AN ABSTRACT OF THE THESIS OF

Richard Wilmarth Frenzel for the degree of Master of Science

in Wildlife Science presented on November 28, 1978

Title: THE EFFECTS OF PRESCRIBED BURNING ON SMALL MAMMAL COMMUNITIES IN LAVA BEDS NATIONAL MONUMENT, CALIFORNIA

Abstract approved: Redacted for privacy

Dr. Edward E. Starkey

The effects of prescribed burning on the abundance, species composition, and reproduction of small mammals were studied over a one year period. Two burn areas were studied, one in sagebrush/bunchgrass and one in cheatgrass. The short-term effects were studied using monthly mark-recapture trapping on two treatment and two control areas totaling 9600 trap nights, with 1208 individuals captured 3650 times. The effects of the fires after a one year period were studied by continuous 15 day removal trapping at two burn and two control areas prior to burning and one year later. Removal trapping totaled 30,000 trap nights with 3994 individuals captured. Results indicated that the number of individuals actually killed in the fires was insignificant. In general, the fires had no major effects on the small mammal communities in terms of species abundance, age and sex ratios, weights and reproductive condition.

The Effects of Prescribed Burning on Small Mammal Communities in Lava Beds National Monument, California

by

Richard Wilmarth Frenzel

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed November 1978

Commencement June 1979

APPROVED:

Redacted for privacy

Professor of Wildlife Science

in charge of major

Redacted for privacy

Head of Department of Fisheries and Wildlife

Redacted for privacy

Dean of Graduate School

Date thesis is presented November 28, 1978

Typed by Clover Redfern for Richard Wilmarth Frenzel

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

Dr. Ed Starkey initiated the study and continued to provide invaluable support and aid throughout the fieldwork, data anlysis, and manuscript preparation. The cooperation, support, and assistance of Paul Haertel, Stu Coleman and the entire staff at Lava Beds National Monument allowed my fieldwork to progress smoothly. Hugh Black and Ed Hooven provided the use of live traps and gave advice regarding field methods. Rose Deering, Bruce Haak, Marylou Schnoes, Roger Schnoes, Dean Shinn, Janet Starkey, and David Zezulak generously volunteered their time during critical periods of the field work. Charles Munson and Stanley Lake assisted in portions of the data collection. Dr. Robert Anthony, Dr. Gordon Matzke, and Dr. Steve Sharrow provided critical comments on the manuscript. Kathy Hemphill provided invaluable aid in the preparation of several drafts of the manuscript.

This research was conducted under the support of U.S.D.I. National Park Service Contract Number CX-9000-6-0069.

THE EFFECTS OF PRESCRIBED BURNING ON SMALL MAMMAL COMMUNITIES IN LAVA BEDS NATIONAL MONUMENT, CALIFORNIA

I. INTRODUCTION

One of the major management objectives of the National Park Service is "maintaining, or where necessary recreating, biotic associations as nearly as possible in the condition that prevailed when the area was first visited by white men" (Leopold et al. 1963). Major changes in the plant communities have occurred at Lava Beds National Monument since approximately 1870, largely as a result of the suppression of fire (Smathers 1966, Johnson and Smathers 1974). Therefore, prescribed burning experiments were begun in the monument in 1972 to determine if this was a feasible means of changing successional trends, and to cause plant communities to revert to conditions extant in about 1850, before disturbance by white settlers. The prescribed burning program was also designed to reduce fuel loads and create natural fire breaks to reduce the possibility of future catastrophic fires.

Small mammals may have a significant influence on plant communities and succession (Ahlgren 1966, Krefting and Ahlgren 1974) and represent important prey species for avian and mammalian predators. Small mammals in the monument are also potentially important vectors of parasites and disease (Nelson and Smith 1976).

Because of the important role of small mammals in the Lava Beds ecosystem, the research described herein was designed to meet the following objectives:

1) determine the immediate and short term effects of prescribed burning on the abundance, species composition, and reproduction of the resident populations of small mammals.

2) determine the response of small mammal communities one year following prescribed burning in terms of abundance, species composition and reproduction.

The effect of fire on mammals has been studied in many habitats (Ahlgren 1966, Baker 1940, Beck and Vogl 1972, Chew and Butterworth 1959, Christian 1977, Cook 1959, Fala 1975, Krefting and Ahlgren 1974, Lawrence 1966, Stout et al. 1971, Tester 1965, and Tevis 1956). Considerable research has been done on the effects of fire on vegetation in plant communities similar to that at Lava Beds (Blaisdell 1953, Harniss and Murray 1973, Loope and Gruell 1973, Mooman 1957, and Wright and Klemmedson 1965). However, few studies of the effects of fire on small mammals have been made in habitats similar to those of Lava Beds.

This study dealt with two different prescribed burns in the northern and central portions of the monument. Concurrent research studying the effects of the fires on vegetation and monitoring burn parameters was carried out by Martin and Johnson (1976), Olson (1978), and M. Champlin and Dr. A.H. Winward, Rangeland Resources Program, Oregon State University.

II. STUDY AREA

Lava Beds National Monument was established in 1925 to preserve and protect the area's extensive volcanic deposits and the location of the Modoc Indian War of 1972-73. The monument is located in extreme northern California near Tule Lake and encompasses 18,600 hectares.

The climate of the area is temperate semi-arid. An average of 33 cm of precipitation falls each year, primarily as snow in winter and early spring. Summers are hot and dry, with daily high temperatures averaging 25°C and lows between 5° and 10°C. Summer precipitation averages less than 3.2 cm per month. Winter daily high temperatures average between 5° and 10°C, with lows between 0° and -7°C.

The geological features of the monument are the result of recent volcanic activity. The soil over most of the area consists of volcanic ash and pumice which covers old lava flows and a network of lava tubes, many of which have collapsed. The terrain is rough and uneven with cinder cones and more recent lava flows dominating the landscape (Johnson and Smathers 1974). The northern boundary of the monument is at the edge of the Tule Lake basin at an elevation of about 1220 m. The southern portion of the monument has an elevation of over 1550 m and lies at the base of the Medicine Lake highlands.

The plant communities of the monument can be categorized into three physiographic zones which are separated altitudinally (Johnson and Smathers 1974). The northern and central two-thirds of the monument (1220-1370 m) is occupied by a shrub-steppe vegetation. Dominant shrub species include big sagebrush (Artemisia tridentata), rabbitbrush (Chrysothamnus viscidiflorus and C. nauseosus) with some antelope bitterbrush (Purshia tridentata) and horse brush (Tetradymia canescens). The common native bunchgrasses include: bluebunch wheatgrass (Agropyron spicatum), needlegrass (Stipa thurberiana and S. occidentalis), Sandberg's bluegrass (Poa secunda), Idaho fescue (Festuca idahoensis) and squirreltail (Sitanion hystrix). Two exotics, cheatgrass (Bromus tectorum) and tumbling mustard (Sysimbrium altissimum) are also abundant.

The southern one-third of the monument (1370-1525 m) is predominantly occupied by a chaparral vegetation. The dominant species are: western juniper (Juniperus occidentalis), curlleaf mountain mahogany (Cerocarpus ledifolius), sagebrush and bitterbrush.

At higher elevations along the southern border of the monument the vegetation is a coniferous forest community dominated by ponderosa pine (Pinus ponderosa), with white fir (Abies concolor) and incense cedar (Libocedrus decurrens). The understory consists largely of bitterbrush and snowbrush (Ceanothus velutinus) (Schnoes 1977).

Because of intensive fire suppression in the monument since about 1925 and overgrazing by domestic livestock prior to the 1940's, mountain mahogany and bitterbrush invaded the ponderosa pine forests in the southern portion of the monument and have developed dense understory shrub communities. These shrubs along with western juniper have increased in the central portion of the monument. The original bunchgrass and sagebrush community in the northern portion of the monument has been invaded by cheatgrass and juniper while sagebrush has increased greatly (Johnson and Smathers 1974).

Fleener Burn

The Fleener burn was an area of approximately 120 hectares in the central portion of the monument (Figure 1). The site was in a shrub-steppe vegetation, dominated by sagebrush, bitterbrush and bluebunch wheatgrass. The Fleener site was burned June 23, 1976 to reduce densities of western juniper, bitterbrush and mountain mahogany. Because of the rough terrain, uneven cover, and natural lava firebreaks in the site, the fire burned unevenly and the burned area was interspersed with unburned patches of vegetation. Seventeen percent of a one hectare plot which encompassed a mark-recapture trapping ring was left untouched by the fire. Twenty-seven

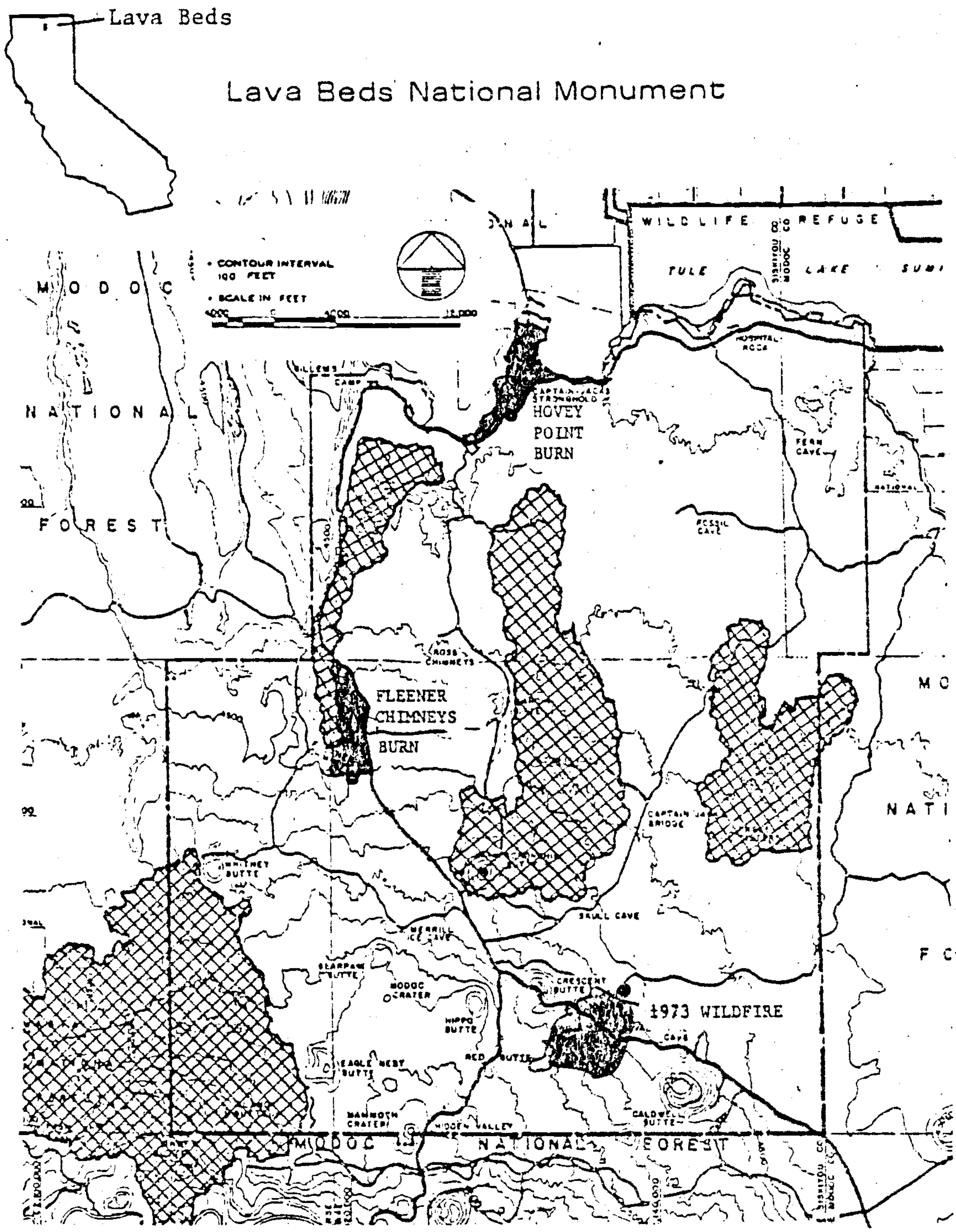


Figure 1. Lava Beds National Monument, showing the locations of the Fleener and Hovey burns (red).

percent of a four hectare plot which encompassed a removal trapping grid consisted of islands of vegetation not burned by the fire.

Hovey Burn

The Hovey burn was an area of approximately 160 hectares near the northern border of the monument (Figure 1). The vegetation of the site was primarily cheatgrass interspersed with low rock ridges supporting sagebrush and other shrubs. The area was burned June 23, 1976 in an attempt to favor native bunchgrasses and decrease the abundance of cheatgrass, an exotic. The fire burned nearly all of the cheatgrass and carried well in the thicker brush leaving only isolated patches of grass too thin to carry the fire and small unburned patches of shrubs scattered in the more rocky areas. Both a one hectare plot and a four hectare plot encompassing a mark-recapture trapping ring and a removal trapping grid, respectively, were completely burned.

The prescriptions for the Hovey burn and the Fleener burn are included in Appendix 3. Basal contact for grass species and line intercept data for shrubs prior to the burns and a year after the burns were obtained from Olson (1978) and are presented in Table 1.

Table 1. Percent cover for vegetation by basal contact (B.C.) and line intercept (L.I.) on Fleener and Hovey sites prior to burning (1976) and one year following burning (1977).

	Fleener Site[1]				Hovey Site[2]	
	1976		1977		1976	1977
Species	B.C.	L.I.	B.C.	L.I.	B.C.	B.C.
Litter	19.8	*	25.3	*	60.4	55.2
Soil	29.7	*	42.2	*	20.2	35.2
Stone	35.0	*	27.0	*	--	0.6
Bromus tectorum	6.4	*	2.7	*	13.8	4.0
Poa secunda	3.0	*	1.3	*	--	0.4
Agropyron spicatum	1.4	*	0.4	*	--	0.2
Sitanion hystrix	0.6	*	0.4	*	--	1.0
Koeleria cristata	0.5	*	--	*	--	--
Stipa thurbiana	0.7	*	--	*	--	--
Stipa spp.	2.2	*	0.2	*	--	--
Descurainia sofia	--	*	--	*	2.6	0.4
Purshia tridentata	*	4.5	*	--	*	*
Erodium cicutarium	--	*	--	*	2.0	2.6
Solidago occidentalis	--	*	0.4	*	--	--
Artemisia tridentata	*	15.0	*	0.8	*	*
Tetradymia canescens	*	0.4	*	--	*	*

* Species not measured by this method.

1. Mean of two 25 m transects (250 points) and two 10 m transects (100 points).
2. Mean of two 25 m transects (250 points).

III. METHODS

The results of small mammal sampling techniques may depend on the weather, species present, intra- and interspecific interactions, population densities and responses to traps (Gentry et al. 1966, Getz 1961, Schamberger 1965). This study used two sampling methods to accomplish the objectives. Mark-recapture trapping was conducted to assess the direct impact of the fires on the small mammals and the short term changes in the structure of the small mammal communities after burning. Removal trapping was conducted on other plots prior to burning and one year later to obtain estimates of species composition unbiased by species dominance or range, and to obtain detailed data on the animals' reproductive condition.

Mark-Recapture Trapping

Prior to burning, a trapping plot was located in each of the two areas to be burned and a control plot was designated for each treatment in an area similar in vegetation and topography that was not to be burned. The Fleener burn plot was located in a stand of sagebrush and bunchgrass-cheatgrass 150 meters inside the burn's edge. The Fleener control plot was adjacent to the treatment plot 180 meters from the burn area. The Hovey burn plot was located in a cheatgrass area 150 meters from the burn's border and a control plot was located approximately five kilometers east of the burn.

Each mark-recapture plot was a circle 97 meters in diameter with 40 stations located along the circumference. The stations were placed 7.6 meters apart and marked with individually numbered metal stakes. Two Sherman-type live traps (8 x 8 x 25 cm or 8 x 9 x 23 cm) were placed at each station, one facing east and the other west. Each station was shaded by a small A-frame shelter made of plywood to protect captured animals from extreme heat. A rabbit-sized welded wire live trap (24 x 24 x 80 cm) was placed within three meters of each odd numbered station. Welded wire traps were baited with apple slices. Sherman-type traps were baited with peanut butter and whole rolled oats.

