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**Technical Report No. 28  
The Small Mammal Community at  
Pinnacles National Monument**

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## ABSTRACT

Small mammals were trapped at Pinnacles National Monument on seven occasions between November 1984 and May 1986 using 16 transects with 20 trapping stations each. A total of 13,625 trap nights resulted in 1,672 captures of 843 individual mammals.

Fifteen species of mammals in nine genera were captured. Fourteen species were rodents and one was a shrew (Sorex ornatus). One non-native species, the house mouse (Mus musculus), was caught in small numbers on one transect. Its low density and limited distribution suggest it is unlikely to have any impact on the native mammals.

Peromyscus truei was the most common species (453 captures) followed by Perognathus californicus and Neotoma lepida with 251 and 232 captures respectively. Two species of kangaroo rats (Dipodomys elephantinus and D. heermanni) and another species of Peromyscus (P. maniculatus) were moderately common with 156, 131 and 137 captures respectively. The other species were caught less than 68 times each and were thus much less abundant.

Chamise chaparral and mixed chaparral are the most widespread habitats at Pinnacles. The two species of Dipodomys were the characteristic species for chamise

chaparral while Perognathus californicus and Peromyscus truei were the most common mice in mixed chaparral. One transect which crossed a boundary between burned and unburned chaparral supported similar numbers of small mammals in the two areas, but the species composition was somewhat different.

An analysis of habitat variables for each trapping station was used to determine which variables related to the abundance of small mammals. The extent of pig rooting was also recorded to evaluate both seasonal and yearly trends. There was a clear increase in both the amount of pig rooting and the number of transects which had rooting between April 1985 and April 1987. It was not possible, however, to demonstrate a negative impact of rooting on any of the species of small mammals trapped.

An additional 1,664 trap nights were accumulated using 88 pitfall traps installed in riparian areas. This trapping resulted in the capture of four Sorex ornatus.

## TABLE OF CONTENTS

|                                       |      |
|---------------------------------------|------|
| ABSTRACT .....                        | ii   |
| LIST OF FIGURES .....                 | vii  |
| LIST OF TABLES .....                  | viii |
| INTRODUCTION .....                    | 1    |
| METHODS .....                         | 3    |
| Sherman Trapping .....                | 3    |
| Pitfall Trapping .....                | 5    |
| Pig Rooting .....                     | 5    |
| Habitat Variables .....               | 5    |
| RESULTS .....                         | 8    |
| Transect Descriptions .....           | 8    |
| Sherman Trapping .....                | 20   |
| Pitfall Trapping .....                | 21   |
| Species Accounts .....                | 21   |
| <u>Dipodomys elephantinus</u> .....   | 21   |
| <u>Dipodomys heermanni</u> .....      | 23   |
| <u>Eutamias merriami</u> .....        | 24   |
| <u>Microtus californicus</u> .....    | 25   |
| <u>Mus musculus</u> .....             | 25   |
| <u>Neotoma fuscipes</u> .....         | 26   |
| <u>Neotoma lepida</u> .....           | 27   |
| <u>Perognathus californicus</u> ..... | 29   |

|                                        |    |
|----------------------------------------|----|
| <u>Peromyscus boylei</u> .....         | 30 |
| <u>Peromyscus californicus</u> .....   | 31 |
| <u>Peromyscus maniculatus</u> .....    | 33 |
| <u>Peromyscus truei</u> .....          | 34 |
| <u>Reithrodontomys megalotis</u> ..... | 35 |
| <u>Sorex ornatus</u> .....             | 36 |
| <u>Spermophilus beecheyi</u> .....     | 37 |
| Habitat Utilization .....              | 37 |
| Chamise Chaparral .....                | 38 |
| Mixed Chaparral .....                  | 39 |
| Burned Chaparral .....                 | 39 |
| Holly-leaved Cherry .....              | 40 |
| Valley Oak .....                       | 41 |
| Blue Oak .....                         | 41 |
| Mixed Riparian Woodland .....          | 42 |
| Introduced Grassland .....             | 43 |
| Burned Grassland .....                 | 43 |
| Rock .....                             | 45 |
| Dry Wash/Barren .....                  | 46 |
| Pig Rooting .....                      | 47 |
| DISCUSSION .....                       | 49 |
| Impact of Pigs .....                   | 49 |
| Distribution of Small Mammals .....    | 52 |
| Diversity of Small Mammals .....       | 54 |

|                                          |    |
|------------------------------------------|----|
| ACKNOWLEDGEMENTS .....                   | 56 |
| MANAGEMENT RECOMMENDATIONS .....         | 57 |
| Pigs .....                               | 57 |
| Other Non-Native Mammals .....           | 57 |
| Prescribed Fire .....                    | 58 |
| Monitoring and Additional Research ..... | 59 |
| LITERATURE CITED .....                   | 60 |

## LIST OF FIGURES

|                                               |    |
|-----------------------------------------------|----|
| Figure 1. Pinnacles National Monument Showing |    |
| Location of 16 Transect Sites .....           | 65 |
| Figure 2. Total Pig Rooting .....             | 66 |

## LIST OF TABLES

|           |                                                           |    |
|-----------|-----------------------------------------------------------|----|
| Table 1.  | Trapping Sessions .....                                   | 67 |
| Table 2.  | Habitat Variables Measured at Each Trap Site .....        | 68 |
| Table 3.  | Effective Trap Nights for Each Transect .....             | 71 |
| Table 4.  | Small Mammals Captured .....                              | 72 |
| Table 5.  | Trapping Success by Species and Transect .....            | 73 |
| Table 6.  | Variables Related to <u>Dipodomys elephantinus</u> .....  | 74 |
| Table 7.  | Variables Related to <u>Dipodomys heermanni</u> .....     | 75 |
| Table 8.  | Variables Related to <u>Neotoma lepida</u> .....          | 76 |
| Table 9.  | Variables Related to <u>Perognathus californicus</u> .... | 77 |
| Table 10. | Variables Related to <u>Peromyscus boylei</u> .....       | 78 |
| Table 11. | Variables Related to <u>Peromyscus californicus</u> ..... | 79 |
| Table 12. | Variables Related to <u>Peromyscus maniculatus</u> .....  | 80 |
| Table 13. | Variables Related to <u>Peromyscus truei</u> .....        | 81 |
| Table 14. | Variables Related to <u>Reithrodontomys megalotis</u> ... | 82 |
| Table 15. | Total Pig Rooting (Old and New) .....                     | 83 |
| Table 16. | Variables Related to Pig Rooting .....                    | 84 |

## INTRODUCTION

Thirty-nine species of mammals are known to occur at Pinnacles National Monument. Fifteen of these are rodents and were the primary species sampled. An additional 10 mammal species are suspected to occur based on their general range and the presence of suitable habitat. Nine of these are bats and the tenth is the trowbridge shrew (Sorex trowbridgii). Both bats and shrews require rather specific, specialized techniques for capture, hence the absence of confirmed sightings reflects the lack of surveys for these species more than an absence from the park.

Three mammals are not native to Pinnacles. Virginia opossums (Didelphis virginiana) were introduced from eastern United States to California in 1910 and have spread throughout much of the state since then. House mice (Mus musculus) are native to Asia. They have become established near buildings and in cultivated fields throughout North America.

Wild pigs (Sus scrofa) are native to Europe and Asia and have been brought to North America as both domestic and wild stocks. The first pigs in San Benito County were kept at the Spanish mission at San Juan Bautista in 1797. The first records of feral pigs date to the 1870's. Until about 1955, however, wild pigs existed in the county as localized populations derived from domestic stocks. At that time, several pig hunters introduced pigs from a less domesticated

stock and the wild pig population dramatically increased in size and range (Barrett and Pine 1980).

This range expansion has included lands within Pinnacles National Monument, especially oak woodland and riparian areas. The oak woodlands provide both cover and food (especially acorns). Riparian areas provide not only water (which is a critical resource during the drier parts of the year), but food and cover as well.

As the wild pig population has expanded, questions have been raised as to how pigs and their rooting affect the native flora and fauna. While pigs are often overlooked by visitors, their presence is obvious from their active rooting. Such rooting has been shown to have a negative impact on both the native flora and fauna (Wood and Barrett 1979, Tisdell 1982).

This study of the small mammal community was conducted to 1) describe the small mammal community at Pinnacles National Monument and 2) determine if introduced pigs were having a measurable impact on small mammals. The work was part of a larger project which included studies of the impact of pigs on plants (Halvorson and Clark, ms. in prep.) and birds (Avery and Van Riper 1986).

## METHODS

Sherman Trapping

Field work was conducted between November 1984 and May 1986 (Table 1). Mammals were trapped using Sherman mammal traps (H.B. Sherman Traps, Inc.). These traps are a standard means of capturing small rodents (e.g. O'Farrell 1978, Feldhamer 1979, Anthony et al. 1981, Johnson 1981, Kitchings and Levy 1981). Large Sherman traps (7.6 x 8.9 x 22.9 cm) were used except in areas where kangaroo rats (Dipodomys spp.) were expected. In those areas extra large traps (7.6 x 9.5 x 30.5 cm) were used to reduce the likelihood that the long kangaroo rat tails would be damaged. Traps were baited with rolled oats. During the winter, cotton was added to each trap so a nest could be built for warmth.

Each animal was identified, weighed to the nearest gram using a Pesola scale and marked with a numbered ear tag (National Band and Tag, size #1). Only the genus was recorded for individuals which could not be identified to species (primarily juveniles). Sex, reproductive condition, age class (adult, subadult, juvenile), parasites and injuries were noted.

Trapping was conducted along 16 permanent transects (Fig. 1, White et al. 1982). Each transect was 200 m long with 20 trapping stations spaced at 10 m intervals. Stations were marked with a wooden stake and a numbered metal tag. Two

traps were placed within 2 m of each of the 20 stakes resulting in a total of 40 traps per transect. Trapping was generally conducted for four consecutive nights (with traps left open during the day), though rain occasionally dictated some deviation from this scheme.

Disturbance to traps was a problem along some of the transects. Bait was occasionally stolen without springing the trap shut and some traps were closed for no apparent reason. Traps were sometimes moved or rolled over, most likely by coyotes, raccoons, bobcats, pigs and/or foxes. Some of these species also used traps as marking stations, i.e. they urinated on the trap to mark it as part of their territory. Because of this disturbance, it was necessary to correct the calculations for traps which were set, but were not as functional as traps which were not disturbed.

Observations of coyotes and bobcats indicated that they visited transects early in the evening. General observations of the other mammals suspected of disturbing traps suggested that they, too, would most likely disturb traps either during the day or early in the evening. Hence traps which had been disturbed by being rolled over or marked with urine, were considered to have been 20% functional. Traps which were closed for no obvious reason could have sprung shut at any time and were thus assumed to have been 50% effective (Nelson and Clark 1973). Traps which had been robbed or moved (but remained functional, though perhaps in a less desirable location) were judged to have been 80% effective.

### Pitfall Trapping

Pitfall traps are the most efficient method for sampling shrews (Williams and Braun, 1983). We installed 88 pitfall traps in riparian areas which appeared to provide good habitat for shrews. Each trap consisted of a one-gallon plastic jar sunk level with the ground and covered by a one foot square piece of plywood. When the trap was in operation, the metal jar lid was removed and the wooden cover remained in place.

### Pig Rooting

Pig rooting was evaluated within a 5 m radius circle around each station during each of the seven trapping sessions. The percent of the ground which had been disturbed by pigs (by churning the soil) was recorded. Rooting was subdivided into old and new categories. If the rooting appeared to be less than 10 days old, it was considered new. Otherwise, it was categorized as old rooting.

