://EDDMapS.org/Ontario) and submit your reports digitally.



The sapwood of trees attacked by the mountain pine beetle (*Dendroctonus ponderosae*) appears blue in colour.

## Species Profiles

## ASIAN LONG-HORNED BEETLE

*Anoplophora glabripennis*



### REGULATION

- » The Asian long-horned beetle is regulated under the authority of the Plant Protection Act (CFIA, 2017).
- » The regulations include an established regulated area in Mississauga and Toronto within which the movement of specific materials is restricted. For more information, please visit: <http://www.inspection.gc.ca/>

### STATUS IN ONTARIO (NOT ESTABLISHED)

- » Intercepted several times in imports to Canada. Two infestations have been found and eradicated in Ontario (OMNRF, 2018).

### ORIGIN

- » The Asian long-horned beetle is native to China and Korea.

### DESCRIPTION

- » Larvae are grub-like and cream coloured.
- » The pupa is off-white or ivory-white, measuring ~ 30-37 mm by 10 mm.
- » Adults measure 2-4 cm long, are shiny and black with irregular white, sometimes yellow spots, and bluish-white legs.
- » Mature beetles have long, black and white banded antennae, one to two times its body length.

## ASIAN LONG-HORNED BEETLE



### SIGNS AND SYMPTOMS

- » Adults leave a round exit hole, ~ 1.5-2 cm in diameter in trees.
- » Other symptoms include oval-shaped egg pits dug on trunk, branches, or exposed roots, leaking sap, yellowing leaves, premature leaf drop, and branch dieback.

### HOST PREFERENCE

- » Nearly all broadleaf trees, preferring native maples.

### IMPACTS

- » Decline in hardwood (broadleaf) trees can cause significant reductions in wood supply and reduce the availability and quality of hardwood to the forest industry. This reduction would impact the maple syrup industry as well.
- » An invasion could cause great damage to ecosystems as the host species dominate both natural and urban environments.

### LOOKALIKE SPECIES

- » White-spotted sawyer beetle (*Monochamus scutellatus*), native to Ontario.

## EMERALD ASH BORER

*Agrilus planipennis*



### REGULATION

- » The emerald ash borer is a regulated pest under the authority of the Plant Protection Act (CFIA, 2017).
- » The regulations include the prohibited movement of specific materials, such as ash material and firewood of all species, from specific infested areas of Ontario and Quebec. For more information, please visit: <http://www.inspection.gc.ca>

### STATUS IN ONTARIO (ESTABLISHED AND WIDESPREAD)

- » Occurs across southern Ontario, from Lambton County north to Grey County and east to Renfrew County and Ottawa; with detections on Manitoulin Island, and a separate infestation in Sault Ste. Marie and east of the city to St. Joseph's Island in Algoma District (OMNRF, 2018).

### ORIGIN

- » The emerald ash borer is native to Asia.

### DESCRIPTION

- » Larvae are 25-32 mm long at maturity, creamy white in colour, with a brown head, and a flat, broad-shaped body.
- » Pupae are 10-15 mm long and creamy white in colour.
- » Adult beetles are a bright metallic green, 8-14 mm long, and 3-3.5 mm wide, with an elongated body and a flat head.
- » The surface of the abdomen beneath the wings is usually a bright red colour.

## EMERALD ASH BORER



### SIGNS AND SYMPTOMS

- » Crown dieback, bark deformities, and woodpecker feeding holes may be visible.
- » Look for D-shaped exit holes. Epicormic branches, shoots growing out of the lower trunk, may also be found.
- » Yellowing of foliage and vertical cracks in the trunk may be visible as well.
- » Peeling back the bark may reveal larval feeding galleries.

### HOST PREFERENCE

- » Attacks and kills all species of North American ash (*Fraxinus spp.*) that it has encountered.
- » A total of 20 species of ash are found in North America, six of which are native to Canada: green ash (*F. pennsylvanica*), white ash (*F. americana*), black ash (*F. nigra*), and much less common blue ash (*F. quadrangulata*), pumpkin ash (*F. profunda*), and Oregon ash (*F. latifolia*) in B.C.

### IMPACTS

- » The economic and social impacts in Ontario from the emerald ash borer are significant.
- » The costs for removing, treating, and replacing ash trees can be immense for municipalities. The environmental impacts of emerald ash borer relate to losses in biodiversity and abrupt ecological changes.

### LOOKALIKE SPECIES

- » Six-spotted tiger beetle (*Cicindela sexguttata*), Japanese beetle (*Popillia japonica*), and Bronze birch borer (*Agrilus anxius*).

