EFFECTS OF FIRE ON SMALL MAMMALS IN THE CHAPARRAL

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ABSTRACT:

The small mammal community in chaparral undergoes a progression of predictable changes that are functions of the fire cycle. Some species of small mammals are killed directly by a fire, and most species are not found in chaparral immediately after a wildfire. Kangaroo rats are the only abundant species of rodent in chaparral immediately after a wildfire. Kangaroo rats survive chaparral fires by remaining in their relatively cool burrows. The number of species and population densities of rodents increase in the second and third years after a fire. Changes in the rodent community continue to take place for at least five years, and probably much longer. The number of species and the population density of small mammals would be maximized by breaking up chaparral into small areas of different ages, maximizing ecotones, emphasizing physical heterogeneity, and leaving a few areas of brush. Piling brush or mechanically disturbing the soil before prescribed burning probably increases the impact of habitat manipulation on small mammals.

INTRODUCTION

Fire in the chaparral community is a regular but nevertheless dramatic event. The most obvious change in chaparral after fire is the difference in the structure of the plant community, going from dense vegetation to barrenness. Like the plant community, the animal community is drastically altered by fire. As with the plants, however, these changes are temporary. The community of small mammal species undergoes a progression of predictable changes that are functions of the fire cycle. This paper reviews the findings of investigators, including myself, about the responses of small mammals to chaparral fires, and discusses some management practices suggested by these findings.

DIRECT EFFECTS OF FIRE

Chaparral animals have not evolved specific adaptations for fire survival. The animals are directly affected by heat, combustion gases, and the consumption of organic matter. They are also indirectly affected by changes in habitat structure that result from the fire. The heat of a chaparral fire sometimes kills small mammals. I have observed the burned and unburned carcasses of dusky-footed wood rats *(Neotoma fusicipes)*, California mice, *(Peromyscus californicus)*, brush rabbits *(Sylvilagus bachmanni)*, and ground squirrels *(Spermophilus beecheyi)* lying on the ground after chaparral wildfires. These carcasses were not distributed randomly over a burned area. Most animals were found in groups along roads and trails, in small clearings, or in small depressions in the ground. After the Village Fire of November 1975 in the San Gabriel Mountains, California, I found partially burned dusky-footed wood rats, brush rabbits, and California mice along old roadcuts, hiking trails, and in burned over areas that offered no apparent shelter from the passing fire. Many of these dead animals had been fed upon by scavengers, and I observed ravens doing so. Along 1.8 km of paved road where the chaparral had burned rapidly and intensely on both sides of the road, I found 44 dusky-footed wood rats, 3 California mice, and 1 brush rabbit. In one 180-meter interval there were 12 wood rats. All of these animals appeared to have died on the road. They showed no singe or other evidence of exposure to intense heat, and all had been run over. These animals apparently fled to the relatively cool road during the fire, where they were killed either by asphyxiation or by being run over by fire vehicles. Several fire fighters reported seeing wood rats running in all directions as flames approached. Two of the California mice were found dead in the same place on the road. One was an adult and the other was a juvenile, but the juvenile was too large to have been carried by the adult. As many as 3 wood rats were also found dead at one spot. Wood rats are normally solitary animals. It is likely that the clusters of dead animals were run over at the same time, either while fleeing or while hiding in common refuges on the road such as behind the tire of a standing fire vehicle. Away from the roads I believe that the dead animals had been driven ahead of the flames to the last places that remained tolerable, only to be surrounded by flames and overcome. Sometimes these animals were charred, but frequently even the fur was not singed. The dead animals not touched directly by the fire were probably overcome either by heat or toxic gases. Chew and coworkers (1959) reported observations similar to these after a wildfire in the Santa Monica Mountains. In a 457-meter transect along a canyon bottom they found 41 dead small mammals, only 2 of which were charred.

It appears that the kinds of animal kills reported here are characteristic of intense chaparral wildfires in mountainous areas. Driven by Santa Ana winds blowing over rugged terrain, a fire front can spread rapidly and erratically, trapping animals in the intense heat. Investigations during controlled fires, which burn less rapidly and with less intensity, do not report these direct kills of animals (Howard et al. 1959, Lawrence 1966).

