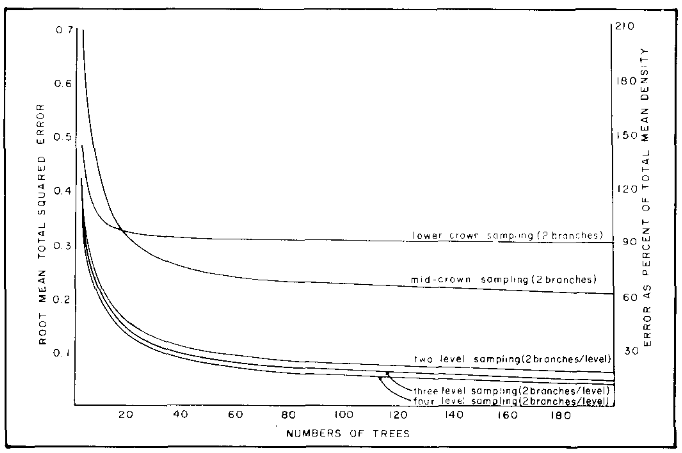
may spin cocoons as late as October. Because of this difference in developmental times, adult flight, mating, and egg laying occur from August to November. The sample periods were chosen, therefore, so as to span the development of the DFTM. One sample of egg masses was taken in spring and one of cocoons and egg masses in autumn. Three larval samples (early, mid, and late) were taken in summer 1976, but only two (early and late) were taken in 1977.

Approximately one-third of each tree's foliage was sampled randomly, measured, and the DFTM life stages (along with 64 other defoliators and predators, including spiders) were counted. Larvae of all the defoliators were returned to the laboratory for rearing of parasites. To select sample branches, each branch was numbered beginning with the first branch on the north side of the first whorl of branches in the crown and running clockwise from whorl to whorl to the top of the tree. A list of sorted random numbers was computer-generated for each sample tree and the branches were selected in this fashion. To take samples one person climbed the tree and numbered and cut branches, while one or two others held a cloth basket. One or two people on the ground beat and measured the branches over a large white canvas trap.

Tree, branch, and insect data were placed on data sheets to be keypunched. Once the distributions for each tree were reconstructed in the computer, it was possible to go back and sample in several different ways for each insect or spider for any sample period. In this way, sampling methods can be compared for overall error and bias. Costs of each method can be computed and the least expensive selected.

Results of the computer sampling of the 1976 DFTM early larval stage show that for low density populations the error in estimating early larval instar density is much higher when sampling two branches in the lower crown or mid-crown than when using multilevel sampling. The 1977 data for the early larval instars of DFTM corroborates the 1976 data. When cost of sampling was figured, the two- and three-crown level sampling procedures were found to be the most economical for all degrees of accuracy. A three-crown larval sampling procedure is currently being used in our studies of sparse DFTM populations.



Total error for each sampling method as a function of the number of trees sampled for early instar Douglas-fir tussock moth larva using 1976 distribution data.

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Fomes annosus in California forests

John R. Parmeter, Jr.

Each spring, fallen trees can be found in stands of large trees, their roots frequently showing a stringy to "laminated" decay. Other dead trees may be found grouped around an old stump or grouped with dead trees at the center and recently killed ones at the margins; generally some "unthrifty" trees stand just beyond them. Examination of these trees, stumps, and snags will often reveal the same decay of root and butt wood. Fungus conks with tan upper surfaces and white, finely-pored under surfaces may be observed in stumps that have been kicked apart or under bark knocked loose. These are the fruiting bodies of *Fomes annosus,* a primary cause of tree root decay and death throughout California forests.

Fomes annosus attacks mainly conifers, although hardwoods can sometimes be infected. Infection may result in several types of damage and loss. Pines are especially susceptible to cambium killing, and infected trees usually die from root girdling or they are predisposed to killing by bark beetles. In nonresinous species, such as red and white firs, or in incense cedar, root decay is more common. This may lead either to bark beetle attack or to windthrow. If trees neither die nor windthrow, decay may extend into the lower trunk, causing volume loss in the valuable butt log. The net result of these losses can be extensive reduction in productivity and usefulness.