## EUROPEAN GYPSY MOTH

*Lymantria dispar*



### REGULATION

- » The European gypsy moth is a regulated pest under the authority of the Plant Protection Act (CFIA, 2017). For more information, please visit: <http://www.inspection.gc.ca/>

### STATUS IN ONTARIO (ESTABLISHED AND WIDESPREAD)

- » Established populations exist south of a line from Sault Ste. Marie east to North Bay and Mattawa; a separate infestation exists in New Liskeard (OMNRF, 2018).

### ORIGIN

- » The European gypsy moth is native to Europe and Asia.

### DESCRIPTION

- » Has four developmental stages: egg, caterpillar, pupa and moth.
- » Eggs are tanned yellow, covered with fuzz, and found as "egg masses".
- » Larvae are up to 6 cm in length, and covered with hairs. The caterpillar is characterized by five pairs of blue dots and six pairs of red dots that run down its back (next page).
- » In the pupal stage, larval caterpillars transition to become winged moths.
- » Male moths are brown with feathery antennae.
- » Females are beige and cannot fly.

## EUROPEAN GYPSY MOTH



### SIGNS AND SYMPTOMS

- » Egg masses found on tree bark and outdoor objects.
- » Leaves with holes or completely defoliated trees.
- » Defoliation will result in the dieback of twigs and branches.

### HOST PREFERENCE

- » Oak, birch, poplar, willow, maple, and others; over 300 known host plant species, about 150 of them are considered favoured hosts.

### IMPACTS

- » In Ontario, the spread of European gypsy moth has had economic, environmental, and social impacts.
- » This moth defoliates large amounts of trees, affecting the many benefits provided by trees and the economic impacts affect all forest users.
- » The environmental impacts relate to losses in biodiversity and abrupt ecological changes. Large masses of caterpillars and moths can be aesthetically displeasing, as well.

### LOOKALIKE SPECIES

- » Eastern tent caterpillar (*Malacosoma americanum*) and forest tent caterpillar moth (*Malacosoma disstria*).

## HEMLOCK WOOLLY ADELGID

*Adelges tsugae*



### REGULATION

- » Import and domestic movement requirements are in place for all hemlock (*Tsuga spp.*), yeddo spruce (*Picea jezoensis*) and tiger-tail spruce (*Picea polita*) trees (and many materials derived from these species) to prevent the introduction and spread of the hemlock woolly adelgid (Canadian Food Inspection Agency, 2015). For more information, please visit: <http://www.inspection.gc.ca>

### STATUS IN ONTARIO (NOT ESTABLISHED)

- » Two detections of HWA have occurred in Ontario. One in Etobicoke in 2012 and the second in Niagara Falls in 2013; these populations have since been destroyed. In 2017, HWA was detected in Southwestern Nova Scotia (Invasive Species Centre, 2015).

### ORIGIN

- » The hemlock woolly adelgid is native to East Asia.

### DESCRIPTION

- » Throughout the nymph stage, the insects are brownish-orange and can measure between 0.44 mm long and 0.27 mm wide to 0.74 mm long and 0.47 mm wide.
- » The adult hemlock woolly adelgid is an aphid-like insect.
- » As an egg, they are oblong and amber in colour.
- » Eggs are contained in spherical “woolly” ovisac made of white waxy threads.

## HEMLOCK WOOLLY ADELGID



### SIGNS AND SYMPTOMS

- » White “woolly” sacs at the base of hemlock needles on most recent twigs, in addition to premature bud and shoot dieback, premature needle loss, thinner, greyish-green crown, and dieback of twigs and branches.
- » Hemlock tree death typically occurs within 4-15 years.

### HOST PREFERENCE

- » The only host for the hemlock woolly adelgid in eastern Canada is the eastern hemlock (*Tsuga canadensis*), while other non-native tree species that are grown as ornamentals in the region may also be at risk.

### IMPACTS

- » Decline in hemlock would present economic, ecological, and social impacts.
- » Hemlock is processed for use in general construction or as pulp.
- » Hemlock trees play an important role environmentally, contributing to ecological services such as the regulation and maintenance of water temperatures as hemlock tends to establish in riparian areas.

## MOUNTAIN PINE BEETLE

*Dendroctonus ponderosae*



### REGULATION

- » Regulations are in place in some Canadian provinces (e.g. Alberta, Manitoba, and Saskatchewan).
- » For more information, please visit: <http://www.nrcan.gc.ca/forests/fire-insects-disturbances/top-insects/13381>

### STATUS IN ONTARIO (UNKNOWN IN ONTARIO)

- » The mountain pine beetle has expanded beyond its historical range and could become an invasive pest if introduced in Ontario (Invasive Species Centre, 2015).

