

MOUNTAIN PINE BEETLE INFESTATION;
CYCLING AND SUCCESSION IN
LODGEPOLE PINE FOREST

W. H. Romme
Department of Natural Science
Eastern Kentucky University

and

J. B. Yavitt and D. H. Knight
Department of Botany
University of Wyoming

Objectives

A research project was initiated in 1980 to study the effects of outbreaks of the mountain pine beetle (Dendroctonus ponderosae Hopkins) on lodgepole pine forest (Pinus contorta Dougl. ssp. latifolia) in Yellowstone National Park and surrounding areas. This native insect apparently has long been associated with lodgepole pine, and reports of small numbers of beetles can be found in Park records as early as 1925. However, in the late 1940's and early 1950's major outbreaks began to occur on the Caribou and Targhee National Forests immediately to the west and southwest of Yellowstone and Grand Teton National Parks. An outbreak in Grand Teton National Park and the adjacent Teton National Forest began in the 1950's, with an explosive increase in 1961 followed by an eventual subsidence in the late 1960's. The first major outbreak in Yellowstone National Park began in the late 1960's in the Bechler and South Entrance areas, reaching a peak there in 1970 and later declining. Yearly aerial surveys conducted thereafter showed a steady northward movement of the outbreak through the western half of the Park at a rate of 1 - 5 km per year. By 1978 the peak outbreak was centered around West Yellowstone, with hundreds of infested trees per hectare. The outbreak is now moving north and east along the Madison and Gibbon Rivers, with the greatest beetle populations currently in the vicinity of Madison Junction.

The immediate effects of a beetle outbreak are well documented: the larger pines in a stand (especially those greater than 15 cm dbh) are killed while smaller pines and other tree species survive; over 50% of the tree density and basal area may be killed over the course of 3 - 6 years (Amman and Baker 1972, Cole and Amman 1980). However, we know much less about the many more subtle functional implications of this massive perturbation on a forest ecosystem. Thus, the emphasis in our present research is on the effects of beetle outbreaks on (1) growth rates in surviving trees and total stand productivity, (2) fuel accum-

ulation and potential fire behavior, (3) nutrient loss through soil leaching, and (4) rate and course of secondary succession.

Methods

We determined growth rates of surviving trees by collecting increment cores from representative canopy, subcanopy, and understory trees (five of each category in most stands) and measuring the widths of annual rings before and after the beetle outbreak. Roe and Amman (1970) presented similar increment core data to show a significant release of understory subalpine fir (Abies lasiocarpa (Hook.) Nutt.) after a recent outbreak, and they interpreted earlier episodes of release in their cores as evidence of earlier outbreaks. However, their sample size was small (6 trees) and they could not be certain that at least some of the variation in growth rate that they detected was not due to variables other than beetle outbreaks, such as fluctuations in weather. Therefore, we collected cores from a large number of trees in a sequence of stands in which the peak beetle population had occurred 2 - 16 years earlier, plus "control" stands having similar characteristics of stand age and structure but no history of a beetle outbreak.

Of even greater interest than the magnitude of release of individual trees is the effects of a beetle outbreak on total stand productivity. Mattson and Addy (1975) presented evidence for the hypothesis that phytophagous insects may help to maximize primary productivity by killing older trees that are no longer capable of maximum rates of productivity, thus freeing from competition the younger trees that still have high rates of carbon fixation. We tested whether the mountain pine beetle has this effect by intensively sampling a small stand (125 m²) with a well-developed understory in which the beetles had killed 63% of the canopy trees 16 years earlier. We mapped the location of all living and dead canopy trees and took an increment core or cross section from each. We also collected a core or cross section from every understory tree greater than 4 cm dbh, and tallied and subsampled all trees less than 4 cm dbh. By measuring the annual rings in these samples, we can reconstruct the total annual increment in stand basal area for each year from the present back to the stand's origin after a destructive fire in 1879. Because of very slow decomposition and minimal disturbance by other than the beetles in this stand, very little woody material has been lost, and we have here a unique opportunity to test Mattson and Addy's (1975) hypothesis.

From our earlier work in Yellowstone we knew that fuels vary significantly with stand age (Romme 1979). Therefore, we decided to examine separately the effects of beetle outbreaks in younger and older stands. For the younger set we selected a chronosequence of 11 stands that had the following characteristics just prior to the beetle outbreak: stand of fire origin; even-aged structure; 80 - 185 years old; average density and basal area for lodgepole pine forests of this area; no other major disturbances. In seven of the stands the peak of the beetle outbreak

had occurred 2 - 16 years earlier, and in one stand the peak beetle population apparently coincided with the time of sampling. In the other three stands the beetles had not yet inflicted significant mortality, but they were located near the front of the advancing beetle outbreak and had characteristics similar to the heavily affected stands. To minimize the variability in fuels attributable to factors other than the beetle outbreak, we carefully selected stands with visually similar density and basal area. It was impossible to control elevation and distance between stands, however, because of the history of the beetle outbreak in this area. Thus, our chronosequence of necessity included stands located in Grand Teton National Park, the Rockefeller Parkway, southwestern and west-central Yellowstone National Park, and the Gallatin National Forest immediately west of Yellowstone, with a range in elevation from 1950 - 2440 m.

