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A SMALL MAMMAL POPULATION IN A COASTAL SAGE SCRUB COMMUNITY

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ABSTRACT

A SMALL MAMMAL POPULATION IN A COASTAL SAGE SCRUB COMMUNITY

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A live-trapping study of a small mammal population in a coastal sage scrub community near Morro Bay, California, was conducted from May 1978 through October 1979. The small mammal population included Dipodomys heermanni morroensis, Peromyscus maniculatus, Peromyscus californicus, Peromyscus boylei, Perognathus californicus, Reithrodontomys megalotis, Neotoma fucipes, and Microtus californicus. Reproductive activity generally occurred during spring and summer; however, P. maniculatus may have bred throughout the year. D. h. morroensis and P. maniculatus were found to be active year-round, while P. californicus, R. megalotis, and Perognathus californicus were not trapped during winter. The majority of double captures involved P. maniculatus, the most abundant species in the association. The occurrence of double captures suggested close spatial proximity between individuals and behavioral tolerance of that proximity, and may be related to population density. The endangered D. h. morroensis population was found to consist of fewer than 1,700 animals occupying 0.49 square miles. The diversity of species and general type of vegetation found were similar to coastal sage scrub communities in southern California.

PREFACE

As an undergraduate student my sole contact with the study of wildlife had been a single class in ecology. Being awarded a six-month graduate assistantship, with which this project was begun, was an incredible opportunity to get "hands on" experience. I am indebted to Jim Lidberg and John Gustafson, of the California Department of Fish and Game, for granting me that opportunity.

I am grateful to Julie Vanderwier and Walter Chesbro, for staying up with me to check traps through a couple of long, cold nights. My most sincere thanks are reserved for my committee members, and especially for my thesis adviser, Aryan I. Roest. Their advice and support in the early stages of my project, and their patience in seeing it through to its conclusion, are deeply appreciated.

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CHAPTER 1

INTRODUCTION

The small mammal population of a coastal sage scrub community near Morro Bay, California, was studied from May, 1978, through October, 1979. The coastal sage scrub community, as described by Munz and Keck (1959), is distinguished by certain indicator species, including Artemesia californica (Coastal Sagebrush), Salvia apiana (White Sage), Rhus integrifolia (Lemonadeberry) and Salvia mellifera (Black Sage).

The mammal populations of two coastal sage scrub communities in southern California have been described. MacMillen (1964) studied an area at the coastal base of the San Gabriel Mountains, three miles northeast of Claremont, Los Angeles County, California. The dominant plant species was A. californica, which was abundantly supported by S. apiana, Eriogonum fasciculatum (California Buckwheat) and Eriodictyon californicum (Yerba Santa). Opuntia occidentalis (Prickly Pear) and E. californicum were common in the more sparsely vegetated areas. M'Closkey (1972) and Meserve (1976) both examined a single area on the Irvine Ranch, Orange County, California. The study plot was located on an exposed, well-drained marine terrace, surrounded by grasslands and wooded gullies. The vegetation was similar to that found near Claremont; the most abundant plant species at this second site was E. fasciculatum.

The small mammal faunas of the two communities included seven (MacMillen, 1964) to eleven (Meserve, 1976) species: Neotoma lepida (Desert Woodrat), Neotoma fuscipes (Dusky-footed Woodrat), Dipodomys agilis (Pacific Kangaroo Rat), Peromyscus californicus (California Mouse), Peromyscus eremicus (Cactus Mouse), Peromyscus maniculatus (Deer Mouse), Perognathus fallax (San Diego Pocket Mouse), Perognathus longimembris (Little Pocket Mouse), Reithrodontomys megalotis (Western Harvest Mouse), Mus musculus (House Mouse) and Microtus californicus (California Vole). The last two species were rarely captured (Meserve, 1976).

Ecological mechanisms, such as temporal and spatial differences in habitat and resource utilization, have been suggested to account for the coexistence of these species (Congdon, 1974); Rosenzweig and Winakur, 1969; Rosenzweig, 1973; Hoover et al., 1977; Wondolleck, 1978; Meserve, 1974; Meserve, 1976; Munger and Brown, 1981; O'Farrell, 1978). O'Farrell (1980) has suggested that species richness on sagebrush desert in Nevada may be augmented by the establishment of an interspecific dominance hierarchy, as well as by food resource allocation, microhabitat selection and temporal partitioning. The behavioral component of species coexistence has been noted by a number of investigators (Eisenberg, 1963; MacMillen, 1964; Mihok, 1979; Evans and Holdenreid, 1943; Stickel, 1968).

The habitat of this study is classified as Coastal Sage Scrub and is located in Los Osos, San Luis Obispo County, California. Coastal sage scrub was locally described by Hoover (1970) as Coastal Sand-plains and Stabilized Dunes; this community is found on the south side of Morro Bay and is most extensively developed on the Nipomo Mesa. The general type of vegetation found in the sage scrub area near Morro Bay was similar to that found in the southern California communities. The Morro Bay community, in addition to A. californica and S. mellifera, included local species of Lupinus, Arctostaphylos, Ceanothus and Eriogonum. Ericameria ericoides (Mock Heather) was abundant. O. occidentalis, however, was not present.

Among the various species of small mammals found in the study area is a subspecies of Heermann's kangaroo rat that is unique in the genus Dipodomys. The Morro Bay Kangaroo Rat, Dipodomys heermanni morroensis, inhabits a very limited range around the southern end of Morro Bay, adjacent to the Pacific Ocean (unlike most members of this genus, which live in more interior regions). It is distinguished by having the darkest pelage among all kangaroo rats and an incomplete hip stripe (among other features). Grinnell (1922) considered the Morro Bay form a distinct species. Boulware (1943), in describing two new subspecies from southern California, reassigned the Morro Bay form to the subspecies level. The reclassification was based on the finding that one of the new subspecies (D. h. arenae) had characters intermediate between morroensis and two other subspecies of D. heermanni (jolonensis and swarthi) found in the same general geographic region.

Since 1960 the range and population of D. h. morroensis has steadily declined. A study by Stewart (1958) indicated the entire range was 4.8 square miles, less than half of which (2.2 square miles) was occupied by 8,000 individuals (Stewart and Roest, 1960).

By 1977 fewer than 2,000 kangaroo rats were thought to inhabit 0.52 square mile (Roest, 1977). Changes in habitat, such as maturation of chaparral communities, and habitat destruction due to conversion into shopping and residential areas, have been put forth as reasons for the decline in population numbers and range size (Congdon, 1971; Congdon and Roest, 1975). As a consequence, the Morro Bay Kangaroo Rat is considered "endangered" by the California Department of Fish and Game (1974) and the U.S. Fish and Wildlife Service.

As part of an effort to preserve this subspecies of kangaroo rat, the California Department of Fish and Game has established an ecological reserve near Los Osos, California, at the southern tip of Morro Bay. In mid-1978 a live-trapping study of the reserve was initiated, with the objective of determining the current kangaroo rat population and developing a habitat management plan. A list of small mammal species sharing the habitat with the kangaroo rats was generated at the same time in the hope that comparable information on these other members of the community would contribute additional insight into kangaroo rat ecology. The sympatric species included N. fuscipes, R. megalotis, P. maniculatus, P. californicus, M. californicus, Peromyscus boylei (Brush Mouse) and Perognathus californicus (California Pocket Mouse).

The habitat of the reserve was found to be marginal for kangaroo rats. About 60 percent of the reserve was judged to be unused by D. h. morroensis because of the dense vegetation; only 5 individuals were captured during the first six months of the study.

However, improvement of the habitat was considered possible by controlling brush growth (Toyoshima, 1978). The study was continued in 1979 with the goal of estimating the total kangaroo rat population and determining what proportion of the original range was currently occupied. In addition to the reserve, four other sites on which kangaroo rats were known to reside (Roest, 1977) were examined. A total of 36 live kangaroo rats was captured in 1979; the reserve yielded two new individuals (one adult female and one subadult female). Based on that data, the total Morro Bay Kangaroo Rat population was estimated to be fewer than 1,700 individuals residing in an area of 0.49 square mile (Toyoshima, 1979).

The data collected throughout the eighteen months of the study are summarized in this report. Observations regarding methods of trapping, distribution of species, reproductive activity, seasonal activity and behavior are discussed. Special problems that arose during the study are enumerated, and modifications for future studies are suggested.

CHAPTER 2

METHODS

THE STUDY SITES

DUNES

This area refers to the 50 acre reserve established by the California Department of Fish and Game, plus some 15 acres of adjacent state park land, shown in Fig. 1 (which also shows the locations of the other sites described below). Morro Bay State Park marks the western boundary of the reserve; Montana de Oro State Park marks the southern boundary. The principal landmark to the east is Pecho Road; to the north is Shark Inlet and Morro Bay (Morro Rock was used as the landmark denoting due north). A couple of jeep trails cross the southwestern side of the site.

In 1978 the distribution and relative height and density of the vegetation present on the reserve and adjacent areas were mapped. The vegetation was divided into three categories: tall and dense, intermediate and less dense, low and least dense. In the first category most plants were greater than 3 feet in height; in some places the vegetation achieved heights greater than 5 feet and was so densely grown that it was impossible to pass through it. In the second category the vegetation ranged from 2-3 feet in height and

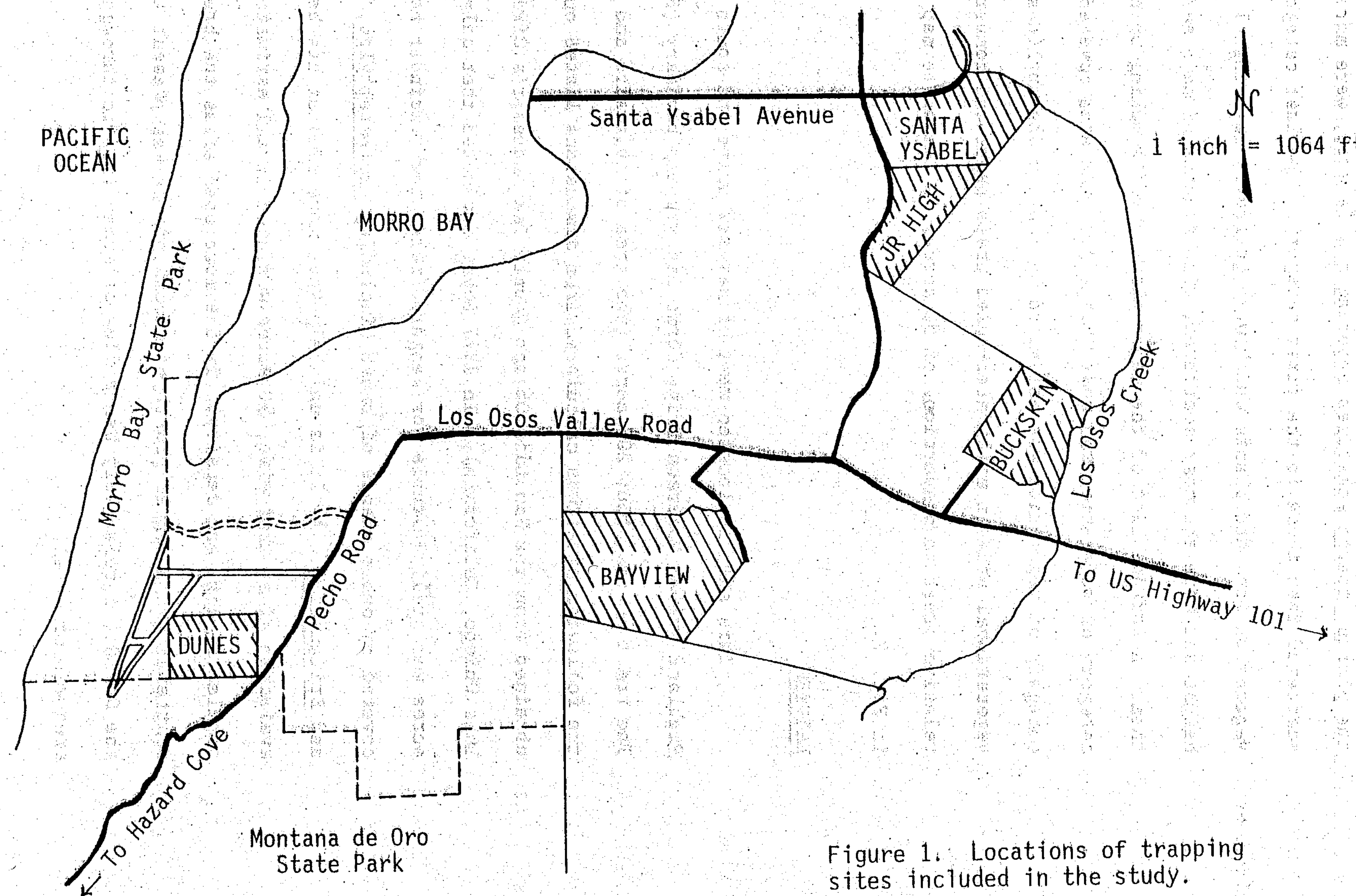

Figure 1. Locations of trapping sites included in the study.

the plants, though sometimes covering a wide area, were more scattered than those in the first category. The last category of vegetation included plants which were generally less than 1 foot in height and were the most scattered, with patches of bare sand between them. A partial list of the major plant species making up each category of vegetation was made (Table 1). The area covered by each category of vegetation was estimated by mapping the outlines of each vegetational area on millimeter-ruled graph paper and converting the relative areas to proportions of 50 acres. A composite map is shown in Fig. 2.