### Habitat Variables

Transects were selected to represent the variety of habitats at Pinnacles National Monument (Fig. 1). In order to describe the habitat along each transect and to allow for statistical analysis of factors influencing the capture rate for each species, both vegetational and physical characteristics were evaluated within a 5 m radius around each of the 320 trapping stations. Percent cover was determined

for each recognizable taxon of vegetation and for the physical variables listed in Table 2. Since cover was estimated independently for each taxon, the total cover at each station usually summed to more than 100% (e.g. 55% for annual grasses and 65% buckbrush). Additional data were collected on elevation, slope, soil moisture, exposure and distance to water. Water was divided into two categories: intermittent and persistent. Intermittent streams flow primarily during the rainy season while persistent water sources generally contained some water at least through the spring. Soil moisture was measured with a meter which provided readings on an arbitrary scale of 0-10 (with no units). A reading of zero indicated no measurable moisture and 10 was completely wet. Four measurements within 5 m of the trapping station were averaged to arrive at a measure of soil moisture.

Vegetation was evaluated in April 1986. Percent cover varies with time of year and between years, especially for the annuals. It has not been possible to take such changes into account.

Extensive statistical analysis of the data including transformations of variables and multivariate models were used to analyze the data with SPSS PC software (Norusis 1984) on an IBM PC. The most appropriate and biologically useful information was obtained when habitat variables were correlated with capture rate (captures/trap day) for each species and for pig rooting. Hence only those data are

presented here. A significance level of  $\alpha = 0.05$  was used for all statistical tests.

## RESULTS

### Transect Descriptions

In the descriptions below, percent cover is given for each plant taxon which averaged more than 10% for a given transect. Variables marked with an asterisk (\*) reached their highest value on the transect noted.

T1. Dry Wash/Barren. While this transect was mapped as barren by Stitt (1983), there was a considerable amount of short grass or herbaceous vegetation. Hence, the transect would be better described as a dry wash. The vegetation was sparse, consisting mostly of annual grasses (57% cover, mostly Avena, Bromus), filaree (34%) and annual lupine with a few digger pines, buckwheat and coast live oaks. The substrate was mostly fine soil (43%, < 1 mm diameter) and sand (41%, 1-5 mm diameter). This transect had the second highest amount of gravel (9%, 5-25 mm diameter). Chalone Creek was located 15-50 m away. There was a slight slope (7%) to the SW and 18% of the ground was bare. The elevation was 940' along the entire transect.

Five species of small mammals were captured on this transect with an average capture rate of 25.4 trap

nights/capture. This was the third lowest capture rate of all the transects.

T2. Valley Oak. This was the only transect with valley oak (14% \*). In addition to the oaks, there were annual grasses (66% cover), coast live oak (32%), buckwheat (22% \*) and herbaceous plants (18%) with 11% bare soil. Transect T13 was the only other transect with more than 15% coast live oak. There was 57% \* cover of oak leaf litter. Coast live oaks were more common only on transect T13. The soils were mostly fine. Chalone Creek was 120-220 m away. The 5° slope was less than any other transect. There was a southern exposure with an elevation of 960'.

Six species of small mammals were caught on transect T2 at an average capture rate of 10.9 trap nights/capture. This was the second highest capture rate for the widespread Peromyscus truei (= Pm. truei).

T3. Blue Oak. The vegetation was primarily annual grasses (78%) and herbaceous plants (47%) with an overstory of blue oak (59% \*). The herbaceous vegetation included miner's lettuce and annual lupine (9% \*) with 9% bare ground. The transect was 190-320 m from Chalone Creek. There was a considerable amount of fine soil (97% \*) and the average soil moisture of 2.4 was fairly high compared

with other transects. Both persistent and intermittent water averaged 268 m away. This was the third greatest distance to water. The slope averaged  $24^{\circ}$  with an eastern exposure. The elevation was 1040'.

This transect had the most pig rooting in both the old (27% \*) and new (7% \*) categories.

Four species of mice were caught at an average capture rate of 29.1 trap nights/capture. Along with transect T12, this was the lowest number of species and the second lowest capture rate. Clearly this was one of the poorer areas for small mammals at Pinnacles.

T4. Mixed Riparian Woodland. The vegetation was quite diverse, consisting primarily of annual grasses (75%) and herbaceous plants (38%) with an overstory of digger pine (33% \*), coast live oak (15%) and a few willows (8% \*). Shrubs included buckwheat, blue elderberry (3% \*) and buckbrush. The herbaceous vegetation consisted primarily of miner's lettuce, filaree, lotus and annual lupines. There was less than 5% bare ground and 16% \* pine leaf litter. The substrate consisted primarily of fine soils (85%). The slope averaged  $9^{\circ}$  to the south and Chalone Creek was 70 m away. The elevation of 920' was the lowest of all the transects.

Five species of mice were caught on this transect at an average capture rate of 11.0 trap nights/capture. This was the highest capture rate for the rather ubiquitous Pm. truei.

T5. Dry Wash/Barren. Like transect T1, this transect was mapped as barren, but the fairly extensive cover of short grasses and herbaceous plants suggest that dry wash would be a better description. The transect was sparsely vegetated with annual grasses (57%) and herbs (32%). The most abundant herbs were filaree, evening primrose (11% \*) and forget-me-nots. Buckwheat shrub cover reached 50% at some stations and a few digger pines were present. Bare ground averaged 26%. Soils were a combination of fine soil (39%) and sand (50% \*). This was one of only four transects with more than 4% cover of gravel. The soil moisture was 2.8 \*. The average slope 7° with a southern exposure. Chalone Creek was 8 to 57 m away and the elevation was 1040'.

Seven species of small mammals were caught on transect T5 at a capture rate of 11.6 trap nights/capture. This transect had the highest capture rate for Dipodomys heermanni, but was generally poor for other small mammals.

T6. Mixed Chaparral. The vegetation was dominated by chamise (44%) with an understory of annual grasses and herbs. The more common herbaceous plants were bird's foot fern (6% \*), buckwheat, forget-me-not and filaree. Bare ground averaged 17%. Soils were a combination of fine soil (48%) and gravel (45%). Average slope was 35° \*. Exposure was to the SW. Chalone Creek was 430-620 m away and elevation ranged from 1080 to 1194'.

Seven species of small mammals were caught at an average capture rate of 11.1 trap nights/capture.

T7. Chamise Chaparral. The vegetation was dominated by chamise (51%) and buckbrush (27% \*). Along with transect T8, this was the only transect with more than 4% cover of buckbrush. The understory consisted of annual grasses (78%), forget-me-nots (24%), coyote mint (14% \*), star lily (11% \*) and miner's lettuce. Bare ground averaged 13%. Soils were mostly fine (56%) with a few scattered rocks. Average slope was 21% with a SW exposure. The soil moisture of 2.6 was second highest of all the transects. Chalone Creek was 350-540 m away and elevation ranged from 1030-1258'.

Five species of small mammals were caught on transect T7 at an average capture rate of 17.7 trap nights/capture.

This was a fairly low capture rate compared with other transects.

T8. Holly-leaf Cherry/Rock. This transect has notably diverse vegetation which included annual grasses (32%) and herbs (37%) with a few shrubs including buckwheat (18%), holly-leaf cherry (12% \*) and buckbrush (13%). Transects T8 and T7 were the only transects with more than 4% cover of buckbrush. Herbs included miner's lettuce, forget-me-nots and Chinese houses. There were a few coast live oaks. Soils were mostly fine (41%) with an average of 5% \* cover of medium rocks (25-125 mm diameter) and 28% cover of large rocks (> 125 mm diameter). The slope was quite variable with an average of 28%. Bare ground averaged 37%. The exposure was also highly variable, averaging to the SW. The north fork of Chalone Creek was 100-125 m away and the elevation ranged from 1164-1285'.

Eight species of small mammals were caught at an average capture rate of 3.7 trap nights/capture. This transect had both the second highest number of small mammal species and the second highest capture rate. This species diversity probably relates to the variety of habitats along the transect. Perognathus californicus (= Pg. californicus) and Peromyscus californicus (= Pm. californicus) both had their highest capture rates on

this transect. Neotoma lepida and Pm. truei also had high rates of capture. Transect T8 was one of only two transects where Neotoma fuscipes was captured.

- T9. Rock/Burned Grassland. The vegetation was dominated by annual grasses (44%) and herbaceous cover (16%) with a few scattered blue oaks, coast live oaks, and digger pines. Avena accounted for 29% of the grass cover. There were also a few buckwheats near the top of the transect. Bare ground averaged 51%. Soils were mostly fine (37%) with some sand (10%) and gravel. The 44% cover by large rocks was only slightly less than transect T10 which had the most large rock. The slope averaged 32° with a SE exposure. Bear Gulch Creek was 160-360 m away and elevation ranged from 1316-1832'.

Seven species of small mammals were caught on transect T9 at an average capture rate of 3.2 trap nights/capture. This was the highest capture rate of any of the transects. Neotoma lepida and Peromyscus boylei (= Pm. boylei) were caught on this transect in greater numbers than elsewhere.

- T10. Rock. Large rocks covered 45% \* of the ground, accounting for nearly all of the 46% bare ground. The vegetation was primarily grasses (33%) with some buckwheat (15%), monkeyflower (12% \*), herbaceous plants,

chamise, buckbrush, holly-leaf cherry and scattered digger pines. Soils were a combination of fine (29%) and gravel (25%). This was the lowest cover of fine soil. The slope averaged  $30^{\circ}$  with a southern exposure. Bear Gulch Reservoir was 50-150 m away and elevation ranged from 1680-1700'.

Seven species of small mammals were caught on this transect at an average capture rate of 6.2 trap nights/capture. Above average capture rates for N. lepida and Pg. californicus contributed to this relatively high capture rate.

T11. Chamise Chaparral. The overstory was almost exclusively chamise (63%) with 89% \* bare ground and only sparse grass. Chamise was more common only on transect T15. The 1% cover of herbaceous plants and 4% grass cover were both the lowest for all transects. This was the only transect with more than one percent manzanita (2%), an important variable for Dipodomys elephantinus. The soils were a combination of fine (44%), sand (33%) and gravel (11% \*). The slope averaged  $12^{\circ}$  with a SE exposure. A tributary to Bear Gulch Reservoir was 500 m away. This was nearly twice as far from water compared with any other transect. Elevation ranged from 1882-1920', the highest of any transect.

Five species of small mammals were caught at an average capture rate of 5.9 trap nights/capture. This was the third highest capture rate for all of the transects. The capture rate was high because D. elephantiinus were caught in large numbers and accounted for 93% of the captures.

T12. Burned Grassland. Grasses provided 90% \* cover. Most of the grasses were annual, but there was some Stipa near the top of the transect. Both Stipa (8% \*) and Avena (72% \*) were far more common here than elsewhere. Herbaceous vegetation covered 40% and was composed mostly of lotus (20%) and a few lupines. Lotus was more common only on transect T15. There were a few scattered blue oaks and both minimum and maximum shade were lower here than elsewhere. Soils were mostly fine (85%). The slope averaged 29° with a southern exposure. Bear Gulch Creek was 80-270 m away and elevation ranged from 1400-1590'.

Four species of mice were caught at an average capture rate of 39.7 trap nights/capture. Along with transect T3, this was the lowest number of species caught on any transect. It was also the lowest capture rate by a large margin. There were several factors which might contribute to this low capture rate. The habitat was rather uniform grass on a relatively steep slope (29%). Also, this transect seemed to be visited by a large number of predators which routinely disturbed traps. It

was not clear whether this disturbance decreased the likelihood of small mammals going into traps or whether the predators may have kept them at a lower population level. Despite this low capture rate, Reithrodontomys megalotis were captured at their second highest frequency on this transect.

