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Damage to West Coast Wood Structures by Decay Fungi, Insects, and Marine Borers

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T.C. Scheffer

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Introduction

Wood is a renewable resource with many unique features that make it a prized material for the construction of buildings, piers, wharves, boats, and poles. It has, however, the disadvantage of being subject to damage by fungi, insects, and certain marine animals. These organisms are all indispensable scavengers in nature, but must be excluded from manufactured structures. Fortunately, they can be controlled by comparatively simple protective measures at a cost that is reasonable in light of the resulting improved and extended service.

Successful control involves understanding the conditions that lead to a biological attack and recognizing hazardous situations. Inspecting wood structures annually to catch damage at an early stage is one of the keys to combatting pests.

This publication focuses on the major organisms attacking West Coast structures and the primary ways of protecting against them. Control measures are mainly in general terms, but the references at the end of each section provide further guidance.

The information is presented in three sections:

- Wood rot: decay fungi
- Insect damage
- Marine borers

Wood Rot: Understanding and Controlling Decay Fungi

What Is Rot?

Most of us at one time or another encounter softened wood in our homes, boats, or other valued structures—and are distressed by the realization that we have a rot problem. Questions immediately arise: Why did it happen? What can be done to remedy the situation? How can future damage be avoided? Some answers to these questions are found in the following sections, along with information about rot and principles underlying its prevention and control.

Rot or decay results from the presence of plant microorganisms called decay fungi that feed on wood. Although often referred to as "dry rot," the rot cannot occur unless the wood is wet enough to support the attacking fungus. Under the microscope, the fungus appears as a network of branching, thread-like strands within the wood. These strands secrete chemicals that break down the wood into sugars that the fungus uses for food. Early stages of decay may not be discernable, but as the wood is progressively attacked it tends to discolor and lose strength until it finally acquires the familiar appearance of rot.

Rot spreads in two ways: either by contact between infected and sound wood with the decay fungus growing directly from one into the other or by means of spores (analogous to seeds) that are produced on the wood surface and disseminated by wind or insects over long distances. When spores come in contact with suitable moist wood they germinate, forming new strands that grow into the wood (Figure 1). Frequently rot and insect damage are associated, increasing the rate of deterioration.

Conditions That Favor Rot

Basic Needs of Rot Fungi

Rot fungi have the same basic needs as green plants—water, nutrients (e.g., wood), mild temperatures, and oxygen. Rot can be controlled by depriving the fungus of one of these needs. Simply keeping wood dry is the best way of preventing rot. Wood may also be protected by applying preservatives that spoil it as a source of food. Although controlling rot by altering temperature in finished products is not practical, the high temperatures applied in preservative treating and in kiln drying kill fungi that may have become established in the wood during processing and storage. Limited advantage has been taken of the need for oxygen by driving untreated piles deep under water or below the water table, but this practice is no longer recommended because permanent complete submersion cannot be assured.

Kind of Wood

Some structural woods are more durable than others because they are protected by naturally occurring preservatives. Heartwood of native species, such as western red-cedar (*Thuja plicata* D. Don), redwood (*Sequoia sempervirens* (D. Don) Endl.), and oak (*Quercus* spp.), exhibits substantial resistance to decay. As posts, these woods commonly serve for 20 years or more. White oak (*Quercus alba* L.) is widely used for boat frames because it combines durability with high strength. On the Pacific coast,

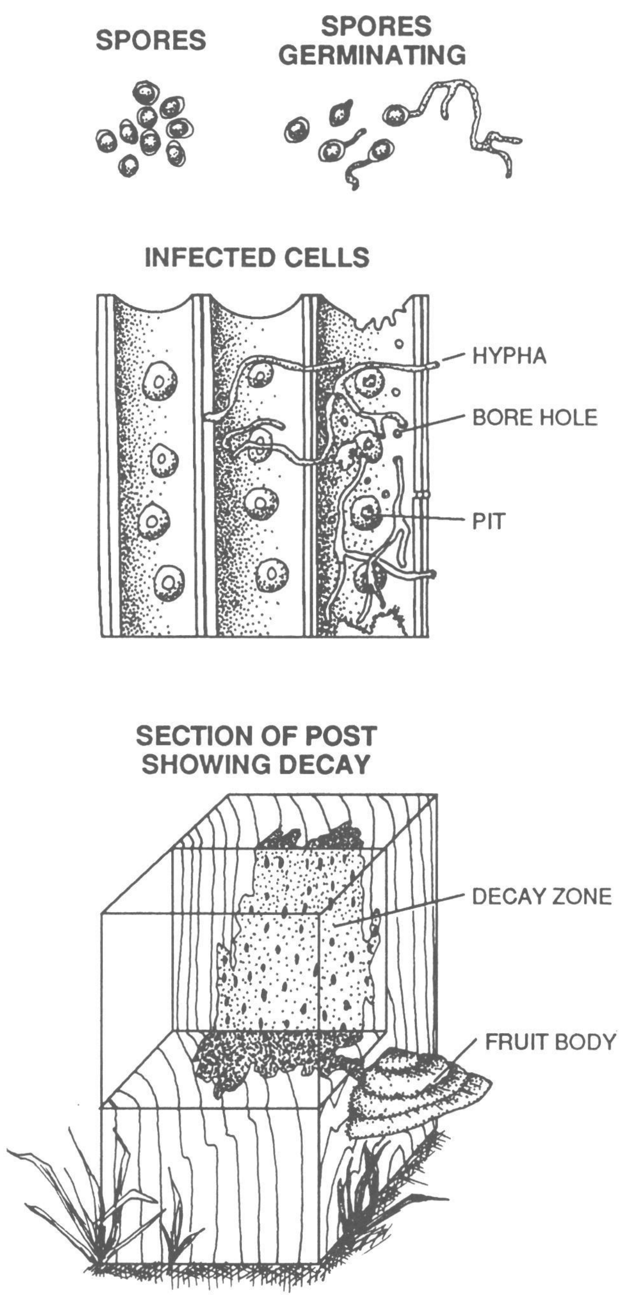

Figure 1. Cycle of decay: Thousands of spores (top left) that developed in fruit body (bottom right) of the decay fungus are distributed by wind or insects. On contacting susceptible wood they germinate and the fungus penetrates the wood, infecting it cell by cell (middle). After causing a certain amount of decay, a fruit body is developed and the cycle is repeated.

Alaska-cedar (*Chamaecyparis nootkatensis* (D. Don) Spach) is also used. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) heartwood, although not very long lasting in the ground, is considerably more durable above ground than is heartwood of species such as hemlock (*Tsuga* spp.), true fir (*Abies* spp.) (e.g., white fir (*Abies concolor* (Gord & Glend.) Lindl. ex Hildebr.), and spruce (*Picea* spp.). No sapwood has significant resistance to decay.

Wood Moisture

To prevent rot of untreated wood, you should aim for conditions that keep the water content below 20 percent (based on oven-dry weight of the wood). Ordinarily, wood can be kept sufficiently dry by preventing it from being wetted by liquid water, such as rain or condensation. Damp air, alone, does not supply enough water to sustain rot. It may, however, favor rot where wood surfaces are cooled enough to result in frequent condensation; moreover, damp air hinders drying-out if the wood does get wet. Enclosed boat compartments are notably subject to these decay-encouraging conditions and should be ventilated.

The rate at which rot develops after it is established depends on the species of fungus attacking the structure, as well as moisture, temperature, and the susceptibility of the wood. Wood that looks or feels wet, yet is far from being water soaked, can rot rapidly if other conditions favoring rot are present.

Climate

Most decay fungi prefer temperatures in the range of 25 to 32°C (77 to 90°F). They do little harm at temperatures near freezing or above 38°C (100°F). The Scheffer Climate Index (C.I.) provides a useful formula for estimating relative decay potentials for rain-wetted wood in use above ground.

$$\text{C.I.} = \sum_{\text{Jan.}}^{\text{Dec.}} \frac{(T - 35)(D - 3)}{30},$$

where T is the mean monthly temperature (°F) and D is the mean number of days in the month with > 0.01 inch precipitation.

A map of climate indexes (Figure 2) can be useful. However, where elevation differences create pronounced differences in climate, such as in mountainous areas, the C.I. should be ascertained for individual localities from the above formula. Examples of C.I. for Pacific coast localities are: Astoria 71, Seattle 50, Olympia 50, Portland 50, Oakland 20, and Los Ange-

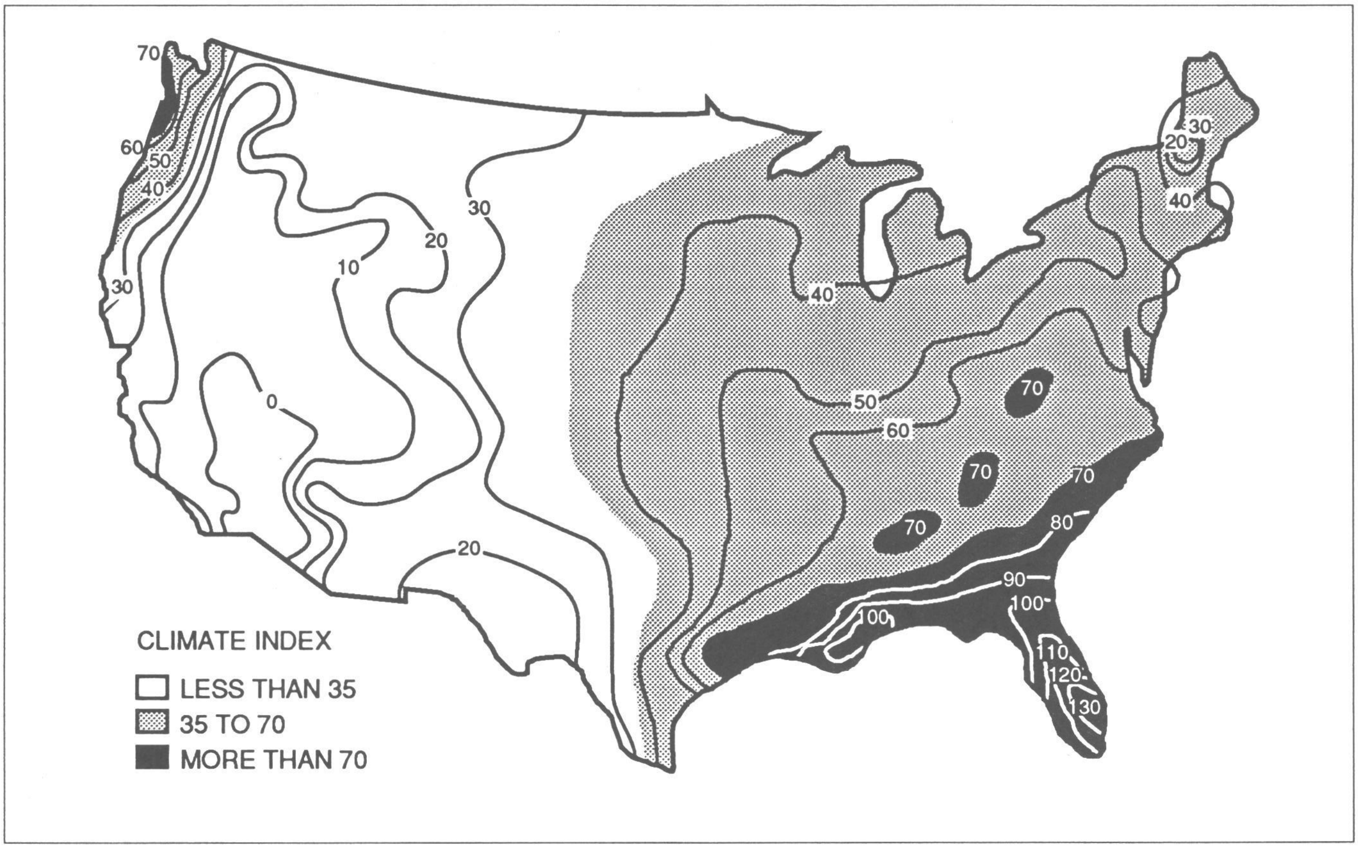

Figure 2. Climate-index map based on the formula given on page 2. Decay hazard is nominally the same along a given line except where there are pronounced differences in elevation. The lowest hazard lies in areas between indexes 0 and 35 and the highest between 70 and 100. Contours courtesy U.S. Weather Bureau.

les 8. Values less than 35 denote relatively low decay potential and values greater than 75, high potential.

Variation in the length of service life of fully exposed wood is associated with differences in climate. Experimental panels of untreated tongue-and-groove flooring of hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and other decay-susceptible woods, situated off the ground in western Oregon (C.I. 47) and in southern Mississippi (C.I. 99), lasted on the average 15 and 6 years, respectively. Experimental post-and-rail assemblies of 2 x 4 inch lumber of the same species and on the same test sites lasted 19 and 10 years, respectively (Scheffer et al. 1971). Douglas-fir deck planks (5 x 12 in.) on piers in Seattle (C.I. 50) have been estimated to last about 15 years, and in Norfolk, Virginia (C.I. 70) about 10 years (Scheffer, unpublished). A much shorter service life is typical for wood in the ground. For example, experimental posts (16 sq. in. section) of untreated Douglas-fir in western Oregon lasted only about 5 years and pine posts, 4 years. In southern Mississippi, pine posts lasted about 3 years.

Protecting Wood with Preservatives

A question that often occurs is: Does every use of wood merit preservative treatment? The answer is always in the affirmative if the construction is such that the item cannot be kept safely dry (<20% moisture). Dollar savings realized from the longer, trouble-free service of properly treated wood outweigh the cost of treatment. For example, the treated posts on the previously mentioned test sites in Oregon and Mississippi lasted 6 and 10 times as long, respectively, as the untreated controls. Dollar differences are apparent in the expense of maintaining the above-water portion of piers and wharves: the annual cost over a 40-year period has been estimated to be 2.5 to nearly 8 times greater for untreated than appropriately treated wood. Pressure-treated poles often have a service life of about 35 years, which is an economic necessity when the cost of replacing a pole is several hundred dollars.

For situations where the chance of decay is moderate or when the replacement value of the product does not warrant the fullest protection, simpler and less expensive treatments are available. The preservative can be applied to dry wood by extended soaking, short soaking (commonly called dipping), or flooding from a coarse spray or brush. All of these methods, except extended soaking, should be restricted to items destined for above-ground service. Dip treating and flooding can be done on the construction site. Flood treating can help maintain some wood components already in service.

Pressure Treating

Maximum protection usually requires commercial treatment. The preservative solution is forced into dry or partially dry wood by applying pressure. This deep preservative protection is necessary for expensive items in ground contact, such as poles, foundation, or marine piles, and for expensive lumber and timbers used in vulnerable parts of buildings. It is also needed in heavy structures, such as bridges, piers, and wharves. Comparable protection can be achieved for some woods and uses by allowing water-borne preservatives to diffuse into the wood while it is still in the green condition. However, wood treated by diffusion is not ordinarily available commercially.

Soaking

The efficiency of soaking depends on the absorbency of the type of wood and the value of the product. Dry wood can be prepared for in-ground use by soaking for several hours or days in a preservative solution. Poles and posts are commonly butt treated by extended soaking. Double soaking—first in a hot, then in a cold, bath—provides superior protection. The hot bath drives out air, easing penetration of the preservative solution.

Unseasoned (green) wood can be treated by what is known as *double diffusion*. Wood is soaked in a preservative solution that enters the wood by diffusion. This is followed by soaking in a second solution containing a chemical that reacts with the first solution to form a leach-resistant preservative. This treatment has been recommended mainly for fence posts.

