Kilgore, B.M. 1971. The Role of Fire in Red Fir Forests.
Transactions of the Thirty-Sixth, North. American,.Wildlife and Natural Resources Conference,
March 7-10, 1971. Wildlife Management Institute, Washington, D. C., 20005

THE ROLE OF FIRE IN MANAGING RED FIR FORESTS

BRUCE M. KILGORE

Office of Natural Science Studies, National Park Service, Sequoia and Zings Canyon National Parks, Three Ewers, California

Fire has long been a major factor in the ecology of forests in North America (Ahlgren and Ahlgren, 1960). Its role in the red fir forest of the Sierra Nevada, however, has received little study. Investigations in mixed conifer forests in Sequoia, Kings Canyon, and Yosemite National Parks by Biswell (1961), Hartesveldt (1964), and Reynolds (1959) lead to the conclusion that fires have been less numerous during the past 50 years than they were in primitive forests. Estimates of frequency in such primitive forests range from a fire every year or two to one every 21 years (Wagener, 1961), with a generally agreed upon average of something like 8 to 10 years between fires for individual trees. A conservative estimate would be that each tree was burned every 10 to 20 years. This is confirmed by the fire scars which some of the trees bear. As such, fires were an integral and important environmental factor in the evolution and maintenance of many plant communities in the Sierra Nevada before effective and widespread fire suppression activities came into being.

Since the early 1900's, attempts have been made to suppress fires – both man-caused and lighting-caused – particularly in the mixed conifer forest type. In an effort to develop a management program aimed at restoring natural environmental conditions to national parks, the National Park Service has initiated studies of the role of fire in various forest types. Since fire hazard is less in a red fir forest than in a mixed conifer forest, red fir was considered a useful type within which to begin study of the eeological impact of preseribed fire on fir thickets.

STUDY AREA

The basin drained by Rattlesnake Creek, a small tributary of the Middle Fork of the Kings River, was chosen for study and experimental management. The headwaters of this creek are above 10,000 feet, while the elevation of its junction with the main stream is 5,000 feet. Within this basin, the 800 acres selected for study and managment range in elevation from 8,400 feet to 9,800 feet. The topography in the Rattlesnake Creek basin varies from fairly level creekside land in certain sections to steeper slopes on the west, north, and. east.

The dominant vegetative cover is red fir *(Abies magnifica).* This is mixed with lodgepole pine *(Pinus contorta)* along the stream and in moist sites. JefFrey pine *(Pinus jeffreyii)* is found in the lower part of the unit, while western white pine *(Pinus monticola)* and white- bark pine *(Pinus albicaulis)* are found on ridges and in the higher elevation segments of the study area.

No permanent weather records are available for this elevation in the Middle Fork of the Kings

River region or even for comparable elevations anywhere on the west side of the Sierra. Standard temperature, humidity, and precipitation readings were taken, however, whenever men were in the area during the course of this project. Minimum temperatures found in August and September in the Rattlesnake Creek basin during 1968 and 1969 ranged from 27 to 58°F. and averaged 41°F. Maximum temperatures for the same period ranged from 52 to 80°F. and averaged 71°F. Only a trace of rain fell during these months. Based on Corps of Engineers storage gauge data, total precipitation at 9,900 feet elevation in Rattlesnake Creek has varied from 27 to 90 inches in the past eight years, with a mean of 48 inches – much of this falling as snow.

HISTORY OF MAN'S IMPACT ON THE AREA

Nearly all of what is now Kings Canyon National Park, including the Rattlesnake Creek drainage, may have been grazed to some extent by sheep in the late 1800's, but the amount of grazing in this high, isolated region was likely to have been negligible. It is thus probable that Western man had some, but relatively little, impact on the Rattlesnake Creek region.