### ORIGIN

- » The mountain pine beetle is native to western Canada.

### DESCRIPTION

- » Pupae are white at first, changing to light brown and are about 5 mm long.
- » Larvae are white and grub-like with red-brown heads and are about 5 mm long in the fourth (final) instar.
- » Adult is small, dull, and cylindrical bark beetle with elbowed, club-like antenna about 3.7-7.5 mm long.
- » Immature adults are light creamy-tan in colour, changing to black as they mature.

### SIGNS AND SYMPTOMS

- » Look for sawdust on the outer bark around beetle entrance holes.

## MOUNTAIN PINE BEETLE



### SIGNS AND SYMPTOMS

- » Pitch tubes (small globs of pitch - the tree's defense) may be present on the outer bark of attacked trees within days of attack and remain visible for many years; however, these may not be present on trees with severely compromised defenses.
- » As foliage dries, a gradual change in colour will occur; needles will turn yellow, orange, and finally red, approximately one year after attack.
- » The crowns of some trees may start to fade in the same year as the attack, depending on environmental conditions.
- » These red needles drop off approximately two to four years after attack and trees appear gray with no needles.

### HOST PREFERENCE

- » Primarily lodgepole pine (*Pinus contorta*), although they can attack almost any species of pine, including jack pine (*Pinus banksiana*), which is of particular concern should the mountain pine beetle spread from western Canada and reach the jack pine dominated Canadian Shield of Ontario.

### IMPACTS

- » Should the mountain pine beetle reach Ontario, the impacts on jack pine, red pine, and white pine could impact the wood supply for the forestry sector and other related industries in Ontario.
- » The ecological impacts would be severe as well, as the host species dominate Ontario's swath of boreal forest, on which many species rely.

## PINE SHOOT BEETLE

*Tomicus piniperda* (L.)



### REGULATION

- » The pine shoot beetle is a regulated pest in Ontario.
- » Regulations are in place under the authority of the Plant Protection Act restricting the movement of some pine materials (CFIA, 2017).
- » For more information, please visit: [www.inspection.gc.ca/plants/](http://www.inspection.gc.ca/plants/)

### STATUS IN ONTARIO (ESTABLISHED AND WIDESPREAD)

- » Occurs across southern Ontario from Sault Ste. Marie, east to North Bay, and south to the north shore of Lake Erie (Natural Resources Canada, 2015).

### ORIGIN

- » The pine shoot beetle is native to Europe, North Africa, and Asia.

### DESCRIPTION

- » Eggs are pearly-white in colour, smooth, oblong, and about 1 mm in length.
- » Larvae are up to 5 mm long, legless, and white in colour with brown heads.
- » Adults measure 3-5 mm; they are cylindrical and black in colour.

## PINE SHOOT BEETLE



### SIGNS AND SYMPTOMS

- » Resin secretions may be present at entry points of females depositing eggs.
- » Larval feeding galleries will be present beneath the bark and brownish frass (larval excrement) may be visible on the surface of the tree.
- » Adults create exit holes in the outer bark that are 2 mm in diameter. Feeding activity may also result in round holes which are visible on the shoots.
- » The shoots will appear reddish-yellow and be bent or broken off from the point at which the beetle entered the pine shoot.

### HOST PREFERENCE

- » All pine tree species are susceptible, including jack pine (*Pinus banksiana*), red pine (*Pinus resinosa*), eastern white pine (*Pinus strobus*), and Scots pine (*Pinus sylvestris*).
- » When the pine shoot beetle is abundant, it can also threaten balsam fir (*Abies balsamea*), Norway spruce (*Picea abies*) and larch (*Larix laricina*).

### IMPACTS

- » Damage to pine trees can affect many industries in Canada relying on high quality wood.
- » Tree damage and mortality may disrupt the ecosystem and impact native species.
- » The pine shoot beetle may have economic and social impacts, as well, such as declines in property value due to changes in woodland aesthetics and costs to homeowners for removal.

## OAK WILT

*Ceratocystis fagacearum*



### REGULATION

- » Regulations are in place under the authority of the Plant Protection Act (CFIA, 2017).
- » For more information, please visit: [www.inspection.gc.ca/plants/](http://www.inspection.gc.ca/plants/)

### STATUS IN ONTARIO (UNKNOWN IN ONTARIO)

- » Oak wilt is not yet present in Canada, but it occurs in 23 U.S. states with close proximity to southern Ontario (Invasive Species Centre, 2015).

