THE ECOLOGICAL SIGNIFICANCE OF FIRE IN CHAPARRAL

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ABSTRACT

California chaparral has evolved with fire as a frequent catastrophic disturbance of the entire plant and animal community. The effects of fire, both planned and unplanned, on animal populations are related in the short term to changes in food and cover availability and in the long term to changes in plant species diversity and productivity. Since fire is now being prescribed for the management of chaparral over large acreages, the effects on animals must be considered in the development of meaningful management strategies. Basic research on the effects of fire on animals must continue and include observations which can be directly related to pre-fire baseline information. Research of the effects of animals on the post-fire plant community is also appropriate.

INTRODUCTION

The effects of fire vary with the intensity, duration, and frequency of the fire event, season of the year, time of day, weather elements such as relative humidity and windspeed, site characteristics (slope, aspect, elevation, vegetative type, soil type), and fuel characteristics. Fuel characteristics expressed as the size, continuity, amount and distribution, fuel moisture, and plant species composition are the components that are most significantly changed by burning and affect wildlife populations to the greatest degree.

Chaparral plant species "evolved" in the typical Mediterranean-type climate with long, dry summers and cool, wet winters (Mooney and Dunn 1970). Unlike many other plant communities, chaparral seems to have evolved in response to fire as a frequent factor of disturbance (Jepson 1930). According to a hypothesis proposed by Mutch (1970), the characteristics of chapparal which enhance its flammability have been evolutionarily selected. Philpot (1977) summarized those characteristics into three categories -- chemical, physical and physiological. The chemical characteristics include a low-silica-free mineral content and high solvent extractives. Physical attributes include high dead biomass and spatial continuity of the multi-stemmed canopy. Physiological attributes include the reduction of fuel moisture and increased concentration of extractive chemicals during hot, dry weather, and the increase of standing dead fuel as the stand ages. As chaparral accumulates dead material it is less palatable and nutritious to browsing animals (Biswell and Gilman 1961), and wildfires in this flammable vegetation result in large expanses of homogeneous vegetation where there may have been significant plant species diversity prior to fire.

Chaparral species growth and development begins immediately after fire. The majority of perennial plants (except many in the genera Arctostaphylos and Ceanothus) sprout new stem tissue from roots, stems, or lignotubers (Wells 1969), some within two weeks after the fire (Plumb 1961, 1963). Herbaceous seeds remaining in the soil may germinate rapidly, usually after the first rainfall (Sweeney 1968; Keeley and Johnson 1977). Many herbaceous species respond positively to chemical stimuli resulting from fire-charred shrubs (e.g. Keeley and Keeley 1982) and are known as "fire followers." Within the first two years following fire many seeds of perennial species also germinate. Within ten years, the canopy, often up to four feet in height, may be closed (> 75% cover) (Longhurst 1978) and by 15-30 years the chaparral community is considered to be at its peak level of productivity. Obviously, all chaparral is not identical in species composition or relative abundance of floristic elements. The proportion of obligate seeding versus predominantly sprouting species influences the timing and quantity of the post-fire flush of growth.

Most information on effects of fire to wildlife in chaparral centers on changes in forage characteristics over a short time span (less than ten years) (e.g. Wirtz 1974; Biswell et al. 1952). One must also consider effects on individual animals as fire traverses the landscape (immediate effect), effects on animal populations over short time periods, and effects on various species adaptions in response to long term evolutionary selection pressures. This paper includes a brief review of research of both immediate and long range effects of fire on animal populations in the chaparral (excellent reviews are found in Wirtz 1977, and Ashcraft 1979). Concomitantly, the implications for chaparral management are discussed along with suggestions for further research on wildlife in chaparral ecosystems.

The assistance of Roger Anderson in the preparation and critical review of this paper is gratefully appreciated. The extensive criticisms and suggestions from the three anonymous reviewers were also invaluable in the preparation of the final manuscript.

IMMEDIATE FIRE EFFECTS

There are obvious direct effects of fire on individual animals in the chaparral. Direct mortality by burning, heart failure from over-exertion or fright, and respiratory failure by suffocation or seared lungs are potential causes of mortality during a fire (e.g. Howard et al. 1959). Although not well documented, it has been theorized that the primary cause of mortality probably is respiratory failure (e.g. Lyon et al. 1978).

