FOREST PEST AND FIRE MANAGEMENT

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Contents

Summary

In nature fire, insects and pathogens act along with other agents, such as wind and floods, to diversify and renew a forest. Humans, however, seek to utilize wood and non-timber products from forests, placing them in competition with fire and pests for the forest resource. In the past, humans have been over zealous in their management efforts. They have excluded fire, leading to increased fire hazard due to the accumulation of excess fuel, and have become trapped on a "pesticide treadmill" requiring annual application of chemical insecticides to protect trees from defoliation by insects. These excesses have in turn led to the adoption of ecologically-based, integrated resource management, of which fire and pest management are key components. Both operate through a continuously recycling model involving assessment of the problem, decision-making and action. Assuming an efficient and effective infrastructure, actions are taken on the basis of selected strategies (broad plans) and tactics (actions taken to satisfy a

strategic objective). Four management strategies include: 1) let nature prevail, 2) prevent a problem from occurring, 3) maintain the problem at a tolerable level, and 4) suppress the problem to a tolerable level. For any strategy, an array of tactics can be selected in three categories: 1) detection, evaluation and decision-making, 2) prevention, and 3) suppression.

Although pest and fire management can be very effective, adapting and strengthening the capacity for management will be essential in the future. This is because: 1) increasing demands for forest products will require effective management to preserve and protect the resource, 2) intensified international travel to serve the global economy will result in the continual introduction of exotic pests, and 3) in the face of global climate change, trees rooted in place will be increasingly offsite and stressed, making them ever more vulnerable to damage from fire and pest depredation.

1. Causes of Death in Natural Forests

1.1. Physical Causes

In nature, all trees are destined to die. Only their age and cause of death vary. Some trees die slowly of old age, increasingly unable to sustain a living crown that is too high or too large to be served by a root system with a finite capacity to take up water and nutrients.

Many die from physical causes, uprooted by erosion and winter winds, broken by the pressure of snow and ice, and struck by lightning. Some die in large groups during catastrophic events such as typhoons, earthquakes, volcanic eruptions, landslides, tsunamis and floods.

1.2. Fire, Insects and Disease

Despite the severity of the above causes, many more trees in nature are killed by the action of fire or biotic agents. Under the "right" conditions of high temperature, low relative humidity, abundance of dry fuel, and high winds, lightning-started fires may burn for days or weeks, killing vast areas of forests, paving the way for new forests to replace them (Figure 1). In the absence of fire, large tracts of forest may be killed through successive years of defoliation by insects, usually the larvae (caterpillars) of moths and sawflies (Figure 2).

Populations of bark beetles, that girdle trees by mining in the inner bark and by introducing pathogenic fungi into the sapwood, periodically build up to outbreak levels, often killing millions of trees before they are spent (Figure 3).

Trees are often killed individually or in small groups when infected by disease agents (Figure 4), such as root-rotting fungi, wilt fungi that block translocation of water in the tree, or needle cast fungi that kill the foliage, robbing the tree of its ability to photosynthesize.

Figure 1. Stand-replacing forest fire burning over a wide front. Note flames consuming the crowns of individual trees and rising well above the forest canopy. (Courtesy J. Flanagan, B.C. Forest Service, Victoria, B.C.).

Figure 2. Defoliation caused by the eastern hemlock looper in Hawks Bay, Newfoundland in 1987. Inset: adult moths on bark of balsam fir tree. (Courtesy W.W. Bowers, Canadian Forest Service, Corner Brook, Newfoundland).