BAYVIEW

This site is located west of Bayview Drive and south of Highland Drive; Roderson Drive forms its western boundary (Fig. 3). The tract covers about 207 acres (the area of this site and those of the following sites was calculated from dimensions listed on maps obtained from the San Luis Obispo County Tax Assessor's Office, San Luis Obispo, California). In 1977 Roest estimated that only about 50 acres was still suitable for kangaroo rats, the remainder being covered by dense stands of brush (including *Arctostaphylos*, *Artemesia* and *Ericameria*). As it is unlikely that more habitat has become available since that time, 50 acres was used in all estimates of population size and density. In the more open areas the brush was scattered and a denser growth of annual plants was present than at the DUNES. A relatively heavy flow of human traffic through this area was observed.

Table 1. Summary of the major vegetation categories mapped in 1978*.

Category	Species (common name)
Intermediate to tall, dense (>3 feet high)	Photinia arbutifolia (Toyon)
	Salvia mellifera (Black Sage)
	Lupinus species (Lupine)
	Ericameria ericoides (Mock Heather)
	Arctostaphylos morroensis (Manzanita)
	Artemisia californica (Coastal Sagebrush)
	Baccharis pilularis (Coyote Brush)
	Prunus ilicifolia (Holly-leaved Cherry)
Intermediate, less dense (2-3 feet high)	Marah fabaceus (Wild Cucumber)
	Lotus scoparius (Deer Weed)
	Ceanothus cuneatus (Buckbrush)
	Prunus punctata (Sand Almond)
	Erysimum insulare (Wallflower)
	Eriogonum parvifolium (Buckwheat)
	Silene laciniata (Indian Pink)
	Achillea Millefolium (Yarrow)
	Dudleya lanceolata (Lance-leaved Dudleya)
	Amsinkia spectabilis (Fiddleneck)
	Cirsium occidentale (Thistle)
	Eschscholzia californica (California Poppy)
	Diplacus aurantiacus (Sticky Monkeyflower)
Low, Least Dense (<1 foot high)	Bromus species (Brome Grasses)
	Cardionema ramosissimum (Sand Mat)
	Orthocarpus purpurascens (Purple Owl's Clover)
	Eriophyllum multicaule
	Chorizanthe diffusa (Chorizanthe)
	Croton californicus (Croton)
	Montia perfoliata (Miner's Lettuce)
	Cryptantha leiocarpa (Popcorn Flower)

* after Hoover (1970)

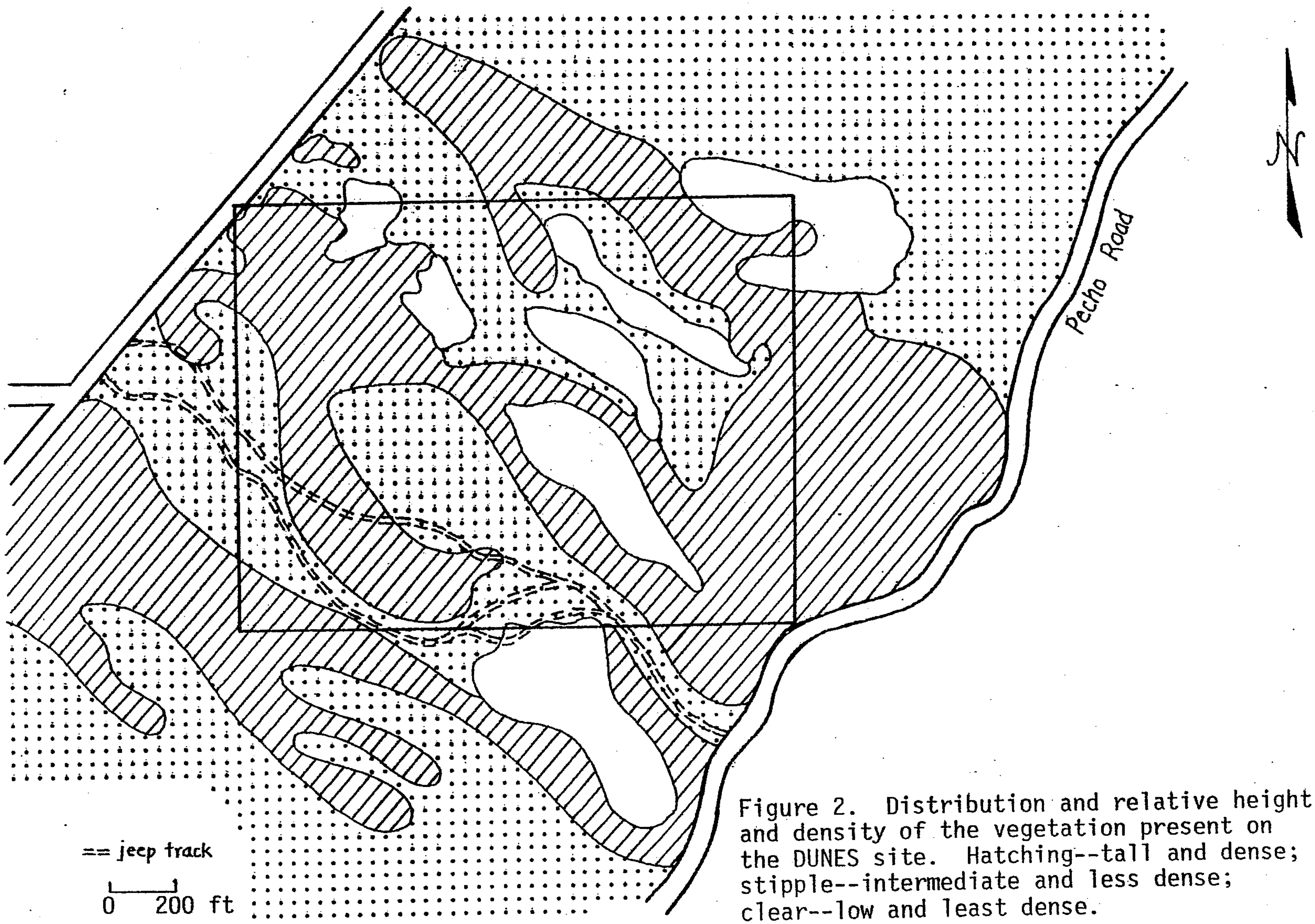

Figure 2. Distribution and relative height and density of the vegetation present on the DUNES site. Hatching--tall and dense; stipple--intermediate and less dense; clear--low and least dense.

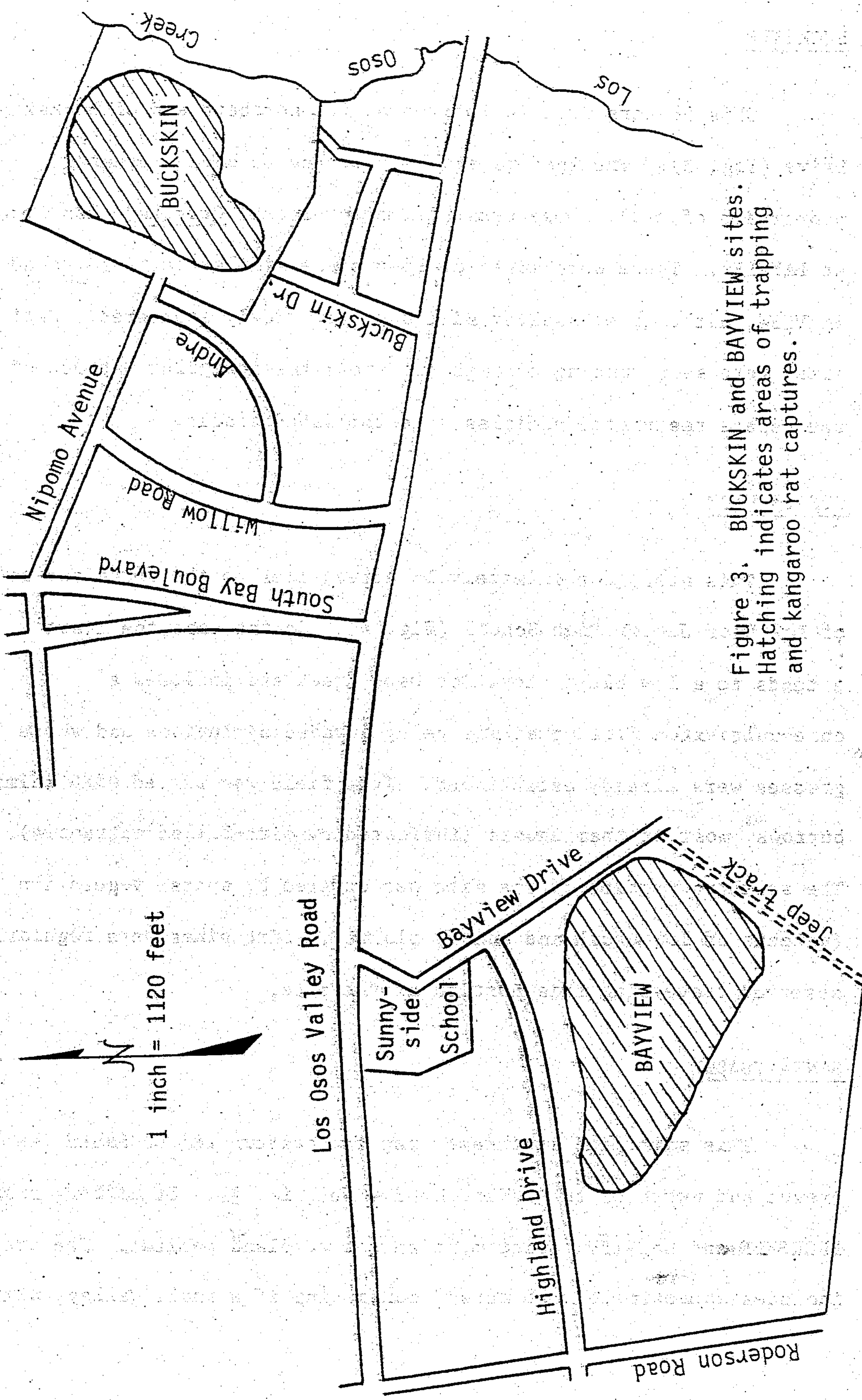

Figure 3. BUCKSKIN and BAYVIEW sites. Hatching indicates areas of trapping and kangaroo rat captures.

BUCKSKIN

This 58 acre site is located at the northern end of Buckskin Drive (Fig. 3). The land generally appeared to have a greater proportion of tall, dense brush (plus scrub oak, Quercus) than found at BAYVIEW. There were areas of open space similar to those found at BAYVIEW, although of smaller size and more widely scattered. Dirt bikes were seen running through the area; the irregular pattern of open space restricted vehicles to established trails.

JUNIOR HIGH

This area (approximately 16 acres) lies to the south and east of Los Osos Junior High School (Fig. 4). On the east the tract extends to a low bluff above Los Osos Creek and includes a once-cultivated field that was being invaded by lupines and where grasses were already established. This field was pitted with animal burrows, most of them unused (indicated by dirt-filled entrances). The southern portion of the site was covered by sparse vegetation (patches of low brush and annual plants). Dirt bikes were regularly observed traversing this portion of the site.