### ORIGIN

- » The origin of the oak wilt fungus is not known.

### DESCRIPTION

- » Oak wilt is a vascular disease caused by the fungus *Bretziella fagacearum*.
- » The fungus develops mats between the sapwood and bark of oak trees.
- » These mats or “pressure pads” found on the trunk or large branches vary in size and are generally produced in late-fall or early-spring, remaining visible for two or more weeks.
- » The mats may appear grey or black depending on progression of the disease.
- » Oak wilt spreads to new hosts via sap-feeding beetles and root grafting with nearby infected oak trees.

## OAK WILT



### SIGNS AND SYMPTOMS

- » The first symptom in red oaks is often a subtle off-green colour shift in the upper-crown which typically happens late June to early July in Northern US, but varies depending on occurrence.
- » Next, in “prototypical” leaves, the bronze discoloration will begin at the leaf margins and move inward in an angular pattern, but this pattern can be variable.
- » White, grey, or black fungal mats may be found just under the bark, sometimes emitting a fruity smell.
- » Pressure from the fungal spore mat exerting outward on the bark may reveal vertical bark cracks in the trunk and large branches.
- » Symptoms vary depending on the species of oak.

### HOST PREFERENCE

- » All species of oak trees (*Quercus spp.*) have been found to be susceptible to oak wilt, with species of red oak being the most seriously affected, followed by bur oak and white oak.

### IMPACTS

- » Although oak wilt has not been detected in Canada at the time of publication, it occurs in 23 U.S. states and is present in states along the southern extent of Ontario.
- » Landscape degradation, loss of shade and flood water retention, and loss of air and water purification.
- » Loss of oak, including the Shumard oak (*Quercus shumardii*), a species of special concern under Ontario’s Endangered Species Act, 2017).

## BEECH BARK DISEASE

*Cryptococcus fagisuga*/*Neonectria* spp. complex



### STATUS IN ONTARIO (ESTABLISHED AND WIDESPREAD)

- » BBD is present throughout all of the Maritime provinces and has moved through the natural beech tree range into Québec and Ontario (Invasive Species Centre, 2015).

### ORIGIN

- » The scale insect comes from Europe and was first introduced into Nova Scotia in the late 1800s.

### DESCRIPTION

- » Beech bark disease is the outcome of an insect-fungus complex, which results when a non-native beech scale insect (*Cryptococcus fagisuga*) feeds on beech bark, creating cracks through which native canker fungi (*Nectria* spp.) can enter into the tree.
- » 50-85% of infected beech trees will die within 10 years of infestation.
- » The *Cryptococcus fagisuga* insects are yellow, soft-bodied scale insects about 0.5 to 1 mm long as an adult.
- » The females are legless and wingless.

### SIGNS AND SYMPTOMS

- » Symptoms and signs depend on the stage of the disease.
- » *Cryptococcus fagisuga* nymphs secrete a white and woolly wax to cover their bodies, which can make infested beech trees look like they are covered in wool.

## BEECH BARK DISEASE

*Cryptococcus fagisuga/Neonectria spp. complex*



### SIGNS AND SYMPTOMS

- » The fungus then causes small cankers that appear on the bark surface, from which small orange-red fruiting bodies are produced in late-summer to fall.
- » Small cankers and black tarry spots may be visible on the surface of beech trees.
- » Other things to look for include wilting foliage, yellowing leaves, thinning crowns, and a waxy wool-like substance on tree stems and branches.

### HOST PREFERENCE

- » American beech (*Fagus grandifolia*) and European beech (*Fagus sylvatica*).

### IMPACTS

- » The disease severely weakens trees, exposing them to other stresses.
- » The marketability of beech wood products is greatly reduced.
- » BBD also affects more desirable timber species (e.g. sugar maple) as regeneration of these species is inhibited by the heavy beech understory that typically follows mortality.
- » This affects forest biodiversity, as young beech saplings (root suckers) proliferate in the understory. Beech bark disease attacks mature trees over 8 inches in diameter.
- » The beechnuts from mature trees are an important food source for wildlife, especially black bears.

## THOUSAND CANKERS DISEASE

*Geosmithia morbida*



### REGULATION

- » No regulations in place at this time.