The Sherman-type traps were pre-baited three days prior to each three day trapping period. All traps were checked and reset once each day, usually in the morning. The data recorded for captured small mammals were station number, species, sex, age (by pelage and size) and external signs of reproductive condition (mammae size, condition of vaginal opening, palpable pregnancy and position of testes). Animals were released when captured after being ear-tagged with individually numbered trout fingerling tags (Salt Lake Stamp Co., fingerling #ff). After the first three trapping periods, Peromyscus spp., Perognathus and Microtus spp. were also given a unique toe-clip because these animals occasionally lost their ear tags.

California ground squirrels (Spermophilus beecheii) caught in welded wire traps were removed from the area to prevent them from triggering the smaller Sherman traps and decreasing the number of available traps each trap day.

All four plots were trapped simultaneously, once in April 1976 and again in May before the two treatment areas were burned. The areas were trapped immediately following the burn in June and at monthly intervals through September 1976. The trapping was repeated in April and May 1977. Exact dates of trapping are included in Appendix 1. Mark-recapture sampling effort totaled 9600 trap nights with 1208 individuals captured 3650 times.

Peterson indices (Seber 1973, p. 59) were used to estimate the numbers of each species on the four areas. The first and second days of each trapping period were used as the marking period and the index calculated from the trapping results of the third day. After comparing the estimate for each species to a minimum population estimate based on the total number of different individuals captured during that period, the Peterson indices of Microtus montanus numbers were considered unreliable and minimum estimates of Microtus numbers were used instead. Peterson indices and the total number of each species caught during each trapping period are presented in Appendix 4.

Populations on the treatment areas were compared to control areas using an F ratio of residual sum of squares from full and reduced models of a curvilinear regression of the four trapping periods following the burns (Draper and Smith 1966) so that not only population levels, but their fluctuations following the fire were taken into account. The chi-square test was used to check for deviations from the expected 1:1 sex ratio for each trapping period. Two x two χ^2 contingency tables were used to test for differences in the number of immature animals, the number of reproductively active animals and the number of tags recovered after burning between treatment and control areas. Statistical hypothesis were tested at the 95% level of confidence.

Removal Trapping

Areas separate from the mark-recapture plots were selected for removal trapping. Prior to burning a trapping plot was located in each of the two areas to be burned and a control plot was designated for each treatment in an area similar in vegetation and topography that was not to be burned.

The Fleener burn plot was located in a stand of sagebrush and bunchgrass-cheatgrass approximately 220 meters inside the burn's edge. The Fleener control plot was located about 1.5 kilometers southeast of the burn.

The Hovey burn plot was located in a flat cheatgrass area approximately 325 meters within the burn's edge. The plot was bordered on two sides by rocky areas supporting sagebrush. The control plot was located in a similar area approximately four kilometers east of the burn. The plot was bordered on two sides by stands of rabbitbrush and sagebrush.

Each removal plot was a 10 by 10 station grid 137 meters (450 feet) on each side. Stations were placed 15.2 meters (50 feet) apart and marked with individually numbered metal stakes. Two Sherman-type live traps (8 x 8 x 25 cm or 8 x 9 x 23 cm) were placed at each station one facing east and the other west, totaling 200 Sherman-type traps per grid. Each station was shaded by a small A-frame shelter made of plywood to protect captured animals from extreme heat. A rabbit-sized welded wire trap (24 x 24 x 80 cm) was placed within three meters of every other station. Welded wire traps were baited with apple slices. Sherman-type traps were baited with peanut butter and whole rolled oats.

The Sherman-type traps were pre-baited three days before a 15 day trapping period to increase the rate of capture and reduce the effects of immigration (Babinska and Bock 1969). All traps were checked and reset once each day. Captures of rabbits and squirrels were recorded and then these species were released approximately 10 kilometers from the place of capture. All other small-mammals captured were sacrificed, placed in individual plastic bags, labeled with date of capture and station number, and frozen at the end of each day's trapping.

All four plots were trapped simultaneously beginning April 24, 1976 prior to the June burning. The same plots were trapped again beginning April 13, 1977 under the same moon phase as the 1976 trapping. Removal sampling effort totaled 30,000 trap-nights.

The total number of animals captured in 1976 was 2636. All animals were identified to species. The weights of 2597 sacrificed individuals were recorded to the nearest .01 gram. Sex and age were recorded for 2356 specimens. Reproductive condition and body and total lengths to the nearest mm were recorded for 1889 specimens. Males were examined externally for scrotal condition. Female specimens were examined externally for signs of lactation and then the reproductive tract was removed and examined under a 7-30 power dissecting scope for number of implantation sites, number of implanted embryos, and presence of corpora lutea.

The small mammals captured in 1977 totaled 1358, of which 1310 were sacrificed. All individuals were identified to species. All sacrificed individuals were weighed, measured and examined for age, sex, and reproductive condition.

Weather data was recorded at the Lava Beds National Monument meterological station located in the southern portion of the monument. Cloud cover was recorded morning and evening for all trapping dates.

Maximum and minimum daily temperatures for prebaiting and removal trapping days are presented in Appendix 2.

For each species the total number of individuals captured on each area during the 15 day period was used as an index of population levels. In this study large numbers of animals were removed during the first two or three days (perhaps in response to prebaiting) and thereafter the trap success fluctuated markedly, apparently in response to some environmental factors (i. e., weather conditions, moon phase). Population estimators applied to removal data using regression techniques (Overton 1971) were rejected because these methods are based on the principle that capture rate decreases as the population is decreased by removal.

Relative abundance of each species as used in this paper is the percent of the total capture of all species comprised of each species. Species diversity indices of the small mammal communities were calculated by Simpson's (1949) diversity:

$$D = 1 - \lambda$$

where

$$\lambda = \sum_{i=1}^{S} \frac{n_i(n_i - 1)}{N(N-1)},$$

n_i = number of animals in species i,

N = total number of animals, and

S = total number of species

Equitability indices were calculated by the formula:

$$\psi = \frac{E}{S}$$

where

$E = \frac{1}{\lambda}$ (MacArthur 1972).

Neotoma spp., *Sylvilagus nuttalli*, *Spermophilus beldingi*, and *Marmota flaviventris* numbers were not included in diversity or equitability calculations because even though they were caught in small numbers, trap success for these species probably was not indicative of their populations.

Age and sex ratios and numbers of animals reproductively active were compared between areas and years using $2 \times 2\ \chi^2$ contingency tables. Where multiple comparisons between years and treatment were appropriate a Bonferroni method for adjusting significance levels on separate tests was used (Neter and Wasserman 1974).

Animal weights, embryos per female and implantation sites per female were compared between areas and years using a test for contrast of means from a one-way analysis of variance (Neter and Wasserman 1974). Animals were categorized by age and sex for analysis of animal weights. Adult females were separated further into groups as pregnant, non-pregnant, and animals exhibiting implantation sites. Comparisons between treatments and controls for weights were made only within the categories. Statistical hypotheses were tested at the 95 percent level of significance.

IV. RESULTS AND DISCUSSION

Mark-Recapture Trapping

A total of thirteen different species were captured on the four mark recapture areas during the study. Four species (*Perognathus parvus*, *Dipodomys heermanni*, *Peromyscus maniculatus* and *Microtus montanus*) were caught in numbers that allowed population estimates to be calculated. The other nine species were represented by low numbers of individuals with few recaptures.

Great Basin pocket mice (*Perognathus parvus*) were trapped regularly at both the Fleener burn and control sites (Figure 2); only two individuals were trapped at the Hovey burn site and none were captured at the control. The numbers of *Perognathus* on the burn and its control fluctuated in a similar manner, both increasing through June and decreasing through the remainder of the summer. The following year numbers of *Perognathus* remained similar during the two trapping periods.

The sex ratios for *Perognathus* differed markedly from the expected 1:1 ratio in April and May of both 1976 and 1977. Captures during these months consisted almost entirely of males; only two females were captured, one in each plot in April, 1977. Spring sex ratios of trappable *Perognathus* favoring adult males are not uncommon and generally are attributed to an earlier emergence of males

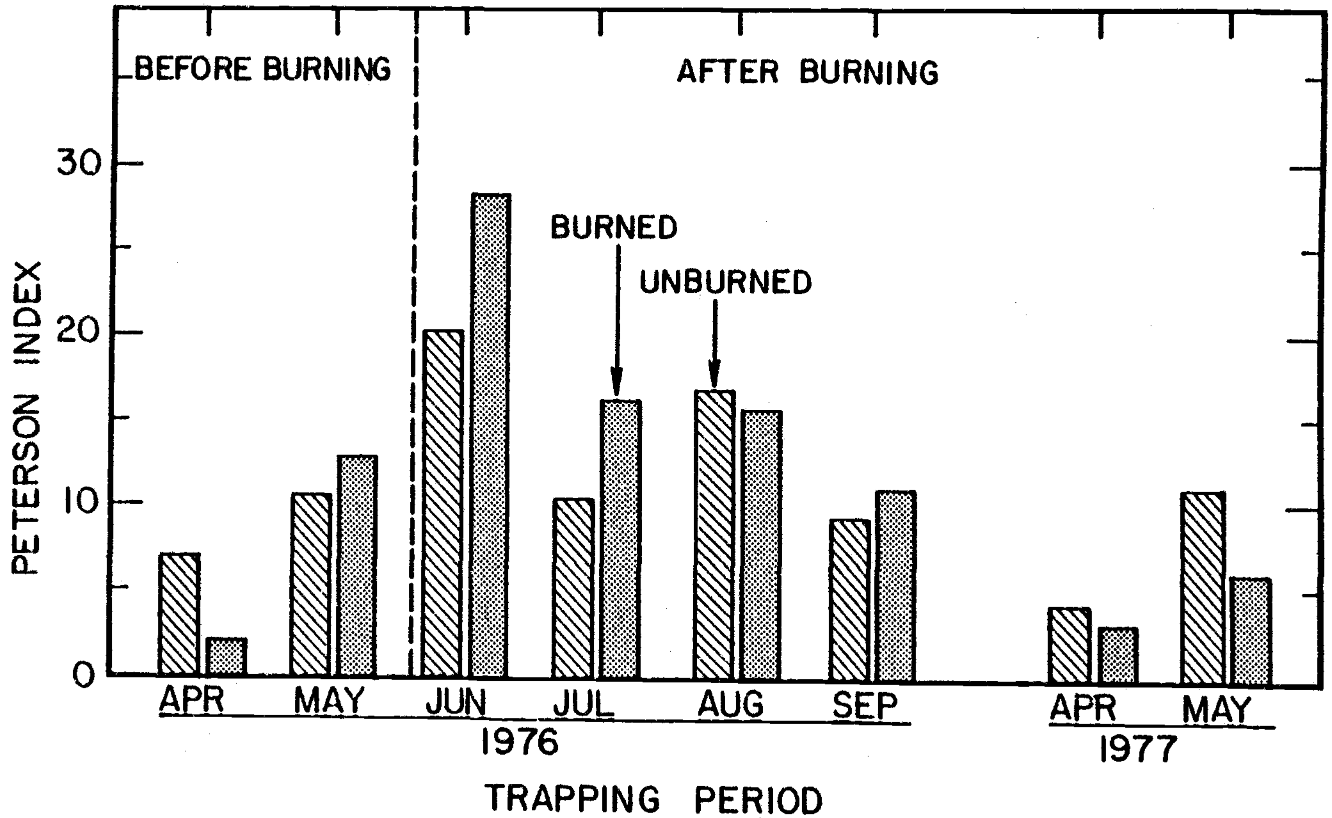


Figure 2. Peterson indices of Perognathus parvus at the Fleener sites.

from torpor (Hoffmeister 1964, O'Farrell et al. 1975). Few immature Perognathus were captured and age ratios did not differ significantly between the treatment and control.

Mark-recapture trapping indicated that the fire had no effect on Perognathus. Few other small mammal studies have been conducted on fire in habitats occupied by Perognathus parvus. However, Lawrence (1966) did find that Perognathus californicus were able to occupy the newly established grassland areas created by fire in chaparral. O'Farrell et al. (1973) reported that Perognathus parvus numbers on an area treated with herbicide did not differ from numbers on a control area.

The other heteromyid found in the area is the Heermann kangaroo rat (Dipodomys heermanni) which was trapped on all sites. Dipodomys were captured regularly at the Fleener control site in 1976 (Figure 3). In 1976, captures were lowest in April, which was the coldest trapping period (Figure 4) and perhaps prior to the emergence of a portion of the Dipodomys population. The highest number of Dipodomys were captured in May and fairly consistent trap success continued through the summer. However, in 1977 no Dipodomys were captured in April and only one individual was captured in May despite warmer temperatures in April compared to 1976 (Figure 4).

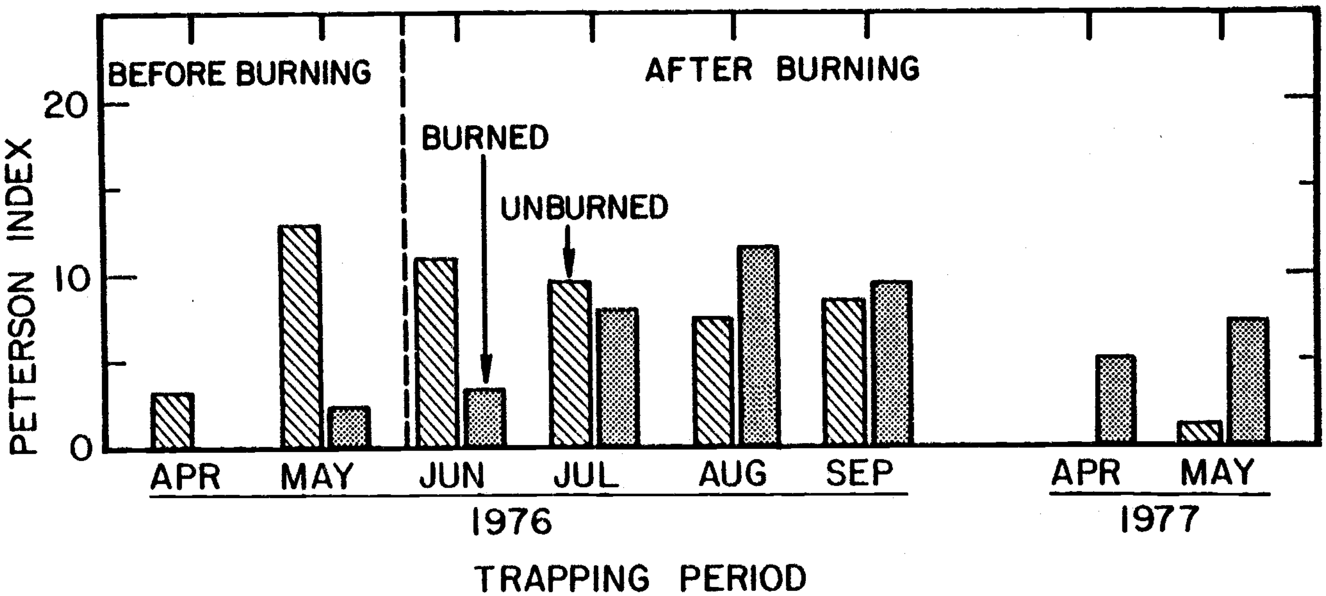


Figure 3. Peterson indices of Dipodomys heermanni at the Fleener sites.

