HISTORICAL PERSPECTIVE: A PREREQUISITE FOR BETTER PUBLIC UNDERSTANDING OF FIRE MANAGEMENT CHALLENGES

George E. Gruell

INTRODUCTION

Uncontrollable fires in the greater Yellowstone area (GYA) during summer of 1988 focused national attention on the issue of fire management in western North American national parks and wilderness. Much public indignation was expressed in the news media over management of both the GYA fires and other large fires that together burned over one-half million acres in Montana. Believing that agencies had the capability of controlling all fires, concerned citizens and politicians were resentful that the suppression effort did not result in prompt control. The fires of 1988 demonstrated once again that the public has misconceptions about fire suppression capabilities and insufficient ecological understanding of fire, not only in parks and wilderness, but on lands managed for multiple use.

Current public attitudes about fire have been shaped by nearly five decades of Smoky Bear messages emphasizing the destructiveness of fire. Media coverage of wildfires that dwell on its sensational aspects have played a large role in promoting the idea that all wildland fires are destructive. As numerous observers have noted over the past 20 years, the overly simplistic Smoky Bear message is misleading the public. Out of context with the times, it badly needs revision to reflect ecological knowledge. The public needs realistic information about the role of fire in wildland management.

One essential missing ingredient is historical perspective on fire. How did fire influence the early landscapes of the American West before European settlement? How did the presettlement vegetation compare to that of today? Is current vegetation as productive as historic vegetation for perpetuating resource values, including wildlife habitat, water yields, livestock forage, timber, recreational values and visual quality? Of paramount importance is a definitive answer to the question: "How does current fuel loading on landscapes of the West compare with the historic setting?"

FIRE HISTORY

Observations recorded in the literature demonstrate that historically, fire was a major perturbation in the American West (Moore 1972, Shinn 1980, Barrett 1981, Gruell 1985a). To understand the role of fire on early western landscapes requires knowledge on how fires burned, particularly the intervals and intensities at which they occurred.

Thanks to a number of fire history studies based on fire-scarred trees, researchers have developed quantitative data on past fire intervals. These data demonstrate that historically, fires occurred at variable intervals because of differences in fuels, ignition sources, topography, and local climate (Arno 1980, Martin 1982). These fires were ignited by lightning and native Indians who intentionally and inadvertently set fire to vegetation (Cooper 1961, Stewart 1963, Moore 1972, Pyne 1982, Lewis 1985, Gruell 1985b).

We now know that fires occurring at differing intervals resulted in very different effects on vegetation. On the dry end of the climatic gradient, fire intervals of 2-20 years have been documented in semiarid regions of the intermountain West where there was a yearly coincidence of ignition, dry fuels, and warm weather (Baker 1925, Burkhardt and Tisdale 1976, Martin 1982, Arno and Peterson 1983). These fires promoted an abundance of grasses, while inhibiting the development of fire-sensitive shrubs and trees such as juniper (*Juniperus* spp.), mesquite (*Prosopis* spp.), curlleaf mountain-mahogany (*Cercocarpus ledifolius*), bitterbrush (*Purshia tridentata*), and big sagebrush (*Artemisia* spp.). Even fire-tolerant species such as oaks (*Quercus* spp.), serviceberry (*Amelanchier alnifolia*), and chokecherry (*Prunus* spp.) were suppressed by frequent fires.

In contrast, within moist temperate and subalpine regions of northern Rocky Mountain forests the historic fire return interval was 50-300 years or longer. This resulted in an abundance of the fire-dependent crown sprouting shrubs and a mosaic of seral and climax conifers (Loope and Gruell 1973, Romme 1979, Arno and Davis 1980, Barrett 1982). These longer interval fire regimes rejuvenated plant communities by creating burn mosaics comprised of herbs, shrubs, and trees in various stages of post-fire development.

Fire's influence on western landscapes changed dramatically shortly after settlement by Euroamericans. Study of fire-scarred trees in various regions of the West consistently show a pronounced reduction in the size and occurrence of fires by the latter 1800s or early 1900s (Stokes and Dieterich 1980). This trend started much earlier, however, in some locales. For example, by the early 1840s settlers in the Willamette Valley of Oregon were preventing Indian burning which had been a yearly practice (Habeck 1961).

What was the cause of this dramatic decline in fire occurrence on the western landscape? The most plausible explanation seems to be that it was the result of a shift in the way human occupants utilized the landscape. Of primary importance was relocation of Indians from their ancestral territories to reservations, thus removing a major ignition source that had been in place for millennia. Introduction of domestic livestock and subsequent yearly consumption of the fine fuels (grasses and forbs) checked the possibility of extensive spreading fires as a result of lightning and other ignitions. Development of irrigated pastures, dryland farms, and construction of roads fragmented the continuity of fuel, thereby limiting fire spread. Lastly, the sedentary life style of settlers, contrasting to the nomadic pattern of Indians, necessitated protection of crops and animals forage. Thus, in the late 1800s began the growing efforts to suppress fires. About this time, the practice of professional forestry that promoted fire suppression resulted in further reduction of fire activity.

CHANGES IN VEGETATION

The sharp reduction in fire disturbance on the landscape soon changed the composition and abundance of vegetation. By the early 1850s, cessation of Indian burning in the Willamette Valley had resulted in the encroachment of oak (*Q. garryana*) and Douglas-fir (*Pseudotsuga menziesii*) into grasslands and development of oak woodlands where oak savannas formerly occurred (Habeck 1961, Thilenius 1968).