The ecological importance of early efforts at fire suppression between 1900 and 1940 in this back country region must also be seriously questioned. National Park Service records in the past 20 years show 13 fires, each less than one-fourth acre in size, in the eight square miles surrounding Rattlesnake Creek; how much impact the resulting suppression activities may have had is debatable. A 1963 lightning fire was studied on the ground in 1968; the fire burned one-fourth acre, and some effort was expended in building line and cutting through down logs. The openness of the surrounding country and relative lack of ground fuels, however, make it appear the fire would have done little more than consume part of the scattered down logs and ground fuels and then gone out, even if it had not been suppressed.

METHODS

Within the 800-acre management area on Rattlesnake Creek, twelve 100 foot-by-100 foot macroplots were laid out for intensive study. These plots were selected as being representative of some of the heaviest fuel types and most dense red fir reproduction areas within the drainage. As such they seemed to reflect most nearly the conditions characteristic of lower elevation, higher fuel hazard zones where white fir thickets are found.

Before and after burning, the following records were gathered for each plot:

(1) species, diameter, and height class of trees more than 12 inches diameter at breast height (dbh);

(2) numbers of red fir and lodgepole pine saplings per acre in four height classes ("sapling" is used here for any tree less than 30 feet-in height);

(3) extent and approximate height of red fir sapling thickets ("thicket," as used here, means a growth of young trees – usually of a shade tolerant species – which is dense

enough to make walking, through the area difficult);
(4) coverage and frequency values for herbaceous and shrub species;
(5) flash fuel and duff weights;
(6) length and diameter of down- trees;
(7) chemical light meter indices for light reaching the forest floor.

Before going into the field, locations of five 50-foot transects were systematically determined for each plot to sample the understory cover and ground cover. Ten 2 foot-by-8 foot microplot samples were taken along each transect. The sampling procedure followed was basically that of Daubenmire (1959), modified to use a 1 to 5 coverage scale. Coverage values were recorded for individual herbaceous, grass, and shrub species, for total ground cover, and for understory cover up to six feet – contributed by both small and large living trees and shrubs plus dead branches. The transects were resampled in 1969 and 1970, one and two years after burning.

The preburn and postburn appearance of vegetation on the plots was recorded by black-and-white and color photography at a series of permanent photo points. An index to the overall density of vegetation was obtained with a 24-hour integrating light meter based on the chemical light properties of anthracene in benzene (Marquis and Yelenosky, 1962). Five points on each of the 14 plots – or 70 points – were analyzed simultaneously by this method. The assumption here is that light received at the forest floor is an inverse function of the percent of canopy cover.

To determine the impact of fire on the range of dead flash fuel and duff weights, samples of these two types of fuel were taken before and after burning. At each of 13 sites, a 2 foot-by-3 foot sampling frame was used and two sub-samples were taken. All branches, loose twigs, needles, and cones found within the frame made up the flash fuel sub-sample, while the partially decayed organic material found in one square-foot unit made up the duff sub-sample. Because of the large weight involved and the uneven distribution, down logs – in various stages of decay – were measured separately. Lengths and diameters of such logs were measured, volumes were calculated, and this volume was converted to an estimated weight per acre using sample field dry weights of decaying down log materials.

Water samples were taken from above and below the burn for water quality analysis, and deer pellet groups were sampled in different vegetative types as an index to deer use.

During August, 1968, Park Service resource managers burned all of the 800-acre management unit except for the 12 study plots. In September, 1968, six of the study plots were burned under known conditions of temperature, humidity, wind, and fuel stick moisture. Heavy concentrations of ground fuels were touched off by a drip torch in as many places around and through the plot as seemed feasible and safe for the Park Service rangers involved. Down punky logs and standing dead snags near the center of the plots were often prime fuel targets for initial ignition. After the fire began in the center, points near the edge were ignited, thus using essentially an area ignition technique. Six plots were retained as control areas.