Dip Treating

Three-minute submersion, popularly termed *dip treating*, is the standard commercial method of protecting exterior pine millwork. It can be remarkably effective on wood situated off the ground, and preservative solutions for this purpose have gained wide acceptance among home and boat owners (Figures 3,4). Although 3-minute dipping is commonly recommended, a longer submersion period of 15 to 30 minutes may sometimes be worthwhile if time permits.

As an alternative to dip treating, some millwork manufacturers attain comparable penetration by the *vacuum process*—creating a vacuum around the wood and then briefly soaking wood in preservative.

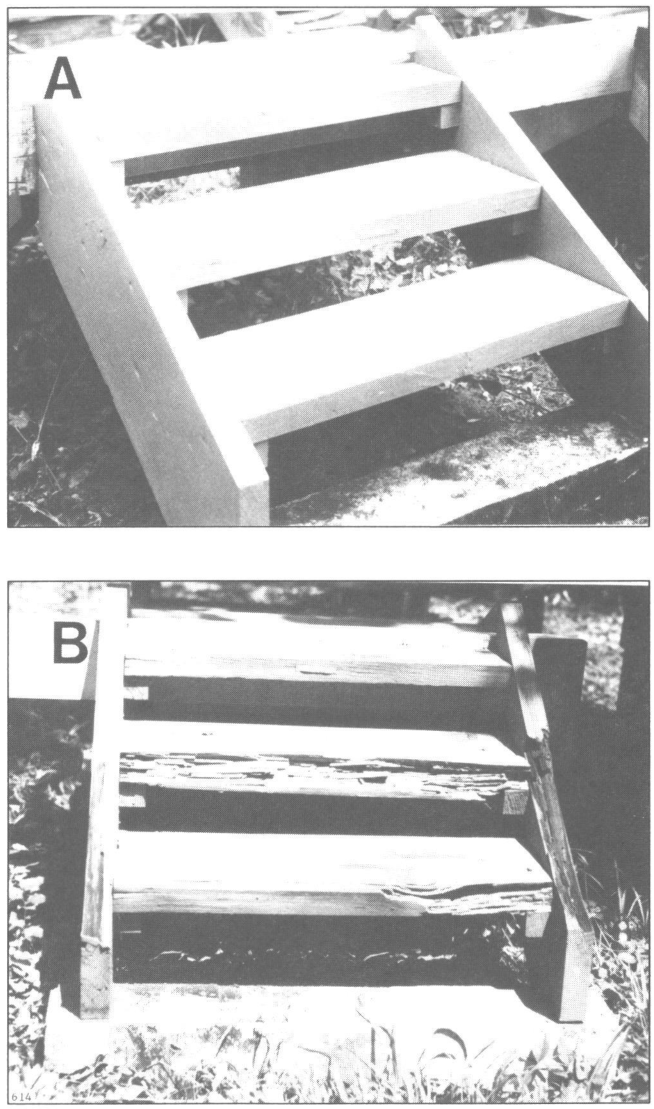

Figure 3. Contrast between dip-treated steps (A) and untreated (B) after 5 years of exposure near Gulfport, Miss. On-site dip treatment consisted of immersing the precut lumber 3 minutes in a light oil solution of 5 percent pentachlorophenol and water repellent.

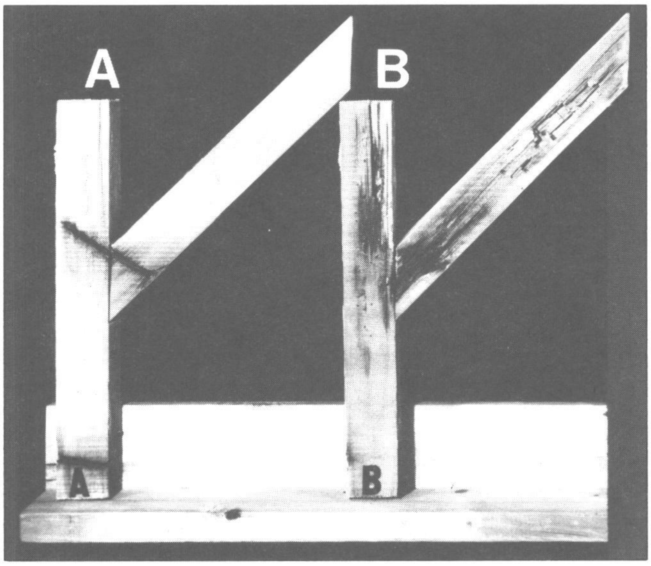

Figure 4. Interior of dip-treated (A) and untreated (B) post-rail units constructed of 2- by 4- inch lumber after 15 years exposure in western Oregon. Post and rail were submerged 3 minutes in a water repellent plus penta (5%) solution in mineral spirits.

Flooding

Flooding is generally reserved for treating items already in place to protect joints and other contacting surfaces not previously treated or insufficiently treated. The preservative solution is applied by a brush or coarse spray, covering the surface with surplus solution so that preservative can seep into locations that trap water, where protection is most needed. Flooding should be done on dry wood, when joint openings are largest. It may be worthwhile to repeat the treatment at yearly or moderately longer intervals.

Many owners of fishing boats clean and flood-treat the bilges annually. Repeated treating may offset the disadvantage of low penetration into the wet wood; continued adherence to the practice suggests that it has merit. The solution will get to the faying surfaces best if the boat has been out of the water long enough to allow seams and joints to open up. Less frequent but more general flood treating below the deck might be worthwhile. The solution should be directed into water-trapping butt and edge joints with a coarse spray, and also into other joints, such as at junctions of planking with frames, stringers, butt blocks, keelson, stem, shelf, and clamp.

Experiments have indicated flooding can also be beneficial on planks of pier and wharf decks, and on porch and patio decks of houses.

Gas Treating

A novel form of preservative that is gaining increasing attention consists of introducing a fungicidal gas in liquid or solid state and allowing it to diffuse through the wood. The treatment has to be repeated at intervals of several years, but it offers the advantage of deep penetration into wood ordinarily not reached by liquid preservatives.

Choosing a Preservative

Before selecting a preservative, check if it is government-approved for the intended use. Consider, also, the method of application, cleanliness, freedom from odor, paintability, and absence of danger to persons or animals.

Leading preservatives for pressure treating are of two kinds: oil soluble and water soluble. Chief oil solubles are creosote, creosote-oil solutions, pentachlorophenol (penta), copper naphthenate, and copper-8 quinolinolate. Penta is carried in heavy petroleum oil, light petroleum, or a volatile solvent to meet different requirements. Penta carried in certain light or volatile solvents will leave wood clean, comparatively odorless, and paintable. The most commonly used water soluble preservatives are copper chrome arsenate and ammoniacal copper arsenate, known commercially as CCA and ACA, respectively. CCA and ACA are favored in specifications for lumber and plywood going into wood house foundations; the toxic chemicals become largely insoluble after entering the wood. The water solubles also leave the wood odor free and ready to paint.

Penta is permitted only for use in commercial pressure treating, thus cannot be used for dip and flood treating. Two comparatively new oil-soluble preservatives, 3-iodo 2-propynylbutyl carbamate (IPBC) and tributyltin oxide (TBTO), are being used for commercial dip treating of mill work. In addition to these, n(trichloromethylthio) phthalimide (Folpet) and zinc naphthenate are in preservative preparations sold "over-the-counter." Copper naphthenate, an older preservative that imparts a green color, has long been used on boats. A solution strength of 1 to 2 percent copper equivalent is appropriate. For treating fish holds and wooden food containers, the preservative must be government approved. Copper 8-quinolinolate is approved for treating wood to be contacted by foodstuffs, and other potential preservatives for this purpose are being examined experimentally.

Materials for gas treating are sodium n-methyldithiocarbamates (Vapam), methylisothiocyanate (MIT), and chloropicrin. Means of introducing these are continually being improved for safe and expeditious handling.

Precautions

Observe the following precautions when preparing or using treated wood:

- Be sure the preservative is legal and meets your requirements for permanence and qualities noted under "Choosing a Preservative."
- When buying pressure-treated stock of high value or items needed for especially long service, specify the preservative wanted, the quantity to be introduced per cubic foot, and the penetration to be attained. Verify that these requirements have been met. Guidance can be obtained from state and federal extension services, from the American Wood Preservers Bureau, and in supplementary sources of information listed on page 12. Pressure-treated wood for ordinary needs can often be bought from a lumber dealer. Penetration of the preservative may be estimated from color change in samples extracted at mid length of the piece. Penetration in well-treated stock can reasonably be expected to be *uniformly* 3/8 inch or more.
- Do not fail to flood treat copiously all untreated surfaces exposed by cutting or boring during construction with at least double strength or double application of preservative. Holes can be treated easily by swabbing.
- Observe safety precautions to avoid getting preservatives into the eyes or lungs, or concentrated on the skin. Keep preservative supplies and equipment securely isolated from children or animals.
- Do not flood treat structures over water unless you can ensure against harmful drip of solution.
- Dispose of hazardous wastes safely.

Guidelines for Controlling Rot

By following a few basic principles for controlling rot, details of what to do in specific situations can usually be developed without great difficulty. Keep in mind that decay fungi require more than 20 percent water (based on oven-dry wood) and that this ordinarily occurs only in incompletely seasoned wood or in wood that is wetted by liquid water.

Certain guidelines apply to any wood structure exposed to the weather:

- Start construction with fungus-free, dry wood, if possible. This means keeping wood stored on the building site off the ground and covered against rain wetting (Figure 5).

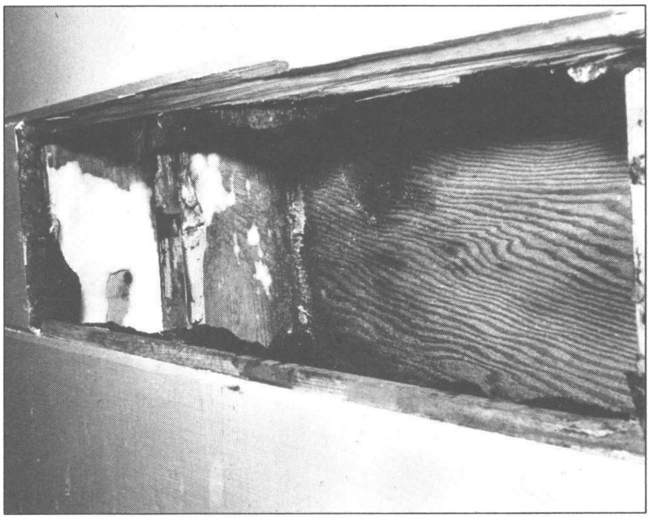

Figure 5. White surface growth of a decay fungus in an exterior wall. The decay resulted from using infected and incompletely dried studs and closing them in shortly after they were installed.

- Adhere to the following good construction practices that prevent dangerous wetting: (a) place untreated wood well off the ground; (b) provide an ample and tight cover against rain wetting, if applicable; (c) ventilate or otherwise protect enclosed spaces (e.g., crawl spaces) against heavy wetting by condensation; (d) design exterior components so as to shed water and present a minimum of water-trapping joints and interfaces; and (e) pay attention to areas where caulking and flashing are usually required.
- Know where preservative-treated wood is needed and in what circumstances supplementary treating may be helpful.
- Inspect decay-vulnerable areas, and remedy hazardous wetting promptly or replace vulnerable wood with preservative-treated material.

Buildings

- Make concrete foundation, walls, or slab high enough to provide separation from exterior grade of at least 8 inches for framing and 6 inches for siding. This also applies to masonry walls. Avoid reducing these tolerances during subsequent landscaping.

- When building over a crawl space, allow a minimum of 18 inches between the ground and wood substructure members. Clearance of 2 feet or more is better because it makes it easier to gain access to areas under the building for inspection or other purposes.
- Ventilate the crawl space with at least 4 vents placed near corners and see that the total unobstructed area of the vents is at least 0.6 percent of the area of the enclosed ground. In addition, where average winter temperatures are 10°C (50°F) or lower and the ground tends to be damp, prevent hazardous condensation on sill plates and exterior joists (Figure 6) by laying a durable vapor barrier (e.g., 60 lb., or heavier, roll roofing or 4-mil polyethylene) on the ground. The vent area can then be as little as one-fifth the standard recommendation, or 0.12 percent of the ground area.
- Allow shingles (or edge flashing if present) to extend at least 1 inch beyond facia or exposed rafters to prevent rain water from curling back and wetting roof edges. Install a gravel stop at eaves and rake for built-up roofing, and extend the drip edge at least 3/4 inch beyond facia or framing (Figure 7).
- Ventilate cornices enclosed by a soffit (Figure 8).

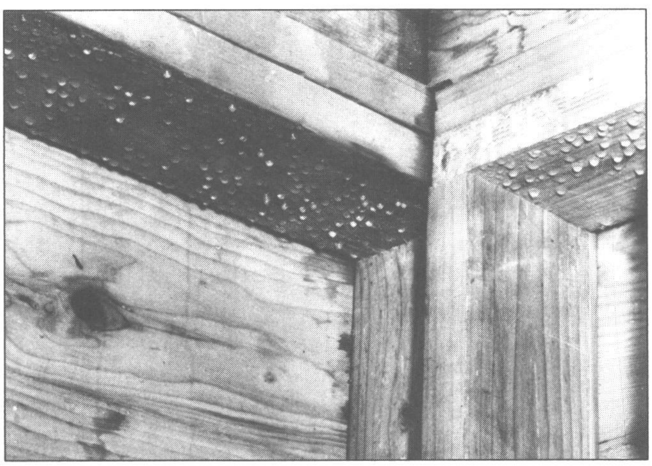

Figure 6. Cold-weather condensation in corner of crawl space; the lumber had recently been installed to replace decayed lumber. The condensation, which continued and threatened further decay, was easily eliminated by laying an inexpensive vapor-resistant cover on the damp ground.

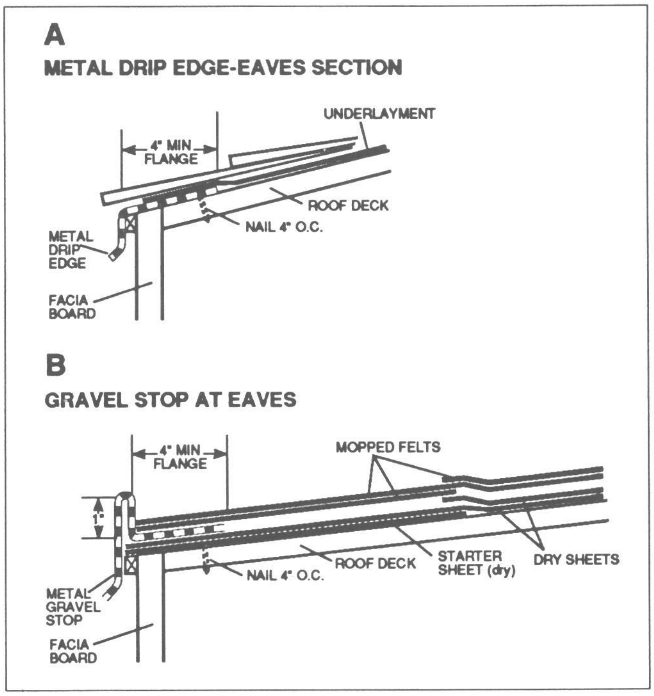

Figure 7. Appropriately designed metal flashing (A) and similar gravel stop (B) provide good protection to edges of built-up roofs. The turned-out lip of the flashing diverts much of the rain water from the facia wall.

