FIRES AS AGENTS OF BIODIVERSITY: PYRODIVERSITY PROMOTES BIODIVERSITY[1]

Robert E. Martin and David B. Sapsis[2]

Abstract. *Fires are diverse in their nature and occurrence. Prehistoric fire regimes varied in the interval between occurrences, seasons of occurrence, dimensions, and fire characteristics. These diverse regimes formed continuums in environmental characteristics and promoted diverse biota. Inevitably, fires will occur, as we have demonstrated after many decades of fire suppression, but we have reduced pyrodiversity and with it have tended to reduce biodiversity.*

Introduction

Fire regimes reflect pyrodiversity, which is variety in interval between fires, seasonality, dimensions, and fire characteristics, producing biological diversity at the micro-site, stand, and landscape level. Prehistoric fire regimes have changed over time, and probably considerably for any given climate and vegetation groups, due to human influence. Modern fire control has attempted to remove fires from wildlands. Instead of removing fires, the result has been a gross distortion in the fire regimes, removing most fires of low and intermediate severity and size, and increasing the proportion of large, high-severity fires. Thus, the pyrodiversity has been reduced, which would in turn reduce biodiversity.

This paper discusses the changes in fire regimes as used by Native Americans, the problems fire suppression has created in removing fires from wildlands, and the reduction in pyrodiversity this has caused. Finally, the paper discusses the effect this may have on biodiversity.

Fire Regimes

Wildland fires are diverse, and the range in diversity among fires might be summarized as differences in fire regimes. The fire return interval, seasonality, dimensions, and fire characteristics might be used to develop the spectrum of fire regimes, as suggested by Kilgore (1981), Gill (1975), and Heinselman (1981). Fire regimes of the Klamath Province generally cannot be characterized as simply as Heinselman was able to do for the northern Lakes States (1973). This is largely due to the complex character of the biotic and abiotic factors operating in the province.

The period of time between successive fires on an area is an obviously important characteristic, and the one often used alone to describe fire regimes. It is generally one of the easier characteristics to describe, but all aspects of it are often not determined or stated. The ***mean fire interval*** or ***mean fire return interval*** is the arithmetical average of all fire intervals in a designated area during a designated time period (Romme, 1980). Dieterich (1980) used the term ***composite fire interval*** which is identical in meaning and perhaps more descriptive.

Fire frequency is the number of fires per unit time in some designated area, and is the inverse of mean fire interval. Fire history studies used to develop the frequencies should also state whether or not ***cross-dating*** was used to correct the chronology of fires as recorded by separate trees in a study with a master tree ring chronology. Ecologically and for management purposes an indication of dispersion around the mean is very helpful, such as an average of 6.3 yrs with a standard deviation of 4 yrs and a range of 2 to 12 yrs. The terms ***fire cycle*** or ***fire rotation*** (Heinselman, 1973; Romme, 1980) is the time required for an area equal to the entire area of interest to burn, and would be expressed in terms of years per area, *e.g.*, 40 yrs for an area equivalent to the total parcel to burn. When reading the literature on fire history, one must be careful to distinguish how the history was determined, as there has been much confusion in the terminology and methods used.

In the past, we talked about the fire return intervals in prehistoric times, trying to reconstruct the fire regimes that produced the floral and faunal patterns that existed before the extreme disturbances of advanced civilizations. Thus, in Australia and North America, we can reconstruct prehistoric fire histories. This is particularly true in western North America, where the disturbance intervals are often short and several species of trees useful in dendrochronology and fire history studies are long-lived.

The fire return interval is dependent upon three groups of factors: ignition sources, phytomass or fuels, and burning conditions. This might be termed the fire history or ***fire regime triangle*** (Figure 1). Ignition sources were primarily the native peoples and lightning, although volcanic activity, meteors, friction, sparks, and refraction may have accounted for occasional ignitions. The second group of factors is adequate amounts, kinds, and distribution of phytomass or fuels to provide for fire spread. The third set of factors is the weather conditions necessary for fire to spread, such as wind, low humidities, and sufficient time following snowmelt or rainfall for fuels to dry.