BEHAVIOR DURING FIRE

Only 2 species of small mammals, dusky-footed wood rats and brush rabbits, are commonly observed running away from chaparral fires. Wood rats appear to be reluctant to leave the protection of their stick houses until the last minute, sometimes running from their nests only as their fur catches fire. On a number of occasions I have seen wood rats that escaped a fire wandering around in the daytime in habitats where they do not normally occur. These displaced animals probably do not survive long without a nest, a familiar home range, or appropriate habitat. I have also seen brush rabbits turn and run back into a fire. I once saw a rabbit emerge from a fire twice, the second time with its feet smoking, only to run into the flames again. This behavior may be the basis of the story, frequently repeated by fire fighters, of seeing rabbits running around with their fur on fire.

Wood rats, brush rabbits, and some species of white-footed mice *(Peromyscus)* live on or above the surface of the ground in shelters made of flammable materials. Since the nature of their nests makes them vulnerable to fires, it is not surprising that these are the species often found dead after a fire.

SURVIVAL DURING FIRE

Small mammals can survive chaparral fires either by fleeing to an area that does not burn or by taking refuge in a microhabitat protected from the direct affects of the fire. Both behaviors do occur. Simple avoidance of the fire, however, is not necessarily important for long term survival. For example, if animals flee they are likely to be excluded from the areas they run to by resident animals of the same species. If they remain in the area where a fire has occurred they will soon die anyway if the habitat is so changed that it is no longer suitable for them.

I conducted a study to determine survival and the short-term effects of a chaparral fire on the rodent community, and to see what role burrows played in fire survival. This study was carried out during an experimental fire conducted by the Pacific Southwest Forest and Range Experiment Station, United States Forest Service. The Buckhorn Ridge fire occurred in the coastal mountains of San Luis Obispo County, California, on July 19, 1977. Since it was a hot summer fire in 50 year old chaparral, the effects of the fire on the small mammals were similar to the effects of a typical wildfire. The burn site was located in the Los Padres National Forest, 48 km east of the Pacific Ocean, at elevations of 490 to 670 meters. The fire consumed 53 ha of a chaparral community dominated by chamise *(Adenostoma fasiculatum)*. The survival and movement of rodents was studied, before and after the fire, by live-trapping and marking individual animals. A long trapline was set across the fire area, with traps at intervals of 15 meters. Thirty-two trapping stations in the center of the line were in old chaparral that burned during the experimental fire. The other 40 trapping stations were at the ends of the line in areas that did not burn. Temperatures were remotely measured with thermistors at several points inside two burrow systems of Heerman kangaroo rats *(Dipodomys heermanni)*. Temperatures were measured during the fire and for six hours thereafter.

The unburned portions of the study area showed no change in the minimum population sizes of rodents at the time of the fire (Figure 1). The minimum populations in the burned portions of the study area changed in two ways. First, six species of rodents disappeared; the California mouse, the deer mouse *(Peromyscus maniculatus)*, the brush mouse *(Peromyscus boylii)*, the pinyon mouse *(Peromyscus truei)*, the dusky-footed wood rat, and the desert wood rat *(Neotoma lepida)*. Second, the Heermann kangaroo rat population declined significantly ($P < 0.05$) by both Mann-Whitney U and t-tests. Slightly more than three out of four kangaroo rats survived the fire. Trapping over a 90-day period after the fire showed no movement of any animal from one area before the fire to another area after the fire. No individual that was absent immediately after the fire was even trapped again.

The rodent population was censused in a second part of the study area along a windrow of dead, piled brush. In this area only one kangaroo rat was found after the fire and five other species of rodents disappeared completely.

Temperatures measured in the soil and in kangaroo rat burrows clearly showed the high insulating capacity of the soil during fire (Figure 2). These temperature curves are similar to those masured by Lawrence (1966) in a chaparral fire. Temperatures in burrows increased somewhat during and after the fire, but at the depth of the nest chamber they remained within the range of physiological tolerance (Table 1).

TABLE 1. Temperature increases after fire in *Dipodomys heermanni* burrows.

BURROW DEPTH (cm)	MAXIMUM TEMPERATURE (C)	TEMPERATURE INCREASE (C)
21	37.0	3.0
21	32.0	5.2
23	35.2	3.9
23	36.0	7.0
24	40.1	13.1
26	33.0	1.5
29	34.0	4.5
33	24.0	3.0

This study showed the Heermann kangaroo rat to be the only species of rodent that survived the fire in significant numbers. The surviving kangaroo rats were the same individuals, on the same home ranges, as before the fire. The other six species of rodents present before the fire were eliminated from the burned area by the fire.