During fires, animal species using burrows sustain mortality which probably is correlated with burrow characteristics, e.g. depth and size of burrow. These factors influence water vapor pressure, oxygen availability, and ventilation, etc. (e.g. Lawrence 1966; Wirtz 1974; Menke and Villasenor 1977). Likewise, young altricial animals and species with low mobility (salamanders, lizards, etc.) above-ground will be unable to escape. Above-ground highly-mobile animals probably flee prior to being overcome by smoke and flames.

SHORT-TERM EFFECTS

The initial ecological impact upon resident animal populations is the significant alteration of microhabitat characteristics (Cook 1959), especially for an individual with homogeneous habitat requirements (e.g. insects, most reptiles, small mammals and rodents). The micro-climate may receive greater insolation and be warmer because vegetative canopy has been removed and physio-chemical alterations of the soil have occurred. If soils are damaged and a water impermeable subsurface soil layer develops, rain may saturate the top layer resulting in slumping and topsoil erosion. Loss of topsoil and duff layer nutrients may result in reduced plant productivity and hence reduce animal productivity. There may be a change in amount or location of available water. If significant amounts of vegetation are removed there will be less foliage structure, usually necessary for birds and other users of trees and shrubs.

An indirect effect of fire resulting in short-term mortality is the lack of food and cover. Death may occur due to reduction in body reserves of energy and nutrients and inability to gain access to suitable cover, making animals more susceptible to predation and disease (e.g. Wirtz 1977). Several authors relate accounts of raptors and insect-feeding birds being attracted to fires and burned areas (e.g. Beck and Vogl 1972; Lillywhite et al. 1977), suggesting a more easily exploited prey base (Wirtz 1977). Some animals may even be injured by caustic ash conditions (McClure 1981). To survive, individuals may emigrate to unburned habitats already occupied by conspecific individuals (except noted by Cook 1959), resulting in intense competition between occupants and emigrants.

Large burned areas (hundreds of acres) which convert several habitats increase the time for recolonization by rodents, herbivorous insects, and seed-eating birds. Even larger herbivorous mammals (e.g. mule deer) may infrequently use much of the large burned areas, allowing the flush of plant growth after fire to proceed relatively unrestrained (Ashcraft 1979).

Large burns may drastically affect the local abundance of larger mammals and resident birds which require several plant communities to meet their needs. Small burns, in contrast, may have very little effect on larger mobile animals even though plant species availability has been initially decreased in the burn. Small animal species diversity in the area surrounding the burned site may increase (e.g. McClure 1981). Therefore, the short-term impact on wildlife population size at the burn site is reflected by the magnitude of individual mortality, amount of relocation, and the abilities of individuals to exploit the altered habitat.

The post-fire diversity of woody and herbaceous seedlings and woody sprouts provides substantial near ground food and cover in the first five years until the annuals and herbaceous perennials die out (see Ashcraft 1979, for a thorough explanation). The short-term result is a shift from bird and small mammal species common in shrub communities to those which are associated with grassland conditions characteristic of post-fire chaparral sites (Cook 1959; Lawrence 1966). Average height of foliage increases as the woody perennials become dominant on the site. It is well known that wildlife species which require chaparral less than ten years old -- e.g. deer, quail, some rodents, and some passerine birds -- experience dramatic population changes or patterns of plant community use in this first decade after fire (e.g. Longhurst 1978).

Post-fire predation (browsing) of plants in areas dominated by obligate seeding species may result in elimination of seeders from the plant community and ultimately a species turnover to sprouters (Biswell and Gilman 1961), perhaps including species found in the coastal sage scrub community. Similarly, sprouters will die if extensively browsed over a longer time period as the carbohydrate reserves in the roots or lignotubers are depleted.

EVOLUTIONARY IMPLICATIONS

The prevalence of fire as a disturbance of chaparral undoubtedly has influenced the distribution and abundance of animal populations. Broad rather than narrow habitat preferences (or large rather than small home ranges, Longhurst 1978) may be selectively advantageous for chaparral animals. Such a hypothesis has been forwarded by Lyon, et al. (1978). Additionally, one might propose sets of behavioral, physiological and morphological characteristics which have allowed animals to exist in this disturbance-prone habitat.