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[2] University of California, Department of Forestry and Resource Management, Berkeley, CA 94720

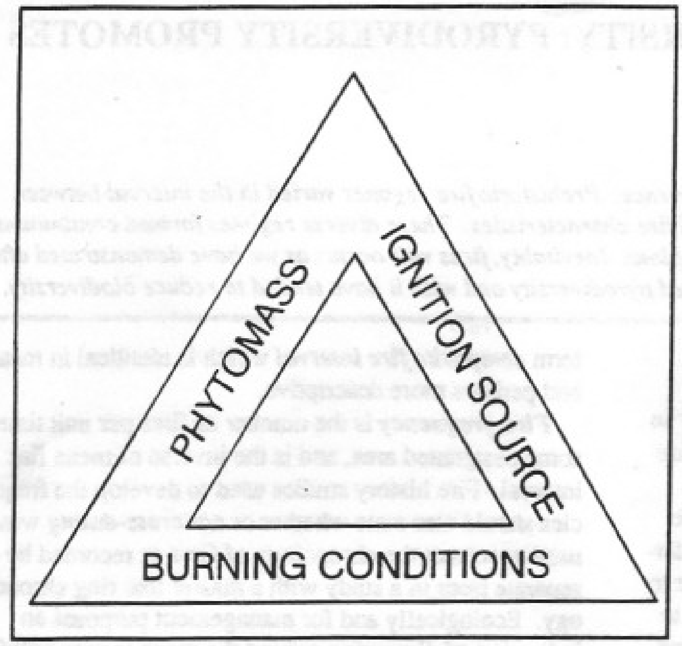

Figure 1. *Prehistoric fires required an ignition source, phytomass, and burning conditions in order for them to ignite and spread— the fire regime triangle*

A summary of the periods between fires for western North America fall in a U-shaped pattern as the climate passes from very warm or dry to cool and wet (Martin, 1982) (Figure 2). This curve was developed from summarizing the results of 31 fire histories. The long periods between fires in the warm-dry regime were interpreted to be caused by lack of fuel, whereas the long periods in the cool-wet regime were the result of poor burning

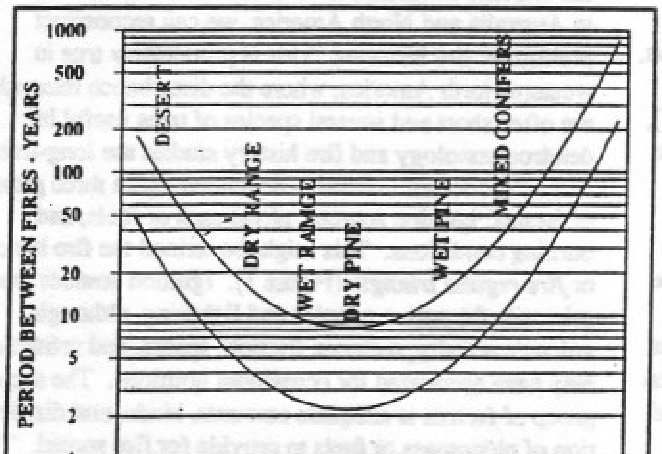

Figure 2. *Prehistoric fires in western North America had longer periods between fires in the warmer, drier areas, where fuels were limiting, and in the cooler, wetter areas, where burning conditions were limiting. The most frequent fires occurred where ignition sources and burning conditions were best, combined with ample phytomass production. (Adapted from Martin, 1982).*

conditions, the fuels being too wet much of the time for fires to spread. An optimal set of factors of fuels, climate, and ignition sources combined to develop a very short period between fires in the dry pine sites

Seasonality of fires describes the propensity of fires to occur during certain seasons of the year. As with the periods between fires, the season of the year during which fires occurred could have a profound effect on the results. Not only the characteristics of the fires might be different, but also the phenological or ontogenetic state of the plants, activity of arthropods which might attack plants, and the reproductive stage of other animals might be such as to bring about different effects, resulting in variability in ecosystem response.

Determining the seasonality of prehistoric fires is often difficult or impossible. In fire scar histories, however, it is often possible to determine the approximate season by the position of scars within the growth ring. This takes far more time than merely determining the year.