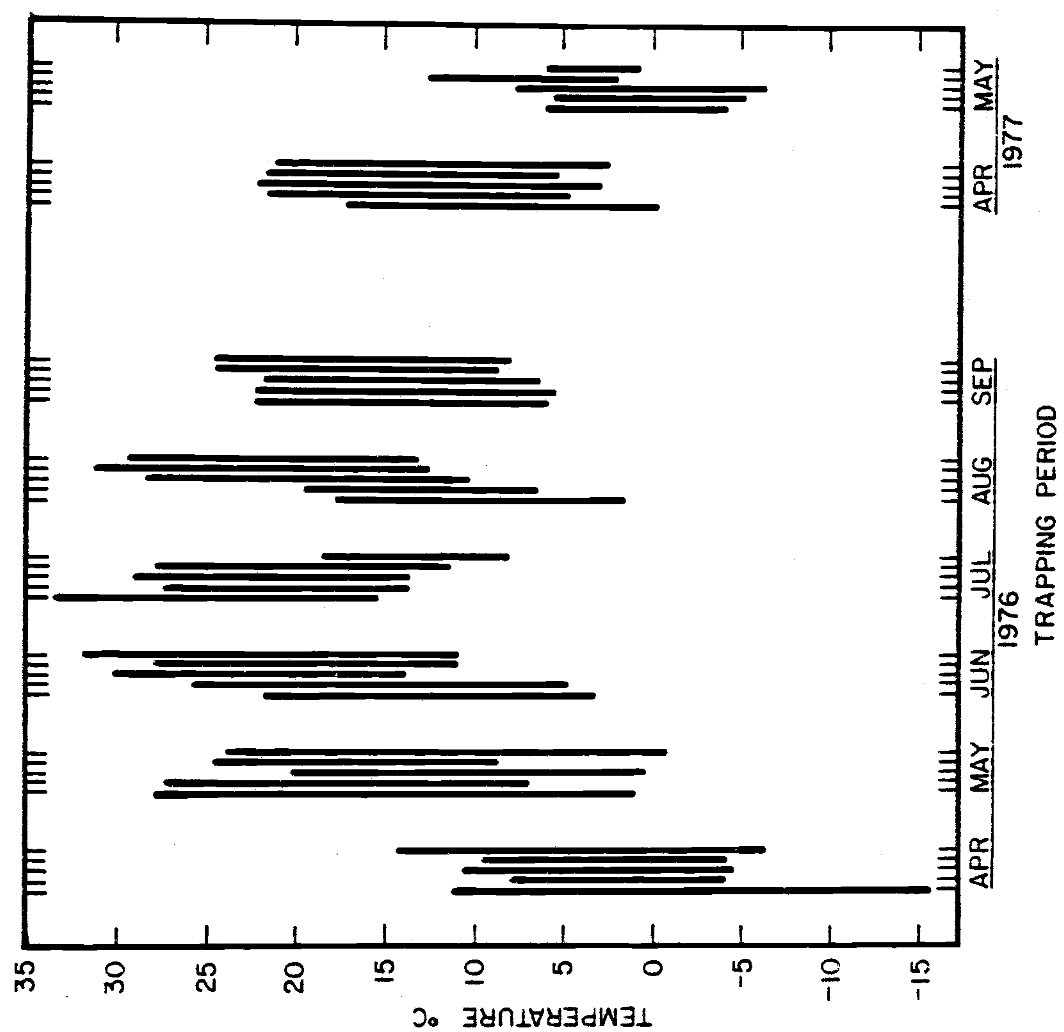


Figure 4. Maximum and minimum daily temperatures during mark-recapture pre-bait and trap days.

The Fleener burn site had only two individual Dipodomys trapped prior to burning (Figure 3). After the fire the Dipodomys showed a general increase in numbers to levels comparable to the control's by July. Dipodomys continued to be caught in similar numbers during April and May of 1977. Dipodomys numbers from the four trapping periods following the burn date show an increasing trend on the burn site that is significantly different ($p < .01$) from the controls. In 1977, nearly one year after the burn, the burn site still supported numbers of Dipodomys while only one Dipodomys was found on the control.

Captures of Dipodomys on the Hovey burn site prior to the fire were very low, with only one individual trapped in April and none in May (Figure 5). There was a marked increase in Dipodomys captured on the burn site immediately after the fire with estimates of approximately ten animals maintained through the summer. In the spring of 1977, numbers of Dipodomys on the burn site had decreased from the previous September, but were higher than the previous spring before the burn.

The Hovey control area maintained a high number of Dipodomys throughout the study (Figure 5). In the spring of 1977 numbers of Dipodomys on the control site had decreased from the previous September and were also lower than the estimated number for the spring of 1976. A comparison of the estimates on the Hovey burn and control

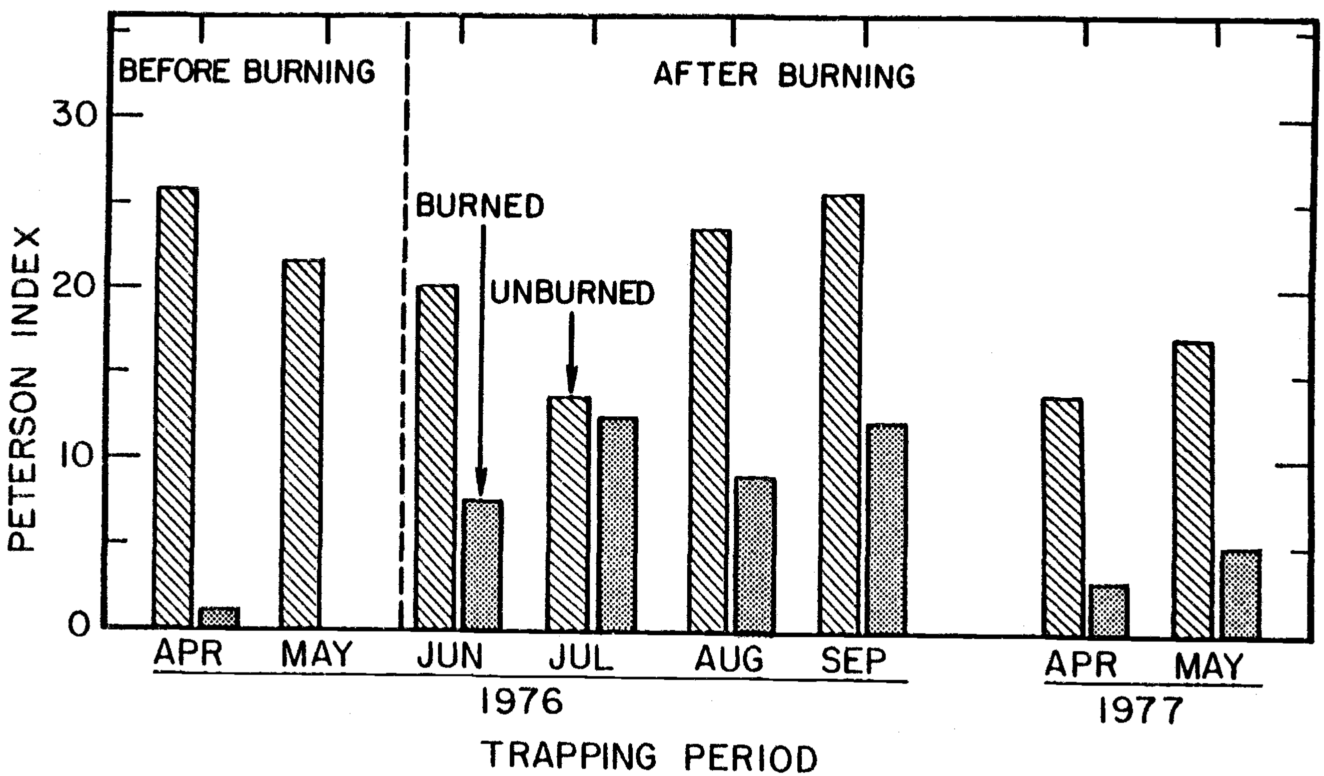


Figure 5. Peterson indices of Dipodomys heermanni at the Hovey sites.

areas after the burn did not reveal a significant difference ($p > .05$).

It appears that Dipodomys heermanni populations increased on both the Fleener and Hovey burn sites. The hypothesis that this species of Dipodomys may favor burned sites and move into these areas following a fire is supported by studies showing certain Dipodomys species favor disturbed sites (Beatley 1976a). The open areas created by the fires may attract Dipodomys heermanni whose saltatorial locomotion may be utilized most efficiently for foraging and evading predators in open country. However, the differences in preburn populations between control and treatment areas at Hovey and Fleener sites, make it difficult to draw any conclusions about the effects of these fires on Dipodomys.

Prior to burning the areas designated to be burned did not appear to support significant numbers of Dipodomys while Dipodomys were captured regularly on the control areas. Ideal control areas would have had preburn populations similar to the treatment areas. Although numbers of Dipodomys increased on the burn areas following the fires and numbers did not change on the controls, it is tenable that the increase on the burns was not a result of the burning. Increases due to dispersal or emergence may have occurred at this particular time on other unburned areas which did not previously have large numbers of Dipodomys. It appears more likely that the fires created Dipodomys habitat on areas that previously were not attractive to

Dipodomys. However, this study does not have a proper control to test this.

Peromyscus maniculatus was the most abundant rodent captured on the Fleener sites. Peterson indices indicate numbers as high as 69 on a plot (Figure 6). The monthly estimates on the two Fleener sites indicate that the populations of the areas were similar before the fire and continued to follow the same general pattern through the summer and again in the spring of 1977. The fire had no immediate effect on the *P. maniculatus* population.

Estimates of the numbers of *P. maniculatus* on the Hovey burn and control sites are presented in Figure 7. Both the burn and control plot on the Hovey sites had definite decreases in the estimated populations of *P. maniculatus* through the summer. Comparison of the curves from the population estimates following the burn does not reveal a significant difference between the treatment and control despite the marked differences in the estimates for June. In 1977 the estimated *P. maniculatus* population on the burn area increased from April to May, to a level greater than any monthly estimate from the previous year while population estimates on the control increased but not as dramatically. Comparison of the preburn population indicated that initially the control area was either not capable of supporting *P. maniculatus* populations as high as the burn areas or the populations were exhibiting asynchronous fluctuations.

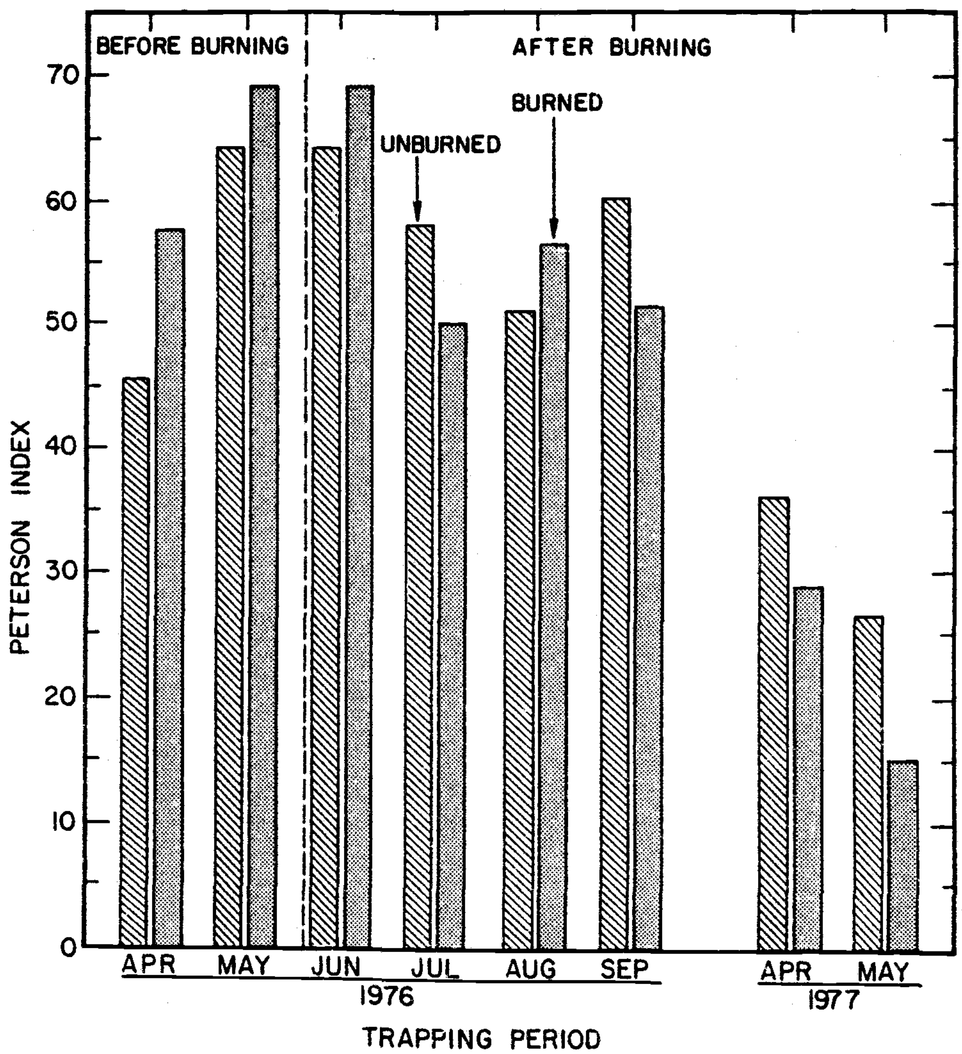


Figure 6. Peterson indices of Peromyscus maniculatus at the Fleener sites.

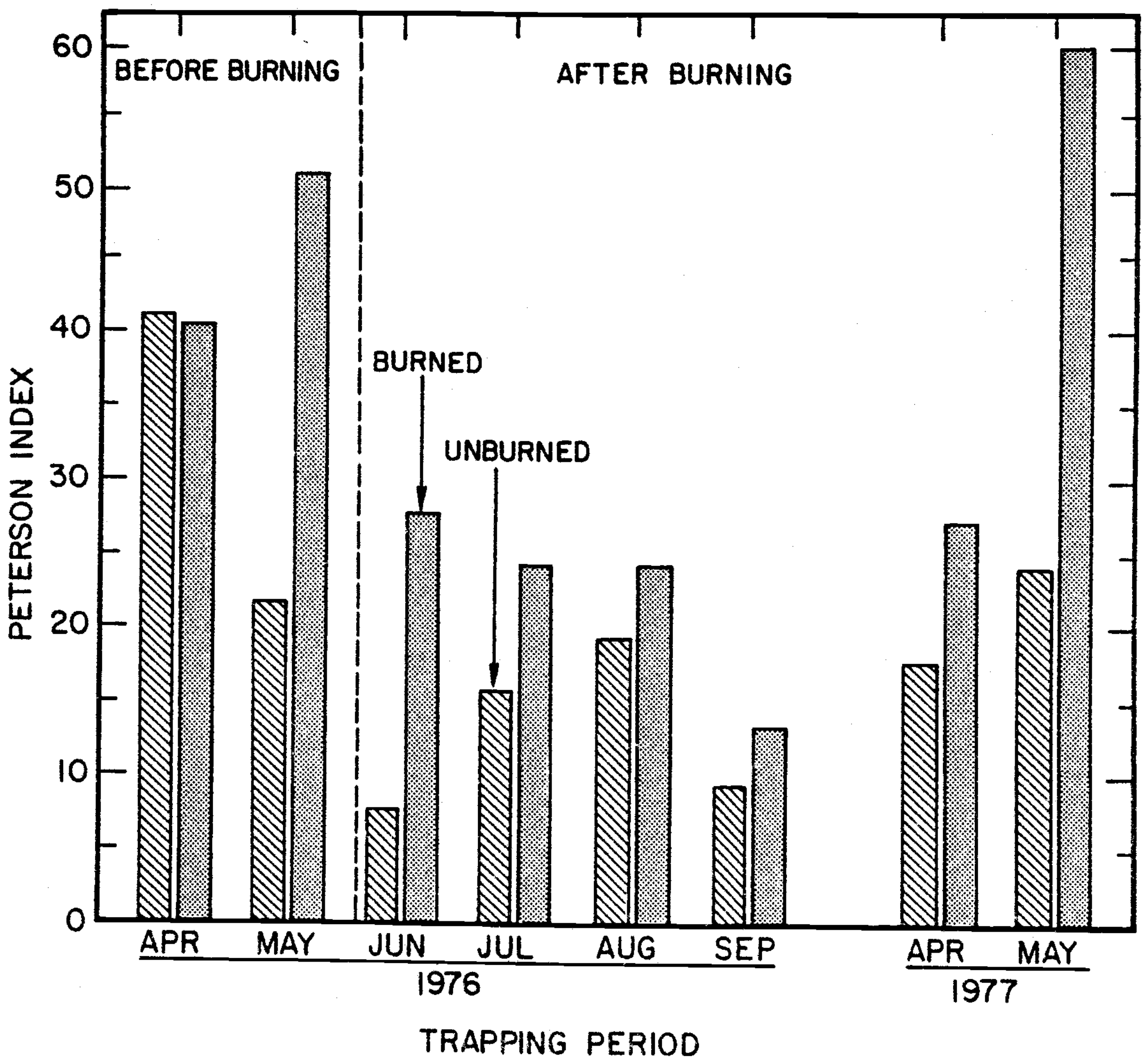


Figure 7. Peterson indices of Peromyscus maniculatus at the Hovey sites.