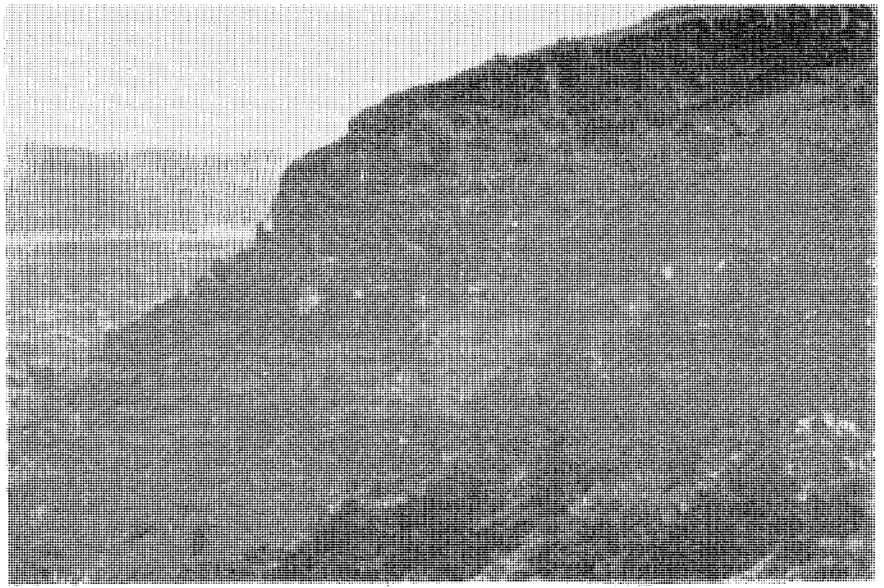
Similarly, by the 1870s sagebrush began to dominate the grasslands of the Cache Valley of Northwestern Utah (Hull and Hull 1974). Cottam and Stewart (1940) recorded a 500 percent increase in junipers in the Mountain Meadows region of southwestern Utah between 1862 and 1934. In western Montana, the absence of fire had allowed Douglas-fir to encroach into former grasslands by the 1890s (Arno and Gruell 1986). Burkhardt and Tisdale (1976) reported that invasion of western juniper (*J. occidentalis*) into a big sagebrush community on the Owyhee Plateau of southwestern Idaho appeared to be directly related to a marked reduction in fires beginning in the 1870.

Likewise, Young and Evans (1981) found that the oldest western juniper growing in big sagebrush communities in northeastern California became established in 1855, and 84 percent of the existing trees became established between 1890 and 1920. Changes in fire frequency appeared to be the most logical explanation for the sudden invasion of trees in big sagebrush communities.

Comparison of over 300 historical photographs with modern retakes at the same locations in Nevada, Wyoming, Montana and Idaho consistently show massive development of woody vegetation in the absence of fire (Gruell, 1966, 1980, 1983). In semi-arid regions, trees and shrubs including ponderosa pine (*Pinus ponderosa*), juniper, pinyon pine (*Pinus* spp.), big sagebrush, bitterbrush, and curlleaf mountain-mahogany dominate landscapes that were formerly occupied by herbs and scattered trees and shrubs (Figs. 1 and 2). The fire-sensitive shrubs and herbs that proliferated in the absence of fire, are now being displaced by conifers or are dying out from the effects of old age, defoliating insects, or deficient moisture (Gruell et al. 1985, Gruell 1986).

In moist or cool plant communities, vegetation mosaics of varying age have been replaced by uniform mature and overmature forests (Figs. 3 and 4). This tree cover is often comprised of Douglas-fir, subalpine fir (*Abies lasiocarpa*), lodgepole pine (*P. contorta*) or spruce (*Picea* spp.). These conifer stands have displayed seral shrubs, herbs, and deciduous trees that had regenerated following early fires.

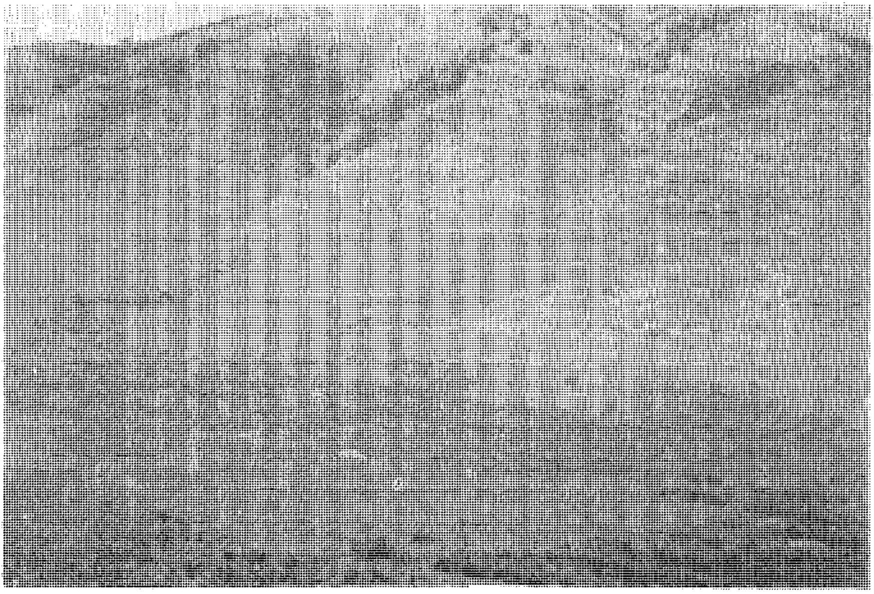
Figure 1. Photo comparison in Ruby Mountains, Nevada.