Wildland fires occur with a wide range of values of some important fire characteristics, and the variation in these characteristics will be important in the effects the fires have on the environment. The characteristics may vary spatially and temporally within a fire, from fire to fire within the same time frame, and among fires at different seasons or different years. All this variation may lead to a great variety of effects as reflected in biological diversity. The degree to which fires affect a site and the biota on it is reflected in the severity of the fire.

Fire severity is the degree to which vegetation and a site have been altered or disrupted by a fire (modified from McPherson *et al.*, 1990). At present, there is no well-defined meaning of the term. In general, it would be a combination of the degree of crown scorch and consumption, bark char, injury or mortality of plant species, organic matter consumption, and the degree of exposure, discoloration, or other immediate changes in the soil.

Dimensions of fires obviously refers to the areal extent which any fire reaches, generally given in terms of hectares or acres. Often the size of a fire may be for an entire complex of fires which burned in the same vicinity at the same time. This often occurs from a group of lightning fires, which tend to be grouped in time and locale. Examples would be the 1988 Yellowstone fires (Romme and DeSpain, 1989) and the 1987 northern California fires. The fires often burn together, and for practical purposes of assessing the size or in fighting them, they are a single fire. Strauss *et al.* (1989) have estimated that 1% of wildfires in the western U.S. result in 80% to 96% of the total area burned.

Another aspect of dimension, which is extremely important from the standpoint of fire effects is the unburned areas within the fires (Eberhart and Woodard, 1987). The unburned "islands" are important as refugia for the biota from which they may repopulate the burned areas. Presence of unburned islands often reduces resources' effects on soil and water. The size, number, and distribution of unburned islands, as well as their physiographic characteristics and subsequent weather, will govern their effectiveness in restoring populations to the burned areas. Similarly, fire shape is an important characteristic that influences the patterns of edge—where burned areas interface with unburned areas. Edges have important ecological significance, particularly in regard to recolonization and spatial pattern of vegetation structure important to faunal habitat.

A third aspect of dimension is the juxtaposition of each fire and its islands with regard to other fires, both temporally and spatially (Romme, 1982; Romme and Knight, 1981; Romme and DeSpain, 1989). This would include past, present and future fires and their characteristics. Future fires may be planned, as in prescribed burning, or unplanned as in prescribed natural fire or wildfires. The significance of dimensions of past and present fires changes when future fires are taken into consideration, as effects accumulate.

Fire history studies indicate fire to be quite frequent in northwestern California. We used information from fire history studies, accounts of Native American burning, deduction, and areas of vegetation types from Barbour and Major (1977) to estimate that anywhere from 5.6 to over 13 million acres burned annually in California, excluding the dry southeast portion of the State where prehistoric fire information is not available. Since the state is approximately 100 million acres in size, the figures presented here would indicate that, on average, up to 13% of the state may have burned each year (Table 1).

Table 1. *Estimated prehistoric burn acreages in California.*

Vegetation Group	Millions of Acres	Millions of Acres/Year Low	High
Forest	23.930	1.119	2.376
Shrub	18.962	0.708	2.117
Grass/Herb	31.359	3.853	8.717
Total	74.251	5.680	13.210

Although these figures may appear high, it is important to note that most of the area burned was in grass/herbaceous-dominated fuels. In addition to providing uniform fuel with low fuel load per unit area, these fuels are conducive to burning over a large portion of the year.

An important consideration here is that prehistorically there was a wide range in the fire regimes—pyrodiversity—and it helped to establish landscape heterogeneity that supported and maintained biological diversity. In the next section, we will look at some of the aspects of pyrodiversity and how we see them in prehistoric fire regimes with and without Native Americans, and then with modern fire control. We know only a small fraction of the details of prehistoric pyrodiversity from data analysis; the rest must come from deductive reasoning on the climate, the occurrence of fires, and Native American use of fire. Also, over the centuries, climate has changed considerably, so that prehistoric fire regimes with and without Native Americans are projected for the same times and thus the same climates. The recorded prehistoric fire regimes included the effects of Native American burning.

Pyrodiversity

The fires that occurred prehistorically occurred in a wide spectrum of regimes. The regimes were variable both spatially and temporally, over spatial scales of fractions of square meters to thousands of hectares and temporally from seconds to years. The issue of scale is perhaps the biggest key to understanding this diversity.

