Fire Ecology

E. V. KOMAREK, SR.
Tall Timbers Research Station

IN PRESENTING this paper on Fire Ecology I find myself in somewhat of a quandary for I have spent about half of my life influenced, taught, and educated against fire in nature and then I have spent the other half of it using fire and trying to understand it. And as I passed the half century mark a few years ago this has been a long time. Now, I wonder how much and from whom has all my information and knowledge and interest come, and I find it impossible to give credit to wherever and to whomever it is due and so to all I say thank you.

Fire ecology can be defined as the study of fire as it affects the environment and the interrelationships of plants and animals therein. It is assumed that through natural selection primarily, over long periods of time, plants and animals have developed "adaptations" that allow them to live where fire is a factor in the environment. Although ecology itself has become well defined and generally understood, fire ecology, like the use of fire by man, has been unduly influenced by an European heritage.

When, however, we try to define fire in nature, we get into difficulty because of its varied nature, for fire becomes one thing to some people, and something entirely different to others. It is not only itself extremely variable but these variations are compounded, one might even say, by arithmetical progression by many other variable factors.

Fire can mean a fire in grass, or in leaves, or in herbaceous plant growth, in forest debris, or even in the crowns of trees. It can travel slowly, quietly, and be as gentle as the whisper of a breeze; or it can travel with tremendous speed, literally roar, and be as destructive as the greatest of storms; and it can change from one to the other and even back again, time and time again with near lightning speed. It can be so cool that one can put his hand under it without discomfort, or its heat can be so intense as to nearly consume one. It can smoulder for days and into weeks, in peat, forest debris, or in the dead dry heart of old trees and then when the sun shines and breezes blow suddenly burst into flame.

Its flames can be an ugly black orange red or they can be a beautiful yellow with flecks of golden dust therein; and the flames can be big or small, broad or narrow, and in fact of every imaginable description. Its smoke can be billowy, cottony, and of white dense clouds, mostly of steam in the most spectacular nature; or the smoke can be black and an ugly red and tumble about like Dante's inferno where moisture can last but an instant. And it can and does occur in all the possible transitional stages from one form to the other.

Fire can slowly creep along, twisting and encircling every blade of grass and shrub and tree in its way so lightly that even the stems of grass will not burn in two, or it can slowly wend its way so that only the most fire-resistant tree can stand in its way.

Fire has all these aspects of varying degree and a great many more. Is it any wonder then that men find it difficult to agree on fire and its place in nature or its use by man?

Fire in nature occurs from the cold of the frozen north to the heat of the tropics and may be affected by different temperatures. Likewise wind in all its varying nature affects fire, and again fire will itself under certain conditions create its own wind.

However water, in its many varying forms, but primarily the water content of the fuel itself, in large measure determines the nature and characteristics of the fire, for fire can occur only whenever the fuel is dry enough to conduct it. Certain kinds of Longleaf Pine forests here in the South, particularly where wiregrass (*Aristida*) predominates as ground cover, will burn within three to four hours after heavy rains have stopped if brisk winds and sunshine develop shortly thereafter. In this region such conditions are rather typical in the spring and much acreage is quickly burned over with what is called "swingeing fire." Likewise in marshes and around bodies of water certain grasses and sedges will carry fire and burn off to within just an inch or two above the water.

Therefore, one of the many challenges in fire ecology is to define and to devise measurements of fire in nature if at all possible. I make this suggestion with considerable hesitation, for in some fields of ecology we already seem to have more terminology than knowledge. In fire the reverse seems to be true. We do, however, have standard and easily understood measurements and definitions for many of the components of climate and environment in spite of their inherent variability. A good example is water, for although it is symbolized as H_2O it can in its various forms be well designated and measured comparably as humidity, dew, snow, ice, rain, steam, run-off, flood, running or still water, soil moisture, etc. With fire, however, we are literally forced because of the lack of terminology either to discuss it in generalities or to assume that all fire everywhere is the same and therefore comparable, even though we know from observation and experience that such an assumption is not so. Because of this assumption many students of fire ecology conduct many well-planned and otherwise accurate experimental studies on, or of, burned areas without a well-described base or a scientific foundation. No reference is made to the kind of fire, under what conditions it burned, the kind, condition or accumulation of the material burned, the past fire history, or any of the other many factors that we know from experience differentiate one fire from another.