T13. Mixed Riparian Woodland. The vegetation along the transect was quite diverse. Buckeye (56% \*) along with coast live oak (35% \*), digger pine (16%) and holly-leaf cherry provided a dense overstory. Transect T2 was the only other transect with more than 15% coast live oak. Digger pines were more common only on transect T4. Both minimum and maximum shade (74% \* and 79% \* respectively) were greater here than on other transects. The understory was dominated by herbaceous vegetation (63% \*), mostly miner's lettuce (11%), bedstraw and fiddleneck. Annual grasses provided 46% cover. Large rocks accounted for 21% cover. Soils were mostly fine (63%). The slope averaged 20% with a SE exposure. Persistent water in the west fork of Chalone Creek was 100-290 m away and the elevation was 1320'.

Five species of small mammals were caught at an average capture rate of 18.7 trap nights/capture.

T14. Introduced Grassland. Introduced annual grasses provided 79% cover second only to transect T12. The herbaceous vegetation (53%) consisted primarily of filaree (41% \*) with some lotus, miner's lettuce and bedstraw. Filaree was more common here than on other transects. Buckwheat (14%) was scattered along part of the transect. Soils were mostly fine (94%). Slope averaged 10% with a southern exposure. A tributary to Chalone Creek provided persistent water 1-25 m away. Elevation was 1400'.

Six species of mice were caught at an average capture rate of 12.2 trap nights/capture. Microtus californicus and R. megalotis were caught at their highest capture rate on this transect.

T15. Burned/Unburned Chamise Chaparral. Approximately half of this transect had been burned 4-5 years prior to trapping. Vegetation was dominated by chamise (69% \*, unburned) and yerba santa (21% \*, burned) with a significant growth of lotus (27% \*). Annual grasses provided 31% cover and herbaceous plants accounted for 39%, mostly lotus (27%) with some forget-me-nots. There was a small amount of buckbrush and buckwheat. This transect had 92% cover of fine soils. Slope averaged 25° with a SE exposure. Both persistent and temporary water were an average of 282 m away. Only transect T11 had

water at a greater distance. Elevation ranged from 1560-1600'.

Nine species of small mammals were caught at an average capture rate of 6.2 trap nights/capture. This was the highest diversity for any of the transects. The diversity is probably related to the presence of two distinct habitats on the transect. While all but one of the species (Pg. californicus) showed a clear preference for either the burned or unburned portion of the transect, there was no overall preference for all of the species combined (44% burned, 56% unburned). Along with transect T10, the capture rate was fourth highest. Pm. maniculatus was caught at its highest capture rate and Pm. californicus at its second highest on this transect.

T16. Blue Oak. Annual grasses provided 80% cover and herbaceous vegetation provided 65% cover along this transect. The herbaceous vegetation was primarily miner's lettuce (18% \*) with lesser amounts of lupine, forget-me-nots, bedstraw and Chinese houses. There was some buckwheat. Along with blue oaks (45%), were a few digger pines and junipers. This transect had 95% cover of fine soils. Slope averaged 31° with a NW exposure. Persistent water was 65-195 m away and elevation was 1400'.

This transect had the second most new pig rooting.

Six species of small mammals were caught at an average capture rate of 12.7 trap nights/capture. This was one of the two transects where N. fuscipes was captured.

#### Sherman Trapping

Table 1 gives the dates for the seven trapping sessions and Table 3 summarizes the effective number of trap nights (after correcting for closed and disturbed traps) for each session. Total effective trap nights ranged from 1,375 to 2,424 per trapping session with a total of 13,625 for the entire study.

Table 4 summarizes the species captured and the percentage of the total for each species. A total of 843 mammals were captured 1,672 times. This included nine genera and 15 species. For some Dipodomys, Neotoma and Peromyscus, it was not possible to identify all individuals to species. For the later two genera, this occurred most often with juveniles which were simply too young to identify. Adult Dipodomys can be exceedingly difficult to identify, especially when dealing with live animals. While some of the unidentified Dipodomys were juvenile, many of the adults could not be identified with confidence. This resulted in a large

unknown group, but those individuals which were identified to species were done so with greater confidence.

To better see how trapping success and distribution of small mammals relates to habitat, the number of captures for each of the 15 species is broken down by transect in Table 5.

#### Pitfall Trapping

We accumulated 1,664 trap nights between February 20, 1985 and May 7, 1986. Two Sorex ornatus were caught on October 30, 1985 and two more were caught on January 5, 1986. All four shrews were in traps along Bear Gulch about 0.5 km east of the Bear Gulch Visitor Center.

#### Species Accounts

For each species, data are presented for 1) distribution within the park and 2) habitat variables which were statistically correlated with distribution. The correlations will be of use in predicting small mammal occurrence in areas away from the transects. For those species caught less than 15 times, it was not possible to calculate statistical correlations and hence we report only the information on distribution.

#### Dipodomys elephantinus - Big-eared Kangaroo Rat.

Dipodomys elephantinus has a very limited distribution, being known from only the Gabilan Mountains in Monterey and San Benito Counties. It is closely related to D. heermanni,

the other kangaroo rat found at Pinnacles. Primarily due to this limited distribution, D. elephantinus is a Category 2 candidate species for listing as threatened or endangered by the Fish and Wildlife Service (USFWS, 1985). Dipodomys feed primarily on seeds which they carry back to their burrows in external, fur-lined cheek pouches.

Dipodomys elephantinus was the more common of the two kangaroo rats with 156 captures of 42 individuals. It also had the highest recapture rate with individuals being captured an average of nearly four times each. For a species which was captured so often, it had a notably restricted habitat preference. Dipodomys elephantinus was caught on only three of the 16 transects. Eighty percent of the captures were on the chamise chaparral transect (T11) above Bear Gulch Reservoir which was characterized by extensive chamise (63%) and bare ground (89%). Thirteen percent of the D. elephantinus were caught on the burned chaparral/chamise chaparral transect (T15) near the Chaparral Ranger Station. All of the D. elephantinus were on the unburned portion which was dominated by chamise in contrast to the burned section which was predominantly yerba santa. The remaining 11 individuals were on the chamise chaparral transect (T7) north of the Chalone Creek Picnic area.

Table 6 summarizes the 25 variables which were significantly correlated with the distribution of D. elephantinus. The most important variables were those typically associated with the chamise chaparral habitat: lack

of water and the presence of bare ground and chamise. Of lesser importance were the presence of small diameter of wood, manzanita, sand and gravel. The presence of wood may relate to the fact that such wood was typically associated with chamise. Elevation was also significant, but it is quite likely that this relates to the fact that most of the chamise sampled was at a higher elevation.

Grass (specifically wild oats), herbaceous plants and a northern exposure were negatively related to the distribution of D. elephantinus. The presence of both grass and herbaceous plants decrease the amount of bare ground. Bare ground is important to Dipodomys since they typically move bipedally, similarly to a kangaroo.

Dipodomys heermanni - Heermann's Kangaroo Rat.

Dipodomys heermanni is known from central and southern California where its range overlaps several other closely related species of kangaroo rats. Like other Dipodomys, it is primarily nocturnal. Dipodomys heermanni feeds on green vegetation as well as seeds.

Thirty D. heermanni were caught a total of 68 times, indicating that they were about half as abundant as D. elephantinus. While at least a few D. heermanni were caught on seven of the 16 transects, nearly half of the captures (46%) were on the dry wash/barren transect (T5) adjacent to Chalone Creek, north of the Chalone Creek Picnic Area. This was a flat, sparsely-vegetated flood plain which allowed for

good mobility by the bipedal kangaroo rats. An additional 13 captures were in the buckwheat shrubs along the valley oak transect (T2) and 10 were on the burned/unburned chamise chaparral transect (T15) on the west side. On transect T15, 70% of the captures were on the burned portion of the transect.

Surprisingly, only two variables were significantly related to D. heermanni distribution, evening primrose and the lack of sandy substrate (Table 7). Evening primrose was much more common on transect T5 (11%) than anywhere else, but it was not clear whether this small herb was really a biologically important factor in the distribution of D. heermanni or whether the correlation was incidental. Without a better range of evening primrose distribution, it is difficult to interpret the results.

Eutamias merriami - Merriam's Chipmunk.

Eutamias merriami is the typical chipmunk of central and southern California where it ranges through the sierran and coastal foothills south to Baja California. Most species of Eutamias live in forests, but E. merriami occurs more frequently in chaparral and rocky areas.

Only one E. merriami was captured. While Eutamias were not particularly abundant at Pinnacles, they were certainly more common and widespread than indicated by the data presented here. The low capture rate was not really surprising, however, since the bait (rolled oats) was more

appealing to other species of small mammals. Our general observations of these rather vocal chipmunks indicate that they were regularly found in rocky riparian areas, especially along Bear Gulch trail, and at the edge of the chaparral community. They were absent from dense chaparral and the other more arid habitats.

Microtus californicus - California Vole.

Microtus californicus is found in grassy meadows from southern Oregon, throughout much of California south to Baja California. Altitudinally it ranges from sea level to mountain meadows. In some areas, it provides a significant prey base for hawks and owls.

Microtus californicus were fairly rare with eight individuals being trapped a total of 16 times. This species accounted for only 1% of the total captures. Most of the Mi. californicus (56%) occurred in a grassy field north of the Chaparral Campground (T14). This habitat was typical for Mi. californicus which feed extensively on grass, but it was also a fairly restricted habitat at Pinnacles. None of the other transects had more than three captures. The capture rate during the trapping was probably a good indication of the low abundance of Mi. californicus at Pinnacles.

Mus musculus - House Mouse.

Mus musculus is native to Asia, though it has become widely established throughout all but the coldest parts of

North America. The albino form is the common white mouse frequently used in lab research and sold in pet stores.

At Pinnacles, one individual was caught a total of four times. That individual was in the grassy field just north of the Chaparral Campground (T14). Transect T14 was the transect closest to human habitation.

Mus musculus were also trapped in several areas not associated with our transects. One area was a grassy field at the very eastern edge of the park, adjacent to the private Pinnacles Campground. Mus musculus were also caught around several of the buildings within the park.

Mus musculus generally inhabits buildings and grassy fields near human activity. This association seems to hold true both Pinnacles and throughout its range in North America. Mus musculus may have been more common both at Pinnacles than the trapping along the transects indicates. Given its limited distribution away from human habitation, Mus musculus is unlikely to have a significant impact on the native small mammals and it is probably impractical to try to eliminate them from the park.

Neotoma fuscipes - Dusky-footed Woodrat.

Neotoma fuscipes is the common woodrat throughout the western portion of California. It is well-known for building large, dome-shaped stick houses in which it nests and stores food.

Neotoma fuscipes were notably uncommon, especially compared with N. lepida. Five N. fuscipes were caught a total of six times. Three of the captures were on a holly-leaf cherry/rock transect near Willow Springs (T8). This transect was distinguished by being especially diverse in vegetation, slope, soil and exposure. The other three N. fuscipes were caught along a blue oak transect (T16) on the west side. This transect had rather high grass and herbaceous cover (80% and 65% respectively).

With so few captures it was not possible to calculate a reliable correlation with habitat variables, but N. fuscipes tended to be associated with human habitation. All Neotoma trapped in buildings and at one residence were N. fuscipes.

It was somewhat surprising that N. fuscipes was so rare along the transects. In other parts of its range, N. fuscipes occurs in chaparral habitats, but that was not the case at Pinnacles. Neotoma fuscipes and N. lepida might have been competing for a limiting resource which N. lepida was able to utilize more efficiently, but neither species was particularly common in the widespread chaparral at Pinnacles. Alternatively, it is possible that N. fuscipes is not well adapted to the generally arid climate of the Pinnacles area, especially compared with N. lepida.

Neotoma lepida - Desert Woodrat.

As the common name implies, N. lepida is primarily a desert and great basin species. Unlike N. fuscipes, it does

not build large stick nests, but typically uses a burrow with only a modest assortment of sticks at the opening.