Of the seven species of rodents originally trapped in study area, the kangaroo rat is the only one known to live in burrows. The burrows, then, function as refuges from the heat of fires. A possible exception may have been burrows near the brush piles, where the concentrated fuels created an exceptionally hot fire. Kangaroo rats are well adapted to the chaparral fire cycle. They forage, excavate burrows, and take dust baths in openings between shrubs. Immediately after fire almost the entire chaparral habitat becomes open ground. After fire, in the absence of other species of rodents, the kangaroo rat population can increase to take full advantage of the expanded habitat. Evidence that such a population increase does occur is discussed in the next section.

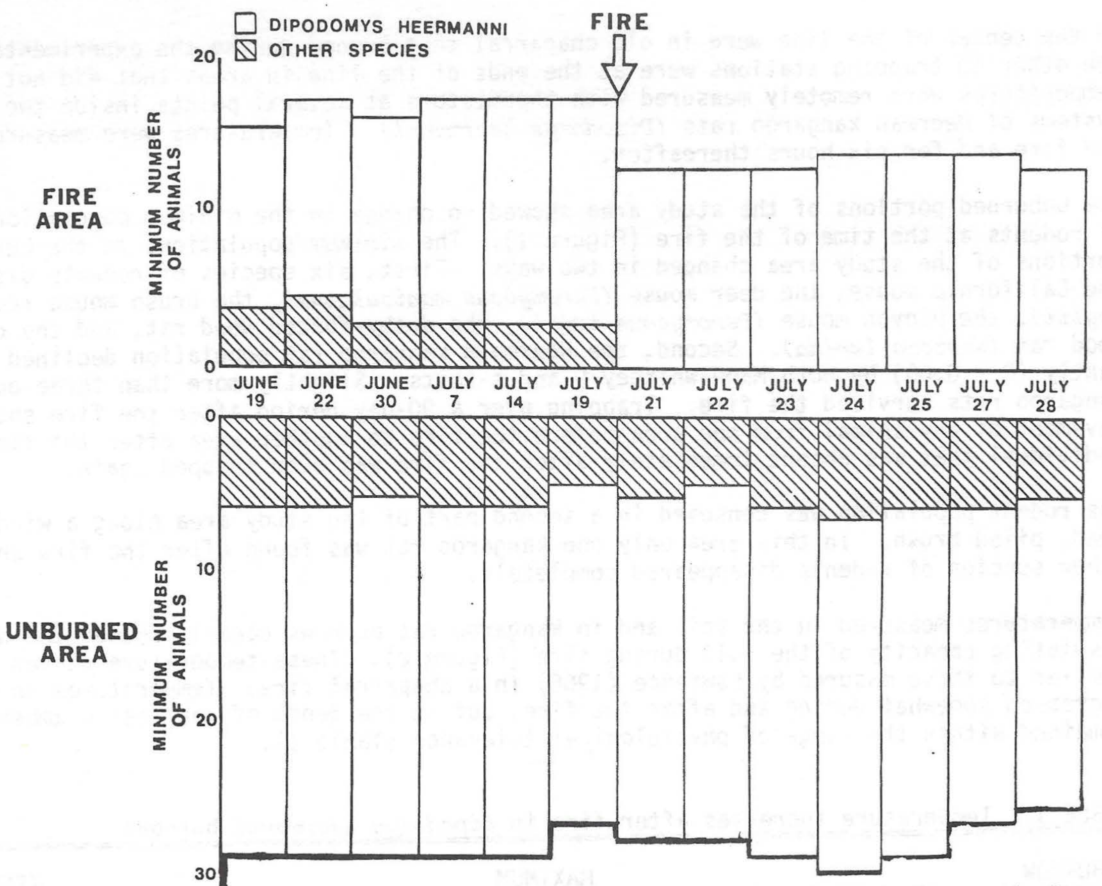

Figure 1. Minimum population sizes of seven species of rodents before and after a chaparral fire.