Sex ratios for *P. maniculatus* generally did not differ from the expected 1:1 ratio. The exception was the September ratio on the Fleener control plot, which was significantly weighted towards males which comprised 65.5 percent of the captured animals. Sex ratios for *P. maniculatus* biased towards males are common in small mammal studies and generally are attributed to larger home ranges and activity in males. However, it may be due to unbalanced sex ratios at birth (Terman and Sassaman 1966) or differential mortality.

Age ratios and number of male *P. maniculatus* that were scrotal did not differ between treatments and controls. Lawrence (1966) reported that after fire in chaparral the number of immature *Peromyscus truei* increased owing to the reduction in the number of resident adults which served to stimulate the reproductive rate. In this study there was neither an increase in immature *P. maniculatus* nor a reduction in resident adults.

The number of female *P. maniculatus* that were reproductively active did not differ between animals examined on the Hovey burn and its control. Significant differences in numbers of female *P. maniculatus* reproductively active between the Fleener burn site and its control occurred twice. In May, 1976, prior to burning, 89 percent of the adult females were reproductively active on the control and 53 percent were reproductively active on the treatment plot ($p < .01$). There were no differences for the remainder of the year. In April of

1977, 6 of 13 females were reproductively active on the control and 1 of 12 was active on the burned area. However, there was no difference between the areas one month later in May.

As an indication of how many P. maniculatus were lost in the fires, or emmigrated from the areas as a result of the burns, the proportion of animals tagged in April and recovered in May when no burn occurred was compared to the proportion of animals tagged in May and recovered in June, immediately after the fires. These comparisons between treatments and controls showed that the recovery of tagged animals was independent of burning.

A study by Howard et al. (1959) outlined some of the factors essential for survival of wildlife in brush burns. They found that wildlife could escape lethal temperatures by hiding in safe habitat or burrowing below the intense heat. The Hovey burn was not a particularly hot burn and it passed through the grassland fairly quickly. The Fleener burn which had a higher fuel load burned longer and hotter in places. However, it also afforded more rocky areas for protection and islands of unburned vegetation for escape. It appears that few small mammals were killed by the fire itself.

Other studies have shown that populations of P. maniculatus and other Peromyscus spp. increase immediately or shortly after a burn (Ahlgren 1966, Black and Hooven 1974, Fala 1975, Lawrence 1966, Sims and Buckner 1972). However, most of these studies dealt with forest fires or slash burns with greater fuel loads than the fires in the shrub-steppe country of Lava Beds. Tester (1965) reported that in an oak savanna, recovery of tagged animals following a fire was very low. Tevis (1956) studying Douglas-fir slash burns reported increases of P. maniculatus after an initial elimination of resident mice. Cook (1959) reported similar results. Stout et al. (1971) attribute these increases in P. maniculatus to an increased food source in the form of seeds and insects. Tevis (1956) believed the immediate increase in P. maniculatus after burning was due to a vacuum in small mammal territories created by the killing of resident mice. Stickel (1946) demonstrated the influx of small mammals into depopulated areas.

P. maniculatus numbers in this study did not change markedly immediately following the burns. It appears that few resident mice were destroyed in the fires and that normal populations were maintained without any marked immigration or emmigration.

Four Microtus were caught on the Fleener burn site and control during the study. M. montanus were trapped regularly on the Hovey sites in April and May (Figure 8). Immediately following the burn in June, no M. montanus were caught on the burned site and only one individual was trapped on the control. No M. montanus were trapped through the summer on either site. M. montanus were trapped on both the treatment and control in April and May 1977, but at lower

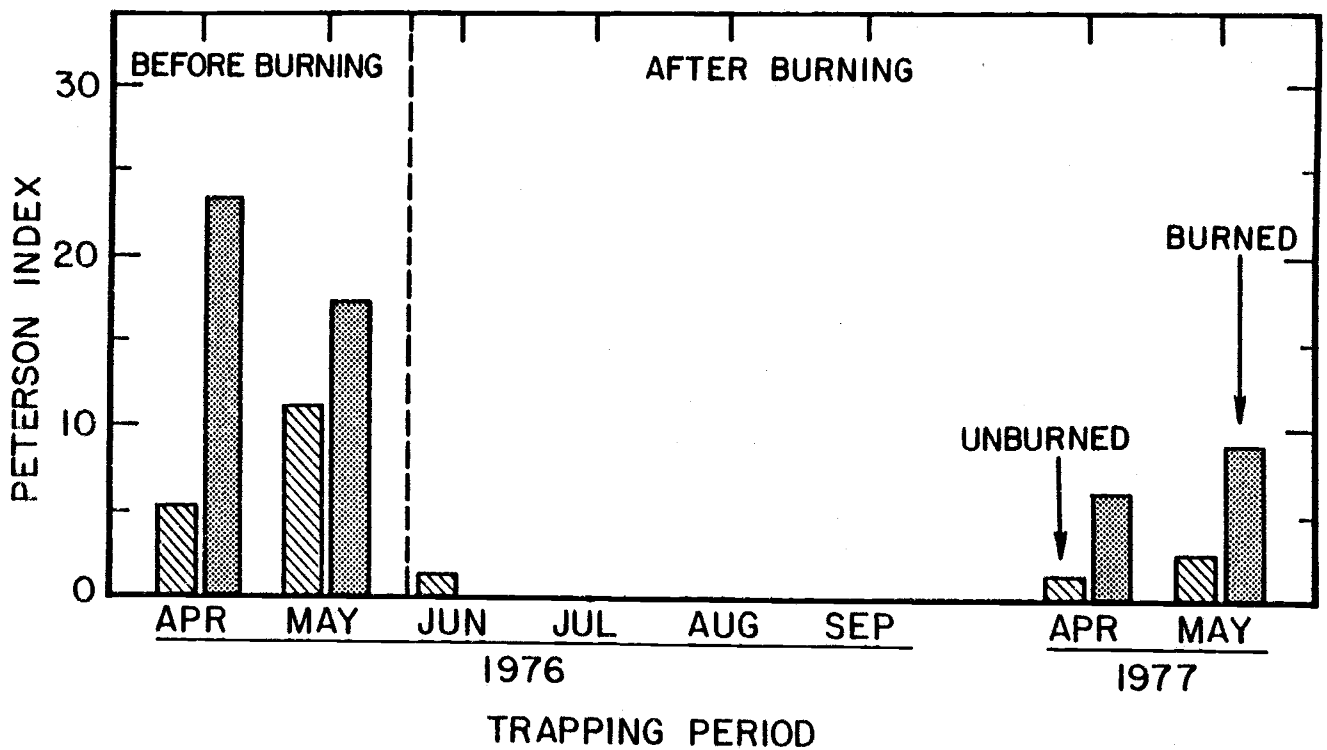


Figure 8. Total number of different Microtus montanus caught during each trapping period at Hovey sites.

levels than the previous spring. There were no differences between the burn and control areas for age and sex ratios or the reproductive status of *Microtus*.

Little information is available regarding the effects of fire on *Microtus montanus*. Sims and Buckner (1972) reported that *Microtus pennsylvanicus* and *Clethrionomys gapperi* favored control areas over burned plots and that *Microtus* numbers on the burned plot did not recover until the autumn of the second year following the fire. Tester (1965) reported that *Clethrionomys gapperi* increased in burned areas after an initial decrease. Fala (1975) reported that herbivores remained low on an area the first year following a fire. Cook (1959) reported that numbers of *Microtus californicus* were initially depleted following a fire but reached densities consistent with controls after one year. Cook concluded that *Microtus* require at least one year's accumulation of mulch to afford cover following a burn.

The results of this study are not conclusive on the effect of burning on *M. montanus*, because so few captures were made on either the control or the treatment following the fire. Whether the *Microtus* populations actually decreased drastically in the summer months or they became untrappable is unknown. *M. montanus* may decrease their activity due to heat stress, or because little cover is available for runways after the spring greenup.

Cottontail rabbits (Sylvilagus nuttali) were trapped on both the Flenner burn and control site before and after the burn date (Figure 9). The increase in Sylvilagus captured on the control area immediately following the burn and the capture of three rabbits on the control in 1977, while none were caught on the burn, indicate that this species either was not as abundant on the burn or was less trap susceptible there. However, the number of this species trapped was too low to draw any conclusions about their populations.

Beldings ground squirrels (Spermophilus beldingi) were trapped on the Hovey burn site which was in the vicinity of a belding's colony. Captures were limited primarily to May and June 1976 and April and May 1977 when the squirrels were not hibernating or estivating. There were too few captures and no control colony to allow speculation on the effects of the fire on this species.

California ground squirrels (Spermophilus beecheyi) were captured in small numbers in welded wire traps at the Fleener sites (Figure 10). S. beecheyi were captured on both the treatment and control prior to the burn dates. In June immediately following the burn two S. beecheyi were removed from the control plot and none were removed from the burn area. No S. beecheyi were captured during July and August. Six, twelve, and two S. beecheyi were removed from the burned plot in September 1976, April 1977, and May 1977 respectively, while none were captured on the control. It

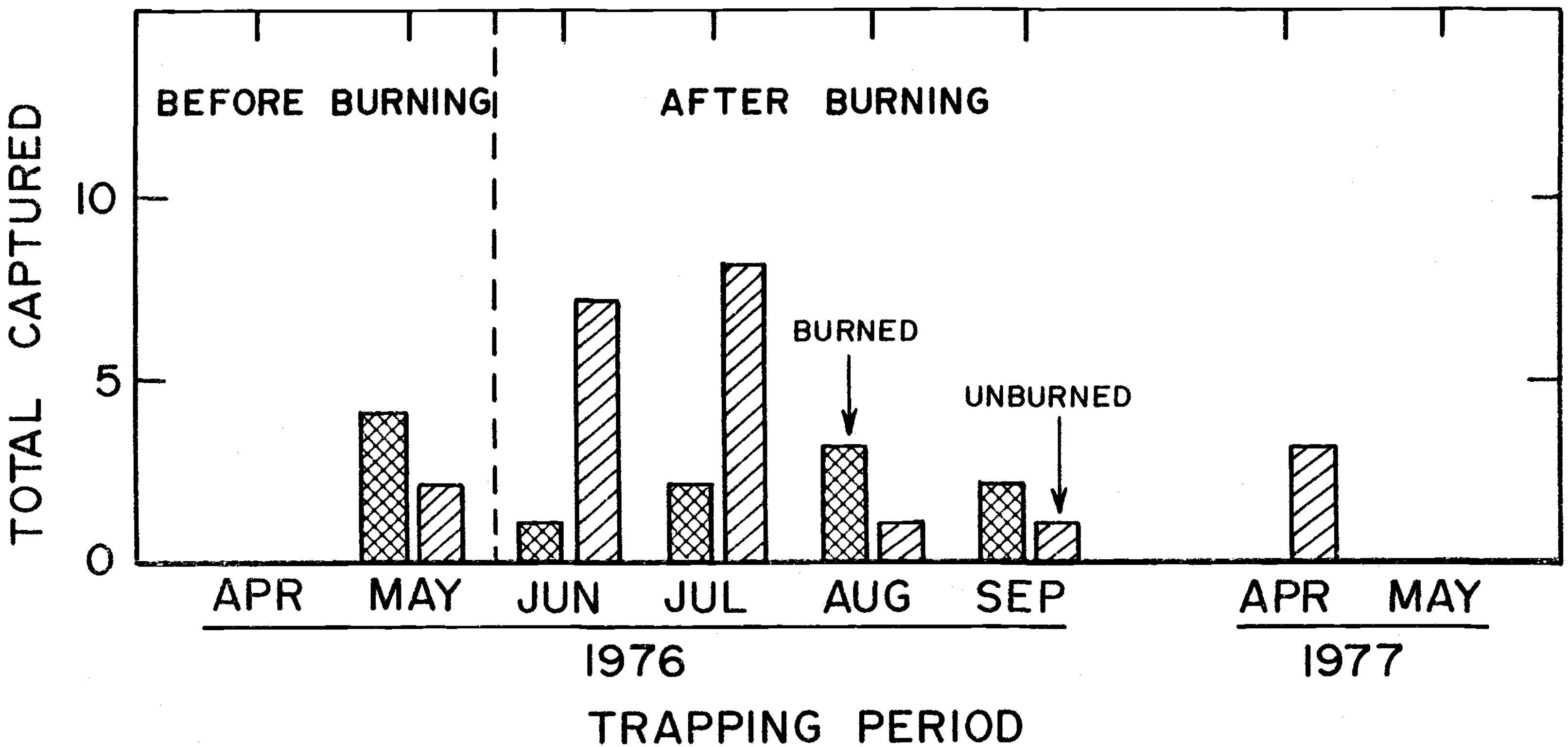


Figure 9. Total number of Sylvilagus nuttali captured during each trapping period at the Fleener sites.

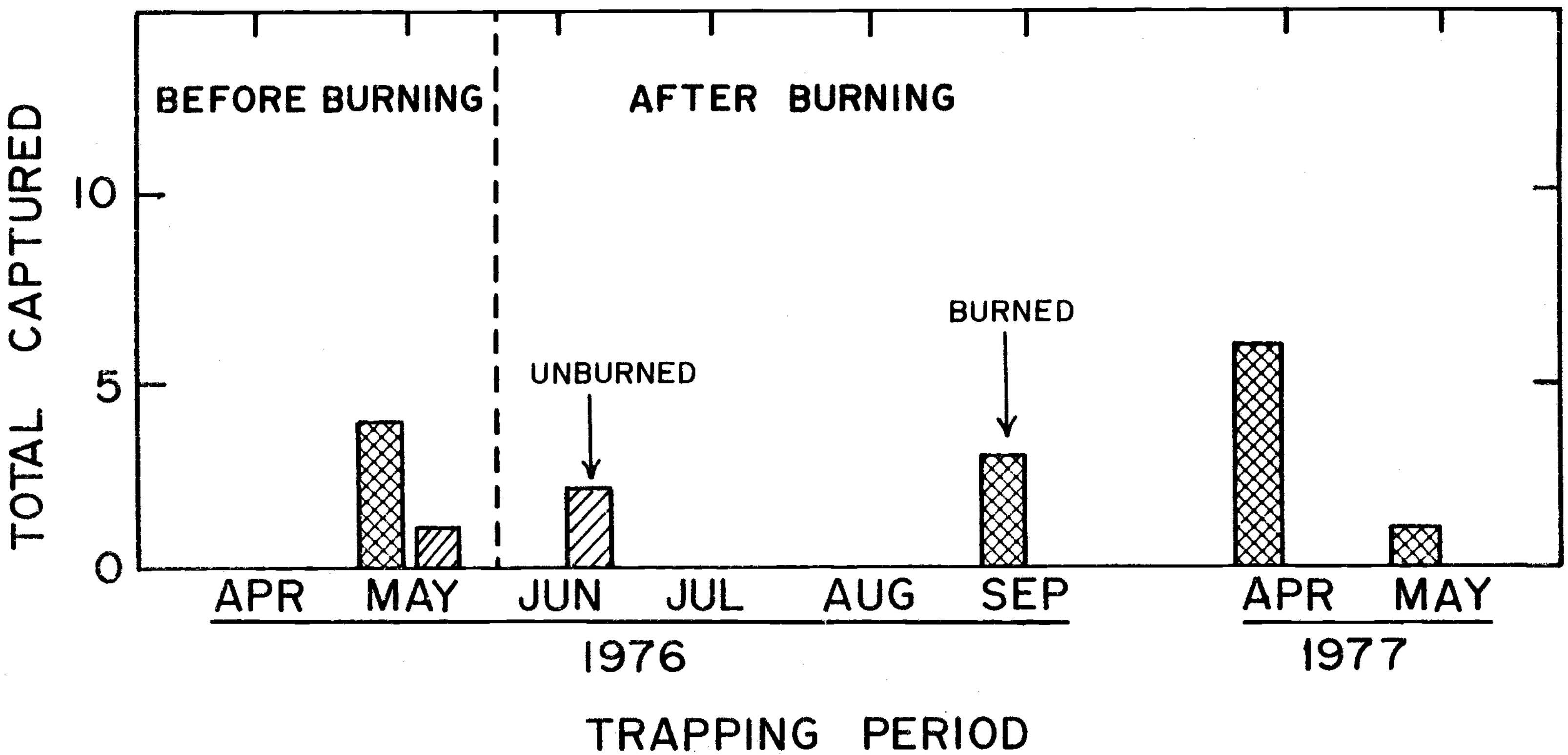


Figure 10. Total number of Spermophilus beecheyi removed from the Fleener sites during each period of mark-recapture trapping.

appears that *S. beecheyi* favor the burned area or were more trap susceptible there. Little information is available regarding *S. beecheyi* and fire. Beck and Vogl (1972) reported that *S. tridecemilineatus* responded favorably to the grasslands created by fire in brush prairie savanna.