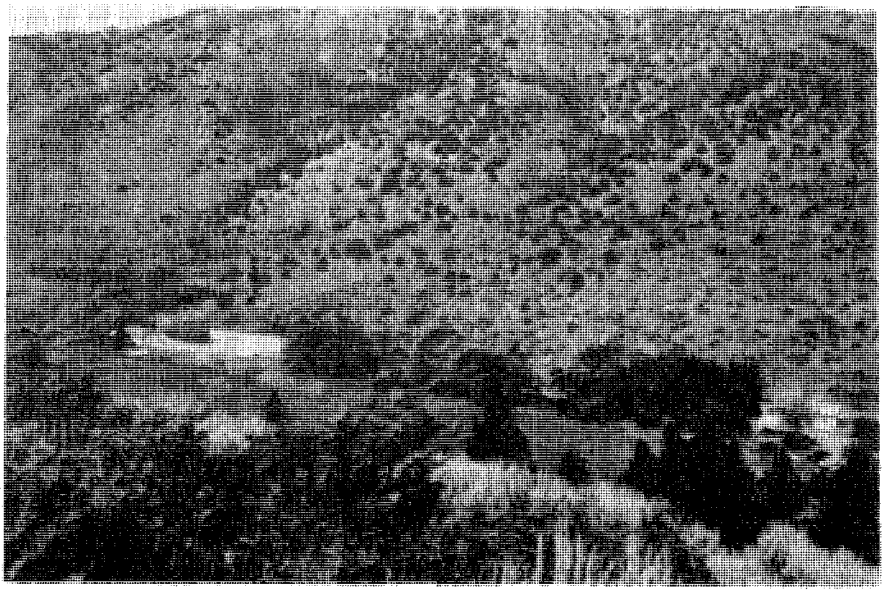
1868: U. S. Geological Survey photo by Timothy O'Sullivan. Curlleaf mountain-mahogany, pinyon and juniper are confined to rocky areas where they have been protected from fire. Arrow points to aspen clone that is in initial stages of development. Note lone mahogany to left of arrow.

July 31, 1982: Retake photo of 114 years later by G. E. Gruell. Mahogany, pinyon and juniper have proliferated in the absence of fire, while the aspen have matured (open arrow). The presence of charred wood and prevailing vegetal conditions in 1868 suggest the last fire occurred in the early to mid-1800s.

Figure 2. Photo comparison on tributary to Portneuf River, Idaho.

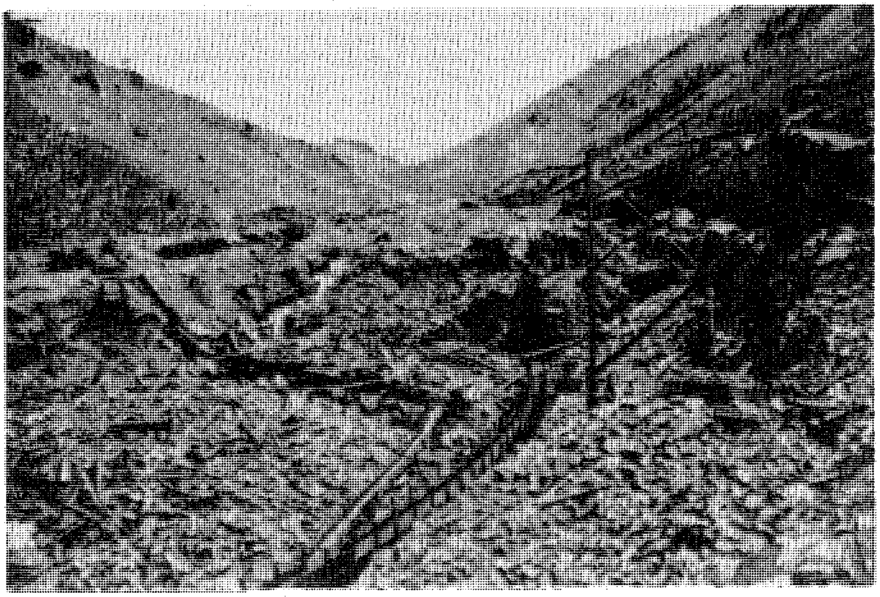


July, 1907: Photograph by Professor Toumey. Juniper in distance are restricted to rocky south exposures where they were protected from frequent presettlement fires. Dark low growing shrubs are bitterbrush that appear to be closely grazed by livestock. Note predominance of herbs in foreground.

