CHAPTER 7

INSECT MANAGEMENT

LEARNING OBJECTIVES

After completely studying this chapter, you should:

- Understand the concept of economic thresholds and know what factors need to be considered to determine them.
- Know the difference between natural (non-chemical) and applied (chemical and non-chemical) controls.
- Know the common forest insect pests in Michigan, their habits and habitat, the type of damage they cause, and management strategies for each.
- Know which forest pest management situations require intensive insect management.
- Know important insect and mite pests of Christmas trees, their habits and habitat, the type of damage they cause, and management strategies for each.
- Know how resistance to insecticides might be prevented or postponed.

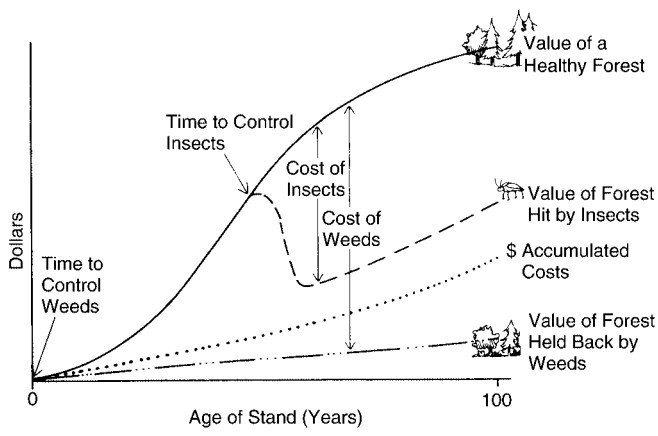
All species of trees are affected by a complex of insect pests. Every part of a tree—its roots, trunk, branches, twigs, buds, leaves, needles, cones, and seeds—may be fed upon by insects. Insects may attack trees of any age. The types of insect pests affecting a specific tree will depend on the age, vigor, location, and susceptibility of the tree.

Stressed trees are often more susceptible to insect attack than healthy trees. Stunting, distortion, weakening, or death of a tree is frequently caused by some combination of adverse environmental factors and insect attack. For example, severe drought stress followed by two-lined chestnut borer infestation may eventually kill an oak tree. In a few cases, insects such as white pine weevil prefer to attack healthy trees.

It is important to realize that not all insects are pests; in fact, only a small percentage cause damage to trees. Most forest insects play important roles in forest ecosystems.

ECONOMIC THRESHOLDS

The decision to control an insect pest lies with the forest owner or manager. Proper decisions can be made only after the trees have been monitored for the level of pest activity, injury potential has been evaluated, and a cost-benefit analysis has been made. By comparing the cost of applying controls to the projected market value of the stand at maturity, we can then know the pest population level at which it becomes economically beneficial to apply control measures. This population level is referred to as the economic threshold.



Generally, insecticide use in a forest is not justified because of the expense of chemical treatment, the low value of individual trees, and environmental considerations.

With Christmas trees and other specialty forest crops, the economic thresholds may be different and the use of insecticides is more often justified.

NON-CHEMICAL MANAGEMENT

Because of environmental issues and the relatively high costs of chemical controls, we can often rely on some non-chemical alternatives to manage insect pests.

Natural Controls

The term "natural control" implies that we are not directly involved in the regulation of insect numbers. The environment applies many pressures that usually keep insect populations from reaching damaging levels. Such environmental factors that limit the abundance or distribution of pest species include biotic (living) and abiotic (non-living) factors.

Biotic factors

Insectivorous vertebrates such as rodents, skunks, and birds.

Predaceous insects such as ladybird beetles, ground beetles, ants, and lacewings.

Parasitic wasps and flies.

Insect diseases caused by microorganisms such as viruses, bacteria, and fungi.

Abiotic factors

Climatic factors, including heat, cold, and too much or too little moisture.

Topographic barriers such as mountain ranges and bodies of water.

Soil conditions, such as compaction, physical make-up, and moisture content.

Disturbances such as wildfire.

Applied Controls

Any method, chemical or non-chemical, used by managers to reduce insect numbers is considered to be applied control. The most important types of non-chemical applied control are discussed in the following sections.