### STATUS IN ONTARIO (UNKNOWN IN ONTARIO)

- » Thousand cankers disease is not yet present in Canada, but it occurs in U.S. states with close proximity to Canada and the southern extent of Ontario.

### ORIGIN

- » Extent of thousand cankers disease is not known as this disease may be confused with other forms of natural mortality.
- » Currently, thousand cankers disease can be found throughout the western United States.
- » The walnut twig beetle which carries the disease is found throughout southwestern United States and Mexico.

### DESCRIPTION

- » Thousand cankers disease is the outcome of an insect-fungus complex, which results when the non-native walnut twig beetle (*Pityophthorus juglandis*) carries spores of a fungus (*Geosmithia morbida*) into eastern black walnut trees as it feeds on its bark.
- » The adult walnut twig beetle is dark reddish-brown, about 1.5-2.0 mm long, and has 4-6 concentric rows of dot-like 'bumps' on the prothorax (first segment on body).

## THOUSAND CANKERS DISEASE



The entrance and exit holes, created by the walnut twig beetle

### SIGNS AND SYMPTOMS

- » Wilting and yellowing of leaves mid-summer and twig and branch dieback leading to a thinning of the canopy. Occurs as a result of the disease disrupting the nutrient-transporting layers beneath the bark.
- » Numerous distinctive circular to oblong cankers will be found growing underneath the bark.
- » The bark surface may have no symptoms, or it could develop a dark-amber to black stain, as well as cracked bark directly above the canker.
- » Entrance and exit holes, created by the walnut twig beetles, may also be visible on the dead or dying branches and trunk.

### HOST PREFERENCE

- » Thousand cankers disease can affect many species of walnut tree (*Juglans spp.*), but black walnut (*Juglans nigra*) is the most susceptible to the disease.

### IMPACTS

- » The economic impacts of thousand canker disease include loss of black walnut trees, a highly valued timber species in North America where it is used for high-end cabinetry and other products.
- » Ecologically, black walnut trees are a staple for wildlife; nuts produced by the tree serve an important nutritional role for a wide range of wildlife.

## BUTTERNUT CANKER

*Ophiognomonia clavignenti-juglandacearum*



### REGULATION

- » No regulations in place at this time.

### STATUS IN ONTARIO (ESTABLISHED AND WIDESPREAD)

- » Occurs throughout the natural range of the butternut tree (*Juglans cinerea*) in North America, including that within Ontario.

### ORIGIN

- » The origin of the fungus (*Ophiognomonia clavignenti-juglandacearum*) that causes butternut canker disease is not known, though some scientists trace it back to Asia.

### DESCRIPTION

- » Butternut canker occurs when the *Ophiognomonia clavignenti-juglandacearum* fungus enters the tree (via wind and a variety of insects) and causes cankers to form on the trunk, branches, or exposed roots, girdling the tree and leading to canopy dieback and tree mortality.

### SIGNS AND SYMPTOMS

- » Dark, sooty patches and cracks may be present on the bark. Canopy decline may also be visible.
- » Cankers first appear as sooty dark patches on the bark and develop into broad, sunken dead areas, which are dark-brown to black in colour.
- » Beneath the bark, *O. Clavignenti-juglandacearum* produces a thick, black mat of hypha. Eventually, the infected bark will crack and fall off.

## BUTTERNUT CANKER



### HOST PREFERENCE

- » The main host tree is butternut (*Juglans cinerea*), although it has the potential to infect other species in the walnut (*Juglandaceae*) family.

### IMPACTS

- » The butternut tree is endangered in Ontario and Canada under the Endangered Species Act and the Species at Risk Act, 2017 respectively.
- » Butternut canker infects and kills healthy butternut trees, reducing the number and quality of seeds it produces.
- » Economic impacts are seen as the commercial value of butternut decreases due to discoloration of wood.

## GLOSSARY OF TERMS

### **Dieback**

a condition in which a tree or shrub begins to die from the tip of its leaves or roots backward.

### **Dorsal**

the upper surface of an organism.

### **Epicormic**

growth emerging from dormant buds along the trunk and branches of a tree.

### **Frass**

debris or excrement produced by insects.

### **Girdling**

to cutting through the bark and cambium around the entire tree or branch circumference.

### **Leaf margin**

is the boundary area extending along the outer edge of the leaf.

### **Pathogen**

a bacterium, virus, or other microorganism that can cause disease.

### **Root Grafting**

the merging of tissues (ie. tree roots) from more than one individual plant.

### **Riparian**

interface between terrestrial and aquatic habitats.

### **Prototypical**

the first, original, or typical form of the leaves.

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