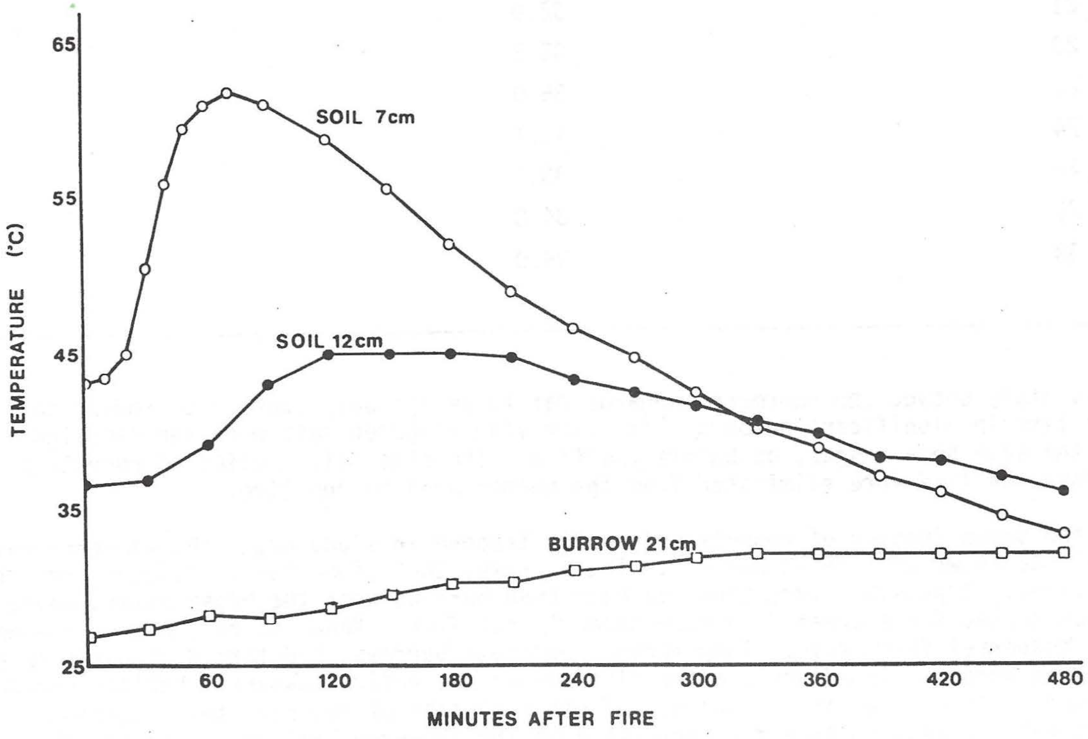

Figure 2. Temperature changes after a fire at three soil depths.

POPULATION DYNAMICS OF A RODENT COMMUNITY AFTER FIRE

I studied changes in rodent populations after a chaparral wildfire in August 1969 in the Santa Margarita Mountains, Riverside County, California. The prefire plant community was dominated by chamise *(Adenostoma fasiculatum)*, scrub oak *(Quercus dumosa)*, and hoary leaf ceanothus *(Ceanothus tomentosus)*. Rodents were live-trapped and marked for five years on a 6.8 ha grid, elevation 520 meters, with 285 trapping stations spaced at 15 meter intervals. Trapping seasons began in early fall and lasted from four to eight months.

Table 2 summarizes some results of that study. A date was selected in the middle of each trapping season, and the minimum number of rodents known to be alive on that date was calculated. During the first trapping season three species of rodents were captured, but only the Pacific kangaroo rat *(Dipodomys agilis)* was found in large numbers. The first time these kangaroo rats were captured, 2-3 months after the fire, they were found to be adults living on stable home ranges. This observation is consistent with the conclusions of the previous section, suggesting that these individuals survived the fire and remained where they had been prior to the fire. In the second year after the fire the total number of species increased to five, but the population density of all species combined increased only slightly, from 15 to 19. A large number of deer mice invaded the study area during this year. Since few deer mice established residence, however, the minimum populations size was quite small. During the third, fourth and fifth trapping seasons the popultation density of all rodent species combined increased threefold over the first two seasons. The total number of species rose from five to seven during the fourth and fifth years of trapping. Three species of *Peromyscus*, the deer mouse, cactus mouse, and California mouse all reached peak populations during the third trapping season and then rapidly declined. The brush mouse appeared for the first time, and in large numbers, during the fifth year after the fire. This was the very time when the other three species of *Peromyscus* had largely disappeared. A similar investigation by Wirtz (1977) in sourthern California chaparral showed similar, but more rapid, changes of species in the rodent community after fire. On two sites he found that trap success increased steadily for 1½ years after a wildfire and the number of species captured also increased. The Pacific kangaroo rat was the most common species overall during his study. The most notable difference between that study and mine was the common occurrence in his study of a second species of burrowing rodent, the California pocket mouse *(Perognathus californicus)*.