- **Regulatory controls** are utilized by governmental agencies to keep pest problems from spreading. Objectives include preventing foreign pest species from entering this country, eradicating newly introduced pests, and containing pest species within defined boundaries. Specific actions include inspecting plant materials, monitoring survey and detection traps, destroying or fumigating infested materials, and establishing and enforcing quarantines. More information on this topic is available in Chapter 10.
- **Mechanical controls** include devices to trap, kill, or prevent free movement of insects. An example is placing sticky bands on trees to trap gypsy moth larvae.
- **Cultural control**s make the environment less favorable for pest activity by modifying cultural practices. Proper site selection results in a favorable habitat for the tree, more vigorous growth, and fewer insect problems from secondary pests such as bronze birch borer that attack only stressed trees. Stand management, including proper species selection, proper thinning, and adjustment of harvest age, can reduce problems caused by some insects such as jack pine budworm. Sanitation is the removal of breeding material, a practice used in control of some bark beetle species.
- **Biological controls** use living organisms or their products to achieve pest control. The results are similar to biotic natural controls, but here we are directly involved in the application of the controls. The major groups of beneficial organisms involved are predaceous and parasitic insects and insect disease organisms. Methods include introduction of new natural enemies from the original home of a foreign pest species; rearing and releasing beneficial predator and ***parasitoid*** species; and conservation of natural enemy populations by providing food, overwintering habitat, alternative prey, or other resources for beneficial species, or by minimizing the use of broad-spectrum insecticides that would kill beneficial insects.

CHEMICAL MANAGEMENT

- **Chemical controls** are also considered applied controls. However, their application is limited in forest situations because of the relatively high cost of application compared with the market value and long rotation age of trees. Chemical controls are used more commonly for Christmas trees because of the high value and the short rotation age of the crop. Chemical control is used for several reasons: it is often effective, its effects are immediate and predictable, it can rapidly reduce damaging populations, and it can be used where needed. However, chemical controls may have negative impacts on non-target organisms, including natural enemies, and may lead to contamination of soil or water.

Table 7.1. Forest types and some common insect pests.

Forest Type	Some Important Insect Pests	Affected Trees
Maple-beech	Forest tent caterpillar	Maple, birch, oak
Aspen-birch	Forest tent caterpillar Gypsy moth	Aspen-birch Aspen-birch
Oak-hickory	Two-lined chestnut borer Gypsy moth	Oak Oak and other hardwoods
Elm-ash-soft maple	European elm bark beetle Native elm bark beetle	Elm Elm
Pine	White pine weevil Jack pine budworm	White pine Jack and red pines

SOME COMMON FOREST INSECT PESTS IN MICHIGAN

Within the scope of this chapter, we cannot discuss all of the major insect forest pests in Michigan. A few important and representative pests have been chosen to serve as useful examples of diagnosis and management.

Forest Tent Caterpillar

Forest tent caterpillars are important defoliators of aspens but also damage maple, birch, oak, ash, and willow. Larvae emerge from overwintering egg masses on branches in late April to late May. Larvae often feed, molt, and rest in groups, massing on trunks during nonfeeding periods. Despite the name, no tents are constructed. Defoliation occurs in June. Heavily defoliated trees refoliate by late July. Larval development takes 5 to 8 weeks. Mature larvae spin cocoons for pupation and emerge as adults after 2 to 3 weeks. Mating and egg laying usually occur from early to mid-July. Trees are rarely killed, but growth loss can be significant.

Management strategy:

- Chemical controls are seldom required in the forest.
- When chemical control is needed, use a microbial insecticide in May when feeding begins.

Gypsy Moth

Gypsy moth larvae eat the leaves of many hardwoods such as oak, birch, and aspen, as well as the needles of some conifers. Complete defoliation of hardwoods is common but seldom kills the trees. Conifers, however, die if the trees are completely stripped. Gypsy moth infestations cause growth loss and detract from tree appearance. Egg masses overwinter and hatch begins in mid-April or May, depending on temperature. Larvae feed on foliage for 1 to 2 months while they complete development. When nearing maturity, they feed only at night and rest under bark, rocks, or litter during the day where they are protected from predators. Pupation occurs on or near tree bases, in litter, or in the tree canopy. Adults emerge in 10 to 14 days, then mate and lay eggs.

Figure 7.1. Larva of forest tent caterpillar (K.E. Gibson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.2. Gypsy moth larva on leaf (J.H. Ghent, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.3. Gypsy moth adult female (R.S. Kelley, Vermont Dept. of Parks and Forests, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- Stand age, condition, and value; severity of the gypsy moth threat; and management objectives must all be carefully considered to determine if a pesticide spray program is warranted.
- Microbial pesticides are effective and have low environmental impact. Spray when insects are in the first to the third instars, usually mid-May to early June.

