FOREST INSECT AND DISEASE IDENTIFICATION AND MANAGEMENT

FOREST PEST MANAGEMENT
USDA Forest Service, Pacific Southwest Region
630 Sansome Street
San Francisco, California 94111

Manual Prepared for National Park Service
Course on Basic Vegetation Management,
University of California, Davis, May 11, 1987

CONTENTS

INTRODUCTION

I. Forest Pest Management

A. Objective. The objective of Forest Pest Management is to reduce damages, losses, and impacts caused by pests (insects, diseases, vegetation, animals) on all forest and rangelands to levels commensurate with resource management objectives.

B. Purpose. The purpose of the FPM Staff group is to provide overall leadership in the Integrated Pest Management (IPM) process to maximize pest management effectiveness and efficiency while minimizing adverse impacts to humans and their environment.

C. Responsibilities. Responsibilities of the FPM Staff include:

1. Providing staff leadership, coordination, and technical assistance in the overall process of integrated pest management.

2. Providing technical leadership, coordination, and assistance in forest insect and disease management.

3. Providing technical leadership, coordination, and assistance in control of pests through the use of pesticides.

II. Integrated Pest Management (IPM)

A. Definitions. The following definitions of IPM should serve to illustrate what IPM is and how it is today perceived by FPM in Region 5, particularly as it relates to forestry.

1. "Integrated Pest Management is a process for selecting strategies to regulate forest pests in which all aspects of a pest-host system are studied and weighed. The information considered in selecting appropriate strategies includes the impact of the unregulated pest population on various resources values, alternative regulatory tactics and strategies, and benefit/cost estimates for these alternative strategies. Regulatory strategies are based on sound silvicultural practices and ecology of the pest-host system and consist of a combination of tactics such as timber stand improvement plus selective use of pesticides. A basic principle in the choice of strategy is that it be ecologically compatible or acceptable. "National Forest System Land and Resource Management Planning, Regulations, 36 CFR 219.3 as published in the Federal Register 47 (190): 43039.

2. "Integrated forest pest management is a part of forest management that deals with regulation of pest populations to minimize their effects on management objectives in an ecologically sound manner. It consists of a decision-making process and action alternatives.

The decision process considers the ecology of the host and its pests throughout the rotation of the forest, and management objectives and economic values of the resource, coupled with monitoring data on pest populations and environmental factors that favor their increase. These data are required to decide for or against action to reduce excessive losses to the resource.

Action alternatives may be oriented toward prevention of losses or in direct response to chronic or catastrophic losses. One or more approaches may be used. These emphasize retention of natural systems and include cultural, mechanical, biological, regulatory, and chemical tactics. A no-action alternative may also be appropriate.

Integrated forest pest management is a dynamic process. It includes monitoring to measure accomplishments, identification of knowledge gaps that interfere with sound decision making and reduction of loss, and implementation of new knowledge to continuously update and increase the effectiveness of the system." "Integrated Pest Management Opportunities in California Forests; Report of a Special Task Force", submitted to D.E. Pesonen, Director, California Department of Forestry (pp. 4-5).

3. IPM is "a process wherein pest management considerations are integrated with resource management considerations to achieve targeted goals and objectives." Douglas R. Leisz, Regional Forester, Pacific Southwest Region, 1976.

B. Elements. These three definitions include the elements considered critical to the IPM approach. IPM is a concept or an approach, not a specific technique or control action. Perhaps the heart of the IPM concept is that it is a part of resource management; it incorporates pest management considerations with the forest and rangeland resource management assessment, evaluation, planning and decision making process. It is a decision support system for resource management.

Native insects and diseases are established elements of forest and range ecosystems, along with other animals and plants, and are not pests *a priori*. A pest may be defined as a plant, animal, insect, pathogen, or environmental stress, acting singly or in combination, which by its presence, abundance or activity, interferes with attainment of resource management goals and objectives. There are two key elements here: 1) management goals and objectives must be explicitly stated so that 2) interference with their attainment can be identified and measured.

C. Damage vs. Impact. Even when goals and objectives are clearly defined, it is often difficult to determine, particularly quantitatively, when and under what circumstances an organism, or complex of organisms, is a pest. It is useful to distinquish between injury, damage, loss, and impact.

Injury - an abnormality or dysfunction in a given host caused by a foreign agent, e.g., canker, feeding on needles/leaves, larval galleries, galls. Injury does not necessarily imply damage.

Damage - any adverse effect(s) on a forest resource(s) caused or contributed to, by an organism, groups of organisms (populations), or environmental stress.

Loss - basically a measurement of damage (mortality, growth loss, deformation, etc.), the difference in resource outputs attributable to the damage as compared to the same resource outputs in the absence of the damage.

Impact - the net effect(s) of a given organism, groups of organisms, and/or environmental stresses, on the productivity, usefulness and values of a given resource or resources with respect to specific resource management goals and objectives. Basically, impact is what the damage means in terms of management goals and objectives.

So, a potential pest becomes a real pest only when it causes, or contributes to, unacceptable negative impacts on defined management goals and objectives. The presence of injury or damage symptoms is not synonymous with negative impact.

D. Implementation. The actual implementation of the IPM approach involves a series of formal steps or elements which are separate, but ideally function as part of a continuum. These steps are 1) Prevention, 2) Detection, 3) Evaluation, 4) Suppression, and 5) Process Evaluation.

1. Prevention. Taking steps to try avoiding completely, or to reduce the impact of, a pest-related problem before it occurs, is a key element of the IPM approach. There are several general categories of prevention.

    a. Regulation - Quarantines

    b. Cultural Measures

1. Matching site and planting stock

2. Regulating stand density, composition, and age

3. Eradicating alternate hosts

4. Avoiding site and tree injury

5. Timing activities

6. Reducing numbers of breeding habitats

7. Use of chemicals

8. Use of biological control agents

c. Development and Use of Genetically Resistant Stock

2. Detection. The early discovery of potential pest problems is critical to successfully preventing pest-caused damage. Detection is the discovery, identification and reporting of damaging insects, diseases, animals, introduced plants and environmental stresses. Detection has two phases:

a. Surveillance is carried out by persons working in the forest on a day-to-day basis in connection with their regular duties. Surveillance is an ongoing, continuous effort.

b. Detection Surveys. Surveillance can at times be supplemented by detection surveys, which are planned, organized and conducted for specific purposes or objectives.

3. Evaluation. The evaluation process includes gathering, analyzing and interpreting technical data to provide a sound base for predicting damage and selecting the alternative(s) best suited to meet management goals and objectives (decision making). Evaluations consider the biological, environmental, and economic feasibility of possible pest management strategies.

a. Biological. An appraisal of the current and potential significance of a pest problem. There are typically three phases to this evaluation: 1) diagnosis, 2) prognosis, and 3) identification and discussion of alternatives.

This evaluation should provide the resource manager with enough information to make an initial decision as to what should be done about the problem, if anything. Depending on the decision at this point, two other evaluations may be needed.

Types of biological evaluations include:

1. Risk. Predicts the susceptibility of stands to pest attack.

2. Initial. Provides the resource manager who has a potential pest problem with the biological information necessary to make a decision on whether control action is needed.

3. Pretreatment. Verifies that treatment is still needed.

4. Posttreatment. Compares the actual effects of a treatment with the predicted effects.

b. Environmental. In accordance with the policies and procedures required by the Forest Service in support of NEPA, an environmental assessment report or environmental statement must be prepared for each proposed prevention/suppression project. This evaluation is intended to be a decision support document rather than a justification statement for a pre-selected alternative.

c. Economic. An economic evaluation is also required that appraises the economic feasibility and justification for the prevention/suppression project.

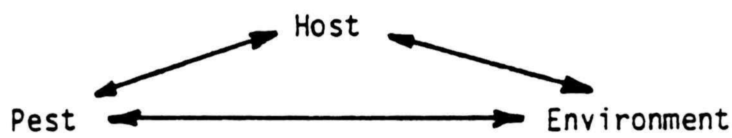
4. Suppression. The reduction of pest-related damage to acceptable levels through the application, individually or in some optimal combination, of various techniques, including silvicultural, mechanical, chemical, or biological methods. The intent or purpose of suppression is not to kill pests, but to prevent or reduce unacceptable loss so that management goals and objectives can be achieved.

5. Process Evaluation. Typically, this step is narrowly interpreted to be the "post-control" or "post-suppression" evaluation - that is, an assessment to determine how well the suppression treatment method(s) used met the intended objectives. In the broad context of IPM, however, it has become more appropriate to evaluate the entire process, not just the suppression element, in order to improve implementation of the process.

III. IPM - Biological Considerations

A. Pest - Ecosystem Interactions. Native pests of the forest do not operate outside of or separately from the forest ecosystem, but rather are a part of this interactive system. As such, they affect and are affected, both directly and indirectly, by the ecosystem.

A triangle can be used to illustrate the interactions between the pest-host-environment.



A pest situation can exist only when the proper conditions are met at each of the three corners. Removing or changing the pest or host, or changing the environment, may eliminate the pest situation.

By recognizing the importance and role of the environment in influencing the pest and host, we should have a better understanding for the pest situation, its effects, and future course. With these ideas, a great many more opportunities for controlling the problem through environmental and cultural changes or manipulations are available. The factors which are included in the environmental corner of the triangle fall into two broad categories: 1) physical factors, and 2) biological factors.

B. Pest Complexes. Pest situations may be affected by other living organisms. One pest may affect a host in such a manner so as to predispose it to other pests. These situations are so common and the pest combinations so predictable that we refer to these combinations of pests as "pest complexes". In California, recent surveys have shown that 75 to 90% of the tree mortality in commercial forests is the result of pest complexes. Two common groups of pest complexes encountered in these surveys were:

1. dwarf mistletoe - bark beetle complexes.

2. root disease - bark beetle complexes.

In both of these complexes, the pathogens involved, dwarf mistletoe or the root disease fungus, reduced the trees' vigor and natural defenses, predisposing them to successful bark beetle attack, which killed the trees.

In the forest, stand and site conditions, and pest complexes, occur and interact in such a way as to affect pest-caused damage. The stand and site conditions may affect either pest in a pest complex, either to minimize or to aggravate the damage. This effect is often most noticeable where unfavorable stand or site conditions aggravate the effects of the predisposing pest and the result is increased damage and mortality caused by the complex.

C. Control of Forest Pests. Control in the broad sense includes any direct or indirect effort to prevent or reduce losses; the objective is to reduce pest losses, not to kill pests.

We have three targets at which we can aim our efforts to control a pest problem: the pest, the host, and the environment. By bringing about the right change in any one of these three factors we can reduce pest-caused losses.

1. We can bring about changes in the host by:

   a. Changing host species, variety, or condition to one that is more resistant to the pest.

   b. Changing the age class of the host exposed to the pest.

   c. Reducing or changing susceptible tissues.

2. We can bring about changes in the pest by:

   a. Spraying a chemical which destroys the pest or obstructs the completion of some portion of its life cycle.

   b. Mechanically destroying the pest.

   c. Effecting biological control by introducing predators, parasites, and diseases of the pest.

3. Finally, we can aim our control efforts at the environment to bring about changes which are not favorable to the pest.

   a. Environmental changes may affect host susceptibility.

   b. Environmental changes which affect the pest may result in reduced losses.

FOREST TREE DISEASES

INTRODUCTION

I. Disease (an "abnormal" physiological process) can be caused by many agents. The most important of these on forest trees are:

- fungi,
- higher plants and
- abiotic factors.

II. Any part of the tree may be attacked. Diseases are often classified based on the part affected:

- root diseases,
- stem diseases,
- foliage diseases, and
- branch cankers and diebacks.

III. Fungi are abundant in the forest. Many types and species play many different roles, most beneficial:

- slash decomposition,
- insect pathogens,
- animal foods
- etc.

IV. Catastrophic forest disease outbreaks are relatively rare, and most western forest tree disease losses can be reduced by cultural practices. Exceptions are diseases caused by introduced pathogens.

V. Diagnosis is the art of putting together clues to come up with the cause or causes of the disease or damage. Look beyond the most obvious clues for predisposing or underlying causes - the damage often is caused by a complex of factors. Clues include the:

- type and pattern of damage,
- signs of pathogens,
- stand conditions and
- cultural practices

MISTLETOES

I. INTRODUCTION

The mistletoes are flowering plants that are widespread and damaging obligate parasites of forest trees. They are divided into two groups, the leafy or true mistletoes, and the dwarf mistletoes. The true mistletoes (genus *Phoradendron*) occur on hardwoods (*Fraxinus*, *Populus*, *Quercus*, and *Salix*) and conifers (*Abies*, *Juniperus* and *Cupressus*). They are sometimes damaging to trees in ornamental situations and can be locally damaging in forest situations. The dwarf mistletoes (genus *Arceuthobium*) are widespread and damaging on most western conifers. They are considered the most serious forest disease agents in many of the western states.

II. TRUE MISTLETOES (*Phoradendron*)

The true mistletoes are usually considered to be curiosities, but they can be serious pests where individual trees are of high value, as in yards, parks, and campgrounds. Species of *Phoradendron* are essentially "water parasites" and are less demanding of their hosts than the dwarf mistletoes, which are dependent on their hosts for water, minerals, and other nutrients.

A. Characteristics

1. Woody plants with mature shoots more than 6 inches long.

2. Foliage leafy or scaly.

3. Fruit a round berry; seed not forcibly ejected, but disseminated by birds.

B. Disease Cycle

True mistletoe infections are spread mainly by birds -- including robins, blue-birds, thrushes, and cedar waxwings -- that feed on the berries. Birds digest the pulp of the berries and excrete the living seeds, often depositing them onto susceptible trees. A viscous coating and hair-like threads on the outer surface of the seeds attach them firmly to twigs and branches, where they germinate and infect the host tissues.

Young or small trees are seldom infected by leafy mistletoe. In nearly all cases, initial infection occurs on larger or older trees because birds prefer to perch in their tops. Severe build-up of mistletoe often occurs in an already-infected tree because birds are attracted to and may spend prolonged periods feeding on the mistletoe berries.

C. Importance and Control

Trees heavily infected by true mistletoe are weakened, reduced in growth rate, and sometimes killed. Weakened trees are predisposed to attacks by insects and often succumb during drought or other periods of stress. Branches and tree tops heavily-laden with true mistletoe often break during storms or high winds and trunk swellings may provide an entrance point for decay fungi, increasing the hazard to people and property in campgrounds and other developed sites.

At present, control of Phoradendron is seldom practiced or needed in forest situations, other than selection against infected trees when practical. When control is needed for ornamental trees where values of individual trees may be high, several options are available.

1. Prune. Prune infected limbs one foot or more below the point of mistletoe attachment, preferably at the bole.

2. Wrap infected branches. Cut off the shoots flush with the limb or bole. Wrap the affected area with a band of black polyethylene to exclude light and tie in place. Since the mistletoe will not survive without light, it may die within a year or two. If the area is not wrapped with plastic, new shoots will develop. Removing new shoots each year will restrict mistletoe development, but will not kill it.

III. DWARF MISTLETOES (Arceuthobium)

The dwarf mistletoes are a major cause of growth loss and reduced vigor in coniferous forests. They, in association with other pests, particularly bark beetles, also are one of the principal causes of tree mortality. Dwarf mistletoes are a major cause of tree mortality in recreation lands and, in combination with bark beetles, have caused severe understocking in recreation areas.

A. Characteristics

1. Jointed shoots, less than 6 inches long.

2. Absence of true leaves.

3. Fruit is oval-shaped, containing one seed/fruit, the seed being forcibly discharged.

B. Disease Cycle

1. Seed dispersal takes place from midsummer to late fall. Seeds are forcibly discharged from the fruit and those that land on host needles stick because of mucilaginous coating.

2. Rains lubricate the sticky coating and the seed slides down the needle to the needle base.

3. The seed germinates, forms a holdfast, and a wedge of tissue penetrates the host bark to initiate infection. Normally the mistletoe will not penetrate a twig more than two years old.

4. A period of 2 to 5 years elapses before aerial shoots are formed. During this period, the parasite develops an absorption system which connects to the host xylem and phloem and enables the parasite to take food from the host.

5. Flowering occurs 1 to 2 years after the shoots appear. It takes another 12 to 14 months before seeds mature and seed dispersal occurs.

C. Signs and Symptoms (recognizing dwarf mistletoe in the field)

1. Aerial shoots of the plant.

2. Swelling of infected branches or stems.

3. Formation of witches brooms.

4. In some cases, subsequent infection by canker-causing fungi results in branch flagging.

D. Effects on Individual Hosts

1. Reduction in growth. The degree of growth reduction depends on the intensity of infection and their location in the tree. It ranges from essentially no measurable effect in lightly infected trees to a 30 to 60% reduction in growth in heavily infected trees.

2. Mortality. Dwarf mistletoes can kill trees directly, but the most common situation is for dwarf mistletoes and insects, particularly bark beetles, working together to cause the death of the heavily infected hosts.

3. Predisposition to other pests. Because of reduced vigor, trees heavily infected with dwarf mistletoe are more susceptible to attack by bark beetles and flatheads. Bole swellings caused by dwarf mistletoe provide a means of entry for decay fungi.

4. Growth abnormalities. Dwarf mistletoe infection causes visible changes in host growth and form, including brooming of branches and bole swellings.

5. Reduced seed production. Heavily infected trees produce fewer seed and, therefore, make poor seed trees.

6. Product degrade. Some product degrade results from bole infection and large knots produced by brooms.

E. Rating of Host Infection

A six-point rating system is commonly used to determine the severity, or degree, of host infection (see F. G. Hawksworth, The 6-Class Dwarf Mistletoe Rating System, Rocky Mtn. Forest and Range Experiment Station, Report RM-48).

F. Characteristics of Dwarf Mistletoe in Relation to Control

1. An obligate parasite which can exist only on a live host. Once an infected tree or branch is cut the dwarf mistletoe is no longer a threat.

2. Dwarf mistletoes are host specific, usually confined to one host or a group of closely related species.

3. Slow generation time -- it takes 4 to 6 years for dwarf mistletoes to complete a life cycle. Thus population buildups are slow and take many years.

4. The rate of spread of dwarf mistletoe is slow due to long generation time and short dispersal mechanism. Average 1 to 2 feet per year in even-aged stands.

5. Dwarf mistletoes and their effects are easily seen and recognized.

6. Juvenile escape. Young trees under three feet in height are usually not infected from associated infected overstory.

G. Control Options

Silvicultural controls are the only effective means of controlling dwarf mistletoes. These can be divided into two types: prevention and suppression.

1. Prevention. Usually, the most efficient and economical method of reducing dwarf mistletoe impact is to prevent an infestation from starting. This can be accomplished by:

   a. Removal of dwarf mistletoe seed source prior to infection of the new stand.

   b. Use of buffer strips around uninfected stands.

2. Suppression. Involves reducing dwarf mistletoe infections to acceptable levels. Suppression may vary from complete stand replacement to removal of infected parts of a tree.

a. Clearcut and regenerate. By removing all hosts we eliminate this obligate parasite. This is one of the oldest and most traditional methods of control, but it still is effective and sometimes the best option. It can be expensive depending upon method, difficulty, and cost of regeneration. The placement of clearcut boundaries is important so as to reduce the chances of dwarf mistletoe moving back into the new regeneration. Use natural barriers such as roads, meadows, species changes, or uninfected stands.

b. Sanitation thinning. The heaviest infected trees are removed and the basal area is reduced to stimulate growth. This results in a reduction in high risk trees and overall stand infection, as well as an increased growth rate of residuals which on good sites will allow the host to outgrow the mistletoe infection.

c. Change in species composition. Because mistletoes are host specific, in mixed conifer stands we can change the species composition through silvicultural processes and in doing so, reduce or eliminate the dwarf mistletoe from the stand.

d. Removal of infected residuals. In many stands because of one reason or another, infected residual overstory trees remain over a young stand. Removal of these old infected residuals is extremely important to prevent destruction of the young stand surrounding them and should be high in priority.

e. Pruning. Pruning of infected branches can reduce the impact of dwarf mistletoe in recreation areas. Removing heavily broomed branches is effective in increasing tree vigor with high value trees in recreation areas. In the West this method is effectively used to prolong the life of valuable recreation trees.

ROOT DISEASES

I. INTRODUCTION

The importance of root diseases was not realized in the past partly due to the difficulty in observing the organisms involved and their association with other organisms, such as bark beetles. It is only after examination of the lower bole and roots of trees that root diseases may be identified in the field, and trees in early stages of infection may show no above-ground symptoms at all. In some instances, laboratory evaluation is the only way of obtaining positive evidence of their existence in a tree. Once established in an area, root disease fungi can be difficult to control and may persist for several years, even decades, in dead roots and stumps.

In general, all root diseases have several similar above ground symptoms. Infected trees decline gradually, with symptoms progressing from the bottom and inside of the crown up and out. Needle retention is poor and needles may be shorter than in healthy trees. This will give the crowns the appearance of being thin and off-color. Root disease in a stand usually progresses outward from a point, resulting in a gradient of symptoms from dead trees at the center to declining and healthy trees at and beyond the margin of infection.

Root diseases are commonly a part of pest complexes, i.e., they are one of several pests simultaneously affecting the same tree. The most common associates of root diseases are various bark beetles. These insects can cause more rapid death of infected trees, as well as attack surrounding healthy trees.

II. An Example -- ARMILLARIA ROOT DISEASE - SHOESTRING ROOT ROT

A. <u>Causal agent</u> - <u>Armillariella</u> (<u>Armillaria</u>) <u>mellea</u>

B. <u>Hosts</u> - conifers and hardwoods

C. <u>Field Recognition</u>

1. Conifer mortality is associated with oak stumps and dead oaks, and is usually restricted to the zone of hardwood root influence. Centers do not enlarge indefinitely.

2. Crown decline similar to that described eariler.

3. Black, shoestring-like rhizomorphs can be found growing from roots, between the bark and wood, or in the soil.

4. White, leathery mycelial fans can be found between the bark and wood of infected roots and trunks.

5. Infected pines may produce an abundance of resin that accumulates in the wood or surrounding soil.

6. Decayed wood is yellow, stringy, often water-soaked, and may have fine black zone lines.

7. In the fall, honey-colored mushrooms may be produced around infected trees. They are gilled and may have a ring around the stalk beneath the cap.

E. Biology

1. Initial infections usually occur in dead or dying oaks.

2. Spread to living conifers is via rhizomorphs growing through the soil or root contact.

3. Spread can continue from infected to healthy conifers also via rhizomorphs or root contact.

4. Infection of living conifers is often associated with stress factors, e.g., drought, defoliation, bark beetles, etc.

F. Effects on the Host

1. Growth reduction

2. Mortality, especially of conifer regeneration around oak stumps.

3. Butt rot

G. Control Options

1. Do not cut or kill oaks near conifers. If the oaks are young, they may be cut and managed for sprouts. Older oaks can be pruned to reduce transpiration and competition.

2. Conifer stump removal has been recommended in certain situations in the Pacific Northwest.

DECAY OF TREES

I. IMPORTANCE

A. Heartrots are one of the major limitations to fiber production in old-growth management.

B. Wood decay is increasingly recognized as an important factor in second-growth management. This is particularly serious because of repeated entries into stands of decay susceptible species.

C. Decay of trees in recreation areas is the major cause of tree failures resulting in damage to persons and property.

D. Most decay fungi are beneficial by functioning in the nutrient cycling process.

II. TYPES OF DECAY

A. White Rot

1. Affected wood is moist and either yellow stringy, white stringy, or has a pocket rot.

2. Fungi that cause white rot utilize both cellulose and lignin.

3. Black zone lines may be formed in wood attacked by white rot fungi.

4. White rot is more common in hardwoods.

B. Brown Rot

1. Affected wood is dry, brown, and develops shrinkage cracks; it is easily pulverized between the fingers.

2. Fungi that cause brown rot do not breakdown lignin.

3. Brown rot is more common in conifers.

III. BIOLOGY OF WOOD DECAY

A. The fungi that decay trees may gain entrance through a variety of openings in the bark.

1. Wounds

    a. fire scars
    b. logging damage
    c. frost cracks
    d. animal damage
    e. sunscald
    f. insect attacks

2. Broken tops

3. Branch stubs

4. Small twiglets

5. Root infections

6. Parent stumps (hardwoods)

B. Initiation of decay occurs when a spore lands on suitable exposed wood, germinates, and invades the woody tissue.

C. Recent research indicates that a succession of microoganisms (including bacteria and non-decay fungi) invade the wood following wounding. Tree response to wounding and microorganism invasion is also important in the success of wood decay organisms.

D. Following invasion, a variety of interactions occur among numerous microorganisms and the tree determining the amount and rate of decay.

IV. EXTERNAL INDICATORS

A. <u>Conks</u> - These fungal fruiting bodies are the most reliable indicators of decay and the only means of positively identifying the causal agent in the field. Certain fungi are prolific in their production of conks, while others produce them rarely and only under special conditions.

B. <u>Swollen Knots</u> - Protrusion of bark and wood around a branch stub.

C. <u>Punk Knots</u> - Decayed branch stubs filled with fungal material. Considered to be places where conks were or where they will develop.