Neotoma lepida was the third most common small mammal with a total of 232 captures of 99 individuals. Unlike the two other common species (Pm. truei and Pg. californicus), N. lepida was quite limited in its habitat preference. All but 10 of the captures occurred on three transects which were rather similar in having more large rock (>125 mm diameter) than any other transect. Even the 10 N. lepida not caught on these three transects were caught in areas with quite a bit of rock.

Similar to the other two species which had a large number of captures, N. lepida distribution was correlated with a large number of variables (Table 8). While large rocks were clearly the most significant variable, other important variables include the presence of medium rock, monkeyflowers, increased slope, bare ground and the lack of fine soil, grass and herbaceous plants. It was difficult to tell whether monkeyflowers were as important as the strong correlation implied. Monkeyflowers averaged more than 1% cover only along the rock transect north of Bear Gulch Reservoir (T10) which had 12% cover. This transect also had the second highest capture rate for N. lepida. Without a better range of monkeyflowers distribution, it is difficult to interpret the correlation.

The correlation of N. lepida with elevation may be incidental since the transects with a lot of medium to large

rock tended to be at higher elevations. There did not seem to be an obvious biological reason why N. lepida would be more common at higher elevations.

Perognathus californicus - California Pocket Mouse.

Perognathus californicus is the common pocket mouse in coastal California. Like Dipodomys, it has external cheek pouches to carry food. These cheek pouches provide an easy means to distinguish Perognathus from other mice of the same size.

Perognathus californicus was quite widespread. It shared with Pm. truei the distinction of being caught on all but one of the transects. Perognathus californicus was also rather abundant, accounting for 15% of the total captures. This abundance was second only to Pm. truei. Sixty percent of the Pg. californicus captured were on four transects. These were the holly-leaf cherry/rock transect near Willow Spring (T8), the rock transect north of Bear Gulch Reservoir (T10), the rock/burned grassland slope NE of the Bear Gulch visitor center (T9), and the mixed chaparral north of the Chalone Creek Picnic Area (T6). The first three of these transects shared the characteristic of having a particularly high proportion of medium and large rocks. The only transect where Pg. californicus was not captured was the rocky canyon at the base of the Balconies Cliffs (T13). That transect was notably cool and shady compared with other areas at Pinnacles.

Similar to other widespread species, the distribution of Pg. californicus was correlated with quite a few variables (Table 9). A distinct slope (up to at least 35°) and the presence of medium to large rocks were the most important variables. The lack of herbaceous plants, fine soils and oak leaf litter were also important. As with N. lepida, it was difficult to tell whether monkeyflowers were as important as the correlation implies. Monkeyflowers averaged more than 1% cover only along the rock transect north of Bear Gulch Reservoir (T10). That transect had 12% cover and also the second highest capture rate for Pg. californicus. Without a better range of monkeyflower distribution, it is difficult to interpret the correlation.

The wide distribution of Pg. californicus at Pinnacles contrasts to some extent with textbook descriptions which indicate that its primary habitat is chaparral. Nearly half of the Pg. californicus captured were in areas which would not be described as predominantly chaparral.

Peromyscus boylei - Brush Mouse.

Peromyscus boylei is found in arid to semiarid habitats in the southwestern United States. It typically lives in rocky areas and is known to be a skilled climber.

Peromyscus boylei was the least common Peromyscus, comprising only 5% of captures for that genus. Twenty-two individuals were caught a total of 36 times. It was caught on nine of the 16 transects. Two of the transects where Pm.

boylei was most common [the holly-leaf cherry/rock transect near Willow Springs (T8) and the rock/burned grassland slope NE of the visitor center (T9)] had more medium rock than any other transect. These two transects account for 36% of all Pm. boylei captures. Transects which were predominantly chaparral or which had extensive grass cover had few or no captures.

Table 10 summarizes the variables which were correlated with Pm. boylei captures. Poison oak was the most important variable, but it was not common on any of the transects, accounting for less than 1% cover, even on the rock/burned grassland transect (T9) which had the most. Nonetheless, those stations which tended to have greatest poison oak cover also caught more Pm. boylei. Medium rock was also important and may be a good indicator of Pm. boylei occurrence at Pinnacles. While bare ground was correlated with Pm. boylei, this may be a bit of an artifact since areas with rock were not covered by plants such as grasses and herbs. Peromyscus boylei were not caught on transects with significant amounts of bare ground where medium size rocks were sparse or lacking. Grass was negatively correlated with the distribution of Pm. boylei.

Peromyscus californicus - California Mouse.

Peromyscus californicus is the largest member of the the genus Peromyscus. It has a somewhat limited range, occurring from central California south into Baja California.

At Pinnacles, Pm. californicus was the third most common species of Peromyscus, accounting for 10% of Peromyscus captures. Thirty-eight individuals were caught a total of 68 times. Most of the mice (79%) were caught on three transects. Thirty-four percent of the Pm. californicus were on a holly-leaf cherry/rock transect near Willow Spring (T8). This was a particularly diverse transect for vegetation, slope, exposure and substrate. Another 26% of the Pm. californicus were on the burned/unburned chamise chaparral transect (T15) on the west side. Nearly all of the mice (83%) were on the burned side which was dominated by yerba santa. Nineteen percent of the mice were on the valley oak transect (T2) along Chalone Creek south of the entrance road. These transects represented a significant range of habitats, thus suggesting a lack of strong habitat preference by Pm. californicus.

The nine variables correlated with the occurrence of Pm. californicus (Table 11) indicate a wide range of factors which influence distribution. The presence of holly-leaf cherry, medium rocks and the wildflower, Chinese houses, along with the lack of grass were the best indicators of distribution. Presence of bare ground, both summer and winter shade, buckwheat and lotus were of less, but significant importance.

In general, Pm. californicus were missing from areas of extensive grass or chaparral. The presence of medium rocks, a diversity of plants and shade seem to be important habitat components for this species.

Peromyscus maniculatus - Deer Mouse.

Peromyscus maniculatus ranges across nearly all of North America and occupies nearly every terrestrial habitat.

Peromyscus maniculatus is often the most abundant mammal within these habitats, reaching densities of 370 mice/ha on Santa Barbara Island (Charles Drost, pers. comm.).

Seventy-five Pm. maniculatus were caught a total of 137 times. This accounted for 20% of the Peromyscus captures and 8% of all small mammal captures. Peromyscus maniculatus was one of the most widespread small mammals at Pinnacles. They were found along 13 of the 16 transects, though only a few mice were caught on most of the transects.

Eighty-two percent of the Pm. maniculatus were caught on only four of the transects. Most of the captures (43%) were on the burned/unburned chamise chaparral transect (T15). Interestingly, Pm. maniculatus showed little preference for either the burned or unburned portion which was in sharp contrast to other small mammals caught on that transect. There was some slight tendency for Pm. maniculatus in the unburned portion to be caught at two stations which straddled a small fire road cutting through the chaparral. Twenty-seven Pm. maniculatus were caught on transect T14, a grassy field north of the Chaparral Campground. Two other transects which yielded 13 mice each were chamise (T7) and rock/burned grassland (T9).

Perhaps not surprisingly, the three dominant plants for the burned chaparral/chamise chaparral transect (T15) were the

best indicators of the distribution of Pm. maniculatus (yerba santa, chamise and lotus, Table 12). The presence of lotus seems to be important since the high elevation chamise transect south of the reservoir (T11) which had no lotus also caught no Pm. maniculatus. Hence chamise by itself was not a good indicator of Pm. maniculatus habitat. The negative relationship with oak leaf litter was also consistent with our observations. Transects with more than 10% cover of oak leaf litter accounted for only three captures of Pm. maniculatus.

Peromyscus truei - Pinyon Mouse.

Peromyscus truei occurs in southwestern United States. It is often found in association with rock outcrops and pinyon pines. Like some other species of Peromyscus, it is a good climber.

Peromyscus truei was both the most common Peromyscus (accounting for nearly 66% of the captures for the genus) and the most common small mammal at Pinnacles, accounting for more than a quarter of all captures. Along with Pg. californicus, it was also the most ubiquitous species, being captured on all but one transect. No single transect was clearly the best for Pm. truei. Six transects had 40 or more captures and only five had less than ten captures. The transect with the most captures was the mixed riparian woodland transect along Chalone Creek (T4). Curiously, Pm. truei was the only species to be caught in significant numbers on this transect. The only transect where Pm. truei was not caught was the burned

grassland north of the visitor center (T12). This was the transect which had the smallest number of captures and also the highest level of trap disturbance.

Not surprisingly for such a ubiquitous species, there were many variables correlated with its distribution (Table 13). Overall, large rocks, shrubs and bushes were the most important while grasses and herbaceous plants were indicative of poor habitat.

Reithrodontomys megalotis - Western Harvest Mouse.

Reithrodontomys megalotis is widespread in the western United States. It feeds primarily on seeds, but also eats insects and some vegetation, especially in the spring.

Twenty-eight R. megalotis were captured a total of 32 times. This represents a notably low recapture rate. Most of the R. megalotis were captured along only two transects. The grassy field north of the Chaparral Campground (T14) accounted for 47% of the captures. This area was composed primarily of annual grasses (79%) and herbaceous plant cover (53%). Another 31% of the R. megalotis were on the burned grassland north of the Bear Gulch visitor center (T12). Grasses provided 90% cover at this site. The other seven R. megalotis were caught on five additional transects with at least some habitat similar to that on the two main transects. No R. megalotis were captured in a strictly chaparral area.

Table 14 summarizes the variables correlated with the distribution of R. megalotis. Two grasses, Stipa bunch grass

and wild oats, were most closely associated with the distribution of this mouse. The negative correlation with soil moisture is indicative of a preference for the drier grasslands.

Sorex ornatus - Ornate Shrew.

Sores ornatus is found in a variety of habitats in the southern two thirds of coastal and central California. Like all shrew, S. ornatus must feed both day and night because of its high energy requirements. It eats mostly insects, but also feeds on vegetation and some carrion. Shrews generally live about a year.

Only one S. ornatus was caught in a Sherman trap. It was captured on the burned portion of the burned/unburned chamise chaparral transect (T15). The burned portion of the transect was characterized by yerba santa and a significant ground cover of both grasses (39%) and herbaceous plants (39%). Shrews are not routinely caught in Sherman traps in part because they are extremely light-weight (less than one ounce) and do not always spring the trap even if they enter it. Hence Sherman trapping should not be used as an indication of the abundance of shrews. Pitfall traps were, therefore, used in addition to assess shrew distribution.

Four S. ornatus were caught in pitfall traps. All four were along Bear Gulch. The area is a typical riparian woodland dominated by California sycamore (Platanus racemosa) with a deep layer of leaf litter.

Spermophilus beecheyi - California Ground Squirrel.

Spermophilus beecheyi lives in burrows which range from 5-200 feet in length. Individuals generally stay within 150 feet of a burrow entrance. Spermophilus beecheyi is strictly diurnal, feeding on vegetation (e.g. seeds, acorns, fruits and berries), insects and small vertebrates.

There were only nine captures of nine S. beecheyi. Six of these (67%) were along the mixed riparian woodland transect in Balconies Canyon (T13). Two were captured in the dry wash/barren transect north of the Chalone Creek Picnic area (T5) and one was on the rock transect north of Bear Gulch Reservoir (T10). In several areas, most notably the Chalone Creek Picnic area and the Chaparral Campground, Spermophilus beecheyi was much more common than indicated by the data. While the data seem to be a good indication of the abundance of ground squirrels along the transects, S. beecheyi were much more abundant in the vicinity of buildings, campgrounds and established picnic areas (especially the Chalone Creek Picnic area) which were not near any of the transects.

Habitat Utilization

The small mammals characteristic of each habitat type are summarized below. This information is a combination of data presented above in the description of transects and in the

species accounts. They are integrated here to provide a quick reference for each of the major habitats at Pinnacles.