Two-lined Chestnut Borer

Two-lined chestnut borer infests low-vigor oak trees that have been stressed by drought or other factors. Branch dieback occurs from the crown downward, and tree death is possible within 2 to 4 years. Healthy trees are seldom affected. Adult beetles emerge through D-shaped holes in the bark from late May to mid-September, peaking in mid-June. Adults feed on foliage, then mate and lay eggs within a month of emergence. Eggs hatch in 7 to 14 days, and larvae tunnel around in the sapwood. This tunneling eventually girdles and kills branches. The larvae then overwinter in the pupal stage and pupate the following summer.

Management strategy:

- Manage oak stands to optimize tree vigor.
- When two-lined chestnut borer outbreaks occur, options include sanitation harvests, salvage, or delay of any activity in the stand that may further reduce vigor or wound trees.

Figure 7.4. Larva and galleries of two-lined chestnut borer (R.A. Haack, USDA Forest Service).

European Elm Bark Beetle

Elm bark beetles are primarily responsible for the long-distance spread of Dutch elm disease (see Chapter 6). The European elm bark beetle is more important than the native elm bark beetle as a vector of Dutch elm disease because of its breeding dominance over the native species. The European species overwinters as a full-grown larva in the inner bark of elm trees. Pupal development is completed in the spring. Adults emerge through small holes chewed in the bark. Emergence continues for several weeks beginning in the middle of May. Adult beetles feed on young bark, usually in twig crotches, where they inoculate elms with the spores of Dutch elm disease. The spores are present in their brood galleries and on their body parts. Unhealthy or recently killed elm trees are chosen for egg laying. The egg-laying gallery is oriented parallel to the wood grain. As the eggs hatch, each larva chews a short tunnel (feeding gallery) radiating away from the egg-laying gallery. Pupation occurs at the end of the feeding gallery when the larva is mature.

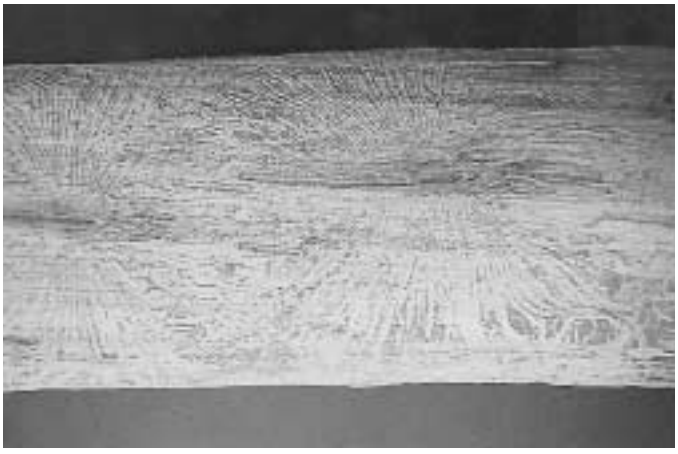


Figure 7.5. The egg-laying galleries of European elm bark beetles run parallel to the wood grain (C. DiFonzo, Michigan State University).

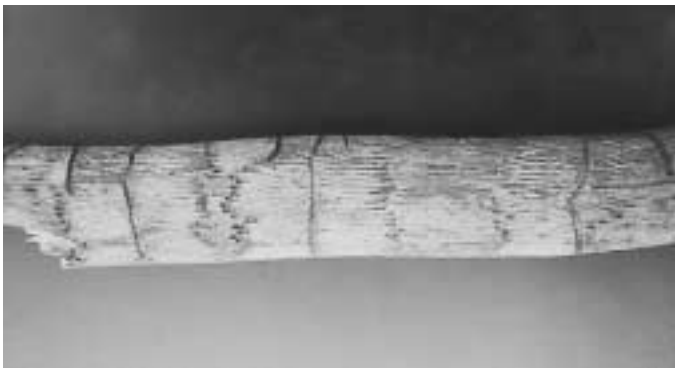


Figure 7.6. The egg-laying galleries of native elm bark beetles run perpendicular to the wood grain (C. DiFonzo, Michigan State University).

Management strategy:

- Salvage recently killed or dying trees. Remove bark from infested trees or logs, or destroy infested material by burning or chipping to prevent egg laying.

