Duplicate

THE EFFECTS OF FIRE ON SMALL MAMMALS OCCUPYING CRITICAL, MORRO BAY KANGAROO RAT HABITAT AT MONTAÑA DE ORO STATE PARK

FINAL REPORT: 1989

CALIFORNIA DEPARTMENT OF PARKS AND RECREATION

STANDARD AGREEMENT NO. 84-04-276

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September 29, 1989

INTRODUCTION

This report summarizes the results of the fifth year of field work on a renewed, long term study of the effects of fire on small mammals inhabiting Coastal Dune Scrub habitat at Montana de Oro State Park. Previous studies conducted at the same study area before the fire and the first three years after the fire have been submitted to the California Department of Parks and Recreation in separate reports (Gambs 1985, 1986e, 1987 and 1988). The purpose of this study is to evaluate the efficacy of fire in enhancing the habitat at Montana de Oro State Park for the endangered Morro Bay kangaroo rat.

Morro Bay kangaroo rats *(Dipodomys heermanni morroensis)* were once quite abundant on private and public land south of Morro Bay (Dixon 1918, Grinnell 1922, Stewart 1958, and Stewart and Roest 1960); however their populations there have been declining since 1957 (Congdon 1971, Congdon and Roest 1975, Roest 1977, Toyoshima 1983, Gambs 1986a, 1986c, 1986d, 1986f, Villablanca 1986, 1987, and Gambs and Holland 1988). Direct loss of habitat; natural change in remaining habitat; predation by cats and dogs; vehicle, livestock, and pedestrian traffic over occupied burrow systems; competition with other burrowing rodents; fragmentation of large populations into small, sub-populations; and increased inbreeding are all factors which appear to have contributed to the long term decline of this endangered subspecies (Gambs 1986c, Gambs and Holland 1988). As a consequence of this decline, the Morro Bay kangaroo rat was listed as an Endangered Species by the U. S. Fish and Wildlife Service in 1970. The following year the California Department of Fish and Game also listed the subspecies as endangered. Today, the only known wild population of Morro Bay kangaroo rats is one occurring on private land referred to as the Bayview site (refer to U.S.F.W.S. 1982, Gambs 1986a, 1986c, Villablanca 1986, 1987, and Gambs and Holland 1988) for details on the distribution and status of *D. h. morroensis).* The present study was conducted as one part of a cooperative effort involving Cal. Poly., California Department of Parks and Recreation, U. S. Fish and Wildlife Service, and California Department of Fish and Game, to implement the Recovery Plan (U.S.F.W.S. 1982) for the endangered Morro Bay Kangaroo Rat.

That portion of Montana de Oro State Park referred to as the Pecho site in the Recovery Plan did support a few Morro Bay kangaroo rats in 1979 (Toyoshima 1983), however none have been found there since 1983 (Villablanca 1987 and Gambs and Holland 1988). Since the Pecho site is designated as Critical Habitat for the endangered Morro Bay kangaroo rat, it follows that most of the efforts to manage the subspecies and its habitat have been directed toward this area. Manual brush removal on 2 experimental plots (DEF and GHI) in 1983 and controlled burns on plot TUVWX in 1984 and plot FF—JJ (this study) in 1985 constitute the extent of habitat management for Morro Bay kangaroo rats since they were listed as endangered in 1970.

The overall effects of the two fires on the plant communities at Pecho were summarized by Gambs and Holland (1988) as follows: increased soil fertility, increased soil pH, and inactivation of allelopathic soil chemicals. Because of the sandy soil, these changes will probably only persist for a few more years. Within a few weeks after the fires, many of the shrubs resprouted and gradually began regenerating a new canopy. Some seedlings of California sagebrush, coastal silver lupine, and mock heather became established, but no seedlings of *Prunus* were noted. By 1986, shrub cover had increased, but the burned plots still had a high species diversity and herbaceous plants still dominated. Several Eurasian weed species invaded the burned plots. On one plot (TUVWX), these weeds were restricted to the same areas where they were common before the fire. On another plot (FF—JJ), weeds such as ripgut brome moved into the plot and assumed a dominant role. Although it is difficult to predict the permanency of these weedy species, it is expected that as the shrub canopy increases, the cover of weedy and opportunistic species gradually will diminish. In contrast to the two cleared plots, the burned plots suffered an overall loss of cover by Morro Bay kangaroo rat food plants. Unfortunately, Morro Bay kangaroo rat forage preference has not been assessed on many of the plants that appeared after the fires so we are unable to predict whether or not Morro Bay kangaroo rats would use these species.