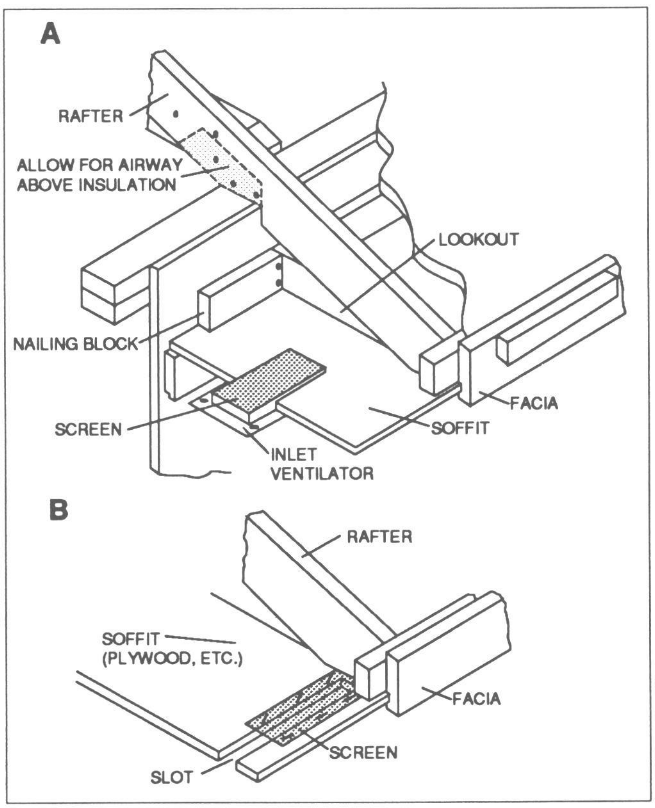

Figure 8. Inlet ventilators: A, small insert ventilator; B, slot ventilator.

- Prevent rain water from collecting against siding or from flowing over siding, windows, and doors in wet climates by: (a) sloping decks and porches away from the building; (b) providing a roof overhang of at least 2 feet; and (c) installing gutters and downspouts.
- Protect exterior joints by flashing, caulking, overlapping construction, and tight joinery (Figures 9, 10).
- Avoid exterior double-board construction and, where possible, exposed contacting surfaces (Figure 11).
- Keep posts and columns dry at the base by setting them on concrete footings or on an elevated metal bracket.
- Prevent rot-inducing condensation in walls by installing the vapor-barrier face of the wall insulation on the room (warm) side of the wall. Rot in walls, however, is generally not a problem.
- In the special case of cold storage rooms, install a vapor barrier on the warm side of the partition (outer side) and insulation on the cold side to prevent condensation from forming on wood inside walls, ceiling, and floor. Note that the position of the vapor barrier is reversed.
- Where construction design cannot ensure keeping a building component safely dry, use treated wood. Pressure treatment is usually recommended, but dip treating can be effective on millwork.

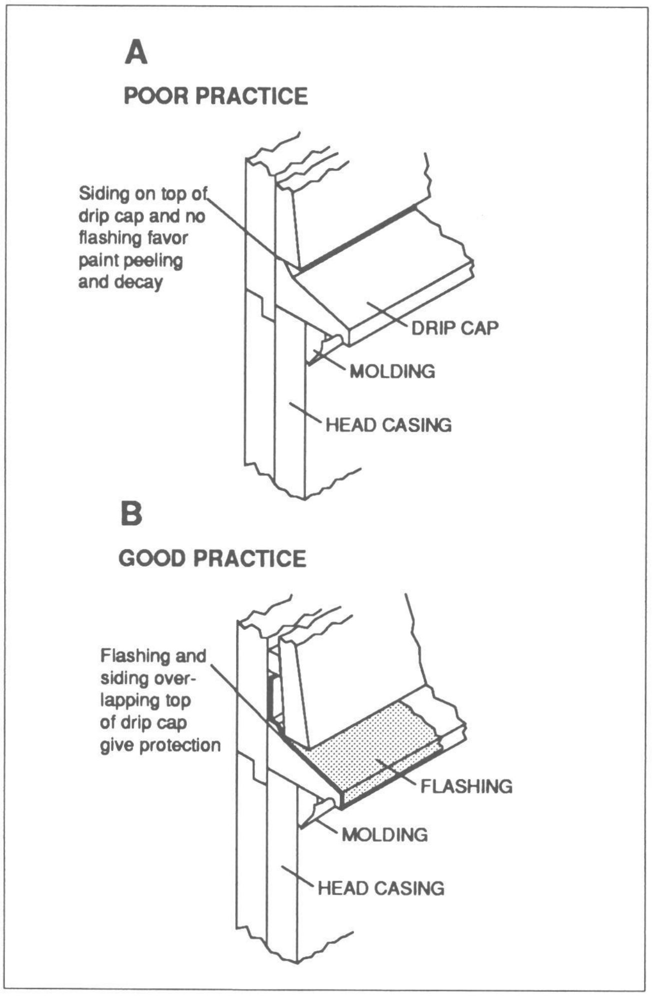

Figure 9. Joining of siding to a drip cap; note how the "poor practice" (A) allows for entry of rain water into several decay-vulnerable joints, whereas "good practice" (B) provides protection by flashing and by siding overlapping top of drip cap.

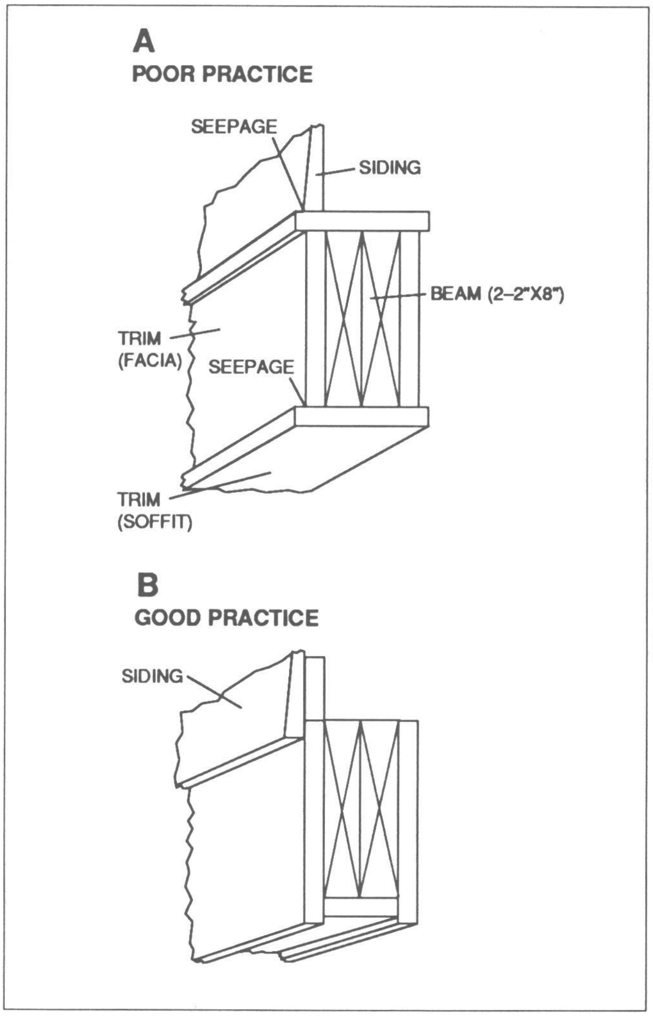

Figure 10. Boxed beam (A) has horizontal ledge that traps rain water. Boxed beam (B) illustrates good construction; boxed similarly to the standard eave, it is less subject to rain seepage because it does not have the rain-trapping ledge.

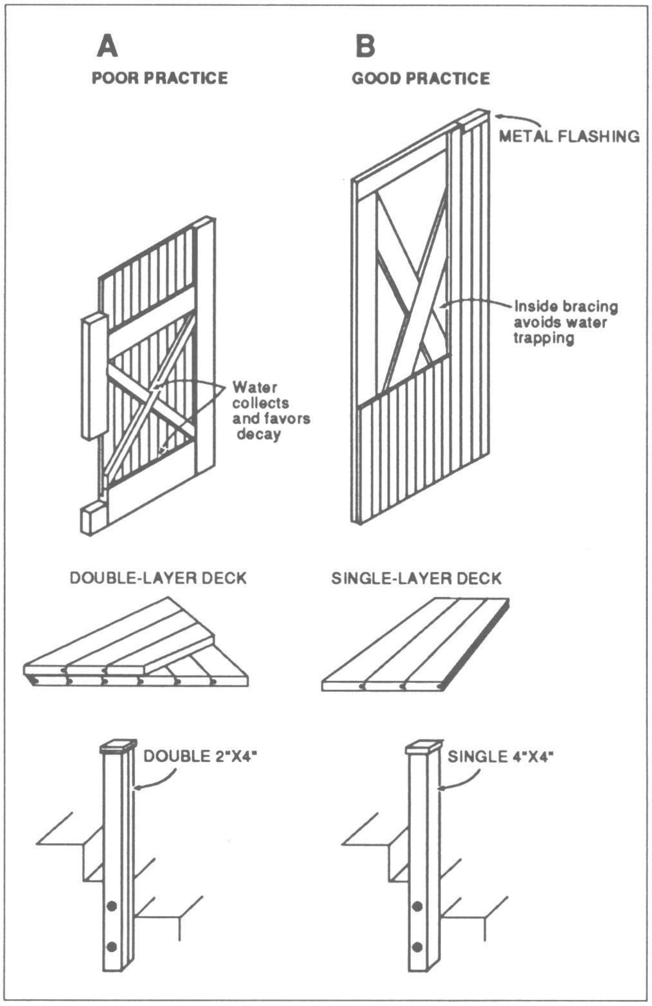

Figure 11. Poor (A) and good (B) practices in construction to avoid trapping rain water. Double thicknesses of lumber and exposed contacting surfaces—especially those required by architectural frills—should be avoided as much as possible.

Boats

Rot in wood boats is promoted by rain seeping into and through the deck to parts below and by wetting from wave splash and seepage through the hull in fresh water. Wetting by salt water is considerably less hazardous because salt accumulation retards fungal growth.

- For long service with minimum maintenance, use wood that has been treated with a "permanent type" water-borne preservative (or use naturally decay-resistant wood) for frames, hull, and deck planking.
- As is the case for buildings, flash where needed and caulk all crevices where water might enter.
- Where practical, moor the boat under shelter.
- To promote drying of wood that may get wet below the deck, avoid dead air spaces. It is particularly important to provide air flow between hull planking and ceiling by some method such as inserting louvers in top and bottom ceiling boards or omitting these boards. Ventilation of storage lockers and stem and transom areas can be promoted by openings in panels and bulkheads that facilitate circulation and exchange of air. When a boat is moored and thus deprived of the air movement created during cruising, areas below deck can be dried out with a fan or by mild warming.
- Untreated wood below the deck that is subject to fresh-water wetting may occasionally be flooded to advantage with preservatives. Aim to get the solution into butt and edge joints, such as in plank seams at junctions of planks with frames, stringers, butt blocks, keelson, stem, shelf, and clamp. Flooding is most beneficial when the boat has been out of water long enough for seams and joints to open up a bit.

Piers and Wharves

Most piers and wharves are constructed of large-dimension material of high value that is fully exposed to the weather. The tendency for the timber to develop deep seasoning checks (Figure 12), the splitting of stringers by spikes (Figure 13), and the prevalence of large overlapping butt joints (Figure 14) combine to produce a great number of water-trapping zones. Therefore, for these structures, pressure-treated wood throughout is usually justified. Supplementary treatment with a gas fungicide for deeper protection is receiving increasing attention.

The inner untreated wood in the cut-off tops of piles is very vulnerable to rot (Figure 15) and needs supplementary protection. The same is true of the cut-off ends of large sawed timbers (Figure 16).

- Flood treat all cut surfaces with at least double-strength preservative, or equivalent repeated flooding, being careful to avoid spilling any solution into the water.
- Cap bearing piles with asphalt-impregnated felt.
- Cap fender and dolphin piles with a thick layer of asphalt or coal-tar pitch (easily renewable if damaged by hawser rubbing) to prevent seasoning checks. These piles are very vulnerable to rot, so flooding and capping should be done early before checks develop.

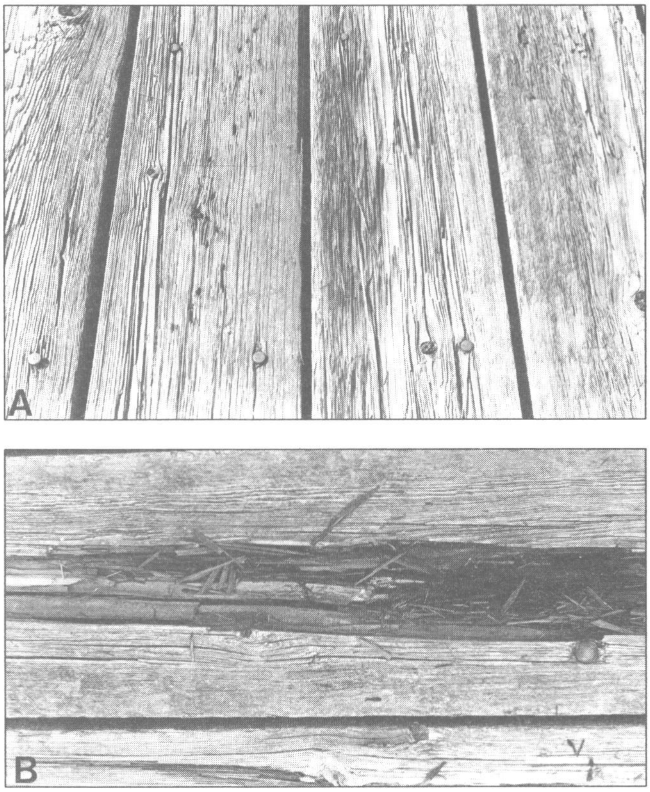

Figure 12. Planks exposed to the weather can develop deep checks (A) in which rain water can be trapped. Wetting in this way makes the planks vulnerable to decay (B) unless they have been appropriately preservative treated. Flooding the planks from time to time with a selected preservative as checks develop can materially delay the onset of decay.

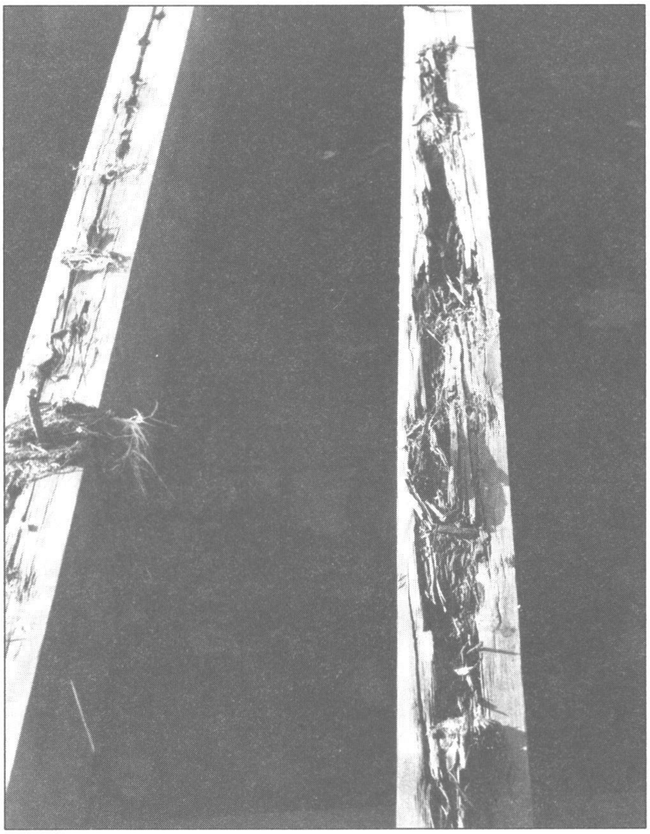

Figure 13. Rot in untreated Douglas-fir pier stringers, promoted by accumulation of water in local splits made by spikes attaching the deck planks. Such decay around nails, spikes, and drift pins causes early loosening of the structures.