Native Elm Bark Beetle

The native elm bark beetle overwinters either as a fully grown larva or as an adult. The life cycle is very similar to that of the European elm bark beetle. However, the egg-laying galleries and the subsequent feeding galleries run perpendicular to the wood grain.

Management strategy:

- The same as for European elm bark beetle.

White Pine Weevil

White pine weevil is an important pest of white and jack pine as well as some spruces. Damage results in growth and productivity loss and distortion of tree form. Adult weevils overwinter in duff below host trees until April, when they begin feeding on the terminal leader. Stout, vigorous tree leaders with thick bark are selected for feeding and egg laying. Egg laying begins a week after feeding starts. Eggs hatch in 2 weeks, and larvae form feeding rings around the leader and feed downward, consuming inner bark. Larvae complete development in 5 to 6 weeks. Pupation occurs in the pith or wood of dead leaders, usually 1 to 3 years below the current growth. Adult weevils emerge in August or September; feed on upper lateral shoots, terminals, and other areas of the crown; then move down to the duff to overwinter.

Figure 7.7. White pine weevil adult (E.B. Walker, Vermont Department of Forests, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.8. White pine weevil damage to terminal (E.B. Walker, Vermont Department of Forests, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series, 1999,* Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- Plant densely so that damaged trees quickly reestablish dominance.
- Plant below an overstory so that trees are less suitable for weevils.
- If an insecticide is needed, spray only the leader of the tree in the spring to kill feeding adults.
- Corrective pruning may be needed to establish a dominant leader.

Jack Pine Budworm

Jack pine budworm defoliates jack, white, and red pines in spring and early summer. Severe or repeated defoliation may kill trees, especially overmature or low-vigor trees. Significant growth loss and topkill also occur.

Figure 7.9. Late instar of jack pine budworm (B. Conway, Michigan State University).

Adult moths lay eggs on 1-year-old needles in midsummer, and hatch occurs in 10 to 14 days.

Larvae overwinter in silk shelters on the bark. Larvae emerge from the overwintering sites in late May or early June and usually begin feeding in pollen cones until current-year needles expand. They clip off and web needles together with silk. Drying out of the clipped and webbed foliage gives the trees a reddish appearance that is characteristic of jack pine budworm damage. The larvae can also damage female cones, and this may reduce the trees'ability to regenerate naturally. Larvae mature and pupate in early summer. Adult moths emerge from pupae in 6 to 10 days and complete egg laying in 3 to 5 days.

Management strategy:

- Maintain stand stocking at 70 to110 square feet per acre.
- Optimal rotation age is 40 to 45 years.
- Chemical control can rarely be economically justified.

INTENSIVE INSECT MANAGEMENT SITUATIONS

Chemical controls are used infrequently to control forest tree insects, but they provide important supplements to cultural practices in Christmas tree plantations and are used occasionally in forest nurseries and seed orchards.

Christmas Tree Plantations

Christmas tree plantations are areas where intensive insect control is often practiced because of the high value of the crop and relatively low tolerance for damage. Insects and their close relatives, mites, are the most common pests of Christmas trees.

Cultural methods of insect management include proper site selection, planting pest-free stock, shearing and pruning damaged or infested shoots, and good sanitation. Knowing the life cycle and needs of each pest will help you modify and time cultural practices to manipulate pest habitat and possibly reduce the need for pesticides.

Pine Needle Scale

Pine needle scale affects all pines and some spruces. The insects suck sap from the needles, thereby weakening the tree and reducing its vigor. The small, white, oyster-shaped scale bodies also cover the needles and detract from the appearance of the tree. Small, reddish eggs overwinter on the needles beneath dead female scales. Crawlers hatch in May, settle on the needles to feed and grow the white, waxy coating that is nearly impenetrable to pesticides. The scales quickly mature and produce a second generation of crawlers by mid- to late July.