I might digress here a little bit. Twenty-seven years ago Dr. W. C. Allee told me that the trouble with ecology has been that, because of the experimental method, the ecologist had moved into a laboratory and when he stuck his head out the window, it was cold. Until proper methods of description and measurement are devised we must use the "experimental method" with extreme caution and weigh the results in conjunction with careful observation. We must, further, relate our experimental findings to the results of "natural experiments" going on around us. Because of the inherent, extreme variability of fire, investigations concerned with fire ecology, today, must lean heavily on the observations of a few individuals who have had long experience and intimate knowledge of the use and behavior of fire under a wide range of conditions.

The idea that man has been responsible for most of the fires in nature from ancient times to the present has become prevalent in recent years. This has occurred in spite of the evidence adduced by early investigators and of much accurate information of more recent date. Clements, in 1916, stated: "The role of lightning in causing fire in vegetation has come to be recognized as very important." He lists as further references Bell, 1897; Clements, 1910; Graves, 1910; and Harper, 1912. Today we have much evidence to prove without any doubt the contentions of these early students of fire, for lightning is a very important climatic factor. The most complete records today are those compiled by the United States Forest Service in its annual Forest Fire Statistics which are gathered in connection with fire control in forest management. No fire is entered in these statistics unless men and equipment are detailed to control it.

From these records we learn that the incidence of such lightning-caused fires varies greatly from year to year. In the past ten years (1951-60 inclusive) a high incidence of 11,459 such fires was reported in 1956 and a low frequency of 5,159 in 1957, with an average of 8,391 per year for the entire period. It has also been reported that 600 such fires occurred in only four days in only parts of four northwestern states. During the month of July, 1940, nearly 2000 such fires were reported, and as many as 325 lightning-caused fires occurred in one day. Remember, I'm talking about what they actually put men and equipment on. In one day, July 12, 1940, 325 fires occurred.

Now when the number of lightning-caused fires is examined in the light of the number of acres of forest listed in these statistics, we find that in 1956 one lightning-caused fire occurred for every 56,000 acres, and in 1957 one such fire occurred for each 125,000 acres.

The "fire year" in Florida was in 1954 and one lightning-caused fire was reported for each 35,000 acres. In Georgia, same year, one lightning fire was reported for each 32,000 acres; Arizona had one per 16,000 acres in 1958; California, one per 9,000 acres in 1960.

In the light of the evidence just presented, plus well-documented information from Canada, Alaska, South Africa, and many other parts of the world, we cannot disregard lightning as a major cause of fire in nature. Moreover, is there any reason to doubt that in ancient geological time there was a great variation in the amount of lightning when even now we have such "fire years" where the incidence of lightning-caused fires is more than double that of other years?

There is much information, though naturally much of it has to be gained by deduction, indicating that extreme changes in climates took place long before man appeared on earth. There were periods of cold climates, warm climates, dry climates, and wet climates throughout the ancient past. Surely in the light of such evidence it is not unreasonable to believe we also had "fire years" or fire climates of a greater frequency and intensity than anything that has occurred in man's historic time. I am sure that meteorologists will agree that the occurrence, frequency, intensity, and location of thunderstorm activity and frontal systems of such nature that produce lightning, can vary with only slight changes in those factors that produce general weather patterns. From a study of such patterns it does not seem necessary to have any drastic change to create conditions leading to extended lightning periods in connection with periods of dry weather.

The ancient record of plants and animals provides us with an insight into past weather conditions as well as with indications of "adaptations" to such climatic changes that occurred. Camp, in his "Forests of the Past and Present," points out that our early fossil records are unfortunately limited to those lowlands where conditions were favorable for the preservation of florofaunal remains, and that upland forest came into being in the Carboniferous Period, even though the records are few. He also explains that these forests as well as lowland swamps were not necessarily characterized by heavy precipitation but that dry periods must have been prevalent at times. He states:

> Although moisture was reasonably constant in the lowland soils, the humidity of the air was not excessive. Careful study reveals that the great majority of the Carboniferous plants had leaves which in some manner resisted water loss through transpiration. Further: The tough leaved pteridosperms of the time were already giving rise to the cycads and cycadeoids, both admirably fitted to less humid—even xeric conditions.