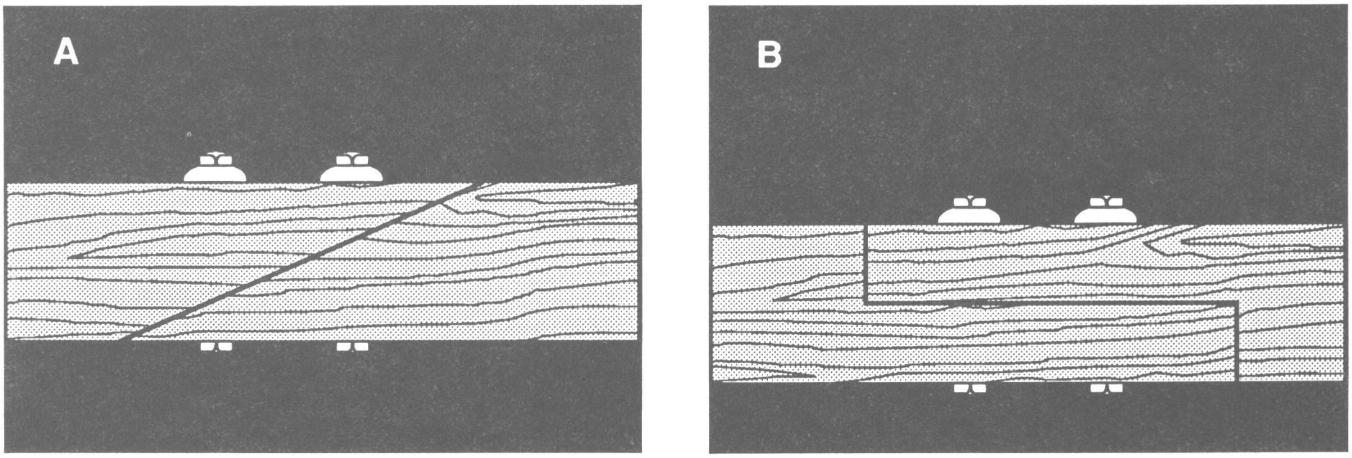

Figure 14. Scarf joining (A) and half-lap joining (B) make possible the joining of the two halves with the same bolts, but they present much more water-trapping contact surfaces than does butt joining.

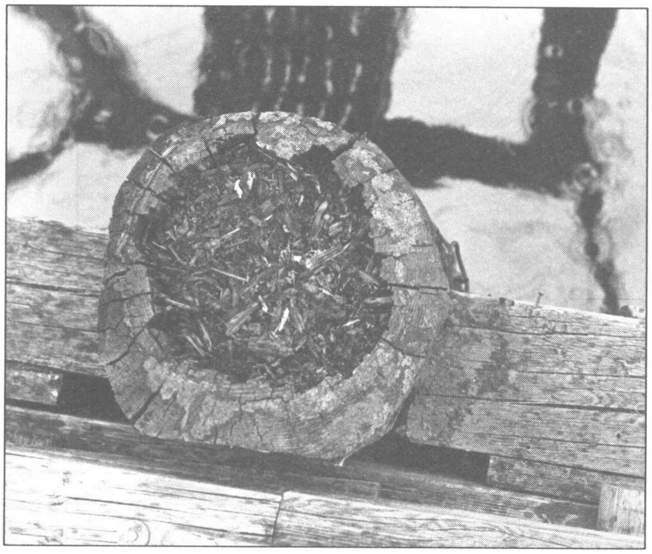

Figure 15. Rot in untreated central portion of piles results from checking of the ends and rain water collecting in the checks. Such rot can be prevented by treating the cut-off surface with preservative and coating the surface with bituminous material to prevent checking. Treating alone is not enough because decay fungi can reach untreated wood exposed by checks.

Figure 16. Rot in central portion of a large timber, resulting from failure to protect the cut-off end with extra-strength preservative.

Poles

Wood poles for carrying power and communication lines are expensive to replace when damaged by rot. They should be protected by pressure preservative treatment according to American Wood Preservers Association standards. The life of poles can be greatly extended at little extra expense by a supplementary treatment with a gas fungicide (see page 5). Customarily, three downward sloping holes are drilled at equal intervals around the pole. After the gas in liquid or solid phase is inserted, the holes are plugged. The diffusing gas not only helps protect the interior of the pole against invasion of decay fungi, but also kills fungi that are already present.

Inspection and Repair

Structures that are particularly subject to decay should be inspected annually. Look for and eliminate the source of any hazardous wetting. If further wetting cannot be prevented, replace the wetted item with a treated one.

Recognizing Early Stages of Rot

- Look for an abnormal or brownish color or a semibleached appearance. Mottled discoloration is especially indicative of decay infection.
- In damp air, decay fungi are sometimes visible on the wood surface as a white overgrowth.
- Rot often discolors paint and causes the wood beneath to collapse. Paint with an overlying brown to black stain coupled with a sunken area is certain evidence of rotted wood underneath.
- An excellent and widely used way to check out suspicious looking wood is to examine its fiber toughness. Do this by lifting a splinter of wood with a knife point or sharpened screw driver and observing the character of the break (Figure 17). First, wet the wood if it is dry. If the splinter lifts out without breaking or breaks into sharp points at the place of fracture, the wood is comparatively sound, but if it breaks abruptly across the grain, the presence of decay is strongly indicated.

Inspecting Buildings

- Look for rain seepage around roof edges (facia, soffit, rafter ends) where components meet adjacent to window and door frames and where components come together on porches, decks, steps, and railings.
- In the crawl space, look for cold-weather condensation or rot in late fall or in winter on sill plates, perimeter joists, and joist ends. Give special attention to corners.

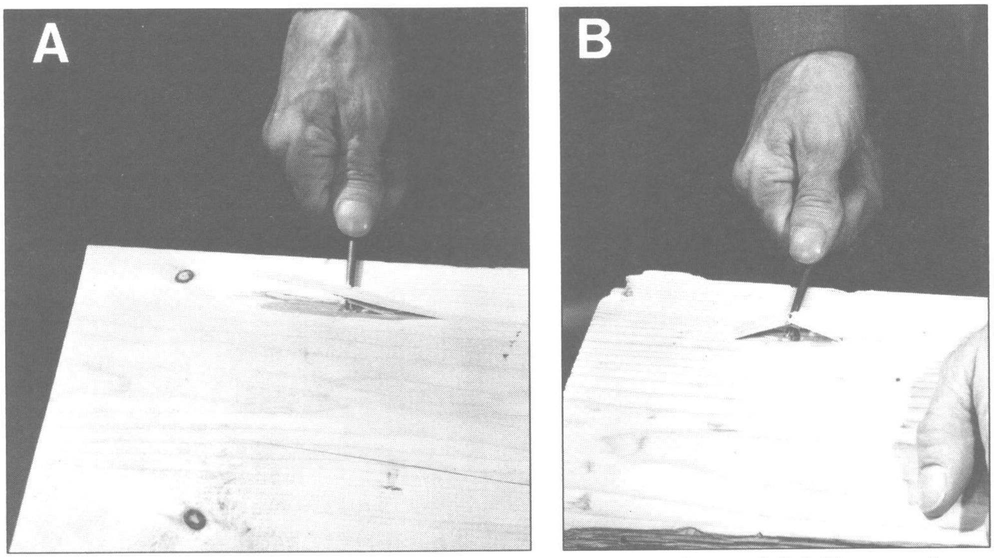

Figure 17. The "pick test" for early decay. Wetted wood if sound (A) lifts as a long sliver or breaks by splintering; if infected (B) it tends to lift in short lengths and to break abruptly across the grain without splintering.

- In the crawl space, look for wet areas of subfloor that might indicate plumbing leaks from above.

Measures for preventing hazardous wetting in buildings are outlined on pages 6 through 9.

Inspecting Boats

Boat hulls are commonly scraped, caulked, and painted annually. This practice ensures close inspection of the surface, making it unlikely that plank seams and butt joints in need of caulking are overlooked.

- Be sure to maintain seam caulking on the deck (or a tight deck cover if present). Keep tight and well caulked junctures of components around the wheel house or cabin, along the waterways, and around hatches, stancheons, and frameheads protruding through the deck. Painting is also helpful in protecting small cracks and crevices in joinery, but *never* rely on a paint coating alone to keep water out.
- Consider occasional flood treating of areas below deck that may become wet from fresh water (see page 5).

Inspecting Piers and Wharves

- Inspect the interface between large contacting members and deep seasoning checks where water might collect.
- Probe checks and joints of superstructure components with an ice pick or sharpened screw driver. A portable drill with 1/8-inch bit may be useful, evidence of rot being indicated by reduced resistance to the drill or a change in character of the extracted chips. Little can usually be done to arrest any rot found, although gas treating, much like that described for poles, can be beneficial. The inspection may reveal members that need to be replaced to avoid dangerous conditions.
- Watch for, and promptly repair, damaged caps installed on fender piles to prevent seasoning checks.

Repairing Rot Damage

Before repairing rot-damaged items, stop the wetting that made the rot possible. If further wetting is prevented and conditions allow the existing wet wood to dry out within a few weeks, you need only remove and replace enough wood to satisfy strength requirements. If, however, there is any question about getting or keeping the item air dry, remove all visibly decayed wood along with wood at least 2 feet beyond and replace it with pressure-treated wood. Remember to treat all surfaces exposed by cutting on the job with at least double-strength preservative.

For Further Information

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Slide Tapes

Wood Preservation Minicourse and Microcourse. Slide-Tape #593. Forestry Media Center, Oregon State University, College of Forestry, Corvallis, Oregon 97331.

Insects: Preventing Wood Damage

Insects To Watch Out For

The three primary groups of insects responsible for damage to wood structures are termites, carpenter ants, and wood-boring beetles. Termites are by far the most destructive, but the others cause serious damage in some areas. You should become familiar with all three groups and do whatever is practical to forestall infestations of pests known to be troublesome in your locality.

Termites

There are three kinds of termites to recognize: subterranean, dampwood, and drywood. Subterranean termites nest in and obtain their water from the ground. After attacking wood they return to their underground nest. The western subterranean termite (*Reticulitermes hesperus* Banks) causes millions of dollars in damage in California and Hawaii. It occurs only sporadically throughout the Pacific Northwest, but the cost of damage and control has been estimated at millions of dollars annually. The Pacific Coast dampwood termite (*Zootermopsis angusticollis* (Hagen)) must have wet wood. It needs no contact with the ground, but the moisture requirement is usually found in wood resting on the ground. Not surprisingly, the dampwood termite is prevalent in the Pacific Northwest, being favored by the damp winters. Although less destructive than the subterranean termite, the dampwood termite can cause serious damage under appropriate conditions. The western drywood termite (*Incisitermes minor* (Hagen)) is prevalent south of San Francisco Bay and in Hawaii. Because it lives in dry wood and needs no contact with the ground, it can be troublesome almost anywhere in a building and may even occur in furniture. Attacks by the drywood termite in the upper part of poles are of some concern.

Carpenter Ants

Carpenter ants are common in the Pacific Northwest and are moderately troublesome in Hawaii and parts of California. Although they use wood only for nesting and not for food, a long-standing infestation can cause damage requiring extensive repairs. They prefer wood softened by decay or wetting, but are not restricted to such wood. Carpenter ants are found mainly in places where moisture persists. Substructure members wetted by condensation or by damp soil, items wetted by rain leakage or "sweating" on pipes, and exterior components directly exposed to rain, such as porches, posts, and steps, are likely targets. Occasionally, they damage telephone poles, and boxes or other wood products in storage.

Beetles

Wood-boring beetles, like termites, derive nourishment from wood. Those occurring on the West Coast are either powder-post beetles (three kinds) or flat-headed borers.

The powder-post beetle lays its eggs in or on dry or partially seasoned wood. Developing grubs (larvae) eat their way through the wood until they emerge to mate as adults after several months or years. Often the first conspicuous evidence of an infestation is the appearance of small round exit (emergence) holes, sometimes with piles of fine particles of wood (frass) below them. On the Pacific Coast and in Hawaii damage by powder-post beetles is not widespread, but it can be considerable in individual cases. Lyctus (true powder-post) and bostrichid (false powder-post) beetles attack sapwood of hardwoods and are problems in hardwood flooring, wall panels, doors, window frames, and furniture. (The bostrichids may also be of minor occurrence in softwoods.) A third group, anobiid beetles, attacks softwoods and hardwoods and can seriously weaken load-supporting sills, joists, and subfloor in crawl spaces.

The most destructive of the flat-headed borers on the Pacific Coast is the golden buprestid (*Buprestis aurulenta* L.), so called because of the iridescent golden or blue-green color of the adult. Buprestids like unseasoned or damp wood. Eggs tend to be laid on dead or dying trees, or sometimes in cracks of freshly sawed lumber, so the beetle is in lumber before it goes into houses. They may also infest furniture. Softwoods, especially Douglas-fir, and hardwoods are both attacked. A buprestid infestation generally resembles that of powder-post beetles.

Which Insect Is Causing the Damage?

To combat insect enemies effectively, it is essential to know which insect is causing the problem. Some of the more helpful identification features are given in Tables 1 and 2 and Figures 18 through 23. Entomologists in state and federal offices can provide assistance on identification.

Termites or Carpenter Ants?

To determine if damage is caused by carpenter ants or termites, open up some of the infested wood and look for the insects at work. Carpenter ant workers are long legged, wasp-waisted, black or reddish black, and 10-15 mm long (Figure 18), and they scurry about a great deal, especially when disturbed. A working colony may produce a faint rasping sound that can be heard in a quiet room. In contrast, termite workers are short legged, thick waisted, and pale yellow to grayish white (Figure 18), and are comparatively sluggish.

Carpenter ant galleries made for nesting are clean. The piles of wood discarded to the outside look like coarse sawdust. Termite galleries are not clean (Figure 19), except for those made by drywood termites.

When the winged (reproductive) adults are swarming, they are easy to tell apart. Carpenter ants

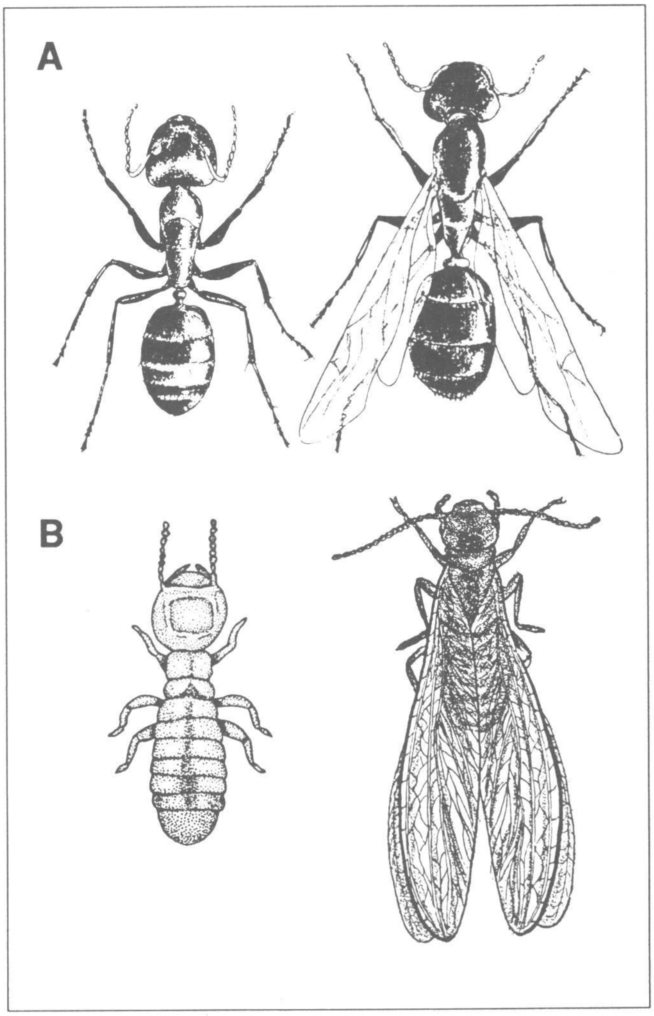

Figure 18. Carpenter ants (A) have a narrow wasp waist and wings of unequal length, whereas western subterranean termites (B) have a thick waist and wings of even length.