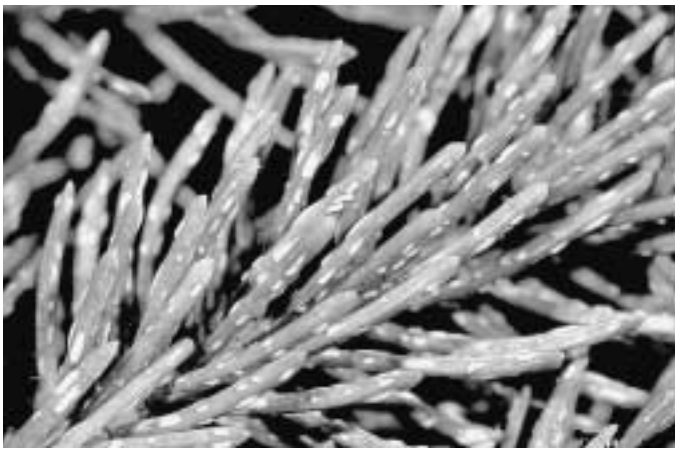


Figure 7.10. Pine needle scale infestation (J.B. Hanson, USDA Forest Service, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- When monitoring, be sure to check lower branches, where many infestations begin.
- Cut, remove, and destroy severely infested trees.

Table 7.2. Christmas tree species and some important insect and mite pests.

Christmas Tree Species	Some Common Insect and Mite Pests
Pines	Pine needle scale Pine root collar weevil Zimmerman pine moth
Balsam, concolor, Fraser fir	Balsam gall midge
Douglas-fir	Cooley spruce gall adelgid
White spruce, blue spruce	Cooley spruce gall adelgid (blue spruce) Eastern spruce gall adelgid (white spruce) Spruce spider mites

- Insecticides or horticultural oil sprays to control crawlers are effective in mid- to late May and again in late July or early August for control of the second generation.

Pine Root Collar Weevil

Grublike pine root collar weevil larvae girdle the root collar (where stem and roots meet below the soil surface) of Scotch, red, and, occasionally, white pine. The root collar may be surrounded by pitch-soaked, blackened soil. Trees fade to yellow, then red, and may topple over or break off at the root collar. Adult weevils lay eggs at the bases of pines in the spring and summer. The larvae hatch and feed on the inner bark of the root collar, then pupate in the nearby soil. Adults emerge in late summer and feed on trees for a short time before overwintering in the litter. The larvae are the most destructive stage of this insect.

Figure 7.11. Damage by pine root collar weevil on Scotch pine.

Management strategy:

- Avoid mixing pine species if pine root collar weevil is a frequent problem in the area.
- Scout trees 1 inch in diameter or larger before mid-May and again before mid-August.
- Remove lower two to three whorls of branches to allow sunlight to reach the root collar. This makes conditions unfavorable to weevils.
- Rake away needle accumulation from root collar area to increase soil temperature and reduce weevil survival.
- Treat root collar and surrounding soil of infested trees with insecticide to kill adults.

Zimmerman Pine Moth

Zimmerman pine moth attacks all pines, especially Scotch and Austrian. Branches may be killed and the top may break off above the point of attack. The caterpillar larvae overwinter in bark crevices. They become active in early April to early May and bore under the bark and into the stem at branch whorls. Pitch masses form on the stem at the entrance to the feeding tunnel. Adults emerge between mid-July and late August, then lay eggs on the bark. After hatching, the caterpillars spin silken cases and overwinter.

7.12. Pitch mass and frass of Zimmerman pine moth at the branch whorl on a young Scotch pine (D. McCullough, Michigan State University).

Management strategy:

- Scout for pitch masses throughout the year, especially as trees reach 5 to 8 years of age.
- Cut and burn infested trees in winter.
- Apply insecticides to the stem and bark of large branches in early to mid-April.
- Northern European Scotch pine varieties are often more susceptible than southern European varieties.

Balsam Gall Midge

The larvae of the tiny balsam gall midge feed on new needles of balsam and Fraser firs, causing small galls to form on the needles. Galled needles drop in October or November, leaving bare spots on branches. Mature larvae overwinter in the soil beneath the tree. Pupation occurs in spring, and flying adults emerge from the soil in late May to early June. Mating occurs and eggs are laid on newly emerging foliage. Developing larvae feed on needles, causing galls to form.

Figure 7.13. Needle galls caused by balsam gall midge on fir.

Management strategy:

- Scout for galls between June and October starting 3 to 4 years before harvest. Consider treating trees if 5 to 10 percent of the needles are galled.
- Natural predators and a competing midge species will take care of light infestations.
- Insecticide is effective between late May and mid-June, just as galls begin to form.