SANTA YSABEL

This site lies southeast from the eastern end of Santa Ysabel Avenue and north of the JUNIOR HIGH site (Fig. 4). It differs from BUCKSKIN and BAYVIEW, being more an oak woodland habitat. The area includes approximately 25 acres, consisting of a small valley, with a

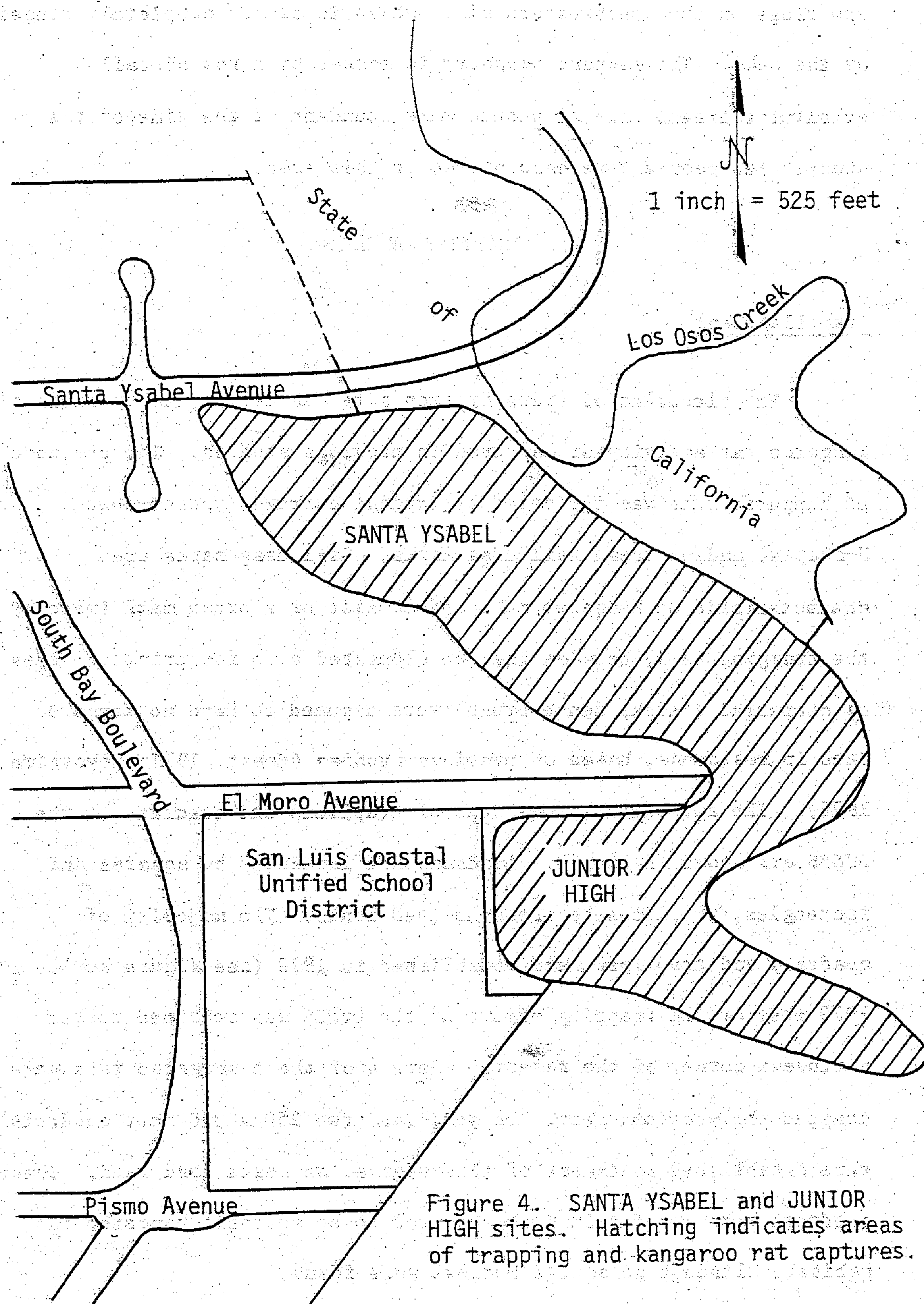

Figure 4. SANTA YSABEL and JUNIOR HIGH sites. Hatching indicates areas of trapping and kangaroo rat captures.

low ridge on the southwestern side, which is almost completely ringed by the oaks. The eastern boundary is marked by a row of tall eucalyptus trees. Annual plants were abundant at the time of the study. Few people were encountered in this area.

TRAPPING METHODS

Trap Placement

The placement of traps on each site was determined by signs of kangaroo rat activity or captures in previous studies. The presence of kangaroo rats was indicated by typical burrows (upside-down U-shapes) and/or fresh tail drag marks. Tail drag marks are characteristic of kangaroo rats and consist of a brush mark (made by the dragging tail) between the two elongated hind footprints. Areas of chaparral (thick, dense brush) were assumed to have no kangaroo rats in residence, based on previous studies (Roest, 1977; Toyoshima, 1978). The approximate locations of traplines and quadrats at the DUNES are shown in Fig. 5. Quadrats are indicated by squares and rectangles, traplines by cross-hatched lines. The majority of quadrats and traplines were established in 1978 (see figure key). In 1979 most of the trapping effort at the DUNES was confined to the northwest corner of the reserve, where 4 of the 5 kangaroo rats were trapped the previous year. In addition, two 250 x 250 foot quadrats were established southwest of the reserve, on state park land. These quadrats were located in what appeared to be suitable kangaroo rat habitat, although no active burrows were found.

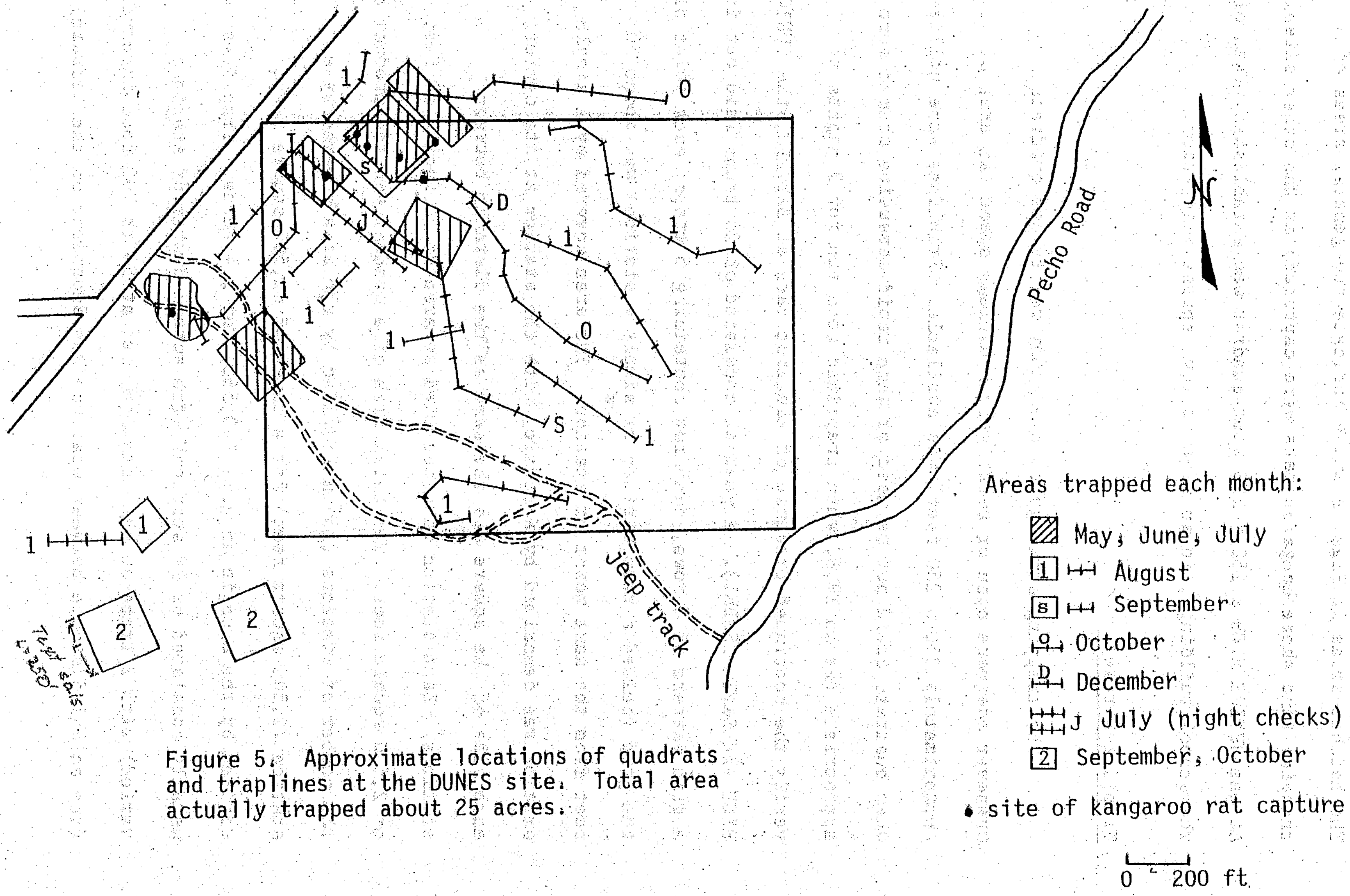

Figure 5. Approximate locations of quadrats and traplines at the DUNES site. Total area actually trapped about 25 acres.

The hatched areas in Figs. 3 and 4 indicate the general areas of trapping (and where kangaroo rats were captured) at the other sites. At the JUNIOR HIGH a 250 x 250 foot quadrat was established south of the school buildings, in an area of low, sparse vegetation.

Trapping Strategy

The trapping strategy of the study was to use quadrats whenever adequate open or relatively brushless space (an area of approximately 250 x 250 feet) was available. Traplines were utilized when quadrats could not be used or when rapid censusing seemed more appropriate (as in 1978, when traplines were run for 3 nights to verify the continued presence of kangaroo rats at BAYVIEW, the JUNIOR HIGH and SANTA YSABEL). A quadrat consisted of 25 traps laid out in a grid pattern of 5 rows, each row containing 5 traps; each point of the grid (called a trap station or simply a station) was about 50 feet from the next point or station. The area covered by a single station was described by a square, with the station at its center; each side of the square was the same as the distance between stations. Each station thus occupied an area of 50 feet x 50 feet, or 2,500 square feet. The total area of a quadrat was the product of the number of stations (25) multiplied by the area covered by a station (2,500 square feet) for a total of 62,500 square feet, divided by the area in an acre (43,560), or 1.4 acres. Traplines usually consisted of 10 stations (the actual number of stations varied) with 2 traps at each station, set at 50 to 100 foot intervals (the actual distance between stations was dependent on the terrain).

The area covered by each station was calculated as for the quadrats described above. Each station in a trapline with 100-foot intervals covered 10,000 square feet (100 x 100 feet). The total area of a trapline was a strip, calculated by multiplying the number of stations by 2,500 or 10,000, and then dividing the product by 43,560. Quadrats and traplines used in the present study followed the same procedure used in previous live-trapping studies of the Morro Bay Kangaroo Rat (Congdon, 1971; Roest, 1975; Roest, 1977).

Traps

Sherman Live Traps, both the collapsible (3 x 3.5 x 9 inches) and non-collapsible (3 x 3 x 10 inches) forms, were used in the capture-recapture method of the study. The traps were usually baited with Quaker Old-Fashioned Rolled Oats. More elaborate mixtures of peanut butter, wild bird seed, rolled oats and bacon grease were used on occasion, but did not appear to be more attractive than plain bait. The mixtures had the disadvantages of being more expensive and attractive to unwanted birds and insects (ants and beetles). All traps were provided with cotton nesting material, as insulation against cool night-time temperatures. All traps were placed beneath vegetation, to shield them from direct sunlight and easy detection by persons other than the investigator. Direct sunlight on the metal traps results in the generation of high internal temperatures, which could lead to death due to hyperthermia to any animal inside. Theft of the traps or of the animal(s) inside was minimized (but not completely avoided) by placing traps in inconspicuous places.

Lastly, traps were set deeply in the sandy soils present on all the sites and covered over with more sand so that just the front of the trap was exposed. The soil retained heat which was transmitted to the traps and helped further insulate the traps from cold. All stations were marked by small flags that were usually unnoticeable to the casual observer. Markers were especially important when dense fog obliterated the landmarks used to orient the quadrats and/or traplines.

Despite the precautions taken, trap injury and/or trap death did occur. A few kangaroo rats lost the brushy tips of their tails, which were nipped off when the trap door closed on them. The animals appeared to be undisturbed by the loss. Animals found dead in traps were taken to California Polytechnic State University, San Luis Obispo, California, for preparation as study specimens. The skins were numbered and cataloged for inclusion in the mammal collection of the Department of Biological Sciences.