An individual western harvest mouse (*Reithrodontomys megalotis*) was captured twice in the Hovey control plot in 1976 while none were trapped on the burn plot (Figure 11). In April and May, 1977 a single *Reithrodontomys* was captured on the control and eight *Reithrodontomys* were captured on the burn plot.

Lawrence (1966) reported that *R. megalotis* were able to occupy the newly established grassland areas created by fire in chaparral. Cook (1959) reported that in a grassland area burned in October, *R. megalotis* showed an initial extirpation and began to invade the burn in the early summer of the first year during maximum seed production. Cook reported that in burned brush areas *Reithrodontomys* were initially extirpated and then increased in numbers greater than those found on the control.

Incidental species which were represented in many cases by only one captured individual were *Sorex vagrans*, *Eutamias amoenus*, *Peromyscus crinitus*, *Neotoma cinerea* and *Mus musculus*. Too few data were collected to make any conclusions about the effects of the fires on these species.

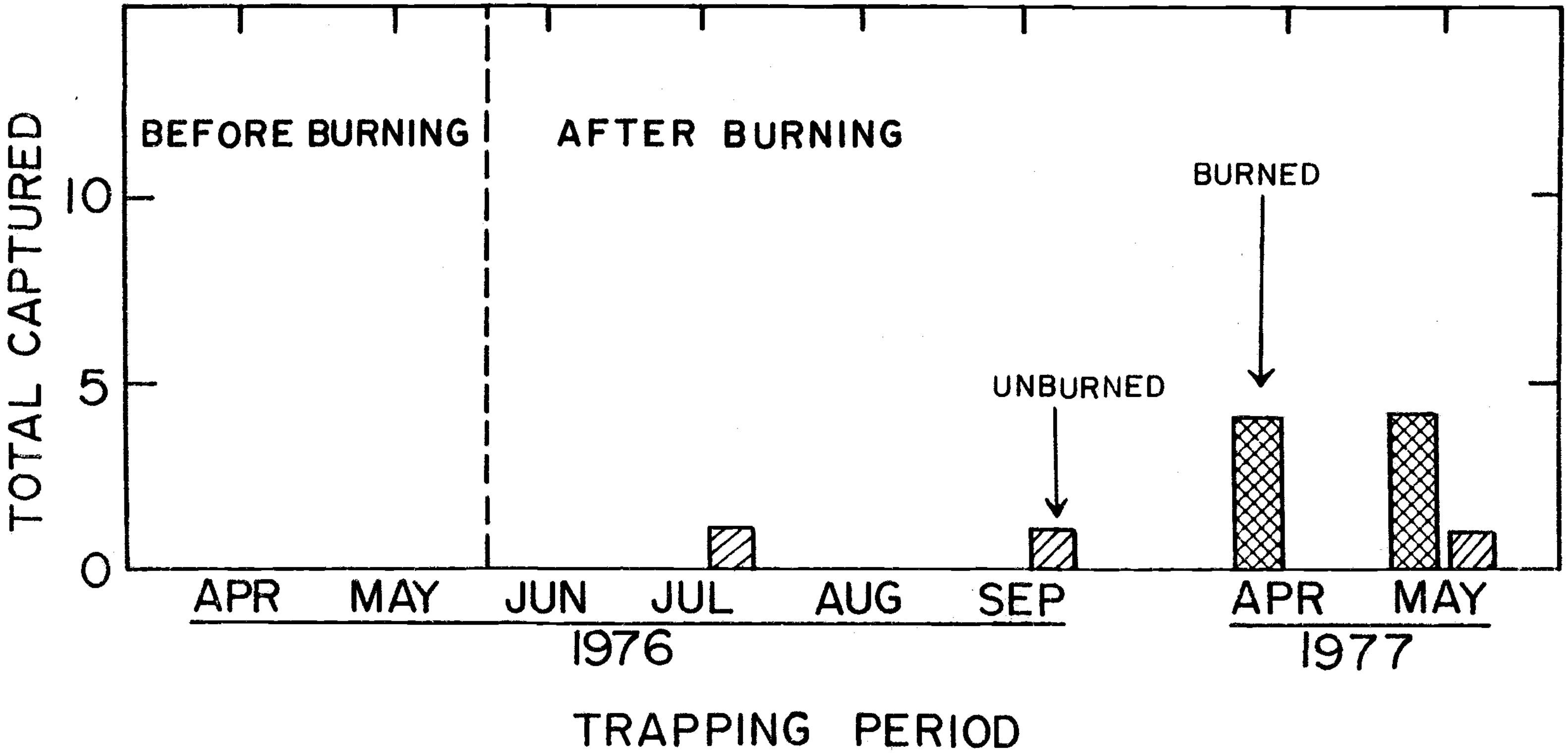


Figure 11. Total number of individual Reithrodontomys megalotis captured during each trapping period at Hovey sites.

Removal Trapping on Fleener Sites

The total number of each species captured at the Fleener burn and control sites in 1976 before the burn and one year later in 1977 is shown in Table 2. In 1976 eleven species were captured on the treatment and ten were caught on the control. The following year ten species were caught on the treatment area and eight were caught on the control. The total number of animals captured on the areas decreased from 1976 to 1977. Total captures on the burn decreased from 310 to 186 and the total number of animals captured on the control decreased from 384 in 1976 to 148 in 1977.

Diversity and equitability indices were nearly the same on the Fleener burn and control areas and did not change markedly from preburn to post burn (Table 3). Diversity and equitability were low on the areas due to the predominance of one species (Peromyscus maniculatus) in the community. Approximately 70 percent of the total captures on the burn and control sites were P. maniculatus both in 1976 and 1977.

The relative abundance of each species on the Fleener sites was consistent from 1976 to 1977 for most species (Table 2). Relative abundance on the control grid changed one percent or less for each species except Dipodomys heermanni which changed from 9.4 percent in 1976 to 5.4 percent of the total in 1977. Eight Dipodomys

Table 2. Total number of individuals (n_i) and relative abundance (p_i) of each species caught during removal trapping.

	Fleener Burn				Fleener Control				Hovey Burn				Hovey Control			
	1976		1977		1976		1977		1976		1977		1976		1977	
	n_i	p_i	n_i	p_i	n_i	p_i	n_i	p_i	n_i	p_i	n_i	p_i	n_i	p_i	n_i	p_i
Sorex trowbridgii	1	0.3	0	0	3	0.8	0	0	0	0	0	0	0	0	0	0
S. merriami	1	0.3	0	0	0	0	0	0	0	0	0	0	1	0.2	0	0
*Sylvilagus nuttalli**	3	-	1	-	2	-	1	-	1	-	2	-	0	-	0	-
*Marmota flaviventris**	0	-	0	-	0	-	0	-	3	-	0	-	1	-	0	-
*Spermophilus beldingi**	0	-	1	-	0	-	0	-	0	-	0	-	7	-	23	-
S. beecheyi	7	2.3	14	7.6	5	1.3	1	0.7	0	0	0	0	0	0	0	0
Eutamius amoenus	7	2.3	4	2.2	0	0	0	0	0	0	0	0	0	0	0	0
Perognathus parvus	40	13.1	17	9.2	48	12.6	19	12.9	16	1.3	10	1.2	1	0.2	0	0
Dipodomys heermanni	8	2.6	5	2.7	36	9.4	8	5.4	79	6.2	53	6.3	135	20.5	40	25.6
Reithrodontomys megalotis	0	0	0	0	2	0.5	3	2.0	12	0.9	18	2.1	6	0.9	17	10.9
Peromyscus crinitus	21	6.9	3	1.6	0	0	0	0	0	0	0	0	0	0	0	0
P. maniculatus	210	68.9	138	75.0	282	73.8	110	74.8	850	66.8	578	68.6	349	53.1	78	50.0
*Neotoma fuscipes**	0	-	0	-	1	-	0	-	0	-	0	-	0	-	0	-
*N. cinerea**	2	-	0	-	0	-	0	-	0	-	1	-	0	-	0	-
Laguras curtatus	0	0	1	0.5	0	0	0	0	0	0	0	0	0	0	2	1.3
Microtus montanus	6	2.0	2	1.1	1	0.3	3	2.0	303	23.8	180	21.4	143	21.8	13	8.3
M. longicaudus	4	1.3	0	0	5	1.3	3	2.0	12	0.9	1	0.1	16	2.4	0	0
Mus musculus	0	0	0	0	0	0	0	0	0	0	2	0.2	6	0.9	6	3.8
Total	310		186		384		148		1276		845		665		179	

*Species not included in calculations for diversity, equitability, or species number.

represented 2.6 percent of the total animals captured on the burn grid in 1976 and in 1977 five Dipodomys were caught, comprising 2.7 percent of the total captures.

Table 3. Total number (N), diversity (D), equitability (ψ), and number of species (S) of small mammals captured at burn and control areas during removal trapping. Numbers of Sylvilagus, Marmota, Spermophilus beldingi, and Neotoma were not used in the calculations.

	Fleener				Hovey			
	Burn		Control		Burn		Control	
	1976	1977	1976	1977	1976	1977	1976	1977
N	305	184	382	147	1272	842	657	156
D	.500	.422	.430	.420	.493	.479	.628	.664
ψ	.201	.217	.220	.247	.329	.274	.336	.504
S	10	8	8	7	6	7	8	6

The relative abundance of P. maniculatus on the Fleener burn grid increased from 68.9 to 75 percent. The captures of P. crinitus on the burn dropped from 21 animals in 1976 to only three the follow-year. However, no captures of P. crinitus took place on the control in either year. Relative abundance of Perognathus decreased 3.9 percent. Spermophilus beecheyi captures increased on the burn grid from 7 in 1976 to 14 in 1977 while they decreased on the control.

Ages, weights and information on reproduction for Perognathus parvus captured on the Fleener sites are presented in Table 4. Sex ratios for Perognathus parvus differed markedly from the expected

Table 4. Ages, weights and reproductive statistics of *Perognathus parvus* removed from Fleener sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Fleener Burn		Fleener Control	
	1976	1977	1976	1977
N	40	17	48	19
% imm.	0	0	2.1 (1)	0
% ♂♂	85.7 (30)	94.1 (16)	77.5 (31)	100.0 (19)
$\bar{x}$ ♂ wgt.	17.5 ± 0.8	15.9 ± 0.9	18.6 ± 1.0	16.1 ± 0.8
% ♂♂ scrotal	3.3 (1)	18.8 (3)	22.6 (7)	26.3 (5)
$\bar{x}$ wgt. non-gravid ♀♀	13.0 ± 1.0	13.3	13.9 ± 1.3	--
% ♀♀ gravid	25.0 (1)	0	14.3 (1)	0
$\bar{x}$ wgt. gravid ♀♀	15.2	--	13.5	--
% ♀♀ w/implant. sites	50.0 (2)	100.0 (1)	57.2 (4)	0
$\bar{x}$ wgt. ♀♀ w/implant. sites	14.6	13.3	13.7 ± 0.4	--
Implant. sites per ♀	7.0	5.0	10.0	--
% ♀♀ with corpora lutea	0	0	0	--
% ♀♀ lactating	25.0 (1)	0	14.3 (1)	--
% ♀♀ repro. active	25 (1)	0	14.3 (1)	--

1:1 ratio on both areas in 1976 and 1977. However, there were no differences between the treatment and control ($p > .05$). Too few female Perognathus were captured for statistical analysis of weights or reproduction. Females comprised only 10 percent of the total Perognathus captured during the study. However, as previously discussed, spring sex ratios of Perognathus favoring adult males are not uncommon.

There was no difference between the treatment and the control for either age ratios of Perognathus of the number of scrotal males ($p > .05$). Weights of adult males decreased from 1976 to 1977 on both the treatment and control areas. There was no difference between the treatment and control for weights of adult male Perognathus ($p > .05$).

Weights of adult male Dipodomys did not differ between the treatment and control areas from 1976 to 1977 (Table 5). Too few Dipodomys were captured to draw conclusions about reproductive activity of males or to make any comparisons for females.

There were no differences between the Fleener burn and control sites for sex and age ratios of Peromyscus maniculatus (Table 6). Sex ratios on both areas shifted from approximately 64 percent males in 1976 to nearly a 1:1 ratio in 1977. Sex ratios for P. maniculatus favoring males are common in small mammal studies (Terman and Sassaman 1966). Stickel (1946) reported that for

Table 5. Ages, weights and reproductive statistics of Dipodomys heermanni removed from Fleener sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Fleener Burn		Fleener Control	
	1976	1977	1976	1977
N	8	5	36	8
% imm.	0	0	0	0
% ♂♂	71.4 (5)	60.0 (3)	69.4 (25)	65.2 (5)
$\bar{x}$ ♂ wgt.	78.3 ± 12.6	91.8 ± 8.7	82.2 ± 4.14	87.2 ± 7.2
% ♂♂ scrotal	60.0 (3)	66.7 (2)	79.2 (19)	100.0 (5)
$\bar{x}$ wgt. non-gravid ♀♀	59.5	84.3	59.3 ± 11.1	83.3 ± 9.1
% ♀♀ gravid	50.0 (1)	50 (1)	81.1 (9)	0
$\bar{x}$ wgt. gravid ♀♀	69.2	85.4	83.1 ± 4.9	--
Embryos per ♀	3.0	3.0	3.4 ± 0.3	--
% ♀♀ w/implant. sites	50.0 (1)	50 (1)	81.8 (9)	0
$\bar{x}$ wgt. ♀♀ w/implant. sites	69.2	85.4	83.1 ± 4.9	--
% ♀♀ with corpora lutea	50.0 (1)	50 (1)	81.8 (9)	0
% ♀♀ lactating	0	0	0	0
% ♀♀ repro. active	50.0 (1)	50 (1)	81.8 (9)	0

Table 6. Ages, weights and reproductive statistics of *Peromyscus maniculatus* removed from Fleener sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Fleener Burn		Fleener Control	
	1976	1977	1976	1977
N	210	138	282	110
% imm.	2.9 (6)	8.0 (11)	3.9 (11)	10.0 (11)
% ♂♂	63.8 (132)	50.0 (69)	64.4 (174)	56.4 (62)
$\bar{x}$ ♂ wgt.	20.1 ± 0.5	18.7 ± 0.6	19.9 ± 0.4	19.7 ± 0.8
% ♂♂ scrotal	59.4 (57)	67.7 (44)	53.4 (78)	69.0 (40)
$\bar{x}$ wgt. non-gravid ♀♀	18.4 ± 1.0	18.1 ± 0.7	18.9 ± 0.7	18.2 ± 1.2
% ♀♀ gravid	24.1 (13)	12.9 (8)	21.4 (18)	19.5 (8)
$\bar{x}$ wgt. gravid ♀♀	21.4 ± 1.4	21.0 ± 1.8	23.1 ± 1.5	22.1 ± 2.3
Embryos per ♀	4.1 ± 0.3	5.1 ± 0.8	4.3 ± 0.5	4.5 ± 0.5
% ♀♀ w/implant. sites	14.6 (6)	29.8 (17)	22.7 (15)	33.3 (11)
$\bar{x}$ wgt. ♀♀ w/implant sites	21.7 ± 1.2	19.9 ± 1.6	22.7 ± 1.1	21.0 ± 1.3
Implant. sites per ♀	4.8 ± 1.9	6.1 ± 1.8	4.9 ± 0.6	4.6 ± 0.7
% ♀♀ with corpora lutea	37.0 (20)	45.2 (28)	26.2 (22)	51.2 (21)
% ♀♀ lactating	5.6 (3)	9.7 (6)	6.0 (5)	7.3 (3)
% ♀♀ repro. active	42.6 (23)	54.8 (34)	32.1 (27)	53.7 (22)

P. leucopus a larger number of adult males than females moved into a depopulated area and she attributed this to larger home ranges and a greater activity for males than females. Fewer animals were captured in 1977 indicating smaller populations. The influx of P. maniculatus caused by removal of resident animals in 1977 compared to 1976 would not have been as great, and the unbalanced sex ratios of immigrating animals would not have influenced the total sex ratio to the degree that it probably did in 1976. The number of immature P. maniculatus increased on both the burn and control plots from 1976 to 1977.