Cooley Spruce Gall Adelgid

This insect is a pest of Colorado blue spruce and Douglas-fir, often moving from spruce to Douglas-fir in the same season. Symptoms are quite different on the two trees. On spruce, overwintered females lay eggs in masses of white, cottony wax near the buds in spring. Feeding by young nymphs causes the new needle growth to form a gall that surrounds the adelgids. The galls are initially green, pineapple-shaped, and 2 to 3 inches long; they are located at the ends of the shoots. The galls turn red and then brown before they open in mid-July. The nymphs leave the galls and either continue their life cycle on spruce or fly to Douglas-fir. On Douglas-fir, adelgids lay eggs on the needles. The young winter on the needles, looking like bits of white cotton. Nymph feeding causes yellow spots on needles, and needles may bend or curl. Galls are not formed on Douglas-fir. Eventually a winged stage takes the adelgid back to spruce, but the cycles can continue on either host.

Figure 7.14. Cooley spruce gall adelgid egg mass (P.C. Johnson, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Figure 7.15. Cooley spruce gall adelgid galls on spruce (K.E. Gibson, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

Management strategy:

- Keep Colorado blue spruce and Douglas-fir plantings separated to limit damage.

Blue spruce

- Scout in April for nymphs.
- If insecticide is needed, spray trees just before buds break in April or early May. A fall application may be needed as well.
- Cut off and burn or bury galls before they open in July.

Douglas-fir

- Monitor trees of all ages throughout the season.
- If it is necessary to control overwintering insects, apply insecticide in fall or before buds break in spring.
- Another application may be needed in late June to mid-July.

Eastern Spruce Gall Adelgid

White, Black Hills and Norway spruce are hosts to eastern spruce gall adelgid. The galls from Cooley adelgid form at the tips of branches, while the smaller galls from the eastern adelgid form along the twigs at the base of new growth. The biology of the insect is similar to that of the Cooley adelgid except that galls caused by eastern spruce gall adelgid are smaller and located behind current-year shoots.

Figure 7.16. Galls on white spruce caused by eastern spruce gall adelgid.

Management strategy:

- Cut and destroy severely infested trees.
- If insecticide treatment is needed, treat in April as buds begin to swell or in the fall after galls have opened.

Spruce Spider Mites

Spruce spider mites can affect all Christmas tree species. Spider mites suck the juices from needles, cause bronzing or grayish discoloration of needles. Fine webbing may also be present. Injury can become severe, especially after hot, dry weather or where overuse of pesticides has killed the natural enemies of the mites. Spruce spider mites are tiny and difficult to see. Spherical eggs overwinter at the bases of needles. Hatch occurs in early summer. In favorable weather, it may take only 2 to 5 weeks to complete a life cycle. Several generations can occur in one summer. Eggs are laid in fall and overwinter.

Management strategy:

- Scout last year's damage in early June, checking older needles near the main stem. Abundance of eggs, webbing, or live mites will determine if a miticide application is necessary.
- Selective products that control spider mites but do not harm predatory mites are available.

Figure 7.17. Adult spruce spider mite.

Forest Nurseries

Insects are rarely important as pests in forest nurseries. White grubs, the larvae of June beetles, will occasionally cause damage by feeding on roots of tree seedlings. Death or stunting may result. If grubs are identified, apply an appropriate insecticide to the affected block according to label directions.

Seed Orchards

Cone and seed insects can be problems in conifer seed orchards. The extent of damage depends on whether the insect damages entire cones or individual seeds, and on the density of the insect population in relation to cone abundance. In some years when insect density is high and cone production is relatively low, a major portion of the seed crop can be lost.

Important seed and cone insects include seed bugs, coneworms, cone beetles, and, occasionally, tip moths. Seedbugs have piercing/sucking mouthparts and feed on seeds within developing cones. They leave few external signs of damage. It is difficult to distinguish between viable seed and damaged seed without running extracted seeds through an X-ray machine. Coneworms and cone beetles bore into cones and may destroy the entire cone or a portion of it. These insects usually leave frass, webbing, and other obvious signs of damage, especially when cones are split open.

Management of seed and cone insects may include cultural strategies and insecticides. Prescribed fire can be used to control insects that overwinter in litter. Insects that overwinter in cones can be controlled by removing or destroying cones on the trees and on the ground. In some high-value seed orchards, registered insecticides may be applied at regular intervals to protect seed trees from a complex of seed and cone insects. If a specific insect pest is causing damage, however, it is best to apply insecticides only during the vulnerable stage of that pest's life cycle. This strategy, along with an emphasis on cultural controls, helps conserve natural insect predators and parasitoids.