#### Chamise Chaparral

Chamise chaparral and mixed chaparral were the most widespread habitats at Pinnacles. Even in the mixed chaparral, chamise was the major component, so clearly chamise represents the most dominant species throughout nearly all of the park. Two transects were in chamise (T7 and T11) and a third straddled a burned/unburned boundary (T15). A total of 1,576 trap nights were accumulated in chamise and 875 on the burned/unburned chamise transect. Approximately half of the trap nights on the later transect were in chamise. Six species were caught on the two chamise transects and three additional species were on the unburned (primarily chamise) portion of transect T15.

Dipodomys was the characteristic small mammal for chamise chaparral. All of the D. elephantinus and most of the D. heermanni were caught in chamise. In the case of D. elephantinus, 80% were on the high elevation transect south of Bear Gulch Reservoir where they were abundant. Dipodomys heermanni was moderately common on the low elevation chamise transect (T7) and rare on the chamise portion of transect T15 where Pm. maniculatus and Pg. californicus were fairly common. Peromyscus truei, Pm. boylei and Pm. californicus were all rare in chamise habitat. The only Sorex ornatus captured in a Sherman trap was in chamise.

### Mixed Chaparral

One transect north of the Chalone Creek picnic area was in mixed chaparral (T6). This transect had 821 trap nights and resulted in the capture of seven species of small mammals.

Perognathus californicus and Pm. truei were common, Peromyscus maniculatus was uncommon and D. heermanni, Pm. boylei, Pm. californicus and R. megalotis were all rare. None of these small mammals were as abundant in the mixed chaparral as they were in their preferred habitat. Since the capture rate for mixed chaparral was about average for all the transects, it seems that mixed chaparral was not particularly notable in either diversity or density of small mammals.

### Burned Chaparral

One transect was deliberately placed so that it crossed the boundary between a burned and unburned section of chamise chaparral (T15). This transect was on the west side of the Monument, northwest of the Chaparral Ranger Station. A total of 875 trap nights were accumulated on the transect with about equal numbers on the burned and unburned portions. Nine species were caught, only six of which were on the burned portion.

Peromyscus maniculatus was common and Pg. californicus was uncommon on the transect, but neither species showed any preference for burned or unburned chaparral. Of those species preferring the burned chaparral, Pm. californicus was uncommon

and D. heermanni was rare. Peromyscus truei was rare on the burned section and a bit more common in the unburned chaparral. The single R. megalotis on this transect was caught in the burned chaparral.

Even though some species showed a clear preference for burned or unburned chaparral, this did not result in a clear difference in either the number or diversity of small mammals in those areas. Hence the effect of fire seems to be to alter the composition of the small mammal community without significantly altering total density. Note that this conclusion is based on only one sample. Other changes might occur which could not be detected by this short-term sample.

#### Holly-leaved Cherry

This habitat was found in patches throughout most of the park. It was most common on steep, north-facing canyon slopes. Only one transect included a significant amount of holly-leaf cherry. This transect (T8) also had a fair amount of rock and was thus called holly-leaf cherry/rock. A total of 780 trap nights were accumulated resulting in the capture of eight species.

Neotoma lepida, Pm. truei, and Pg. californicus were all common and Pm. californicus was fairly common along the holly-leaf cherry transect. Holly-leaf cherry was significantly correlated with the abundance of all four of the above species, especially N. lepida and Pm. californicus. Peromyscus boylei, Pm. maniculatus, N. fuscipes, and Mi.

californicus were also present on the holly-leaf cherry transect, but all these species were rare. The one Mi. californicus was captured twice at one trapping station at the edge of a intermittent creek its presence was probably unrelated to holly-leaf cherry.

#### Valley Oak

This was a very restricted habitat at Pinnacles, occurring only along Chalone Creek, south of the entrance road on the east side of the Monument. Transect T2 was in this habitat and caught six species of mammals with a total of 1,087 trap nights.

Peromyscus truei was the most commonly-trapped species. It was more common in mixed riparian woodland, but even in valley oak, it would be considered abundant. Both D. heermanni and Pm. californicus were uncommon, being captured only in small numbers (13 each). Perognathus californicus, Pm. maniculatus and R. megalotis were all rare.

#### Blue Oak

Blue oaks occurred in scattered areas throughout the lower elevations, mostly on grassy slopes adjacent to Chalone Creek. Two transects were in blue oak habitat, one on the east side near Frog Canyon (T3) and one just south of the west-side entrance road near the Chaparral Ranger Station (T15). These transects accounted for 1,699 trap nights. Six species were captured in blue oak habitat.

Peromyscus truei was nearly as abundant in blue oak as it was in valley oak. It accounted for 71% of the 95 captures of mice in blue oak. Perognathus californicus was very uncommon (13 captures) and Mi. californicus, N. fuscipes, Pm. boylei and Pm. maniculatus were all rare. Hence, blue oak was not particularly diverse with Pm. truei being the predominant species.

#### Mixed Riparian Woodland

Mixed riparian woodland was the primary habitat along all of the lower drainages of Chalone Creek. It occurred in a linear pattern, generally not extending out more than a 100 m from the creek. Two transects, T4 (along Chalone Creek south of the east entrance road) and T13 (along the Balconies Trail just west of Balconies Caves), accumulated a total of 1,705 trap nights resulting in the capture of seven species.

Peromyscus truei was abundant in mixed riparian woodland with 88 captures. It accounted for 69% of the captures in this habitat. Perognathus californicus was the only other mouse which was not rare. The 12 captures of Pg. californicus would make it uncommon in mixed riparian woodland. The other small mammals included Pm. boylei, Pm. californicus and Spermophilus beecheyi, all of which were rare. Similar to several other habitats, there was only moderate diversity in the rodent species with Pm. truei making up most of the captures.

### Introduced Grassland

While a number of transects had significant amounts of introduced grasses, only one transect was mapped as being introduced grassland on the vegetation map of the park (Stitt 1983). This transect was north of the Chaparral Campground (T14) on the west side. A total of 962 trap nights were accumulated resulting in the capture of six species.

Peromyscus maniculatus, Pg. californicus and R. megalotis were all uncommon in this habitat. Microtus californicus was rare, but along with R. megalotis, had the distinction of being more abundant here than on any other transect. Hence introduced grassland was the preferred habitat for both Mi. californicus and R. megalotis at Pinnacles. Peromyscus truei was also rare, being much more common in almost all of the other habitats. One Mus musculus was caught four times on this transect, but, as discussed in the species account, grassland was not really the preferred habitat. This mouse probably represented an individual which dispersed from a population associated with the nearby buildings.

### Burned Grassland

Two transects north of the Bear Gulch visitor center included burned grassland. One was exclusively grassland (T12) and the other was rock/burned grassland (T9). The grass burned in 1979 and had largely recovered so that it was not obvious from casual observation that the area has ever been burned. Nonetheless, we referred to it as burned since it was

mapped as such by Stitt (1983). A total of 874 trap nights were accumulated on the burned grassland and 617 on the rock/burned grassland. Four species of mice were captured in the burned grassland and an additional four were on the rock/burned grassland transect.

In the burned grassland, R. megalotis and Pg. californicus were uncommon and Mi. californicus and Pm. maniculatus were rare. Grassland represented the preferred habitat for R. megalotis. It was most common on the unburned (introduced) grassland transect (T14) on the west side.

With the addition of rock outcrops, several species found in burned grassland were more common and several additional species were present. Neotoma lepida was abundant and Pm. truei, Pm. maniculatus and Pg. californicus were all more common than in the pure grassland. Peromyscus boylei was uncommon, but it occurred in the greatest density in the rock/burned grassland combination.

Reithrodontomys megalotis and Mi. californicus were both less common in the rock/burned grassland than in the unburned grassland. While the sample size was only one for Mi. californicus, this trend seemed to be real for R. megalotis which had two versus ten captures. Hence at least R. megalotis and perhaps Mi. californicus preferred pure grassland.

## Rock

Rock was the predominant habitat along one transect (T10) north of Bear Gulch Reservoir and was a significant part of two other transects, the rock/burned grassland transect (T9) northeast of the Bear Gulch visitor center and the holly-leaf cherry/rock transect (T8) near Willow Springs. The rock transect accumulated 918 trap nights and the other two transects accounted for 617 and 780 trap nights respectively. A total of 11 species were caught on these three transects.

Neotoma lepida was notably abundant on all three of the rock transects, with its highest capture rate on the rock/burned grassland transect (T9). Both Pm. truei and Pg. californicus were nearly as abundant on all three transects. Peromyscus californicus was common only on the holly-leaf cherry/rock transect. Peromyscus boylei was absent on the rock transect, but was caught in moderate numbers on the other two. The capture rates of all five of the above species were correlated with medium and/or large rocks. Eutamias merriami and Spermophilus beecheyi were both rare on rock transects. Two of the species (Mi. californicus and Pm. maniculatus) caught on the transects with rock were probably associated with other habitat variables, with rock being incidental to their presence. This resulted in nine species being clearly associated with rock habitat.

### Dry Wash/Barren

This habitat is typically called a dry wash, but was mapped as barren by Stitt (1983). In spite of the name "barren," the habitat actually had a considerable amount of both introduced grass and herbaceous cover. The cover tended to be fairly sparse, though, especially compared with transects with more of an overstory. This habitat was quite restricted at Pinnacles, occurring primarily along the major drainages.

Two transects (T1 and T5) along Chalone Creek were classified as dry wash/barren. A total of 1,689 trap nights were accumulated on these transects and seven species of mammals were caught. Dipodomys heermanni was the only species which was found predominantly in this habitat and was also the most plentiful species with 44 captures. It would still be considered uncommon, however. Perognathus californicus and Pm. truei were the next most abundant species, but they would be considered uncommon as well. Neotoma lepida, Pm. boylei, Pm. californicus, Pm. maniculatus, and Spermophilus beecheyi were also captured, but they were rare in this habitat.

Given the limited vegetational and structural diversity, it was not surprising that both diversity and density were quite low.

### Pig Rooting

Pig rooting along 15 of the 16 transects increased significantly between December 1985 and April 1987. (The 20 trapping stations for transect 7 were not used since data were missing for the December 1985 sample.) Figure 2 shows the increase in total rooting for 300 of the trap sites for which the data are complete. There was a small, but significant correlation between time from the start of the study and total rooting ( $r^2 = 0.14$ ,  $p < 0.001$ ).

Pig rooting was not evenly spread throughout the park. Table 15 summarizes the rooting for each transect. Pigs were present primarily along Chalone Creek south of the entrance road (T1 - T4) and in the blue oaks on the west side (T16). Transects T1 - T4 averaged 24% pig rooting between December 1985 and April 1987. The most extensively impacted transect was the blue oak transect (T3, 46% rooting) just south of the confluence of Frog Creek and Chalone Creek. Other transects with extensive rooting were the blue oak transect on the west side of the park (T16, 30%) and the mixed riparian woodland transect along the southern part of Chalone Creek (T4, 20%).

An analysis of the habitat variables indicates that the presence of blue oak, grass, distance to intermittent water and lower elevation were the most important factors influencing where pig rooting occurred. Table 16 lists all 13 of the variables which were significantly correlated with the occurrence of rooting. This analysis may be somewhat incomplete since there were no transects in strictly riparian

areas (such as along Bear Gulch Trail) due to the abundance of poison oak. Hence there may be other significant variables in those areas.

Pig rooting was not significantly correlated with the distribution of any of the small mammals trapped.

## DISCUSSION

### Impact of Pigs

The amount of disturbance to the ground caused by pig rooting increased significantly during the course of the study. This change represents both an increase in the extent of disturbance along transects and an increase in the number of transects with rooting. While we did not attempt to census pigs directly, the data strongly suggest that both the number of pigs and range of pigs have been increasing, particularly in the riparian and oak woodland habitats. Chaparral areas were also impacted, but to a lesser extent.