The stringy-to-laminated decay of rootwood in fallen trees signals the presence of ***Fomes annosus*****, a primary cause of tree death.**

In addition, root-rotted trees can endanger users of recreational developments within forests. *Fomes annosus* is frequently associated with the loss of giant sequoias, and it is widely distributed in recreational pine stands of Yosemite Valley and southern California. Of immediate concern are the protection of visitors and the need to plan for development and maintenance of facilities.

Broad aspects of *F. annosus* biology are well known. The fungus is spread by windborne spores to fresh stump surfaces or to basal wounds on trees. When these spores germinate, the fungus grows through the wood or along root surfaces. Where the roots of an infected stump or tree contact the roots of a healthy tree, the fungus may spread to that tree. Once a forest stand is invaded, the disease produces an enlarging "center" or "pocket" of dead and dying trees as the fungus spreads outward from tree to tree along the roots.

University research, often in cooperation with the U.S. Forest Service and National Park Service, has been directed towards stand/host/fungus/insect interactions and towards evaluation and control in commercial and recreational forests.

As part of a joint UCB-USFS-NPS study, 59 large incense cedars in Yosemite Valley were uprooted with heavy equipment. The amount of decay in their roots was compared with the condition of the tree crowns, and guidelines were developed to permit early recognition of root-rotted trees so that they can be removed before they endanger visitors. Similar guidelines for pines and firs are being developed.

Long-term plots have been established in Yosemite Valley to monitor annual rates of infection center enlargement. Present estimates indicate that the fungus progresses through stands at between 1.5 and 3.0 feet per year. At these rates, if infection centers are numerous, *F. annosus* can virtually destroy a forest stand within a few decades, as is happening now in Yosemite Valley. With this information, managers can predict future losses and make long-range plans for the location or relocation of recreational facilities requiring forest cover.

In timber stands, observations and survey records indicate that *F. annosus* is not uniformly distributed or damaging in the many areas, sites, and timber types in California. Management methods to reduce damage depend largely on identifying those site and stand factors associated with high or low root-rot damage. University scientists, in cooperation with Forest Service pathologists, have initiated a statewide survey of *F. annosus* in red and white firs by examining aerial photographs to locate dead trees and then ground-checking to determine the causes of their death. These data will indicate where and under what site and stand conditions *F. annosus* is damaging firs.

Few means are presently available to reduce *F. annosus* damage. Treatment of stump surfaces with powdered borax prevents or reduces invasion of stumps. U.C. scientists have found, however, that the fungus may also enter root systems below ground. If direct infection of roots is common, protection of stump surfaces may not prevent stand invasion. Because of these uncertainties, large-scale, long-term testing of stump treatment to prevent stand invasion is underway.

Fire might be used to reduce *F. annosus* damage. Current studies in Sequoia Kings Canyon National Park and U.C.'s Whitaker's Forest indicate that prescribed fires consume infected stumps and snags that contain fungus fruiting bodies. This may reduce the number of spores and may also destroy infected roots that provide the inoculum to infect those young trees that become established near stumps.

While information immediately useful to resource managers is being developed, U.C. pathologists and entomologists are:

(1) Exploring aspects of basic root-disease biology and the likelihood that root-attacking insects introduce *F. annosus* into roots of uninfected trees or stumps, thus initiating new centers;

(2) Attempting to determine how *F. annosus* changes host physiology to allow successful bark beetle attack and how root-rotted trees contribute to bark beetle population dynamics;

(3) Investigating how *F. annosus* in firs leads to the formation of wetwood, which in turn may interfere with host water uptake and with host resistance to bark beetles; and

(4) Seeking understanding of the relationship between host resistance, fungus virulence, and environmental factors.

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