Some fire regimes had very short fire intervals, occasionally as short as two years, although within the same area intervals may have stretched into decades. The season of fires was probably variable as well. Although the greatest numbers of fires, and the largest fire events occurred in the late summer and early fall in western North America, the climate is variable enough to allow fires to occur during "windows" in the early summer, spring, and even winter. The dimensions of fires and their characteristics also would have varied, such that any fire of any dimension would vary widely in character both temporally and spatially. All this amounts to a wide range of pyrodiversity—particularly when viewed at the landscape or regional spatial scale, and over the course of many millennia.

The role of Native Americans in modifying fire regimes is often considered unnatural and not part of a "natural" fire regime. Yet, we cannot separate their role over the last 12,000 to 17,000 years from "natural" agents. Changes in climate have contributed to changes in fire regimes, as have Native Americans. Along with all this, the biota has gone through many generations, which might have led to changes to genetic strains more adapted to the recent fire regimes.

If anything, Native Americans would probably have reduced the periods between fires and also the variability in fire intervals (Figure 3). Whereas fires started by lightning would occur only under meteorological conditions promoting the formation of thunderstorms and ignition and fire spread, and where fuels were sufficient for fire spread, Native Americans could start fires at any time conditions were right for ignition and spread. If fires were needed to enhance their living, Native Americans would have the opportunity to start them. In contrast to the effect of Native Americans, fire control has increased the period between fires, on the average, and also reduced the dispersion in fire intervals.

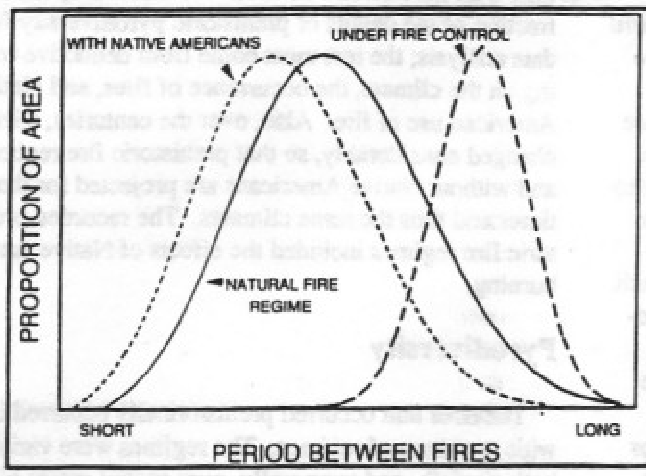

Figure 3. *Native Americans probably reduced the period between fires, as ignition sources were available if they intentionally or accidentally set fires. Modern fire control has greatly increased the period between fires.*

The seasonality of fires has also been changed by Native Americans and fire control. Native American burning should have spread the curve of natural fires (Figure 4). Whereas under natural regimes, the necessary phytomass and burning conditions might have existed without an ignition source, when Native Americans were present, they could have supplied the ignition. Thus, we would have to suspect that they extended the season of burning, especially if that burning would help meet their needs. Fire control, however, has been able to suppress most fires rather quickly during the seasons with generally

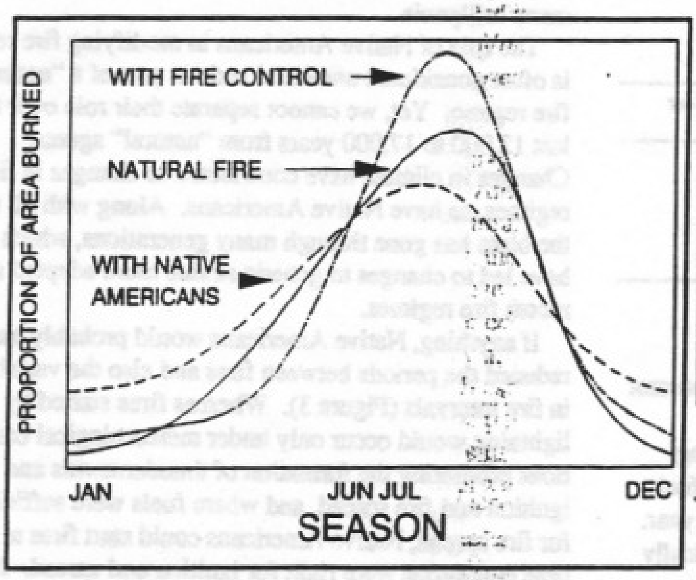

Figure 4. *The proportion of area burned by prehistoric fires was most likely distributed more broadly among seasons as a result of Native Americans. Fire suppression, on the other hand, would easily control fires in the off season and most of the area covered by modern wildfires would be during the severe fire weather of late summer and early fall.*