The distribution of pig rooting at Pinnacles is similar to that found by other workers in California. On both Santa Catalina and Santa Cruz Islands, pigs preferred cool, moist canyon bottoms during the dry season. In the wet season they were much more widely dispersed, and were primarily influenced by the availability of food (Van Vuren 1984, Baber and Coblentz 1986). In northern California, Barrett (1982) found that pigs were most common in live oak thickets (on the cool north slopes and riparian forests) and in irrigated pastures. In spite of the nocturnal use of pasture, the presence of dense cover seemed to be of critical importance. Their preference for dense cover and proximity to water is no doubt related to the lack of sweat glands and hence the need to

thermoregulate behaviorally (Mount 1968, Signoret et al. 1975).

Pig rooting has been shown to affect vegetation in the Great Smoky Mountains (Bratton 1974, 1975, Singer et al. 1984), the Auckland Islands (Challies 1975), the Galapagos Islands (Coblentz and Baber 1984), and the Hawaiian Islands (Becking 1970, Jacobi 1976, Lamoureux and Stemmerman 1976, Diong 1982, Spatz and Mueller-Dombois 1975). In general, the effect of rooting has been to alter the habitat to an earlier successional stage and, in some cases, to favor non-native plants over native species.

Rooting affects the vegetation directly, yet it is not always easy to demonstrate the relationship statistically (Bratton 1975). Impacts on the fauna can be even harder to quantify. The fauna may be affected directly (e.g. predation) or indirectly (e.g. changes in habitat, competition for food). Pigs are well-known to feed on carrion including deer and small mammals (Hanson and Karstad 1959, Pine and Gerdes 1973). Predation on living small mammals has not been documented. While mice and other vertebrates have routinely been found in small quantity in pig stomach contents, it is not clear whether the mice were already dead when eaten or whether there was actual predation. Peromyscus was found to be the most common vertebrate in the diet of pigs in South Carolina (Wood and Roark 1980). Pine and Gerdes (1973) reported that vertebrates (deer, gophers, ground squirrels, and unidentified mice) were minor parts of feral pig diets in California. We

expect that pigs at Pinnacles feed at least occasionally on small mammals, but perhaps only as carrion.

Indirect impacts of pigs through alteration of habitat have been demonstrated for red-backed voles (Clethrionomys gapperi) and northern short-tailed shrews (Blarina brevicauda) in the Great Smoky Mountains (Singer et al. 1984). Both of these species have specific habitat requirements which make them especially susceptible to habitat disturbance. No similar impact could be detected for white-footed mice (Peromyscus leucopus), deer mice (Peromyscus maniculatus) or for four species of salamanders (Plethodon jordani, Desmognathus ochrophaeus, D. wrighti, Eurycea bislineata) as part of the same study.

Since it was not possible to sample shrews effectively with Sherman traps, we cannot evaluate the possible impact of pig rooting on shrews. Furthermore, we were not able to find a statistical relationship between the abundance of any of the other small mammals and the presence of rooting. Since pig rooting was fairly restricted at the start of the study, it may be that the impacts would need to be studied over a longer period of time.

Even though there were no statistical relationships between pig rooting and the abundance of small mammals, disturbance to the habitat was obvious. Given the well-documented impact of pigs on vegetation in other areas, it is reasonable to expect that changes in the habitat caused by

rooting will eventually result in changes in small mammal populations.

#### Distribution of Small Mammals

Since Mus musculus is an introduced species, its potential impact on the native small mammals is of some interest. Mus musculus was found on only one transect, the introduced grassland north of the Chaparral Campground. Mus musculus does occur elsewhere in the park, but it was notably restricted to areas near human habitation. The only other Mus musculus were in the grassland adjacent to the private campground on the east side of the park. If Mu. musculus do not extend their limited distribution into more of the native habitat, there seems to be little threat to either the native flora or fauna.

Curiously, N. fuscipes was also much more common in areas near human habitation. Occasional trapping conducted in and around buildings resulted in the capture of N. fuscipes, but only an occasional N. lepida. Additionally, the distribution of N. fuscipes along the transects was extremely limited. Neotoma lepida was common in rocky areas and perhaps excluded N. fuscipes in those habitats, but there was no obvious reason for the lack of N. fuscipes in mixed riparian woodlands and oak woodlands where N. lepida was absent, especially since N. fuscipes occupies woodland habitats in other parts of its range.

Dipodomys elephantinus occupies a very limited area in the vicinity of Pinnacles National Monument. It seems to have a very specific habitat, occurring almost exclusively in pure chamise chaparral. At Pinnacles, chamise chaparral was a common and extensive habitat and D. elephantinus was clearly the dominant small mammal there. Dipodomys elephantinus not only occurred in large numbers where chamise was found, but the recapture rate was also the highest of all the small mammals with an average of 3.7 recaptures of every marked individual.

By contrast, R. megalotis, had the lowest recapture rate (for species caught at least ten times) with an average of only 1.1 recaptures. This finding reflects a trend in the data for larger species to have higher recapture rates than smaller species. Since larger species generally have longer life spans and thus remain in the population longer, their higher recapture rate is not surprising.

Peromyscus truei, Pg. californicus and, to a lesser extent, Pm. maniculatus were found on nearly every transect. Peromyscus truei and Pg. californicus also shared the distinction of being the two most common species at Pinnacles. Peromyscus truei is a widespread species in the semiarid parts of the western United States where its habitat is described as pinyon pine, juniper and rocky outcrops. At Pinnacles, the distribution of Pm. truei was not significantly correlated with juniper. The widespread distribution of Pg. californicus is much less surprising. Perognathus californicus is found

most commonly in chaparral or live oak habitats which were the dominant habitats at Pinnacles. Peromyscus maniculatus is the most widely distributed mouse in North America, being found in nearly every terrestrial habitat. It was not surprising that Pm. maniculatus was found in a variety of habitats at Pinnacles.

The only habitat which was not thoroughly sampled was the mixed riparian woodland where Sorex trowbridgii (trowbridge shrew) might be present in low density. Because of the prevalence of poison oak, this habitat was not sampled with Sherman traps. We did, however, accumulate 1,664 trap nights of pitfall trapping which resulted in the capture of four S. ornatus.

#### Diversity of Small Mammals

The rocky areas had the greatest diversity of small mammals (11 species) at Pinnacles. Since trapping did not occur in areas which were exclusively rock, the animals caught were probably inhabiting not only rocky areas, but also the adjacent habitats, usually chamise or grassland. Since it is well known that diversity is usually highest at such ecotonal boundaries, it was not surprising that rock transects had such great diversity. Furthermore, adjacent chamise and grasslands also had nearly as great of diversity as the rocky areas.

Valley oak, blue oak and introduced grassland habitats were fairly low in species diversity with only six species in

each of these habitats. All of these habitats were fairly restricted at Pinnacles.

## ACKNOWLEDGEMENTS

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## MANAGEMENT RECOMMENDATIONS

Pigs

Past research on feral pigs has clearly shown that pig rooting has a negative impact on the vegetation and at least one study demonstrated a negative impact on small mammals (Singer et al. 1984). While we are not aware of any detailed soil studies, Bratton (1975) postulated that there might be a loss of soil in areas with pigs in the Great Smoky Mountains.

Since pigs are not native to Pinnacles and they have been shown to have a negative impact on the native flora and fauna in many other areas, pigs should be eliminated from Pinnacles by whatever means practical.

Other non-native mammals

Didelphis virginiana and Mus musculus are both known from Pinnacles. Mus musculus were trapped along one transect near the Chaparral Campground and also in a field on the east side, adjacent to the private campground outside the park. These data indicate that Mus musculus is both rare and of limited distribution within the park. No attempt was made to trap or otherwise assess the population status of Didelphis virginiana. Since none were seen during the study and no road kills were found, it seems reasonable to assume that they are present only in low numbers or in local areas.

Unless there is some indication that Mus musculus or Didelphis virginiana are having a negative impact on the flora or fauna, it is probably not worthwhile to attempt to eliminate or control them, particularly since the area surrounding the park would act as a reservoir for animals which could readily disperse into the park.

#### Prescribed fire

This study was not designed to evaluate the effect of fire on small mammals. Since one transect was placed across a burned/unburned boundary, however, it is possible to draw some conclusions for a limited point in time. Data from transect T15 indicate that fire alters the composition of the small mammal community, but does not significantly affect the overall density of small mammals. Without following changes in the mammal community over a longer period of time (especially immediately after a fire), it is risky to draw specific conclusions about the density or distribution of specific species. It is reasonable to conclude, however, that native mammals living in a fire-adapted community would not be seriously impacted by fire even though their density and local distribution might fluctuate with each successional stage after the fire. This would be especially true if prescribed fires were small and thus maintained a mosaic of burned and unburned chaparral.

### Monitoring and additional research

One goal of this study was to evaluate the effect of pigs on small mammals. The study has demonstrated, at the very least, the difficulty of measuring such an impact. Hence, monitoring of small mammals would not seem necessary or productive in order to document pig impact. Many studies have shown that pigs have a negative impact on vegetation. Since it is relatively easy to document this, monitoring of pig impacts should focus on vegetation. It is also important to monitor the density and distribution of pigs so the park can assess the combined success of the fencing and pig reduction programs.

Additional research on the effect of fire on small mammals could be conducted, but a prescribed burn program should not be delayed or altered for lack of such a study. As described above, it is reasonable to assume that small mammals living in a fire community have adapted to occasional fires and will thus not be threatened by a prescribed burning program which mimics a natural fire regime.

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# Pinnacles National Monument

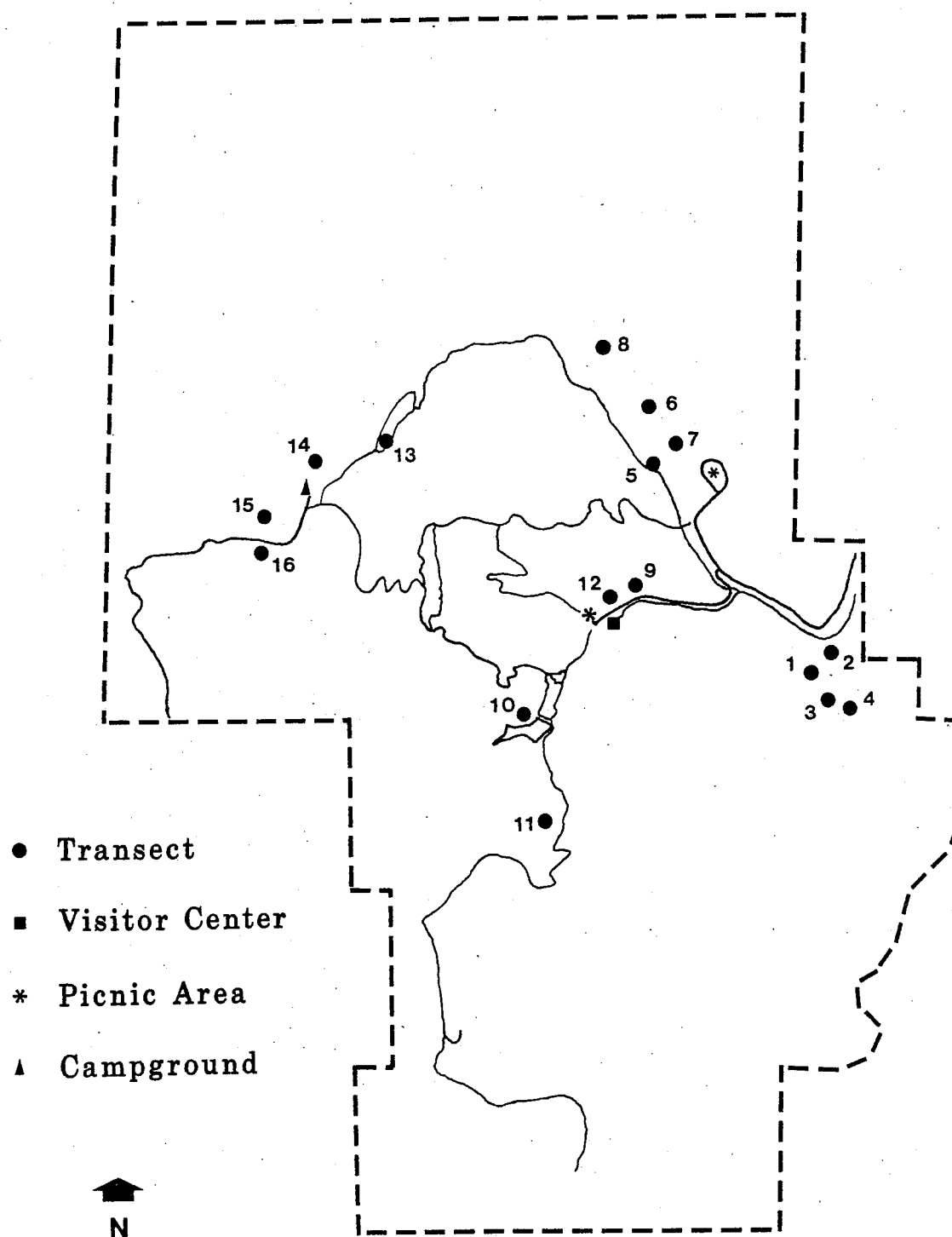


Figure 1. Pinnacles National Monument Showing Location of the 16 Transect Sites.