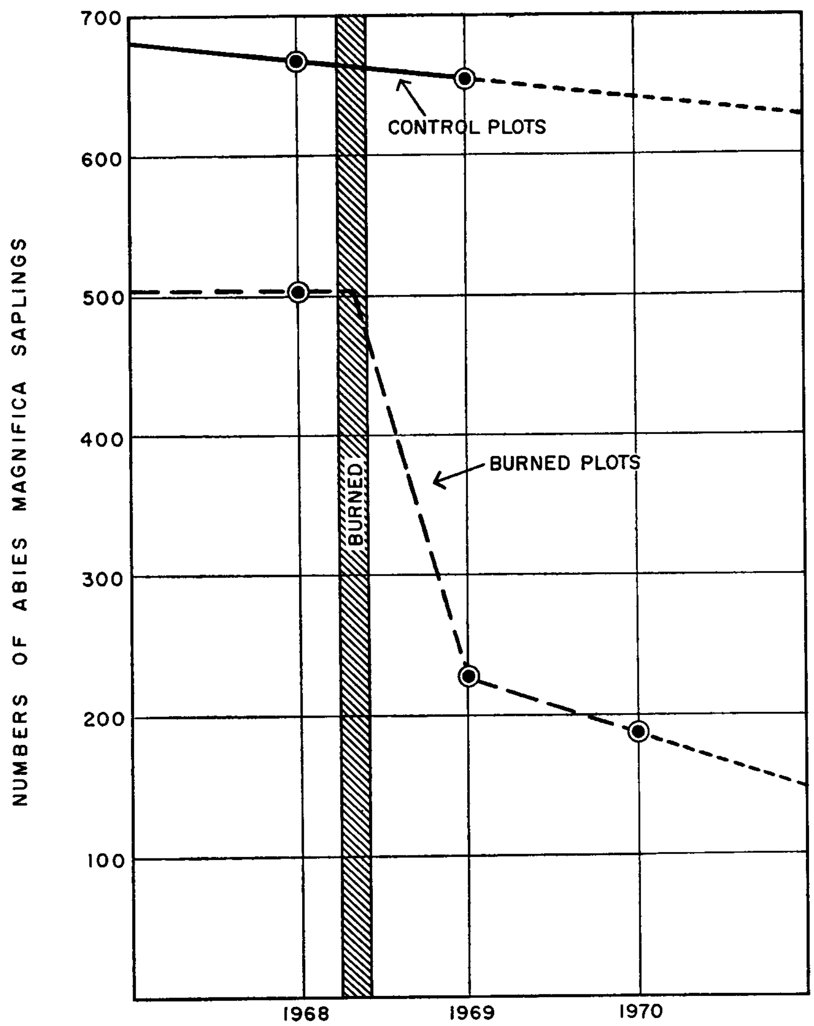

Figure 1.– Changes in numbers of *Abies magnifica* saplings on 300 two-foot by three-foot microplots before and after burning.

RESULTS

Red fir is the dominate species in canopy height, density, and frequency in this area. Trees more than 12 inehes dbh averaged 85 per acre. Its principal associate was lodgepole pine, which averaged 18 per acre. The burning program caused relatively little change in numbers of these larger trees. Six of the total of 80 trees more than 12 inches dbh on the burned plots were killed, while 8 of 12 snags were largely redueed to ashes. The thin-barked lodgepole pine was far more susceptible to burning than red fir. Many lodgepole would catch fire at the base, burn completely through, and fall without the upper canopy being burned. The only sizeable red fir trees killed were found on plot 13 where a surface fire became intense as it burned a number of large down trees and dense thickets of reproduction.