Table 1. Some distinguishing features of the three kinds of termites.

	Western subterranean	Pacific dampwood	Western drywood
Winged form: color & length (inc. wings)	• entirely black • 8-9 mm	• yellowish to cinnamon brown • up to 25 mm	• dark brown with reddish head • 11-12 mm
Usual nesting site	• ground	• wood	• wood
External manifestations	• swarming winged adults, or shed wings • shelter tubes between ground and wood; may be free standing (Figure 20)	• swarming winged adults or shed wings	• swarming winged adults or shed wings • piles of fecal pellets extruded through crevices or special "kick-out" holes
Character of invaded wood	• galleries tend to follow the early wood part of the growth rings, leaving sheet like layers of late wood (Figure 19) • walls of galleries coated with whitish excrement; frequently contain depositions of soil	• galleries tend to follow early wood. Late wood also attacked if layers partially decayed. • gallery surfaces velvety appearing • sometimes covered with dried fecal material	• some galleries broad, pocket-like, extensively cutting across the grain of the wood • galleries "clean" with smooth surfaces
Fecal pellets	• very small, not distinctive	• hard and round at both ends, sometimes spherical	• large quantities in galleries; rounded at ends, and with six flattened or depressed sides.
Typical condition of wood when attacked	• usually dry, but may be wet	• damp or wet (required); often decaying	• dry and sound
Relative prevalence			
Pac. N.W.	• occasional	• common	• rare
California	• common	• occas. but common in northwest	• occas. but common in extreme south
Hawaii	• common	• rare	• common
Items prevalently infested	• building substructure members • porch and deck members	• building substructure members • porch and deck members	• all building members but most commonly above the substructure • poles in S. Cal.

Table 2. Some distinguishing features of western wood-boring beetles in structures.[1]

	Lyctus (Powder post)	Bostrichid (False powder post)	Anobiid	Golden buprestid (Flat-headed borer)
Adult beetle:				
color	• reddish brown to black	• reddish brown to black	• reddish brown to black	• golden or blue green
length	• 2-5 mm	• 3-6 mm	• 3-6 mm	• 18 mm
Larvae (grub)	• curved • up to 6 mm	• curved • similar to anobiid but without spines	• curved • has tiny spines ("hairy") • up to 12 mm	• elongated with flattened head and thorax • 35-40 mm
Exit holes	• circular • 0.75-1.5 mm	• circular • 2.5-7 mm	• circular • 1.3-3 mm	• oval • 3-12 mm
Wood infested	• dry sapwood of hardwoods with large pores	• partly seasoned to dry sapwood of hardwoods mainly, including diffuse porous woods. Minor in softwoods	• mainly sapwood of old, seasoned hardwoods and softwoods, especially when surface is rough	• unseasoned softwoods (especially Douglas-fir) and hardwoods
Galleries	• circular, 1.6 mm, tend to follow wood grain • loosely packed with frass, which is very fine and conspicuously spills out of exit holes	• circular, 1.6-10 mm distributed in all directions • packed with fine to coarse particles of frass that tend to stick together and do not easily spill outside exit holes. No pellets in the frass.	• circular, up to 3 mm cut across wood grain, producing "honey-comb" effect • loosely packed with frass, some of which spills out. Frass, a fine powder in elongated pellets. Has gritty feel.	• oval (others are round) in all directions relative to wood grain • packed with mixture of fine frass and excrement
Oviposition	• in pores	• in galleries made by adult	• mainly in cracks & crevices on rough surface • sometimes in cracks on freshly sawed lumber	• on dead, dying, or injured trees with bark on, and in seasoning checks on poles
Reinfestation	• possible (rarely after 10 years)	• rare	• possible if wood moisture is above 12%	• rare
Time to emergence	• few months to 1 year, occasionally several years	• few months to 1 year	• commonly up to 1 or 2 years, but often many years	• few to many years
Relative prevalence				
Pacific Northwest	• occasional	• occasional	• occasional	• common
California	• occasional	• common	• occasional north	• absent or rare
Hawaii	• occasional	• no data	• no data	• absent or rare
Items commonly infested	• hardwood lumber, flooring, walls, trim, doors, windows, furniture, tool handles	• as for lyctus	• subfloor, sills, and joists in crawl space • flooring, walls, & trim • poles • bridges • unused structures[2]	• as for anobiid

[1] Data pertaining to species encountered most on the West Coast and in Hawaii.

[2] Most conspicuous in unheated or periodically unused structures, e.g., coastal second homes and shelters, park buildings, and bridges.

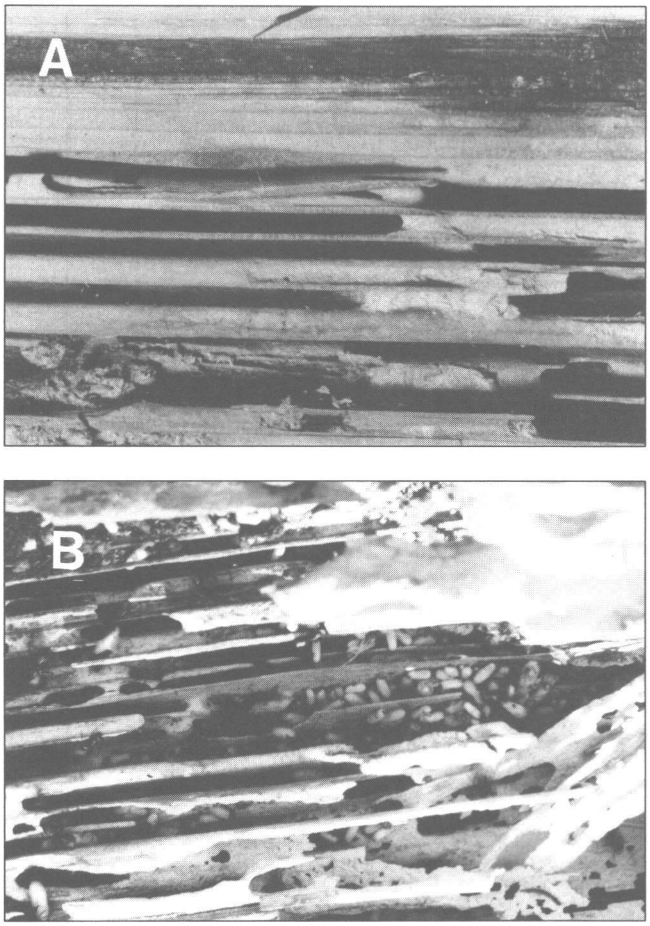

Figure 19. (A) Clean galleries made by carpenter ants. (B) Galleries of the western subterranean termite typically contain dried fecal matter.

have a narrow waist and their front wings are much larger than the hind pair, whereas flying termites have a thick waist and the two pairs of wings are approximately equal in size (Figure 18). You should not assume, however, that the presence of swarming insects necessarily denotes infestation of a structure, since wood debris also is attacked. Nevertheless, if you see them, make a careful inspection and consider precautionary measures (page 21).

Termites or Wood-boring Beetles?

The distinction between termites and wood-boring beetles is easy if adults are present. Beetles, though small, have hard wing covers and the typical beetle appearance. Small holes on the wood surface (Figure 21) indicate a beetle attack. The holes are made by the emerging adults. Piles of fine wood powder or splotches of powder on the wood surface are further confirmation of beetles.

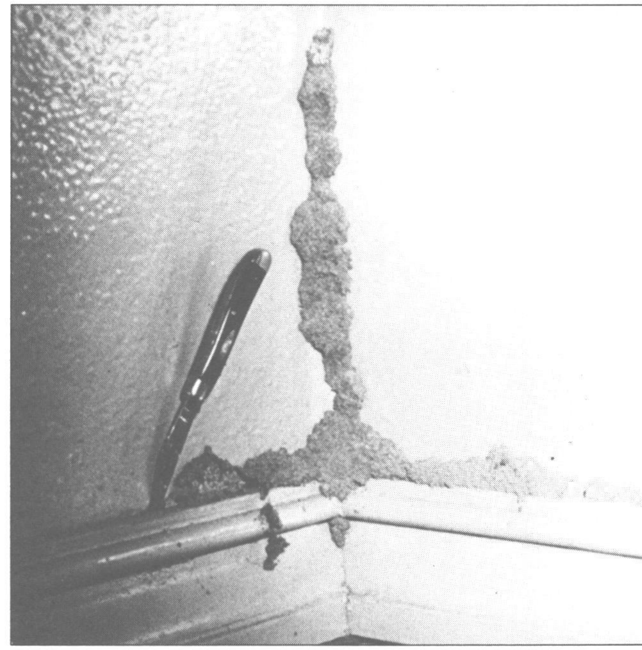

Figure 20. Earthen shelter tubes are one sure indication of termite infestation. They are used by the termites to travel between wood members and the moist ground.

By looking at the galleries inside infested wood, you can determine which kind of insect is present. Termites are at work if the galleries are comparatively large and contain dried fecal matter (except for drywood termite). Beetles are involved if the galleries are narrow and any wood residue in them is very fine (powdery). The beetle grubs (larvae), which make the galleries, tend to be curved in a C shape (Figure 22) (except for buprestids) and are immobile when disturbed, whereas the termite workers look quite different (Figure 18) and crawl slowly when disturbed. Other distinguishing features can be found in Tables 1 and 2 describing termites and wood-boring beetles and their damage.

Which Termite?

Table 1 provides help in identifying the three main termites in the Pacific areas. For positive identification it is safest to consider more than one feature, although sometimes a single feature, such as the wood-and-mud shelter tubes of the subterranean termite (Figure 20) or the depressed sides of the fecal pellets of the drywood termite, can be diagnostic. The

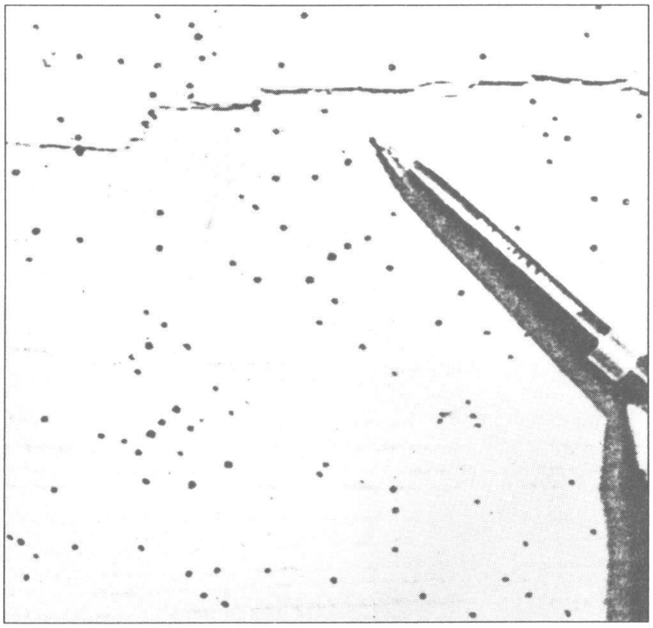

Figure 21. A 10-inch square of pine covered by anobiid exit holes. Exit holes of lyctus and bostrichid beetles would look much like this except for some differences in size.

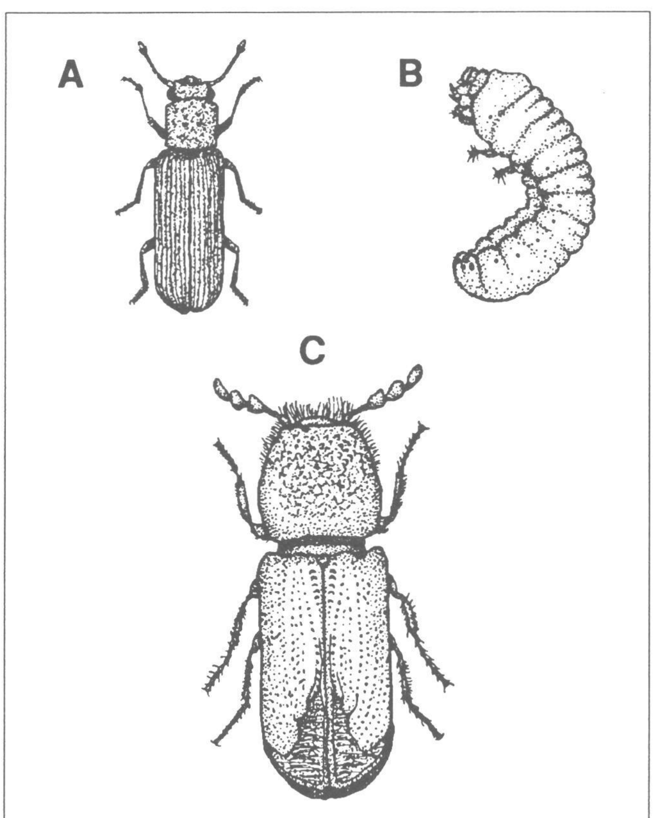

Figure 22. An adult lyctus beetle (A), and larva (B). Bostrichid beetle (C).

relative prevalence of the three termite groups in a particular region can be a helpful guide to start from; for example, in the Pacific Northwest dampwood and subterranean termites are much more likely to be encountered than is the drywood termite.

Which Wood Borer?

Table 2 and Figures 21 to 23 can be of help in determining which of the wood-boring beetles is responsible for an infestation. With the beetle identified, you will then know whether or not the infestation is likely to continue and, if it is, what steps can be taken to control further attack. The type of gallery, characters of the larvae and their frass (fine wood particles and excrement), size and shape of exit holes, and kind of wood infested are all useful clues. Although "time to emergence" is only marginally helpful, it is included to show that infestation generally occurs a few months to several years before evidence of damage, such as exit holes or piles of frass. Using "time to emergence" to assign responsibility for an infestation is usually difficult because the time of origin is uncertain.