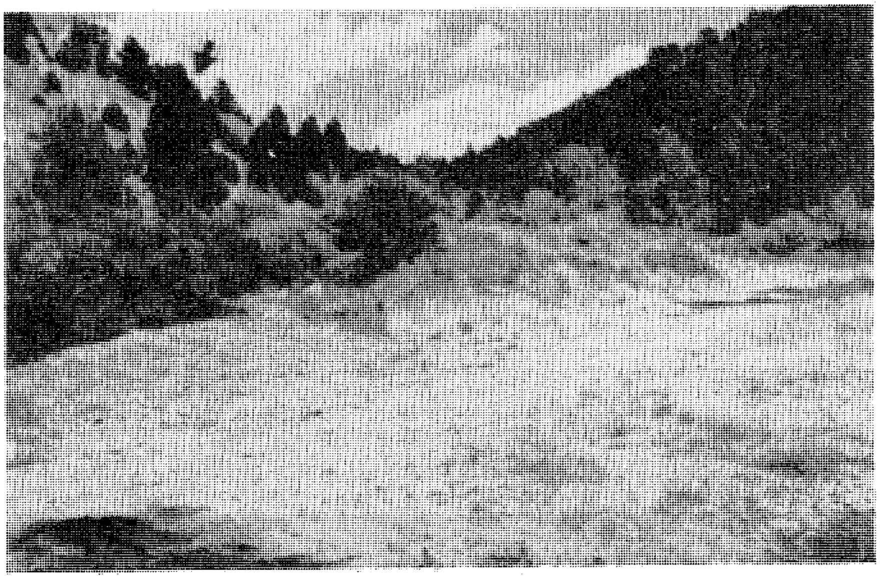


September 8, 1982: Retake photograph 75 years later by G. E. Gruell. Juniper markedly increased in density by spreading to deeper soils that formerly supported perennial grass cover. Bitterbrush increased in size and density, but is declining in vigor and dying out. The general increase in woody vegetation is illustrated in the foreground.

Figure 3. Photo comparison on Alder Gulch near Virginia City, Montana.

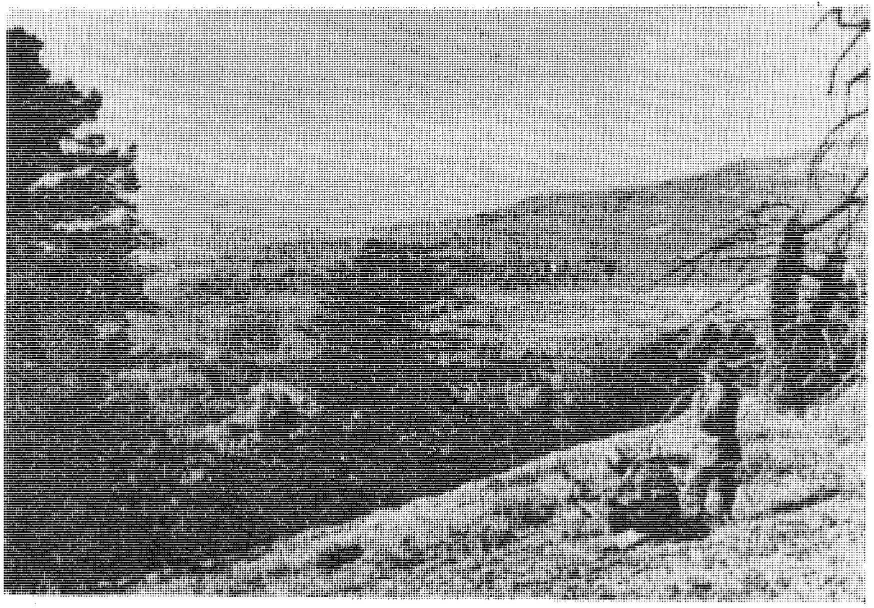


1871: Photograph by W. H. Jackson, courtesy of Montana Historical Society. Placer mining following discovery of gold in 1863 caused extreme disturbance of canyon bottom. The south facing slope on left supports a few Rocky Mountain juniper in rock outcrops. As indicated by stumps, low density Douglas-fir formerly occupied the north facing slope at right. Two fire scarred stumps suggested the occurrence of four fires before 1871.



July 28, 1981: Retake photograph 110 years later by G. E. Gruell. Rubble in canyon bottom was covered to accommodate road. Arrow points to Douglas-fir that can be seen in original photo. South slope now supports an open stand of Douglas-fir and juniper. Aspen, narrow leaf cottonwood, willow and chokecherry occupy canyon bottom. A dense stand of Douglas-fir prevails on the north slope.

Figure 4. Photo comparison on slopes above Buffalo Fork River north of Jackson, Wyoming.



September, 1878: U. S. Geological Survey photograph by W. H. Jackson. Landscape has been dusted by an early season snowstorm. The cool, moist forest type supports Douglas-fir, lodgepole pine, spruce, and subalpine fir which were subject to infrequent fires. A burn mosaic is evident on the slopes below.

September 4, 1968: Retake photograph 90 years later by G. E. Gruell. In the absence of fire, the old burn conspicuous in the 1878 photograph is covered by a maturing conifer forest. Tall forb openings on the far slopes show no apparent change.

Noteworthy examples of a decline in the productivity of seral plants include displacement of aspen (*Populus tremuloides*) communities that are widely recognized for their aesthetic appeal and value to wildlife. Snowbrush ceanothus (*Ceanothus velutinus*), a seral shrub important as ungulate browse has generally become displaced by less fire-dependent vegetation. Scouler willow (*Salix scouleriana*), which was formerly well represented in early successional coniferous forests, is now in a senescent condition in the northern Rockies (Loope and Gruell 1973, Gruell 1980).