I believe that careful study might also reveal that they were fitted to fire conditions as well as to xeric. Upon what evidence are we to presume that meterological conditions and climate of that time did not produce lightning if dry and wet periods occurred in the Carboniferous Period? Are we to assume, and if so upon what evidence, that lightning was not a part of weather at that time?

From that period to the Cretaceous there were great climatic changes, and surely lightning and "fire periods" were also present.

Camp writes:

> In Triassic times deserts. . . . probably existed, and the widespread occurrence of numerous cycads and cycadeoid types suggest large subhumid areas. But the giant pinopsid trunks, abundant in the Petrified Forest of Arizona and elsewhere in Triassic formations, testify to extensive forest. . .

It is my belief that these forest types occurred in savanna or open forest grassland, subject to fire, and that in the next period, the Jurassic, when many of our modern genera began to appear, fire became a very major element. By the time such highly evolved herbaceous plants as the sedges and grasses became an important part of the vegetation of the uplands in the Cretaceous, fire became of such importance that it was a major factor in the development and evolution of grasslands and savanna or open-type forests.

Many of the petrified forest trees are araucarias or their close relatives, which can be considered early forerunners or ecological counterparts of our pines of today. Perhaps the most widespread araucaria of today is the so-called Parana Pine of South America. This "pine" makes up what has recently been called the largest and most valuable evergreen forest in the whole of the Southern Hemisphere. This forest of open or savanna type occurs in the drier parts of South America that are frequently swept by fire. Both in thickness of bark, which may be over four inches, and in seeding habits, these trees appear to be well adjusted to repeated fires.

The most fire-resistant tree we know today is the Sequoia which is considered to be a relic of a past ancient forest that once was predominant over vast areas. This seems to me to be truly a "fire relic" of a period of intense fires, for only in that way could natural selection concentrate such fire resistant qualities in the Sequoia. It occurs today in an area where the incidence of lightning-caused fires is exceedingly high.

Concerning the Sequoia, Viemeister writes (1961:186):

> The absence of resin combined with the insulating capabilities of its bark—sometimes two feet thick—make it resistant to forest fires. A single fire could not kill a big tree. For heat to reach and damage the living tissues beneath the insulating bark, weeks of burning would be needed. . . .

Here's another quotation:

> Most of the lightning fires cannot be doused immediately, however, for the flames often burn at a height beyond the reach of water pumps. Often the best that can be done is to prevent the fire from spreading to other trees. On March 23, 1959, lightning struck near the top of a 200-foot big tree. Firemen brought powerful water pumps into play, but the stream of water splattered before reaching the burning part of the tree. Park personnel had to be content to extinguish falling debris. One branch, weighing several tons, crushed a woodshed . . . It wasn't until the fire had burned to within 100 feet of the ground that a large limb

> was pulled off with a cable to split open the shell so that firemen could pump water into the smouldering fire inside the tree. All told, two dozen men helped fight the fire, which burned for eight days.

Gentlemen, that was one tree.

Under what conditions and for how long was it necessary for natural selection to develop such fire resistance?

In the late Cretaceous, grasslands must have multiplied abundantly for by the late Paleocene, and for a period of over 35 million years, there was a most remarkable adaptive radiation of mammals which lived largely on grasses and herbaceous plants. During the early part of this period most of the modern orders of mammals became clearly defined; the even-toed and the odd-toed, hooved mammals were distinguishable; ancestral camels, horses, tapirs, and rhinoceroses could be recognized; and rabbits and squirrel-like rodents became evident. Primates, insect eaters, and opossum-like mammals were carried over from earlier periods. Members of the four superfamilies—horses, tapirs, rhinoceroses, and titanotheres — were all well represented in the many fossil beds in North America. The extinct titanotheres were not only well represented but included the largest land animal at that time, virtually a herbivorous giant, *Uintatherium robustum.*

The evolutionary development of the even-toed mammals came in the later part of this period, and at this time modern taxonomic groups (families, etc.) of mammals more closely allied to our living forms became recognizable. Thus for a period of over 35 million years there developed a vast assemblage of herbivores and of carnivores that preyed upon them, and these mammals occurred over much of North and South America, Asia, Europe, Africa, and elsewhere. The abundance of these herbivores must have been of such magnitude, judging from the fossil record, as to make even the large numbers of buffaloes on our western plains and the vast numbers of grassland mammals in Africa seem small by comparison.