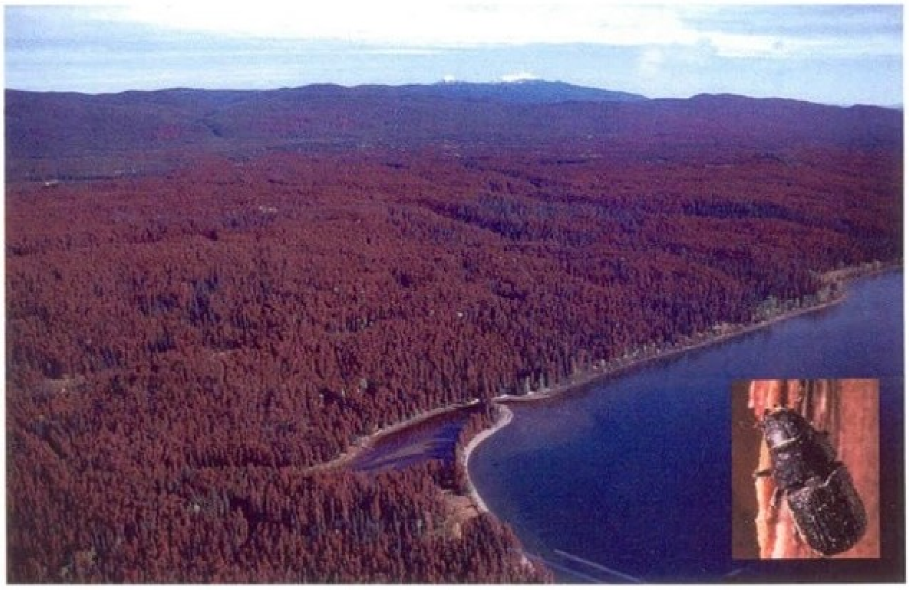

Figure 3. Aerial view of extensive mortality of lodgepole pines killed by the mountain pine beetle (inset) near Eutsuk Lake in north-central British Columbia, 2000. (Courtesy D. Cichowski, B.C. Forest Service, Smithers, B.C.).

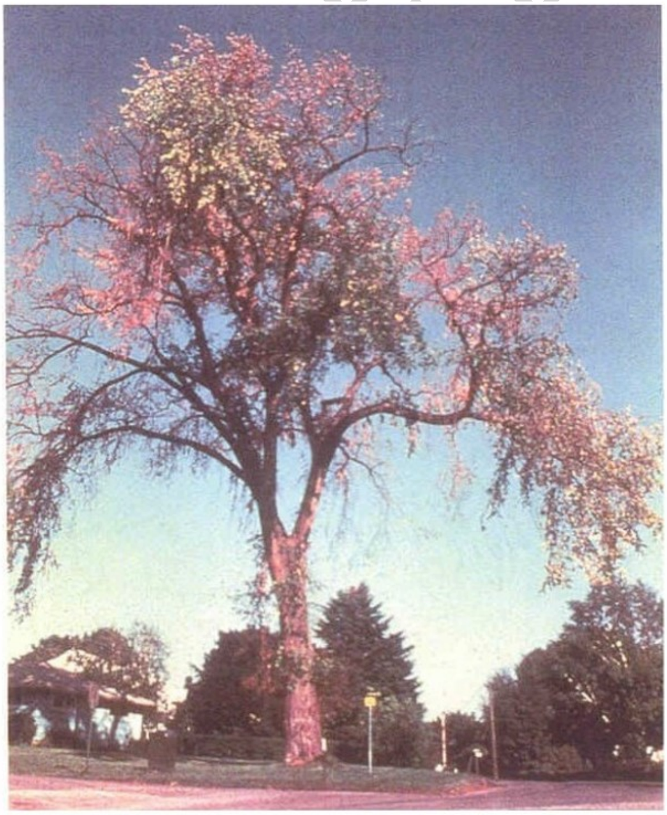

Figure 4. American elm tree wilting and dying from Dutch elm disease in Syracuse, New York, in 1976. (Courtesy D.C. Allen, College of Environmental Science and Forestry, State University of New York, Syracuse).

1.3. Non-lethal Effects of Fire, Insects and Disease

Dead trees in the forest serve as a habitat for wildlife, and when they fall, as coarse woody debris, breaking up the impact of heavy precipitation, and gradually releasing nutrients into the soil and carbon into the atmosphere. This process is facilitated by insects, such as termites, carpenter ants, wood wasps and wood-boring beetles which mine tunnels in the wood, opening the way for many species of wood-rotting fungi.

Many trees are not killed by fire or biotic agents, but suffer deformations, chronic or periodic set backs in their growth, or decreased capacity to reproduce. In many forests, periodic surface fires (Figure 5) may reduce fuel levels to the extent that the hazard of large and lethal crown fires is minimized, but at the same time they may partially kill the bark around the base of the bole, causing irregular radial growth. The larvae of terminal weevils mine in the inner bark of the leaders of pines and spruces, causing crooks and forks in the bole, or bushy trees, depending on whether one, two, or several competing lateral branches assume dominance in place of the dead leaders. Defoliation by insects and fungi may cause growth rates to plateau periodically, and infection by parasitic dwarf or true mistletoes may cause chronically diminished growth (Figure 6).