Trapping Periods

Trapping periods ranged from 3 to 7 nights in duration. Quadrats or traplines were established in the late afternoon, left undisturbed through the night and checked for captures the next morning (generally at dawn, before the sun was high enough to shine directly down on the traps). Early in the study the traps were left open during the day, as most of the animals were nocturnal or crepuscular, a practice which was probably responsible for at least half of all trap deaths recorded in 1978. Later in the study the traps were kept closed during the day and reset in the late afternoon; this resulted in a reduction in the number of trap deaths recorded in 1979. The only exceptions to the procedure described above were in July of 1979. On two occasions traps were checked every 1.5 to 2 hours from 9:00 P.M. to midnight and twice between 6:00 and 9:00 A.M. the following morning. The traps were set out in two parallel lines with 2 traps at each station and 100 feet between stations. Each line had 12 stations. Six foot stakes with strips of fluorescent orange tape tied to the upper ends marked the locations of the traps and facilitated their detection in the dark. The rationale for checking the traps more frequently was to determine how many additional animals would be captured if traps were made available more than once within a given 12 to 14 hour period.

Data Collected

Captured animals, with the exceptions of birds and larger species (woodrat, ground squirrel and rabbits), were ear-tagged with numbered Monel metal chick wing tags to facilitate identification of individuals. At the time of capture information regarding species, sex, age (approximated by size and pelage color), reproductive condition (scrotal testes, signs of lactation, pregnancy) and the presence of external parasites (fleas, ticks and, rarely, botfly larvae) were recorded for each individual. The animal was then released at the site of capture. Recaptured animals were checked for reproductive condition and external parasites. Changes in age (i.e, maturing of non-adults) or external appearance (molting) were noted.

Animals that lost their ear tags (determined by the presence of a tear in the ear cartilage) were noted, retagged and the new number recorded. Some animals escaped before pertinent information could be recorded and/or prior to application of an ear tag; special note was made of those animals.

DEFINITIONS AND CALCULATIONS

Trap Night

A trap-night is defined as one trap left out for one night (Grinnell, 1914). A quadrat of 25 traps left out for one night constitutes 25 trap-nights.

Relative Abundance

Due to the differing number of trap-nights in each month (most of the trapping was done in the summer months), standardization of some sort was needed to allow comparison of the trapping data from one month to the next, of data from the different sites, and of data from different species. The relative abundance, expressed as the number of captures per 100 trap-nights, was calculated for each species of small mammal captured during the study, on a month-by-month basis. Only live animals were considered, as those individuals lost through trap death could not be restored to the population. In any given month only first captures were included in the calculations; an individual captured more than once in the same trapping interval or in the same month, was counted only once.

However, if an individual captured one month was recaptured 3 months later the relative abundance for each month would include that individual. Captured animals that escaped prior to the application of a numbered tag were also excluded from the calculations, as those individuals could not be positively identified.

Relative Density

Relative density was calculated as the number of captures per acre trapped. Only the area actually covered by traplines or quadrats was included. On the majority of sites the most suitable kangaroo rat habitat was patchily distributed; to have extrapolated the number of individuals trapped to the entire acreage of each site would have resulted in overestimations of population size. The placement of traps was determined by the investigator's estimation of the likelihood that kangaroo rats were present; including only the area trapped would reflect a more realistic estimation of population size. Relative density was calculated for each month and for each site trapped. If a trapline or quadrat was used more than once in a month, only the acreage initially covered was included in the totals.

Species Turnover

One way to monitor changes in the composition of a population is to examine the number of new (i.e., previously untagged) captures trapped over a common unit of time. The percentage of new captures was calculated for each species on a monthly basis. Animals found dead in the traps or that escaped prior to tagging were excluded from the calculations.

Sex Ratio

The ratio of male to female captures was calculated by dividing the number of males trapped during the study by the number of females trapped. Animals found dead in the traps or that escaped prior to tagging were excluded from the calculations.

Age Ratio

The ratio of adult to non-adult captures was calculated for each species at each site. Animals were classified as adults or juveniles on the basis of relative size and pelage color. No attempt was made to distinguish between immatures and juveniles.

Kangaroo Rat Population Estimate

In 1977 Roest outlined four non-conventional methods for estimating the size of the Morro Bay Kangaroo Rat population. The rationale for using these methods was based on the finding that very few kangaroo rats were caught despite a considerable expenditure of trapping effort. It was felt the estimates were more reasonable, given the available data, than might be expected from estimates based on more conventional methods, such as the Lincoln Index. The assumptions made for each method described below were based on actual trapping data.

Method 1: Assumed territory size. The distance between the station of the first capture and subsequent recapture at a different station was assumed to be the minimum distance within which one kangaroo rat would not allow another to establish a home burrow.

The assumed "territory" was described as a circle with a radius of the minimum distance mentioned above. The results yield that portion of an acre occupied by one kangaroo rat, from which a density value (rats per acre) could be calculated. The product of density multiplied by the total estimated acreage of the occupied portion of the range equals the estimated total number of kangaroo rats present.

Method 2: Density per site. In this method the population estimate is calculated from the product of the estimated acreage of a given site multiplied by the actual number of kangaroo rats captured per acre of area covered by traplines and/or quadrats. The site estimates were summed to yield a total population estimate.

Method 3: Average density over the range. This method is similar to the previous method except it is based on an average density value (average number of kangaroo rats per acre trapped) multiplied by the area of the occupied portion of the range.

Method 4: Proportional relative abundance. The last method utilizes relative abundance and density values to estimate the number of kangaroo rats at each site, which are then summed to yield the population estimate. The following equation was used to calculate R, the estimated number of rats per acre:

$$R = \frac{\text{"normal" relative density}}{\text{"normal" relative abundance}} \times \text{relative abundance at each site}$$

where "normal" relative density and relative abundance values are assumed to be those of the "best" site for kangaroo rats (i.e., the site with the greatest number of rats). The product of R multiplied by the acreage of a site results in population estimates for each individual site, which are then summed to obtain an overall population estimate.

CHAPTER 3

RESULTS

SUMMARY OF TRAPPING DATA

Species Composition and Distribution

Data for each small mammal species captured at all the sites included in the study are summarized in Table 2. The total number of animals trapped and marked is listed; values in parentheses indicate individuals lost through trap death. Note the conspicuous absence of P. maniculatus from all sites but the DUNES (with a single exception). BAYVIEW yielded the greatest number of kangaroo rats. P. boylei was present only at BUCKSKIN and SANTA YSABEL. Also listed are the total trapping effort (trap-nights) and area covered by traplines and quadrats at each site. Estimated total area of each site is listed.

Kangaroo Rat Captures

Table 3 summarizes the trapping data for D. h morroensis, listed in chronological order by site location. At the DUNES two animals (Nos. 990 and 539) were trapped in both 1978 and 1979. Animals found dead in the trap or that died while under observation were so noted.

Table 2. Summary of trapping data (numbers in parentheses are those individuals found dead in the traps).

	Species	Number of animals trapped				
		DUNES	BK	BV	JH	SY
70-80g	Dipodomys heermanni morroensis (Morro Bay Kangaroo Rat)	8	5 (1)	24 (2)	8	8
10-30g	Peromyscus maniculatus (Deer Mouse)	185 (17)	0	1	0	0
18-29g	Chaetodipus / Perognathus californicus (California Pocket Mouse)	27 (1)	13	3 (2)	0	4
8-15g	Reithrodontomys megalotis (Western Harvest Mouse)	14 (1)	3	1	0	4
33-54g	Peromyscus californicus (California Mouse)	10	3	0	4	8 (1)
30-81g	Microtus californicus (California Vole)	3 (2)	0	1	0	0
205-360g	Neotoma fuscipes (Dusky-footed Woodrat)	1	0	0	1	5
	Peromyscus boylei (Brush Mouse)	0	1	0	0	2
	Lepus californicus (Black-tailed Jackrabbit)	2	0	0	0	0
	Spermophilus beecheyi (California Ground Squirrel)	0	0	0	1	0
	Total trap-nights	3,268	224	366	228	218
	Total acres trapped	25	6	8	7	6
	Total acreage per site (approx)	50	58	50	15	26

BK = BUCKSKIN, BV = BAYVIEW, JH = JUNIOR HIGH, SY = SANTA YSABEL.

Table 3. Summary of trapping data for tagged D. h. morroensis at all sites included in the study.

Site	Tag #	Dates of Capture
DUNES		
(1978)	998	5/23
	997	5/24; 6/28-7/7; 7/23-28; 9/21-22
	912	6/1 (First trapped and marked on 4/15/77)
	990	7/1-3; 7/5; 9/22; 12/21-22
	815	7/23-27
	539	12/22
(1979)	990*	1/20-21; 2/4-5, 2/7; 3/11; 3/20; 3/31; 4/1; 5/19-20
	539*	3/10-12; 3/19-20; 4/1; 5/19-20; 6/13-15; 6/22-24
	570	5/19
	727	8/1
BAYVIEW		
(1978)	846	8/9-11
	847	8/9-11
	851	8/10-11
	855	8/11
	856	8/11
(1979)	578	7/7, 7/9
	579	7/8/, 7/11 (Kept under observation until 7/21/79)
	---	7/9 (Found dead in a trap displaced 200 feet)
	581	7/10-13
	582	7/10-11
	585	7/11
	741	8/15-17, 8/24
	---	8/15 (Escaped prior to marking with ear tag)
	742	8/15-17, 8/24
	723	8/15-17 (Died in captivity on 8/17/79)
	744	8/16
	745	8/16-17, 8/22-23
	746	8/16-17, 8/22-23
	747	8/17, 8/22, 8/24
	748	8/17, 8/22
	750	8/17, 8/24
	751	8/17, 8/22-24 (Kept under observation until 8/27/79)
	753	8/23-24 (Died in captivity on 8/24/79)
	754	8/23
	756	8/23
	758	8/24

* First captured and marked in 1978

Table 3 (continued)

Site	Tag #	Dates of Capture
JUNIOR HIGH		
(1978)	891	8/23-24
	895	8/24
(1979)	598	7/24
	599	7/24-25
	706	7/25
	707	7/25-28
	713	7/26, 7/28
	720	7/28
SANTA YSABEL		
(1978)	896	8/31
	897	8/31, 9/1
	---	9/2 (No tag available to mark animal)
(1979)	595	7/24-28
	704	7/25
	705	7/25-26, 7/28
	711	7/26
	719	7/28
BUCKSKIN		
(1979)	583	7/11
	723	8/7
	---	8/9 (Died in captivity on 8/9/79)
	733	8/10-11
	737	8/10

Trap Deaths

Total trap losses (trap deaths) are summarized in Table 4. No visible wounds were observed on any of the birds, and the exact causes of death were unknown. It was assumed the birds entered traps during the day and were unable to escape; death may have been due to hyperthermia. The causes of death listed for the mammals give the most likely possibilities, given the conditions under which they were found. In cases where one animal was partially cannibalized by the co-captive animal, it was not known whether the death of the first animal was from natural causes (starvation, hypothermia) or the result of an aggressive attack by the second animal. The eating of flesh was assumed to be a survival strategy.

Double Captures

A total of 45 cases of double capture were noted during the present study--43 pairs of conspecific animals (summarized in Table 5) and 2 pairs involving members of different species. In 11 cases the sex, age or reproductive state of one deer mouse could not be ascertained, either because the animal escaped before it could be checked and the information recorded, or it was cannibalized by the co-captive animal. The other intraspecific double captures involved _R. megalotis_ (all male/female pairs) and _P. californicus_ (an adult male was captured with a lactating adult female).

The first case of interspecific double capture was of an adult male _P. maniculatus_ trapped with an adult male _P. californicus_; (neither in active breeding condition), captured in the summer.

Table 4. Total losses due to trap deaths during the study.

Species	n	Probable cause of death
P. maniculatus	4	Caught by trap door (asphyxiated)
	7	Unknown; cannibalized by co-captive P. maniculatus
	6	Unknown--possibly due to "stress"?
R. megalotis	1	Caught by trap door when attempting to escape
Perognathus*	1	Unknown; cannibalized by co-captive P. maniculatus
D. h. morroensis	1	Shock, "stress"
	2	Hypothermia, self-inflicted injuries
	1	Found dead in the trap
M. californicus	1	Found dead in trap--"stress"?
Zonatrichia leucophrys (White-crowned Sparrow)	3	Hyperthermia?
Thryomanes bewickii (Bewick's Wren)	1	Hyperthermia?

* Perognathus californicus

Table 5. Summary of intraspecific double capture data collected during the study.

Sexes	P. maniculatus	R. megalotis	P. californicus
Male/Male	3*	0	0
Female/Female	5	0	0
Male/Female	18	5	1
Unknown**	11	0	0

* numbers indicate the number of pairs involved

** sex of one co-captive could not be determined (see text)

The second case involved an adult female P. maniculatus in a non-reproductive state captured with a Perognathus of unknown sex, age and reproductive state. The deer mouse had consumed part of the pocket mouse (head and viscera); whether the latter animal had a numbered tag was unknown. This case occurred in the fall.