The number of male P. maniculatus that were scrotal was larger in 1977 than in the first year on both Fleener sites with no differences between the treatment and control. The number of P. maniculatus on the Fleener sites that exhibited pregnancy, lactation, or implantation sites did not differ between the burn and control plots. The number of females with corpora lutea increased significantly ($p < .025$) on the control area from 1976 to 1977. The number of females with corpora lutea also increased on the burn plot, but not significantly ($p > .05$). The number of females with corpora lutea did not differ between the treatment and control area in either year.

A one-way analysis of variance comparing treatment and control did not reveal a significant effect of the fire on litter size of P. maniculatus as determined by embryos per pregnant female or implantation sites per female. However, embryos per female increased between 1976 and 1977 on the Fleener burn (t test, $p < .025$).

There was not a significant effect of the fire on weights of *P. maniculatus*. Weights of adult males decreased from 1976 to 1977 on the Fleener burn plot ($p < .001$) while no change took place on the control, but comparisons from analysis of variance do not reveal a significant effect of the fire [$t(417\ d.f.) = 1.94$, $t_{.05}(\infty d.f.) = 1.96$].

Removal Trapping on Hovey Sites

The total number of each species captured at the Hovey burn and control sites in 1976 before the burn and one year later in 1977 is shown in Table 2. In 1976 eight species were caught on the treatment area and ten were caught on the control. The following year nine species were caught on the burn and seven were caught on the control. Trap success was lower in 1977 compared to 1976. Total captures on the Hovey burn site decreased from 1276 to 845 and on the control site total captures decreased from 665 in 1976 to 179 in 1977.

Diversity and equitability were lower on the Hovey burn site than on the control site both before and after burning (Table 3). These higher values on the control are due to the relatively lower importance of P. maniculatus which comprised approximately 50 percent of the catch on the control during both years and comprised over 66 percent of the catch on the burn plot. The relative abundance of each species changed very little on the burn site from 1976 to 1977. A decrease in Microtus longicaudus and an increase in Reithrodontomys megalotis on the burn were parallelled on the control. Despite the decreased number of species the diversity index on the control is higher in 1977 because of increased equitability. The equitability increased because of increases in the relative abundance of Reithrodontomys and Mus, and the decreased relative abundance of M. montanus, which was the second most prevalent species in 1976. A slight increase in Mus also occurred on the burn plot although few captures were made.

More male than female Dipodomys were captured in both years on the Hovey sites (Table 7). Sex ratios differed significantly from an expected 1:1 ratio on the control site in 1976 ($p < .01$) and on the burn in 1977 ($p < .05$). However, sex ratios did not differ between the burn and control sites. As previously discussed, sex ratios of trapped rodents commonly favor males. The number of scrotal male Dipodomys was higher on the control area compared to Hovey burn in 1976 ($p < .025$). The number of scrotal males increased from 1976 to 1977 on both the burn ($p < .001$) and the control areas ($p < .025$). There was no statistical difference between

Table 7. Ages, weights and reproductive statistics of _Dipodomys heermanni_ removed from Hovey sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Hovey Burn		Hovey Control	
	1976	1977	1976	1977
N	79	53	135	40
% imm.	2.5 (2)	28.3 (15)	11.1 (15)	0
% ♂♂	59.3 (35)	64.2 (34)	62.2 (74)	57.5 (23)
$\bar{x}$ ♂ wgt.	75.6 ± 5.2	93.4 ± 5.7	80.5 ± 3.8	87.4 ± 3.3
% ♂♂ scrotal	46.9 (15)	96.0 (24)	72.7 (48)	100.0 (22)
$\bar{x}$ wgt. non-gravid ♀♀	61.8 ± 12.6	80.9 ± 6.5	69.7 ± 7.5	79.9 ± 3.01
% ♀♀ gravid	19.0 (4)	38.5 (5)	58.3 (21)	23.5 (4)
$\bar{x}$ wgt. gravid ♀♀	93.4 ± 7.9	93.2 ± 3.4	83.7 ± 3.8	76.9 ± 5.9
Embryos per ♀	3.5 ± 0.6	3.6 ± 0.5	3.0 ± 0.2	2.8 ± 0.5
% ♀♀ w/implant. sites	17.6 (3)	62.5 (5)	33.3 (5)	38.5 (5)
$\bar{x}$ wgt. ♀♀ w/implant sites	93.0 ± 5.5	89.5 ± 3.5	83.4 ± 3.2	80.8 ± 3.7
Implant. sites per ♀	3.3 ± 0.7	3.8 ± 0.4	3.0 ± 0.6	3.4 ± 0.5
% ♀♀ with corpora lutea	19.0 (4)	38.5 (5)	58.3 (21)	29.4 (5)
% ♀♀ lactating	14.3 (3)	30.8 (4)	8.3 (3)	23.5 (4)
% ♀♀ repro. active	33.3 (7)	69.2 (9)	66.7 (24)	52.9 (9)

the treatment and control in 1977.

A larger number of immature *Dipodomys* were captured on the control than on Hovey burn in 1976 ($p < .05$). The number of immature *Dipodomys* increased significantly ($p < .001$) on the burn from preburn to postburn sampling and in 1977 the number of immatures captured on the burn was significantly greater ($p < .001$) than on the control. There was no significant change ($p > .05$) in the age ratio on the control from 1976 to 1977, although the number of immature *Dipodomys* decreased.

The *Dipodomys* captured on the Hovey control site had a higher proportion of pregnant females ($p < .01$) and females exhibiting corpora lutea ($p < .01$) than the *Dipodomys* on the burn site in 1976 prior to burning. Although there was no difference between the burn and control sites in the number of *Dipodomys* exhibiting implantation sites in 1976, the number of reproductively active females (females exhibiting pregnancy, lactation or corpora lutea) was greater on the control ($p < .05$) than the treatment area in 1976. On the control site the number of pregnant females was significantly lower from 1976 to 1977 ($p < .05$), while there were no differences for numbers of *Dipodomys* exhibiting corpora lutea, implantation sites or lactation. Numbers of reproductively active females increased on the burn site (though not significantly), so that in 1977 there were no significant differences between Hovey burn and the control site for numbers of reproductively active females. Comparisons from one-way analysis of variance did not reveal a significant effect of the Hovey fire on litter size of Dipodomys as determined by embryos or implantation sites per female.

There was not a significant effect of the fire on weights of female Dipodomys. Weights of adult males increased significantly ($p < .05$) on the burn area in comparison to the control. Increased weights of adult males corresponded to an increase in the proportion of males that were scrotal. Weights increased on both the burn and control areas from 1976 to 1977. However, the weight increase was greatest on the burn site, parallelling the larger increase in the proportion of males that were scrotal.

Sex ratios of P. maniculatus differed from the expected 1:1 ratio on the Hovey sites in 1976 (Table 8). Sex ratios of P. maniculatus on the burn site favored females ($p < 0.01$) which comprised 54.6 percent of the total. Sex ratios on the control favored males ($p < .025$) which comprised 56.8 percent of the total. Sex ratios differed between the treatment and control areas in 1976 ($p < 0.001$) but there was no difference in 1977 when sex ratios on both areas did not differ from 1:1. Because sex ratios of P. maniculatus commonly favor males (Terman and Sassaman 1966), the sex ratio on the burn site in 1976 favoring females is unusual. Populations of P. maniculatus were very high on the Hovey burn site. The number of

Table 8. Ages, weights and reproductive statistics of <u>Peromyscus maniculatus</u> removed from the Hovey sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Hovey Burn		Hovey Control	
	1976	1977	1976	1977
N	850	578	349	78
% imm.	11.2 (95)	13.0 (75)	15.2 (53)	9.0 (7)
% ♂♂	45.4 (364)	51.0 (295)	56.8 (187)	51.3 (40)
$\bar{x}$ ♂ wgt.	18.7 ± 0.3	18.8 ± 0.3	19.5 ± 0.5	18.6 ± 1.0
% ♂♂ scrotal	17.2 (35)	44.0 (118)	64.7 (88)	64.9 (24)
$\bar{x}$ wgt. non-gravid ♀♀	18.3 ± 0.4	18.1 ± 0.4	19.4 ± 0.8	18.3 ± 0.9
% ♀♀ gravid	4.6 (10)	6.0 (14)	33.3 (37)	0
$\bar{x}$ wgt. gravid ♀♀	18.1 ± 0.5	21.4 ± 1.7	21.8 ± 1.0	--
Embryos per ♀	4.3 ± 0.3	4.1 ± 0.5	4.4 ± 0.3	--
% ♀♀ w/implant. sites	25.4 (53)	24.8 (56)	40.5 (30)	41.2 (14)
$\bar{x}$ wgt. ♀♀ w/implant. sites	18.9 ± 0.5	20.8 ± 0.7	21.8 ± 0.7	19.2 ± 1.3
Implant sites per ♀	5.1 ± 0.7	5.5 ± 0.8	4.6 ± 0.5	5.4 ± 1.0
% ♀♀ with corpora lutea	16.4 (36)	36.8 (86)	56.8 (63)	23.5 (8)
% ♀♀ lactating	7.3 (16)	5.6 (13)	1.8 (2)	8.8 (3)
% ♀♀ repro. active	23.7 (52)	42.5 (99)	58.6 (65)	32.4 (11)

P. maniculatus removed from the burn site in 1976 totaled 850 while 349 were removed on the control. It is possible that the influx of P. maniculatus caused by the removal of animals was not as great on the burn site as on the control. Removal trapping did not deplete the resident population of P. maniculatus as rapidly on the highly populated burn site as on the control site. The influx of Peromyscus into a depopulated area is generally dominated by males (Stickel 1946). If the population was not depleted as quickly, the influx of males into the area would not be as great and would not have altered the sex ratio as much as the influx of animals on the control. Chi square analysis was used to compare sex ratios during the first five days of trapping with the last ten days of trapping in 1976. Sex ratios from late trap days significantly favored males more than early trapping on the control, but on the burn site sex ratios from late trap days significantly favored females more than early trapping ($p < .025$). No difference in sex ratios between early and late trap days occurred on either area in 1977 when sex ratios did not differ from 1:1.

The number of male P. maniculatus that were scrotal was significantly higher on the control compared to the Hovey burn plot both prior to burning ($p < 0.001$) and the year following the burn. This occurred despite an increase in the number of scrotal males on the burn area ($p < .001$). The number of scrotal males did not change on the control from 1976 to 1977. The lower number of scrotal males on the burn site may be a function of high population densities in both years. Decreased development of testes for Mus in populations with high densities has been demonstrated (Christian 1956). Reproduction in P. maniculatus populations is considered sensitive to population densities (Christian 1970, Terman 1973). The number of scrotal males on the burn was higher in 1977 than in 1976 when the largest number of P. maniculatus were captured.

The number of reproductively active female P. maniculatus was significantly higher $(p < 0.001)$ on the control than on the burn plot in 1976. The P. maniculatus removed from the control in 1976 had a significantly higher number of females that exhibited pregnancy $(p < 0.001)$, corpora lutea $(p < 0.001)$, and implantation sites $(p < .025)$. The number of reproductively active females increased $(p < 0.001)$ on the Hovey burn site from 1976 to 1977. This increase was due largely to an increase in the number of females exhibiting corpora lutea $(p < 0.001)$. Numbers of reproductively active females decreased on the control $(p < 0.025)$ due to decreases in females exhibiting pregnancy $(p < 0.001)$ and corpora lutea $(p < 0.01)$. There was no difference in numbers of reproductively active females between the burn and control in 1977.

Comparisons from one-way analysis of variance did not reveal a significant effect of the Hovey fire on number of implantation sites or number of embryos per female for P. maniculatus. Comparisons indicate a significant difference ($p < 0.001$) between the burn and control for changes in weights of females exhibiting implantation sites; mean weights increased on the burn and decreased on the control. However there were no other significant differences for changes in weights of other P. maniculatus.

The increase in the number of reproductively active male and female P. maniculatus on the treatment area can not be conclusively attributed to the effects of the burn. The increased number of reproductively active individuals may be a function of a lower population density (Christian 1956). The highest densities of P. maniculatus encountered during this study were at the Hovey burn site in 1976; 850 P. maniculatus were captured on the Hovey burn site and 349 were captured on the control which had the second highest density in 1976. The total number of 578 P. maniculatus removed from the Hovey burn site in 1977 was 68 percent of the number removed in 1976.

Sex ratios of Microtus montanus did not differ between the treatment and control and did not differ from the expected 1:1 ratio (Table 9). Data on Microtus reproduction did not differ between the burn area and the control in either year although few data are available for the control in 1977. The number of reproductively active females decreased significantly ($p < 0.001$) on the burn site from 1976 to 1977. This decrease was due largely to decreases in the

Table 9. Ages, weights and reproductive statistics of *Microtus montanus* removed from Hovey sites. Actual numbers of animals in samples possessing each characteristic are shown in parentheses. 95% confidence intervals are presented with means.

	Hovey Burn		Hovey Control	
	1976	1977	1976	1977
N	303	180	143	13
% imm.	6.6 (20)	7.2 (13)	10.5 (15)	7.7 (1)
% ♂♂	47.1 (122)	46.1 (83)	43.7 (52)	46.2 (6)
$\bar{x}$ ♂ wgt.	38.2 ± 1.9	35.7 ± 1.9	38.1 ± 3.1	25.2 ± 4.8
% ♂♂ scrotal	49.5 (51)	65.8 (50)	55.3 (26)	83.3 (5)
$\bar{x}$ wgt. non-gravid ♀♀	31.8 ± 1.7	28.6 ± 1.2	29.5 ± 2.5	25.1 ± 3.8
% ♀♀ gravid	40.5 (45)	9.9 (9)	34.5 (19)	33.3 (2)
$\bar{x}$ wgt. gravid ♀♀	36.7 ± 1.7	35.7 ± 4.1	39.2 ± 4.6	30.9 ± 2.9
Embryos per ♀	5.4 ± 0.4	4.4 ± 1.2	5.4 ± 0.5	4.5 ± 1.0
% ♀♀ w/implant. sites	37.9 (25)	47.6 (39)	41.7 (15)	20.0 (2)
$\bar{x}$ wgt. ♀♀ w/implant. sites	36.6 ± 1.5	31.4 ± 1.7	37.7 ± 2.9	30.9
Implant. sites per ♀	5.3 ± 0.9	7.3 ± 1.3	6.0 ± 1.2	--
% ♀♀ with corpora lutea	51.4 (57)	19.8 (18)	41.8 (23)	33.3 (2)
% ♀♀ lactating	8.1 (9)	2.2 (2)	9.1 (5)	0
% ♀♀ repro. active	59.5 (66)	22.0 (20)	50.9 (28)	33.3 (2)

number of females exhibiting corpora lutea ($p < 0.001$) and pregnancy ($p < 0.01$).