We developed a second approach for estimating fuel increase following a beetle outbreak. From our data and from the results of other studies in this region (Roe and Amman 1970, Cole and Amman 1980) we can estimate with reasonable accuracy which trees will be killed in an outbreak, based on their diameters. We can then estimate the quantities of various fuel components contained within these dead trees using regressions developed by Brown (1978). We collected data on the rate at which dead woody material of different size classes falls from the canopy, plus background fuel levels in stands representing a range of age and site conditions in the Yellowstone area. We have estimates of decomposition rates from our research in lodgepole pine forests of the Medicine Bow Mountains. We will combine all of these data into a model that will simulate a beetle outbreak and the resultant fuel accumulation over a period of ca. 25 years. This will yield a much more precise estimate of the magnitude of changes in fuels likely to occur after an outbreak. We will then evaluate the actual risk of fire and potential fire behavior in these stands before and after a beetle outbreak by applying our fuels data to a mathematical model of fire behavior such as that developed by Rothermel (1972).

To measure the amount of nutrient loss associated with a beetle outbreak, we established 36 tube-tension lysimeters in the fall of 1980 in two different stands near West Yellowstone where the beetle outbreak was just beginning to subside. Each lysimeter was embedded in the soil beneath the major rooting zone (50 cm), where it will collect soil leachate during the spring snowmelt and after occasional heavy summer rains. We collected the leachate during the 1981 snowmelt period and plan to do so again in 1982.

Results

From even casual inspection of our increment cores, it is evident that a beetle outbreak is followed within one year by significant release in many surviving canopy, subcanopy, and understory trees. Release is most marked in individuals located within a few meters of a beetle-killed snag;

individuals entirely surrounded by other surviving trees generally show no obvious increase in growth rate. Tree-ring analysis will be completed for this and other stands during the next two months.

We examined three different categories of dead woody fuels in our chronosequence of young stands affected by a major outbreak 0 - 16 years ago. Each fuel category has a primary influence on a different aspect of fire behaviour. Needle litter appears to increase two years after the outbreak, perhaps due to needle-fall from beetle-killed trees, then to decrease over the next 14 years, possibly because of reduced annual litter fall and ongoing decomposition under the thinner canopy. However, neither of these apparent trends is significant at ($p < 0.10$) that would seem to be related to beetle-induced changes.

Total energy release in a fire is a function of total fuel mass, which increases significantly ($p < 0.001$) after a beetle outbreak. However, it has been observed that in most intense fires in Yellowstone National Park only the rotten material and the sound material less than 7.5 cm in diameter burns completely; most of the larger 1000-hour timelag sound material is not consumed by the fire (D. G. Despain, Park Biologist, personal communication).

Fuels in which fires may persist during cool or damp weather are important because many uncontrolled lightning-caused fires in Yellowstone National Park have been observed to flare up and burn large areas on two or more separate occasions during a summer/fall season; during intervening rainy periods the fires smoldered in duff and rotten wood (Sellers and Despain 1976, Despain and Sellers 1977). However, we found no significant trend ($p < 0.10$) in these fuels after a beetle outbreak. Our data do suggest a downward trend in large rotten material and an upward trend in duff depth, but these weak patterns may be spurious.

Continuity between ground and canopy fuels increases the probability that a surface fire will spread to the canopy. Nearly all fires that have been observed to cover large areas in Yellowstone's subalpine forests burned through the canopy (Sellers and Despain 1976). Surface fires apparently burn relatively small areas in Yellowstone's high elevation forests, though this may not be true of forests at lower elevations in surrounding areas. We visually estimated the mean distance between ground and canopy fuels in each of our 11 stands, but our results show no apparent trend in the aftermath of a beetle outbreak.

During the next two months we will examine relationships between fuels and parameters such as pre-outbreak tree density, basal area, % canopy mortality, site index, and elevation to determine the contribution of these other factors to observed variability in fuels. In addition, we will complete the analyses needed for our estimation of the effects of a beetle outbreak on fuel loads and potential fire behavior in individual stands, total stand productivity, and nutrient output.

Literature Cited

- Amman, G. D., and B. H. Baker. 1972. Mountain pine beetle influence on lodgepole pine stand structure. *J. Forestry* 70: 204-209.
- Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA For. Serv. Gen. Tech. Rep. INT-16.
- Brown, J. K. 1975. Fire cycles and community dynamics in lodgepole pine forests. Pages 429-456 in: D. M. Baumgartner (ed.), *Management of Lodgepole Ecosystems Symposium Proceedings*, Washington State Univ. Cooperative Extension Service, Pullman, WA.
- Brown, J. K. 1981. Downed dead woody fuel and biomass in the Northern Rocky Mountains. USDA For. Serv. Gen. Tech. Rep. INT-117.
- Cole, W. E., and G. D. Amman. 1980. Mountain pine beetle dynamics in lodgepole pine forests. Part I: Course of an infestation. USDA For. Serv. Gen. Tech. Rep. INT-89.
- Deeming, J. E., R. E. Burgan, and J. D. Cohen. 1977. The national firedanger rating system -- 1978. USDA For. Serv. Gen. Tech. Rep. INT-39.
- Despain, D. G., and R. E. Sellers. 1977. Natural fire in Yellowstone National Park. *Western Wildlands* 4: 20-24.
- Mattson, W. J., and N. D. Addy. 1975. Phytophagous insects as regulators of forest primary production. *Science* 190: 515-522.
- Roe, A. L., and G. D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv. Res. Pap. INT-71.
- Romme, W. H. 1979. Fire and landscape diversity in subalpine forests of Yellowstone National Park. Ph.D. Thesis, Univ. of Wyoming.
- Rothermel, R. C. 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Res. Pap. INT-115.
- Sellers, R. E., and D. G. Despain. 1976. Fire management in Yellowstone National Park. Pages 99-113, in: *Proceedings of the Montana Tall Timbers Fire Ecology Conference and Fire and Land Management Symposium No. 14, 1974*. Tall Timbers Research Station, Tallahassee, Florida.