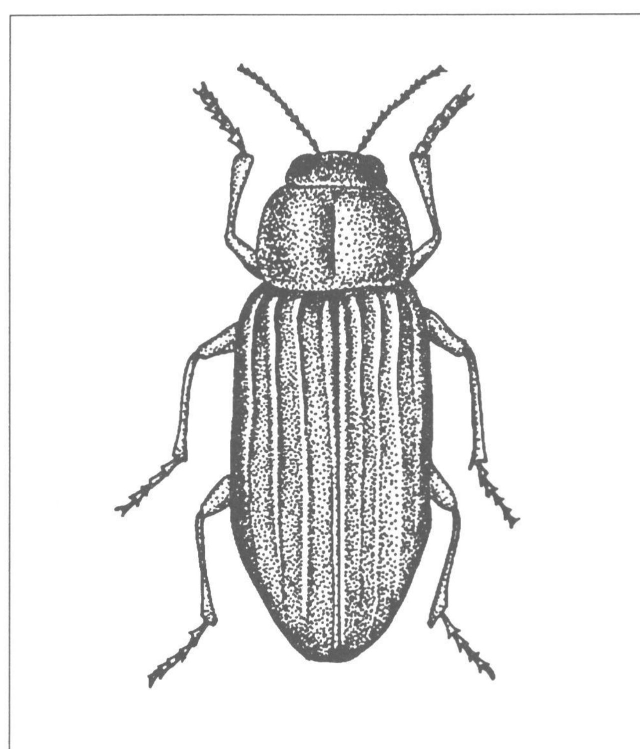

Figure 23. The golden buprestid beetle. The oval shape of the exit hole characterizes flat-headed borers and usually is the first sign of damage.

How To Prevent a Termite Attack

Consult local building codes and state agencies to find out if special construction practices to avoid termites are needed in your area. If termites pose a potential problem, a number of simple measures can be taken, avoiding more costly control later. Many of these preventative measures also work against rot.

Even after following recommendations for discouraging termites, you should inspect structures at least once a year to make sure that an infestation has not become established despite precautions. Although it may be a disagreeable job, do not neglect any part of the crawl space. Look for evidence of either termites or beetles (see Tables 1 and 2), and also for signs of wetting or decay. If you find suspicious signs of insect infestation or decay, "sound" the wood with a hammer for evidence of diminished interior firmness, which might be caused by internal decay. Presence of cavities or softened wood can often be confirmed by probing with a small drill or an ice pick.

Subterranean Termites

The following basic precautions are directed at eliminating conditions that attract subterranean termites and at preventing termite movement from ground to wood.

- Remove all wood refuse, such as stumps, lumber scraps, grade stakes, and concrete forms from the building site and from under the building and porches. Forms bridging the ground and substructure are especially hazardous. Do not store wood on soil in a crawl space.
- Cap block-concrete and masonry foundations with 4 inches of reinforced concrete, so that termites cannot move up inside the foundations. If they are forced to build shelter tubes outside (Figure 24), their presence is evident. Do not rely on metal shields to cap the foundation; they are often poorly installed, and termites can build tubes around them.
- Keep untreated substructure wood and wooden porches and steps well separated from the ground (Figure 24). If a foundation of impenetrable concrete or masonry is also used, termites will be forced to build shelter tubes (Figure 20).

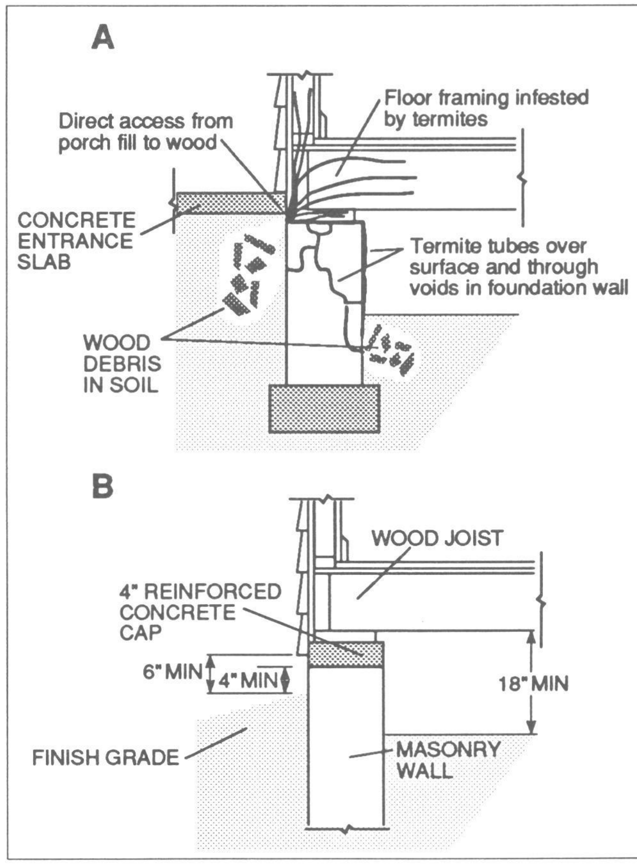

Figure 24. (A) Ways in which subterranean termites gain access to a building substructure from debris in the soil. (B) Use of a concrete cap to prevent termites from traveling to wood through a masonry foundation. Also, suggested minimal spacing between soil and substructure. A crawl space clearance greater than 18 inches often makes it easier to inspect the area for termites and decay.

- Allow enough space (at least 2 in.) for inspection between porches and the building, and also between the building and ornamental items, such as wood trellises and planter boxes.
- Pressure treat all wood intended for foundation or piers. Surfaces exposed by cutting or boring on the job should be flooded with triple-strength preservative.
- Treat the soil under, or adjacent to, the foundation with an environmentally acceptable pesticide (Figure 25). Treating the soil is by far the most reliable and effective precautionary measure and should be used where the subterranean termite is common. Treated soil provides a barrier through which the termite cannot pass to reach wood above. State agencies and the local building code

can advise about need for and methods of soil treating. The chemicals must be used in accordance with their registered labels, state regulations, and National Pest Control Procedures for Subterranean Termite Control. To make a chemical barrier, dig a trench on both sides of the foundation and treat the replacement soil (Figure 25), or inject the chemical into the soil under pressure with a specially designed probe with holes along the shaft.

If you combine soil treating with the other precautionary measures, you have added insurance of good termite control. Do not rely on pressure-treated or "naturally durable" wood in foundation components to serve as a barrier to attack on untreated wood above. Although treated wood is immune to attack, termites can tube over it.

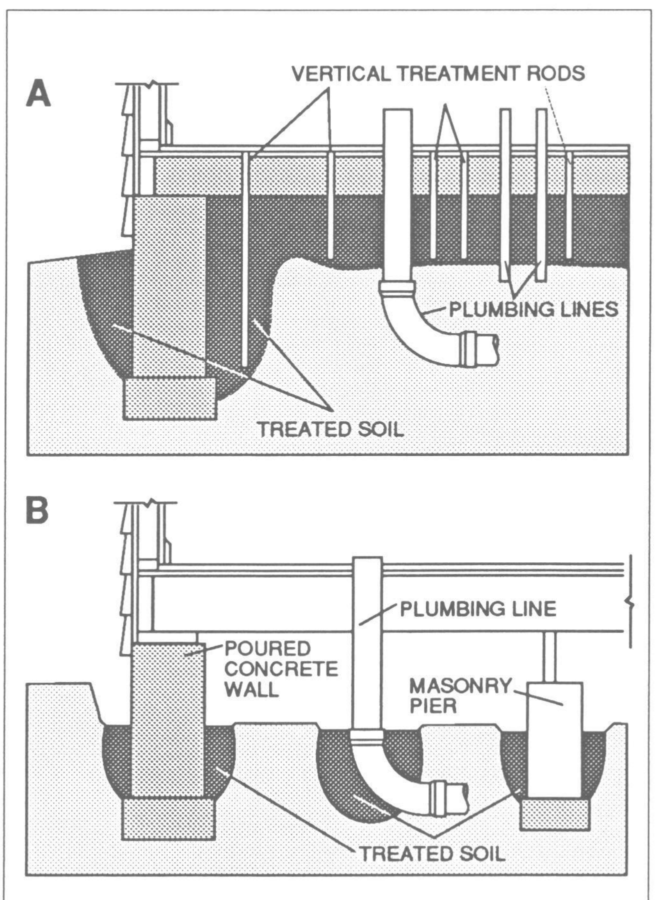

Figure 25. Treating soil adjacent to foundation to control subterranean termites. (A) Treating through a concrete slab foundation by drilling through the slab and injecting chemicals through grouting rods. (B) Treating soil around foundation wall and around pipes and piers in a crawl space.

When treating ground around a building, consider the type of foundation.

- If the building has a crawl space, treat the soil along both sides of supporting walls, around piers and pipes, and under the slab crawl space floor if present. Also, treat voids in masonry.
- If construction is slab-on-ground, treat the entire ground area beneath the floor slab and also beneath porch and carport slabs in accordance with instructions by the pesticide manufacturer. Allow the treatment to extend *beyond the slab areas sufficiently to permeate the soil alongside the slab perimeter.* Treat before vapor barrier and slab are laid. The slab itself is a poor termite barrier because it tends to crack and usually is penetrated by pipes. To minimize runoff of the chemical solution, treat the soil when it is dry enough to allow good penetration. If the slab is on untreated soil, the soil can be made termite resistant by treating it through holes bored through the slab, but this is expensive.
- If the building has a basement, treat as for slab-on-ground. Also, treat voids in masonry.

Dampwood Termites

Avoiding conditions that favor decay also combats dampwood termites, since both require moist wood. In addition, preventive measures against the subterranean termite are effective against dampwood species with a ground connection. Because this termite prefers damp wood softened by decay and has no need for ground moisture, attention should be paid to construction details to avoid prolonged wetting of wood components. Keep crawl spaces dry and free of wood scraps.

Drywood Termites

Because these termites live continuously in dry wood and do not require contact with the ground, imposing barriers other than screening of openings is not necessary. In southern coastal and central California and Hawaii where this termite is a problem, lumber should be carefully inspected before building. Infested lumber should be removed for non-critical uses or sterilized by heating or fumigating. All door, window, and louver openings should be screened against entrance by winged adults. Having a pest-control operator coat the wood surfaces with a sorptive dust (e.g., silica aerogel) prevents attacks in attics and on wood members of the substructure. When drywood termites crawl on the dusted wood, the under sides of their bodies collect some of the dust, which causes loss of a protective wax, resulting in rapid water loss and death. Where the hazard is extreme, all wood members in a house above the top plate, including ceiling joists, rafters, and roof sheathing, should be pressure treated.

What To Do If Termites Get Started

If you discover that termites have become established, do not be unduly alarmed. They rarely cause structural failure, and steps can be taken to eliminate them.

If you are dealing with the subterranean termite, first put into effect sanitation and construction measures recommended for the time of building (page 19), in so far as possible. Soil treating, the most effective of these measures, probably was not included during construction; though comparatively expensive, it could be worth doing. The most difficult places to work in are under floor, basement, and porch slabs, and inside concrete-block foundations. These can be treated by injection through holes drilled through the concrete, being careful to avoid drilling into pipes, ducts, or wiring in or beneath the concrete. Use of a gas rather than a liquid insecticide deserves consideration because it means drilling fewer holes. A termite-control professional should be called in for all toxic-chemical application.

Elimination of the dampwood termite primarily depends on moisture control since these insects only cause serious damage in damp wood. If these termites are in the substructure of a building in a crawl space, the first thing to do is to improve ventilation in the crawl space and cover the ground with a vapor barrier. Also, remove any scrap lumber or other wood debris from the area.

If your problem is the drywood termite, the approach to eradication may depend on the extent and location of the infestation. To control a limited infestation, locate galleries by probing with an ice pick or exploratory drilling with a fine bit, and then drill holes and blow an insecticidal dust or inject a liquid fumigant into the galleries. For an extensive infestation or where the infestation is located in inaccessible places, fumigation may be the only practical option. An entire house can be fumigated by first covering it with a tarpaulin or plastic membrane. Such general fumigation is the surest, but also the most expensive method. All treating, local or general, should be done by a licensed operator.

Infestations in poles by drywood or dampwood termites can be eradicated by gas treating, as described for controlling rot in poles (page 5).

What To Do about Carpenter Ants

Measures can be taken to discourage carpenter ants from nesting in a building or from becoming a nuisance by crawling or swarming inside.

- Eliminate known colonies and all wood waste including any in fuel wood near the building. Store any ant-infested fuel wood well away from the building.
- Construct the building with as few open cracks or crevices as possible. A tightly constructed house with concrete foundations, good elevation above grade, and a full basement is least subject to infestation.
- By good construction and maintenance, prevent wood from getting and staying wet. Carpenter ants prefer wood softened by water or decay. Leaking or heavily sweating pipes and overflowing gutters can sometimes make wood wet enough to attract them. Also, wood inside walls may be wetted by condensation produced by vapor transfer from an overly humid bathroom, laundry room, or kitchen.

To get rid of carpenter ants that are already established, apply insecticide by dusting, flooding from a brush, or spraying. Highly effective chemicals are available for the purpose, but regulations may prohibit their use except by a licensed operator. Commonly used compounds are Dursban and diazinon. For indoor application, paint or spray baseboards and cracks in door frames and window sills. Dust behind baseboards in inaccessible areas. For outdoor application, sprinkle dust or spray in nest openings, around foundations, and in other places where ants have been seen. Colonies inside an exterior wall can sometimes be eradicated by dusting or sprinkling the ground along a 1-foot strip near the foundation wall during warm dry weather, so that ants contact the insecticide when foraging. The insecticide is carried back to the nest on the ants' bodies, where it poisons other members of the colony. This method should be tried before incurring the expense of going inside the wall.

For poles and posts, try to get the insecticide directly into nest cavities. Fumigants now being used to control interior rot in poles offer great promise of also being highly effective against carpenter ants or other insects. They are easy to apply and diffuse many feet from the points of application (see page 11).

What To Do about Wood-boring Beetles

Infestation by wood-boring beetles generally starts in lumber or plywood during storage (powder-post beetles) or in the wood of weakened or dead trees (golden buprestid). In contrast to the situation with termites and carpenter ants, beetle damage may show up in a building even when all the ordinary precautions against insects are in place. The first step toward controlling wood-boring beetles is to protect susceptible wood products during production and storage, and then inspect them before installation. Be particularly critical of material that has been stored for a long time and reject any showing signs of infestation or treat it to destroy the beetles.

Lyctus

Lyctus powder-post beetles are generally the most troublesome of the wood borers. The following measures prevent them from laying eggs.

- The initial step of treating lyctus-susceptible hardwood lumber should be undertaken at the sawmill by dipping green lumber in a water emulsion of an approved insecticide as it comes off the saw. A hot solution of borax or suspension of microfine sulfur withstands subsequent kiln drying and protects the lumber against egg laying so long as it is not surfaced. Certain hydrocarbon insecticides are effective, but because of health hazards, advice on these should be otained from pest-control agencies or state or federal entomologists.
- If the lumber is surfaced, the insecticide is removed and the stock must be dipped again to provide further protection. The insecticide may need to be carried in a volatile oil rather than water to avoid raising the grain.
- If you are installing a costly lyctus-susceptible item, such as flooring, wall paneling, or trim, that has been stored without chemical protection, make sure that it goes into the building free of live beetles by fumigating the material or by heating it at 140°F (60°C) with a high relative humidity for several hours, depending on the item thickness. Keep in mind that this does not make the wood immune to later infestation.
- Subsequent lyctus infestation is unlikely if all surfaces are painted, varnished, or waxed. This prevents egg laying by filling the wood pores.
- Surfaces that are to be stained, or items such as unfinished hardwood furniture, tool handles, or pallets, can be protected by dipping or copious brush-treating with an oil solution of appropriate insecticide.
- If pin holes and accumulations of wood powder indicate that lyctus beetles have emerged, there are ways of eliminating those still in the wood. This prevents further damage by grubs inside the wood and more pin holes by emerging adults. Consider thoroughly flooding (more than once, if necessary) all exposed surfaces with a long-lasting insecticide in moderately volatile light oil. See that the solution soaks into emergence holes, joints, and other crevices. To get best results, first remove the wood finish. If the solution is applied over a finish, avoid touching it after treating until it regains its normal hardness. Fumigation may be necessary if the infestation is extensive. Furniture and other movable items can be treated by moist heating (140°F), but make sure that the process does not damage the finish or glued joints.