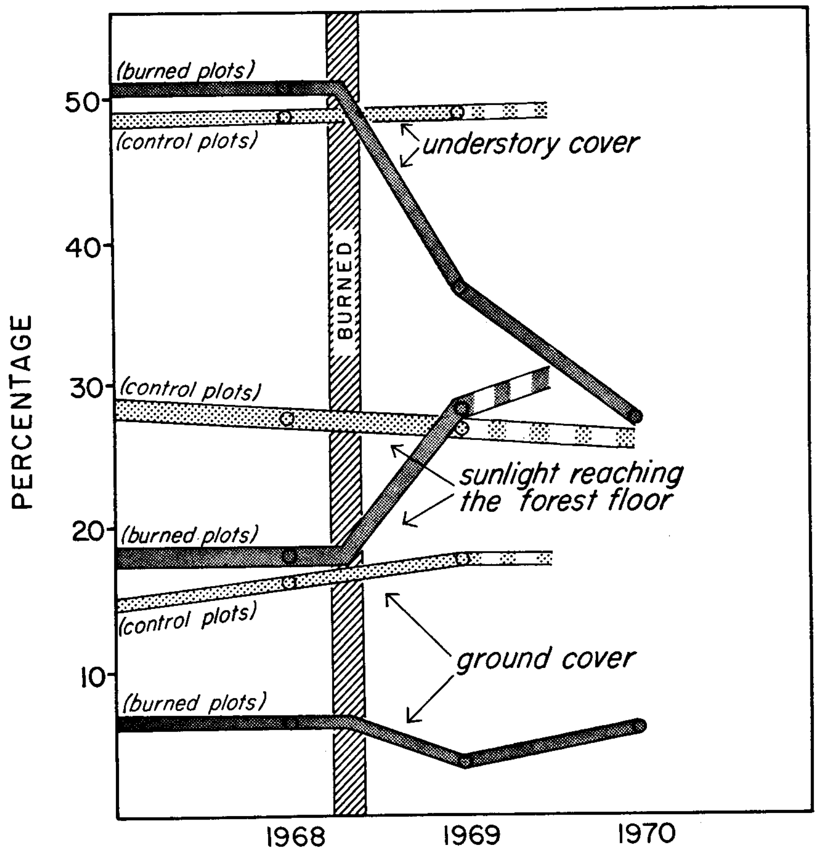

Figure 2.– Changes in understory cover, ground cover, and sunlight reaching the forest floor before and after burning.

As shown in Figure 1, control plot numbers of fir saplings for 800 microplots remained almost the same between 1968 and 1969. Numbers of small red fir on treated plots, however, decreased more than 60 percent following burning. Trees less than three feet tall made up about 70 percent of the fir saplings on both control and burn plots. Numbers of fir saplings averaged 12,000 per acre on burn plots and 16,000 per acre on control plots in 1968. Following burning, numbers decreased to 5,500 per acre on burn plots in 1969 and 4,900 in 1970, while remaining at 16,000 on control plots.

The understory foliage of trees arid shrubs occurring between one foot and six feet covered about 50 percent of these plots. Two years following burning, understory cover had decreased to less than 28 percent (Figure 2). Accompanying this decrease in cover on burn plots was an increase in amount of sunlight reaching the forest fioor. On control plots, between 26 and 27 percent of full sunlight was recorded in both 1968 and 1969. Burn plots, however, showed an increase from 18 to 28 percent in amount of sunlight received at the forest floor – presumably a direct function of a decrease in overall vegetative density above the measurement stations.

Ages were determined for a sample of 20 red fir less than six feet tall, growing in dense thickets.