moderate burning conditions—winter, spring, and late fall. The reduced period between fires brought about by Native American burning might have resulted in a shift in the nature of fires, but little change in the diversity of fire effects, such as fire severity. We can look at the percentage of area burned by fires of different severity under natural and Native American regimes compared to those under fire control. Not knowing the percentage of area burning under the natural regime, we can level it out as a "norm" and use it as a base for comparison to the other regimes (Figure 5). The curve depicting fire severity with Native American burning would probably be skewed a little toward the less severe, whereas that depicting fire severity with fire control would be grossly skewed to the right, with most of the area burned being in the severe fire effects range. We put out many of the fires with low and moderate fire characteristics, and fires generally become large, with severe characteristics, because their fire behavior precludes our suppressing them.

Fire size with fire control thus becomes bimodal in comparison to the distribution under natural or Native American burning (Figure 6). Under low or moderate fire conditions, fires are generally controlled quickly, resulting in very small fires. Under severe fire conditions, with the increased fuel loads under fire suppression, the fires become quite large.

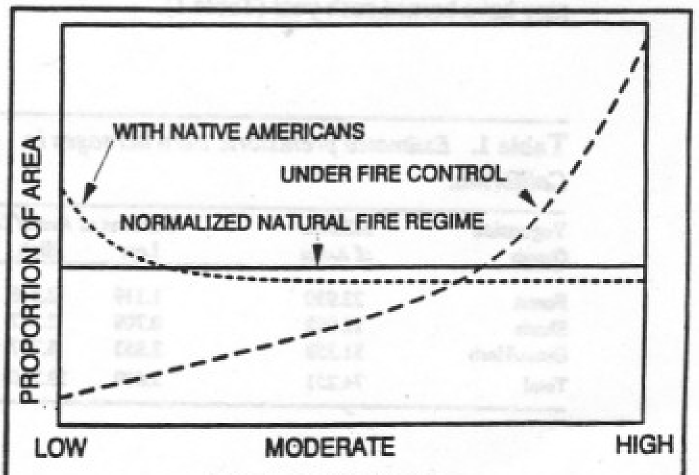

Figure 5. *The proportion of area covered by prehistoric fires of different severity was probably not changed greatly by Native Americans, but some shift toward less severe fires might have occurred. In contrast, fire suppression easily extinguishes fires of low severity, greatly shifting the proportion of area burned toward the high severity end of the scale.*

Fires will be part of the natural systems, and we are far better off accepting and using fires than to attempt to

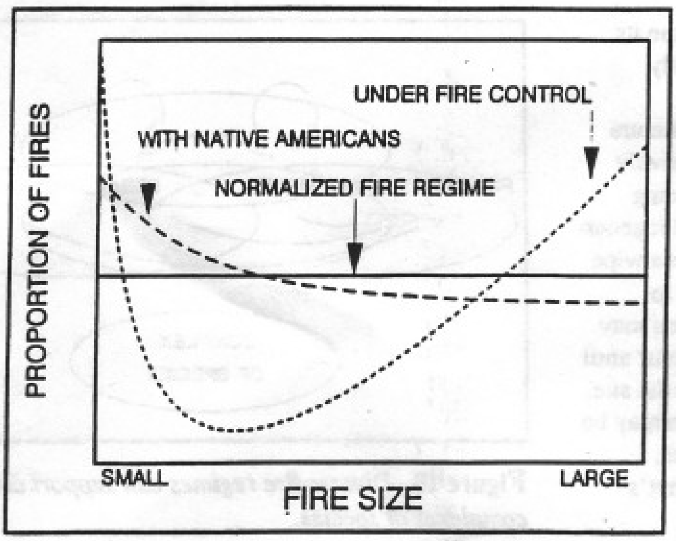

Figure 6. *Native Americans probably reduced the fire size slightly from that of the natural regime because of the reduced fire period. In contrast, under fire control, we would expect the proportional area covered by fires of different sizes to be bimodal, with some fires extinguished readily, and others becoming quite large.*