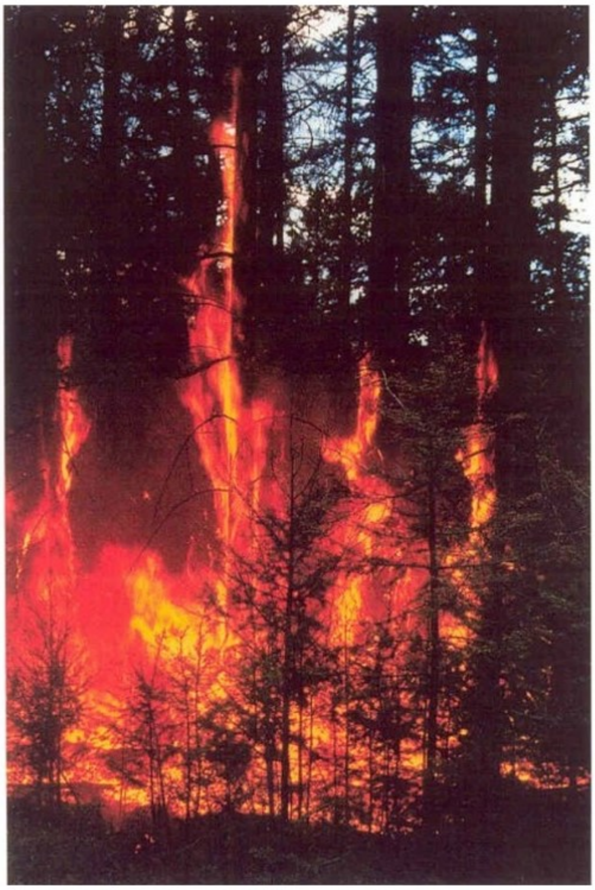

Figure 5. Surface fire achieved in a prescribed burn simulating a natural fire (see Figure 10), in which understory vegetation and other surface fuels are consumed. Note fire burning up the trunks of trees (almost all of which survived), but not into the crowns. (Courtesy L.E. Maclauchlan, B.C. Forest Service, Kamloops, B.C.).

Figure 6. Lodgepole pines in British Columbia showing mortality, poor form, reduced growth and prolific branching ("witches' brooms") at site of infection by dwarf mistletoe (inset).

Infection by cone and gall rusts, and infestation by cone beetles, coneworms, and seed maggots, weevils and bugs may almost completely inhibit reproduction by forest trees. Selection pressure by these agents probably underlies the evolution of occasional mast years, in which trees produce massive amounts of seed, allowing them to outstrip the ability of insects or disease to destroy the crop. Once on the ground, however, seeds are voraciously consumed by deer, pigs, rodents, birds and insects. Germination is inhibited by pathogenic fungi. The same or other fungi may kill new seedlings, which also may be girdled by cutworms or weevils, or snipped off by deer or rodents.

2. Problems Caused by Human Activity

In the absence of human experience, the above interactions are neither harmful, nor beneficial. They just happen. Over time, old trees and forests die, and new ones take their place. The duration that this takes is of no consequence.

Human civilizations, however, demand that forests continuously supply them with wood for fuel and for manufacturing of wood products and paper. They also demand non-timber products and services, such as edible fungi, medicinal plants, forage for livestock, a ready supply of clean water, and recreational opportunities. These demands place mankind in conflict with fire and pests that can kill, consume or diminish the very products and values that humans seek from the world's forests. In their quest to win the battle, humans have often exacerbated the conflict. Two examples serve to illustrate this point.

2.1. Unforeseen Consequences of Fire Control

In the interest of preserving forests for timber harvest (and sometimes other uses), humans have become very adept at putting out fires, despite occasional failures that have only increased their resolve. This is particularly true in western North America, where "Smokey Bear" is an icon of the careful, wise and courageous fire fighter. However, the absence of fire has prolonged the lifespan of large tracts of over-mature forests, leaving them vulnerable to attack by insects, particularly bark beetles. For example, beginning in the 1970's the mountain pine beetle, *Dendroctonus ponderosae*, has killed many billion dollars worth of lodgepole, ponderosa and white pine, *Pinus contorta* var. *latifolia*, *P. ponderosa*, and *P. monticolae*, respectively, throughout the U.S. and the Canadian west.