D. <u>Wounds</u> - Indicative of places of entry for decay fungi. The location of the wound on a tree may influence which decay organisms are involved in the decay process.

E. <u>Dead or Broken Tops</u> - Like wounds, these may serve as avenues for infection by certain decay fungi.

V. MANAGEMENT OPTIONS

A. Old-Growth Stands

1. Harvest trees before pathological rotation age if volume production is a major consideration. This age varies with tree species and geographic location, but usually other factors, such as economics and annual increment, dictate harvesting prior to the attainment of pathological rotation age. If partial cuts are to be performed, then cut trees should be selected on the types and number of decay indicators present.

2. In recreation areas old-growth, predominant individuals are often retained. Many times, these same trees develop decay columns in the butt and/or bole. Further maintenance or removal of these trees must be decided upon on a tree-by-tree basis. Consult the "Hazardous Tree Evaluation" section for guidelines.

RUSTS OF CONIFERS

Rust diseases are caused by a specialized group of fungi that develop only on living hosts, passing through several spore stages in their life cycles. Many produce spores on two unrelated hosts, and must alternate from one to the other to complete their life cycles. Others parasitize only a single host.

Rust fungi can infect foliage, twigs, branches, or stems, and develop within the host to form leaf spots, swellings, systemic infections, or cankers. Severe infections may reduce wood quality, retard growth, and kill individual trees.

The most damaging rust -- white pine blister rust -- was introduced from Europe, and continues to pose a serious threat to the regeneration and management of pines in the United States. Native pine rusts are generally less damaging: they include pinyon rust, stalactiform rust, filamentosum rust, western gall rust, and comandra blister rust.

I. GENERAL CHARACTERISTICS OF RUSTS

A. Obligate parasites (i.e., they require a living host).

B. May or may not require an unrelated alternate host to complete their life cycles.

C. May produce up to five different spore stages.

D. Retard host growth, reduce wood quality, and occasionally kill individual trees.

II. BIOLOGY OF PINE RUSTS

White pine blister rust is typical of the long-cycle rusts that have up to five spore stages and infect an alternate host. The following life cycle exemplifies these rusts. By contrast, a short cycle rust - western gall rust, for example - has a single spore stage that is capable of directly infecting the pine host.

A. Life Cycle of a Macrocyclic (long-cycle) Rust.

1. Basidiospores (= sporidia) are formed on the alternate, herbaceous host, and are wind-borne for short distances to the pine.

2. Basidiospores germinate on pine needles and their germ tubes enter through stomates; the fungus then grows through the bark of branches and into the main stem.

3. A few years after initial infection, pycnial drops exude from branch swellings. The next spring, white blisters containing

orange-colored aeciospores are formed where the pycnia were produced the year before.

4. The fungus continues to grow through the bark until it may eventually girdle the tree. Blisters with aeciospores are formed once a year, usually in the spring.

5. Aeciospores are wind-disseminated to the alternate host. Aeciospores may spread as far as 800 miles or more, but most infect alternate hosts close to the pine source.

6. Aeciospores infect the leaves of the alternate host, and the fungus produces yellow to orange pustules containing urediospores.

7. Urediospores are wind-disseminated short distances to other individuals of the same host species. As the urediospores scatter and germinate on the alternate host, the rust intensifies.

8. In late summer or fall, brown telial columns are formed in the urediospore pustules, and these produce teliospores.

9. Teliospores germinate in place under the proper climatic conditions to produce basidiospores, which in turn infect nearby pines.

III. CHARACTERISTICS OF RUSTS IN RELATION TO CONTROL

A. Two hosts are required for most rust fungi to complete their life cycles. The absence or elimination of one host will prevent the completion of the disease cycle.

B. The disseminating spore stages of the rust (basidiospores, aeciospores, and urediospores) are dependent on favorable moisture and temperature regimes for successful germination and host infection. Susceptible pines on sites unfavorable for the fungus will have little or no rust disease.

C. Rust fungi are obligate parasites that can exist only on living hosts.

D. Some trees have inherent genetic resistance to rust infection.

E. Growth of the rust through conifer tissues is slow, generally 1-2 inches per year.

NEEDLE DISEASES OF CONIFERS

I. INTRODUCTION

A. Needle diseases are principally a result of infection by fungi, although some abiotic factors may cause similar symptoms.

B. The effect of most needle diseases is reduction of photosynthetic area available to the plant, resulting in reduced growth rate.

C. Most needle diseases of conifers attack either current year's foliage or older foliage, but rarely both. Therefore, mortality caused by the disease is rarely a problem.

D. In Christmas tree plantations needle diseases can be important because of the reduction in quality of the crop as a result of dying foliage or defoliation.

II. GENERALIZED BIOLOGY/LIFE CYCLE

A. Spore production usually restricted seasonally.

B. Spores produced in fruiting structures on needles.

C. Spores transported by rain splash or wind and infect other needles.

D. One to several years required for formation of new fruiting structures.

III. CONTROL

A. In forest stands, control is rarely necessary nor economical.

B. In high-value stands, chemical treatment may be advisable.

IV. An Example -- ELYTRODERMA DISEASE

A. Recognition

1. Needle reddening in the spring.

2. Formation of compact, globose witches' brooms,

3. Brown necrotic flecks in inner bark of infected twigs.

B. Important Biological Characteristics

1. Following needle infection the fungus grows into the twig. It can then spread into the bud, infecting and deforming new growth.

2. The disease occurs in epidemic outbreaks only occasionally during favorable conditions.

3. Certain areas and sites appear more favorable to repeated infections, although the variables involved are not well understood.

C. Control

1. Maintain proper stocking and eliminate low vigor trees. By increasing stand vigor tree mortality from insect attacks may be reduced.

2. High-risk areas should be defined following disease outbreaks.

3. In high-risk areas favor non-susceptible species.

CANKER DISEASES OF CONIFERS

I. INTRODUCTION

A canker is a localized area of dead bark and cambium on stems or branches. The fungi that cause cankers are not usually aggressive pathogens. They enter susceptible tissues through wounds or other openings in the bark, such as branch stubs. Most canker fungi are restricted to bark and cambium tissue and do not penetrate into the wood. Cankers do not normally reduce tree height or diameter growth, but may cause stem breakage, provide an entrance for decay organisms, and cause dieback of girdled tops, branches, or twigs.

In the West, cankers are not a serious problem in coniferous forests even though there are many different canker diseases. They do present a more serious threat to plantations, Christmas trees, ornamentals, and other high value trees.

ABIOTIC DISEASES

I. INTRODUCTION

Abiotic diseases are caused by non-living, non-infectious agents that physiologically or functionally impact a plant. They are a result of stresses, either natural or man-induced, that occur in the environment. Those diseases that result from aberrations in the natural environment usually can not be diagnosed without an analysis of the past weather conditions. Sudden changes or abnormal occurrences in the area's weather are indicative of possible causes. Evaluation of man-induced stresses requires examination of the physical environment associated with the affected plants plus past activities that might have had an adverse effect.

Diagnosis of abiotic diseases is complex and may require making some subjective determinations as to the effects of changes in the environment. Specific determinations of certain abiotic diseases (e.g., road salt, mineral deficiences) may require laboratory analysis.

Some abiotic diseases do not act alone in damaging forests, but interact with other abiotic and biotic factors. They add additional stress to already impacted plants, or weaken them, resulting in predisposition to other pests.

The following are various abiotic factors that can reduce stand productivity. Included are symptoms that can aid diagnosis and possible management tactics that can reduce their impact.

II. TEMPERATURE EXTREMES

A. <u>Sunscald</u>

1. Localized death of the cambium resulting from sudden exposure to direct sunlight.

2. Provides a wound for entry of decay organisms.

3. Symptoms

   a. canker development usually on the south or southwest side.

   b. most common on thin-barked species, especially young growth.

   c. usually occurs within a few years following heavy thinning or selective cutting.

4. Management. In stands with susceptible species, give consideration to the potential damage that may result if the stand is heavily thinned. Stands on south-facing slopes should be

given highest consideration. Reducing intensity of thinning or increasing number of entries can reduce damage.

B. <u>Frost Injury</u>

1. Frost can be damaging either in autumn (early frost) or spring (late frost), the latter being the more common.

2. Late frost damages active buds and shoots, while early frost affects shoots that have not hardened off.

3. Symptoms

    a. bud and shoot death.

    b. shoots may form shepherd's crooks, a curling of killed shoots.

    c. needle reddening.

    d. damage is usually associated with topographic depressions, "frost pockets".

    e. most injury occurs within a few feet of the ground and adversely affects regeneration.

4. Frost sensitivity varies between species.

5. Management. In areas where frost damage is likely, regeneration may be protected by retention of a partial canopy until the understory has grown out of the susceptible area within the first few feet of the ground.

C. <u>Frost Cracks</u>

1. Vertical cracks develop during periods of sudden cooling when tangential shrinking of wood is greater than radial.

2. Provides entry court for decay organisms and organisms that cause wetwood.

3. Symptoms

    a. Splitting of the wood along the bole usually in the butt log.

    b. Callus formation during the healing process.

    c. Frost cracks are susceptible to reopening in subsequent years resulting in frost ribs.

    d. Slime flux may exude from old, partially healed frost cracks.

4. Management. Discriminate against the affected individuals during thinnings.

D. Winter Drying

1. A dessication of needles, resulting from excess transpiration, when the soil is frozen and warm dry winds occur.

2. Symptoms

    a. foliage becomes yellow to dark brown in spring.

    b. most pronounced on windward side.

3. Management. Unless extremely severe, buds are not affected and trees survive, although growth may be reduced. No special management techniques are necessary in most situations.

III. MOISTURE EXTREMES

A. Drought

1. This can be a local problem when plants are growing on soil with a low mositure-holding capacity or more widespread when insufficient precipitation occurs.

2. Reduced moisture availability increases susceptibility of plants to insects and diseases.

3. Symptoms

    a. extent depends on severity of drought.

    b. initial symptoms on youngest needles with discoloration of needle tips and needle browning.

    c. with increasing drought older needles become affected.

    d. symptom expression and dieback from the top down and outside in of the crown.

4. Management

    a. maintain proper stocking levels for the site.

    b. minimize the impact and levels of insects and diseases in stands through proper management practices during periods of "normal" precipitation.

B. Flooding

1. Generally, periodic in nature along shorelines or river banks.

2. Not a common forest problem, except where beaver populations may be large.

3. Symptoms

   a. variable; may be similar to some root disease symptoms.

   b. generally, yellowing and browning of foliage to mortality.

4. Management. Little can be done, except salvage of severely affected individuals. Consider possible damage during construction of water impoundments.

IV. CHEMICAL EXTREMES

A. Road Salt

1. Injury along roads treated with deicing salt.

2. Symptoms usually within 100 feet of road on downslope side, although distance may increase along drainages.

3. Symptoms

   a. symptom severity decreases with increasing distance from road.

   b. needle tip dieback that may be scattered or continuous throughout a tree.

   c. "halo" effect on pine branches when viewed from the end.

   d. advanced symptoms include complete browning to tree death.

   e. spiraling of symptoms up through crown occurs on true firs.

4. Management

   a. confirm suspected areas of damage by consulting highway department as to salt application and have foliage analysed for chloride content.

b. in damaged areas, or areas prone to damage:

1. try to have amount of salt used reduced.

2. divert run off.

3. plant vegetation at least 30 feet from the road.

4. plant salt tolerant species.

B. Herbicide Injury

1. Most herbicide injury is a result of improper application.

2. Injury is usually found along roads, rights of way, fuel-breaks, dwellings or other areas where herbicides are often used.

3. Symptoms vary with the type and amount of herbicide used.

a. preemergence (e.g. simazine) - high rates cause chlorotic banding.

b. postemergence

1. hormonal (e.g., 2,4-D; 2,4,5-T; picloram, silvex) - abnormal growths, curled leaves, twisted petioles and needles, distorted shoots and twigs.

2. nonhormonal (e.g., amitrole, dalapon) - yellow-white bleaching, chlorosis and necrosis of tissues throughout crown.

c. contact (e.g., sodium arsenite, paraquat, Silvisar 510) - injury results from drift causing small necrotic spots on foliage.

4. Management - follow label directions as to rate and method of application.

V. AIR POLLUTION

A. Particulates

1. The principal concern is from road dust that covers foliage along well-traveled routes.

2. Heavy dust loads can reduce photosynthesis.

3. Reduces predator population of pine needle scale; scale populations can then increase resulting in growth reduction and, in extreme cases, mortality.

4. Management - In areas where trees are severely affected, treating roads to reduce the amount of dust or reducing traffic can limit further damage.

B. Sulfur Dioxide

1. This has been a local problem near where fossil fuels are combusted.

2. Increasing use of high sulfur fuels may result in increased levels of damage.

3. Symptoms

a. older needle whorls affected first with symptoms progressing from bottom of the crown to the top.

b. needles develop reddish brown discoloration in bands beginning at the needle tip.

4. Management - Favor less susceptible species.

VI. MECHANICAL DAMAGE

A. Snow

1. Accumulation of heavy, wet snow can cause bending and breakage of saplings and pole-size trees, and top breakage of older trees.

2. Severely bent seedlings and saplings usually straighten out with no visible damage in later years, but height growth may be reduced for several years.

3. Pole-size trees in high density stands are more susceptible to stem breakage, especially dominant individuals.

4. Management - Thin dense, sapling-size stands, especially at high elevations where late wet snows occur.

BASIC ENTOMOLOGY

A. INSECT DIVERSITY

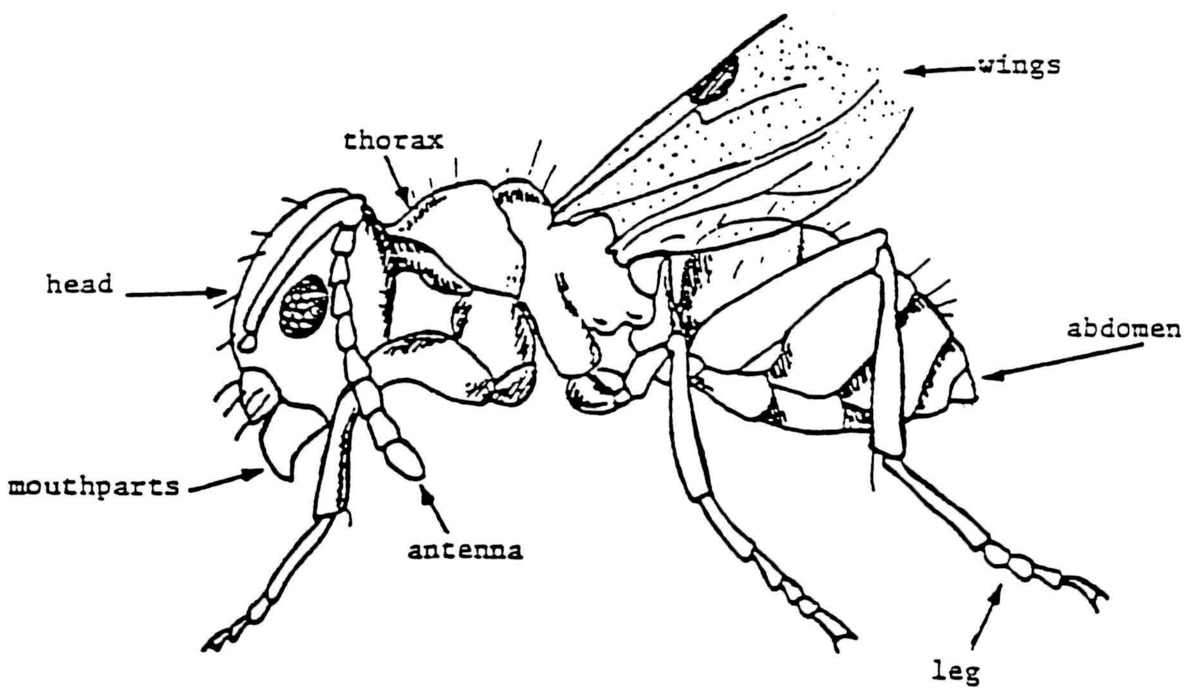
- The many different kinds of insects stagger the immagination.
- To date, approximately 850,000 species have been identified. About a million different ones probably exist.
- The greatest number of these species belongs to the beetle, fly and wasp-bee-ant groups.
- Not only in number of kinds are they diverse, but also in appearance and size. Some of the smallest are less than a millimeter, while some of the largest are larger than half a foot.
- There are many different "jobs or roles in nature and insects of one kind or another fill all of these. To mention just a few:

  Predators, parasites, plant feeders, fungus feeders, dead animal feeders, and dead plant material feeders;

  and they perform these "jobs" in both aquatic and terrestrial habitats.

B. INSECT ANATOMY

- Insects vary from man and other vertebrates by having an exterior or "exoskeleton."
- Insects have three body regions: a head, thorax and an abdomen. Each of these parts usually has distinctive accessories.

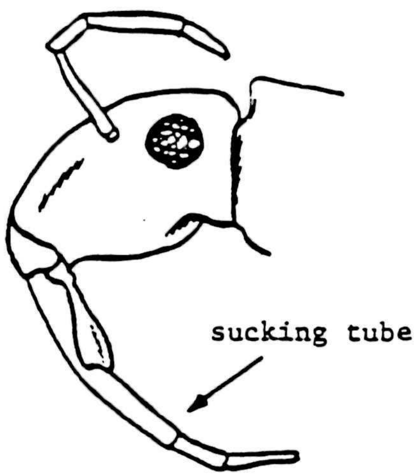


Art Retan and Art Antonelli, Extension Entomologists, Washington State University, Pullman, WA. In: Forest Pesticides in the Pacific Northwest - 1984. Washington State Univ. Coop. Ext. Serv., Pullman, WA.

C. SEPARATION OF CLASSIFICATION OF INSECTS

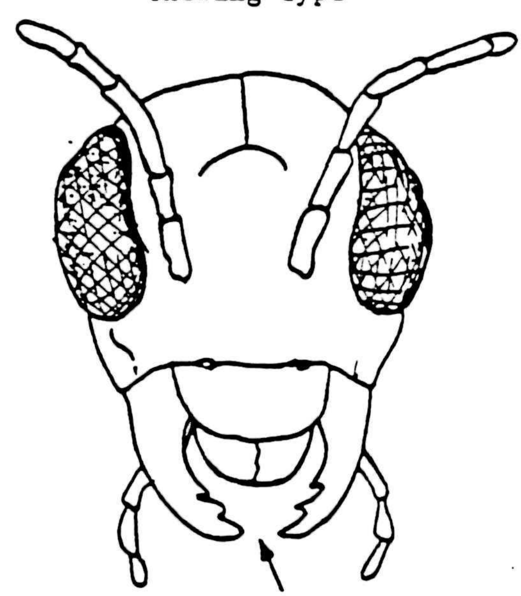
- There are several methods for separating of categorizing insects.

1. The professional uses body parts for identification and observes differences in these parts through the use of a microscope. He or she tracks down the identity by using a written insect "key." The anatomy of an insect will place it into a specific insect group called an order.
   - If you are around entomological activities much, you'll often hear the phrase "keying it out." This simply means identifying the insect.
2. Insects are also classified by the type of damage they cause.
   - Some examples are: "root maggot," "twig girdler," or "crown borer."
   - Destructive insect activities help narrow down the multitude of possibilities and often aid in making insect identifications quicker and simpler.
3. Another form of separation is in the manner of feeding mechanisms or mouthparts.
   - The broadest grouping is chewing versus sucking mouthparts.



Sucking Type

Chewing Type



- Although this manner of separation is somewhat helpful for identification, its greatest value is in determining if a certain kind of pesticide will work or not. For example, systemic insecticides "generally" don't work as well on chewing insects as on sucking ones.

- Proper identification is extremely important. If a beneficial insect or a non-damaging one is improperly identified as a pest, a pesticide application that is not needed usually disrupts a natural control agent. The disruption of this beneficial's activity may have induced the need for the chemical. Chances are you may have made an application that did no more for you than cost money.

  * Don't make recommendations based on the verbal description of a pest by a client. Insist on seeing it or at least its damage before you volunteer anything. Too many misidentifications are made this way. Wrong identification leads to ineffective control measures and unnecessary expense or problems.

D. INSECT RELATIVES

- There are a number of insect relatives that are often mistakenly called insects. Some of these are:

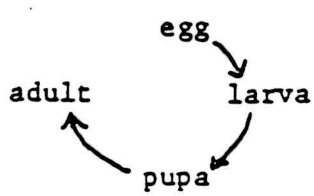
  Spiders, mites - 8 legs, 2 main body regions
  Centipedes, millipedes - many legged (more than 8)
  Sowbugs - also many legged

* Remember that insects have to have 3 main body regions: head, thorax, abdomen. They also have six legs and usually have wings of some form. Learn these differences between them and their relatives.

E. INSECT STAGES

- Insects change or go through metamorphosis in the time they go from an egg to adult.
- There are basically 2 types of change.

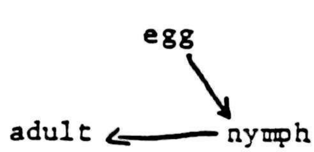
1. Complete or drastic change in which the stages are:



Examples: beetles, flies, moths, wasps, and others.

Those that go through this kind of change appear to have no similarity between the immature and adult stages.

2. Incomplete or gradual change in which the stages are:



Examples: bugs, termites, grasshoppers, aphids, leafhoppers, and others.

Those that go through this kind of change have a basic similarity between the immature and adult stages. There may be extreme variability in those that have caste systems, such as the termites.

F. SPECIFIC INSECT GROUPS

Examples of those that make a complete change.

1. The two winged flies (order: Diptera)

   - Mouthparts are generally sucking or sponging in the adult, although some are piercing.
   - One of the most common groups.
   - Most important group medically in terms of man and animals. Some, such as bot flies, are parasites as immatures on mammals. Others are often disease vectors, such as mosquitoes or deerflies. In other words, they can transmit such diseases as tularemia and malaria. The housefly has been suspect of mechanically transmitting such diseases as polio to food surfaces. Some flies 'such as the face flies' activities disrupt or annoy livestock, causing the cow or other animal to stop feeding.
   - Some flies are beneficial as decomposers or organisms.
   - Some are effective parasites of destructive species.

2. The bees, ants and wasps (Order: Hymenoptera)

   - Mouthparts are of the chewing type.
   - Form social colonies.
   - Have four wings and are often brightly colored with reds, blacks, yellows and white, or some combination which serves as warning coloration.
   - A very large group (one of the largest).
   - Often sting.
   - Usually beneficial, but can be annoying or, if antagonized, may cause severe injury or even death.

   Activities:

   Bees - Beneficial: pollinators of crops and honey producers.
   - Harmful: they sting and may cause severe allergenic reactions in some persons.

   Ants - Beneficial as predators on harmful insects and as decomposers of rotting stumps or logs (recyclers).
   - Harmful as structural pests of buildings, etc. Also, some species can sting.

   Wasps - Beneficial as predators or decomposers (i.e., yellowjackets).
   - Harmful — they sting; some are plant feeders (i.e., gall wasps).

3. Beetles and weevils (Order: Coleoptera)

   - This group has four wings but differ from other insects, as the forewings are generally hard and form a hard shell over the hindwings, making the underwings appear invisible.
   - The group performs many functions in nature that may be either beneficial or harmful to man, depending on circumstance and species.
   - Largest group (according to some authorities of insects in the world.

4. Moths and butterflies (Order: Lepidoptera)

   - Sucking mouthparts in the adult (feed on pollen and nectar).

- Chewing type in the immature form.
- Possess 4 wings which are generally covered with scales, which come off readily when handled.
- Many species can be very damaging to crops.
- Some of the most beautiful adult insects in the world belong to this group.

- Examples of insects that make an <u>incomplete change:</u>

1. The true bugs (Order: Hemiptera)

   - Mouthparts of the sucking type.
   - Possess four wings.
   - The forewings are partially leathery or hard. The tips of the forewings are membranous and often flimsy or even clear.
   - Many are beneficial predators and others are plant feeders.
   - Damaging in all active stages.

2. Scales, aphids and leafhoppers (Order: Homoptera)

   - Have sucking mouthparts.
   - Similar to true bugs but generally smaller, softer bodied and often wings are membranous and clear. Also hold their wings "rooflike" over their backs when at rest.
   - All are plant feeders.
   - Many transmit plant diseases.
   - Damaging in all active stages.

3. Termites (Order: Isoptera)

   - Have chewing mouthparts.
   - When they are winged, the wings are equal in size and shape and membranous and highly veined.
   - Often structural pests, but serve a useful purpose as decomposer organisms.
   - Once a colony is formed, adults drop their wings much like ants.
   - Superficially look like ants, but differ in that the waist is not obviously constricted, as in the ants.

4. Grasshoppers, cockroaches, crickets, etc. (Order: Orthoptera)

   - Chewing mouthparts.
   - Possess long, straight, leathery forewings with hindwings membranous and often colorful.
   - Some are serious defoliators of plants.
   - Damaging in all active stages.
   - Some members such as the grasshoppers possess large hind legs, which enable them to jump several feet.
   - Eggs laid in masses, attached together.