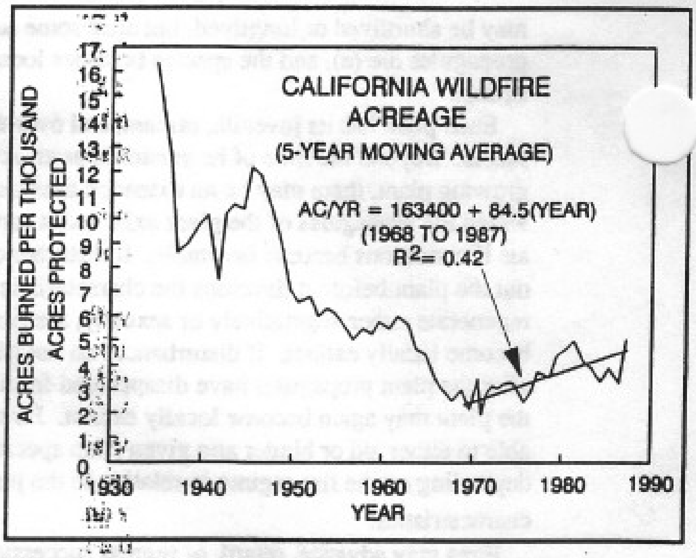

Figure 7. *Wildfire data using a five-year moving average indicate decreasing area burned each year until the late 1960s, but almost a doubling of wildfire acreage in California since then.*

eliminate them. Almost a full century of fire suppression has demonstrated that what we can do is to greatly distort the fire regimes toward the longer fire intervals with more area proportionally being covered by larger fires with more severe fire characteristics during narrower seasonal periods. In the last 20 years or so, we have experienced almost a doubling in wildfire acreage in California (Figure 7), with little increase in the numbers of fires. It seems that past success in fire suppression has led to present failure. This is not a condemnation of fire suppression, as fire suppression is very necessary in our modern society. What is needed, however, is fire policy that recognizes the need for fire and makes extensive use of fire in meeting natural resource goals. Coincident with such a policy would be economic studies which address the long-term effects of fire policy. Economic studies have not addressed the long-term issue. Basically, Figure 7 would indicate that past success in fire suppression is leading to present failure, and as we shall see, reduced biodiversity.

Pyrodiversity had to contribute to biodiversity. For each set of climatic and physiographic conditions capable of supporting a diverse biota, fires would contribute to having different assemblages of biota at different stages of development on any given site. Whereas some of the biota might be common to all or most stages of development, others would be greatly reduced or eliminated locally if the fire regime is reduced in diversity, toward either to infrequent or too frequent fire, with the associated changes in other characteristics of fire regimes.

The Role of Fires in Wildlands

Fires may have many roles in wildlands, interacting with the other abiotic elements and with the biota. Using diagrams similar to those of Noble (1981), we might look at the fate of any plant as time progresses (Figure 8). This diagram is set up for only some of the vascular plants, but we might suppose it could be established for other plants and for animals. In the diagram, plants establish at some time after a disturbance, noted by the beginning of the line. After a period of time, depending on the nature of the species, it reaches maturity (m), after which time it can reproduce sexually. The plant eventually reaches the end of its lifespan (l), at which time it dies. Its propagules

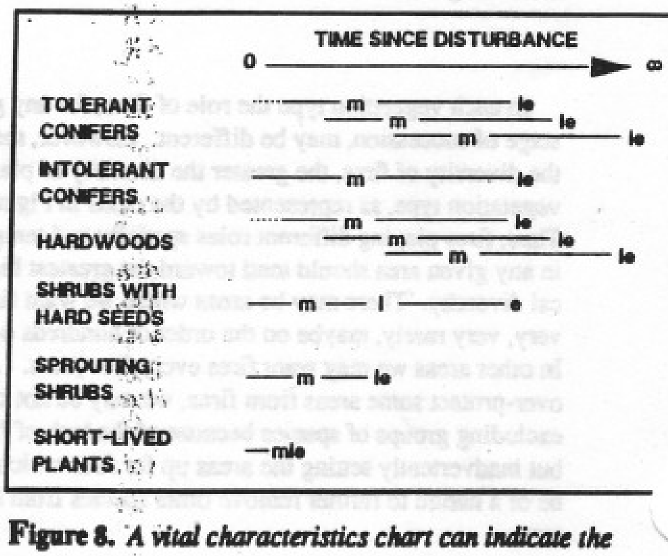

Figure 8. *A vital characteristics chart can indicate the needs of different groups of species for propagation.*

may be shortlived or longlived, but after some time its propagules die (e), and the species becomes locally extinct.