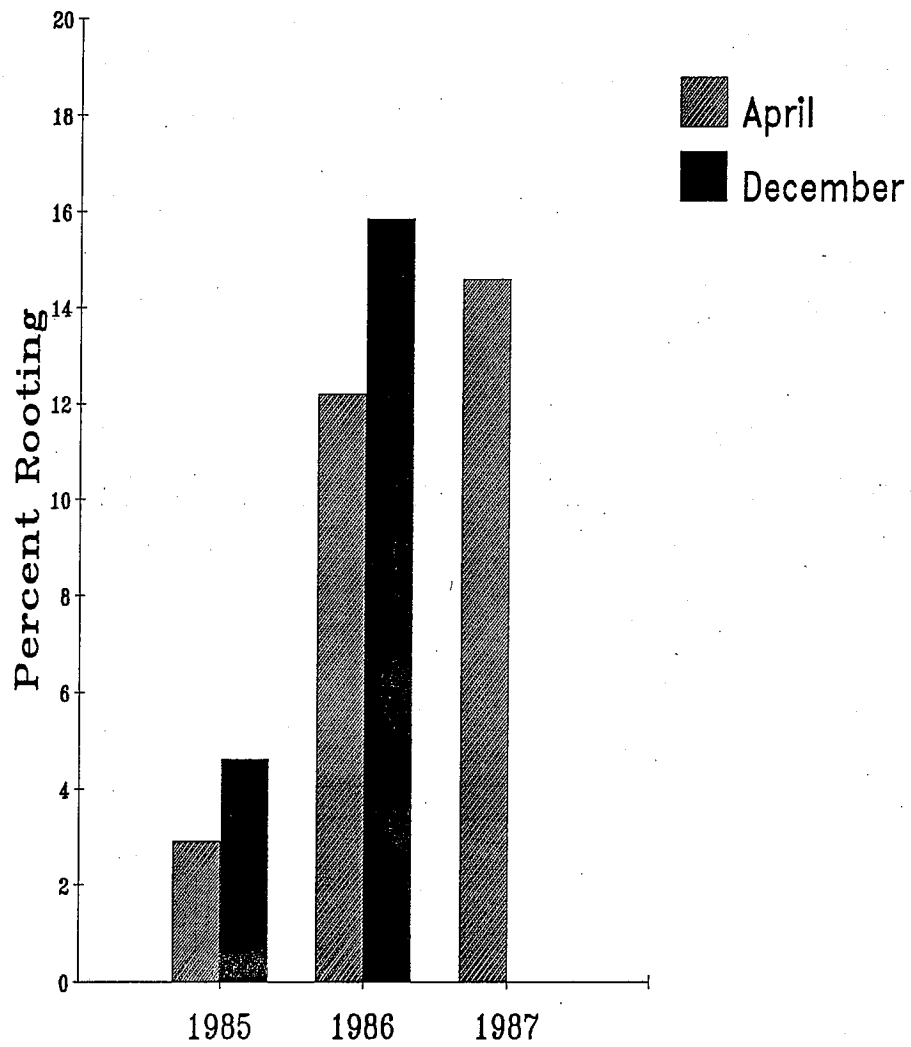


Figure 2. Pig Rooting Along Transects.

Table 1. Trapping Sessions.

| <u>Trapping<br/>Session</u> | <u>Beginning Date</u> | <u>Ending Date</u> | <u>Moon<br/>Phase*</u> |
|-----------------------------|-----------------------|--------------------|------------------------|
| 1                           | Nov 27, 1984          | Dec 17, 1984       | FQ - 10/30             |
| 2                           | Feb 11, 1985          | Mar 5, 1985        | LQ - 2/12              |
| 3                           | Apr 9, 1985           | May 1, 1985        | LQ - 4/12              |
| 4                           | Oct 17, 1985          | Nov 5, 1985        | FQ - 10/20             |
| 5                           | Dec 8, 1985           | Jan 5, 1986        | NM - 12/12             |
| 6                           | Feb 11, 1986          | Mar 10, 1986       | FQ - 2/16              |
| 7                           | Apr 19, 1986          | May 8, 1986        | FM - 4/24              |

\* Moon phase and the month and day are given for the first phase after the initiation of trapping. NM = new moon, FQ = first quarter, FM = full moon, LQ = last quarter.

Table 2. Habitat Variables Measured at Each Trap Site.

Elevation - average for trapping station (in feet).

Slope - average for trapping station (percent slope).

Exposure - average for trapping station (recorded as one of the eight cardinal points).

Percent cover for the substrate size classes below.

|                |               |
|----------------|---------------|
| <1 mm diameter | (fine soil)   |
| 1-5 mm         | (sand)        |
| 5-25 mm        | (gravel)      |
| 25-125 mm      | (medium rock) |
| >125 mm        | (large rock)  |

Wood - percent cover for each of the size classes below.

|                 |
|-----------------|
| <10 mm diameter |
| 10-100 mm       |
| >100 mm         |

Shade - percent cover

|                                            |
|--------------------------------------------|
| Shade with minimum annual vegetation cover |
| Shade with maximum annual vegetation cover |

Distance to water

|                                                       |
|-------------------------------------------------------|
| Seasonal                                              |
| Persistent (= water generally present through spring) |

Soil Moisture - average of five measurements using a soil moisture meter using a scale of 1-10 (without units).

Leaf Litter - percent cover

|      |
|------|
| Pine |
| Oak  |

Pig damage - percent cover

|                                                 |
|-------------------------------------------------|
| Old damage (estimated at more than 10 days old) |
| New damage                                      |

Percent Cover

|             |
|-------------|
| Bare ground |
| Grass       |
| Herbaceous  |

Table 2. - continued

## Percent Cover

|                                    |                     |
|------------------------------------|---------------------|
| <u>Adenostoma fasciculatum</u>     | chamise             |
| <u>Aesculus californica</u>        | California buckeye  |
| <u>Amsinckia</u> sp.               | fiddleneck          |
| <u>Arctostaphylos</u> sp.          | manzanita           |
| <u>Avena</u> sp.                   | wild oats           |
| <u>Bromus</u> sp.                  | brome grass         |
| <u>Camissonia (=Oenothera)</u> sp. | evening primrose    |
| <u>Ceanothus</u> sp.               | buckbrush           |
| <u>Claytonia perfoliata</u>        | miner's lettuce     |
| <u>Collinsia concolor</u>          | Chinese houses      |
| <u>Cryptantha muricata</u>         | forget-me-not       |
| <u>Delphinium</u> sp.              | larkspur            |
| <u>Dichelostemma</u> sp.           | blue dicks          |
| <u>Eriodictyon</u> sp.             | yerba santa         |
| <u>Eriogonum</u> sp.               | buckwheat           |
| <u>Erodium cicutarium</u>          | red-stemmed filaree |
| <u>Eschscholzia californica</u>    | California poppy    |
| <u>Galium</u> sp.                  | bedstraw            |
| <u>Juniperus osteosperma</u>       | Utah juniper        |
| <u>Lotus</u> sp.                   | lotus               |
| <u>Lupinus</u> sp.                 | lupine              |
| <u>Mimulus</u> sp.                 | monkeyflower        |
| <u>Monardella villosa</u>          | coyote mint         |

Table 2. - continued

## Percent Cover

|                                   |                    |
|-----------------------------------|--------------------|
| <u>Pellaea mucronata</u>          | bird's foot fern   |
| <u>Pinus sabiniana</u>            | digger pine        |
| <u>Prunus ilicifolia</u>          | holly-leaf cherry  |
| <u>Quercus agrifolia</u>          | coast live oak     |
| <u>Quercus douglasii</u>          | blue oak           |
| <u>Quercus lobata</u>             | valley oak         |
| <u>Rubus vitifolius</u>           | blackberry         |
| <u>Salix</u> sp.                  | willow             |
| <u>Sambucus mexicana</u>          | blue elderberry    |
| <u>Stipa pulchra</u>              | purple needlegrass |
| <u>Toxicodendron diversilobum</u> | poison oak         |
| <u>Zigadenus</u> sp.              | star lily          |

Table 3. Effective Trap Nights for Each Transect. \*

| Tran-<br>sect | Trapping Session |        |        |        |        |        |        | Total    |
|---------------|------------------|--------|--------|--------|--------|--------|--------|----------|
|               | 1                | 2      | 3      | 4      | 5      | 6      | 7      |          |
| 1             | 93.9             | 98.0   | 157.6  | 119.2  | 73.9   | 189.6  | 155.2  | 887.4    |
| 2             | 142.4            | 139.6  | 156.8  | 148.0  | 107.8  | 242.4  | 150.4  | 1087.4   |
| 3             | 147.2            | 123.3  | 136.8  | 121.6  | 52.8   | 167.2  | 124.8  | 873.7    |
| 4             | 160.0            | 129.1  | 152.8  | 142.4  | 110.9  | 170.4  | 128.0  | 993.6    |
| 5             | 133.6            | 144.0  | 128.0  | 64.0   | 59.2   | 144.8  | 128.0  | 801.6    |
| 6             | 107.2            | 136.9  | 141.6  | 62.5   | 65.6   | 152.0  | 155.2  | 821.0    |
| 7             | 143.2            | 144.8  | 111.2  | 47.2   | 59.2   | 146.4  | 152.0  | 779.6    |
| 8             | 132.6            | 140.0  | 96.0   | 70.7   | 76.8   | 117.1  | 146.4  | 779.6    |
| 9             | 109.7            | 101.9  | 137.9  | 46.2   | 35.2   | 84.0   | 102.4  | 617.3    |
| 10            | 148.8            | 141.7  | 97.6   | 130.4  | 116.0  | 144.0  | 139.2  | 917.7    |
| 11            | 116.3            | 110.7  | 80.0   | 81.9   | 93.6   | 156.8  | 156.8  | 796.1    |
| 12            | 125.9            | 138.4  | 125.6  | 53.0   | 36.8   | 206.2  | 188.0  | 873.9    |
| 13            | 20.6             | 122.7  | 119.8  | 92.0   | 98.4   | 121.6  | 136.1  | 711.2    |
| 14            | 37.6             | 156.2  | 152.8  | 172.8  | 129.6  | 157.6  | 155.2  | 961.8    |
| 15            | 12.4             | 158.4  | 153.6  | 145.6  | 141.6  | 111.2  | 152.0  | 874.8    |
| 16            | 24.0             | 144.8  | 146.4  | 132.8  | 118.4  | 112.8  | 145.6  | 824.8    |
| <hr/>         |                  |        |        |        |        |        |        |          |
| x=            | 1655.4           | 2130.5 | 2094.5 | 1630.3 | 1375.8 | 2424.1 | 2315.3 | 13,625.9 |

\* Effective trap nights = trap nights corrected for closed traps and disturbance from large mammals. See text.