5. Silverfish and firebrats (Order: Thysanura)

   - Chewing mouthparts.
   - One of the few insect groups that <u>do not</u> possess wings.
   - Bristles on tip of abdomen.
   - Household pests feeding on such things as paste, paper, crumbs, etc.

G. PREDATORS AND PARASITES

1. Predators kill and feed on prey outright; predators generally are larger than prey.

2. Parasites are usually smaller and often weaker than they prey and kill gradually by injecting eggs, which develop on, within, or near insect over a period of time. They may sting and paralyze prey, and stock their nests in which the larvae or eggs are developing. The immature parasite will then consume the paralyzed insect at its leisure.

   - Predators and parasites account for much of the reduction of pest insect populations in nature. However, in agricultural or garden situations their effects are often not dramatic enough to satisfy a farmer or homeowner. There are, of course, exceptions. Additionally, many pesticide applications kill these beneficials, thus reducing their effects. Beneficials can be useful, but they usually need some cultural encouragement. This takes careful crop management, often too involved for many homeowners to accomplish.

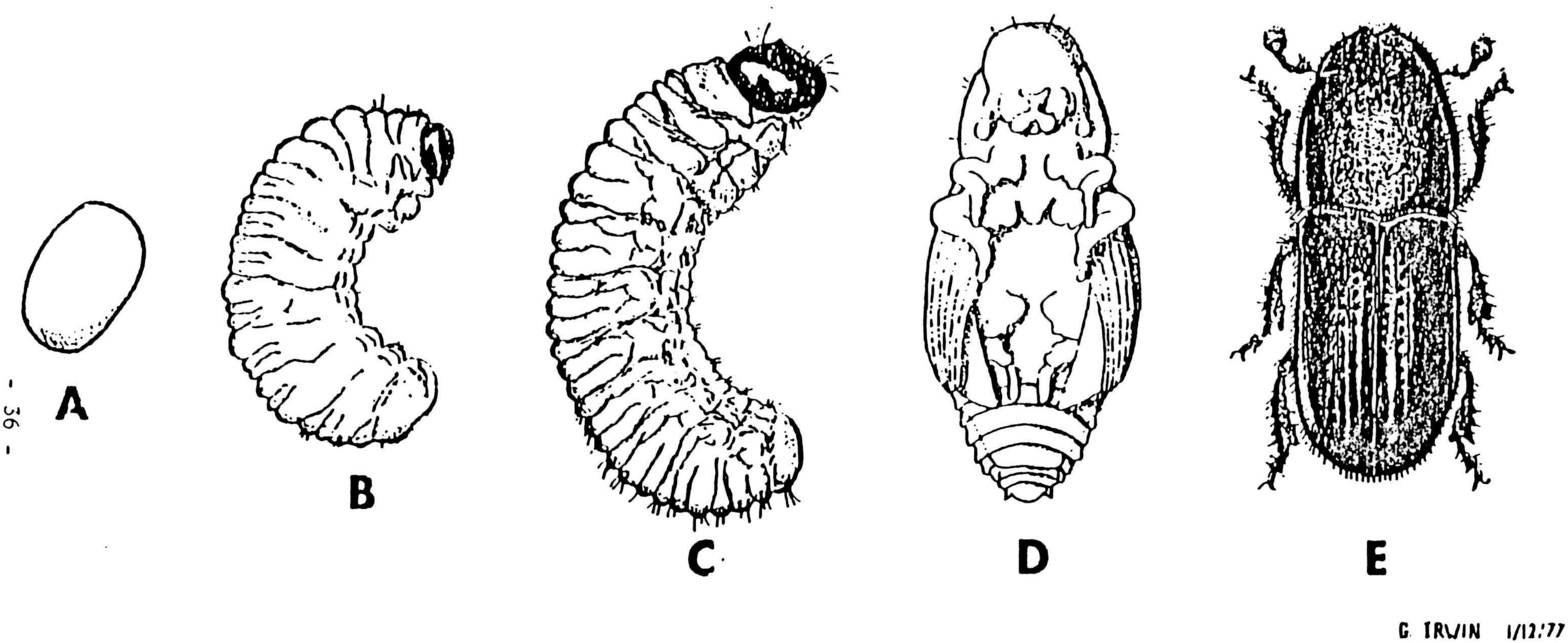


FIG. 1 COMPLETE METAMORPHOSIS OR GROWTH

(A) EGG (B&C) LARVAE (D) PUPAE (E) ADULT

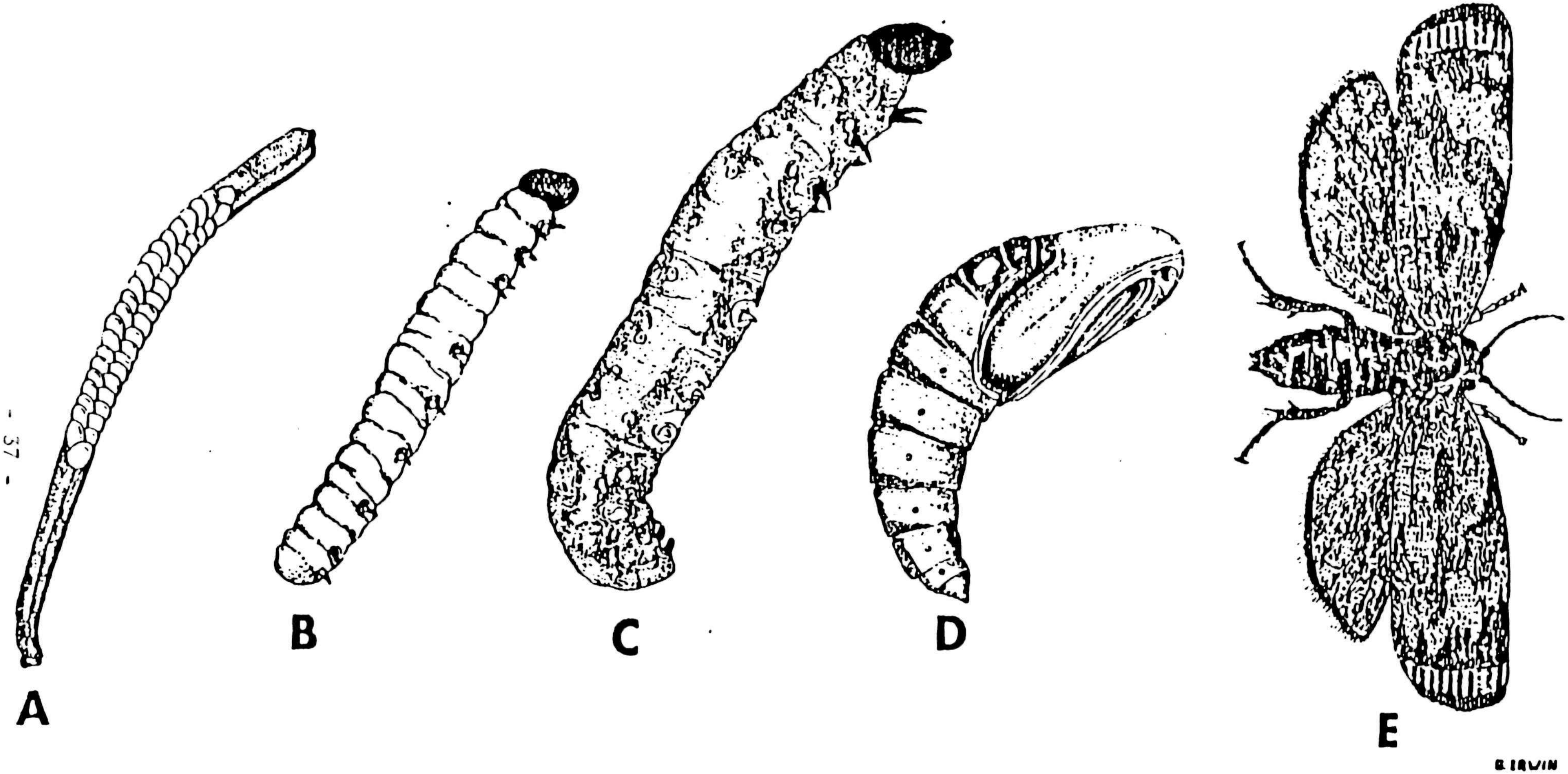


FIG. 2 COMPLETE METAMORPHOSIS OR GROWTH

(A) EGGS (B & C) LARVAE (D) PUPAE (E) ADULT

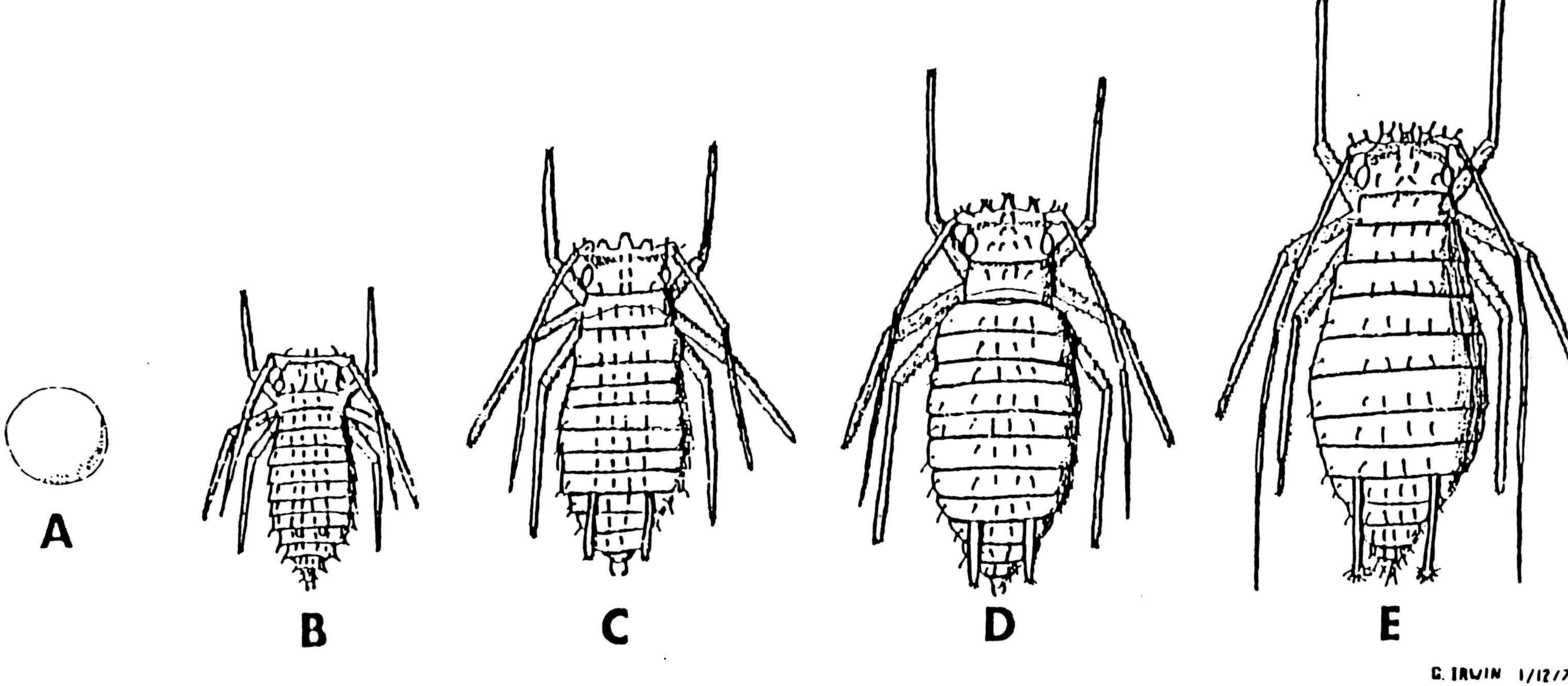


FIG.3 SIMPLE METAMORPHOSIS OR GROWTH

(A) EGG (B, C & D) NYMPHS (E) ADULT

CATEGORIES OF MAJOR FOREST INSECTS —THEIR PROBLEMS AND CONTROLS—

INSECTS AND THEIR POSITION IN THE ANIMAL WORLD

Insects are in the largest phylum of the animal kingdom - Arthropoda. The name is derived from the Greek terms arthron (joint) and pous (foot), referring to the jointed feet.

Within the phylum Arthropoda is the class Hexapoda or Insecta. The term Hexapoda is derived from the Greek, nex (six) and pous (feet) relating to the six feet of most adult insects. Insects compose the largest numbers, both in species and individuals, of the animal kingdom.

An insect can be generally defined as an air-breathing arthropod with a distinct head, thorax, and abdomen; one pair of antennae; three pairs of legs; and usually one or two pairs of wings in the adult stage.

Insects in contrast to many other forms of animals go through several different stages or forms during their development. This process is called metamorphosis. Most forest insects have complete metamorphosis in that the insect goes through four stages - egg, larva, pupa, and adult. The beetles, moths, and butterflies are examples of this group. (See Figs. 1 & 2) The aphids, scales, and true bugs have simple metamorphosis in that the insect goes through three stages - egg, nymph, and adult. The nymph looks similar to the adults. The principal changes during growth are in size, body proportions, development of the eyes, wings, and occasionally other parts. (See Fig. 3)

INNER-BARK, WOOD BORING INSECTS

Insects in this category belong primarily in the orders Coleoptera (bark beetles, ambrosia beetles, powder post beetles, weevils, flathead and roundhead wood borers); Lepidoptera (pitch moths); Hymenoptera (horntail wasps, carpenter ants); and Isoptera (termites). A few other insects may be in this category but are considered to be of minor concern to the forester.

The order Coleoptera contains insects that are the most destructive of all insects to forest and forest products. Most, but by no means all, of the injury is done by the larvae. These insects are characterized by having a complete metamorphosis and biting mouth parts. The first pair of wings, the elytra are hardened. The true wings when present are folded beneath them.

BARK BEETLES

The bark beetles, super family Scolytoidea, will be considered first as they are without question the most destructive group of insect pests to be found associated with coniferous forests. Besides killing living trees and breeding in the dying cambium of freshly felled trees and slash, some species bore pinholes through the sapwood of green logs and seriously reduce the value of the timber. Other members of the group are secondary in their attacks, and some breed only in dead and decaying wood.

By LeRoy Kline, Oregon Department of Forestry, Salem. In: Forest Pesticides in the Pacific northwest - 1984, Washington State Univ. Coop. Ext. Serv., Pullman, WA

General Habits

The Scolytoidea differ from most other groups in that the adults mine beneath the bark and excavate egg galleries in fresh phloem and so spend most of their active life out of sight.

The general method of attack is for the female beetle in monogamic forms or the male in polygamic forms, to select a host and find a suitable place for starting the burrows. Some species have no trouble starting their entrance on smooth bark, but others will spend considerable time seeking a roughened area, a crevice, or a junction of branch and trunk, evidently desiring to secure a firmer foothold while starting the excavation.

The entrance tunnel is gnawed by the parent adults through the bark, usually at a slight upward angle until the wood is reached. As the work progresses, fine reddish-brown boring dust and excrement are extruded through the entrance hole and collect in the bark crevices; or in the case of those species which attack the cambium of pine trees, pitch and sap exude from the entrance hole and harden at the surface in various forms of pitch or resin tubes. These external signs are the first indicators that a tree is currently infested with beetles.

The adult bark beetles carry with them the spores of fungi which germinate and apparently aid the beetle in overcoming the tree. The egg tunnels are constructed from the entrance tunnel along the surface of the wood. With some species the tunnels are almost completely within the bark and may or may not be packed with boring dust and excrement. Eggs are laid along the sides of these tunnels. The eggs hatch into larvae or grubs that construct mines away from the egg tunnel at different angles depending upon the species. These mines are packed with excrement and boring dust. With some species of bark beetles the mines are completely in the inner bark nd are exposed when the bark is removed. Others mine for a short distance in the outer bank, while some feed entirely in the outer bark.

The pattern of egg tunnels and larval mines of many species are separate and distinct from one another and is very useful in identifying the species of bark beetle.

Pupation occurs at the end of the larval mine in a cell constructed by the larva for that purpose. This may be in the outer bark or exposed in the inner bark. When the adult has become fully mature it emerges through a separate hole gnawed by it through the bark. Or in the case of species that work en masse, many individuals may use the same exit hole.

The adults may emerge at once and fly to attack new host trees or may congregate in cavities under the bark of the old host tree and hibernate or wait until sexually mature before emerging. Most adults do a certain amount of feeding under the bark before emerging. A few, upon emerging, feed upon twigs, buds, or bark of other trees before again breeding in the bark of new host. The food tunnels made in this way are quite distinct in character from the regular egg tunnels.

Life Stages

The adults are small, cylindrical, dark-brown, reddish-brown, or black beetles, ranging in size from 1mm in length to 10mm. Most species are unicolored, either shining or dull.

The head is either exposed or more or less hidden by the pronotum. The mouthparts are of the chewing type with well-developed mandibles. The antennae are elbowed at the middle and clubbed at the tip. The abdomen is completely covered by the elytra and has five segments beneath.

The eggs are usually very small, clear or pearly white, and oval, round, or slightly elongate.

The larvae are always legless, cylindrical and curved, white, or cream-colored, with a distinct head and prominent mandibles which are dark-colored.

The pupae are white when first transformed but gradually take on a yellowish color as they approach the time for transformation to the adult. The antennae, mandibles, legs, and wing pods are plainly visible on full-formed pupae.

Detection Methods

Bark beetle killed trees are best detected by ground and aerial surveys with the latter being the most efficient for large areas. The only problem with this method of detection is that in normal years most bark beetles have left the tree before it turns reddish-brown. There are some exceptions, during dry years infested trees may turn yellow-green in the late fall and winter. Infested pines may also fade while the mountain pine beetle is still in the tree.

The best method of detecting currently infested trees with bark beetles is by ground surveys, examining each tree for the presence of boring dust or pitch tubes. Final confirmation can always be done by removing a piece of bark.

Evaluation Methods

A rough estimate of population trend and damage can be made by comparing the numbers of previous years' faded tree crowns with current infested trees. Another method of determining population trend is to sample beetle populations under the bark. This method of sampling provides an opportunity to evaluate natural control factors that influence brood development.

Control Methods

Control of bark beetles can be classed into direct or indirect.

The objective of direct control is to kill or reduce the population of beetles in an area. Infested trees can be treated by one of several methods to destroy the brood. Often the attacked trees are sacrificed to protect their neighbors. No method has, as yet, been developed to save a tree once it has become infested with bark beetles.

Direct control practices in the past, and still used occasionally today in small areas, are fell-peel-burn, fell-deck-burn, fell-peel, fell-peel-spread bark, solar heat, and submerging the infested log. The trap-tree method that has been used in Europe has had varying degrees of success in the West. Penetrating oils and various insecticides began to be used since WW II on individual trees. Some preventive of prophylactic types of insecticides have also been used to protect high value standing trees and logs.

All of the above treatments are very costly and time consuming and therefore are not practical over large areas.

Another method that may be considered as direct control is the cutting and salvage of the infested trees through logging operations. This method serves the dual purpose of reducing some of the beetle population and salvaging timber that otherwise would be completely worthless within a short time. There are several problems with this method, however. Currently infested trees as mentioned under detection methods, have to be located and removed before beetles emerge. The practice is also limited to economic species and accessible stands.

Recently tests have been conducted using various chemical compounds called pheromones, attractants, or antiaggregates to manipulate beetle populations. Some of these techniques appear very promising and may be operational in the future.

However, the best long-term approach is through indirect silvicultural practices. For the most part the approach is by managing vigorous, healthy trees and stands by maintaining the stocking and age at certain levels for each species and site.

WEEVILS

A few species of weevils will infest weakened trees in much the same way as bark beetles. Their impact is usually insignificant.

The greatest problem with weevils is in regeneration. They will be discussed in greater detail under the regeneration chapter.

PITCH MOTHS

These moths in the order Lepidoptera are also called clear-winged moths because of the narrow, more or less transparent wings. The adults are strikingly beautiful and wasplike, looking generally nothing like moths. They are day fliers and move very swiftly and hence are seldom seen.

Eggs are laid on the bark and wounds of trees. Healthy and faster-growing trees seem to be preferred. Young stands are most susceptible to injury. Older trees having rough and thick bark are more immune, except where old wounds invite reinfestation.

The larvae are whitish and have a dark rounded head. Most of their activity is in the cambium region of the tree. Two years can be spent in the larval stage. The larvae are seldom directly responsible for the death of a tree. However, growth is reduced and the tree weakened with numerous attacks around the circumference of the tree. Damage consists of pitch seams, pitch pockets and checks in what would otherwise be absolutely clear lumber.

The problem caused by these moths can be reduced only on high value :rees. Control over extensive areas is not practical.

WOOD BORERS

This group contains many types of insects and each will be discussed separately. As a rule they are generally considered as being secondary, infesting weakened and dead trees, and various forest products. Detection, evaluation, and control methods for this group are similar to the bark beetles.

Ambrosia Beetles

This group of beetles has the habit of excavating their mines directly into the sapwood and heartwood of various trees, making so-called "pinholes." The frass or boring dust that these insects create is whitish and thus a means of separating their attack from bark beetles.

These insects are known as the ambrosia beetles because of their habit of propagating certain fungi called ambrosia which are eaten by both adults and larvae. This is one group of beetles that care for their young in much the same manner as do certain forms of social Hymenoptera, bees, ants, and wasps. The adult beetles carry in the fungus spores, prepare beds for them, and tend the gardens, whice are fertilized by larval excrement. Each species has its own special variety of fungus. There must be a certain amount of moisture present in the wood or the fungus will not grow. Each colony will continue in a given host as long as conditions are right for the growth of their fungus food, but will abandon a tree as soon as it begins to dry out. Trees attacked by these beetles are dead or dying and the wood in a fermenting condition before the attack is made.

The principal injury is caused by the pinhole galleries and the staining of the wood around the galleries by the ambrosial fungus. Little effort has been made in controlling these beetles outside of Canada.

Powder Post Beetles

These insects like the ambrosia beetles work entirely in the wood. They prefer dead trees and very old, dry wood. The beetles can live generation after generation in the same material, ultimately completely honeycombing it and reducing much of it to a condition of fine powder, hence the common name.

In the virgin forests these insects are most useful in that they assist in doing away with old, useless woody materials. Most of the destruction occurs when they attack the lumber and wood products such as furniture, docks, ax handles, etc.

Flathead or Short Horn Beetles

The larvae of the family Buprestidae are white, legless, and flatheaded resembling a horse shoe nail, thus the name flatheads. The boring dust produced is whitish and coarse. Adults are often beautifully marked, metallic-colored, oval beetles with relative short antennaes and are called short horn beetles.

The adults in contrast to the bark beetles do not mine under the bark. They lay eggs on the bark of freshly felled, fire killed, or weakened trees, and in a few cases, fresh sawn lumber. The larvae mine the cambium and eventually into the sapwood. Pupation occurs in the wood, cambium, or inner bark, depending upon the species. Some species have a one year life cycle and have habits similar to bark beetles. Others can spend many years (15 years have been reported for some species) in the log or processed lumber. Most of the beetles can be considered secondary by the forester. However, a few species appear to be more primary in that they can infest standing trees, apparently severely weakened by drought of other environmental factors.

The wood borers that mine stumps, branches, and old dead trees are beneficial as their mines increase the rate of disintegration in such material.

Some preventive type of treatments have been developed with insecticices. Proper forest management and sanitation is the best, long-term solution.

Roundhead or Long Horn Beetles

Adults of the family Cerambycidae are much larger than the preceding groups and have long antennae, often three times as long as their body and thus the name long horn beetles. The larvae are creamy-white and cylindrical and are called roundheads.

The whitish boring dust is more coarse than the other borers, often containing long fibers of wood.

The habits, life cycle, damage, and control of insects in this family is similar to the Buprestids.

Horntails

These wasps in the order Hymenoptera and family Siricidae are called horntails because the abdomen bears a hornlike projection. This projection is short in the male, but longer and spear-shaped in the female. The ovipositor is attached to the middle of the abdomen and is fitted for boring. The female lay their eggs through the ovipositor which is thrust into the bark for distances up to an inch. At times the insect is unable to remove the ovipositor from the bark and the living or dead bodies are sometimes found fastened on the trunks of trees.

Adults are attached to freshly felled timber and trees that have been scorched by fire. Females have been observed ovipositing in scorched logs that are too warm to keep one's hand on. These wasps seem to be attracted to smoke and can become so numerous so as to be a nuisance to firefighters.

The larvae which have a prominent spine at the top of the body mines in the wood. Damage is similar to the flat and round headed wood borers.

Carpenter Ants

The ants, like the horntail wasps, are in the order Hymenoptera but in the family Formicidae. They often construct their tunnels in stumps, fallen logs, and portions of standing trees. For the most part, they are beneficial to the forester in helping to decay waste wood. Species in the genus *Camponotus* are most destructive when they infest structural timbers.

Carpenter ants bore in wood to provide living quarters, but do not feed on it. They expel their borings or "sawdust" from their mines. In contrast termites consume the wood in which they live and hence no "sawdust" marks their presence.

Preventive and corrective controls can be applied by pest control operators and home owners.