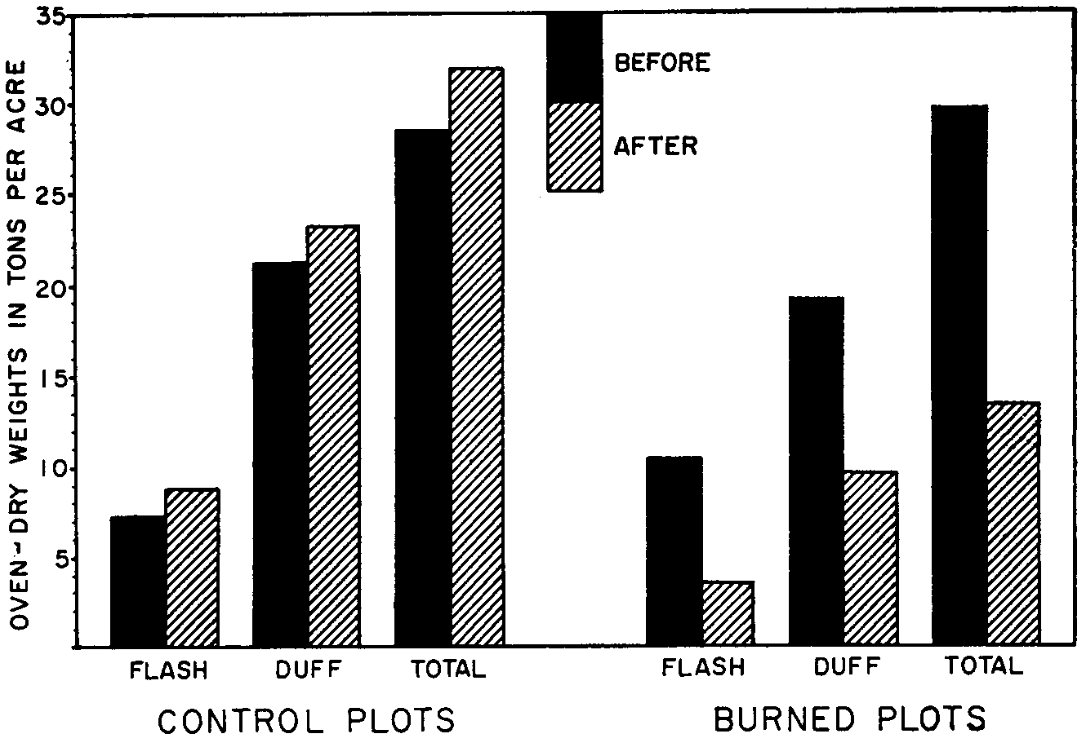

Figure 3. Flash fuel and duff weights before and after burning.

These small trees ranged from 17 to 60 years old and averaged 48.8 years. Since snow depths at 9,900 feet in Rattlesnake Creek Basin average 111 inches between February and May (Department of Water Resources, 1965-1969), the dense thiekets of red fir less than nine feet tall are probably an example of the phenomenon described by Oosting and Billings (1948) wherein most red fir saplings never grow to a height exceeding the average depth of winter snow. This is true because unless the terminal shoot can grow vigorously in a single season from below the pack to a foot above the pack, snow blast and low temperature just above the snow kill back the terminal shoots.

Large numbers of ”seedling” red fir (less than two inches high) were found in 1968, averaging from 17,000 to 21,000 per acre. By 1969, through natural mortality factors, seedling numbers had dropped to 1,200 per acre on control plots. Numbers on burn plots were further reduced to 500 per acre, apparently the result of both direct kill during burning and less favorable growing conditions created by fire. In contrast, no seedling lodgepole pine were found before burning in 1968. In 1969, 33 newly germinated seedlings were found on the same transects within burn plots (about 80 per acre), with only five (or 12 per acre) on control plot transects. Based on the location of the 33 burn plot seedlings, it seemed clear that burning had created conditions favorable for seedling establishment of this species. Eight of these seedlings (19 per acre) were still present in 1970, two years after the fire, while none remained on control plots.

Two shrubs, seven grasses, and approximately 40 species of forbs were found on one or more of the study plots during the three years. Although there were essentially no shrubs on the plots before burning, numbers and frequency of *Ribes cereum* seedlings increased on the plots after burning. Adjacent to the study plots, in a heavily burned montane chaparral area on the south-facing slope, a special survey found more than 11,000 seedlings per acre of *Ceanothus cordulatus* and lesser numbers of *Ribes* sp., *Arctostaphylos patula,* and *Prunus emarginata.*

Herbaceous plant cover remained stable at about 16 percent on control plots. The burn plots had 6.5 percent herbaceous ground cover in 1968 which decreased to 3.8 percent the first year after burning, but returned to 6.0 percent in 1970 (Figure 2). Individual species coverage values were too low to be meaningful. Frequency values, however, seemed to show an increase in *Phacelia hydrophylloides* after burning, and a decrease in frequency of *Pedicularis semibarbata, Hieracium albiflorum,* and *Viola purpurea.* Five species which increased only slightly in frequency and coverage on burn plots were more strongly favored by conditions after burning in scattered areas throughout the total management unit. These were *Descuriana richardsonii, Gayophytum diffusum, Mentzelia dispersa, Epilobium* sp., and *Cryptamtha ajpnis.* One plot showed a noticeable increase in both frequency and coverage of several mosses and of *Senecio triangularis.* This may have resulted from some of the same conditions described by Hoffman (1966) who found that the moss *Funaria hygrometrica* exhibited a strong affinity for burned areas and concluded that the moss was probably responding to favorable nutrient concentrations in the charred soil surfaces, favorable moisture relations, favorable light and temperature conditions, and perhaps lack of competition with other species. The remaining 30 species of herbaceous plants and grasses found on the plots did not show an appreciable response to the burning program.