Land managers and the public generally do not recognize that large areas of grasslands in cool regions of the Rocky Mountains have been invaded by Douglas-fir (Gruell 1983, Arno and Gruell 1986). The increase of forest encroachment is indicated by a comparison of data from 40 survey corners (including 135 witness trees) in the Galena Gulch near Butte, Montana (Charles Bushey, Intermountain Fire Sciences Laboratory, Missoula, Montana). When the original survey was made in 1878, 48 percent of the corners were described as being in forested terrain. In contrast, when the corners were relocated in 1984, 75 percent of them fell within forest terrain.

MANAGEMENT IMPLICATIONS

The unprecedented vegetation changes resulting from the absence of fire on the western landscape has profound implications for natural resource management including livestock forage, wildlife habitat, visual quality, recreational values, water yield, timber, pest management, and fuels. Recurrent fire disturbance was instrumental in producing a mosaic which included an abundance of grasses and other vegetation highly palatable to livestock when the first cattle and sheep were introduced in the mid-1800s. These lands were abusively grazed by millions of livestock for over 60 years. Concerns over the impact of livestock on vegetation led to a comprehensive investigation in the mid-1930s which revealed that the forage resource in the West had been heavily depleted (Clapp 1936). As a consequence, livestock numbers have experienced a dramatic reduction in the past 50 years. It is also clear that livestock carrying capacities were significantly reduced by encroachment of conifers and development of tall shrubs on open terrain once occupied by grasses, forbs, and palatable shrubs. This expansive but slow transformation of the western landscape was inextricably tied to the absence of fire over the past 80 to 130 years or more (Gruell 1980, Gruell 1983). Wise use of fire on livestock ranges is badly needed, particularly in those regions where encroachment of conifers and development of deciduous shrubs and trees have displaced forage plants.

In the absence of fire succession advances toward dense conifers and shrublands; this has had an unfavorable influence on most wildlife species since they require diversified habitats that include early and midsuccessional stages. Development of conifers and various shrubs towards climax has resulted in displacement of forage plants and reduced palatability of others that are of advanced age. Mule deer (*Odocoileus hemionus*) habitats which had improved greatly by the 1940s because of widespread increased in shrubs, have experienced a marked decline in productivity (Gruell 1986). Displacement of aspen and willows by conifers in riparian zones has resulted in major losses of beaver (*Castor canadensis*) habitat. The decline in aspen has also been a major factor behind reduced ruffed grouse (*Bonasa umbellus*) numbers in the Rocky mountains. Snowshoe hare (*Lepus americanus*), a species that proliferates during early stages of forest succession, are usually scarce in mature and old growth forests (Grange 1965). Thickening conifers on bighorn sheep (*Ovis canadensis*) ranges have reduced forage availability, foraging efficiency, and may deprive sheep of the predator-detection advantages large herds have in open terrain (Risenhoover and Bailey 1985).

Advanced stages of vegetal development have favored those wildlife species dependent upon mature and old growth trees. For example, old aspen and conifer snags provide nest sites for a variety of cavity nesting birds, while mature conifers are essential habitat for pine marten (*Martes americana*) and tree squirrels (*Tamiasciurus hudsonicus*). Although some wildlife species that require mature and old-growth forest habitats are displaced and sometimes destroyed by intense fires, there are long-term benefits to these species (Conner 1978, Koehler and Hornocker 1977). Periodic fire assures regeneration of aspen and important seral conifers and provides snags and downed logs on which many animal species depend.

The immediate post-fire environment presents wildlife with a sudden and drastic modification of habitat structure. This results in both positive and negative effects depending upon the habitat requirements of individual species. When viewed over the longterm fire is a rejuvenating process that results in greater forage yield, increased forage availability, increased palatability, increased edge, and improved diversity. There is a great need to rejuvenate wildlife habitats with fire.

Although fire is blamed for destroying visual quality, it is an essential agent in forested regions for enhancing viewing opportunities and biological diversity.

The dense tree growth in today's forests restricts viewing and detracts from the outdoor experience. This is particularly true in ponderosa pine forests that were formally open and park-like, but which are now characterized by dense thickets of small trees. The extensive use of prescribed fire on the Apache Indian Reservation in Arizona since the 1950 has shown the potential fire has for improving aesthetics through restoration of the open park-like condition similar to that described by early settlers (Warskow 1978). Surveys of recreationists have shown that people prefer more open landscapes where views are not obstructed by heavy cover. It is also evident that recreational opportunities have declined because of reduced access resulting from thickening of the vegetal cover. In mountain shrub and chaparral communities the mass of shrubs is literally impenetrable.

Massive increases in tree and shrub cover in various regions of the West have resulted in reductions in the flow of late- season streams and the drying of springs. The increased density of trees and shrubs creates an umbrella effect that can prevent substantial amounts of precipitation from reaching the ground. Increased density also places more demand on groundwater through increased evapotranspiration. Historically, higher amounts of precipitation reached the ground and evapotranspiration was lower because the vegetation cover was largely comprised of grasses and low-density trees and shrubs.

Early watershed research demonstrated the potential for renewal of springs and an increase in late-season stream flows in regions where annual precipitation is 38 cm or more. Bates and Henry (1928) showed an increase in stream flow following cutting of aspen, spruce and fir in the Wagon Wheel Gap study area of Colorado. After many years of research, Warskow (1978) concluded that fire can and should play a dominant role in the future management of southwestern ponderosa pine forests and chaparral types for water production.