Termites

These insects are in the order Isoptera. They are like the carpenter ants in that they are very destructive to wood and wood products. However, they are beneficial in the forest in helping to decay logs and stumps.

Termites are a dirty-white, yellowish, or light-brown. There is no constriction between the thorax and abdomen as in the case of ants.

Their activity is usually associated with moist wood, dry-rot, and sometimes carpenter ants. Some species can live without contact with the ground, whereas others need soil connection.

Prevention and control measures are generally the same as for carpenter ants.

DEFOLIATING INSECTS

Defoliating insects next to the beetles are undoubtedly the most important group affecting forest trees. The larvae feed on and in the needles of conifers and leaves of broadleaf trees, thus depriving the trees of the ability to assimilate and manufacture food. In some cases, the entire tree may be defoliated in a short time and the tree killed. Where defoliation is not too severe, top, branch, twig, bud and cone damage occurs. Growth, both height and diameter, is also reduced. The weakened trees are very susceptible to bark beetle attack or attack from other destructive pests.

Most of the forest defoliators are in the order Lepidoptera (moths, butterflies, loopers, case bearers, needle miners) and Hymenoptera (sawflies).

General Characteristics

Adult insects in the order Lepidoptera have the following general characteristics: the presence of two pair of functional wings (Douglas-fir tussock moth female has only tiny rudimentary wings) which are covered with scales; the forewings are larger than the hind wings. The venation of the wings may be used to separate families and occasionally species. In most species, the mouthparts are modified into a characteristic long, slender, flexible, sucking proboscis.

The larvae or caterpillars are well-known and readily recognized by most people. They are generally characterized (with few exceptions) by possessing three pairs of jointed legs on the first three segments behind the head and from three to five pairs of short, fleshy, unjointed legs called prolegs on the abdominal segments. The mouth parts are of the chewing type.

The order Lepidoptera is divided into two groups, the moths and butterflies. They may be easily separated in the mature stage by the following characteristics:

1. Moths: Antennae of various forms, but never with a knobbed tip. Most are night or twilight fliers. Wings usually folded along abdomen or spread horizontally when at rest. The pupa is often enclosed in a silken cocoon.

2. Butterflies: Antennae slender for most of its length, with the tip dilated to form a knob. Most are day fliers. Wings are held vertical when at rest. Pupa is exposed, never enclosed within a cocoon.

Detection Methods

In the past outbreaks of forest defoliators were generally first detected during aerial surveys and occasionally on the ground. By this time the epidemic was well on its way and with damage already occurring. In recent years other detection methods have and are being developed. The first of these was the establishment of monitoring plots in susceptible stands. The lower branches of selected trees are beaten or shaken with a stick to dislodge insects. The insects fall onto a cloth, are collected, counted and identified. Populations can thus be monitored, increase in numbers noted, predictions made, and perhaps control measures taken before significant damage occurs. The main targets of this system are the western and Modoc budworms, Douglas-fir tussock moth and sawflies.

Pheromones (sex attractants) are being developed and appear promising for the Douglas-fir tussock moth and budworms. The chemicals are placed in traps and the males caught as they respond. Again as in the case of the "beating plots" the objective is to detect populations and make predictions before significant damage occurs.

Evolution Methods

When significant populations or damage is detected, evaluation surveys are made of the eggs and in some cases the larvae. Larval populations per given unit of foliage can thus be estimated after analyzing various factors such as number of eggs, egg viability, parasitism, etc.

Control Methods

Control of defoliators has been the most widespread, successful and even controversial of the forest insect programs. Suppression measures have been and probably will continue to be by applying insecticides from the air. The insecticides include conventional chemical compounds, viruses, bacteria, pheromones, juvenile horomones and feeding deterrents. Insect parasites can be at times effective in regulating certain populations. Entomologists have tried establishing foreign parasites in the case of introduced defoliators such as the larch case bearer. Stand management practices may have some effect upon defoliator management, but much more research is needed.

SUCKING INSECTS

All the insects discussed in the preceding section feed upon the tissues of trees by ingesting the solid parts. All of them have mandibulate or chewing mouth parts. There is another large and important group of insects that live upon the sap of plants. Their mouth parts are of the sucking type in which the parts have become slender bristle-like organs enclosed in a sheath. The mouth parts thus form a beak, used to pierce the tissues and such the fluid therefrom.

The effect of sucking insects upon trees is much less conspicuous than is the effect of defoliators and bark beetles. Only a few species seem able to kill trees directly.

Sucking insects may injure forest trees in the northwest in two ways: (1) directly by sucking the sap, thus robbing the plant of a part of its supply of food and water; and (2) indirectly by producing necrotic spots of swellings.

The sucking insects attacking trees belong to two orders: the Hemiptera and Homoptera.

MITES

The mites, in the class Archnida, do not belong to the same class as the insects, class Insecta. However, most people consider them as kinds of insects and the entomologist is usually called upon to provide information in regard to them. They have bodies divided into two segments instead of three and have four pairs of legs instead of three. The mites are extremely small and have sharp-pointed, piercing mouth parts.

Most of the mites considered to be important on forest or ornamental trees are called SPIDER MITES in the genera Tetranychus and Paratetranychus. They suck the juices from needles causing spotting, fading, yellowing, or heavy needle fall. Heavy infestations make the trees appear as if they were scorched. Heavy silvery webs are often associated with the damage.

Populations of mites often increase after periods of long, dry, hot weather and in areas receiving repeated insecticide treatments. Direct control can be achieved by "washing" individual trees with high water pressure, applying dormant sprays, some insecticides, or miticides.

REGENERATION INSECTS

This section will deal with a broad cross section of insects that attack the seeds, cones, seedlings, and plantations of forest trees. As the old growth forest are being replaced by intensively managed stands of high quality trees, these insects will be more important. This area is just now beginning to receive attention and techniques being developed.

CONE AND SEED INSECTS

Insects that destroy the seeds of forest trees have an important bearing on reforestation, regardless of whether the seeds are in natural areas or seed orchards.

In the natural forests the impact of cone and seed insects is quite variable. Most tree species produce heavy seed crops periodically, the heavy crops being interspersed by years when seed production is light. This periodic production appears to have a profound effect upon insect populations that feed upon seeds and cones. When their food is scarce, the insect populations become low and generally when a bumper crop occurs, the number of seed eaters present is too low to destroy a large proportion of the seeds. Occasionally, however, there may be two successive "seed years." When this happens the seed insects may build up to high numbers during the first seed year so that the crop produced the following season may be almost completely destroyed.

The variation between the number and size of trees, acres, terrain, and seed years makes management of cone and seed insects in natural forests difficult and relatively uneconomical. Little effort has been made to reduce the impact of these insects. Their damage goes unchecked and foresters take what they can get.

In recent years attention has been directed toward the improvement of tree varieties by selecting and breeding elite individuals either in seed production areas or seed orchards.

Seed orchards lend themselves to best insect management and it is also here that the greatest impact can occur. Destruction of seeds may be caused by insects that attack the buds, flowers, immature, and mature cones, as well as by those that attack the seeds themselves.

Cone and seed insects include representatives from a number of orders and families of insects. They include various species of beetles, borers, moths, maggots, chalcids, and true bugs.

Increase in sound seed from seed production areas and seed orchards is being studied and conducted through (1) prevention practices; (2) direct control using chemicals; and (3) an integrated approach using several methods.

Prevention methods include (1) The establishment of seed orchards remote from, rather than adjacent to, natural stands of the same species - in this way they are less likely to be infested by insects that occur in natural stands. (2) Delay the flowering time of trees by spraying with cold water or other methods - most of the major seed-destroying insects lay their eggs in the spring when flowers of the host are being pollinated. Trees that flower earlier or later than normal are less susceptible to attack. (3) Removal of all cones from orchard areas each year may ensure that most harmful insects are removed and thus reduce the likelihood of severe attack the following year. (4) Protective screen wire cages around each cone can also increase the sound seed yield per cone.

Seed losses to insects in seed orchards or seed production areas can also be reduced with insecticides if preventive measures do not prove satisfactory. To date, best results have been achieved by applying systemic insectides as granules or liquid around the base of each tree, foliar sprays or injections into the trunk.

The use of synthetic pheromones or attractants and blacklight trapping may also reduce insect populations. Then too, a combination of several techniques may be useful in pest management system.

NURSERY INSECTS

Seedlings in forest nurseries, whether grown in containers or as bare roots, are susceptible to a number of insects that attack the roots, stems, and leaves. These insects are able to inflict more injury at this stage than later when the trees have developed larger root, stem, and needle systems. Nurseries like seed orchards can have more pest problems because of the monoculture environment.

The major groups of insects infesting seedlings are weevils, white grubs, cutworms, wireworms, aphids, scales, sod webworms, beetles, earwigs, grasshoppers, thrips, and mites. Some of these insects are considered forest insects, while others are agricultural-related insects adapting themselves to a new environment. The insect problems can be quite variable between nurseries and from year to year.

Some preventive measures such as soil fumigation or treating the soil with insecticides are done on an annual or biennial basis for soil inhabiting insects. To date, most of the control measures have been the use of conventional chemicals. Nurseries like the seed orchards lend themselves to other types of insect management techniques such as blacklight trapping, pheromones, and attractants. Plowing beds and planting them to cover crops or allowing them to remain fallow for at least a year may help to reduce some insect populations. Other procedures are being developed and used to monitor insect populations in some nurseries and control action taken before significant damage occurs.

PLANTATION INSECTS

This group of insects like the cone and seed and nursery insects has received very little attention in the past, as foresters and entomologists have been more concerned with insects in old-growth stands. The number and size of plantations are increasing as we go into young growth management and we can expect these insects to cause more problems.

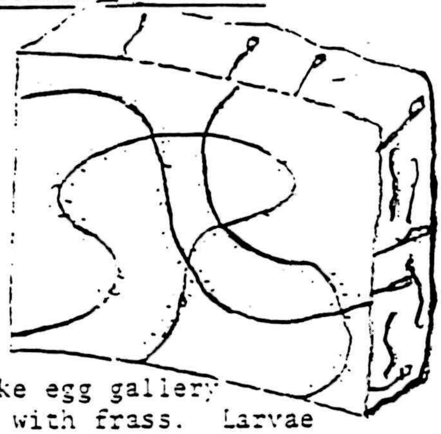
These insects cause impacts to young trees by (1) extensive killing of lateral branches and terminal leaders; (2) deformation of the trees, resulting in forked or multiple tops; (3) reduction of tree growth which prolongs the time required for trees to reach merchantable size; and (4) occasionally trees are killed.

INSECT	Ponderosa pine	Jeffrey pine	Sugar pine	Lodgepole pine	Coulter pine	Douglas-fir	White fir	Red fir	Incense-Cedar	Redwood
	HOSTS									
CAMBIUM FEEDERS										
Bark Beetles										
Western pine beetle <u>Dendroctonus brevicomis</u>	DB				DB					
Mountain pine beetle <u>D. ponderosae</u>	DM		DM	DM						
Jeffrey pine beetle <u>D. jeffreyi</u>		DJ								
Douglas-fir beetle <u>D. pseudotsugae</u>						DP				
Red Turpentine beetle <u>D. valens</u>	DV	DV	DV	DV	DV					
Cedar bark beetles <u>Phloeosinus</u> spp.									PH	
Redwood bark beetle <u>P. sequoiae</u>										PR
Engravers										
Fir engraver <u>Scolytus ventralis</u>							SV	SV		
Douglas-fir engraver <u>S. unispinosus</u>						SU				
Borers										
California flatheaded borer <u>Melanophila californica</u>	MC	MC	MC		MC					
Fir flatheaded borer <u>M. drummondi</u>						MD	MD	MD		
Roundheaded fir borer <u>Tetropium abietis</u>							TE	TE		
DEFOLIATORS										
White fir sawfly <u>Neodiprion</u> spp.							SF	SF		
Douglas-fir tussock moth <u>Orgyia pseudotsugata</u>							OP			
White fir needleminer <u>Epinotia meritana</u>							EM	EM		
Jeffrey pine needleminer <u>Coleotechnites</u> spp.		CN								

INDICATORS FOR BARK BEETLES, ENGRAVERS AND FLATHEADED BORERS

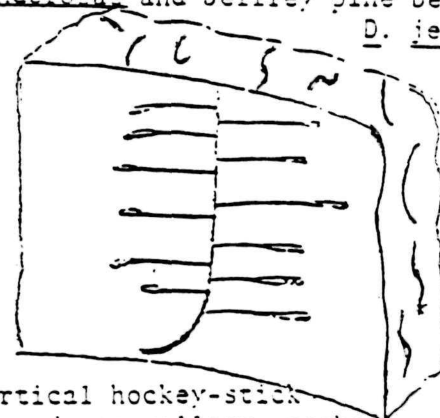
Indicator	Insect								
	DB	DJ	DM	DP	DV	IP	SV	MC	MD
Portion of tree attacked	Entire bole to an 8" top	Entire bole to an 8" top	Entire bole to a 6" top	Entire bole to an 8" top	Generally, the basal 3'	Tops of large trees and entire bole of small trees	Tops, patches and entire bole	Entire bole and limbs	Entire bo and limbs
Resin flow, pitch tubes or boring dust	Pitch tubes (Small)	Pitch tubes (Medium)	Pitch tubes (Medium)	Boring dust (Red)	Pitch tubes (Large)	Standing trees -- small pitch tubes and boring dust. Slash-- boring dust	Resin flow	Resin flow and coarse boring dust	Resin flo and coars boring du
Woodpecker work	Flaking in large patches -- cambium not exposed	Individual holes to cambium layer	Individual holes to cambium layer			Flaking in patches--cambium partially exposed		Individual holes to cambium layer	
Gallery Pattern	SEE NEXT PAGE								
Hosts	PP, CP	JP	SP, PP, LPP	DF	All Pines	All Pines	RF, WF	All Pines	RF, WF, D Bigcone D

DB
Western Pine Beetle
Dendroctonus brevicomis



Net-like egg gallery packed with frass. Larvae in bark.

DM & DJ
Mountain pine beetle, Dendroctonus ponderosae and Jeffrey pine beetle, D. jeffreyi



Vertical hockey-stick shaped egg gallery, packed with frass--1' to 3' long. Horizontal larval mines in phloem-cambium layer

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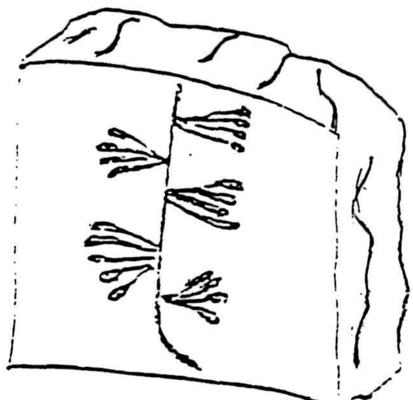
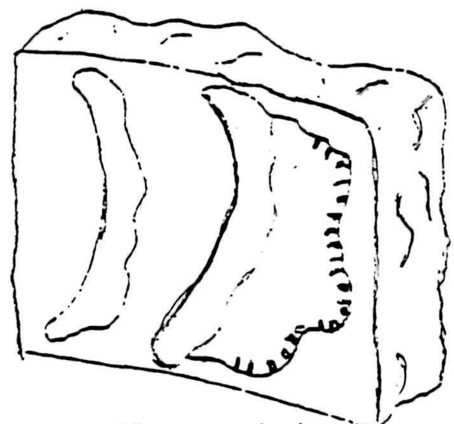
DP
Douglas-fir beetle, Dendroctonus pseudotsugae



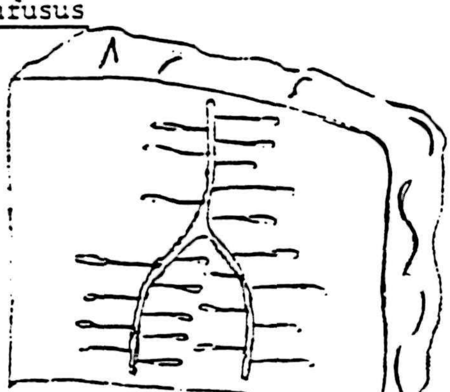
Vertical hockey stick-shaped egg gallery packed with frass--1' to 3' long. Horizontal larval mines in phloem-cambium layer.

DV
Red turpentine beetle, Dendroctonus valens



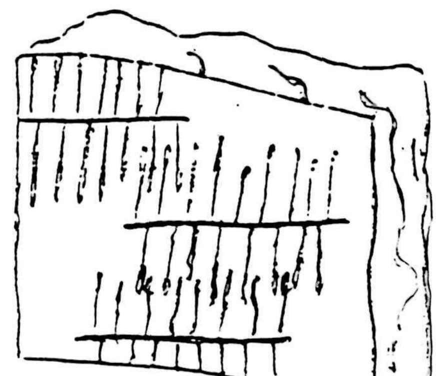
Large egg gallery packed with frass. Larvae clustered in large excavation.

IP
California fivespined ips, Ips paraconfusus

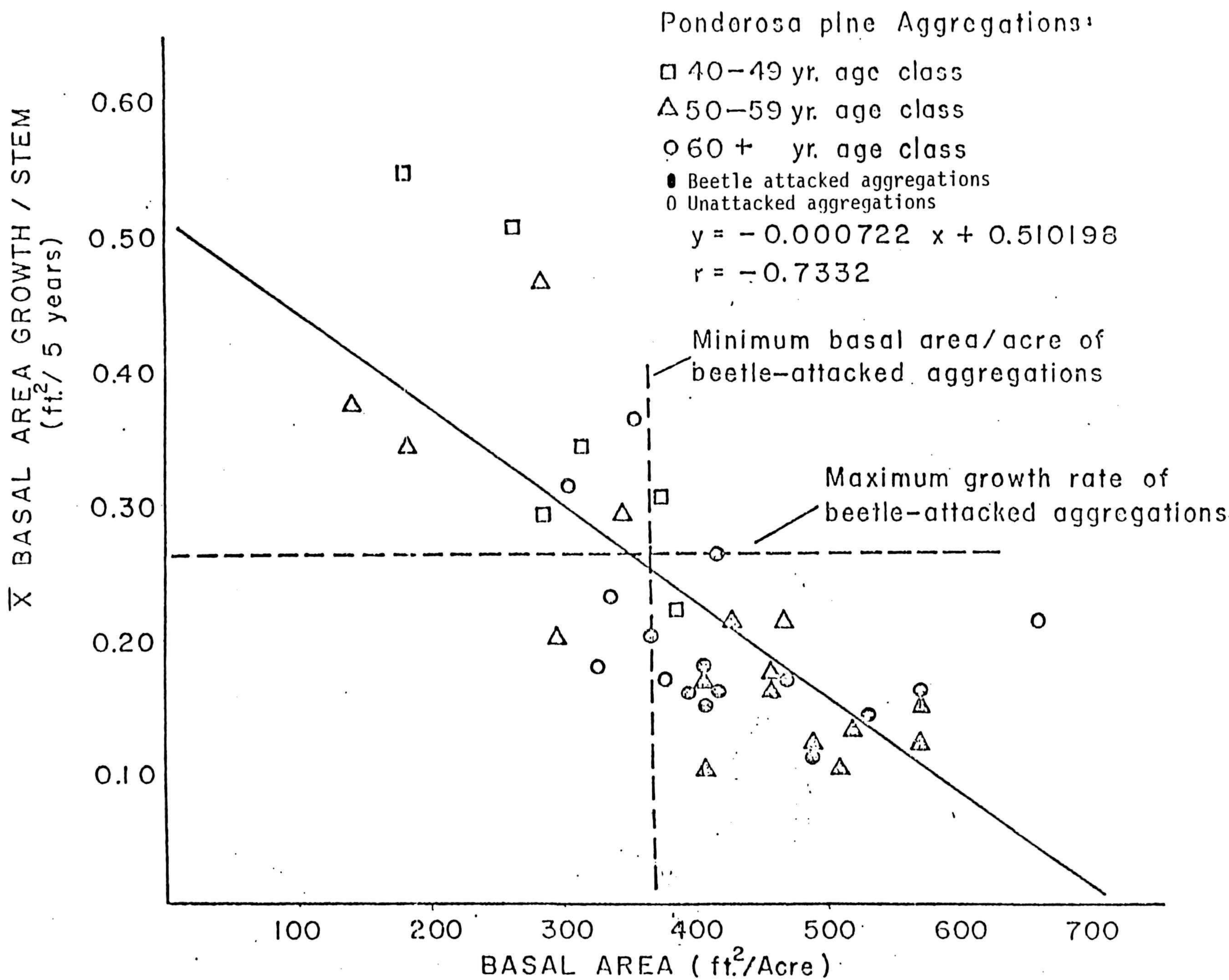


Tuning fork-shaped egg gallery, free of frass. Xylem is etched.

SV
Fir engraver, Scolytus ventralis



Horizontal egg gallery with vertical larval mines. Xylem is etched.



tural treatments to reduce losses to bark beetle. Cal. Agr. 32(7):12-13

BASAL AREA GUIDELINES FOR MIXED CONIFER

SITE[2]	NORMAL[1]					TAHOE DESIRED						55 PERCENT OF NORMAL[4]				
	1A	1	2	3	4	1A	1	2	3	4	%[3]	1A	1	2	3	4
AGE																
30	164	155	146	138	131							90	85	80	76	72
40	219	208	196	184	175							120	114	108	101	96
50	257	244	230	216	205	183	174	163	153	145	71	141	134	127	119	113
60	278	264	248	234	222	204	193	182	170	161	73	153	145	136	129	122
70	295	280	264	248	236	222	210	198	185	175	75	162	154	145	136	130
80	310	294	277	260	247	237	224	211	198	188	76					
90	322	305	288	271	257	250	237	223	209	199	77					
100	333	316	298	280	266	261	247	232	218	207	78					
110	342	324	305	287	273	271	257	241	226	215	79					
120	350	332	312	294	279	280	265	249	234	222	80					
130	357	338	319	300	285	287	272	256	240	229	80					
140	363	344	324	305	290	294	279	262	247	234	80					
150	369	350	329	310	294	297	281	264	249	234	80					

1/ Normal; Dunning and Reinecke (1933)
2/ Sites correspond to Dunning and Reinecke's 80, 70, 60, 50, 40 respectively
3/ For all sites desired basal areas range from 71 to 80% of normal
4/ 55% of normal is probably not a good guideline in stands over 70 years