Figure 3 compares the oven-dried ground fuel weights in 1968 and 1969 on two control plots and two burn plots. Weights for the six-square-foot samples ranged from 48 to 255 ounces before burning. After burning, control plot weights remained almost the same, while burned plot weights had decreased considerably. Preburn measurements indicated that the total flash fuel and duff was approximately 80 tons per acre. Following burning, this was reduced by more than 50 percent. Fire also reduced volume of down logs by 80 to 50 percent on most plots. The estimated log fuel weights decreased from 7 to 4 tons per acre.

In order to monitor any impact which burning might have on the quality of water in Rattlesnake Creek, measurements of pH and dissolved oxygen were made upstream and downstream from the burning both before and after the fire. No changes in either characteristic were found after the first rain following burning. Water samples were also collected at these same sites and submitted to the California Department of Water Resources laboratory for chemical analysis. Analyses of turbidity, settleable solids, hardness, alkalinity, sodium, chloride, magnesium, conductivity, and specific conductance did not indicated a measurable change in water quality following burning.

A survey of deer use of the several vegetative types in the Rattlesnake Creek Basin was made in 1968 and 1969 by biologists from the California Department of Fish and Game. Their unpublished results indicate no substantial change in numbers of deer during this brief period. However, numbers of shrubs sprouting and numbers of seedling shrubs established following burning should contribute to range improvement in the next few years and may the eventually have an impact on deer numbers

While detailed study of bird populations in the area before and after burning was not possible, general observations at Rattlesnake Creek plus previous work in the mixed conifer forest type (Kilgore 1971) make it appear that little change would be expected in bird numbers as a result of the burning program unless the upper canopy was altered substantially. No such change took place in the study area.

DISCUSSION AND CONCLUSIONS

In summary, the impact of fire on certain biotic and abiotic elements of a red fir forest ecosystem was studied by measuring these elements before and after prescribed burning Fire reduced the litter, duff, and humus by about 50 percent Fire hazards were reduced accordingly. Few older red fir were affected, but many fir saplings and seedlings were killed resulting in both decreased coverage of fir thickets and more sunlight reaching the forest floor. Many mature lodgepole pine were readily killed by fire, while germination of lodgepole seedlings was stimulated. Numbers of seedlings of nine shrubs and herbaceous species increased substantially, and three shade-tolerant species decreased in frequency. No changes in deer or bird numbers were noted. Water quality of the creek was not altered by the burning.

Prescribed fire had a relatively mild impact on the climax forest of this high elevation ecosystem. Such burning was considerably different from fire at lower elevations in the drier, heavier fuel conditions of the mixed conifer type. There was little problem with fire crowning; some individual trees did flare up, but generally the fire did not move from one tree to another at such times. A lightning fire which started in 1968 in a similar forest type on the south side of the Middle Pork of the Kings River Canyon in early July was not suppressed. Throughout August and September it continued to burn, primarily through scattered down logs, litter, and duff, with only occasional burning of standing trees. In two months, it covered less than ten acres.

Based on this study and such evidence from natural fires in red fir forests, Pre suppression seems to be of questionable value in this near-climax vegetation type unless there is danger to human life and property. If natural environmental conditions are to be maintained in national parks and wilderness areas, it would seem desirable to allow most lighting fires in red fir forests to burn without suppression.