Other studies have reported similar results. Both Lawrence (1966) and Cook (1959) found declines in rodent population densities after chaparral fires, but densities returned to levels equal to the controls during the second year after the fires. Both found reductions in the number of California mice and pinyon mice, and increases in numbers of California pocket mice, harvest mice *(Reithrodontomys megalotis)*, and deer mice. In addition, Lawrence (1966) reported that the pinyon mice remaining in the area after the fire experienced a loss of body fat. Bell and Studinsky (1972) made comparisons between rodent communities is unburned and recently burned chaparral and found that the latter had the highest density and diversity of rodents. In unburned chaparral California mice and dusky-footed wood rats were relatively common, while chaparral burned two years earlier supported relatively large numbers of California mice and deer mice.

SMALL MAMMALS AND CHAPARRAL MANAGEMENT

Neither wildfires nor prescribed fires ever exterminate a species of small mammal from chaparral. Were this possible the frequent wildfires of the past would have long since done so. Only those species of animals that can survive periodic fires can persist in chaparral. Over the short term chaparral fires do, however, temporarily reduce population densitites and alter relative abundances in the small mammal community. Indeed, some species may even be locally exterminated or driven away from areas that have been entirely burned over. Nevertheless, burrowing species such as kangaroo rats and pocket mice do survive in numbers on fire sites, and other species continue to live in the islands of unburned vegetation that remain after chaparral fires. The extent to which animals are destroyed is related to fire intensity, with severe wildfires producing the largest number of direct deaths. The rate of recovery of the rodent community depends not only on the nature of the fire, but also on the rate of recovery of the vegetation. Vegetative recovery is influenced by a number of factors, including weather and the physical characteristics of the site, such as slope. High population densitites did not occur in the

TABLE 2. Minimum population sizes in a 6.8 ha study area for 5 trapping seasons after fire.

TRAPPING SEASON	I	II	III	IV	V
Date of Estimate Species	12/20/69	11/15/70	11/21/71	12/20/72	11/10/73
Dipodomys agilis	13	14	33	47	15
Perognathus californicus	1	1	1	1	1
Neotoma lepida		1		1	2
Peromyscus eremicus	1	1	8	6	
Peromyscus maniculatus		2	21	3	1
Peromyscus californicus			7	4	1
Peromyscus boylii					28
Reithrodontomys megalotis				1	5
TOTAL NUMBERS OF ANIMALS	15	19	70	63	53
TOTAL NUMBER OF SPECIES	3	5	5	7	7

Santa Margarita Mountains until the third year after the fire, while such densities were realized in the second year after fire in the studies of Lawrence (1966) and Cook (1959). High population densities do not indicate a condition of community stability. The Santa Margarita study showed that after five years the rodent community was still undergoing rapid changes. Furthermore, trapping I have done in chaparral older than 30 years showed that the rodent community can eventually be reduced to one or two species with very low population densities.

From this knowledge it seems that the best way to maximize population densities and species diversity of small mammals in chaparral would be to establish and maintain a mixture of age classes of brush and to avoid areas that are so old as to become, in the words of Hanes (1971), senile. On the basis of data collected over the past 27 years at the Hopland Field Station of the University of California, Longhurst (1978) concluded that only two species of small mammals will increase in chaparral older than 10 years, while 13 species of small mammals will have decreasing populations in old chaparral. The pattern of mixed age classes of vegetation is consistent with the programs of fuel management by means of prescribed fires, a method that is receiving increasing attention by chaparral land managers and landowners throughout California. Since the optimum habitat for many species of rodents occurs for only a relatively short time during post-fire recovery, the best way to fit the maximum number of rodent species into a given area is to break it up into smaller areas with different ages of shrubs. Since small mammals have small home ranges that overlap one another (Table 3), the minimum area within which populations of small mammals can be successfully managed can be as small as a patch of brush around a few trees, a small spot fire, or a short strip along the edge of a fuelbreak. Breaking a wide expanse of chaparral into numerous small patches will also maximize the ecotone between brush stands of varius ages and between brush and open areas. Ecotones between mature chaparral and areas burned or otherwise opened up provide optimal feeding areas for brush rabbits (Biswell et al., 1952, Bartholomew 1970, Quinn unpublished data). Bradford (1976) found that the activities of three out of four species of chaparral rodents were concentrated near an ecotone.