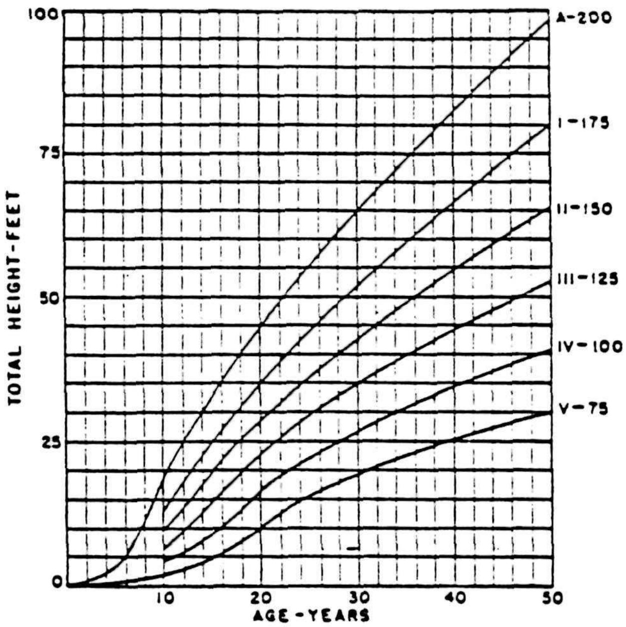


FIG. I

Res. Note No. 28

A SITE CLASSIFICATION FOR THE MIXED CONIFER SELECTION FORESTS OF THE SIERRA NEVADA

1942

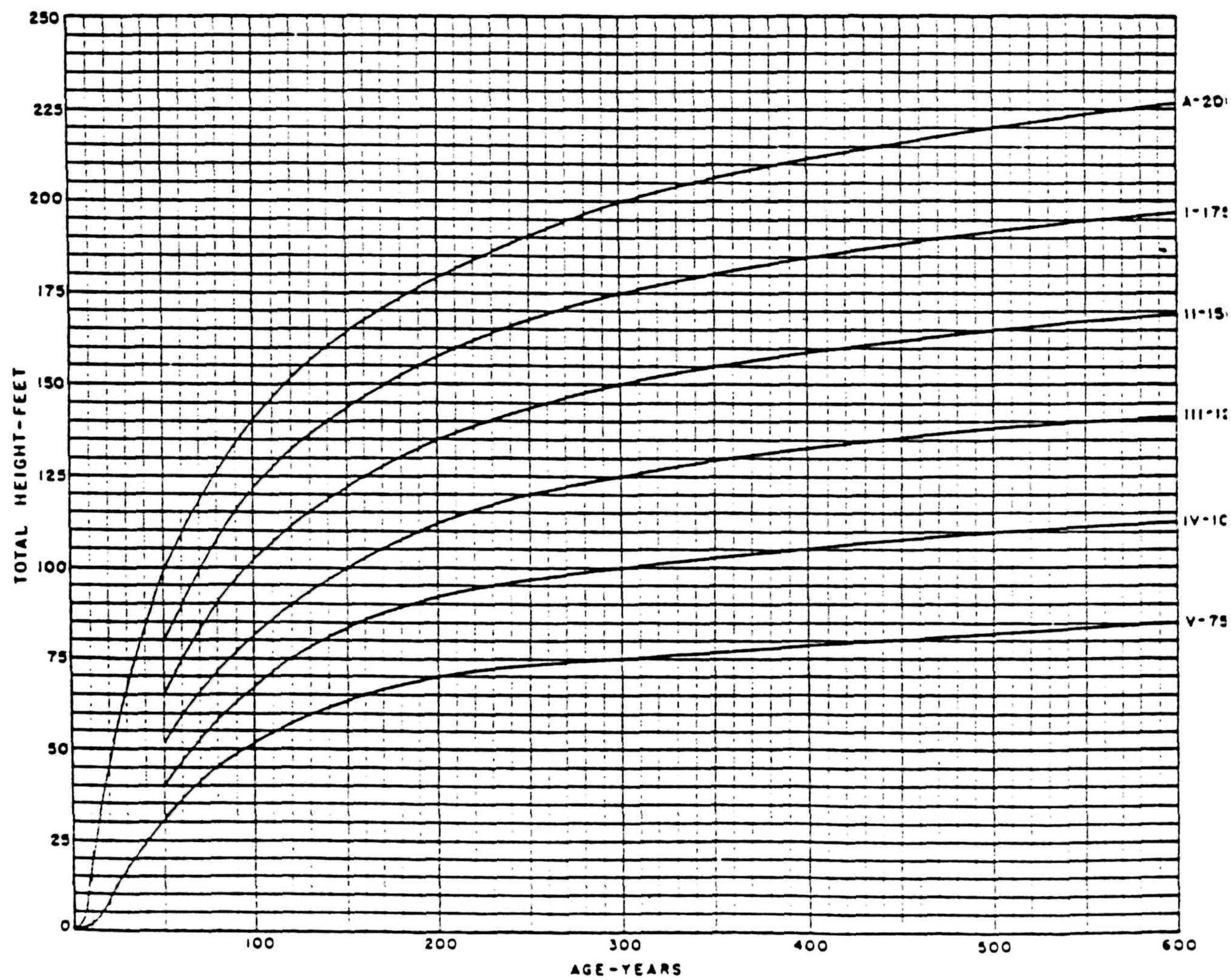
Duncan Dunning

CALIFORNIA FOREST & RANGE EXPERIMENT STATION

M. W. Talbot, Acting Director

Forest Service

U.S. Department of Agriculture



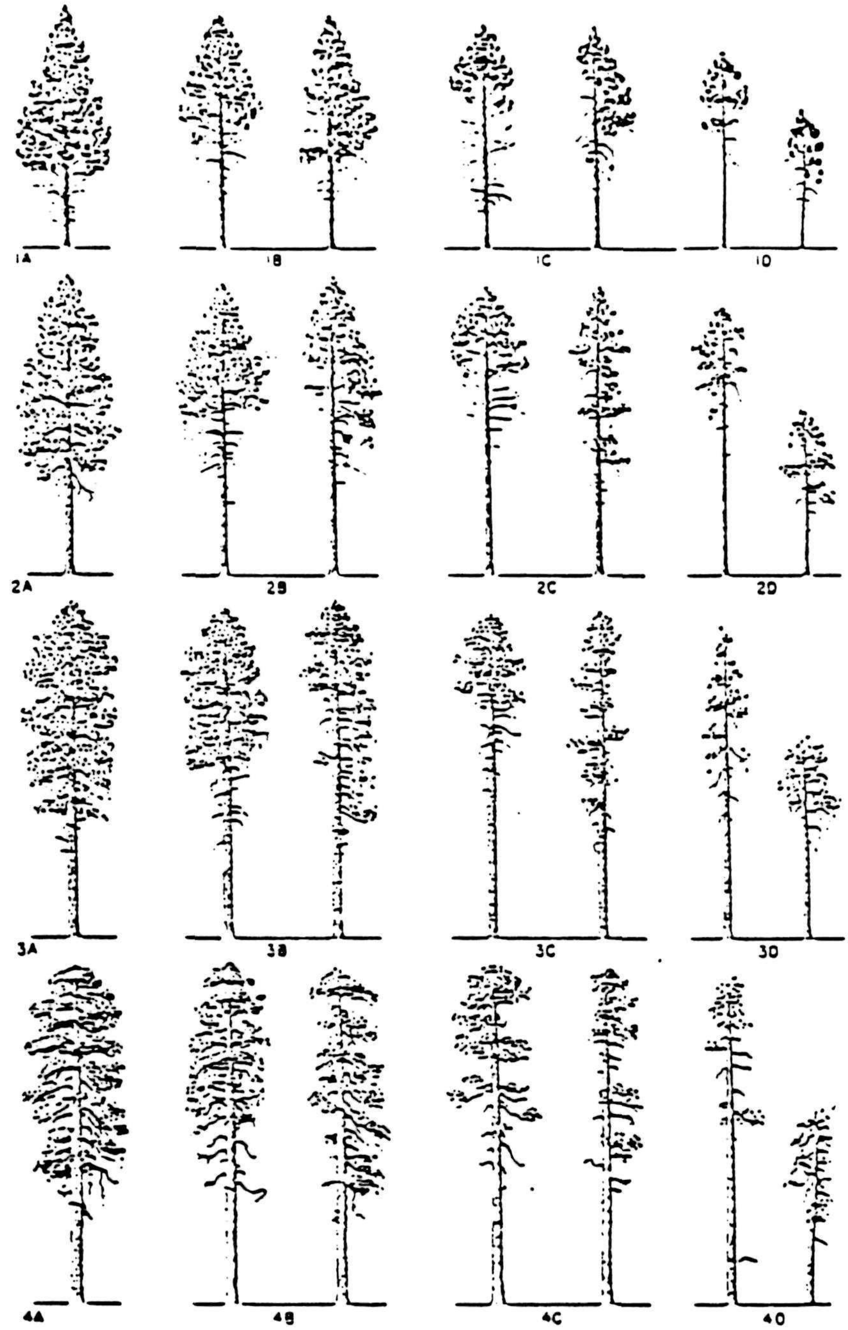


FIGURE 40.—A ponderosa pine tree classification based on age and vigor.

Table 1

Description of Keen's Tree Classes

Age Classes

Class 1	Class 2	Class 3	Class 4
Young trees. Commonly referred to as "bull pines" or "black jacks"; thrifty trees making rapid height and diameter growth; age usually less than 80 years. D.b.h.--Rarely over 20 inches. Height.--In lower crown canopy; usually less than 60 per cent of total mature height. Bark.--Dark, grayish brown to black; rough, and deeply furrowed without plates, but with narrow ridges between the fissures (sometimes coloring at extreme base). Branches.--Upturned and in whorls for upper three-fourths of crown; small for diameter of bole. Top.--Usually pointed, with distinct whorls.	Immature trees. Still making rapid height and diameter growth in thrifty trees; age approximately 80 to 180 years. D.b.h.--Rarely over 30 inches. Height.--Usually less than 90 per cent of total height at maturity. Trees still under the general crown canopy. Bark.--Dark reddish brown, with narrow, smooth plates between the fissures on lower half of bole; dark, rough bark on upper half. Branches.--Mostly upturned and in whorls for upper half of crown; horizontal near middle, horizontal or drooping below; small to medium size for diameter of bole. Top.--Usually pointed, sometimes rounded, but with whorls indistinct.	Mature trees. Height growth practically complete; diameter growth slow; age approximately 180 to 300 years. D.b.h.--Rarely over 40 inches. Height.--Practically that of the general crown canopy, except intermediate, suppressed, or top-killed trees. Bark.--Light reddish brown with moderately large plates between the fissures on lower three-fourths of bole; dark bark showing in upper quarter. Branches.--Upturned near top, middle crown horizontal, lower ones drooping; moderately large for size of bole. Top.--Usually pyramidal or rounded, occasionally pointed; whorls indistinct except at extreme top.	Overmature trees. Making no further height growth; diameter growth very slow; age more than 300 years. D.b.h.--Wide latitude in diameters, but usually large in dominant trees. Height.--Full height of general crown canopy, except suppressed, spike-topped, or broken trees. Bark.--Light yellow and uniform for entire bole, except in extreme top; plates usually very wide, long, and smooth; fissures often rather shallow. Branches.--Large, heavy, and often gnarled or crooked; mostly drooping except in extreme top. Top.--Usually flat; occasionally rounded or irregular.

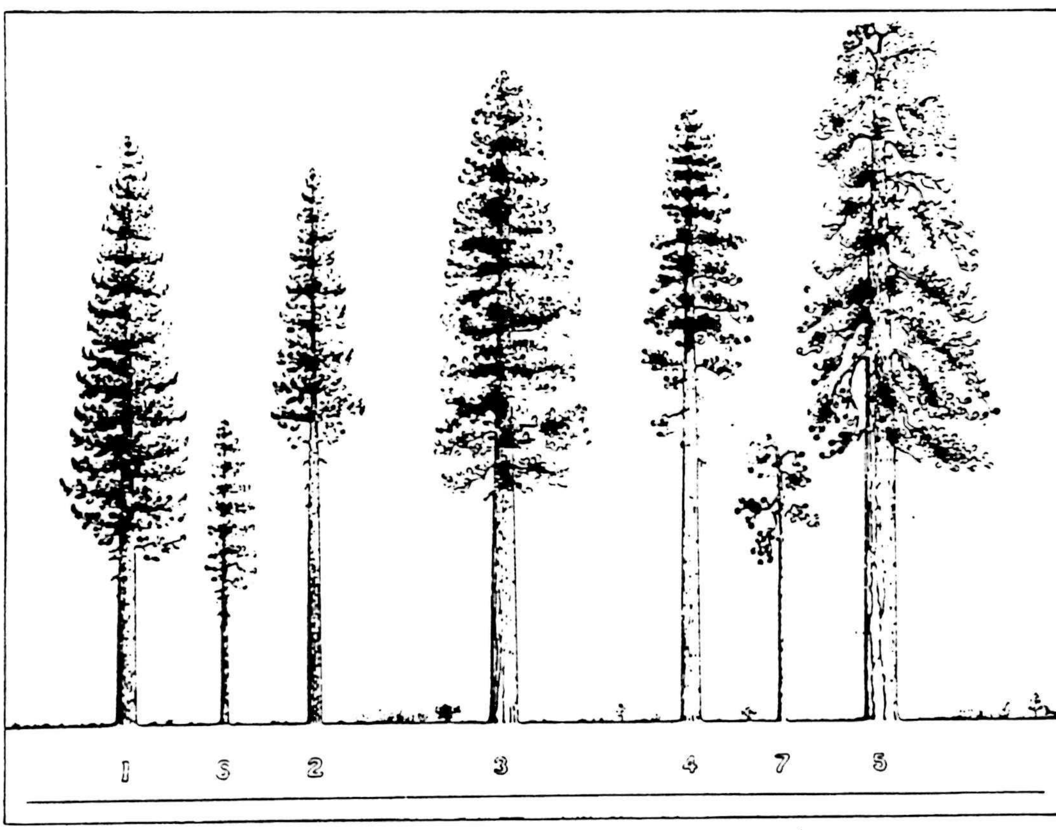
Crown-Vigor Classes

Class A Full Vigor	Class B Good to Fair Vigor	Class C Fair to Poor Vigor	Class D Very Poor Vigor
Crown.--Full vigorous crowns with a length of 55 per cent or more of the total height, and of average width or wider; with density average or better, for its age class. Foliage.--Needles of average length or longer, usually dense and thrifty. Position.--Usually isolated or dominant, rarely codominant. D.b.h.--Large for age.	Crown.--Good to moderately vigorous crowns, with length from 30 to 55 per cent of total height, if of average width and density; or a longer crown if narrow or somewhat thin; but neither sparse nor ragged. Foliage.--Needles of average length, usually dense and thrifty. Position.--Usually codominant, but sometimes isolated or dominant; rarely intermediate. D.b.h.--Average or above for age.	Crown.--Fair to poor crowns, with length from 10 to 30 per cent of total height if of average width and density, or long, sparse, and narrow; often flat on one or more sides. Foliage.--Needles often short and thinly distributed, but of normal length and density when confined to top one-third of crown. Position.--Usually intermediate, sometimes codominant or suppressed, but rarely isolated. D.b.h.--Usually below average for age; sometimes large in decadent trees.	Crown.--Very short, less than 10 per cent of the total height; sometimes merely a tuft at top of tree, or somewhat longer when sparse and ragged; usually very narrow or limbs all on one side. Foliage.--Needles often short, and foliage sparse or scattered, or only tufts at end of twigs; but of normal length and density if reduced in quantity. Position.--Usually suppressed or intermediate, but may occupy other positions if greatly reduced in vigor. D.b.h.--Decidedly subnormal for age, but very old decadent trees may be of large diameter.

Notes

DESCRIPTION OF DUNNING'S TREE CLASSES

Item	1	2	3	4	5	6	7
Age Classes (Approximate)	Immature-Thrifty (60-150 Yrs)	Immature-Thrifty (60-150 Yrs)	Thrifty-mature or mature (150-300 Yrs)	Mature (150-300 Yrs)	Over-Mature (Over 300 Years)	Immature (60 - 150 Yrs)	Mature and Over-mature (Over 150 Yrs)
Position	Isolated or Dominant	Usually Co-dominant	Isolated or Dominant	Usually Co-dominant	Isolated or Dominant	Intermediate or Suppressed	Intermediate or Suppressed
Crown lengths (Approximate)	65% or more	Up to 65%	65% or more	Up to 65%	Any length	Usually short	Usually short
Crown width	Average or wider	Less than Average	Average or wider	Less than Average	Any width	Any width	Any width
Seed bearing capacity	Fair	Poor	Very good	Greatest insect risk. Fair to Good.	Very good	Very poor	Poor
Form of top	Pointed	Pointed	Rounded	Rounded	Flattened	Pointed Rounded	Flat
Vigor	Good	Good - Moderate	Moderate	Moderate - Poor	Poor	Moderate - Poor	Poor
Diameter (Approximate)	Rarely over 30 inches.	Up to 24"	18" to 40"	Except for the small, poorly developed crown, smaller size, and lower vigor, similar to Class No. 3.	Largest Trees	12" to 16"	Rarely over 18".
Bark	Dark, Ridges or small plates.	Dark; Ridges or small plates	Light brown or yellow; mod. large plates		Light yellow; wide, long smooth plates	Dark and rough ridged	Light yellow, thin and flat
Foliage	Rich green, dense, needles long and coarse	Rich green, mod. dense, needles long and coarse	Lighter green than #1, mod. dense; shorter than #1		Pale green, thin, tufty on ends of twigs.	Not so dense as #1 and #2	Very thin
Annual whorls	Distinct except on lower crown	Less distinct than #1	Nodes indistinct, branches horizontal or drooping		Branches drooping, gnarled and twisted, top flat	Internodes short	Indistinct. Branches few, and gnarled and drooping
Risk	Good	Good	Fair to good	Poor to fair	Poor	Fair to good	Poor



COMMON CALIFORNIA FOREST DEFOLIATORS

NAME	HOSTS	TREE SIZE	DAMAGE	FIELD I.D.	PREVENTION/ CONTROL	NOTES
Douglas-fir Tussock Moth *Orgyia pseudotsugata*	WF, inland DF	All sizes & classes	Initially new foliage, then older	Cocoons & egg masses, colorful larvae*	Silvicultural Pheromones (?) NPV (virus) Bt, Sevin-4-oil	Many natural enemies, urticating hairs; *orange-tipped tussock, red-orange spots
Pine Sawflies *Neodiprion* sp.	PP, JP MP	Common in yg, open-grown stands	Clip old and new foliage	Naked caterpillars, gn to brownish, >5 pair prolegs	Silvicultural (?), parasites & predators, NPV	Feed singly on new foliage
White-fir Sawfly *Neodiprion abietis*	WF	More common in dense 2nd growth	Old foliage only			Gregarious feeders
Silverspotted Tiger Moth *Halisidota argentata*	DF, WF, LPP, WH, MP, others	Apparently all sizes	Prefer previous years growth, do not attack buds	Fall: in colonies; Spring: large hairy, red-bn, yl & black caterpillars	Generally regarded as not economically important	Urticating hairs, conspicuous because its first to resume feeding in the spring
White-fir Needleminer *Epinotia meritana*	RF (Primary) WF (2ndary)	Overmature, mature, understory	Branch killing Deterioration of tree crown, susceptibility to Scolytus beetles	Needle mining, discoloration; WF: needles tied by silk	Parasites	RF: 2 yr life cycle with overlapping generations; WF: 1 gen/yr; less impact on RF than WF

COMMON CALIFORNIA FOREST DEFOLIATORS

NAME	HOSTS	TREE SIZE	DAMAGE	FIELD I.D.	PREVENTION/ CONTROL	NOTES
West. Spruce Budworm *Choristoneura occidentalis*	DF, true firs	All sizes & classes	Mine buds; web needles into feeding shelter Damaged needles retained on branch tips in loose web giving tree a brownish appearance. Feed on staminate flowers	Large larvae w/ brown head & body, prominent ivory spots; pupae yl-bn w/ amber brown case.	Parasites, predators, adverse weather. Stand mgt.	Large, west-wide research program underway. Pupae found among webbed needles.
Modoc Budworm *Choristoneura viridis*	WF			Mature larvae green w/ lt-yl or pale buff head. Pupae green w/ light grayish transparent case.		Sporadic outbreaks, locall important. Change in name pending. Pupae found among webbed needles.
Sugar Pine Tortrix *Choristoneura lambertiana*	LPP, SP, PP			Different host. Larvae rust color w/ reddish tan head, pupal case amber colored		Sporadic outbreaks; no great damage. Presently a taxonomic complex. Pupae found among webbed needles.
West. Tent Caterpillar *Malacosoma californicum*	Wide range of hardwood trees & shrubs	All sizes & classes	When abundant, strip foliage from trees & shrubs over wide area.	Silken tents, clusters of hairy caterpillars* near or in tent.	Parasites, predators, NPV	Egg masses are spiral rin encircling small twigs. * Head blue to black; bod mix of black, orange & bl

COMMON INSECTS FOUND ON TREE REGENERATION

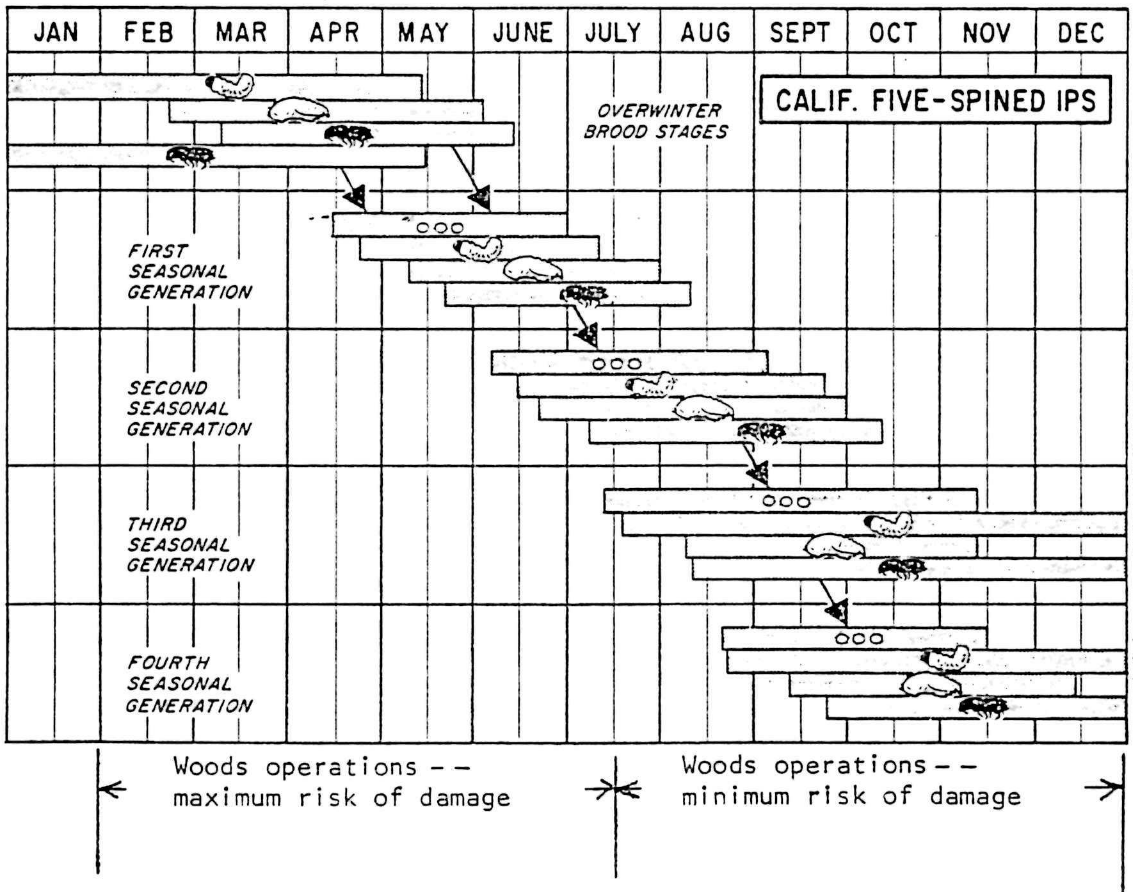
NAME	HOSTS	TREE SIZE	DAMAGE	FIELD I.D.	PREVENTION/ CONTROL	NOTES
CAMBIUM FEEDERS						
Pine engravers <u>Ips</u> spp.	PP, JP, SP LPP, CP	Sapling Pole	Tree Killing Top Killing	Tuning Fork Gallery	Slash Disposal, Brush Control, Thinning, Chemical	Many spp. Will breed in slash
Fir engraver <u>Scolytus ventralis</u>	WF, RF	Sapling Pole	Tree Killing Top Killing	Horizontal Gallery	Slash Disposal, Thinning	Will breed in slash
Douglas fir engraver <u>Scolytus unispinosus</u>	DF	Sapling Pole	Tree Killing Top Killing	Vertical Gallery	Slash Disposal Thinning	Will breed in slash
Pine Repro. Weevil <u>Cylindrocopturus eatoni</u>	PP, JP, SP	Seedling Sapling	Tree Killing Top Killing	Needle feeding Pupal chambers	Brush and grass Control	
Doug. fir Repro. Weevil <u>Cylindrocopturus furnissi</u>	DF, WF?	Seedling Sapling	Tree Killing Top Killing	Pupal chambers	Brush and grass Control	
Gouty Pitch Midge <u>Cecidomyia piniinopis</u>	PP, JP	Seedling Sapling	Twig Death, Deformity	Pink larvae pitch pockets		Very common in some years
DEFOLIATORS						
Needle Sheath Miner <u>Zelleria haimbachi</u>	PP, JP, LPP	Seedling Sapling Pole	Defoliation, Growth loss?	Hole in needle sheath		No growth loss trees under 10 years old

COMMON INSECTS FOUND ON TREE REGENERATION

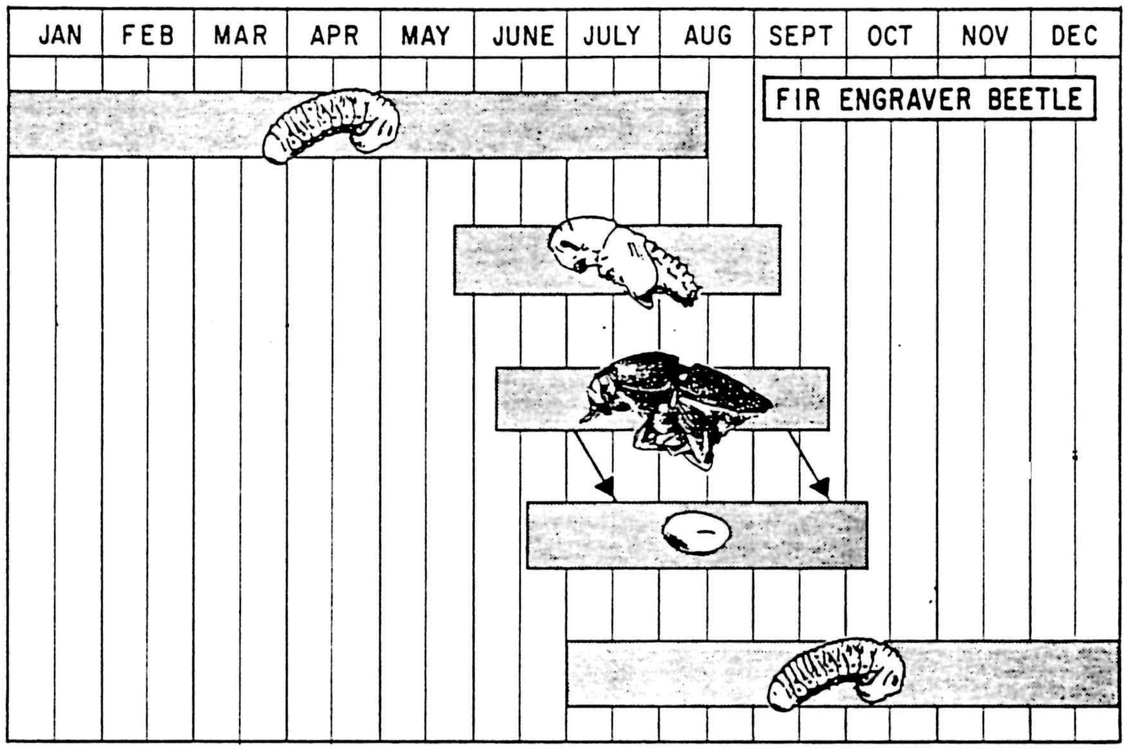
NAME	HOSTS	TREE SIZE	DAMAGE	FIELD I.D.	PREVENTION/ CONTROL	NOTES
DEFOLIATORS						
Doug. fir Needle Midge *Contarinia* spp.	DF	Seedling Sapling Pole	Needle Discolor. Defoliation Twig Death	Discolored Needle gall		3 spp., very common some years
Grasshoppers	All species	Seedling Sapling	Debarking Defoliation	Indiscriminant Feeding	Avoid grassy sites, Chemical	Common on re-planted burns
SCALES						
Pine needle *Chionaspis pinifoliae*	All pines, DF, IC	Seedling Sapling Pole	Growth Reduction?	Elongated White Scale	Reduce dust, Chemical	Associated with Fumes, Dust, Smog, and Spray Drift.
Black Pine Leaf *Nuculaspis californica*	PP, JP, SP, MP, DP, DF	Seedling Sapling Pole	Sparse foliage, Growth Reduct. Mortality	Black oval Scale	Reduce Dust, Chemical	Old Scales not Removed by Insecticides.
Cooley Spruce Gall Aphid *Adelges cooleyi*	DF Spruces	Seedling Sapling Pole	Needle Discolor. Twisted Needles, Defoliation	White "wooly aphid" on DF	Chemical	Galls formed on Spruces, Serious only to DF seedlings
SHOOT BORERS AND TIP MOTH						
Western Pineshoot Borer *Eucosma sonomana*	JP, PP	Seedling Sapling Pole	Short leaders, Forking	Short leaders, Short clumped needles		Damage seen on East side sites only
Ponderosa pine Tip Moth *Rhyacionia zozana*	PP, SP, DP	Seedling Sapling	Bud and shoot Mortality	Frass and silk "tents" around buds.		