Table 4. Small Mammals Captured.

| <u>Species</u>                   | <u>Captures</u> |          | <u>Individuals</u> |
|----------------------------------|-----------------|----------|--------------------|
|                                  | <u>Number</u>   | <u>%</u> | <u>Number</u>      |
| <u>Dipodomys elephantinus</u>    | 156             | 9.3      | 42                 |
| <u>Dipodomys heermanni</u>       | 68              | 4.1      | 30                 |
| <u>Dipodomys sp.</u>             | 131             | 7.8      | 60                 |
| <u>Eutamias merriami</u>         | 1               | 0.1      | 1                  |
| <u>Microtus californicus</u>     | 16              | 1.0      | 8                  |
| <u>Mus musculus</u>              | 4               | 3.8      | 1                  |
| <u>Neotoma fuscipes</u>          | 6               | 5.7      | 5                  |
| <u>Neotoma lepida</u>            | 232             | 13.9     | 99                 |
| <u>Neotoma sp.</u>               | 9               | 0.5      | 9                  |
| <u>Perognathus californicus</u>  | 251             | 15.0     | 143                |
| <u>Peromyscus boylei</u>         | 36              | 2.2      | 22                 |
| <u>Peromyscus californicus</u>   | 68              | 4.1      | 38                 |
| <u>Peromyscus maniculatus</u>    | 137             | 8.2      | 75                 |
| <u>Peromyscus sp.</u>            | 62              | 3.7      | 51                 |
| <u>Peromyscus truei</u>          | 453             | 27.1     | 221                |
| <u>Reithrodontomys megalotis</u> | 32              | 1.9      | 28                 |
| <u>Sorex ornatus</u>             | 1               | 0.1      | 1                  |
| <u>Spermophilus beecheyi</u>     | 9               | 0.5      | 9                  |
| Total                            | 1,672           |          | 843                |

Table 5. Number of Mice Trapped on each Transect. \*

| Trans-<br>sect | Species |    |    |    |    |    |     |     |    |    |     |     |    |    |    | Total  |
|----------------|---------|----|----|----|----|----|-----|-----|----|----|-----|-----|----|----|----|--------|
|                | De      | Dh | Em | Mc | Mm | Nf | Nl  | Pg  | Pb | Pc | Pm  | Pt  | Rm | So | Sb |        |
| 1              | 0       | 4  | 0  | 0  | 0  | 0  | 0   | 17  | 2  | 0  | 3   | 9   | 0  | 0  | 0  | 35     |
| 2              | 0       | 13 | 0  | 0  | 0  | 0  | 0   | 5   | 0  | 13 | 1   | 66  | 2  | 0  | 0  | 100    |
| 3              | 0       | 0  | 0  | 3  | 0  | 0  | 0   | 4   | 0  | 0  | 1   | 22  | 0  | 0  | 0  | 30     |
| 4              | 0       | 0  | 0  | 0  | 0  | 0  | 0   | 12  | 2  | 3  | 0   | 72  | 1  | 0  | 0  | 90     |
| 5              | 0       | 31 | 0  | 0  | 0  | 0  | 3   | 9   | 2  | 0  | 7   | 15  | 0  | 0  | 2  | 69     |
| 6              | 0       | 2  | 0  | 0  | 0  | 0  | 0   | 33  | 1  | 1  | 7   | 29  | 1  | 0  | 0  | 74     |
| 7              | 11      | 7  | 0  | 0  | 0  | 0  | 0   | 4   | 0  | 0  | 13  | 9   | 0  | 0  | 0  | 44     |
| 8              | 0       | 0  | 0  | 2  | 0  | 3  | 78  | 42  | 5  | 23 | 2   | 55  | 0  | 0  | 0  | 210    |
| 9              | 0       | 0  | 0  | 0  | 0  | 0  | 86  | 36  | 9  | 1  | 13  | 44  | 2  | 0  | 0  | 191    |
| 10             | 0       | 0  | 1  | 0  | 0  | 0  | 58  | 40  | 0  | 1  | 1   | 45  | 0  | 0  | 1  | 147    |
| 11             | 125     | 1  | 0  | 0  | 0  | 0  | 1   | 1   | 0  | 0  | 0   | 7   | 0  | 0  | 0  | 135    |
| 12             | 0       | 0  | 0  | 1  | 0  | 0  | 0   | 9   | 0  | 0  | 2   | 0   | 10 | 0  | 0  | 22     |
| 13             | 0       | 0  | 0  | 0  | 0  | 0  | 6   | 0   | 2  | 8  | 0   | 16  | 0  | 0  | 6  | 38     |
| 14             | 0       | 0  | 0  | 9  | 4  | 0  | 0   | 18  | 0  | 0  | 27  | 6   | 15 | 0  | 0  | 79     |
| 15             | 20      | 10 | 0  | 0  | 0  | 0  | 0   | 12  | 7  | 18 | 59  | 13  | 1  | 1  | 0  | 141    |
| 16             | 0       | 0  | 0  | 1  | 0  | 3  | 0   | 9   | 6  | 0  | 1   | 45  | 0  | 0  | 0  | 65     |
| Total          | 156     | 68 | 1  | 16 | 4  | 6  | 232 | 251 | 36 | 68 | 137 | 453 | 32 | 1  | 9  | 1,470* |

\* Small mammals identified only to genus not included.

Table 6. Variables Related to Distribution of Dipodomys  
elephantinus. Variables listed in order of  
significance.

Variables which are  
Positively Correlated

Variables which are  
Negatively Correlated

Distance to Water \*\*

Bare Ground \*\*

Chamise \*\*

Elevation \*\*

Distance to Permanent Water \*\*

Grass \*\*

Wood < 10 mm Diameter \*\*

Gravel (5-25 mm) \*\*

Herbaceous Plants \*\*

Manzanita \*\*

Exposure \*

Sand (1-5 mm) \*

Min. Shade \*

Max. Shade \*

Wild Oats \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 7. Variables Related to Dipodomys heermanni.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Camissonia \*\*

Variables which are  
Negatively Correlated

Sand (1-5 mm) \*\*

\*\* Highly Significant  $p < 0.01$

Table 8. Variables Related to Neotoma lepida. Variables listed in order of significance.

Variables which are  
Positively Correlated

Large Rock (>125 mm) \*\*  
 Monkeyflower \*\*  
 Medium Rock (25-125 mm) \*\*  
 Slope \*\*  
 Bare Ground \*\*  
 Holly-Leaf Cherry \*\*  
 Wild Oats \*\*  
 Buckwheat \*  
 California Poppy \*  
 Elevation \*

Variables which are  
Negatively Correlated

Fine Soil (< 1mm) \*\*  
 Grass \*\*  
 Herbaceous Plants \*\*  
 Chamise \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 9. Variables Related to Perognathus californicus.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Monkeyflower \*\*  
Slope \*\*  
Medium Rock (25-125 mm) \*\*  
Large Rock (>125 mm) \*\*  
Buckwheat \*\*

Larkspur \*\*

Holly-Leaf Cherry \*

California Poppy \*

Variables which are  
Negatively Correlated

Herbaceous Plants \*\*

Fine Soil (<1 mm) \*\*

Oak Leaf Litter \*\*

Grass \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 10. Variables Related to Peromyscus boylei.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Poison Oak \*\*

Medium Rock (25-125 mm) \*\*

Bare Ground \*

Variables which are  
Negatively Correlated

Grass \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 11. Variables Related to Peromyscus californicus.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Holly-Leaf Cherry \*\*

Medium Rock (25-125 mm) \*\*

Chinese Houses \*\*

Variables which are  
Negatively Correlated

Grass \*\*

Bare Ground \*

Minimum Shade \*

Maximum Shade \*

Buckwheat \*

Lotus \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 12. Variables Related to Peromyscus maniculatus.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Yerba Santa \*\*

Chamise \*\*

Lotus \*\*

Variables which are  
Negatively Correlated

Oak Leaf Litter \*

Soil Moisture \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 13. Variables Related to Peromyscus truei. Variables listed in order of significance.

Variables which are  
Positively Correlated

Large Rock (>125 mm) \*\*

Buckwheat \*\*

Poison Oak \*\*

Blue Dicks \*\*

Medium Rock (25-125 mm) \*

Holly-Leaf Cherry \*

Variables which are  
Negatively Correlated

Filaree \*\*

Herbaceous Plants \*\*

Grass \*

Stipa Bunch Grass \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 14. Variables Related to Reithrodontomys megalotis.  
Variables listed in order of significance.

Variables which are  
Positively Correlated

Stipa Bunch Grass \*\*

Wild Oats \*\*

California Poppy \*

Lotus \*

Buckwheat \*

Variables which are  
Negatively Correlated

Soil Moisture \*

\*\* Highly Significant  $p < 0.01$

\* Significant  $p < 0.10$

Table 15. Total Pig Rooting (Old and New) Along Transects.\*

| Tran-<br>sect | Trapping Session |      |     |      |      |      |      |      |
|---------------|------------------|------|-----|------|------|------|------|------|
|               | 1                | 2    | 3   | 4    | 5    | 6    | 7    | 8    |
| 1             | 2                | 6    | 4   | 7    | 21   | 16   | 13   | 14   |
| 2             | 2                | 9    | 0   | 27   | 38   | 47   | 24   | 9    |
| 3             | 20               | 62   | 24  | 50   | 61   | 79   | 56   | 20   |
| 4             | 7                | 13   | 12  | 21   | 33   | 33   | 22   | 23   |
| 5             | 0                | **   | 0   | 0    | 0    | 0    | 0    | 7    |
| 6             | 0                | **   | 0   | 0    | 2    | 10   | 4    | 11   |
| 7             | 0                | **   | 19  | 8    | **   | 30   | 27   | 19   |
| 8             | 0                | **   | 0   | 0    | 0    | 12   | 0    | 15   |
| 9             | 2                | **   | 0   | 0    | 0    | 2    | 0    | 43   |
| 10            | 0                | **   | 0   | 0    | 0    | 0    | 0    | 4    |
| 11            | 0                | **   | 0   | 0    | 0    | 0    | 0    | 0    |
| 12            | 11               | **   | 0   | 4    | 4    | 11   | 13   | 57   |
| 13            | 0                | 0    | 0   | 0    | 0    | 0    | 0    | 0    |
| 14            | 15               | 22   | 4   | 54   | 34   | 23   | 4    | 4    |
| 15            | 0                | 0    | 0   | 0    | 0    | 0    | 0    | 2    |
| 16            | 11               | 19   | 0   | 76   | 46   | 45   | 36   | 10   |
| x =           | 4.4              | 16.4 | 3.9 | 15.4 | 15.9 | 19.3 | 12.4 | 14.9 |

\* Rooting recorded as percent of surface disturbed.

\*\* Data missing

Table 16. Variables Related to Pig Damage. Variables listed in order of significance.

Variables which are  
Positively Correlated

Blue Oak \*\*

Grass \*\*

Intermittent Water \*\*

Chinese Houses \*\*

Herbaceous Plants \*\*

Slope \*\*

Valley Oak \*\*

Fine Soil (<1 mm ) \*\*

Variables which are  
Negatively Correlated

Elevation \*\*

Lotus \*\*

Large Rock (>125 mm) \*\*

Chamise \*\*

Digger Pine \*\*

\*\* Highly Significant  $p < 0.01$

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