TABLE 3. Mean home range size (m^2) of rodents recaptured fiver or more times. Home ranges are calculated by the convex polygon method, using a boundary strip. The number of individuals is given in parentheses.

	YEARS AFTER FIRE					
	0-1	1-2	2-3	3-4	4-5	Mean
Dipodomys agilis	6699(5)	5032(5)	3087(11)	3561(19)	2210(2)	4017(42)
Peromyscus maniculatus		3928(2)	4754(12)	11048(2)	11258(1)	5780(17)
Peromyscus eremicus			4212(1)			4212(1)
Peromyscus boylii					4187(10)	4187(10)
Reithrodontomys megalotis					11888(2)	11888(2)
Perognathus californicus					3192(1)	3192(1)

One reason for managing chaparral to maximize densities of small mammals would be to maximize food for mammalian and avian predators. Opening up the habitat with fire may make detection and pursuit of small mammals by some predators easier than in older chaparral. At Santa Margarita I observed the greatest number of coyote and gray fox signs during the second and third years after the fire. Wirtz (1977) analyzed predator scats and pellets for 12 months before and 12 months after a chaparral wildfire and found that after the fire more birds were taken by all predators, more reptiles were taken by red-tailed hawks, and more deer were taken by coyotes. The consumption of small mammals by predators, however, either remained the same or declined slightly.

In addition to age class diversity in shrubs, physical heterogeneity is undoubtedly important in the management of small mammals. Recesses in rock outcroppings provide places where animals can take refuge during fires (Cook 1959, Lawrence 1966). Trapping for small mammals after a fire is sometimes most successful near sites that offer some protection (Lawrence 1966, Lillywhite 1977). At Santa Margarita, on the other hand, I found that a population of desert wood rats living in a rock outcrop was eliminated by the fire, but within a year after the fire the outcrop had been recolonized by the same species. Trees, when interspersed with chaparral, probably increase the number of species of small mammals present. The dusky-footed wood rat is often associated with trees (Linsdale and Tevis 1951), and the brush mouse has been live-trapped in the branches of trees (Matson 1974).

Management practices, including prescribed fires, are used in chaparral areas to establish mosaics of different vegetation types. Within these mosaics it is important to include islands of older, undisturbed vegetation. These islands act as refuges for populations of small mammals requiring heavy chaparral. As vegetation in the areas surrounding islands becomes sufficiently dense, animals from the islands will move into the developing vegetation and establish populations there. This is probably what happens after chaparral wildfires. Species of small mammals destroyed in the burned over areas survive in islands of chaparral missed by the fire. There is no other simple explantation for the sudden appearance of animals like dusky-footed wood rats, brush mice, and brush rabbits in a fire area several years after it has burned.

Populations of small mammals can be affected by the method used to prepare chaparral for prescribed fire or fuel reduction. Preparation for prescribed fire often includes cutting and piling brush, or using a bulldozer to push up windrows of brush around the margins of a standing brushfield. The study at Buckhorn Ridge showed that even though most of the Heermann kangaroo rats survived the fire, they were almost totally eliminated from the area where piles of dry brush had burned. I believe that excessive heating of the burrows near these bonfires was the cause of this population drop. Furthermore, the intense heat undoubtedly destroyed seeds at greater soil depths, making the area less attractive to foraging granivores.

Various types of machinery are used for mechanical fuel reduction in the chaparral. Most involve the use of a bulldozer with attachments such as brush rakes and rangeland disks (Roby and Green 1976). These methods, to one degree or another, mechanically disturb the upper layers of the soil. This disturbance destroys the burrow systems and underground retreats of small mammals, reptiles, and invertebrates. This complex of underground tunnels is probably not quickly reestablished. Small animals in undisturbed soil are likely to reexcavate an old tunnel that has become clogged with debris, rather than to dig a new hole. This is particularly true where it is difficult to dig in the soil. Burrow systems are often used by many generations and species of animals. Far more potential burrows are available at a given time than are actually in use. When this legacy of underground retreats is removed by mechanical soil disturbance, the underground avenue of escape from fire is eliminated and the usefullness of the area to animals that spend time underground is temporarily reduced or lost.

Fire is not a disasterous event for the chaparral rodent community. The characteristics of the rodent community at any particular time are predictable, and are a function of the structure of the plant community. Since the plant community changes continuously between periodic fires, so too does the rodent community. Fire management practices that regulate the frequency, intensity, size, and pattern of chaparral fires will also affect the rodent community.

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