The majority of double captures occurred during the summer and fall (29 of 45 = 64 percent). When trapping effort per season was taken into account, the number of double captures per 100 trap-nights for P. maniculatus was 4.0 in the winter, 0.8 in the spring, 0.7 in the summer, and 2.0 in the fall. For R. megalotis, the number of double captures per 100 trap-nights was 0.4 in the winter, 0.2 in the fall and 0.1 in the summer; for P. californicus, 0.2 in the fall.

Night Checks

Table 6 summarizes the data collected on the two occasions when traps were checked for captures between 9:00 P.M. and 9:00 A.M. the following morning. On the first occasion (July 19-20, 1979) two pocket mice (Nos. 829 and 590) were captured before midnight and between midnight and 6:30 A.M.; the second animal had traveled about 100 feet from the site of initial capture. (These animals were counted only once in the calculations of relative abundance, relative density and trapping effort.) The single deer mouse captured had been previously tagged. On the second occasion (July 31-August 1, 1979), no animals were recaptured. Two of the deer mice captured had been tagged earlier in the study. A new kangaroo rat (No. 727) was captured, the only non-adult animal trapped at the DUNES.

Table 6. Night check trapping data collected at the DUNES.

Date	Time of check	Species	Tag #	Sex	Age	Site #
July 19	9:00 PM	No captures				
	10:30	Perognathus[1]	829	Male	Adult	7
		Perognathus[2]	590	?	?	12
	12:00 AM	P. maniculatus[2]	600	Male	Adult	15
July 20	6:30 AM	Perognathus	829			7
		Perognathus	590			14
		Perognathus[3]	---	Male	Adult	14
July 31	9:00 PM	No captures				
	10:15	P. maniculatus[4]	728	?	?	21
	11:00	No captures				
August 1	6:30 AM	P. maniculatus[5]	562	Male	Adult	1
		P. maniculatus[6]	524	Male	Adult	13
		D. h. morroensis	727	Female	Subadult	17
		Perognathus	721	Male	Juvenile	24
	8:30	No captures				

1 Perognathus californicus

2 Had tag when captured; no previous record found

3 Escaped prior to tagging

4 Age and sex not recorded

5 First captured 4/15/79

6 First captured 10/15/78

POPULATION DYNAMICS

Relative Abundance

Monthly relative abundance values for each species captured at the DUNES are summarized in Table 7. Relative abundance values for the entire study are included. P. maniculatus was the most abundant species and N. fuscipes the least abundant. Values for D. h. morroensis in 1979 (January through June) reflect the repeated capture of 2 individuals, Nos. 990 and 539.

Table 8 summarizes the relative abundance values for each species trapped at BAYVIEW, BUCKSKIN, the JUNIOR HIGH and SANTA YSABEL. Comparison of Tables 7 and 8 indicate BAYVIEW was the best site for kangaroo rats and the DUNES for P. maniculatus.

Relative Density

Monthly and overall values for each species captured at the DUNES are summarized in Table 9. Values for species trapped at the other sites are summarized in Table 10.

Turnover of Individuals

Table 11 summarizes the monthly (and overall) turnover of individuals trapped at the DUNES. The repeated captures of individual kangaroo rats result in a low overall turnover value (the lowest of all species found at this site). All N. fuscipes and R. megalotis captures were of untagged animals. The capture of new deer mice tended to be higher in summer and fall.

Table 7. Relative abundance (captures per 100 trap-nights) of small mammals captured at the DUNES.

Month	Dhm*	Pm	Pc	Rm	Pgc	Mc	Nf
May, 1978	0.9				0.4		
June	1.1	1.7		0.6	0.6		
July	0.4	5.7		0.7	1.1		
August		9.0	0.7	0.5	0.9		0.2
September	1.7	18.3	0.9		3.5		
October		13.1	1.0		1.9		
November							
December	1.0	25.0					
January, 1979	1.1	5.7					
February	1.1	6.8		2.3			
March	1.2	5.9	0.6				
April	2.0	14.0	1.0		3.1		
May	2.0	4.0			0.7		
June	0.7	2.0			1.3		
July		2.1			4.2		
August	2.1						
September		3.0				2.0	
October		6.4	1.3	0.6		1.3	
Cumulative	0.2	5.7	0.3	0.4	0.8	0.1	0.3

Dhm = *D. h. morroensis*, Pm = *P. maniculatus*, Pc = *P. californicus*, Rm = *R. megalotis*, Pgc = *Perognathus californicus*, Mc = *M. californicus*, Nf = *N. fuscipes*

* Reflects repeated captures of 2 individuals; see text

Table 8. Relative abundance (captures per 100 trap-nights) of small mammals captured at BAYVIEW, BUCKSKIN, the JUNIOR HIGH and SANTA YSABEL.

Site	Dhm	Pm	Pc	Rm	Pgc	Pb	Mc	Nf
BAYVIEW								
1978 July	9.3							
1979 July	3.0			0.6			0.6	
August	9.7	0.7			2.1			
Cumulative	6.6	0.3		0.3	0.8		0.3	
BUCKSKIN								
1979 July	1.6		1.6	3.1	6.3	1.6		
August	1.9		1.3	0.6	5.6			
Cumulative	1.8		1.3	1.3	5.8	0.4		
JUNIOR HIGH								
1978 August	4.2		8.3					2.1
1979 July	3.3							
Cumulative	3.5		1.8					0.4
SANTA YSABEL								
1978 September	3.8		6.4					6.4
1979 July	3.6		2.1	2.9	2.9	1.4		
Cumulative	3.7		3.7	1.8	0.9	0.9		2.3

Dhm = *D. h. morroensis*, Pm = *P. maniculatus*, Pc = *P. californicus*, Rm = *R. megalotis*, Pgc = *Perognathus californicus*, Pb = *P. boylei*, Mc = *M. californicus*, Nf = *N. fuscipes*

Table 9. Relative density (number of captures per acre trapped) of small mammal species trapped at the DUNES.

Month	Dhm	Pm	Pc	Rm	Pgc	Mc	Nf
May, 1978	1.4				0.7		
June	0.7	2.1		0.7	0.7		
July	0.4	6.8		0.8	1.4		
August		3.8	0.3	0.2	0.4		0.1
September	0.5	5.7	0.3		1.1		
October		3.8	0.3		0.6		
November							
December	2.9	17.4					
January, 1979	2.5	6.2					
February	3.5	10.0		3.5			
March	0.8	3.8		0.4			
April	3.8	26.9	1.9		5.8		
May	1.0	2.1			0.7		
June	0.7	2.1			0.7		
July		0.7			1.4		
August	0.7						
September		2.1				1.4	
October		2.6	0.5	0.3		0.5	
Cumulative	0.2	7.4	0.4	0.6	1.1	0.1	0.04

Dhm = *D. h. morroensis*, Pm = *P. maniculatus*, Pc = *P. californicus*, Rm = *R. megalotis*, Pgc = *Perognathus californicus*, Mc = *M. californicus*, Nf = *N. fuscipes*

Table 10. Relative density (number of captures per acre trapped) of small mammals captured at BAYVIEW, BUCKSKIN, the JUNIOR HIGH and SANTA YSABEL.

Site	Dhm	Pm	Pc	Rm	Pgc	Pb	Mc	Nf
BAYVIEW								
1978 August	9.6							
1979 July	1.8			0.4			0.4	
August	5.1	0.4			1.1			
Cumulative	3.0	0.1		0.1	0.4		0.1	
BUCKSKIN								
1979 July	0.4		0.4	0.8	1.6	0.4		
August	0.8		0.5	0.3	2.5			
Cumulative	0.7		0.5	0.5	2.2	0.2		
JUNIOR HIGH								
1978 August	0.5		1.0					0.3
1979 July	2.6							
Cumulative	1.1		0.6					0.1
SANTA YSABEL								
1978 August	1.0		1.7					1.7
1979 July	1.6		0.9	1.2	1.2	0.6		
Cumulative	1.3		1.3	0.7	0.7	0.3		0.8

Dhm = *D. h. morroensis*, Pm = *P. maniculatus*, Pc = *P. californicus*, Rm = *R. megalotis*, Pgc = *Perognathus californicus*, Pb = *P. boylei*, Mc = *M. californicus*, Nf = *N. fuscipes*

Table 11. Turnover of individuals of each species trapped at the DUNES.

Month	Proportion of new individuals captured each month*						
	Dhm	Pm	Pc	Rm	Pgc	Mc	Nf
May, 1978	100				100		
June	50	100		100	100		
July	67	100		100	100		
August		90	100	100	60		100
September	0	86	100		75		
October		81	100		100		
November							
December	50	67					
January, 1979	0	60					
February	0	50		100			
March	0	70		100			
April	0	50	100		67		
May	33	83			50		
June	0	67			100		
July		100			50		
August	100	0			100		
September		100				100	
October		90	100	100		50	
Cumulative	33	83	100	100	87	75	100

Dhm = D. h. morroensis, Pm = P. maniculatus, Pc = P. californicus, Rm = R. megalotis, Pgc = Perognathus californicus, Mc = M. californicus, Nf = N. fuscipes

* New captures each month/total number of captures each month

All individuals of all species trapped at BAYVIEW, BUCKSKIN, the JUNIOR HIGH and SANTA YSABEL were new captures when turnover was considered on a monthly basis. Some individuals were recaptured within a given trapping period, but not in different trapping periods.

Sex and Age Ratios

Table 12 summarizes the sex and age ratios calculated for the species trapped at the DUNES. Female kangaroo rats and harvest mice were more often trapped than males of either species. Equal numbers of male and female pocket mice were trapped. For all species more adults than non-adults (juveniles) were captured.

Table 12 also summarizes the sex and age ratios of animals trapped at the other sites included in the study. At BAYVIEW the captures of *D. h. morroensis* were equally divided between males and females; the greatest number of juveniles were also trapped at this site (juvenile kangaroo rats were also favored at BUCKSKIN). At SANTA YSABEL more female than male kangaroo rats were trapped. At the JUNIOR HIGH all *P. californicus* trapped were adult males.

Estimation of Kangaroo Rat Population

The following calculations were based on data collected between June and October, 1979. During this time all the sites included in the study were sampled (in the previous year trapping was not carried out at the BUCKSKIN site). The occupied portion of the range was assumed to be approximately 214 acres (from Table 2), the total acreage of the sites included in the study.

Table 12. Cumulative sex and age ratios for the small mammals trapped at each site.

Site	Ratio*	Dhm	Pm	Pc	Rm	Pgc	Pb	Mc
DUNES	M/F	2/6	113/88	8/2	6/7	12/12	---	2/1
	A/J	7/1	165/36	8/1	12/2	21/3	---	2/1
BAYVIEW	M/F	12/12	1/0	---	0/1	1/2	---	0/1
	A/J	14/10	0/1	---	0/1	1/2	---	1/0
BUCKSKIN	M/F	3/1	---	1/2	2/1	7/6	0/1	---
	A/J	1/3	---	2/1	2/1	8/5	1/0	---
JUNIOR HIGH	M/F	6/2	---	4/0	---	---	---	---
	A/J	5/3	---	4/0	---	---	---	---
SANTA YSABEL	M/F	3/5	---	4/4	2/2	4/0	1/1	---
	A/J	5/3	---	8/0	2/2	1/3	2/0	---

Dhm = D. h. morroensis, Pm = P. maniculatus, Pc= P. californicus, Rm = R. megalogtis, Pgc = Perognathus californicus, Pb = P. boylei, Mc = M. californicus

* M/F = male/female; A/J = adult/juvenile

Method 1: Assumed average territory size. A total of 22 kangaroo rats were trapped more than once during a given trapping session. Of those, 15 returned exclusively to the site of original capture, 2 were recaptured in traps 200 and 700 feet from the initial capture site, and 5 were found 100 feet from the site of original capture. The assumption was made that each of the latter 5 rats was trapped within the limits of its territory, either leaving or returning to its burrow. The territory was assumed to extend at least 50 feet in all directions from the home burrow. The distance of 50 feet was chosen because 15 of 22 kangaroo rats were trapped less than 50 feet from the initial site of capture. A circle with a radius of 50 feet covers an area of 0.18 acre (7,845 square feet). Assuming that a single rat occupies 0.18 acre, then a density of 5.5 kangaroo rats per acre (the reciprocal of 0.18) can be calculated. The product of density (5.5 kangaroo rats per acre) multiplied by the occupied range (214 acres) yields a population estimate of 1,172 kangaroo rats.

Method 2: Density per site within the range. A density value was calculated for each site, which was then multiplied by the acreage of the site to yield a site population estimate. The site estimates were summed to yield an overall population estimate. This method resulted in a population estimate of 345 kangaroo rats (details regarding the density of *D. h. morroensis* at each site, the acreage actually trapped and the number of kangaroo rats at each site are summarized in Table 13).

Table 13. Kangaroo rat population estimate (by Method 2): density (kangaroo rats per acre) at each site trapped multiplied by the area of each site (from Toyoshima, 1979).