Bostrichids

Many of the above control measures are also appropriate for bostrichids (false powder-post beetles). A few special considerations may be noted. Adult beetles prefer incompletely seasoned sapwood. They lay eggs in galleries made for that purpose. Where bostrichids cause a severe problem, logs should be sprayed with insecticides developed for this pest. Because bostrichids do not depend on the wood pores to start their infestation, closing the pores with paint, varnish, or wax is not a deterrent. They do not like dry wood and so rarely reinfest. Insecticidal surface treating of seasoned wood is not helpful, except as a means of eliminating an existing infestation.

Anobiids

On the West Coast anobiid beetles occur both in living quarters and in substructure wood in the crawl space. Control of infestations in substructures is especially important because of the load-bearing function of their members.

- Flood all visibly affected surfaces (evidenced by tiny exit holes) with an appropriate, long-lasting insecticide. These beetles can reinfest wood in damp air. If the infestation appears to be active with fresh frass outside exit holes, and general rather than localized, flood treat surfaces in addition to those visibly infested.
- Fumigation may be necessary if the infestation has spread upward into the walls.

Anobiid infestations of utility poles can be eliminated by the commercial pole fumigants described for carpenter ants.

Buprestids

The golden buprestid beetle prefers incompletely seasoned wood for egg laying. The best time for control is during the manufacture or processing of lumber. Infestations are least likely in lumber from recently cut logs from healthy trees. Avoid lumber with bark attached. Surface treating lumber with an insecticide does not give much protection, but kiln drying ensures freedom from infestation.

Once infested wood is place in a building, larvae can only be kept from completing their development by fumigation. Fortunately, infestations seldom are extensive enough to cause serious structural weakness, and the danger of reinfestation is small. The appearance of the wood surfaces can be improved by plugging beetle holes and refinishing.

Utility poles in the Pacific Northwest are sometimes subject to attack by golden buprestid beetles, which presumably are attracted by the prevalent dampness of pole wood in the region. They can be eradicated by one of the recently developed commercial pole fumigants.

Precautions Regarding Chemical Protection

In many of the foregoing situations the use of an insecticide has been recommended. In the past these could be obtained over the counter and used on a do-it-yourself basis. Because of the danger of environmental contamination or of injury to those doing the treating, legal restrictions no longer permit the use of many insecticides long favored for protecting wood. However, licensed pest-control agents have access to some of these chemicals and permission to use them. They know what chemicals are available and which are best for a given situation.

Except for insecticides available over-the-counter that can be applied safely, you should get qualified commercial help to do the treating. Determine who in your locality has the reputation of successful work and the proper credentials to handle the job. The insect to be controlled must be correctly identified. Not every commercial operator can do this. You may need the assistance of state or federal entomologists. These sources also can provide advice about appropriate insecticides and treatments. Keep in mind that chemicals must be used in accordance with their registered labels and according to state and national regulations. Should you be present when treating is being done, avoid getting chemical on your skin and especially in your eyes or lungs.

If you use pressure treated wood, be sure that the preservative is legal and also that it meets your needs as regards permanence, paintability, and freedom from odor. When purchasing stock of high value or for especially long service, specify quality, quantity per cubic foot, and penetration of preservative, and verify that your requirements have been met. Copiously flood treat with at least triple strength or triple application of preservative all untreated surfaces exposed by cutting or boring during construction. Guidance can be obtained from government wood preservation specialists and from the American Wood Preservers Bureau.

For Further Information

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Marine Borers: Protecting Waterfront Structures

Marine borers infest oceans and brackish estuaries everywhere, attacking wood and causing enormous damage. They are sometimes referred to as "termites of the sea" and have been known for over 2000 years. Underwater portions of piers, wharves, and bulkheads in harbors and estuaries are notoriously subject to damage by these borers, which tunnel into the wood for shelter and food. Untreated piles have been destroyed in as short a time as a year, and in the days of large sailing ships, the hulls could be seriously damaged in the course of a long voyage. No coastal area is immune from attack but damage is less rapid in cold than in warm waters. Rate of attack is also affected by other factors such as salinity, presence or absence of pollutants, and species of borer.

The cost of damage to waterfront facilities in the United States by marine borers below the water line and by rot fungi above water has been estimated at half a billion dollars per year. Obtaining an exact figure is impossible because countless routine replacements of damaged items are unreported. Even a cursory observation of wood structures in our coastal waters reveals a widespread need of protective measures—particularly for preservative treatment. That the benefits of preservation far outweigh the cost of application becomes increasingly apparent as the supply of high grade timbers diminishes and prices increase.

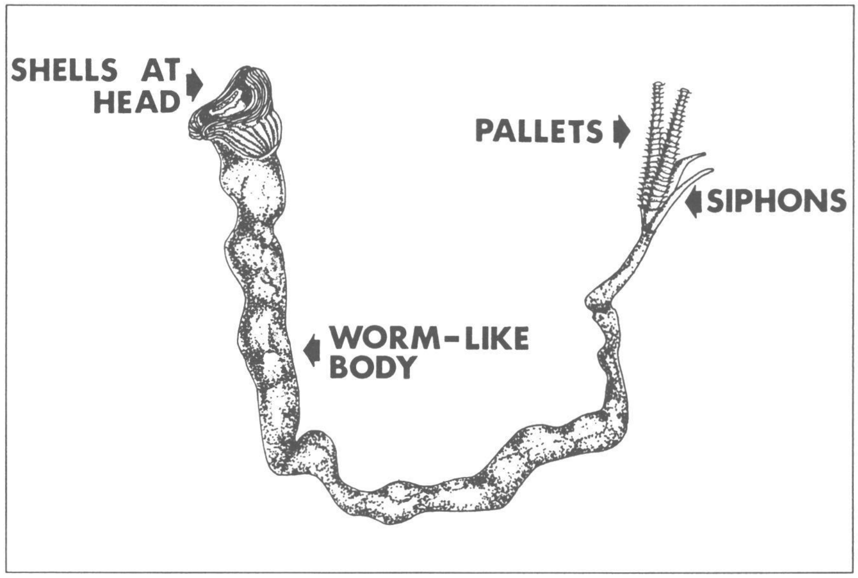

Figure 26. The adult shipworm Bankia, *showing the boring shells at the head and the multiple bladed pallets at the opposite end.*

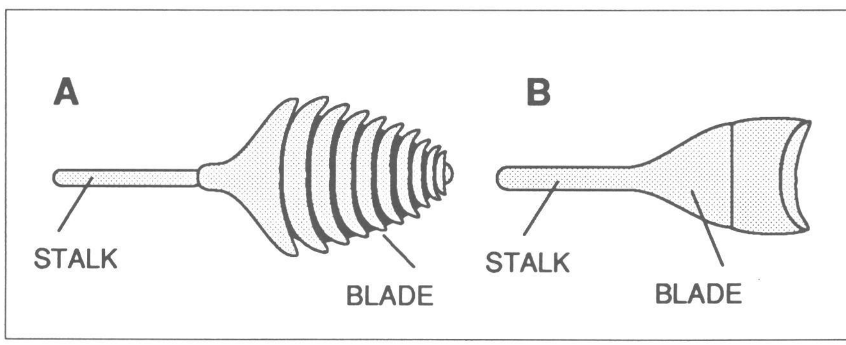

Figure 27. Pallets of Bankia *(A) and* Teredo *(B).*

Recognizing Marine Borers

Marine borers belong to one of two groups: mollusks or crustaceans. Familiar relatives of the molluscan borers are oysters and clams. Marine boring mollusks use their shells to penetrate wood. Crustaceans are characterized by having a segmented body and several legs. Crustaceans bore into wood by means of tiny jaws with rasp-like edges. Their relatives include shrimp, crayfish, lobsters, and crabs. Principal wood-destroying members of the two groups and some of their identifying characteristics are shown in Table 3.

Mollusks or Shipworms

Two genera of mollusks, *Teredo* and *Bankia*, have long soft worm-like bodies and a small shell at the head end (Figures 26, 27). Due to their appearance they are popularly known as shipworms. *Teredo* eggs are retained for a time in the female's gill cavities, where they are fertilized by sperm in the water that is drawn in through the intake siphon. Larvae leave the gills and drift about until they attach themselves to wood and penetrate it, entering through small inconspicuous holes made by scraping the wood with their shells. These holes never become very large. *Bankia* develops in the same way except that the eggs as well as sperm are discharged into the water for fertilization. As the shipworms mature they go deeper, rhythmically moving their enlarged shells to scrape and rasp away the wood to produce burrows where they will spend the rest of their lives. Shipworms penetrate deeply, and ultimately the interior wood may be riddled with burrows (Figure 28). The attack is not readily apparent, however, because the surface of the wood is unaffected except for the inconspicuous entrance holes through which the adult draws water for respiration. If a shipworm does not have to compete for space and food, it may attain a length of a few feet.

Two siphons project from the posterior of the body (Figure 26). One admits water containing oxygen and food to the gills and digestive system, and the other discharges waste products. The siphons remain at the water end of the burrow no matter how long the body grows. Two structures, called pallets, which can be seen alongside the siphons (Figures 26, 27), are for protection. When a shipworm is disturbed or threatened by impure water, it draws in the si-

Table 3. Some identifying characteristics of marine borers in Pacific Coast waters.

Characteristic	Borer type		
	Mollusks		
General description	Soft, wormlike body. Inconspicuous shell at head end, used for boring deep into wood. Permanently confined once wood is entered.		
	Teredo navalis	*Bankia setacea*	
Adult length	0.3 - 0.6 m	1.5 - 1.8 m	
Adult diameter	1.3 cm	1.3 cm	
Upper size of entrance holes	1.6 mm	3.0 mm	
Pallets	Single spade-shaped blade	Multiple blades with featherlike appearance	
	Crustaceans		
General description	Somewhat resembles a wood louse or sow bug. Segmented body and legs. Bore into wood only slightly below surface. Not confined to one piece of wood.		
	Limnoria tripunctata	*L. lignorum*	*Sphaeroma* spp.
Adult length	3 - 6 mm	3 - 6 mm	9 mm or more
Limnoria differentiation	3 tubercles on telson (Figure 30A)	No tubercles on telson (Figure 30B)	

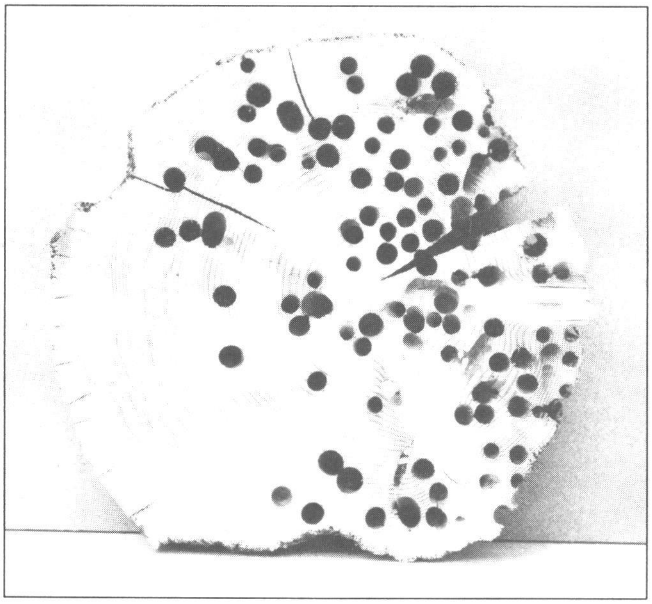

Figure 28. Cross section of pile showing large burrows made by Bankia *and smaller ones by* Teredo. *The irregular perimeter of the pile was caused by* Limnoria *attacking the surface wood.*

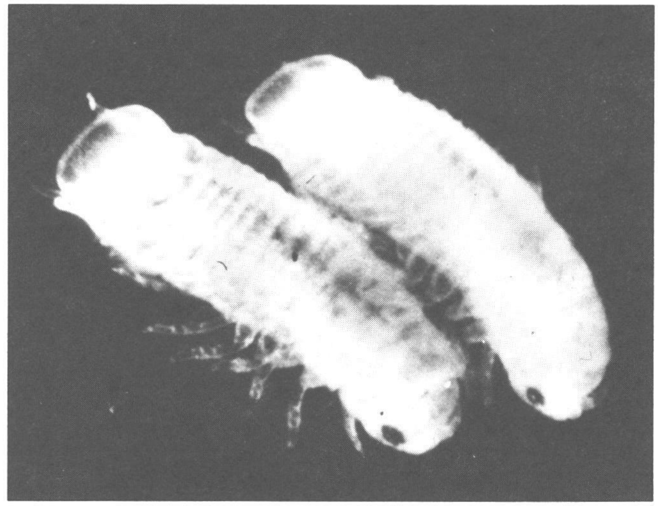

Figure 29. Limnoria *(gribbles) along the West Coast.*

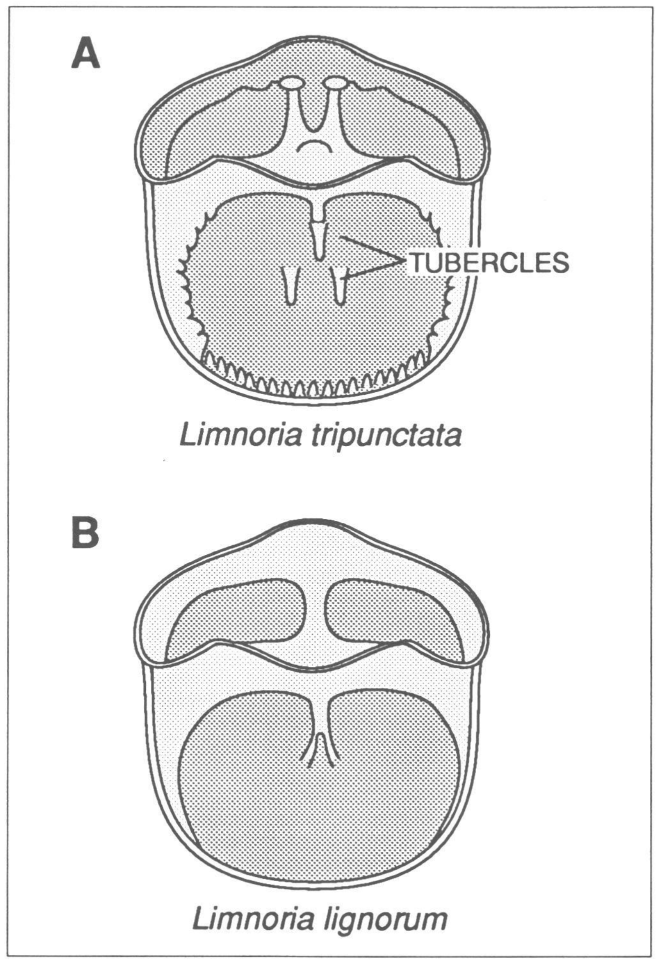

Figure 30. Enlargement of telson showing distinguishing features between (A) Limnoria tripunctata *and (B)* L. lignorum. L. tripunctata *is outstandingly tolerant of creosoted wood.*

phons and plugs its entrance hole with the pallets. *Teredo* and *Bankia* can be distinguished by the structure of these pallets (Figure 27) and by certain other features (Table 3).

Another group of mollusks, called pholads, differ markedly from shipworms. On the West Coast they bore conspicuous holes in rocks, but are not known in wood. They are completely encased in a shell and look much like clams.