Figure 7.18. Leaffooted pine seed bug adult (L.R. Barber, USDA Forest Service, Parks & Recreation, *Forest Pests of North America, Integrated Pest Management Photo CD Series,* 1999, Bugwood and the University of Georgia, Tifton, Ga.).

PEST RESISTANCE TO INSECTICIDES

The insects left alive after a pesticide application may be more tolerant to a pesticide, and, over time, the insect population can evolve genetic resistance to the pesticide. Insects can also develop cross-resistance. Cross-resistance occurs when an insect population that has developed resistance to a certain pesticide also develops resistance to other related or unrelated pesticide compounds to which it has never been exposed.

Resistance to insecticides can be prevented or postponed indefinitely by following label directions and these guidelines:

- Use integrated control strategies.
- Limit the use of pesticides as much as possible.
- Rotate different brands and classes of insecticides.

CHAPTER 7

Review Questions

Chapter 7: Insect Management

Write the answers to the following questions and then check your answers with those in the back of the manual.

1. What steps should be taken before making a decision about the control of a forest insect pest?

2. What is meant by the economic threshold when controlling forest insect pests?

   A. The pest population level at which it becomes economically beneficial to apply control measures.

   B. The pest population level at which controls are no longer a viable alternative.

   C. The market value of the stand and the overall stand condition.

   D. The market value of the stand and the average age class.

3. The environment applies many pressures—i.e., natural controls—that limit the abundance or distribution of pest species.

   A. True

   B. False

4. Give an example of a natural biotic control.

5. Give an example of a natural abiotic control.

6-14. Match the following applied control methods to the example given.

A. Regulatory control
B. Mechanical control
C. Cultural control
D. Biological control
E. Chemical control

_____ 6. Inspection of plant materials.
_____ 7. Introduction of new natural enemies from the original home of a foreign pest species.
_____ 8. Proper site and species selection.
_____ 9. Spraying in late May to control balsam gall midge on balsam and Fraser firs.
_____ 10. Establishment and enforcement of quarantines.
_____ 11. Placing sticky bands on trees to trap gypsy moth larvae.
_____ 12. Proper thinning.
_____ 13. Rearing and releasing beneficial predator and parasitoid species.
_____ 14. Minimizing the use of broad-spectrum insecticides that would kill beneficial insects.

15-23. Match the following forest insect pests to the appropriate description.

A. Forest tent caterpillar
B. Gypsy moth
C. Two-lined chestnut borer
D. European or native elm bark beetle
E. White pine weevil
F. Jack pine budworm

_____ 15. Larvae overwinter in silk shelters on the bark of pines.
_____ 16. Responsible for the spread of Dutch elm disease.
_____ 17. Adult beetles emerge from D-shaped holes in the bark of low-vigor oak trees from late May to mid-September.
_____ 18. Larvae clip off and web needles together with silk. The drying out of the clipped and webbed foliage results in a reddish appearance of the pine trees.
_____ 19. Larvae commonly defoliate hardwoods such as oak, birch, and aspen. When nearing maturity, larvae feed only at night and rest under bark, rocks, or litter during the day.
_____ 20. An important defoliator of aspens but will also damage maple, birch, oak, ash, and willow. Larvae often feed, molt, and rest in groups, massing on trunks during non-feeding periods.
_____ 21. Adults overwinter in duff below host trees until April, when they begin feeding on the terminal leader.

_____ 22. Egg-laying galleries are below the bark. As the eggs hatch, each larva chews a short tunnel (feeding gallery) radiating away from the egg-laying gallery.

_____ 23. Pupation occurs in the pith or wood of dead leaders, usually 1 to 3 years below the current growth; adults emerge in August-September and feed on upper lateral shoots, terminals, and other areas of the crown, then move down to the duff to overwinter.

24. Which would be an appropriate management strategy for control of gypsy moth?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

D. Use microbial pesticide sprays when insects are in the first to third instars.

25. Which would be an appropriate management strategy for control of European or native elm bark beetles?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

D. Use microbial pesticide sprays when insects are in the first to third instars.

26. Which would be an appropriate management strategy for control of two-lined chestnut borer?

A. Plant below an overstory so that trees are less suitable for attack.

B. Spray only the leader of the tree in the spring to kill feeding adults.

C. Sanitation harvests, salvage, or delay of any activity in the stand that may further reduce vigor or wound trees.

D. Use microbial pesticide sprays when insects are in the first to third instars.

27. Which would be an appropriate management strategy for control of jack pine budworm?

A. Plant below an overstory so that trees are less suitable for attack.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. Use microbial pesticide sprays when insects are in the first to third instars.