Area Trapped	Acreage Sampled	Number Captured	Number per Acre	Total Acreage	Population Estimate
DUNES	5.0	2	0.4	50	20
BAYVIEW	5.5	19	3.5	50	175
BUCKSKIN	2.8	4	1.1	58	64
JUNIOR HIGH	2.1	6	2.9	15	44
SANTA YSABEL	3.2	5	1.6	26	42
	18.6	36	1.9 (mean)	214	345

Method 3: Average density within the range. Mean density (calculated from the site density values in Table 13) was multiplied by the area of the occupied range to result in a population estimate of 409 kangaroo rats.

Method 4: Proportional relative abundance. The site with the highest overall relative abundance and density was BAYVIEW, with 6.1 kangaroo rat captures per 100 trap-nights (Table 14) and 3.5 kangaroo rats per acre. The relative density and abundance of the other sites were compared to the relative density and abundance of the "best" (i.e., BAYVIEW) site by the relationship given in Equation 1. The resulting values of R for each site were then multiplied by the area of the site to yield a site population estimate. The site estimates were summed, resulting in a population estimate of 331 kangaroo rats.

A summary of the population estimates generated by the four methods described above is presented in Table 15. An additional 500 kangaroo rats may exist in small pockets of suitable habitat not trapped during the study (Roest, 1977).

BIOLOGICAL DATA

Breeding Season

Reproductive activity for each of the species below is graphically summarized in Fig. 6.

D. h. morroensis. Males with scrotal testes were trapped in July. Lactating females were trapped in May, July and August. One female (No. 997) was trapped in July, 1978, and was observed to have

Table 14. Density and population estimates based on relative abundance of kangaroo rats (rats per 100 trap-nights) for each area. The basic ratio (relative abundance:relative density) is based on data from the BAYVIEW site, considered to depict the "normal" population (from Toyoshima, 1979).

Area Trapped	Basic* Ratio	Relative Abundance	Rats per Acre: R	Total Acreage	Population Estimate
DUNES	0.57	0.81	0.46	50	23
BAYVIEW	0.57	6.06	3.45	50	173
BUCKSKIN	0.57	1.64	0.93	58	54
JUNIOR HIGH	0.57	3.33	1.89	15	28
SANTA YSABEL	0.57	3.57	2.03	26	53
				Total	331

* from Equation 1

Table 15. Summary of D. h. morroensis population estimates generated by four different methods (taken from Toyoshima, 1979).

Method	Estimate
Assumed territory size	1,172
Density x Acreage per site	345
Mean density x Area of range currently occupied	409
Proportional relative abundance	331

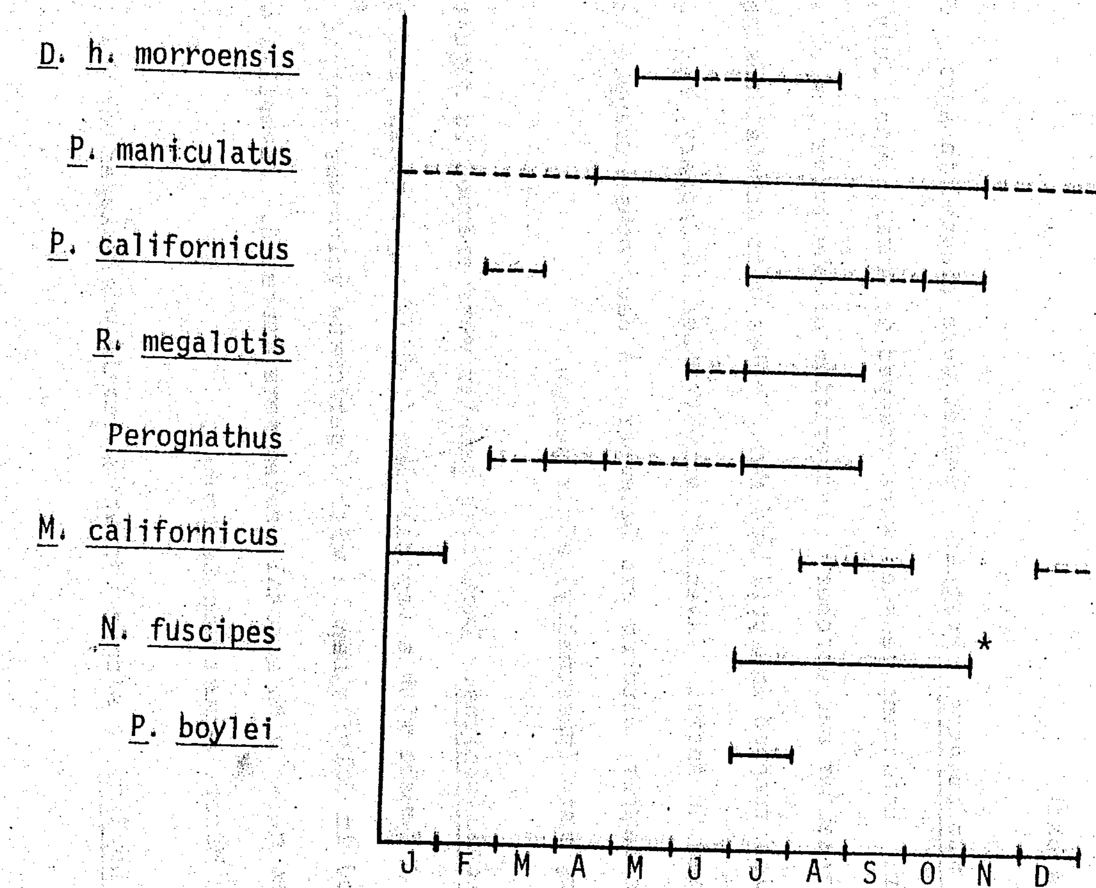

Figure 6. Periods of reproductive activity noted for each species occurring in the study area. Solid lines represent periods of known reproductive activity; broken lines represent probable periods of reproductive activity (see text).

* from Linsdale and Tevis (1951)

a bloody discharge from the vagina, which had disappeared by the following day; the cause of the discharge was unknown. The discharge was not thought to be the result of giving birth, as this female had not appeared to be pregnant when captured during earlier trapping periods. Juvenile kangaroo rats were captured from early July to early September; one juvenile captured in August had a molt line across its back.

P. maniculatus. Pregnant females were trapped in April, July and August. Lactating females were trapped in April, June, July, August, September and October. Perforation of the vulva was noted in nine females trapped in April and May. Males with scrotal testes were trapped in April. Juveniles were trapped in January, May, June, August, September, October and December. A deer mouse trapped in May was molting into (presumably) adult pelage.

P. californicus. Lactating females were trapped in August and October. A female with a vaginal plug (indicating a recent mating) was trapped in July; a female with a perforate vulva was trapped in August. No males with scrotal testes were captured. Juveniles were trapped in March, August and September.

P. boylei. A single lactating female was trapped in the spring.

R. megalotis. Pregnant and lactating females of this species were trapped in July and August. A male with scrotal testes was trapped in July. Juvenile animals were trapped in July and August.

Perognathus californicus. Although field data concerning reproduction in this species were sparse, indications are for active breeding in spring and summer. Lactating females were trapped in July and August; juvenile animals were trapped in April, July and August. No pregnant females or males with scrotal testes were trapped during the present study.

M. californicus. Juvenile animals of this species were trapped in January and September, indicating active breeding took place in late summer and late fall-early winter.

N. fuscipes. No data were recorded during the present study regarding the reproductive activity of this species.

Longevity

Examples of long-lived small mammals trapped at the DUNES are listed in Table 16.

Travels

The majority of recaptured animals tended to return to the site of initial capture or to a nearby site. This was especially true of D. h. morroensis; one of the kangaroo rats trapped at the DUNES in both years of the study (No. 990) had remained within 150 feet of the site of original capture, and did not move more than 50 feet between any two captures. The pocket mouse that survived for 356 days was last trapped within 200 feet of the site of initial capture.

Table 16. Time between first and last captures for selected species.

Species	Tag #	# of Days	Dates of Capture First	Dates of Capture Last
D. h. morroensis	912	411	4/15/77	6/01/78
	990	323	7/01/78	5/20/79
	539	184	12/22/78	6/25/79
	997	121	5/24/78	9/22/78
P. maniculatus	823	262	7/25/78	4/13/79
	836	255	8/02/78	4/14/79
	993	175	6/30/78	12/22/78
	838	186	8/03/78	2/05/79
	516	119	10/08/78	2/04/79
P. californicus	833	261	8/24/78	4/21/79
*Perognathus**	829	356	7/28/78	7/19/79

* *Perognathus californicus*

Long distance moves between trapping periods (i.e., greater than the distance to the next trap station--50 to 100 feet) were usually accomplished over a long period of time. A deer mouse was found to have traveled a distance of about 700 feet over a period of 79 days.

CHAPTER 4

DISCUSSION

The association of a given mammal species with a given habitat type has been studied by a number of investigators. A variety of cues upon which selection of optimum habitat are based have been suggested. D. deserti has been found to show a strong preference for stabilized dunes, which a change in habitat quality did not alter. Moreover, this species will behaviorally exclude sympatric species, such as D. merriami and Perognathus longimembris, from the preferred habitat (Congdon, 1974). Sympatric species may coexist by exploiting different portions of the same habitat, as shown for Perognathus penicilliatus and D. merriami by Rosenzweig and Winakur (1969). The sculptural profile of the vegetation was believed to be one of the cues used by the two species in selection of habitat, which Rosenzweig (1973) tested by tailoring test plots to alter the height and density of vegetation. The pocket mouse was common only when foliage over 45 cm high formed an important part of the vegetation. The population density of the kangaroo rat was found to be inversely proportional to the density of the foliage layer between 8 and 45 cm (3 to 18 inches). Hoover et al. (1977) found evidence that soil type may influence the distribution of two sympatric species of pocket mice, Perognathus penicilliatus and Perognathus intermedius, in Arizona. A behavioral component was indicated by the behavioral dominance of penicilliatus over intermedius in laboratory trials.

The physical presence of one species may influence the way a second species utilizes the same environment, as shown by Wondolleck (1978) for Perognathus amplus and D. merriami. The smaller granivore, which tended to forage in areas of clumped and scattered vegetation, would shift into the open microhabitat normally occupied by D. merriami when the latter species was physically removed.

Food resource allocation is another means of promoting continued coexistence among sympatric species. Physical separation of forage areas, competitive displacement of subordinate species from preferred foods and flexible feeding strategies of the subordinate species (to ensure continued coexistence during periods of changing food availability) may have been in operation among the species studied by Meserve (1974, 1976). Competition for food resources has been shown to influence the organization of a desert rodent community (Munger and Brown, 1981). Physical exclusion of the larger granivores (D. spectabilis, D. ordii, D. merriami) from 50 by 50 meter plots led to a 350 percent increase in the density of smaller granivorous rodents (P. maniculatus, R. megalotis, Perognathus penicillatus and Perognathus flavus). Presumably the same food sources can be used by all the species, but the smaller granivores are unable to do so in the presence of the larger animals.

The establishment of physical distance between individuals of the same and different species is another way of reducing competition. The spatial distribution of animals has been analyzed in terms of home range, the area occupied during normal daily activity (Burt, 1943). A number of techniques have been devised to collect and analyze home range data (reviewed by Sanderson, 1966).

The statistical analysis of home range began when Hayne (1949) calculated the center of activity, which simplified locational data by reducing them to a single point. The usefulness of this measure lies in separating the ranges of individuals whose locational data overlap a great deal. The center of activity, however, represents the geometric center of a scatter of points, and is not necessarily of any biological importance. Koeppl et al. (1975) felt that the center of activity, coupled with behavioral observations, may provide a link between the mathematical analysis of home range and its actual use by an animal. Principle component analysis has been used to calculate home range values for rodents in a sagebrush community (O'Farrell, 1978). This method has the ability to deal with changing home range configurations, and is useful in assessing the orientation of mammal movements relative to habitat features and coexisting individuals. Intra- and interspecific overlap in spatial distribution as indices of social interaction were examined (O'Farrell, 1980). Overlap within a species suggested social tolerance, and a social hierarchy was inferred from the degree of overlap allowed by individuals (dominant individuals would tolerate the least amount of overlap). Interspecific overlap suggested differential habitat specificity. Dominant species would tend to exhibit less tolerance (lesser degrees of overlap) than subordinant species. Habitat specialists would tend to exhibit a more clumped pattern of distribution than would species with more general habitat requirements.