It is my contention that during this period there were climatic conditions that increased the frequency of lightning and the length and severity of dry periods, so that lightning fires were started easily and spread more widely. Further, I believe that during this long 35-million-year period there were fire eras and that during such periods fire-resistant genera and species of grasses, herbaceous plants, shrubs, and trees became widely spread over the land areas of the globe.

J. F. V. Phillips (1930) wrote that the vast numbers of grazing-type mammals in Africa convinced him that fire was a natural climatic factor in nature. From his thoroughgoing studies on the relationship of fire to grasslands he had already come to the conclusion that fire was necessary for the formation and continuation of the many types of grassland and savannas in Africa.

The tremendous development of this ancient mammalian fauna during the Tertiary, with a seeming predominance of herbivores and grassland-type rodents, has convinced me that we had long periods over a long time when fire was even more of a natural climatic factor than it appears to be at present. Just as the climatic pendulum swung from humid to xeric, and from cold to warm periods and back again, so also the prevalence of fire, in varying degree, shifted and changed. Fire was not only a major factor then, long before the time of man, but it remains one today. Indeed it is responsible to a large degree for the complexity of both vegetation patterns and the distribution and abundance of animals on the land. Because of this long period of fire selection we have a great many plant adaptations that make these plants resistant to fire in many ways. Many plants that have such characters have been variously labeled as fire indicators, fire types, fire forests, fireweeds and—frankly, gentlemen—the list is endless. In fact the number of these species is far too long to list here, and at this time.

In mammals various characteristics as burrowing habits, clean areas around the holes, underground storage, etc., seem to be best developed in grassland-type rodents, and these may be adaptations to fire.

The ability of herbivores to move over fairly large distances may also be characteristically necessary for survival, for many of these are able to locate green grass on burned land—a habit that man soon found out and used to his advantage. The gliding habit in mammals may have been caused by the action of fires on forest types, gradually over a long period, converting them to park-like and gallery-type forests. The interesting thought intrudes itself that even man's erect stature may have been caused by fire in a similar manner: thus, his very early ancestors may have been literally forced to come down out of the trees if they were true forest creatures to begin with. Even today man is a grassland mammal, for his plant diet is based on grasses which he has improved: wheat, rice, rye, barley, and maize. The animals on which he feeds, except where he resides near water, are largely those that graze on grass.

It is interesting to speculate that fire may have been man's first tool; that at first he learned to play with fire, and then later to make use of it in a primitive way. The Australian aborigine even today does use fire as follows. The following excerpt is from Finlayson (1943):

> The whole procedure adopted appears to have become standardized and perfected by age-long repetitions. First runners are sent into the wind with fire-sticks . . . they soon have an open horseshoe flame.
>
> The subsequent events form three distinct phases, during each of which some kills are made. . . . The fire, of course, makes rather slow headway against the wind, but as it creeps on, all life forsakes the tussocks well in advance of the flame and a concentration of living things that are above ground is effected. As the flames advance into the wind, the party recedes from them slowly, keenly watching for a breakaway from every likely looking tussock, and should a maala (a kind of a rabbit) break cover within range, his chance of dodging the throwing sticks is slender.
>
> The second phase: With the wind full behind it, the closed line now rushes back towards the starting-point, and to the steady roar of the leeward fire is added the sudden menacing boom of the windward one, changing from time to time to a crash, as some isolated patch of mulga or corkwood is engulfed. . . . The party now gathers the spoils already taken and dashes through the leeward fire to the safety of the burnt ground beyond, and there, in line, await