Suggested Guidelines for Minimizing the Buildup and Subsequent Damage of Slash Breeding Insects

Pine Engravers, _Ips_ spp. In Pine Slash



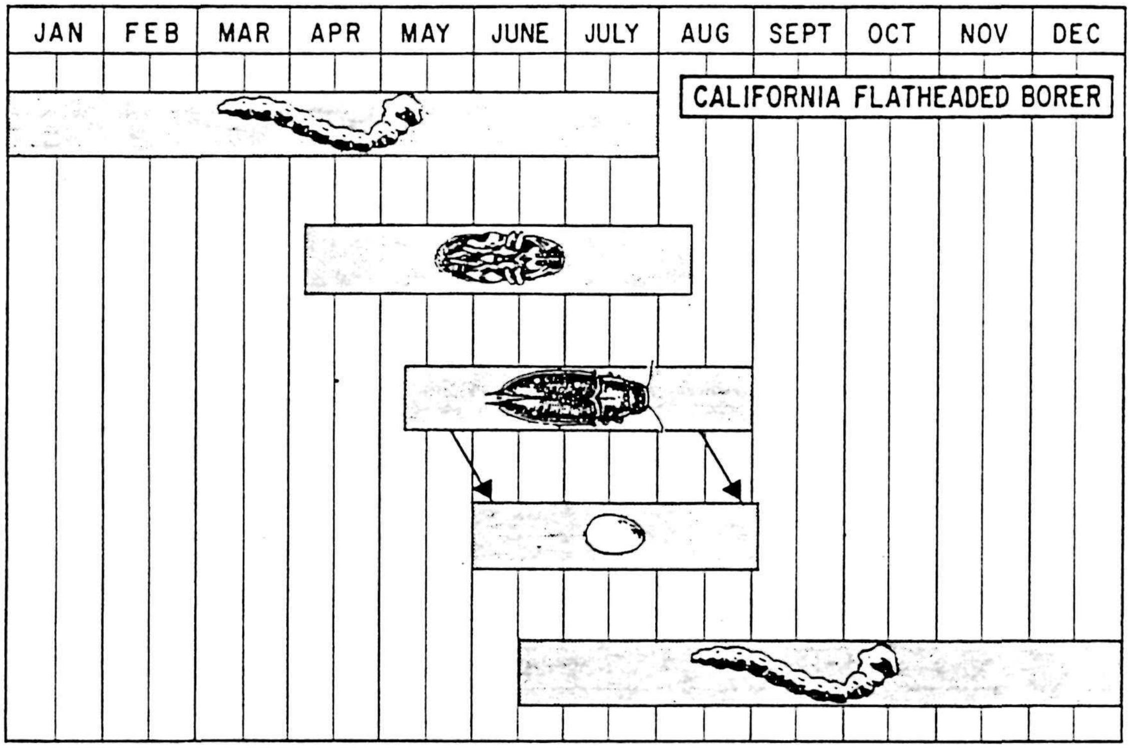
Fir Engraver, <u>Scolytus ventralis</u> In Fir Slash



Woods operations -- minimum risk of damage

Woods operations -- maximum risk of damage

Woods operations -- minimum risk of damage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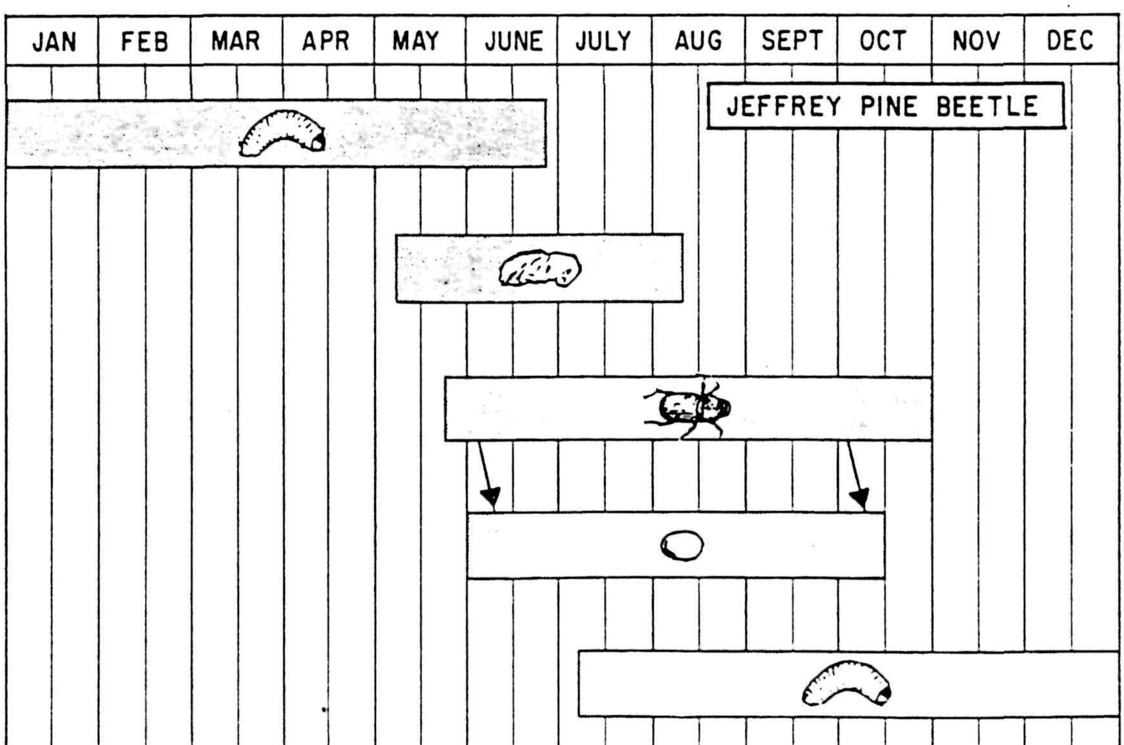
CALIFORNIA FLATHEADED BORER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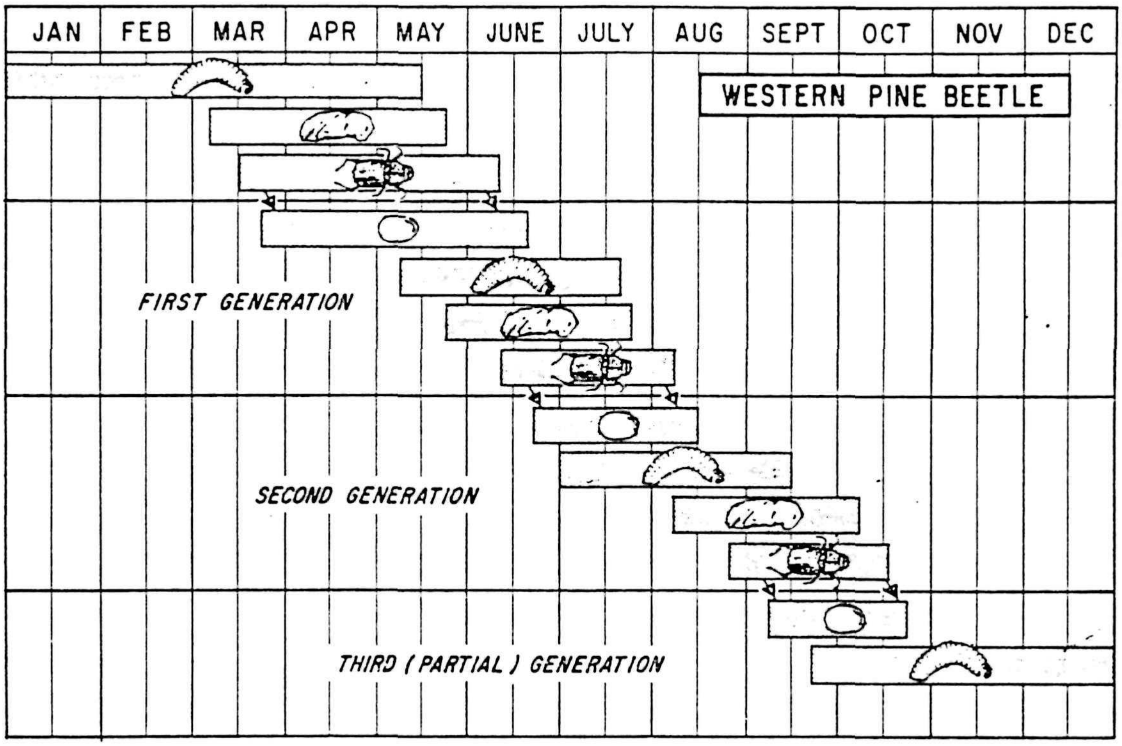
JEFFREY PINE BEETLE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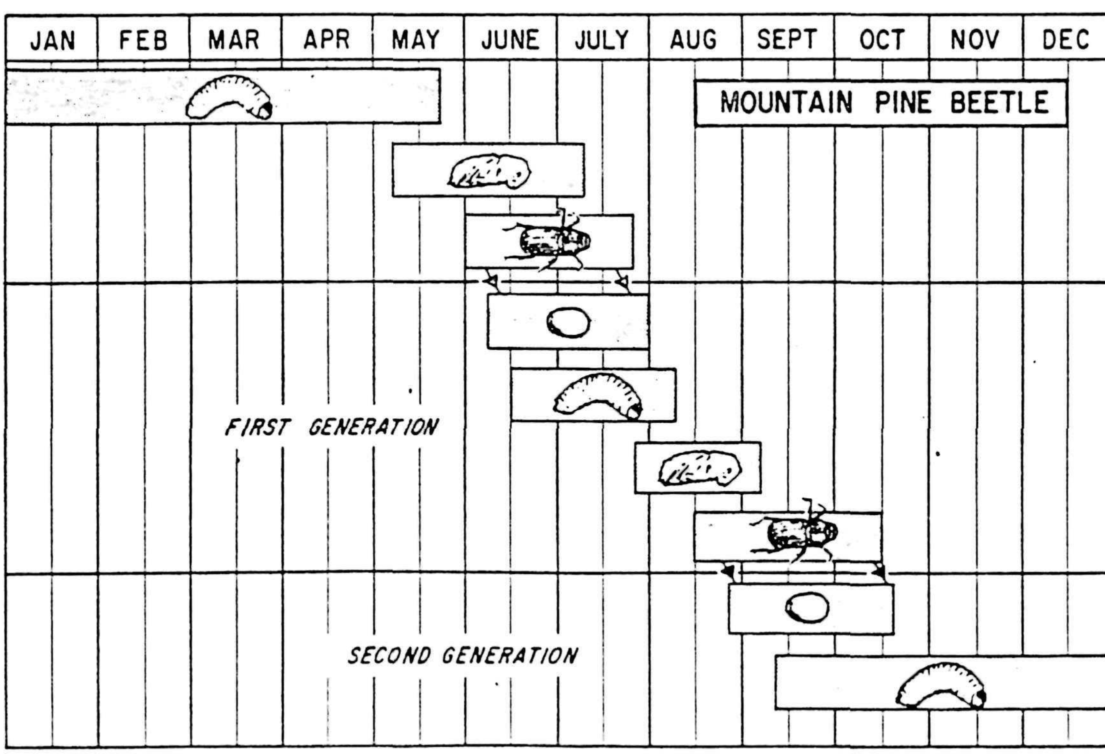
WESTERN PINE BEETLE
FIRST GENERATION
SECOND GENERATION
THIRD (PARTIAL) GENERATION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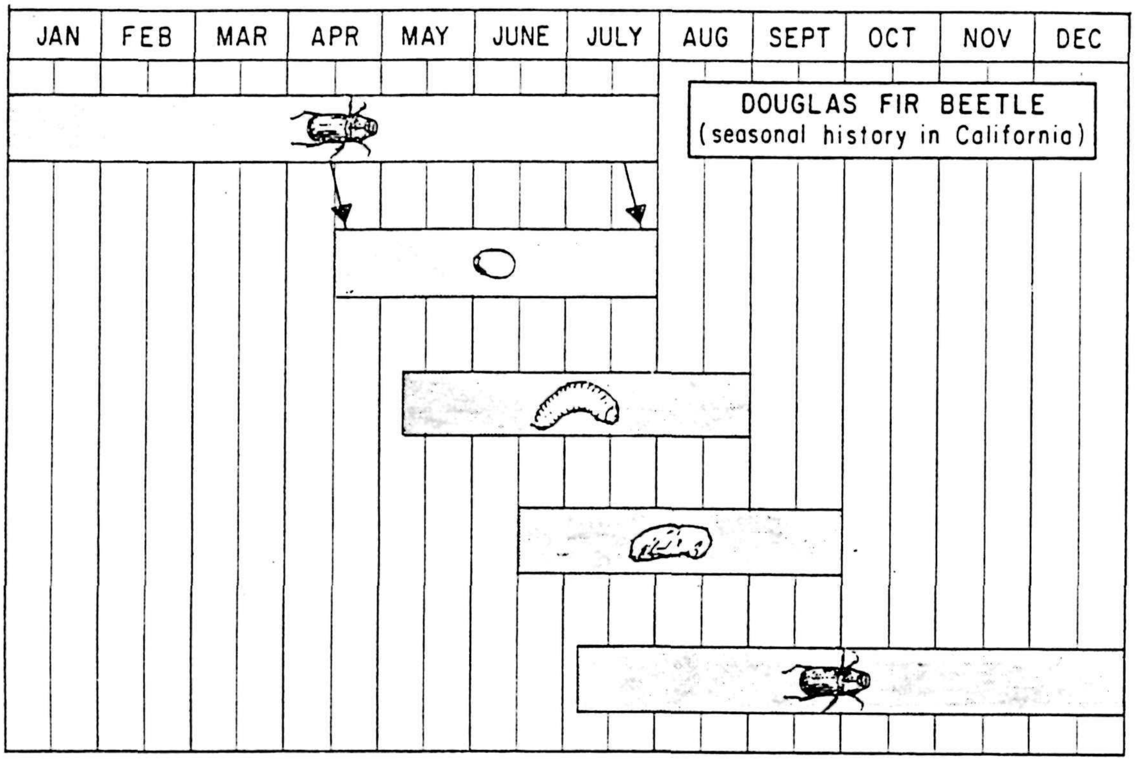
MOUNTAIN PINE BEETLE
FIRST GENERATION
SECOND GENERATION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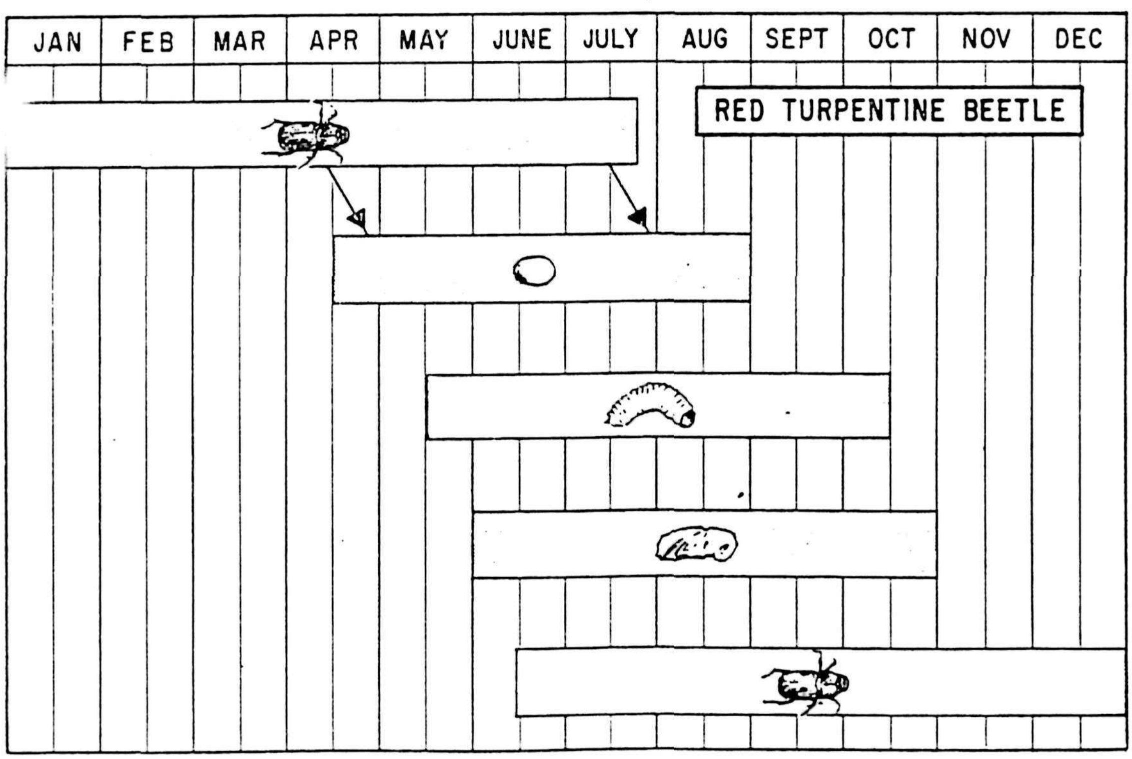
DOUGLAS FIR BEETLE
(seasonal history in California)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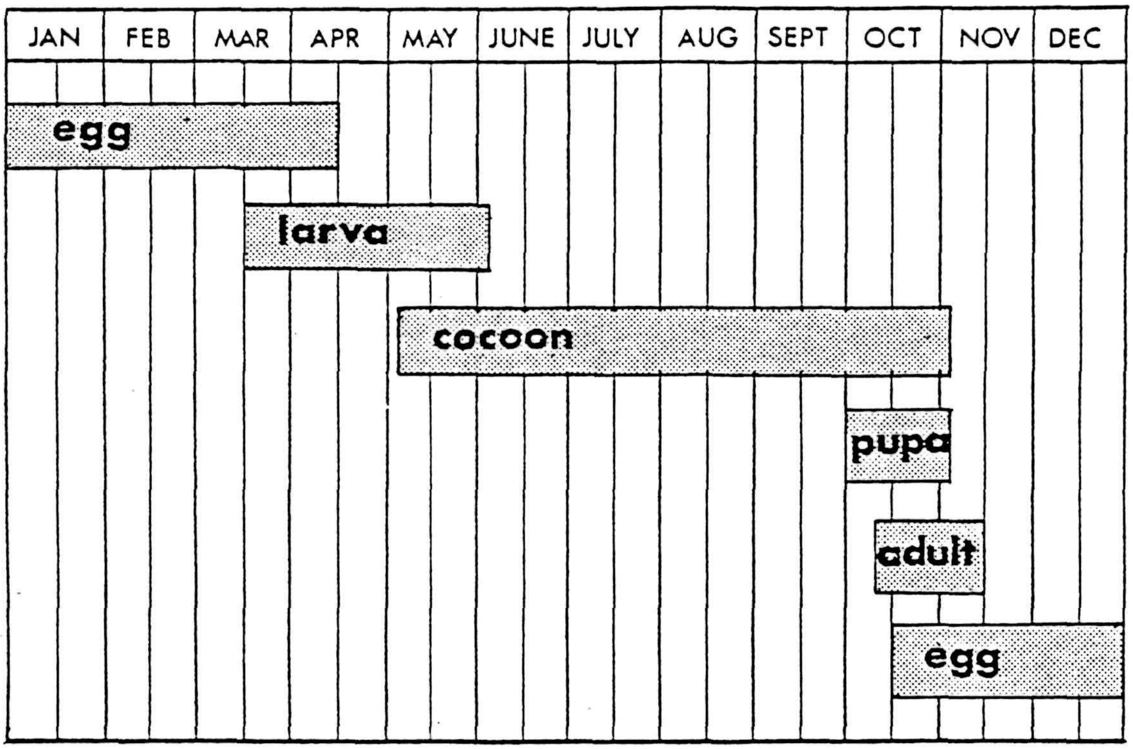
RED TURPENTINE BEETLE

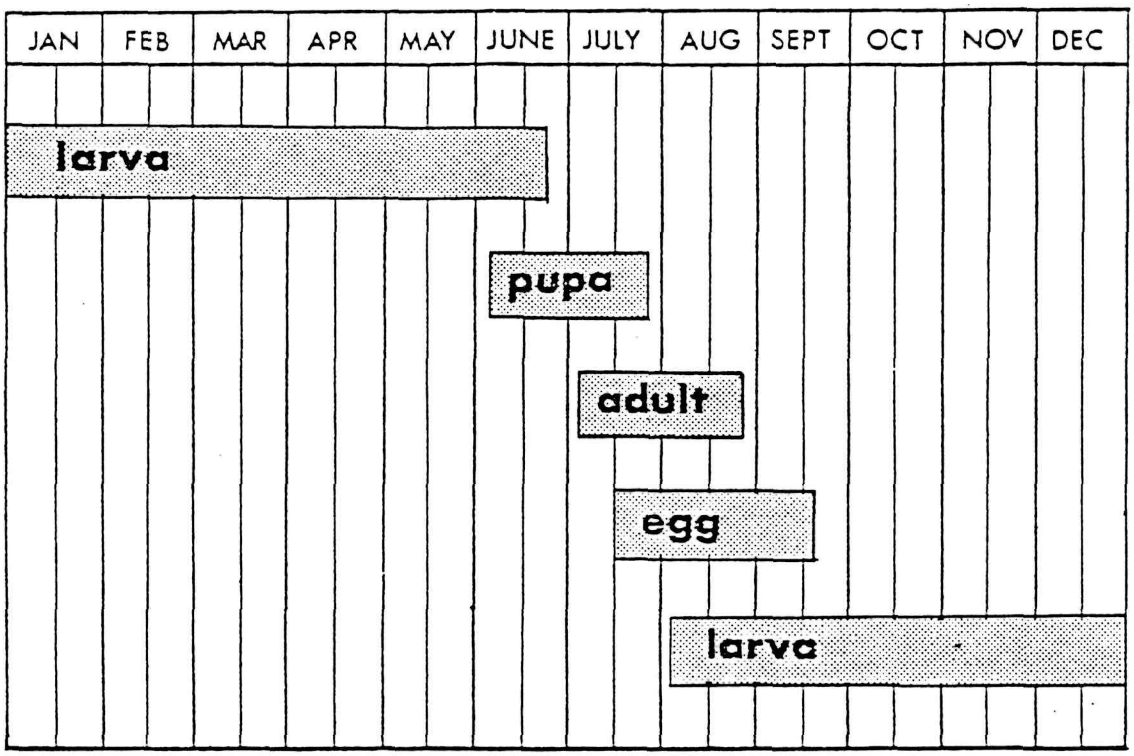
PINE SAWFLY



Name: *Neodiprion fulviceps* (complex)

Hosts: *Pinus ponderosa*, ponderosa pine; *P. jeffreyi*, Jeffrey pine; *P. radiata*, Monterey pine (occasional)

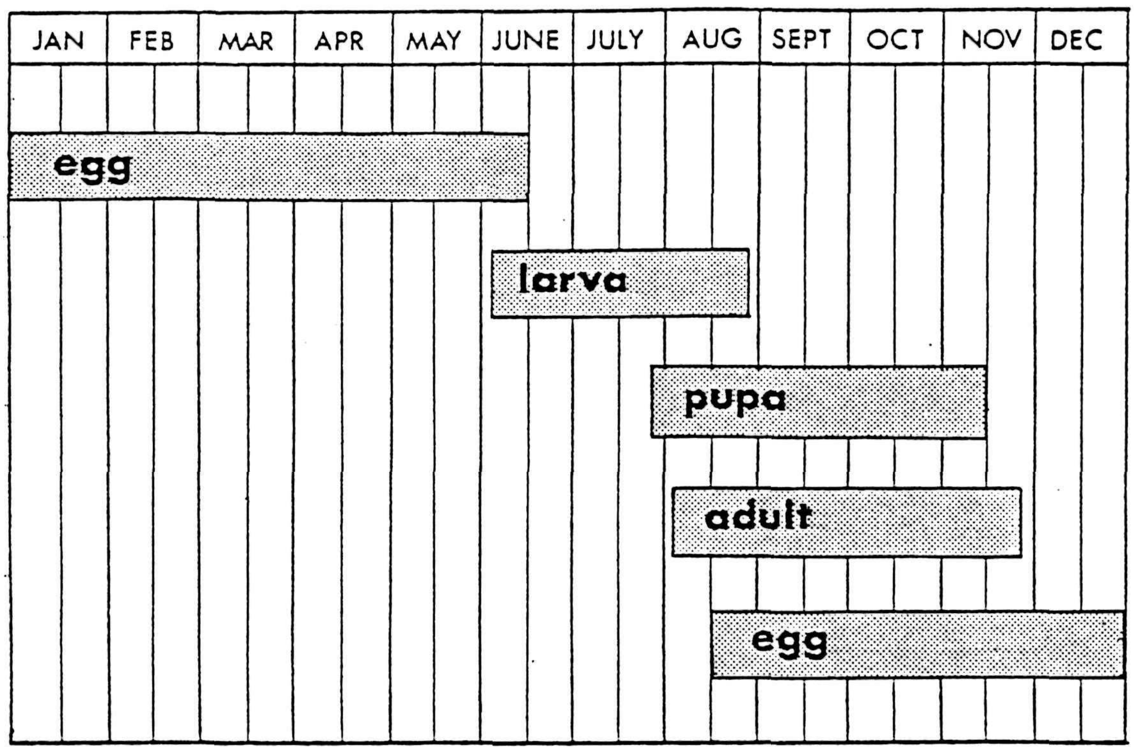
SILVERSPOTTED TIGER MOTH



Name: <u>Halisidota argentata</u> Packard

Hosts: Several conifers.