Spatial separation at discrete points in time is partially accomplished by behavioral mechanisms. The interactions between individuals are difficult to study in the field. The usual method is to take specimens from the field, place pairs of individuals in a neutral arena in the laboratory, and observe their behavior when a chance encounter brings the two animals together (Eisenberg, 1963; MacMillen, 1964). MacMillen (1964) found that N. lepida was the dominant species in the coastal sage scrub community. The subordinate animals tended to avoid contact with or flee from N. lepida. Encounters between N. lepida and N. fuscipes were characterized by extreme aggression. N. lepida, P. californicus and P. maniculatus were found to be socially tolerant of conspecifics, while Perognathus fallax, P. eremicus and D. agilis were not.

In the field, behavioral data based on multiple captures may suggest the nature of inter- and intraspecific interactions. There are two requirements that must be met in order for multiple captures to occur: close spatial proximity and behavioral tolerance of that proximity. Mihok (1979) examined natural populations of Cleithrionomys gapperi (Red-backed Vole) and P. maniculatus in a subarctic community. Multiple capture traps were used, and approaching individuals were able to see previously captured animals. The frequency of multiple captures among the voles was low, compared to P. maniculatus; fewer individual voles participated in each multiple capture, compared to the number of participating deer mice. Interspecific multiple captures were very rare. The difference in spatial organization between the two species could explain part of the variation in frequency and pattern of multiple captures. The capture of two animals in a single capture trap ("double captures") was reported by Evans and Holdenried (1943). Frequent occurrences of double capture were noted while trapping small mammals in Madera and Alameda Counties, California. In more than half the cases where one or both of the animals was found dead, there was evidence of fighting. This was particularly true when *Peromyscus* was trapped with *Perognathus* (the latter species was found dead more often). It was suggested that *Perognathus* was at a disadvantage when confined with *Peromyscus*, possibly because the pocket mouse could not make use of its superior jumping ability to escape. MacMillen (1964) found *Perognathus fallax* behaviorally subordinant to *P. maniculatus* and *P. eremicus*. The usual response of the pocket mouse to each species of *Peromyscus* was flight.

The examples of habitat selection, food resource allocation, and spatial distribution as means of maintaining population stability among sympatric species have been presented as discrete topics. However, it must be kept in mind that no one mechanism is at work in a given association, but that combinations of mechanisms are involved. A well-established social structure was a common feature of the mechanisms discussed.

The genera of small mammals trapped during the present study were also similar to those found in the southern California communities. The species composition differed slightly, as some species found in southern California are not found near Morro Bay (summarized in Table 17).

Table 17. Comparison of small mammal species present in three coastal sage scrub communities in California.

Species	MacMillen (1964)	M'Closkey (1972)	Meserve (1976)	Morro Bay (1978-9)
N. lepida	+	+	+	0
N. fuscipes	+	+	+	+
P. californicus	+	+	+	+
P. maniculatus	+	+	+	+
P. boylei	0	0	0	+
R. megalotis	0	+	+	+
Perognathus fallax	+	+	+	0
Perognathus longimembris	0	+	+	0
Perognathus californicus	0	0	0	+
D. agilis	+	+	+	0
D. h. morroensis	0	0	0	+
M. californicus	0	0	+	+
M. musculus	0	0	+	0

+ = present, 0 = absent

N. fuscipes was infrequently captured, but when present was found where vegetation most nearly approximated chaparral-like conditions. The relative abundance of this woodrat was highest at the SANTA YSABEL site, a mixture of coastal sage scrub and oak woodland, where it was trapped under large clumps of Arctostaphylos. The single woodrat trapped at the DUNES was caught in the midst of a dense stand of Artemesia.

P. californicus was also trapped in areas of tall, dense vegetation, particularly Ericameria, Ceanothus, Prunus, and Artemesia. This species was most abundant at the SANTA YSABEL site (but absent from BAYVIEW, the site with the least proportion of chaparral elements, compared with the other sites in the study area).

P. maniculatus is the most widespread North American rodent, whose success has been attributed to the nonspecific nature of its habitat requirements, which allows it to live in areas that are suboptimal for other species (MacMillen, 1964). Deer mice were trapped at the DUNES, but were not associated with any particular area. Within the entire study area, however, deer mice were restricted to the DUNES site. The data suggest that deer mice, the most abundant species of the association, were more general in their habitat requirements than either N. fuscipes or P. californicus.

Perognathus californicus is associated with chaparral and live oak habitats. Previous studies indicate this species has not been trapped in the DUNES area since 1957 (Stewart and Roest, 1960). Its current presence may be suggestive of the change in vegetation. The relative abundance of pocket mice was highest at the BUCKSKIN site, which was also found to be relatively poor kangaroo rat habitat.

P. boylei was captured in low numbers at the SANTA YSABEL and BUCKSKIN sites. The normal habitat of this species of Peromyscus includes chaparral areas of arid and semiarid regions, and rocky situations. Both sites where this rodent was trapped have chaparral or chaparral-like areas.

The overall relative abundance of R. megalotis in the study area was low; the highest values were calculated for the SANTA YSABEL and BUCKSKIN sites. Many typical stands of coastal sage scrub are mixed with varying amounts of grass. Clumps of grass were randomly scattered throughout the study area; harvest mice were generally trapped in those areas.

M. californicus normally inhabits moist or wet ground (salt and fresh water marsh areas, wet meadows), although some subspecies exist in more arid areas, such as on dry, grassy hillsides (Kellogg, 1918). Along the central coast, this species of vole is usually found on low ground closer to Morro Bay, or in low-lying fields further inland. It is possible that the presence of the voles outside their normal habitat was the consequence of a population boom, which forced an outward movement in search of food and shelter. In a more normal year this species would not be expected on the DUNES site.

D. h. morroensis was associated with relatively open areas, where vegetation was low and scattered. The need of kangaroo rats for open habitat has been related to their mode of locomotion: a bipedal hopping in which the first few hops are the most important in escape, particularly from predators (Bartholomew and Caswell, 1951).

The relative abundance of the Morro Bay Kangaroo Rat was not uniform throughout the study area, but varied with the relative proportion of open space available. Large areas of open space were present at the BAYVIEW site, although tall brush species were beginning to encroach upon them. The vegetation in the areas where kangaroo rats were trapped tended to be herbaceous and low (except for relatively large, scattered clumps of *Ceanothus*, *Artemesia*, *Lupinus* and *Arctostaphylos*). *Ericameria* and *Croton* were fairly abundant. Tail drag marks were most easily found at this site, although active burrows were more difficult to locate. Trapping data verified this as the most suitable current habitat for *D. h. morroensis*. The greatest number of kangaroo rats (including the greatest number of juvenile animals) were captured at this site. The site is heavily used for hiking, riding, and walking dogs. The kangaroo rats did not appear to be disturbed by the human traffic, as long as the habitat was suitable. Stewart (1958) made a similar observation, which may be related to the nocturnal habits of kangaroo rats; under normal circumstances little direct contact with people occurs.

The DUNES site was of particular interest as the land was acquired by the State of California for the express purpose of establishing an ecological reserve for the Morro Bay Kangaroo Rat. At one time the area supported a good kangaroo rat population; however, the present study found over 60 percent of the site covered by tall, dense chaparral, in which no signs of kangaroo rat activity were observed and no kangaroo rats were captured. Kangaroo rat burrows tend to be found in areas of low scattered brush, primarily on the higher ground along low ridges, where the soil surface is firmer and able to support tunneling (Roest, 1973). A few burrows were found along the edges of road cuts, where the vegetation was cleared of heavy brush. Approximately 5 acres of the reserve (restricted to the northwest portion) were considered to be suitable kangaroo rat habitat, which was reflected by the low number of animals captured, given the trapping effort expended (3,268 trap nights) and the area trapped (about 25 acres). Other untrapped areas may support kangaroo rats, although the numbers are likely to be low. Breaking up the dense vegetation, undisturbed since the 1950's, may encourage the establishment of a healthy population. Such a situation occurred in 1956. That year the U.S. Army went into the area with heavy equipment to plow up and remove unexploded shells and other debris (such as rifle ammunition casings, which are still being found) left over from World War II days, when the dunes were used as a mortar practice range. The destruction of the brush resulted in an increase of kangaroo rats in the area, and by 1958 the population of _D. h. morroensis_ was very high (Roest, 1973; Stewart, 1958). Subsequent investigators have noted the decline in the kangaroo rat population as the plant community matured and human construction destroyed other parts of the habitat. Recommendations for habitat management have included control of brush growth and protection of existing habitat from development by outright acquistion of the tracts involved (Congdon and Roest, 1975; Roest, 1973). The decline in the number of kangaroo rats at the DUNES (as a consequence of the decline in open space) may be providing

Perognathus californicus with the opportunity to utilize that portion of habitat normally occupied by D. h. morroensis. The relative "health" of kangaroo rat habitat at the DUNES might be monitored by the relationship of the two rodent populations. The suitability of the other sites for D. h. morroensis graded between BAYVIEW, the best site, and the DUNES, the poorest site. SANTA YSABEL had historically been considered the most productive of kangaroo rats (Stewart, 1958; Roest, 1977); however, that finding was not confirmed by the present study.

Both D. h. morroensis and P. maniculatus were trapped in every season, indicating that both species are permanent residents but that neither hibernates. The assumption that D. h. morroensis does not enter a period of inactivity above ground is based on the repeated capture of a single male (No. 990) during the winter months, and the initial capture of No. 539 in December of 1978. MacMillen (1964) noted a seasonal pattern of residence in deer mice which he interpreted as evidence of summer aestivation; no such pattern was noted in the present study. Perognathus californicus was absent from the DUNES during the winter months. Not all individuals trapped were new animals, suggesting that this species is also a permanent resident, with a small population. Meserve (1976) noted a similar pattern of residence for Perognathus longimembris, which may have been the result of winter dormancy. It is not known if the seasonal occurrence of Perognathus observed in the present study was due to winter dormancy. P. californicus trapped near Morro Bay was captured in the spring, summer and fall.

Meserve (1976) noted a seasonal (spring to summer) increase in the population of *P. californicus*, due to immigration of younger animals from peripheral chaparral habitats, which were found to support stable, year-round populations of *P. californicus*. It could not be determined from the available data if a similar phenomenon occurred during the present study. In general, *R. megalotis* showed a pattern of residence similar to that of *P. californicus*. Harvest mice were not trapped during the winter months, unlike the winter increase noted for this species by M'Closkey (1972), which was due to the immigration of adult animals. Only a few captures of *N. fuscipes*, *M. californicus* and *P. boylei* were made; the lack of trapping data does not permit comment about the activity of these species outside the months in which they were trapped.

Reproductive activity was seasonal, observed during spring and summer, as seen in the southern California rodent associations. Breeding in *D. h. morroensis* was noted from April to September. Eisenberg (1963) observed that *D. nitratoides* will molt into its adult pelage at about 12 weeks. If a similar schedule is assumed for *D. h. morroensis*, the August molting juvenile was probably born in late spring. Previous studies (Stewart, 1958; Roest, 1977) have suggested major breeding periods in the early spring and in the fall, with some young produced during the summer months. The present study tends to confirm the occurrence of a major breeding period in the spring. The capture of juvenile and subadult animals in July and August probably reflects dispersal of young, born in the spring, from the maternal burrow. Whether there is a major breeding period in the fall could not be determined from the available data.

The normal gestation period of Peromyscus averages 23 days, and most species are weaned between 3 and 4 weeks of age (Layne, 1968). Association with the mother may occur past the age of weaning, but assuming the young deer mice leave the maternal nest immediately after weaning, the captured juveniles would have been conceived at least 2 months earlier. Based on those assumptions, active breeding of deer mice in the Morro Bay community appears to have occurred throughout the year. Reproductive activity during spring, summer and autumn has been reported (Jameson, 1953); year-round breeding of P. maniculatus in central eastern Washington was noted by Scheffer (1924). In the present study males with scrotal testes were trapped only in the spring. Brant (1962) did not consider position of the testes a useful index of breeding condition; he found the temperature of the trap would alter the extent to which testes were scrotal or abdominal. This may account for the lack of males with scrotal testes, even at times when pregnant and lactating females were trapped.

The periods of reproduction suggested for the remaining species were based on limited data, as these animals were not trapped in abundant numbers. P. californicus appeared to breed during spring, summer and fall. Reproductive activity in R. megalotis was noted during summer. Active breeding of Perognathus californicus was noted in spring and summer. Data for M. californicus is incomplete, although this species is known to breed year-round. Data on N. fuscipes reproduction near Morro Bay was unavailable, but it has been reported that this species breeds during summer and fall (Linsdale and Tevis, 1951).