> the meeting of the double wall of flame, when every living thing which has remained above ground must come within their range.
>
> It is a time of most stirring appeal. The world seems full of flame and smoke and huge sounds. . . . The boys can scarcely control their movements in their excitement; they swing their weight from foot to foot, twirling their throwing sticks in their palms, and as they scan the advancing flames their great eyes glow and sparkle as the climax draws near. It is their sport, their spectacle, and their meat-getting all in one.
>
> Later in the day begins the third and final phase. It might be thought that such a fire would wipe out every living thing in its path, but that this is by no means so can be seen from inspection of the ground afterwards, when fresh mammal tracks are in plenty; it follows also from the fact that the whole business has been carried out systematically for untold generations and over enormous areas of country. At such times the burrowing habit is the salvation of both mammals and reptiles. . . and it is only a matter of a few hours before most of the forms are on the move again. . . . But the prickly vegetation having been swept away, the sites of the burrows are exposed and the subsequent operations much facilitated. The maala, which makes only a shallow pop hole, now falls an easy victim.

Man's use of fire for over a long period of time in itself proves to me that there has been, and still is, a remarkable resistance in plants and animal communities to fire, and that fire has always been a component of the climate. For these reasons I am led to the following concept:

In nature, fire is a great regenerative force, one might even say rejuvenative force, without which plant and animal succession, in the absence of climatic upheaval or physiographic cataclysm (or at least of great climatic or physiographic change), would be retarded so that old, senescent, and decadent communities would cover the earth. I have been unable to find a single exception to the rule that fire always changes the succession to a younger stage. The intensity and the frequency of fire determines how youthful such a stage will be. Without fire, plant succession ultimately seems to lead to catastrophe, for increased hazard to fire apparently is in direct ratio to age. The older plant communities become more and more vulnerable to fire until finally, unless some violent upheaval occurs, fire rejuvenates the succession, sometimes even to the bare rock itself.

And now in final conclusion I wish to acknowledge my indebtedness to the following "natural laboratories," for it is here, in outdoor settings such as these, where most of the studies of fire ecology must be made.

To the Sonoran Desert of Arizona where I not only learned that even deserts would burn under the right conditions but also learned through observing our children, Eddie and Betsy, "playing with fire." They soon learned by themselves that cholla cactus would flame up brilliantly, and it was apparent how easily primitive man began to use fire—simply by playing with it.

To the Sequoia groves of California that impressed upon me that not only was fire ancient but that fire conditions must have been very severe for natural selection to have developed in the big trees such a tremendous resistance.

To the Rain Forest in the Olympic Peninsula, up the Quinalt, for emphasizing upon me that wet-type forests can and do burn. Fortunately, I was up there during the dry period.

To a very old and over-mature virgin White Spruce forest near Lake Nipigon in Ontario, where I was amazed by the decadence and senescence of such a forest.

And then finally to a camp site in Nova Scotia in young stands of conifers and such fire indicators as Aspen, these leading me to the realization that if it were not for fire, or some climatic or land-mass upheaval, our plant and animal communities, geologically speaking, would soon become decadent.

LITERATURE CITED

Camp, Wendell H. 1956. The Forest of the Past and Present. *In* Haden-Guest et al. (1956) A World Geography of Forest Resources. Ronald Press, New York.

Clements, F. E. 1916. Plant Succession. Pub. 242, Carnegie Institution, Washington, D. C.

Finlayson, H. H. 1943. The Red Centre—Man and Beast in the Heart of Australia. Angus and Robertson Ltd. Sydney, Australia.
Phillips, J. F. V. 1930. Fire: Its Influence on Biotic Communities and Physical Factors in South and East Africa. South African Jour. of Sci. 27:352-367.
United States Forest Service 1944-1960. Annual Fire Reports for the National Forests. U. S. Dept. of Agr., Forest Service, Washington, D. C.
United States Forest Service 1944-1960. Forest Fire Statistics—Annual Reports. Division of Cooperative Forest Fire Control, U. S. Dept. Agr., Washington, D. C.
Viemeister, Peter E. 1961. The Lightning Book. Doubleday and Company, Inc. New York.