28. Which would be an appropriate management strategy for control of white pine weevil?

A. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. Use microbial pesticide sprays when insects are in the first to third instars.

29. Which would be an appropriate management strategy for control of forest tent caterpillar?

A. Remove bark from infested trees or logs and destroy infested material by burning or chipping to prevent egg laying.

B. Maintain stand stocking at 70 to 110 square feet per acre; optimal rotation age is 40 to 45 years.

C. Spray only the leader of the tree in the spring to kill feeding adults.

D. When needed, use microbial pesticide sprays in May when feeding begins.

30. The native elm bark beetle is more important than the European elm bark beetle as a vector of Dutch elm disease.

A. True

B. False

31-37. Match the following Christmas tree pests to the appropriate description.

A. Pine needle scale
B. Pine root collar weevil
C. Zimmerman pine moth
D. Balsam gall midge
E. Cooley spruce gall adelgid
F. Eastern spruce gall adelgid
G. Spruce spider mite

_____ 31. A pest on both Colorado blue spruce and Douglas-fir; forms galls on blue spruce but not on Douglas-fir.

_____ 32. Causes small galls to form on needles. Galled needles drop in October or November, leaving bare spots on branches.

_____ 33. Girdles the root collar, often resulting in pitch-soaked, blackened soil around the root collar.

_____ 34. Sucks the juices from needles, causing bronzing or grayish discoloration of needles. Fine webbing may also be present.

_____ 35. Sucks sap from the needles, weakening the tree; small, white, oyster-shaped bodies cover the needles.

_____ 36. Larvae overwinter in bark crevices and become active in early April to early May and bore in the stem at branch whorls. Pitch masses form on the stem at the entrance to the feeding tunnel.

_____ 37. Galls form along the twigs at the base of new growth (not at the tips of branches).

38. Which would be an appropriate management strategy for control of spruce spider mites?

A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.

B. Cut off and burn or bury galls before they open in July.

C. Apply insecticides to the stem and bark of large branches in early to mid-April.

D. Scout last year's damage in early June, checking older needles near the main stem. If necessary, use selective products to control.

39. Which would be an appropriate management strategy for control of Cooley spruce gall adelgid on blue spruce?

A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.

B. Cut off and burn or bury galls before they open in July.

C. Apply insecticides to the stem and bark of large branches in early to mid-April.

D. Rake away needle accumulation.

40. Which would be an appropriate management strategy for control of pine root collar weevil?

A. Rake away needle accumulation.

B. Use horticultural oil sprays to control.

C. Use natural predators for light infestations.

D. Keep Colorado blue spruce and Douglas-fir plantings separated.

41. Which would be an appropriate management strategy for control of balsam gall midge?

A. Rake away needle accumulation

B. Use horticultural oil sprays to control.

C. Use natural predators for light infestations

D. Keep Colorado blue spruce and Douglas-fir plantings separated.

42. Which would be an appropriate management strategy for control of Zimmerman pine moth?

A. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.

B. Cut off and burn or bury galls before they open in July.

C. Apply insecticides to the stem and bark of large branches in early to mid-April.

D. Keep Colorado blue spruce and Douglas-fir plantings separated.

43. Which would be an appropriate management strategy for control of pine needle scale?

A. Rake away needle accumulation.

B. Use horticultural oil sprays to control.

C. Use natural predators for light infestations.

D. Keep Colorado blue spruce and Douglas-fir plantings separated.

44. Which would be an appropriate management strategy for control of eastern spruce gall adelgid?

A. Use insecticide in April as buds begin to swell or in the fall after galls have opened.

B. Use horticultural oil sprays to control.

C. Remove lower two to three whorls of branches to allow sunlight to reach the root collar.

D. Rake away needle accumulation.

45. How do white grubs cause damage in forest nurseries?

A. By feeding on roots of tree seedlings.

B. By infesting entire cones or individual seeds.

C. By causing branch galls to form.

D. By damaging the terminal leader.

46. What controls may help manage seed bugs, coneworms, or cone beetles in seed orchards?

47. What does cross-resistance in an insect population refer to?