Mean weights of *Microtus* in general decreased on the control and remained consistent on the burn plot. The changes in weights from preburn to postburn on the burn and control plots were significantly different ($p < 0.025$) for adult male *M. montanus*. Total numbers of *M. montanus* captured on the burn area dropped 41 percent from 1976 to 1977 but the relative abundance of *M. montanus* was the same both years. The number of *M. montanus* captured on the control plot dropped 91 percent from 1976 to 1977 and the relative abundance of *M. montanus* decreased from 21.8 percent in 1976 to 8.3 percent in 1977.

Although the reproductivity of *M. montanus* decreased on the burn from 1976 to 1977, densities on the burn were not as drastically reduced as on the control. Only six males and seven females were captured on the control. There were too few data to make a conclusion about reproduction of *Microtus* on the control.

General Discussion

The most obvious result of a fire is the immediate destruction of vegetation. This affects all species of small mammals in terms of cover but in terms of food resources it is expected to affect herbivores the most. Stout et al. (1971) stated that a major result of a burn appears to be a marked change in species importance in energy flow and that granivores should be favored. Many studies have demonstrated this increase in seed-eating species (Fala 1975, Tevis 1956, Cook 1959, Lawrence 1966, Sims and Buckner 1972).

Ahlgren (1966) reported that the number of insects and seeds available increased on a burn. Cook (1959) reported that food in the form of seeds was unaffected by fire. Many studies have reported the invasion of P. maniculatus on burned areas following an initial decrease. One would expect a generalist to favor well in comparison to specialists in an environment subject to dramatic changes (i.e., fire). In terms of diet, P. maniculatus represents an opportunist (Jameson 1952). However, the heteromyids are specialized for harsh environments (Whitford 1976, Beatley 1976a) and are not strictly granivorous. Dipodomys (Beatley 1976b), Perognathus and Peromyscus (Kritzman 1974) all alter their diets seasonally according to the availability of food. In terms of diet these species probably become opportunistic following a fire.

In general, the burns in this study had no immediate short term effects on the major small mammal species. No large changes were observed in numbers or in the timing or intensity of breeding. The possible exception to this may be Dipodomys heermanni which appeared to favor the burned areas. The initial extirpations of small mammal species often reported in studies of fires in different plant communities was not found in the fires in the shrub-steppe community of Lava Beds. The possible exception would be Microtus montanus. However, the decrease in numbers of this species on the burn was also seen on the control where no burning took place. Numbers of Reithrodontomys megalotis on the Hovey burn and numbers of Spermophilus beecheyi on the Fleener burn may have increased by spring following the burn, however their small numbers do not represent a major change in the small mammal communities on the burned areas.

Studies of small mammals and fire in other habitats have reported lower total numbers of animals on burned areas compared to controls one year following a burn (Cook 1959, Lawrence 1966, Fala 1975). Total numbers of animals captured during the removal trapping in this study decreased on both the Hovey and Fleener sites from 1976 to 1977. Total captures decreased on both burn and control sites but populations on the burned areas did not decrease as much as on the controls. The total number of animals captured on the Fleener burn and the Hovey burn decreased 40 and 34 percent, respectively. Total numbers captured on the Fleener and Hovey control sites decreased 61 and 73 percent, respectively. The most dramatic decrease occurred for M. montanus on the Hovey control site. The only species that were caught in larger numbers in 1977 than in 1976 were S. beecheyi on the Fleener burn site and R. megalotis on the

Hovey burn and control sites.

The relative abundance of small mammal species did not change dramatically on the two areas that were burned. S. beecheyi slightly increased on the Fleener burn. Small changes in relative abundance did take place on the control sites. Dipodomys decreased slightly on the Fleener control and the relative abundance of Microtus montanus decreased 13.5 percent on the Hovey control.

Studies of the effects of fires on small mammals in clearcuts (Fala 1975), forests (Ahlgren 1966), savanna (Beck and Vogl 1972), and chaparral (Lawrence 1966) have shown marked changes in the small mammal communities, both in densities and relative abundance. Species that did well on the burned areas in these studies were species that are typically associated with openings or grassland habitats and the decreased cover created by fire. However, the gross vegetational changes caused by fire in shrub-steppe may not be as great as changes in forest, woodland, shrub and savanna communities. Thus, the small mammal fauna at Lava Beds may be more influenced by elevation (Kritzman 1974), moisture (Beatley 1976b) or many other environmental factors (Whitford 1976) than by the effects of fire.

The major small mammal species in Lava Beds are typically considered granivores. These species are actually generalists in their diet which may be advantageous in a harsh environment. The major species present in Lava Beds prior to burning would be expected to do well in the new habitats created by the fires. The small mammal communities at Lava Beds evolved in association with an ecosystem which was strongly influenced by periodic fire.

The typical decrease in Microtines following a burn may not be detectable by sampling only one year following a burn. Cook (1959) reported that Microtus required a year's accumulation of mulch to afford cover before increasing on a burned area. Sims and Buckner (1972) reported that Microtus numbers did not recover until the autumn of the second year following a burn. Microtus represented the second most prevalent species in the Hovey sites in this study. The mark-recapture portion of this study could not determine the short term effects of the fire on Microtus. Analysis of data from the removal trapping indicate that although reproduction of Microtus montanus decreased from preburn to postburn sampling on the burn site, the density of M. montanus on the burn did not suffer as great a reduction as the population on the control. Microtus populations typically display synchronus fluctuations (Jameson 1955, Golley 1961, Christian 1971, Krebs and Myers 1974). Changes in Microtus populations on the two sites should be similar. Perhaps the vegetation that recovered one year after the burn afforded more cover for M. montanus than the vegetation on the control.

Christian (1977) states that if critical resources are depleted by fire, animals would be expected to breed less, suffer increased mortality, and range over larger areas to obtain necessities. Christian reported that a fire in a desert grassland did not effect either the intensity or timing of breeding of the two major rodent species. Lawrence (1966) reported that on burned chaparral reproduction of P. truei increased. P. truei was the most predominant species in the area. Lawrence attributed the increased reproduction to decreased densities of P. truei immediately following the fire. Lawrence also reported decreased weights of adult P. truei for three years following the burn and concluded that this was a result of exposed foraging areas.

Analysis of reproduction and weights of the animals captured on the Fleener sites does not reveal any differences between the treatment and control for any species. Analysis of data from the Hovey sites indicates that reproduction of Dipodomys and P. maniculatus was higher for animals on the burned area compared to the control. Weights of male Dipodomys and female P. maniculatus exhibiting implantation sites increased from 1976 to 1977 on the burn site. The actual effects of the fire on these species may be difficult to determine. Density and relative abundance estimates do not indicate that the differences in reproduction for these two species was having a marked effect on their populations. The changes in Dipodomys and P. maniculatus reproduction from 1976 to 1977 may have been the result of density-dependent suppression of reproduction on the burn area in 1976 or simply an artifact of asynchronous population fluctuations on the burn and control areas (Jameson 1955).

V. SUMMARY AND CONCLUSIONS

Studies of the effects of fire on small mammals in many habitats have demonstrated marked changes in the species composition of the small mammal community and often the initial extirpation of many species. The mark-recapture trapping on burned and unburned areas in this study did not indicate that major changes occurred in the small mammal communities immediately following the fires. The fires had no short term effects on the numbers, age and sex ratios, or breeding of the dominant species, *Peromyscus maniculatus*. Analysis of tag returns indicates that actual mortalities of *P. maniculatus* in the fires were insignificant. Numbers, age and sex ratios and breeding of *Perognathus parvus* were not affected by the fires. Too few data were obtained to determine the short term effects of the fires on *Microtus montanus*.

The burned areas designated for mark-recapture trapping which previously did not support large numbers of *Dipodomys* were invaded by *Dipodomys heermanni* after burning. No changes in numbers of *Dipodomys* occurred on the control areas which had supported numbers of *Dipodomys* prior to burning. Both treatment and control areas designated for removal trapping supported similar numbers of *Dipodomys* prior to burning and one year following the burn. It appears that on areas that previously had not been attractive to

Dipodomys, the fires created favorable habitat, but the fires did not affect numbers of Dipodomys on areas that already supported Dipodomys. However, because of the differences between preburn treatment and control populations our results are not conclusive.

Mark-recapture trapping of Spermophilus beecheii, and Reithrodontomys megalotis indicate that these species favor burned areas. However, their small numbers do not represent a major change in the small mammal communities of the burned areas.

One year following the burning no major effects on the small mammal communities were evident in terms of numbers, relative abundance or diversity. Removal trapping prior to burning on the Fleener sites and one year later indicated that the fire had no effects on numbers, age and sex ratios, weights, or reproductive condition of any species. Although few captures were made, numbers of Spermophilus beecheii did increase on the burn and decrease on the control. These results are supported by the mark-recapture trapping in this study.

Removal trapping on the Hovey sites prior to burning and one year later indicates that the fires had no effects on the relative abundance of Peromyscus maniculatus or Dipodomys heermanni. Weights of male Dipodomys and female P. maniculatus exhibiting implantation sites increased on the burned area. Reproduction of P. maniculatus and Dipodomys increased slightly on the burned area compared to the control, however this did not drastically affect the abundance of these species and may be a result of asynchronous breeding or density-regulated reproduction. Numbers of *Microtus montanus* on the burn did not suffer as great a loss as on the control. However, too few *Microtus* were captured to draw conclusions about weights or reproduction.

The results of this study indicate that prescribed burning of the shrub-steppe and grassland vegetation in Lava Beds National Monument does not drastically alter the small mammal communities in terms of density or relative abundance of species. Burning did not cause significant direct mortalities of the small mammals, nor were changes in the plant communities great enough to favor parallel changes in the small mammal communities.

LITERATURE CITED

Ahlgren, C.E. 1966. Small mammals and reforestation following prescribed burning. J. Forestry 64:614-618.

Babinska, J. and E. Bock. 1969. The effect of pre-baiting on captures of rodents. Acta Therio. 14:267-270.

Baker, R.H. 1940. Effect of burning and grazing on rodent populations. J. Mammal. 21:223.

Beatley, J.C. 1976a. Environments of kangaroo rats and effects of environmental change on populations in southern Nevada. J. Mammal. 57(1):67-93.

Beatley, J.C. 1976b. Rainfall and fluctuating plant populations in relation to distributions and numbers of desert rodents in southern Nevada. Oecologia 24(1):21-42.

Beck, A.M. and R.J. Vogl. 1972. The effects of spring burning on rodent populations in a brush prairie savanna. J. Mammal. 53(2):336-346.

Black, H.C. and E.H. Hooven. 1974. Response of small-mammal communities to habitat changes in western Oregon. Wildlife and Forest Mgmt. in the Pacific N.W. Proc. Symposium Sept. 11-12, 1973. Forest Res. Lab. School of Forestry O.S.U. Corvallis, OR.

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the upper Snake River plains. U.S. Dep. Agr. Tech. Bull. 1075. 39 p.

Chew, R.M., B.B. Butterworth, and R. Grechman. 1959. The effects of fire on small mammal populations on chaparral. J. Mammal. 40(2):253.

Christian, D.P. 1977. Effects of fire on small mammal populations in a desert grassland. J. Mammal. 58(3):423-427.

Christian, J.J. 1956. Adrenal and reproductive responses to population size in mice from freely growing populations. Ecology 37(2):258-273.

Christian, J. J. 1971. Fighting, maturity, and population density in Microtus pennsylvanicus. J. Mammal. 52(3):556-567.

Christian, J. J. 1970. Social subordination, population density, and mammalian evolution. Sci. 168(3927):84-90.

Cook, S. F., Jr. 1959. The effects of fire on a population of small rodents. Ecology 40(1):102-108.

Draper, N. R. and H. Smith. 1966. Applied regression analysis. John Wiley and Sons, Inc. New York. 407 pp.

Fala, R. A. 1975. Effects of prescribed burning on small mammal populations in a mixed oak clearcut. J. Forestry. Sept. pp. 586-587.

Gentry, J. B., F. B. Golley, and J. T. McGinnis. 1966. Effect of weather on the capture of small mammals. Amer. Midl. Nat. 75:526-530.

Getz, L. L. 1961. Responses of small mammals to live traps and weather condition. Amer. Midl. Nat. 66:160-170.

Golley, F. B. 1961. Interaction of natality, mortality, and movement during one annual cycle in a Microtus population. Amer. Midl. Nat. 66(1):152-159.

Harniss, R. O. and R. B. Murray. 1973. Thirty years of vegetal change following burning of sagebrush-grass range. J. Range. Manage. 26(5):322-325.

Hoffmeister, D. F. 1964. Unusual sex ratios in winter and spring taken pocket mice (Perognathus) in the southwest. Southwest. Nat. 9(4):252-254.

Howard, W. E., R. L. Fenner, and H. E. Childs. 1959. Wildlife survival in brush burns. J. Range Manage. 12(5):230-234.

Jameson, E. W., Jr. 1952. Food of deer mice, Peromyscus maniculatus and P. boylei in the northern Sierra Nevada California. J. Mammal. 33(1):50-60.

Jameson, E. W., Jr. 1955. Some factors affecting fluctuations of Microtus and Peromyscus. J. Mammal. 36:206-209.

Johnson, A.H. and G.A. Smathers. 1974. Fire history and ecology, Lava Beds National Monument. Tall Timbers Fire Ecology Conf. Proc. 15:103-115.

Krebs, C.J. and J.H. Myers. 1974. Population cycles in small mammals. Adv. Ecol. Res. 8:267-399.

Krefting, L.W. and C.E. Ahlgren. 1974. Small mammals and vegetation changes after fire in a mixed conifer-hardwood forest. Ecology 55(6):1391-1398.

Kritzman, E.B. 1974. Ecological effects of Peromyscus maniculatus and Perognathus parvus in E. Wash. J. Mammal. 55(1): 172-188.

Lawrence, G.E. 1966. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology 47:278-291.

Leopold, A.S., S.A. Cain, I.N. Gabrielson, I.M. Cottams, and T.L. Kimball. 1963. Wildlife management in the national parks. Living Wilderness 83:12-19.

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

MacArthur, R.H. 1972. Geographical Ecology. Harper and Row. New York. 269 pp.

Martin, R.E. and A.F. Johnson. 1976. Fire ecology and management of Lava Beds National Monument. Proceedings of the First Conference on Scientific Research in the National Parks. Nov. 9-12, 1976. New Orleans (In press).

Mooman, J.C. 1957. Some effects of grazing and fire on vegetation in the Columbia Basin Region, Washington. State College of Wash. Publication No. 20, 486.

Nelson, B.C. and C.R. Smith. 1976. Ecological effects of a plague epizootic on activities of rodents inhabiting caves of Lava Beds National Monument, California. J. Med. Ent. 13(1):51-61.

Neter, J. and W. Wasserman. 1974. Applied Linear Statistical Models. Richard D. Irwin, Inc. Homewood, Ill. 842 pp.

O'Farrell, T.P., J.D. Hedlund, R.A. Gies and R.E. Fitzner. 1973. Population dynamics of Perognathus parvus on manipulated shrub-steppe ecosystems. p. 7.21-7.23. BNWL-1750, Vol. 1, Part 2, UC-48, Biol. and Medicine, Battelle Pacific Northwest Lab., Richland, Washington.

O'Farrell, T.P., R.J. Olson, R.O. Gilbert, and J.D. Hedlund. 1975. A population of great basin pocket mice, Perognathus parvus, in the shrub-steppe of south-central Washington. Ecol. Monogr. 45(1):1-28.

Olson, G. 1978. Unpublished report to Lava Beds National Monument. (On file in LBNM headquarters library.)

Overton, W.S. 1971. Estimating the numbers of animals in wildlife populations. Pages 403-455 in R.H. Giles, Jr., Ed. Wildlife Management Techniques. The Wildlife Society. Washington, D.C.

Schamberger, M.L. 1965. An analysis of a small mammal population census. O.S.U. (M.S. Thesis). 41 pp.

Schnoes, R.S. 1977. The effects of prescribed burning on mule deer wintering at Lava Beds National Monument. M.S. Thesis. Oregon State Univ. 70 pp.