Each plant has its juvenile, mature, and over-mature stages. Beyond the time of its existence as an actively growing plant, there may be an extended time during which the propagules of the plant exist and it can regenerate if conditions become favorable. If disturbances wipe out the plant before it develops the characteristic to regenerate either vegetatively or sexually, the plant may become locally extinct. If disturbances do not occur until after the plant propagules have disappeared from the site, the plant may again become locally extinct. Fires may be able to either aid or hinder any given plant species, depending on the fire regime in relation to the plant's characteristics.

Fires may advance, retard, or regress succession, depending on the fire regime and the species present (Figure 9). In many vegetative types, frequent fires with moderate to low severity characteristics may hold succession at any given stage, regress succession toward earlier stages, or even advance succession.

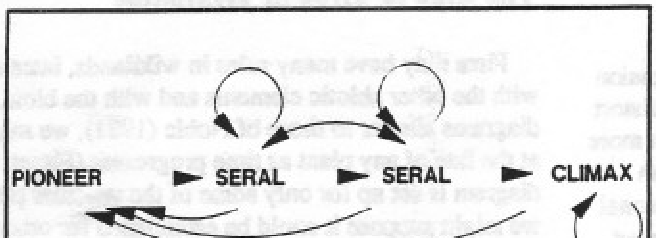

Figure 9. *Fires may play a wide range of roles in vegetation types, retarding, regressing, holding, or even advancing succession.*

In each vegetation type the role of fires, for any given stage of succession, may be different. However, the wider the diversity of fires, the greater the diversity of plants in a vegetation type, as represented by the ovals in Figure 10. Thus, fires playing different roles spatially and temporally in any given area should tend toward the greatest biological diversity. There may be areas where we want fires very, very rarely, maybe on the order of hundreds of years. In other areas we may want fires every few years. As we over-protect some areas from fires, we may be not only excluding groups of species because of the lack of fires, but inadvertently setting the areas up for fires which will be of a nature to further remove other species from the area.

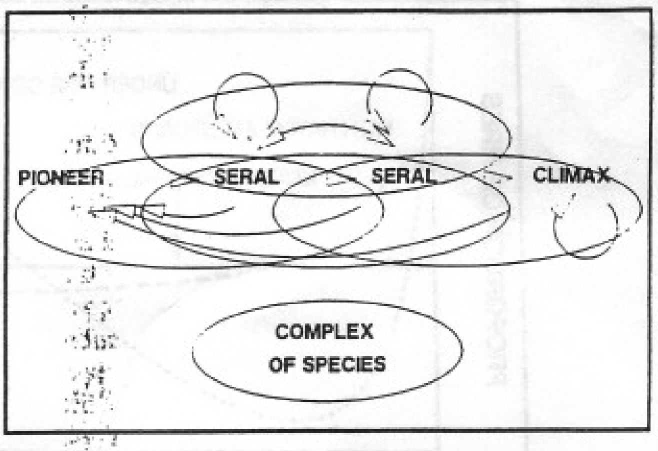

Figure 10. *Diverse fire regimes can support diverse complexes of species.*

Restricted Pyrodiversity

We might look at the effects of fire control on pyrodiversity, especially as this is superimposed on species with different vital characteristics. Using the vital characteristics chart of Noble (1981), we can see the potential effects of a diverse and a narrow fire regime on vascular plants. Figure 11 shows the potential effects of a natural fire regime with diverse periods between fires. It depicts several different groups of vegetation, but is not intended to account for all possible plants. The broad diversity in period between fires allows for plants of widely different regeneration requirements to propagate.