Insects and disease are weakening and killing large areas of conifers that have reached advanced age and are growing in dense stands under heavy competition for moisture and nutrients (Byler 1984). Present infestations are much larger than in the past when mosaics of forest vegetation, with a wide distribution of age, species diversity, and size tended to prevent wide-spread epidemics.

The continuing absence of fire is implicated as a factor that allowed the spruce budworm (*Choristoneura occidentalis*) to develop into a chronic epidemic status in Montana (Carlson et al. 1983). Holland (1986) concluded that the increased abundance of shade-tolerant conifers resulting from fire exclusion disrupted the mosaic of forest communities and allowed extensive areas of forest land to develop into multistoried stands, a pattern that favors budworm attack. The persistent defoliation associated with budworm outbreaks predisposes the trees to Douglas-fir beetle (*Dendroctonus pseudotsugae*) and root rots. Dwarf mistletoe (*Arceuthobium* spp.) has also proliferated in the absence of fire. Over time, this pathogen reduces tree vigor and creates a stand that is more susceptible to bark beetle and root diseases.

A high percent of lodgepole pine in the northern Rockies has reached an advanced successional stage and is vulnerable to mountain pine beetle (*D. ponderosae*) epidemics. Beetle infestations during the past 30 years have killed vast acreages of lodgepole pine in the Island Park area of eastern Idaho, Jackson Hole area of western Wyoming, the Unita Mountains of Utah and and the Flathead River drainage of northwestern Montana. Considering the advanced successional stages of lodgepole pine forests in the West, it is predictable that severe epidemics of pine beetles will occur periodically. Increasing damage from insects and diseases will continue to impact the timber resource over large areas and also increased the susceptibility of forests to catastrophic fires.

WILDFIRE OCCURRENCE

The long term buildup of both living and dead fuels in wildlands of the West has resulted in an untenable situation—the ingredients for catastrophic fire are in place over much of the landscape. Massive increases in living and dead fuels, along with drought, resulted in extreme fire behavior and over 900,000 ha burned in 1988 in three northern Rocky Mountain states alone. In addition to the social concerns associated with catastrophic fires, there is the problem of increased habitat uniformity; the mosaic nature of the landscape is disappearing.

The trend toward extreme wildfires is exemplified by recent events in the USDA Forest Service's Intermountain Region that covers Utah, Nevada, western Wyoming, and much of Idaho. During the 59-year period from 1930 to 1978 there had been only two years (during the 1930s) that 40,000 ha or more had burned per season. Since 1979 the region has experienced five years in which that much or more burned. Fire suppression personnel are convinced that massive fuel buildup is responsible for high intensity wildfires that defy suppression efforts.

Montana had not experienced massive severe fires since that 1919 wildfire in the western part of the state. However, during the week of August 26, 1984 eighteen wildfires burned over 100,000 ha before being extinguished by heavy rains. Unlike historical fires at lower elevations that were mostly confined to the surface and were of low intensity, these wind-driven fires burned at high intensity and carried long distances in the crowns. Historically crown fires were uncommon in ponderosa pine/Douglas-fir forests because frequent surface fires removed ground fuel before it could accumulate and kept the stands open by preventing the development of a dense forest understory.

The trend toward extreme fire activity during drought years is demonstrated by recent experience in California and Oregon. During the 1985 fire season, $310,000,000 were spent fighting fire in California that burned 300,000 ha. Eleven lives were lost. Extreme conditions took place again in 1987 when over 400,000 ha burned in California and Oregon with suppression costs running $350,000,000.

Drought and extreme fire weather returned to the northern Rockies in 1988. Nearly all media attention was focused on the Yellowstone complex where 570,000 ha were affected by fire. Northward in Montana, more than 1,200 wildfires burned 350,000 ha costing the state and federal agencies $680,000,000 to fight. Included was the 100,000 ha Canyon Fire on the eastern slope of the Rocky Mountains that swept through many miles of dense Douglas-fire forests at lower elevations. Some of these stands had regenerated following a 1889 fire. Several landscape photographs taken in the Canyon Creek burn area in 1900 show that prior to the 1889 fire the tree cover in the foothills was sparse (Gruell 1983). This condition reflected the influence of fires "that had repeatedly overrun the foothills" (Ayres 1901).

CONSEQUENCES OF EXTREME WILDFIRES

Given the magnitude of fuel buildup in the West, coupled with recurrent drought, severe wildfires will continue to occur and perhaps become more prevalent during the coming years. Some of these fires will inevitably sweep through communities, destroying dwellings and perhaps killing people. (Nationwide in 1986, 1400 homes were destroyed by wildfire, while in 1988 about 450 were lost.) Very large uncontrollable wildfires will continue to destroy or damage commercial timber that is vulnerable to fire kill because of long-term fuel buildup. In contrast, in areas where homes, facilities, and commercial timber are not involved many wildfires will actually benefit natural resources, rather than bringing the devastating losses simplistically portrayed in Smoky Bear messages.

Stand-replacing fires in high elevation or moist noncommercial forests are necessary to eliminate old conifers and regenerate new ones, release understory plants, and rejuvenate shrub-fields, aspen communities, meadows and riparian bottoms. Viewed over the course of decades, there are countless examples of wildfires that have revitalized decadent plant communities. A mosaic of burned areas on the landscape can play a significant role in limiting the size of individual wildfires (Minnich 1983). Observations of fire behavior over many years have shown that previously burned areas provide a buffer inhibiting fire spread.