ACKNOWLEDGMENTS

This study is a contribution from the National Park Service’s Office of Natural Science Studies under RSP SKC-N-25a. R. Riegelhuth, Management Biologist at Sequoia and Kings Canyon National Parks, helped select and lay out study plots and offered useful suggestions throughout the project. Superintendent J. S. McLaughlin and Chief Ranger P. H. Schuft made possible the assistance rendered by rangers and naturalists, including field help by M. J. Zarlus and J. Roekwell. Special thanks are due to: California Department of Fish and Game for surveys of deer use by G. C. Ashcraft and advice on sampling water quality by R. R. Ehlers; California Department of Water Resources and V. B. McIntyre for laboratory determinations of water quality; University of California Herbaria at Berkeley and Davis and Helen K. Sharsmith and B. Crampton for identification of plant specimens; U. S. Forest Service for advice of C. E. Conrad and H. E. Sehimke of the Pacific Southwest Experiment Station; Department of Chemistry, Fresno State College, and Helen Gigliotti, for assistance in spectrophotometric analysis; and P. J. Zinke; P. W. Rundel, and H. Weaver.

LITERATURE CITED

Ahlgren, I. F. and C. E. Ahlgren 1960. Ecological effects of forest fires. The Botanical Review 26: 483-538.

Biswell, H. H. 1961. The big trees and fire. Nat'l. Parks Mag. 35 (April): 11-14.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33(1): 43-64.

Department of Water Resources, State of California 1965- Water conditions in California. F'all Reports. Bulletins No. 120-65, 1969. 120-66, 120-67, 120-68, and 120-69. Sacramento.

Hartesveldt, R. J. 1964. Fire ecology of the giant sequoia: controlled fires may be one solution to survival of the species. Nat. Hist. Mag. 73: 12-19.

Hoffman, G. R. 1966. Ecological studies of *Funaria hygrometrica* Hedw. in Eastern Washing- ton and Northern Idaho. Ecol. Monogr. 86(2): 157-180.

Kilgore, B. M. 1971. Response of breeding bird populations to habitat changes in a giant sequoia forest. Amer. Midland Naturalist, 85(1): 135-152.

Marquis, D. A. and G. Yelenosky 1962. A chemical light meter for forest research. U. S. Forest Service, N. E. For. Expt. Station. Paper No. 165. 25 p.

Oosting, H. J. and W. D. Billings 1943. - The red fir forest of the Sierra Nevada: *Abietum magnificae.* Ecol. Monogr. 13(3): 259-274.

Reynolds, R. 1959. Kffect upon the forest of natural fire and aboriginal burning in the Sierra Nevada. Unpubl. Thesis, Geography Dept., Univ. Calif., Berkeley. 262 p.

AVagener, VT. *W.* 1961. Past fire incidence in Sierra Nevada forests. Jour. Forestry 59: 739-748.

DISCUSSION

FROM THE FLOOR: Is soil erosion increased significantly after these fires?

Dr. KILGORE: We found no evidence of that. Our controlled measurements are few but we have been there two years now and have gone over these 800 acres very extensively and we found no real problem.

Dr. CLARENCE COTTAM (Texas): I would like to say that that was a fine paper. However, have you done any work in relation to sequoias?

Dr. KILGORE: We have a short preliminary paper out on the impact of fire on germination of sequoia seedlings. We do have many sequoia and some brush seedlings coming into the area, where none were found before the fire.

Mr. ROBERT LOWE: Do you find any time of year better for doing work in relation to such trees as the red fir, or do you just do it in the summer?

Mr. KILGORE: For practical reasons, our studies took place during the summer, There is snow in the area until late May or early June. Therefore, to do any burning of the ground cover, we have to work during the summer. As soon as snow arrives in the fall, burning is finished for the season.

I should also mention that 65 percent of the 800,000 acres that make up Sequoia- Kings Canyon National Parks is now designated as a natural fire zone in whieh lightning fires are allowed to burn. This is high elevation area – generally above 8,000 feet – and does not include any sequoias.

CHAIRMAN: WALLACE: Ladies and gentlemen, this has been a most excellent series of papers. I would like to have you give reeognition to our speakers for the fine job they have done.