DOUGLAS-FIR TUSSOCK MOTH



Name: <u>Orgyia</u> <u>pseudotsugata</u> (McDunnough)

Host: <u>Abies</u> <u>concolor</u>, white fir

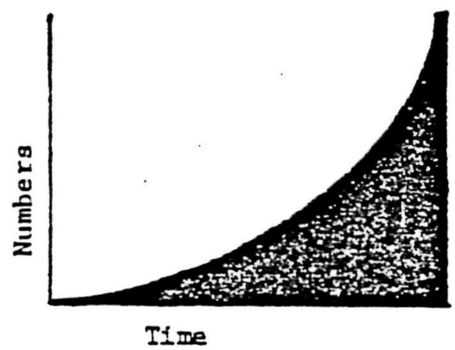
INSECT POPULATIONS

In order to comprehend the effects of pesticides on pest populations, an understanding of the ecological dynamics of populations under a variety of conditions is necessary.

A. Growth potential of populations

When environmental conditions are uniformly favorable to a pest population, growth is exponential or logarithmic and is a function of the reporductive potential (offspring produced per parent) and the length of time needed to reach sexual maturity, e.g., an insect population with 4 generations a year and producing 100 eggs per pair would grow, in a favorable environment, as shown:

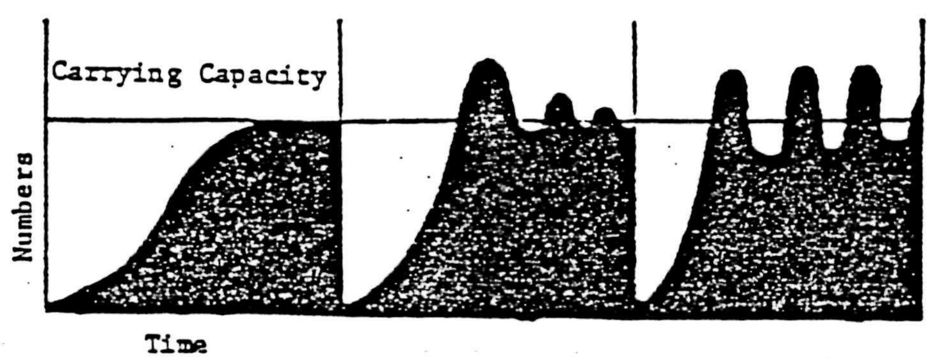
Generation	Population
1	2
2	100
3	5,000
4	250,000



B. Concept of carrying capacity

It is obvious that growth cannot proceed indefinitely in the manner illustrated above because pests do not inhabit uniformly favorable environments, nor is there an unlimited supply of resources, such as food and space.

The carrying capacity of the environment is defined here as the maximum number of pests that can occupy a given environment and is set by the resource which is depleted first. Thus, the carrying capacity may be set by the food supply, nesting sites, site characteristics, etc. Under this condition the pest population grown exponentially at first but as it nears the carrying capacity growth slows until it reaches zero at the carrying capacity or fluctuates around it.

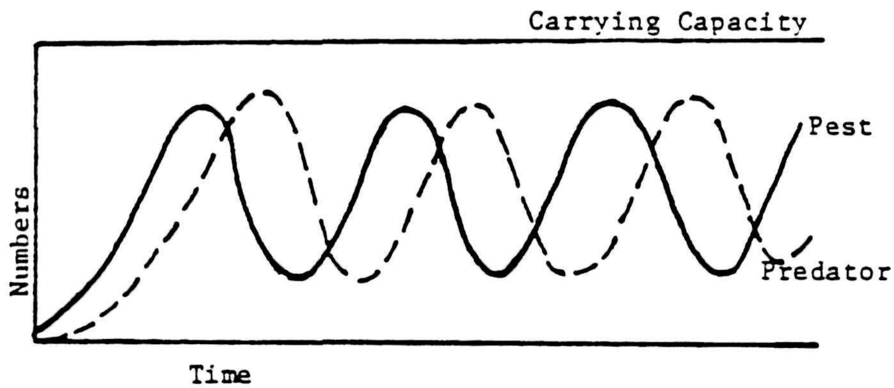


A. A. Berryman, Prof. of Forest Entomol., Washington State University.
In: Forest Pesticides in the Pacific Northwest - 1984, Washington State Univ. Coop. Ext. Serv., Pullman, Wa, 99164

The equilibrium properties of the population at the carrying capacity are determined by the rates of depletion and renewal of the limiting resources.

C. Control by predation

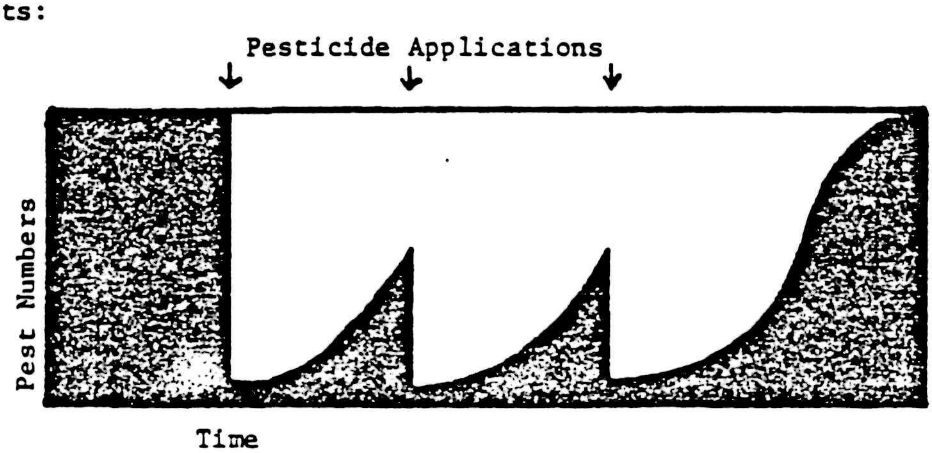
Many pest populations are regulated below their potential carrying capacity by predators. The pest can be considered a renewable resource which may set the carrying capacity of the predator. In this case, when the pest population grows it provides more food for the predator population which, with a reporductive time-delay, also starts to grow. The outcome of this kind of interaction is usually a series of oscillations below the carrying capacity of the pest; the oscillations are caused, to a large extent, by the reproductive time-delay.



Control by predation is usually less permanent than control at the carrying capacity. If environmental conditions occur which limit the reproductive capacity of the predator, or otherwise disrupt this rather tenuous balance, the pest population may be released to grow exponentially to its carrying capacity. Disruptive elements are often unpredictable climatic phenomena.

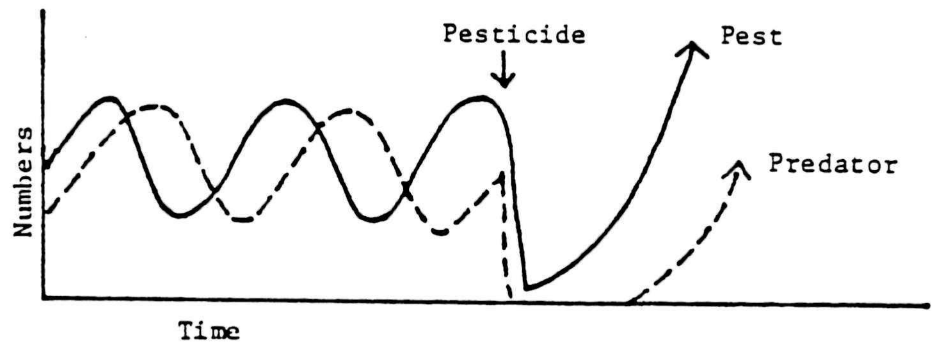
D. Pesticide effects on population dynamics

When pesticides are applied to a population of organisms they disrupt the natural population control menchaisms by catastrophic reduction of the population to very low levels. The effect of this application in time depends on the rate of chemical breakdown of the pesticide and the rate of its removal from the environment (e.g., evaporation, rainfall, leaching, etc.). Because of this, repeated applications of pesticides are often necessary to maintain a pest population at economically tolerable limits:

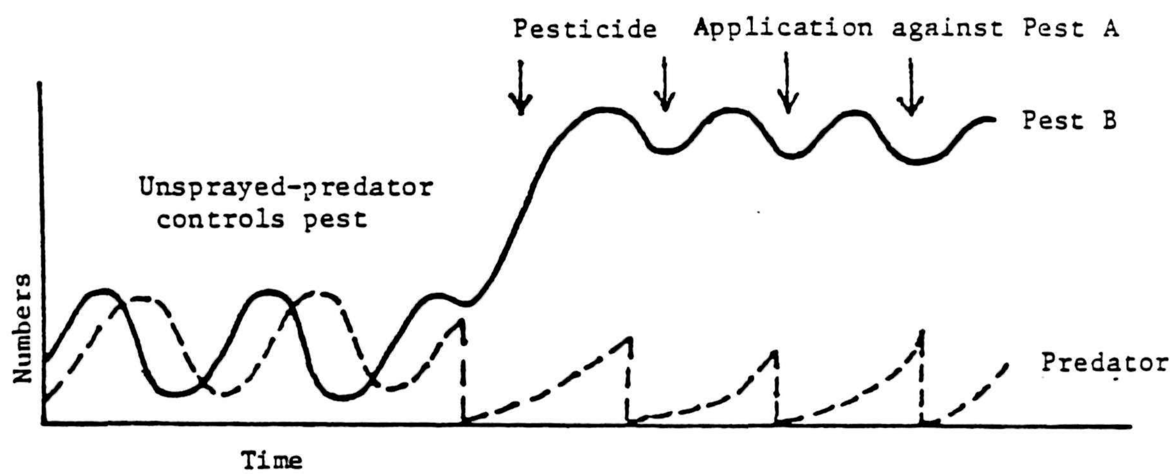


However, many of the pesticides used today are toxic to a wide range of organisms and their use may result in problems not initially foreseen, particularly when populations controled by predators are involved. For example:

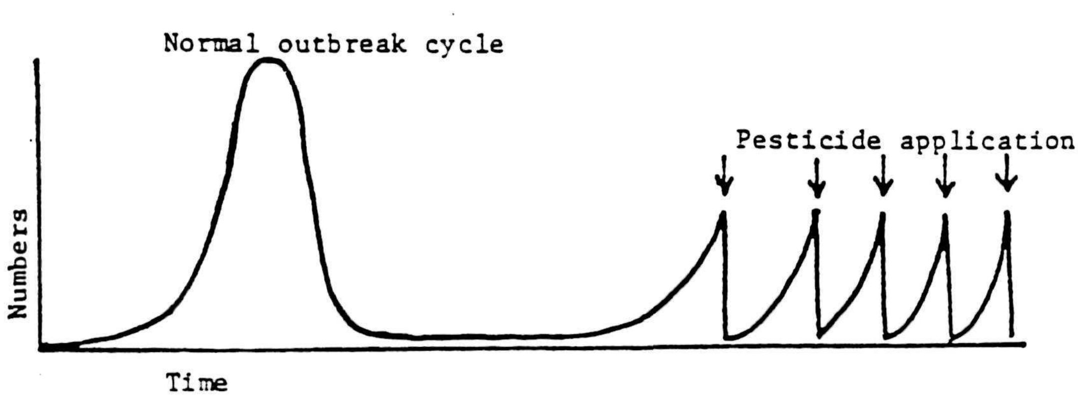
1. Resurgence of pest to a higher level when predators are killed or starve because the pest has been reduced to very low numbers.



2. Outbreaks of secondary pests when predators are killed by pesticides aimed at primary pests.



3. Prolonging an outbreak by interrupting the natural control factors.

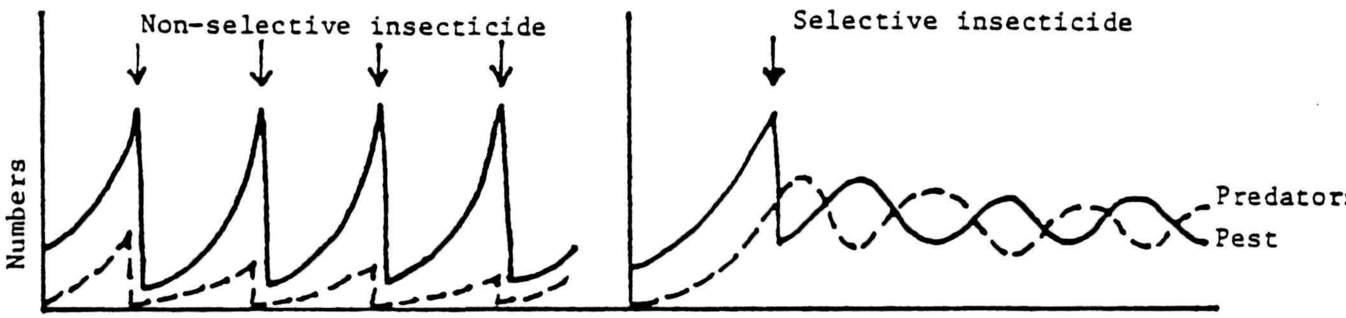


E. Pesticides—hammer or scalpel?

In the past, particularly in the field of insect pest control, pesticides have been used as a hammer to smash down pest populations, without cognizance of the possible ecological consequences. This has resulted in problems of resurgence, secondary pest outbreaks and massive multiple application schedules. The huge amounts of insecticides poured into the environment eventually precipitated the anti-insecticide movement, the formation of government bureaucracy and the stricter regulation of pesticide usage. Most of these problems resulted from the philosophy of "overkill" and the use of non-selective persistent pesticides.

A new philosophy is becoming more prevalent which envisions pesticides as a scalpel to be used with restraint and intelligence. New generation pesticides are being produced which are more selective and more readily biodegradable, and are used to attain "optimal kill" to maintain pest populations below economically defined damage thresholds. Some of the uses of the pesticide scalpel are:

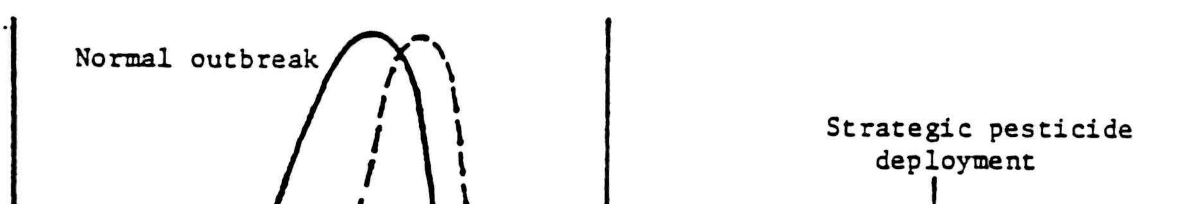
1. Reduce pest populations to allow predators to catch up; use selective pesticide at concentrations to obtain optimal pest kill to enable predators to overcome and control pest.



2. Prevent outbreaks of secondary pests by using selective pesticide which kills primary pest but has little or no effect on secondary pest and predators.

3. Encourage growth of preferred species by selectively killing competing species. General approach in weed and brush control with herbicides.

4. Prevent outbreaks by readjusting pest population so that parasites and predators can re-exert control using selective insecticides, optimal kill, and precise timing.



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US Department of Agriculture, Forest Service, Washington, D.C. Series begun in 1955. Over 100 leaflets to date. Reference to number in series of leaflets on important insects and diseases, giving practical information on identification, habits, and control.

I. INTRODUCTION

Defective trees may represent a hazard to people, structures, equipment, and powerlines within the developed areas of the forest. Some of these defective trees can be recognized by tree characteristics, indicators and/or symptoms. It is the land manager's responsibility to recognize and eliminate or modify these hazards to acceptable standards.

The Federal Government manages hundreds of developed sites within the forest environment. The Federal land manager has the financial, legal, and moral responsibility to provide for an organized systematic tree hazard control program. The goal of such a hazard evaluation and control program should be to provide an acceptable level of public and employee safety at minimum cost and with the least damage or impact to the environment.

II. RATING TREE HAZARD

Accident hazard is concerned with the potential for damage to an object of value. For a tree to be hazardous the following conditions must be met: (1) there must be a potential for the tree to fail; (2) there must be a potential target within range of the failing tree at least part of the time; (3) the weakened and failing part of the tree must be capable of inflicting damage to the target; and (4) the target must be of some value to us or others. All four of these factors should be considered in estimating the hazard posed by any one tree.

Probability of Tree Failure. Every tree will ultimately fail unless it is removed. However, the hazard inspector is primarily concerned with those trees which because of their condition, location, or defective structure are unusually susceptible to failure between now and the next inspection cycle. An estimate of the probability of failure should consider the type and magnitude of the defect and the frequency and occurrence of environmental conditions (e.g., winds) which cause failure to occur from the observed defect.

Probability of Target Impact. The hazard inspector must estimate the proportion of time when a target is within striking range of the defective tree. In the case of buildings and other property this would be 100 percent. For human occupancy, such as in recreation areas the percent of time the site is occupied should be used.

Damage Potential. A small limb or tree will cause less damage when it fails than a large tree. This potential to cause damage varies with the part of the tree and the size of the tree expected to fail. Bole and root failures are more damaging than limb failures. The potential for damage when roots or butts fail roughly doubles for every 10 inches increase in dbh from 10 to 50 inches in dbh.

Target Value. The value of targets within developed areas varies, and should be considered as a factor in the development of a hazard estimate. The value of individuals is difficult to fix, but far exceeds that of fixed property. For fixed property, use the value of the property or of that portion that would be destroyed by a 70-inch dbh softwood.

III. DEFECTS LEADING TO TREE FAILURE

The defects which weaken trees and lead to their failure are presented here according to the part of the tree in which they occur. This method of presentation was chosen as being the most useful format for the tree inspector who should be inspecting the trees part by part in a systematic manner.

ROOT DEFECTS are those defects which occur in the root system, root crown and the surrounding soil.

1. Root rots are the most important of the root defects contributing to uprooting and root failure. The rots decay roots, reducing the structural strength of the root system. Indicators of root rot are exposed, broken, rotting roots; injuries at the soil line; presence of conks on the roots, root crown, or in adjacent stumps; rodent excavations in or under the root crown; and a thin crown with scattered dead branches and reduced terminal growth. Trees judged to have root rot in critical locations should be considered for removal. If the tree with root rot is leaning, the potential for failure greatly increases.

2. Undermined roots most often occur along the edges of streams or the top edges of road cuts, both of which are common in and around developed areas. Slight undermining, where there is no tree lean, is usually not hazardous and can be easily corrected by shoring up the bank or the road cut. In advanced undermining where soil support appears marginal or inadequate the tree usually should be removed. If the tree is valuable and has a good crown, attempts to save the tree by shoring and filling the undermined area and cable bracing the top may be effective and justified.

3. Severed roots can lead to tree failure if several major roots, particularly on one side of the tree, are cut. The cutting of roots also reduces tree vigor and resistance to pests and may lead to future root decay. Such root disturbances in developed recreation areas should be kept to a minimum during construction and reconstruction activities.

4. Loosened, cracked, or broken roots often result from saturated soils, high winds, construction, or combinations of these factors. Indicators of such root damage are newly developed lean, mounds or ridges of soil movement in the root zone, and exposed and damaged roots. Shallow rooting in thin, porous soils may also pose a high risk of failure of healthy trees.

BUTT DEFECTS are those that occur in the lower six feet of the bole.

1. Heart rots are the main butt defect contributing to tree failure. Heart rot fungi usually gain entrance into the tree through fire scars and construction/logging wounds. Indicators of heart rot of the butt are fire scars, wounds of the butt, and conks. Sounding the butt with the poll of an axe provides some indication in thin-barked trees. If a more positive test is needed an increment borer should be used to detect the extent of heart rot and the amount of sound wood around the tree's circumference. However, the examiner should remember that the increment borer could introduce decay into the tree, so increment boring should not be taken unnecessarily.

The probability of failure of butt-rotted trees is influenced or affected by several factors, the most important of which are: (1) the amount of sound radial wood, (2) the basic form of the tree, (3) the rate of radial growth, (4) the presence and orientation of butt wounds and (5) the presence of other defects. A hollow tree, like a tube, is relatively strong provided the surrounding wall is uniform and not too thin. Minimum safe standards for sound radial wood in heart-rotted trees have been computed and are presented by 4-inch-diameter classes in Table 3. The rate of diameter growth is important because it affects the amount of sound wood which will exist in the near future. If the growth rate is relatively rapid, then future loss due to heart rot will be more than offset by this newly-added sapwood. The strength of a tube is greatly diminished by defects in the wall of the tube. Wounds in the sound sapwood wall of a butt-rotted tree have a similar effect. The orientation of a wound in relation to prevailing winds is also important. Wounds in the wall which are oriented either directly windward or leeward have a greater weakening effect than do wounds on the faces parallel to the wind direction. Other defects such as sap rot, cracks, and splits may further weaken butt-rotted trees to the point that they become hazardous. Lean of the tree, by adding much greater stresses, also increases the probability of failure of butt-rotted trees.

2. Sap rots affect both the butt and bole of the tree in a similar manner. Sap rots are usually localized, occurring behind wounds, injuries, or areas of the bark killed by other causes. Older trees with extensive areas of sap rot usually should be removed from developed areas. Hardwoods are usually more susceptible to sap rots behind stem and branch cankers than are conifers. When sap rot extends around half or more of the circumference of a tree with heart rot the tree should be considered a serious hazard and probably removed.

3. Cracks and splits of the butt and bole are produced in several ways including: (1) failure of the wood parallel to or across the grain, (2) lightning action, and (3) frost action. Wood failures often occur in conjunction with other defects as a result of the new stresses these defects put on parts of the butt and bole. As such, they are to be considered serious and usually require control action. Lightning damage may vary from a shallow furrow running the length of the tree, to a shattering of part or all of the tree. Lightning damage can render the tree an immediate hazard

or, by providing the entrance court for decay fungi, may lead to significant hazard in future years. Frost cracks usually heal relatively quickly and do not lead to significant hazard problems.

4. Multiple defects of the root, butt, or bole usually weaken the tree to a far greater extent than any one defect occurring alone. The tree inspector should be alert for such multiple defects. Particularly important are the heart rots in combination with defects of the outer sapwood shell such as sap rot, cracks, injuries and leaning trees.

BOLE DEFECTS are those defects which occur above six feet on the main trunk of the tree.