The difference between correlation and cause and effect in understanding the short-term behavioral (functional) and longer-term population changes of vertebrates in a habitat changed by fire may be seen by looking at the distribution, abundance, and productivity of plants and arthropods. Understanding trophic level interactions allows greater predictability of vertebrate distribution and abundance. Soil invertebrates seem to be killed by fire (Lyon et al. 1978); egg, larval and pupal arthropods which inhabit the topsoil, duff, or shrubs may be especially susceptible, depending upon the season of the burn. Adult surface insects and other arthropods may not be eliminated as they can fly away from the fire, move into tunnels in the soil, or be insulated from heat and smoke by the bark of the trees.

MANAGEMENT OPPORTUNITIES

If our objective is to manage an animal species in perpetuity then we must propose and execute a planned, long-term, cyclic vegetation management program. We know that short-term projects in this vegetation have short-term "benefits", but may have long-term implications (either beneficial or detrimental) as well. Many animal species utilize ecotones (transition zones between vegetation types) with adequate amounts of both cover and forage. Large animals may use a larger ecotonal zone, but small species may travel only short distances into the burned site over the short term. Additionally, in some species individuals require several distinctly different habitats for satisfaction of all their requisites through the year. Quite possibly, there is an optimal balance between burn size and habitat heterogeneity for each animal species. It is important to consider that this balance point is probably different for different animals and plants.

Whether it is appropriate to emulate a "natural" fire cycle in chaparral is at this time a rather moot point. The magnitude of our prescribed fire program is insignificant in comparison to other forms of ecosystem habitat disturbance. Our concentrated efforts to conduct "controlled" prescribed burns may have a positive short-term impact on the species escape behavior and site recolonization of many species because the size of burned areas is relatively small at any one time. It also is conceivable that planned changes in forage and cover may increase the animal population carrying capacity of a particular area (e.g. Lillywhite et al. 1977). Needless to say, it is unknown at this time what effects this "kind" of fire will have on the long-term probability of plant and animal species extinction or adaptability and evolution. Our efforts in chaparral vegetation management may provide habitat for many organisms surviving displacement by human development.

Appreciating the varied effects of fire on individuals and populations of wildlife, managers attempt to create a heterogeneity of chaparral environments. Ideally, islands of chaparral old growth are retained; other small areas are converted to grasslands; the majority of shrubland is manipulated in a planned mosaic scheme of some level of vegetative productivity and diversity to maximize the benefits to animals. A reasonable first approach is to consider the sequence of projects, particularly when using prescribed fire. Design the sequence utilizing existing type conversions, fuelbreaks, roads, natural barriers, and recent wildfire burns to minimize costly and time consuming line construction. Once initial treatment is accomplished, successive projects can "tie in" to this original site and ease of implementation will increase. When there is limited capability for extensive vegetative manipulation for reasons such as limited funds, few days with adequate weather conditions, or lack of personnel, it is best to concentrate efforts in a few areas to maximize the heterogeneity over time. A balance should be struck between habitat type abundances and distribution, that is habitat heterogeneity, and individual habitat sizes. Habitat corridors in chaparral mosaics may be important to reduce effects of natural and man-caused catastrophies and to reduce possible negative genetic effects of inbreeding especially in larger habitat specific mammals (e.g. mountain lion).

RESEARCH OPPORTUNITIES

There is a significant lack of knowledge about most of the potential effects of fire on animal populations. It is unknown what percentage of animal populations are killed by fire. Since few dead animals are observed shortly after a fire (except Chew et al. 1959) the causes of death are also undocumented (Cook 1959). The number of animals using burrows for escape and the characteristics of those hiding places are also unknown. Additionally, there is little pre-fire baseline information on plant/animal communities from which to compare post-fire research findings. The post-fire effects of changes in plant community composition on animals and the concurrent effects by animals on plants are not at all clear. We need long-term monitoring of animal populations in a variety of habitats in combination with observations and experimentation associated with wildfire and prescribed fire. Perhaps then we can develop some understanding of the ecological significance of fire to animals inhabiting Mediterranean-type ecosystems.

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