Seber, G.A.F. 1973. The estimation of animal abundance and related parameters. Hafner Press, New York. 506 pp.

Sims, H.P. and C.H. Buckner. 1972. The effect of clearcutting and burning of Pinus banksiana forests on the populations of small mammals in S.E. Manitoba. Amer. Midl. Nat. 90(1):228-231.

Simpson, E.H. 1949. Measurement of diversity. Nature 163:688.

Smathers, G.A. 1966. A resources mgmt. plan for Lava Beds NM. (Unpublished manuscript on file at Lava Beds NM library.)

Stickel, L.F. 1946. The source of animals moving into a depopulated area. J. Mammal. 27:301-307.

Stout, I.J., A.L. Farris, and V.L. Wright. 1971. Small mammal population of an area in N. Idaho severely burned in 1967. NW Sci. 45(4):219-229.

Terman, C.R. 1973. Reproductive inhibition in asymptotic populations of prairie deer mice. J. Reprod. Fert., Suppl. 19:457-463.

Terman, C.R. and J.F. Sassaman. 1966. Sex ratio in Peromyscus population. Abstract, Vir. J. Sci. 17:284.

Tester, J.R. 1965. Effects of controlled burn on small mammals in a Minnesota oak-savanna. Amer. Midland Nat. 74:240-243.

Tevis, L., Jr. 1956. Effect of a slash burn on forest mice. J. Wildl. Manage. 20(4):405-409.

Whitford, W.G. 1976. Temporal fluctuations in density and diversity of desert rodent populations. J. Mammal. 57(2):351-369.

Wright, H.A. and J.O. Klemmedson. 1965. Effects of fire on bunchgrasses of the sagebrush-grass region in southern Idaho. Ecology 46:680-688.

APPENDICES

Appendix 1: Trapping Dates of Mark Recapture Trapping

First three days of each period are prebait days.

10 April - 15 April, 1976.

12 May - 17 May, 1976.

25 June - 30 June, 1976.

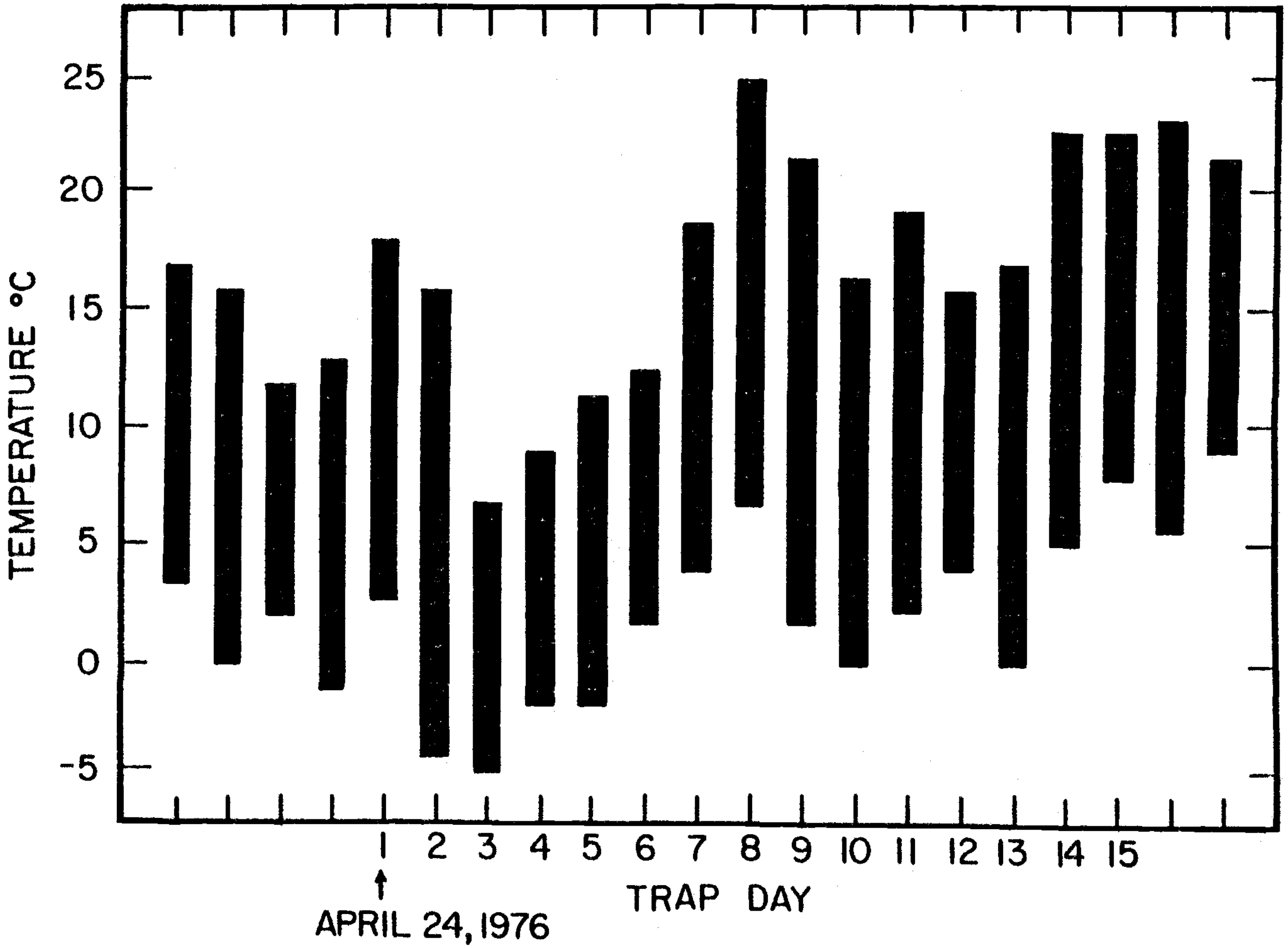
28 July - 2 August, 1976.

25 August - 30 August, 1976.

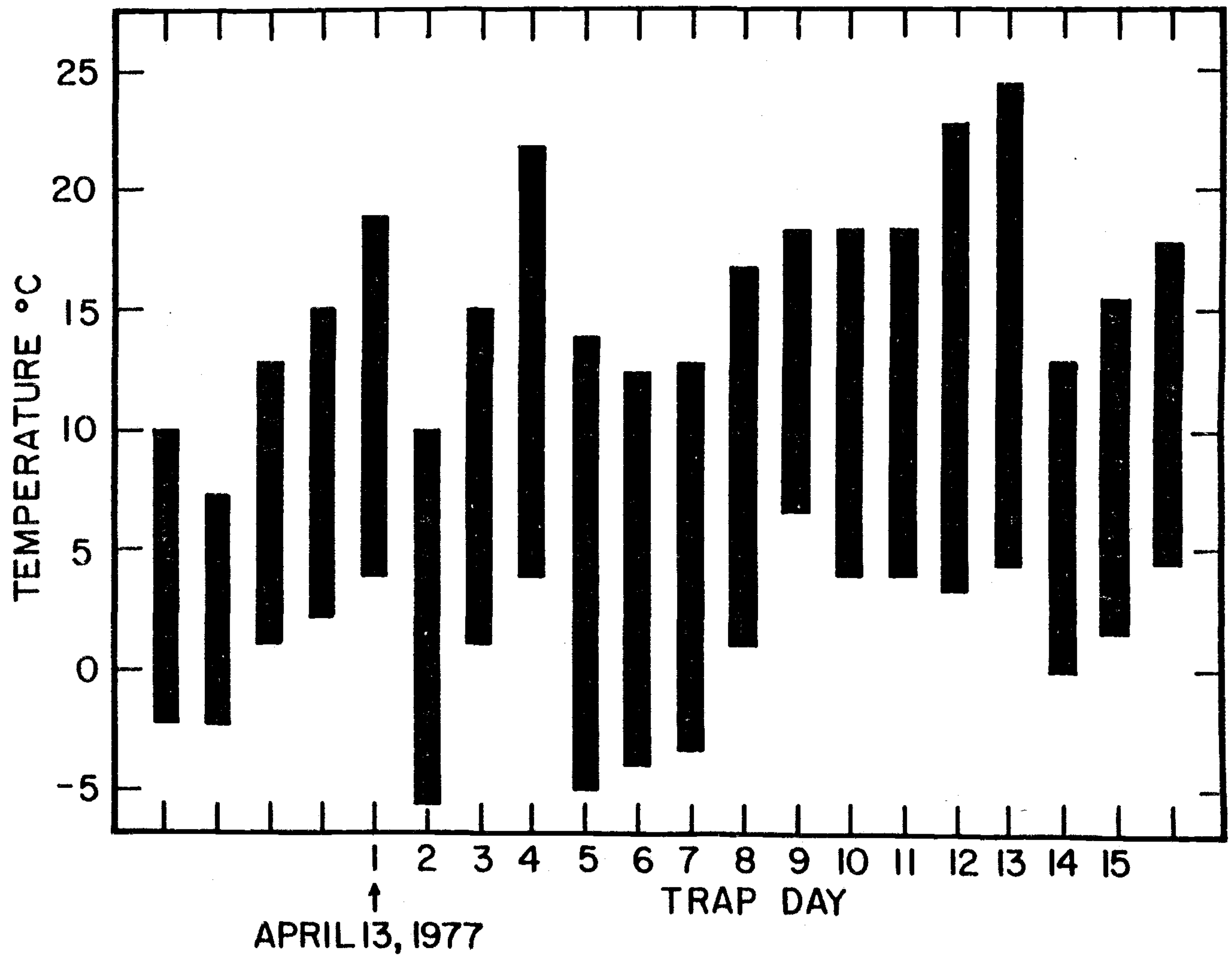
21 September - 26 September, 1976.

3 April - 8 April, 1977.

5 May - 10 May, 1977.



Appendix 2a: Daily temperature range during prebaiting and removal trapping, 1976.



Appendix 2b: Daily temperature range during prebaiting and removal trapping, 1977.

Appendix 3: Conditions for Prescribed Burns Conducted at Lava Beds National Monument, 22 June 1977.

Hovey Point Burn

418 Acres   0% Slope

Light sagebrush, rabbitbrush, cheatgrass and bunchgrasses.
5-8 tons/acre

Allowable Burning Limits

Burning Index	up to 20
Temperature	50° - 75°F
Relative humidity	10 - 50%
Wind velocity	0 - 15 mph

Actual Burn Conditions

Days since last rain 2   Amount 0.2 in
Wind 0-7 mph   Dry conditions
Relative humidity 34 - 39%
Temperature 63°F

Fleener Chimneys Burn

350 Acres   0-5% Slope   East aspect

Bitterbrush, sagebrush, rabbitbrush, juniper, mountain mahogany, bunchgrasses and cheatgrass.
15-20 tons/acre

Allowable Burning Limits

Burning Index	up to 18
Temperature	50° - 75°F
Relative humidity	10 - 20%
Wind velocity	0 - 12 mph

Actual Burn Conditions

Days since last rain	11	Amount	0.25 in
	9		0.02
	2		0.02

Wind 3-7 mph   gust to 12 mph   N to NW
Temperature 73°F

Appendix 4a: Total number of individuals (n_i) and Peterson indices (N) with 95% confidence intervals for each species caught during each mark-recapture trapping period at the Fleener burn site.

	1976												1977			
	April		May		June		July		Aug		Sept		April		May	
	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N
Sylvilagus nuttalli	0	--	4	--	1	--	2	--	3	--	2	--	0	--	0	--
S. beecheyi	0	--	4	--	0	--	0	--	0	--	3	--	6	--	1	--
Eutamius amoenus	1	--	1	--	0	--	0	--	0	--	0	--	0	--	0	--
Perognathus parvus	2	--	12	12.7 ±2.2	19	27.8 ±12.7	16	--	15	15.5 ±1.7	10	10.6 ±1.8	3	--	6	--
Dipodomys heermanni	0	--	2	--	3	--	7	7.8 ±2.2	11	11.2 ±1.0	9	--	5	--	7	--
Peromyscus crinitus	5	--	0	--	0	--	2	--	3	--	1	--	0	--	0	--
P. maniculatus	57	57.4 ±1.4	65	69.0 ±6.0	65	68.8 ±5.7	49	50.0 ±2.2	55	56.4 ±2.6	45	51.0 ±7.1	28	28.4 ±1.4	15	--
Neotoma cinerea	0	--	0	--	0	--	2	--	0	--	0	--	0	--	0	--
Microtus montanus	2	--	0	--	0	--	0	--	0	--	0	--	1	--	2	--

Appendix 4b: Total number of individuals (n_i) and Peterson indices (N) with 95% confidence intervals for each species caught during each mark-recapture trapping period at the Fleener control site.

	1976												1977			
	April		May		June		July		Aug		Sept		April		May	
	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N
Sylvilagus nuttalli	0	--	2	--	7	--	8	--	1	--	1	--	3	--	0	--
Spermophilus beldingi	0	--	0	--	0	--	0	--	0	--	0	--	1	--	0	--
S. beecheyi	0	--	1	--	2	--	0	--	0	--	0	--	0	--	0	--
Perognathus parvus	7	7.0 ±3.3	10	10.2 ±1.1	15	19.8 ±8.0	10	10.2 ±2.7	16	16.5 ±1.6	9	9.3 ±1.2	4	--	9	--
Dipodomys heermanni	3	--	12	12.7 ±2.2	8	10.7 ±5.5	9	9.3 ±1.2	7	7.2 ±0.9	8	8.0 ±3.2	0	--	1	--
P. maniculatus	43	45.6 ±4.1	60	63.9 ±5.0	59	64.2 ±6.2	54	57.9 ±5.2	47	51.0 ±5.5	60	60.0 ±4.3	34	35.7 ±1.4	26	26.4 ±1.4
Microtus montanus	1	--	0	--	0	--	0	--	0	--	0	--	1	--	0	--

Appendix 4c: Total number of individuals (n_i) and Peterson indices (N) with 95% confidence intervals for each species caught during each mark-recapture trapping period at the Hovey burn site.

	1976												1977			
	April		May		June		July		Aug		Sept		April		May	
	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N
Spermophilus beldingi	0	--	20	--	24	--	3	--	0	--	0	--	17	--	17	--
Perognathus parvus	0	--	0	--	1	--	2	--	0	--	0	--	0	--	0	--
Dipodomys heermanni	1	--	0	--	6	7.3 ±3.3	11	12.2 ±3.2	8	8.4 ±1.9	11	11.9 ±2.3	3	--	5	--
Reithrodontomys megalotis	0	--	0	--	0	--	0	--	0	--	0	--	4	--	4	--
P. maniculatus	38	39.9 ±3.6	46	50.7 ±6.0	27	27.3 ±5.3	23	23.9 ±2.3	23	23.9 ±2.3	13	13.2 ±0.9	25	26.8 ±4.4	54	60.2 ±7.7
Microtus montanus	23	--	17	--	0	--	0	--	0	--	0	--	6	--	9	--

Appendix 4d: Total number of individuals (n_i) and Peterson indices (N) with 95% confidence intervals for each species caught during each mark-recapture trapping period at the Hovey control site.

	1976												1977			
	April		May		June		July		Aug		Sept		April		May	
	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N	n_i	N
Sorex vagrans	0	--	0	--	0	--	0	--	0	--	0	--	1	--	0	--
Dipodomys heermanni	25	25.7 ±3.3	20	21.2 ±3.3	19	19.9 ±2.3	13	13.4 ±1.6	23	23.4 ±1.5	25	25.2 ±1.1	12	13.7 ±3.7	17	17.3 ±1.3
Reithrodontomys megalotis	0	--	0	--	0	--	1	--	0	--	1	--	0	--	1	--
P. maniculatus	40	40.9 ±2.2	20	21.4 ±4.3	7	7.8 ±2.2	14	15.7 ±3.7	19	19.4 ±1.4	9	9.3 ±1.2	14	17.7 ±8.1	22	22.6 ±1.8
Microtus montanus	5	--	11	--	1	--	0	--	0	--	0	--	1	--	2	--
Mus musculus	0	--	0	--	0	--	0	--	0	--	0	--	0	--	1	--