In contrast, the fire regimes with a narrow range but long period between fires would tend to exclude those plants with a short life and short propagule endurance

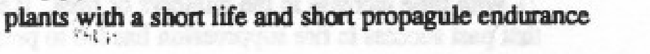

Figure 11. *The vital characteristics chart indicates how diverse fire regimes can help support a diverse biota.*

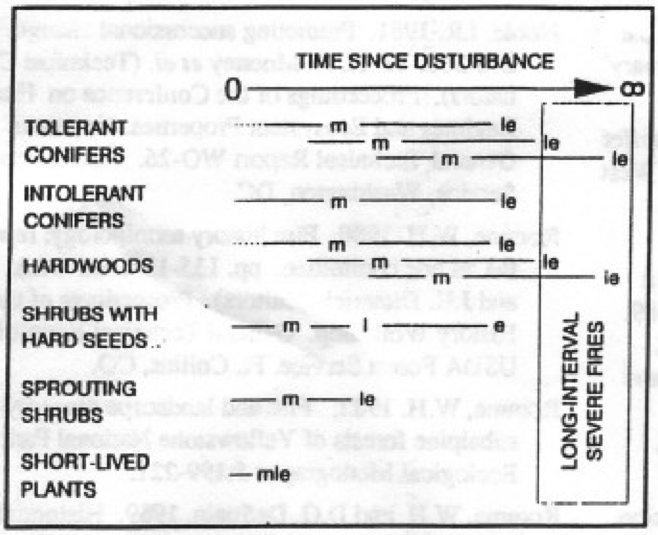

Figure 12. *Narrow fire regimes with long periods between fires, as might be imposed by fire control, would limit the groups of species which can propagate on a given site.*

(Figure 12). Also, the severity, seasonality, and dimensions might be changed in ways which would also reduce the chance of some biota to propagate in areas with restricted pyrodiversity.

Toward a New Policy on Wildland Fires

Fires have been in most terrestrial vegetative systems for eons, and the fire regimes have changed with changes in climate and ignition sources. The fire regimes have had great diversity both spatially and temporally, promoting biodiversity. Fire suppression has led to a reduction in pyrodiversity, which in turn has led to a reduction in biodiversity. We argue that, given this interdependency, a different way of approaching fires in wildlands is needed.

We need to develop a better assessment of the role of fires in different vegetative types. We have enough information now to change fire policy, but to fine-tune policy and plans for any system, more information would be needed.

A new policy on fire management should address the extent and role of fires in each vegetative type and then develop the plans and strategy to meet that role. It makes no sense to have the same policy for all types, regardless of the role of fires in them. Some types should have no fire except perhaps during very restricted periods such as regeneration. Others should have fires extensively during their progression, except perhaps at certain sensitive times.

Such a policy would require extensive prescribed burning, as we could not return to natural fire regimes. First, we have greatly disturbed the systems and have accumulated large amounts of biomass or fuels. Second, the natural fire regimes would lead to damage to the structures and special amenities we want from our wildlands. Burning would put large amounts of smoke in the air, but this would occur in any event from wildfires, and perhaps at undesirable times. With prescribed fires we can choose the time and amount.

We might raise the objection that we would spend many, many years ever getting enough prescribed burning done to meet the objectives of such a policy. We agree, but at least we would be moving in the right direction. We will never do without fire suppression in our modern society, unless, of course, we do away with wildlands. We now need fire suppression more than ever. With such a new policy, we could eventually reduce the fire suppression needs in some areas. Some Eastside types—pine and range types—might be the ones where we could make the most rapid progress.

Along with such a new policy, we could begin to reintroduce the pyrodiversity that has contributed to biodiversity.

Summary

Fires have occurred in a wide range of patterns—return intervals, seasons, dimensions, and fire characteristics. This range of characteristics may have changed some with the fire activities of Native Americans, but this was a shift in fire regimes, not a constriction. Pyrodiversity prevailed over long periods of time. Now, however, our present fire management policies, directed first at fire control and then allowing some exceptions to control, are drastically narrowing the range of fire regimes. Further, our present fire management policies are not successful over the long run, if one looks at increased wildfire acreages over the last two decades. A new fire policy should first allow decisions on what should be the extent and role of fires in each vegetation type and site, then make plans accordingly.

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