The unprecedented crown fires that have occurred recently in juniper, pinyon-juniper, ponderosa pine and Jeffery pine (*P. jeffreyi*) types are indicative of a trend. Understory plants important for wildlife forage are in a deteriorated condition because of closure of tree crowns. Severe wildfire results in excessive loss of fire-sensitive shrubs that will take generations to become reestablished. A sound alternative to these wildfires would be the cutting of trees followed by prescribed fires to reduce fuels and to enhance conditions for plant regeneration.

Although there are exceptions, state wildlife departments generally resist manipulation of habitats, because of concern for big game security cover. Ironically, these habitats are steadily declining in their ability to support big game and other wildlife. Ultimately the cover that is being "preserved" will be wiped out in vast areas by wildfires. This has been evidenced in Montana and Nevada in recent years by wildfires of 4,000 to over 24,000 acres in size. Vegetative communities and their dependent wildlife are inherently dynamic, living and dying and recycling; they cannot be "preserved" in a given state, but can be managed to maintain desirable conditions.

SUMMARY AND CONCLUSIONS

For thousands of years prior to 1900 A.D. fire was the most widespread and effective disturbance factor that rejuvenated vegetation on western landscapes. Euroamerican settlement disrupted fire regimes, resulting in a great reduction in the number and size of fires. Within a matter of a few years, plant communities began to change as a result of the absence of fire. By the mid-1900s, woody vegetation had thickened and forests had become dense. This was, in effect, a pronounced buildup of woody fuels. Effective fire suppression aided this trend; fuels continued to increase and resource values declined. Now, we are facing an era of catastrophic fires due to long-term fuel buildup coupled with periodic drought.

Bigger and better fire suppression efforts will not solve the problem of increasing wildfire danger. Successful fire suppression only allows vegetation to age and fuels to further increase. Inevitably, this results in uncontrollable wildfires that burn until they consume available fuels or are extinguished by precipitation. Well-trained fire suppression forces are, of course, essential in our modern society to protect commercial timber, dwellings and other valuable property, and lives. On the other hand, excessive expenditure of public funds in future fire fighting efforts or to suppress beneficial fires is politically motivated and should be replaced by sound ecologically-based decisions.

There is no clearcut solution to this dilemma; however a growing number of fire researchers and fire suppression personnel are convinced that the best approach is reduction of fuels in priority areas through cutting of conifers and use of prescribed fire. To the credit of a few dedicated people, this is being done on a small scale on some public lands in the West. Funding is deficient and the lack of incentive to risk the escape of prescribed fire often results in cool prescriptions that do not meet management objectives. Prescribed fire experiences contrast sharply with fire suppression assignments, which have payoffs. Suppression efforts are looked upon as high-priority work, allowing people to get away from their assigned jobs and take part in an exciting experience while being compensated with an increase in pay due to overtime hours worked.

The present policy of spending enormous sums on fire suppression with only token amounts on fuel management will not change until there is widespread recognition of the need for reducing fuels and maintaining productive vegetation. Once the public realizes that the long term vitality of wildland ecosystems lies in timely disturbance of vegetation rather than preservation, a real effort in fire management direction can begin. This enlightenment will require an intense educational effort by concern individuals. It will be hampered by those who continue to disperse the old fire suppression dogmas.

LITERATURE CITED

Arno, S. F. 1980. Forest fire history in the northern Rockies. Journal of Forestry 78(8):460-465.

Arno, S. F. and D. W. Davis, 1980. Fire history of western red cedar/hemlock forests in northern Idaho. Pages 21-26 *in* Proceedings, Fire History Workshop. General Technician Report RM-81. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Tucson, Arizona.

Arno, S. F. and G. E. Gruell. 1986. Douglas-fir encroachment into mountain grasslands in southwestern Montana. Journal of Range Management 39:272-276.

Arno, S. F. and T. D. Peterson. 1983. Variation in estimates of fire intervals: a closer look at fire history on the Bitteroot National Forest. USDA Forest Service Intermountain Forest and Range Experiment Station Research Paper INT-301.

Ayres, H. D. 1901. Lewis and Clark Forest Reserve, Montana. 21st Annual Report, Part 5. U.S. Department of the Interior, Geological Survey. Washington, DC

Baker, F. S. 1925. Aspen in the central Rocky Mountain region. U.S. Department of Agriculture Bulletin 1291. Washington D.C.

Barrett, S. W. 1981. Relationships of Indian-caused fires to the ecology of western Montana forests. Master's Thesis. University of Montana. Missoula.

Barrett, S. W. 1982. Fire's influence on ecosystems of the Clearwater National Forest—Cook Mountain fire history inventory. USDA Forest Service Clearwater National Forest, Orofino, Idaho.

Bates, C. G. and A. J. Henry. 1928. Forest and streamflow experiment at Wagon Wheel Gap, Colorado. U. S. Monthly Weather Review Supplement 30.

Burkhardt, J. W. and E. W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. Ecology 57:472-484.

Byler, J. W. 1984. Status of disease pests in the interior Douglas-fir and grand fir types. Pages 46-50 *in* Proceedings of a symposium held February 14-16, 1984. Spokane, Washington.

Carlson, C.E., D. G. Gellin, and W. C. Schmidt. 1983. The western spruce budworm in northern Rock Mountain forests: a review of ecology, past insecticidal treatments and silvicultural practices. Pages 76-103 *in* Management of second growth forests: The state of knowledge and research needs.