Crustaceans

Species of *Limnoria,* popularly called gribbles, are the most destructive of the crustacean borers (Figures 29, 30). They occur mainly between the high water mark and mudline. *Limnoria* eggs are fertilized inside the female and are retained in a broad pouch on the underside of the body. The free-swimming young, which resemble the adults, attach themselves to wood within a few days and bore in with their hard mouth parts (mandibles). *Limnoria* burrows are relatively shallow, but the organisms can completely destroy timber by making thousands of small interlacing burrows. The affected wood is easily eroded by waves or flowing water, or by the rubbing action of floating debris, which exposes progressively deeper layers of wood to attack. Affected piles become progressively smaller in diameter and tend to acquire an hour-glass shape (Figure 31). Ultimately they may be entirely cut through.

Sphaeroma resembles *Limnoria* but is not of great economic importance as a wood borer on the West Coast. It sometimes attacks styrofoam dock floats.

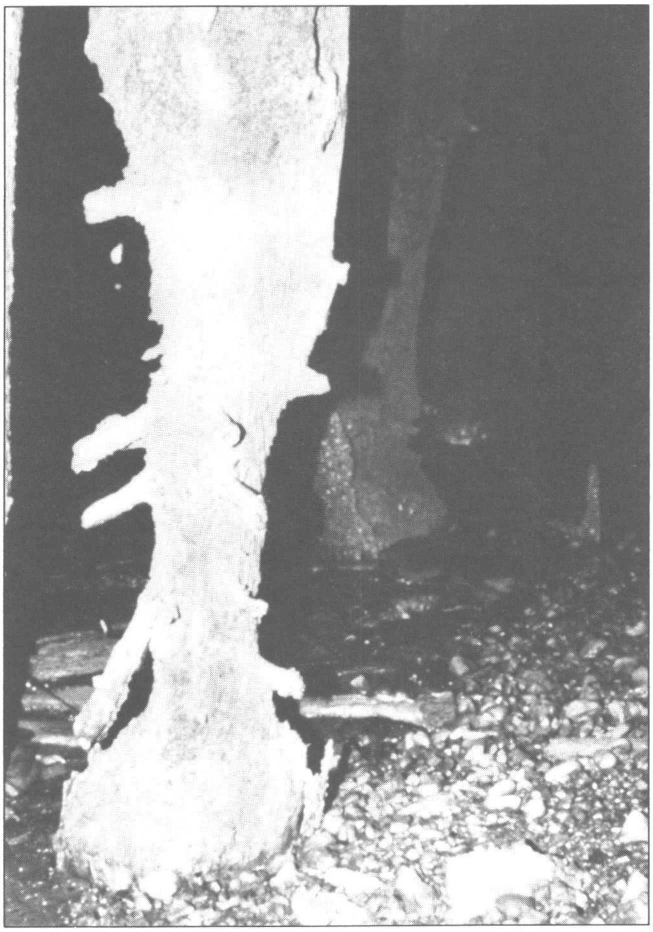

Figure 31. Hour glass appearance of a pile attacked by Limnoria. *The outer wood is destroyed and worn away by abrasive action of water and flotsam, especially in the lower half of the tidal range.*

Conditions That Favor Marine Borers

Salinity

Marine borers have specific salinity and water-temperature requirements for successful reproduction, and also need a pollution-free environment.

Undiluted sea water contains slightly more than 30 parts of salt per thousand (3%). All borers have been found active in water with as low as 2 percent, and they can tolerate even less salinity, for example in estuaries. No West Coast species, however, lives in fresh water. Reported lethal salinities range from about 1 to 0.4 percent, depending on the species. *Teredo navalis* has been said to survive where salinity falls to 0.5 percent once a month or more often. *Limnoria* and *Bankia setacea* seem to require higher salinities.

It is important to learn the salinity characteristics of water in estuaries and to be aware of seasonal fluctuations. Borers have damaged timbers in estuary locations thought to be free of danger. This happens during years of abnormally low rainfall—when river flow is limited, causing an increase in salt concentration.

Water Temperature

Temperature limits for marine borers are broad, ranging from about -4 to 32°C (25 to 90°F), so they can cause trouble almost everywhere wood structures occur in sea water. The geographical limit of a particular species is determined by the average range of water temperature. For example, *B. setacea* is the only shipworm that is a problem north of San Francisco, whereas the crustacean *L. tripunctata* is the most prevalent species to the south. Activity, except for breeding in some cases, increases with water temperature. In northern waters of the Pacific Coast, *T. navalis* breeds when the water is relatively warm but *B. setacea* breeds in the colder months. This variability prolongs the period of borer attack in colder waters.

A combination of temperature and salinity may determine what species of borer is active in a particular locality. Only a small change in temperature can have a comparatively large influence on species distribution in a harbor. For some species and situations temperature is the dominant controlling factor and for others, salinity.

Effect of Pollution

A factor that occasionally influences the concentration of borers in a harbor is pollution by industrial or sewage effluents. Toxic chemical pollutants arising from manufacturing wastes tend to suppress borers and in some places have eliminated them. Sewage effluents provide more food for many marine microorganisms, enabling them to multiply and deplete the oxygen in the water. Marine borers are then inhibited by oxygen shortage, although the effect is rarely significant. With increasing emphasis on reducing pollution, protection of waterfront structures by pollutants can be discounted.

How to Prevent a Marine Borer Problem

Assess Need for Protection

In practically all coastal waters except the higher reaches of estuaries, wood requires protection against borers. The following considerations will help you to determine the risk in your locality.

- Before building in river-diluted water, determine whether the salinity near shore is high enough for long enough periods to support marine borers. Salinity that often reaches 5 percent should be regarded as a sign of potential danger. Remember that periods of drought and low water can result in dangerously high salinities at a particular location and also move the danger zone further upstream. Salinity can be measured with sufficient accuracy with an inexpensive hydrometer, a thermometer to determine the water temperature, and a chart showing the relation between density of the water and percent salinity.

- Look for evidence of past borer damage. To obtain direct information on the potential for borer damage, look at the condition of untreated wood in the water in question between mean low-water level and the mudline. If the wood has been in the water for a long period it will reflect the influence of water temperature and salinity on borer activity and thus indicate what you can expect in the future. The items examined should, if possible, be in a number of separate locations. *Limnoria* shows on the surface; *Teredo* and *Bankia* burrows must be looked for inside, ideally on cross sections (Figure 28).

- Check on local experience. As well as inspecting wood on and near the intended construction site, learn as much as possible by consulting people who have long had responsibility for maintaining structures in the local water. See what you can learn from service records and recollections of replacements and structural repairs. Keep in mind that traditions and recalled experiences can have inaccuracies.

- Determine present borer activity. To assess present activity of borers, suspend small panels of vulnerable wood in the water, below low-tide level. Active *Limnoria* or *Teredo* should be apparent within a few months during summer. Open panels to look for *Teredo* burrows. Remember that absence of attack denotes only the current situation.

Preservative Treatment

Where marine borers are a hazard, endangered wood should be protected by suitable preservative treatment. Untreated wood is often used in brackish water, but the practice is, in most instances, "penny wise and pound foolish." The lower initial cost of untreated wood can be overshadowed by repeated outlays for maintenance and replacements and increased danger of injury from structural failure. Even where borer activity is slight, the expense of preservative protection can be justified as economical insurance against serious damage. Moreover, as supplies of large structural timbers dwindle, it becomes increasingly important to conserve this prized natural resource.

Creosoted Douglas-fir piles, protected from physical damage and top decay, have served for more than 40 years in British Columbia waters and 15 to 30 years in California waters. This is remarkable considering that the amount of creosote in the older piles may have been no more than about 12 pounds per cubic foot, which was the common marine retention a few decades ago. Longer service can be expected from piles better protected by modern treating (Table 4).

Greater quantities of preservative are required to protect against marine borers than against rot and insects. Also, marine preservatives have to be tailored to combat different borers. Recommended treatments are given in Table 4 for different borers. Where the hazard is low or moderate, retentions may be somewhat less than those shown—as permitted in federal or American Wood Preservers Association (AWPA) standards. Federal and AWPA standards also give the depths in the wood to which the prescribed retentions should be attained.

Wood is usually treated differently for marine use than for service on land or in fresh water. Pressure treating is always essential. To obtain the prescribed high retentions, wood cells are filled (insofar as practicable) with the preservative by the "full-cell" process. The highest level of protection (needed especially against *Limnoria*) is provided by a dual treatment. The

Table 4. Preservative treatments for protection of western piles and timbers against marine borers.[1]

Organisms, expected or known	Recommended treatment
Limnoria tripunctata, Teredo (extreme borer hazard)	Dual treatment: ACA, CCA, or ACZA[2] in water solution followed by marine-grade creosote (AWPA Std. p1/13) or (except with Douglas-fir) marine-grade creosote coal tar (AWPA Std. P2)
	or
	ACA, CCA, or ACZA alone in high retention (AWPA Spec. Marine piles C3, 1.12)
Borers other than *L. tripunctata*	Creosote or creosote coal tar alone (AWPA Spec. Marine piles C.3, 1.11)

[1]Based largely on AWPA standards C3 and C18 for piles and timbers in marine construction. These references should be consulted for penetrations of preservative required and for depths of wood to be sampled for ascertaining retentions.

[2]ACZA is ammoniacal copper zinc arsenate.

item is first impregnated with a water solution of ammoniacal copper arsenate (ACA) or of copper chrome arsenate (CCA). After much of the water is eliminated by drying, the item is treated to virtual refusal with marine-grade creosote or creosote-coal tar mixture.

Treating Cautions

Once material has been treated there still remains the essential step of ascertaining that retentions and penetrations meet specifications. It is customary for both the treater and the purchaser to do this. Commercial inspection services are available. The purchaser can ask for a detailed inspection; it is wise to have inspected at least as large a proportion of items as recommended in Federal Specification TT-W-571 or by the American Wood Preservers Bureau.

It is important to adhere to the following treating cautions.

- Always require certification by the treater of the procedure used and the record of what was accomplished.
- Try to have all necessary cutting and boring done before treating. This precaution is not always possible, but when followed, it can forestall trouble. Cutting and boring on the construction site may expose untreated wood. Even if this is hand treated afterward, the job often is inferior. New bolt holes and cut surfaces should be flooded with one of the following, conforming to the preservative applied commercially:

  a) marine-grade creosote—three spaced applications;

  b) triple strength ACA or CCA; and

  c) double strength ACA or CCA followed by marine-grade creosote.

  Surfaces can be treated by a brush or bolt holes by swabbing or by pressure using special bolt-hole treating equipment.

- Never attach untreated bracing or blocking to piles below water. Once borers attain adult growth in vulnerable wood, they can attack, contacting creosoted wood that otherwise would be immune.

- In handling treated piles, avoid piercing the treated shell with tools except in places that will be well below mudline or eliminated in cutting the pile to length. In driving, use recognized good practice to avoid splitting. Carelessness in these respects can provide borers with points of entry.

Protective Coverings on Piles

Various protective covering materials, such as paint coatings, staves of treated wood, concrete jackets, copper sheathing, and wraps of heavy plastic film, have been tried on piles. Their purpose is to create stagnant water and so restrict the supply of oxygen and nutrients to any borers in the wood. Although these coverings are useful for preventing or eliminating borer infestations in untreated wood, they ordinarily should not be used in place of good preservative treatment.

Naturally Durable Wood

Some woods are endowed with natural preservatives that provide good protection in the marine environment. These are all tropical and subtropical woods. The more familiar names are blue gum, jarrah species of eucalyptus, and greenheart. Disadvantages of relying on natural borer resistance include:

a) variability in resistance among trees of the same species;

b) difficulty in obtaining amounts needed commercially;

c) insufficient resistance against all borers; and

d) finding species that combine the right physical qualities with durability.

Despite its lack of resistance to borers, untreated Douglas-fir is used to some extent on the Pacific Coast because of its availability and excellent physical qualities. When not treated, piles with the bark still on are generally preferred because this affords some protection, but the advantage is slight as bark cover rarely is complete enough to be effective. Records indicate that the service life of untreated piles in northerly waters commonly may be only 6 or 7 years, and 4 or 5 years in California waters. Failure may even occur within the first year. The annual cost of untreated piles may be greater than realized by those who use them in preference to treated stock; moreover, such limited service life is contrary to growing concerns about maintaining an adequate timber resource.

Keeping a Structure Sound

Inspections

Even with excellent protective measures, some places may have been overlooked, or unforeseen developments may lead to a reduced quality of protection. Structures should be routinely inspected and promptly repaired, and developments corrected that reduce service life. The inspections should be made and records kept according to an established plan.

- Keep logs, timbers, and other wood debris from accumulating around piles. As well as furnishing breeding grounds for borers, the larger debris may chafe the piles with the changing tide and expose untreated wood.
- Consider a sonic method of appraising the interior of piles for *Teredo* damage. The intensity and character of impact pulses imparted to the pile are electronically measured a short distance along the pole. The measurements indicate the amount of sound wood remaining. A diver can examine a hundred piles a day with the sounding device.
- You can spot serious weakening of piles by gribbles by the reduced pile diameter because these animals work from the surface. At low tides, look for an hour-glass shape between mudline and high-water mark (Figure 31). Also examine bracing around bolt holes and surfaces near places where the wood may have been cut into during construction.
- Besides looking for marine-borer damage, the inspection program should include the above-water portions of waterfront structures. These are subject mainly to rot caused by fungi in wood wetted by fresh water. See section on "Wood Rot: Understanding and Controlling Decay Fungi."

What To Do about Established Borers

Even when borers gain a foothold in piles, the battle has not been lost. You can wrap the pile with a protective covering or repair the existing covering if it has been broken. A good cover limits water exchange and reduces the oxygen and nutrient content so that the borers die. Information about selection and cost of covering materials can be obtained from commercial manufacturers and installers. Bracing cannot easily be covered and should be replaced when weakened.

Fumigant treating shows promise as a means of excluding or eradicating shipworms from both piles and large superstructure timbers. A chemical, in solid or liquid form, is inserted into holes bored and the toxic vapor diffuses through the wood.

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Films

Wood Preservation—Inspection for Wood Destroying Organisms. United States Navy. No. MN-816a. 20 minutes. Navy Facilities Engineering Command, 200 Stovall Street, Alexandria, VA 22332.

Wood Preservation—Control of Wood Destroying Organisms. United States Navy. No. MN-816b. 22 minutes. Navy Facilities Engineering Command, 200 Stovall Street, Alexandria, VA 22332.

Slide Tapes

Wood Destroyers in the Marine Environment (75 slides, 15 minutes. Cat. No. 716.1). Describes the organisms involved in marine wood deterioration, the nature of their attack on wood, and the conditions that favor their development. Rental $25, purchase $70. Oregon State University Extension Service, Corvallis, OR 97331.

Improving the Performance of Wood in Waterfront Structures (77 slides, 15 minutes. Cat. 716.2). Prescribes proper design and construction techniques to obtain good serviceability of wood in a harsh environment. Rental $25, purchase $130. Oregon State University Extension Service, Corvallis, OR 97331.

Scheffer, T.C. 1991. DAMAGE TO WEST COAST WOOD STRUCTURES BY DECAY FUNGI, INSECTS, AND MARINE BORERS. Forest Research Laboratory, Oregon State University, Corvallis. Special Publication 22. 32 p.

A condensed account of the chief wood-destroying organisms on the West Coast, with guidance on ways of recognizing and controlling them. Suggestions are provided on how to avoid conditions that favor rot or invite insect damage in buildings or boats. Protection of waterfront structures against marine borers is discussed.

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