In the absence of fire, which kills its host, and sometimes the beetle as well, the mountain pine beetle has killed more trees than the expected combined natural impact of the fire plus the beetle in the same duration.

Two other unforeseen consequences of effective fire control have occurred in the same region. One is the build-up of fuel levels on the ground (dead branches, leaves and herbaceous plants), and the survival of lower branches as ladder fuels on many unshaded trees. Periodic, lightning-caused surface fires, which would normally consume the above fuels, now have the potential to ladder up into the crowns of trees, and thus to become large, stand-replacing fires. This potential was frequently met in the last two decades of the 20th century. When these fires occur at the urban-rural interface, they may consume dwellings and cost human life.

The second consequence of over-zealous fire control is frequently the growth of a dense understory of young trees, e.g., Douglas-fir, *Pseudotsuga menziesii*. The young trees have thin bark, and most would normally be killed by periodic surface fires. When an outbreak of the western spruce budworm, *Choristoneura occidentalis*, occurs, the larvae have a much more abundant food supply than in the past, and the population of budworms can grow explosively. The outbreak can then expand over larger areas, last longer and kill and maim more trees, before natural factors, or additional human intervention, e.g., costly aerial spraying with a microbial pesticide, *Bacillus thuringiensis* (Bt), can bring it in check.

2.2. Unforeseen Consequence of Control of an Insect Outbreak

One example of an unintended consequence of pest control occurred in the use of toxic chemical insecticides to control the spruce budworm, *Choristoneura fumiferana*, in eastern North America. In the past, budworm outbreaks have occurred at about 30-60-year intervals, and usually subsided after 7-10 years, because most of its preferred hosts, balsam fir, *Abies balsamia*, were killed, thus removing the food source of the budworm larvae. Like fire in the west, the budworm is a stand-replacing agent.

In 1951, when a budworm outbreak threatened to destroy the timber supply in the Canadian province of New Brunswick, a decision was made to use DDT to protect the infested trees. The next spring, 77 702 ha of forest were aerially-sprayed at a rate of 1 kg of DDT per ha of forest (Figure 7), saving the trees from death. In doing so, the following year's food source of the budworm larvae was also saved, while many parasites and predators were killed along with the budworm larvae. The combined effect prolonged the outbreak, and over a 37-year period, insecticides were applied annually (excluding 1959) on an average of 1.2 million ha per year, until the outbreak mysteriously disappeared in 1990. Similar control programs were run in New England and other Canadian provinces.

Figure 7. Stockpile of 200,000 gallons of DDT next to a newly-constructed airfield prior to the first aerial spraying to control the spruce budworm in New Brunswick in the spring of 1952. (Courtesy of the Canadian Forest Service).

As time progressed, the dose of DDT was lowered to 0.5 kg per ha. By the end of the outbreak, DDT was no longer used, having been replaced by other insecticides, mainly the organophosphate fenitrothion, a compound with greater acute toxicity to non-target vertebrates, but much less persistence in the environment.

Beginning in 1980, one positive outcome of the search for alternative insecticides was extensive research and development focused on Bt, proving it to be an effective microbial insecticide for the control of budworms and other insect defoliators in the future. Bt is now the only insecticide used operationally for control of forest insect defoliators in Canada and much of the rest of the world. Looking backward, the Canadian experience was a perfect example of being trapped on a "pesticide treadmill."

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Biographical Sketch

As a child, **John Borden** spent many summers exploring British Columbia with his archaeologist father. After earning a B.Sc. degree in entomology at Washington State University, and M.Sc. and Ph.D. degrees from the University of California, Berkeley, he returned to British Columbia in 1966 to join the faculty at Simon Fraser University. There he has taught forest pest management, and has retraced his childhood adventures while conducting research on the chemical ecology and management of forest insects. He is a member of the Association of Professional Foresters of British Columbia, and is a Fellow of the Royal Society of Canada.