Montana Forest and Conservation Experiment Station, University of Montana, Missoula.

Clapp, E. H. 1936. The major range problems and their solution—a resume. In The western range. Senate Document No. 99. U.S. Government Printing Office. Washington D.C.

Conner, R. N. 1978. Snag management for cavity nesting birds. Pages 120-125 *in* Proceedings of workshop, management of southern forests for nongame birds. General Technical Report SE-14. U.S. Department of Agriculture Forest Service, Southeastern Station. Asheville, North Carolina.

Cooper, C. F. 1961. The ecology of fire. Scientific American 204:150-156.

Cottam, W. P. and G. Stewart. 1940. Plant succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862. Journal of Forestry 38:613-626.

Grange, W. 1965. Fire and tree growth relationships to snowshoe rabbits. Pages 111-123 *in* Proceedings Fourth Tall Timbers Fire Ecology Conference. Tall Timber Research Station, Tallahassee, Florida.

Gruell, G. E. 1966. Unpublished photo pairs on file at: U.S. Department of Agriculture, Forest Service, Humboldt National Forest, Elko, Nevada.

Gruell, G. E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Volume 1—photographic record and analysis. Research Paper INT-235. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Ogden, Utah.

Gruell, G. E. 1983. Fire and vegetative trends in the northern Rockies: interpretations from 1871-1982 photographs. General Technical Report INT-158. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Ogden, Utah.

Gruell, G. E. 1985a. Fire on the early western landscape: an annotated list of recorded wildfires in presettlement times. Northwest Science. 59:97-107.

Gruell, G. E. 1985b. Indian fires in the interior West: a widespread influence. Pages 68-74 *in* J. E. Lotan, B. M. Kilgore, W. C. Fischer, and R. W. Mutch, eds. Proceedings, Wilderness Fire Symposium. U.S. Forest Service, Intermountain Forest and Range Experiment Station, Missoula, Montana.

Gruell, G. E. 1986. Post-1900 mule deer irruptions in the intermountain West: Principal cause and influences. General Technical Report INT-206. U.S.

Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Ogden, Utah.

Gruell, G. E., S. C. Bunting, and L. F. Neuenschwander. 1985. Influence of fire on curlleaf mountain-mahogany in the intermountain West. Pages 58-72 *in* J. E. Lotan and J. R. Brown, compilers. Fire's effect on wildlife habitat-symposium proceedings. General Technical Report INT-186. U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Missoula, Montana.

Habeck, J. R. 1961. The original vegetation of the mid-Willamette Valley, Oregon. Northwest Science 35(2):65-77.

Holland, D. G. 1986. The role of forest insects and diseases in the Yellowstone ecosystem. Western Wildlands 12:19-23.

Hull, A. C. and M. K. Hull. 1974. Presettlement vegetation of Cache Valley, Utah and Idaho. Journal of Range Management 27:27-29.

Koehler, G. M. and Hornocker, M. G. 1977. Fire effects on marten habitats. Journal Wildlife Management. 41:500-505.

Lewis, H. T. 1985. Why Indians burned: specific versus general reasons. Pages 75-80 *in* Proceedings—Symposium and Workshop on Wilderness Fire. General Technical Report INT-182. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Missoula, Montana.

Loope, L. L. and G. E. Gruell. 1973. The ecological role of fire in the Jackson Hole area, northeastern Wyoming. Quaternary Research 3:425-443.

Martin, R. E. 1982. Fire history and its role in succession. Pages 92-99 *in* Symposium Proceedings Forest Succession and Stand Development Research in the Northwest. Oregon State University, Forest Resources Laboratory, Corvallis.

Minnich, R. A. 1983. Fire mosaics in southern California and northern Baja California. Science 219:1287-1294.

Moore, C. T. 1972. Man and fire in the central North American grassland 1835-1890: a documentary of historical geography. Ph.D. Dissertation, University of California, Los Angeles.

Pyne, S. J. 1982. Fire in America—a cultural history of wildland and rural fire. Princeton University Press. Princeton, New Jersey.

Risenhoover, K. L. and J. A. Bailey. 1985. Foraging ecology of mountain sheep: Implications for habitat management. Journal Wildlife Management 49:797-804.

Romme, W. H. 1979. Fire and landscape diversity in subalpine fir forests of Yellowstone National Park. Ph.D. Dissertation. University of Wyoming.

Shinn, D. A. 1980. Historical perspective on range burning in the inland northwest. Journal of Range Management 33:415-422.

Stewart, O. C. 1963. Barriers to understanding the influence of use of fire by aborigines on vegetation. Pages 177-126 *in* Proceedings Second Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, Florida.

Stokes, M. A. and J. H. Dieterich. 1980. Proceedings of the Fire History Workshop. General Technician Report RM-81. Rocky Mountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. Fort Collins, Colorado.

Thilenius, J. F. 1968. The *Quercus garryana* forests of the Willamette Valley, Oregon. Ecology 49:1124-1133.

Warskow, W. L. 1978. Fire impacts on water production in the southwest. Pages 55-58 *in* Proceedings of the Rangeland Management and Fire Symposium. Rocky Mountain Fire Council and Intermountain Fire Council Meeting. Montana Forest and Conservation Experiment Station, University of Montana. Missoula.

Young, J. A., and A. E. Evans. 1981. Demography and fire history of a western juniper stand. Journal of Range Management 34:501-505.