Skewing of the sex ratio in favor of male kangaroo rats was previously noted by Helsel (1962) and Roest (1977). Helsel attributed this to the male venturing farther from its burrow, in search of food or a mate, than the female, who may be tied to the burrow by the presence of young. In the present study males were more frequently trapped at BUCKSKIN and the JUNIOR HIGH, while at the DUNES and SANTA YSABEL more females were trapped. More adult animals than juvenile animals were captured at all sites except BUCKSKIN. The trapping of a greater number of females than males at the DUNES may be a reflection of low reproductive activity (also indicated by the single, unrepeated capture of one subadult animal over the study period). The scarcity of juvenile kangaroo rats at the DUNES suggests a habitat able to support only a few new individuals. The preponderance of females at the SANTA YSABEL site may have been due to the time of year when trapping was done (females had completed weaning of that spring's young). Seasonal decreases in the age ratio may indicate periods of juvenile dispersal, as at BUCKSKIN.

A preponderance of males in trapping data has been noted for most species of <u>Peromyscus</u> studied (Terman, 1968). This was found to be true for <u>P. maniculatus</u> and <u>P. californicus</u> during the present study. Males tend to have larger home ranges than females (Terman, 1968; Taitt, 1981), which may partially account for their greater frequency of capture. Generally speaking, the number of adult captures was much greater than the number of juvenile captures, for all species. A few exceptions were noted, but these tended to occur when few individuals were trapped.

The arrangement of animals in a habitat or community is generally analyzed on the basis of home range. Home range values could not be calculated for any of the species included in the present study, as most methods require a minimum of four recaptures per animal (Hayne, 1949; Taitt, 1981). Only three deer mice were recaptured four or more times. If estimates of home range are desired, future studies must be modified so as to increase the number of repeat captures. This can be done either by trapping large areas at one time or by checking traps for captures at intervals throughout the night, rather than just once the following morning (O'Farrell, 1978).

The interaction between individuals of one species or of different species is difficult to study in the wild; this is particularly true of small nocturnal animals. Behavioral observations are usually made in the laboratory. No laboratory observations of social behavior were made during the present study, but some comments about interspecific and intraspecific interactions can be made based on the double capture data. The capture of two individuals in one single-capture trap suggested that the animals had either entered together or in fairly rapid sequence. It was not known how two animals came to be in one trap, but two possibilities were considered: 1) the triggering mechanism was not set at a sufficiently sensitive level to detect the weight of one animal, and consequently was not tripped until the weight of the second animal was added; 2) the second animal followed the first so closely that both animals were in the trap when it snapped shut.

Seven cases of cannibalism, where one animal ate the flesh of the co-captive, were noted. It was not known whether the cannibalized animals were dead before the co-captive consumed parts of the body or if the surviving animal had killed the other. The first possibility was more likely. Most of the double captures involving cannibalism occurred in late summer and fall, when food resources are likely to be low, and the baited traps represented reliable, plentiful sources of food. With two animals in one trap, however, the amount of bait may have been insufficient for the 8-12 hours that passed between capture and release. One captive may have died, of starvation or shock, and the co-captive may have resorted to cannibalism to survive. The survivors tended to consume soft organs (brain and viscera), although in a couple of instances a limb was found missing.

The preponderance of double captures involving P. maniculatus, 43/45 = 96 percent, suggests that individuals of this species were in closer spatial proximity (i.e., had more extensively overlapping home ranges) and/or were more tolerant of close approach by a conspecific than either R. megalotis or P. californicus. Double captures of different species of Peromyscus were found to be peaceful, with only one of ten cases showing evidence of fighting (Evans and Holdenried, 1943). At the DUNES a deer mouse was captured with a California mouse, with no signs of fighting noted. The tolerance of P. maniculatus for conspecifics has been noted by a number of investigators (Eisenberg, 1963; MacMillen, 1964; Mihok, 1979). The actual behavior exhibited, however, is dependent on the age, sex, and reproductive condition of the animals involved, and whether an animal is familiar with the area in which the encounter takes place (MacMillen, 1964; Stickel, 1968). The infrequency of double captures involving R. megalotis and P. californicus may have been a reflection of the low relative densities of the two species in the study area. The double captures of R. megalotis imply this species is compatible with conspecifics, as no evidence of fighting was noted. Only male-female pairs were trapped, and the generalization may only apply to such pairs. No double captures involving pairs of kangaroo rats, pocket mice, brush mice, voles or woodrats were noted. For the larger species, the lack may be explained by the fact that the weight of one animal was more than sufficient to trip the mechanism. In the case of P. boylei and M. californicus, the relatively low density of individuals could explain why double captures were not noted for the two species. In the case of Perognathus californicus, it has been reported that heteromyid rodents tend to be solitary, except for a brief time during the breeding season (Eisenberg, 1963).

SPECIAL CONSIDERATIONS

Decline In The Morro Bay Kangaroo Rat Population

The four methods of estimating the current kangaroo rat population have placed their numbers between 331 and 1,172 individuals. Roest (1977) speculated that an additional 500 animals (on an additional 100 acres) may exist in small pockets that were not trapped or were trapped but did not produce kangaroo rats.

The addition of these individuals raises the estimates to 831 and 1,672, respectively. The discrepency between the first and the latter three methods may be due to the possibility that the actual territory size is greater than the acreage calculated in Method 1. The distance a kangaroo rat will travel from its burrow was assumed to be 50 feet because that was the most frequently occurring distance between capture sites for animals not returning to the site of initial capture; the actual distance _D. h. morroensis_ will travel is not known. Bartholomew and Caswell (1951) noted a foraging distance of 50-70 feet from the home burrow for _D. merriami_ and _D. panamintinus_. Fitch (1948) observed that _D. h. tularensis_ tended to forage within 100 feet of its main burrow; of 1,270 kangaroo rats captured more than once, 37 percent were less than 50 feet, and 18 percent less than 100 feet, from their burrows. Fitch felt that most of an individual's foraging range was in a familiar area 100 to 400 feet across. A territory size of 0.18 acre could represent a minimum area, and the figure of 1,172 could represent an upper limit to the population (1,672 if the additional 500 animals are included). The latter three methods agree fairly well, primarily because the calculations are based on actual trapping data, and the results may be considered representative of a lower limit to the population. The occupied portion of the range was considered to be the 214 acres that make up the combined acreage of the five study sites, plus the 100 additional acres that may harbor small pockets of untrapped kangaroo rats, or 314 acres/640 acres per square mile, or 0.49 square mile.

The trend since 1960 has been one of decline in both the population size and occupied range of the Morro Bay Kangaroo Rat. Physical changes in the habitat (maturation of chaparral communities) and removal of available habitat (conversion into housing tracts and shopping areas) have created isolated pockets of kangaroo rats, hence the necessity for trapping on five different sites within the study area. An additional threat to the kangaroo rat population may be predation by domestic cats, which have increased in numbers along with the increase in housing development (Roest, 1973; Congdon and Roest, 1975).

Trap Habit

One phenomenon which must be taken into consideration during an extended live-trapping study of a given area is the development of a "trap habit" by a given animal. This is the repeated return of an animal to the site of original capture. During the course of the present study, this was particularly noted for *D. h. morroensis*. Among those individuals trapped in more than one trapping period, Nos. 997 and 990 returned to the same trap 18 times; No. 539 returned 13 times. The kangaroo rat marked during the 1977 study (No. 912) had a record of 6 recaptures (Roest, 1977).

In order to thoroughly trap an area, an investigator may either set out a great number of traps for short periods of time, or trap a particular area for extended periods of time. In the case of *D. h. morroensis*, the first method may be the better choice. An animal that repeatedly returns to the same trap removes the potential for capture of a new individual, and population estimates based on trapping data may be low. Based on the present investigator's personal experience, it is recommended that trapping periods last no more than three nights, and if only a limited number of traps are available, that the traplines and quadrats be frequently moved. This will not only discourage "trap-happy" kangaroo rats, but is also a protective action against theft of traps.

Loss Of Traps and Trap Stress

With the exceptions of the DUNES, access to the study sites was via residential streets; it was not possible to approach the sites without being observed. If traps are left in one location for extended periods of time (more than three nights), there is the danger that location(s) of traps will be discovered and the trap(s) disturbed, and/or the animal(s) inside taken. Frequent shifting of trap locations will help to keep disturbance of traps to a minimum. Actual loss of a trap occurred at the SANTA YSABEL site. The trap was missing from its station; a search of the area failed to turn it up. It was not known if an animal had been captured.

In a few instances the disturbance of a trap was apparently linked to death from "trap stress". Displacement of a trap, by about 200 feet, was noted once; inside was a dead kangaroo rat. There were no external wounds to indicate the animal had been injured prior to capture. One possible explanation for the displacement is that a dog picked it up, carried it a short distance, and then, for some inexplicable reason, dropped it.

Another possibility is that a wild animal (fox or raccoon) picked up the trap to carry it off, but also abandoned it shortly thereafter. It is possible that an insufficient amount of bait resulted in death from starvation. An alternate theory is that the stress of being confined in an unfamiliar environment (known as "trap stress"), and then jostled about by the carrier, overwhelmed the animal and resulted in its death.

On two separate occasions kangaroo rats were found in a debilitated condition when the traps were checked for captures (one at BAYVIEW and the other at BUCKSKIN). The animals were chilled, weak, and had blood smeared on their coats; the tips of their noses were raw. It was conjectured at the time that the animals had battered themselves against the walls of the trap while trying to escape. The cotton nesting material placed in all the traps during the study was trampled and pushed to the back of the trap; in previous studies it was noted that D. h. morroensis did not use the cotton to insulate against chilling, as did the smaller species (Roest, 1977). These two kangaroo rats were taken to the Department of Biological Sciences, California Polytechnic State University, San Luis Obispo, where they died shortly thereafter. Before death the animals exhibited some sort of convulsion--peculiar muscular spasms of the limbs and a wild circular thrashing of the tail. A third kangaroo rat was found in a similar condition at BAYVIEW; this animal, however, recovered and was released back into the field. In future studies extra care must be taken to ensure that adequate quantities of bait are used and that every precaution is taken to prevent chilling of the animals and reduce time spent in the trap.

Other species of animals were also found dead in traps, with little to suggest what caused the death, or were found in a chilled and weakened state when the traps were checked for captures (these animals, a pair of harvest mice, recovered and returned to the field). Any death due to trapping is regrettable, but more so when the death is of a species whose numbers are already limited, as is the case for D. h. morroensis.

SUMMARY

The general type of vegetation found in a coastal sage scrub community near Morro Bay, California, was similar to that found in two coastal sage scrub communities in southern California.

The genera of small mammals found in the Morro Bay community were the same as those found in southern California, and included species of Peromyscus, Perognathus, Dipodomys, Neotoma and Microtus.

The distribution of species was not uniform throughout the study area. Peromyscus maniculatus was found almost exclusively at the DUNES site. The relative abundance of Dipodomys heermanni morroensis was greatest at BAYVIEW and lowest at the DUNES, reflecting differing proportions of optimum habitat at each site.

Double captures imply close spatial proximity and behavioral tolerance of the close approach by another animal. Peromyscus maniculatus, Reithrodontomys megalotis and P. californicus appear to exhibit behavioral compatibility when trapped with conspecific animals. Perognathus californicus was found dead when trapped with P. maniculatus. The frequency of double capture may be influenced by seasonal fluctuations in food resources or population density.

Sex and age ratios indicate the proportions of male and female animals in the trappable population, and reflect the success of reproductive activity. Skewing of the sex ratio towards females may be indicative of little or no maternal activity (i.e., rearing of young); a very high adult to juvenile ratio is indicative of low reproductive output.

Species diversity within a community can be maintained by habitat selection, allocation of resources, temporal partitioning and by establishment of a social hierarchy. Seasonal immigration, flexible feeding and behavioral strategies, and specialization may be used to avoid competition for similar food resources.

The current population and range of *Dipodomys heermanni morroensis* is believed to consist of fewer than 1,700 individuals occupying an area of 0.49 square mile. The decline in population and in area occupied (due to deterioration and destruction of habitat) noted in previous studies continues to threaten the future of this unique subspecies.

Breaking up the thick vegetation currently present on the DUNES site may lead to the rejuvenation of the kangaroo rat population in residence, by increased reproductive output or by immigration from other areas. A program of brush control must then be implemented to ensure that the habitat remains suitable for kangaroo rats.

The relative proportions of *D. h. morroensis* and *Perognathus californicus* captures at the DUNES may be an important index of the relative suitability of the habitat for kangaroo rats.

The species appear to be inversely related: as the number of pocket mice increases, the number of kangaroo rats decreases. A relatively high number of kangaroo rats combined with a relatively low number of pocket mice may be indicative of good kangaroo rat habitat, and vice versa.

Future studies of the coastal sage scrub community found near Morro Bay, California, should emphasize the need for obtaining more complete ecological data. Such information is important for a better understanding of the spatial distribution and diversity of species present in the community. Close examination of habitat selection will be essential for the development of long-range management programs.

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