1. Heart rots of the bole are less important than rots of the roots and butt in rendering a tree hazardous. Heart rot fungi enter the bole through branch stubs and wounds. Indicators of heart rot in boles are conks, swollen knots, and open or closed wounds. Heart rots can and often do occur with no exterior indicators of their presence. When important, ladders may be used to climb the tree in order to sound or bore the bole at various heights for evidences of heart rot. True firs are particularly susceptible to heart rots of the bole. The presence of conks of the Indian paint fungus more than 6 inches wide or separated by 10 feet or more indicates a potentially hazardous tree. The same minimum standards of sound sapwood apply to the bole as to the butt (Table 3). Again, multiple defects are quite important.

2. Sap rots develop in the same manner and cause the same defects in the bole as they do in the butt of the tree. See the discussion of sap rots in the section on butt defects.

3. Bole deformation or deviations from the usual round form can weaken the bole and lead to breakage. The main causes of bole deformations are dwarf mistletoe infections, rust cankers, Atropellis cankers, and injuries. Dwarf mistletoe stem swellings are most prevalent and damaging in true firs. They become hazardous after the bark dies in the center and allows decay fungi to enter and rot a portion of the stem. Rust cankers, most common on hard pines, are not hazardous unless the depressions are deep and they are located 16 feet or more above the ground. The hazard caused by Atropellis stem cankers in lodgepole pines is unknown.

4. Crotches. Forked trees with tight V-shaped crotches are susceptible to splitting and breaking at the crotch. The problem is most severe in mature trees in which the stems above the fork have grown long and heavy. Hardwoods are more susceptible to this kind of failure due to their spreading crowns. The inspector should examine forked trees carefully for

cracks, splits, or callus ridges at the junction of the fork, indicating older cracks. Decay often enters through these cracks and further weakens the crotch. Crotches oriented at right angles to the wind are more apt to fail than those parallel to the wind.

5. Cracks and Splits - refer to the section on butt defects.

6. Multiple Defects - refer to the section on butt defects.

LIMB DEFECTS

As a class the hazard posed by defective limbs is less serious than that of defective roots, butts, or boles. The damage done (damage potential) by a falling limb is less and the target area is smaller. Dead limbs are not hazardous in themselves until some defect such as decay, cracks, splits, insect galleries, or bird holes have affected their strength. Hardwoods are more susceptible to limb failure than conifers due to differences in branch form and weight and the frequent extension of hardwood trunk rot up into the branches. The hazard posed by defective limbs can be reduced by removing all or part of the limb or by bracing it.

DEAD TOPS

Dead tops are considered hazardous in some conifers. Experience indicates that dead tops of redwood, pines, incense-cedar, and Douglas-fir are considered non-hazardous until defects like cracks, splits, and/or wood-pecker holes become evident. On the other hand, dead tops in true firs must be considered hazardous and should be removed as soon as possible.

LEANING TREES

Leaning trees deserve special attention because of the greater potential for failure they add to other defects of the roots, butt, and bole. Leaning trees may be classed as (1) natural leaners in which lean is an inherent growth characteristic and (2) un-natural leaners in which the lean is or was caused by an outside force. Natural leaners which are sound pose little hazard. It is the un-natural leaners which are the most hazardous, particularly when they occur in combination with soil disturbance, construction, saturated soils, lifting of the root mass behind the leaning tree, or large fire scars.

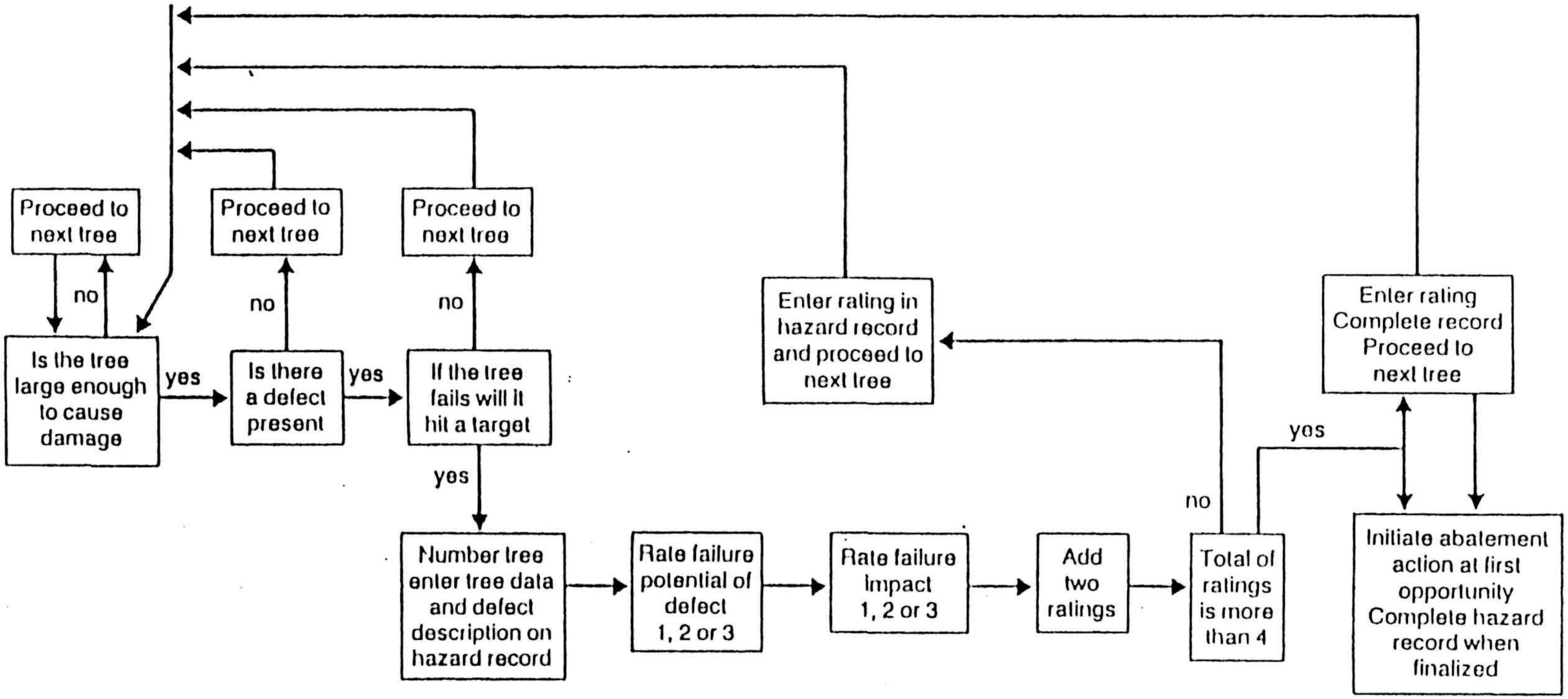
TABLE 1. MINIMUM SAFE STANDARDS FOR RADIAL WOOD IN DEFECTIVE TREES.1/

Diameter of tree inside bark	Thickness of sound wood2/	Diameter of tree inside bark	Thickness of sound wood
Inches	Inches	Inches	Inches
16	2.5	44	6.5
20	3.0	48	7.0
24	3.5	52	8.0
28	4.0	56	8.5
32	4.5	60	9.0
36	5.5	64	9.5
40	6.0	68	10.0

1/ Assumes heart rot or hollow exists with no other weakening defects such as cracks or openings in radial wood, sap rot, cankers, deep flat areas, or lean of tree. Where such additional defects are present, the above figures will not be applicable.

2/ Figures are rounded to nearest one-half inch and represent the thickness of sound wood outside of the rot column. Since the internal rot column is seldom uniform in radial dimension, either horizontally or vertically, average values are given. The inspector should take a minimum of two increment borings from which to estimate the thickness of sound radial wood. He may wish to take more than 2 borings if his judgement or local experience indicates the need for additional borings.

Fig. 3 Flow diagram of a procedure that may be followed for tree inspections.[1/]



1/ From: Wallis, G. W., D. J. Morrison, and D. W. Ross. 1980. Tree hazards in recreation sites in British Columbia: management guidelines. British Columbia Ministry of Lands, Parks, and Housing, and the Canadian Forestry Service, Joint Report No. 13. 52p.

IV. MANAGEMENT AND PREVENTION OF TREE HAZARD

The management and prevention of hazardous trees in recreation areas involves: the identification of hazardous trees through inspections; the reduction of unacceptable hazard; and the prevention of future hazardous tree conditions.

A. Hazard Tree Inspection.

1. A hazard tree inspection should be systematic and uniform in both planning and execution. The areas within each management unit should be routinely and systematically examined as should each tree within an inspection area. The method of tree examination should be uniform and thorough. When examining a tree one should start either at the bottom of the tree and work up to the top examining each part of the tree in turn (roots, butt, bole, branch) or vice versa. When examining any one part of the tree the inspector should look for all possible defects characteristic of that part of the tree, recording and rating each in its turn. A check-list of tree parts and their potential defects may be useful when first starting an inspection to be sure that all potential defects are being considered (Appendix I).

Successful hazard rating depends in part, on the examiner's familiarity with recreation site pathology, and on his ability to recognize symptoms of tree defects and faults and to evaluate their effects on the tree's stability and strength. In addition he should be familiar with local weather conditions, the characteristics of individual sites, and the kinds and occurrences of past tree failures.

B. Tree Hazard Management.

The objective of Tree Hazard examination and management is to identify those hazardous situations which are unacceptable and to reduce or eliminate them through some control activity. Usually the first thought is tree removal, but that is only one of the control options which should be considered. The available control approaches are:

1. Hazardous Tree Removal. In this option the hazardous tree is felled.

2. Removal of Hazardous Tree Parts. If only a part of the tree is hazardous (e.g. branch or top) this portion of the tree can be removed. If the whole tree is hazardous, but the potential for failure can be reduced by removing a portion of the tree, this also may be done; e.g., removal of a portion of the crown to reduce stresses on bole or butt defects.

3. Addition of Mechanical Support. Cables, rods, shoring, etc. can be used to help support trees or portions of trees which exhibit a high and unsatifactory potential for failure.

4. Target Removal. If the tree is valuable and other developed sites are available at a reasonable cost the hazard problem can be controlled by removal of the target so that if the tree fails there will be no target for it to hit.

C. Selection and Maintenance of Developed Recreation Sites.

Many of the hazardous recreation sites and situations we now must deal with could have been prevented if hazardous trees were considered during site selection and construction in light of the information we now possess. When selecting and/or maintaining recreation sites the following factors should be considered:

1. Stand Age. Older stands tend to have greater amounts of root, butt, and heart rot than younger stands. This is particularly important in stands of true fir, which become extremely decadent and defective with age. Furthermore, future stand maintenance is limited and difficult if there is not at least a portion of the stand which is young, vigorous, and responsive to stand management treatments.

2. Stand Density. Dense stands have trees with limited root development and individual trees develop with only limited wind stress. Opening up a heavily stocked stand for recreation purposes may subject the remaining individual trees to wind stresses which they are unable to withstand, and root, butt, or bole failure may result.

3. Tree Species and Form. Some tree species are more subject to certain kinds of failure (e.g. - true fir to root failure). Tree form as it influences probability of failure is also important (e.g. lodgepole pine stands with numerous forked trees might be considered hazardous especially if there was evidence of failure of these forks). On the other hand stands of mixed species and age classes would be desirable from the standpoint of pest problems leading to failure and the ability to control the pest problems in the future.

4. Stand Health and Vigor. Pest problems often lead directly into hazard problems (e.g. root disease to root failure, heart rots to butt and bole failure, dwarf mistletoe to bole failure). Experience indicates that in developed areas these pest problems tend to become more severe with time. Thus stand health and vigor should be a consideration when selecting a recreation site for development. One should be particularly concerned about root diseases already present in a potential site and stands with a high incidence of heart rot.

5. Site Construction. Many hazardous tree situations are the result of site construction activities which injure or adversely affect the tree. The cutting of roots in the construction of building foundations or water and sewer lines structurally weaken the tree, often place it under moisture stress and open the tree to root and butt rots. Consideration of the stand and its future health and vigor should be a major factor in the planning and construction of physical improvements of the site.

After an area has been selected and developed, the stand should be maintained. One objective of a maintenance program should be to prevent the development of future hazardous trees and situations. Since pest problems often lead directly into hazard tree problems, one aspect of this program should be aimed at maintaining a healthy vigorous stand that has a high resistance to insects and diseases. It is suggested that stand management move toward the development and maintenance of all-aged, mixed species stands. Hardwoods are a desirable component of such stands. A recreation stand of moderate to low basal area will be better able to withstand future drought-associated bark beetle problems.

FORM 1

Sheet ________ of ________

TREE HAZARD SITE INSPECTION RECORD

District: ______________ Site: ________________ Officer: ______________ Date: ____________

Tree	Sp.	dbh cm	Location	Description of defect	Failure Potential rating (1)	Description of target	Failure Impact rating (2)	Hazard rating (1 + 2)	Action Recommended	Action Completed	
										Date	Initials

FORM 2

TREE FAILURE REPORT

District: ________________ Park: _____ Location: __________ Officer: ___________

Time of Failure: ________________________________ Site open for use: Yes ___ No ___

hour day month year

Tree and Stand

Tree species: ______________________

Approx. diameter (cm) ______________________

Approx. age ______________________

Stand age class: ___ overmature

___ mature

___ young growth

___ all aged

Class of Mechanical Failure

___ upper bole (top half)

___ lower bole

___ butt (bottom 2 metres)

___ branch

___ root, including uprooting

Tree Defect Leading to Failure

___ tree dead (snag)

___ dead top

___ root or butt rot

___ stem rot

___ wound-type ________________

___ dwarf mistletoe canker

___ twin stems

___ cracks or splits

___ leaning

___ other ________________

___ unknown ________________ none

Contributing Factors

___ wind

___ snow

___ soil bank erosion

___ erosion (other)

___ lightning

___ soil saturation

___ shallow rooting

___ other ________________

____

___ unknown ________________ none

Consequences

None: ______________________

Cleanup work only required: ___________

Property damage: (describe giving approx. value): ______________________

____

____

Injuries (describe and note if medical attention was required): ________________

____

____

____

Comments: ____

____

____

Record only failures capable of inflicting damage or injury. **Do not** report the death of a tree or parts of a tree unless it fails. Trees, or parts thereof, removed prior to failure should not be reported.

REFERENCES

Mills, L. J., and Russell, K. 1980. Detection and correction of hazard trees in Washington's recreation areas: a how-to guide for recreation site managers. State of Washington, Dept. of Natural Resources, DNR Report No. 42. 37 pages.

Paine, Lee A. 1971. Accident hazard evaluation and control decisions on forested recreation sites. USDA For. Serv., PSW Research Paper 68. 10 pages.

Paine, Lee A. 1973. Administrative goals and safety standards for hazard control of forest recreation sites, USDA For. Serv., PSW Research Paper 88. 13 pages.

Wallis, G. W., Morrison, D. J., and Ross, D. W. 1980. Tree hazards in recreation sites in British Columbia: management guidelines. British Columbia Ministry of Lands, Parks, and Housing, and the Canadian Forestry Service, Joint Report No. 13. 52 pages.

Wagener, W. W. 1963. Judging hazard from native trees in California recreation areas. USDA For. Serv., PSW Research Paper - P1. 29 pages.

APPENDIX: CHECK LIST OF TREE PARTS, THEIR DEFECTS, AND DEFECT INDICATORS

A. Root Defects

1. Root Rots

    a) Crown Condition
    b) Root and Butt openings
    c) Conks
    d) Rodent Inhabitation

2. Undermined Roots

3. Severed Roots (signs of construction)

4. Loosened, Cracked or Broken Roots

B. Butt Defects

1. Heart Rots

    a) Fire scars, Wounds, and Openings
    b) Rodent Inhabitation
    c) Sounding and Increment Borings

2. Sapwood Rots

    a) Cankers
    b) Injuries

3. Cracks and Splits

    a) Wood Failure
    b) Lightning
    c) Frost Cracks

C. Bole Defects

1. Heart Rots

    a) Conks
    b) Wounds
    c) Increment Borings and Soundings

2. Sapwood Rots

   a) Cankers
   b) Injuries

3. Bole Deformation

   1. Dwarf Mistletoe Cankers, open
   2. Rust Cankers
   3. Mechanical Injury
   4. Crotches
   5. Cracks and Splits

D. Limb Defects

1. Rot

   a) Reduced Growth
   b) Stunted Leaves
   c) Injuries
   d) Conks

E. Dead Tops

F. Leaning Tree

   a) Ground Movement
   b) Signs of Construction

FOREST INSECT AND DISEASE LEAFLETS

The next eight pages contain an alphabetized list of forest insect and disease pamphlets currently available. Each leaflet deals with a single pest and describes history, biology, damage, control, etc. All Forest Pest Management offices have some of these publications, but not all. Our Washington Office keeps a supply of each and may be contacted at:

USDA Forest Service
Forest Pest Management
P. O. Box ~~2417~~ 96090
Washington, D.C. 20013
(703) 235-1554
FTS 235-1554

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REFERENCES

FURNISS, R.L., and V.M. CAROLIN. 1977. Western Forest Insects. USDA Misc. Publ. 1339. 654 p.

Most recent, up to date reference. Unfortunately for foresters, it is arranged for entomologists; it assumes insect orders, families, genera are known. Has a diagnostic host index in back. Useful, but could be improved. Available from: Superintendent of Documents, Washington D.C. 20402. Stock No. 001-000-03618-1. Hard and paper back ($8.75).

KEEN, F.P. 1952. Insect Enemies of Western Forests. USDA Misc. Publ. 273. 280 p. (Out of print).

An old standby, although out of date. Arranged by location of damage in tree or stand; therefore, geared to forester's needs. Makes a good complement to Western Forest Insects, but hard to find.

GRAHAM, S.A., and F.B. KNIGHT. 1965. Principles of Forest Entomology. 4th ed. McGraw-Hill Book Co., New York. 417 p.

General treatment of forest insect problems throughout the U.S. It is organized by the part of the tree attacked.

BEGA, R.V., tech. coord. 1978. Diseases of Pacific Coast Conifers. USDA Forest Service Agri. Handbook No. 521. 206 p.

The standard text for California forest tree diseases. Has keys, descriptions, photos and selected references. The first place to look for identification and biology of diseases. Does not include control procedures.

FOSTER, R.E., and G.W. WALLIS. 1974. Common Tree Diseases of British Columbia, 2nd ed. Can For. Serv. Publ. No. 1245. 116 p.

Can hardly be said to concentrate on local problems, but adequately covers many diseases important in California, although from the Canadian point of view. Short and to the point, with emphasis on photography.

PARTRIDGE, A..D., and D.L. MILLER. 1973. Major Wood Decays in the Inland Northwest. Natural Resource Series 3. Idaho Research Foundation Inc., Moscow. 125 p.

More than you ever wanted to know about decays, their causes, appearances, predictors, and amount of cull. Covers important and rare decays. The Northwest appears to have many decays not common in California, so there is a lot to wade through. Keys are excellent, arranged by type of decay and by fruiting body characters. The profuse photos are all in color.

SCHARPF, R.F., and J.R. PARMETER, JR., tech. coords. 1978. Proceedings of the Symposium on Dwarf Mistletoe Control through Forest Management, April 11-13, 1978, Berkeley, CA. USDA For. Serv. Gen. Tech. Rep. PSW -31. 190 p.

HEPTING, G.H. 1971. Diseases of Forest and Shade Trees of the United States. USDA For. Serv. Agr. Hdbk. 386. 658 p.

Lists and describes diseases by host. A good reference.

PARTRIDGE, A.D., E.R. CANFIELD, and D.L. KULHAVY. 1978. Keys to Major Disease, Insects and Related Problems of Forests in Northern Idaho, rev. ed. Forestry, Wildlife and Range Exp. Stn. Misc. Publ. T-2. Univ. of Idaho, Moscow. 100 p.

This guide approaches insects and diseases from the problems they cause. It focuses first on stand, then to trees and tree parts, then to the range of pests which might be causing the problem, and concludes with control options. Illustrated, but the photos are small and in black and white; the author told me it will be redone in color. Highly recommended, even though it is designed for northern Idaho.

GLOSSARY

AERIAL SHOOT - stem-like portion of dwarf mistletoe outside the host bark.

ALTERNATE HOST - another host plant species required to complete development of an insect or pathogen.

BASAL CUP - the cup-like remnant of a dwarf mistletoe infection which remains visible long after the disintegration of an aerial shoot.

BLIGHT - a loose term for a disease causing rapid death or dieback.

BROOD - all the individuals that hatch at one time from eggs laid by one series of parents.

BROWN ROT - a light to dark brown decay of wood that is friable and rectangularly checked in the advance stage. Caused by fungi that attack mainly the cellulose and associated carbohydrates. The residue is chiefly lignin.

BUTT ROT - a rot characteristically confined to the butt or lower trunk of a tree.

CANKER - a definite, relatively localized, necrotic lesion primarily of the bark and cambium.

CONK - the large, often bracket-like fruiting bodies of wood destroying fungi.

CRAWLER - the active first-instar larva of a scale insect.

CULL FACTOR - a calculated percentage of the amount of merchantable wood lost from a tree as a result of decay or other defect.

DIEBACK - the progressive dying, from the tip downward, of twigs, branches, or tops.

ELYTRA - the anterior leathery or chitinous wing covers of beetles.

ENDEMIC - a pest population which is at its usual normal balanced level within a region to which it is indigenous.

ENTRANCE COURT - the point of invasion of a disease organism into its host.

EPIDEMIC - pertaining to pest populations that expand to a level causing disturbances of the normal relationships in the forest association, often to the point of causing economic loss.

FLAGS - conspicuous dead branches with foliage remaining as a result of rapid killing by adverse abiotic conditions, insects, or disease agents.

FRASS - solid excrement of insects; wood residue left by boring insects.

FUNGUS MAT - dense, leathery mass of fungus mycelium often formed in decayed wood by certain wood rotting fungi.

GALL - enlarged, swollen growth of plant tissue.

GALLERY - a passage, burrow, or mine excavated by an insect in plant tissue for feeding, oviposition, or exit.

HEART ROT - a decay characteristically confined to the heartwood.

HONEYDEW - sugary liquid excretion of aphids and scales.

HOST - the plant on or in which a pathogen or insect exists.

HOST SPECIFIC - a term used to describe certain disease organisms that attack only certain species of hosts.

INCIPIENT ROT - the early stage of wood decay in which the wood is invaded and may show discoloration but is not otherwise visibly altered.

INOCULUM - the spores or tissues of a pathogen which infect a host or crop.

LARVA - immature form of an insect such as a caterpillar, grub, or maggot.

MAGGOT - a legless larva without a well-defined head.

MINED FOLIAGE - leaves or needles in which the inner leaf tissues are eaten by insects.

MYCELIAL FANS - similar in structure to mycelial felts but fan-shaped.

MYCELIAL FELT - a mass of fungus filaments that are arranged in a flat plane and resemble a thin felt-like paper or cloth.

MYCELIUM (IA) - a mass of hyphae which form the vegetative filamentous body of a fungus.

NECROSIS - death of plant cells usually resulting in darkening of the tissue.

NYMPH - immature form of an insect resembling the adult except for incomplete wing development.

OBLIGATE PARASITE - a parasite incapable of existing independent of live host tissue.

PARASITE - an organism living on and nourished by another living organism.

PATHOGEN - an organism which causes a disease.

PERENNIAL CANKER - the recurrent yearly killing back and healing over of the bark and cambial tissues of woody plants by certain disease organisms.

PITCH TUBE - a tubelike accumulation of pitch around a bark beetle entrance hole on the bark of a tree.

POCKET ROT - a characteristic pattern of rot caused by certain fungi. The rot occurs in distinct, scattered pockets within the heartwood of a tree rather than in a distinct column.

PREDISPOSITION - the effect of one or more environmental or biotic factors which makes a plant vulnerable to attack by a pathogen or insect.

PROLEGS - fleshy false legs on abdomen of caterpillars.

PUPA - inactive stage of an insect; a transition stage from larva to adult.

RESINOSIS - the unnatural and profuse flow or accumulation of resin from conifers injured or attacked by insects and disease.

RHIZOMORPHS - a specialized thread- or cord-like structure made up of parallel hyphae with a protective covering.

SAPROPHYTE - an organism using dead organic material as food.

SETA - a bristlelike hair.

SKELETONIZED FOLIAGE - leaves or needles in which the soft tissues have been eaten by insects from between the veins, leaving only the veins.

SYMPTOMS - the noticeable evidence of disturbances in the normal development and life processes of the host plant.

TUBERCLE - a small rounded projection from the surface of an insect.

VECTOR - a carrier of a disease-producing organism.

WETWOOD - a discolored, water-soaked condition of the heartwood of some conifers presumably caused by bacterial fermentation.

WHITE ROT - decay caused by fungi that attack all chief constituents of wood and leave a whitish or light colored residue.

WITCHES BROOM - an abnormally profuse, dense mass of host branches and foliage. This is a common symptom induced by dwarf mistletoes as well as other parasitic and abiotic agents.

ZONE LINES - narrow, dark brown lines in decayed wood.