The overall effects of the two fires on the small mammal communities at Pecho were summarized by Gambs and Holland (1988) as follows: the species richness of small mammal communities occupying burned habitat at Pecho sharply dropped to 3 species (deer mice, pocket mice, and harvest mice) after the fires. Although the effects of burning were more immediate than those of brush removal, the general small mammal population responses were comparable on burned and cleared sites (ie. deer mice and pocket mice persisted, woodrats and harvest mice disappeared, and ground squirrels appeared). The fires may have created corridors of open habitat which enabled ground squirrels living at the base of the dunes to invade the burns and then spread eastward into cleared and undisturbed habitat near the burns. The spread of ground squirrels into manipulated habitats represents a serious obstacle to the future establishment of Morro Bay kangaroo rats at these sites.

Even though burning and clearing did not produce a numerically depauperate small mammal community like that seen at Bayview, burning and, after several years, brush removal did suppress populations of woodrats, California mice, and harvest mice. Although the two manipulated habitat types had more bare ground and herbaceous growth and less mock heather, golden yarrow, coastal silver lupine, sand almond, dead plant litter, coastal buckwheat, and California sagebrush; the lack of statistical segregation among the 3 habitat types suggests that clearing and burning did not bring the plant cover into a high degree of congruency with habitat that presently supports Morro Bay kangaroo rats at Bayview. Gambs and Holland (1988) concluded that of the 3 habitat types available for reintroducing Morro Bay kangaroo rats at Pecho, the burned and cleared areas were preferable to the undisturbed areas.

In 1988, 2 female and 2 male Morro Bay kangaroo rats from the captive breeding colony at Cal Poly were introduced into a protective enclosure on Pecho habitat that had been burned in 1984 (Gambs and Nelson 1989). By the end of the field season (November) we were confident that the two females were still inside the enclosure. We lost track of one male shortly after it was introduced and we knew that the other male escaped by burrowing under a wire barrier more than 2 1/2 ft below the surface. It is possible that one or more of these animals has taken up residence in the Pecho area; however no signs have been detected so far this year.

METHODS

STUDY AREA

The study area is located in the SE 1/4 of Section 14, T30S, R10E; Mt. Diablo Meridian; Morro Bay South Quadrangle; Longitude 120° 52', Latitude 35° 18'; San Luis Obispo County, California (Fig. 1) The SE corner of the study area coincides with the respective corners of sections 13, 14, 23, and 24. The dimensions of the study area are approximately 2,000 ft along the N / S axis by 1,000 ft along the E / W axis (Area ≈ 45.9 Acres = 18.6 hectares). The slope of the landscape on the site is ≤ 10%. Dirt roads surround the study area and one dirt road roughly divides the study area into northern and southern halves (Fig. 1). Vehicle traffic through the study area has been prohibited since 1986, but the area still receives considerable equestrian and foot traffic.

STUDY PLOTS

A staff compass traverse survey was conducted in order to reference the two study plots to existing surveyed points (Fig. 1). Each plot encompassed an area of 1 ha (100 m X 100 m) and consisted of a grid of 25 equidistant trapping stations placed 25 m apart. Each trapping station was identified with double letters (AA to JJ) which represent lines spaced 25 m apart and numbers (e.g. 0+00, 0+50, 1+00) which represents distance (m) from the base (0+00) of each line. Each station was marked with a 1" X 2" X 18" redwood stake projecting 4"—6" above the ground and a 1" X 3" X 3' stake projecting 12"—18" above the ground. Both stakes were marked with the appropriate letter and number designation. Stations at the corners of the plots were marked with a 1/2" X 3' piece of rebar projecting 6"—8" above the ground. Plot FF—JJ, located in the northern half of the study area, represents the experimental plot in the sense that it is roughly in the center of a 20 — 25 acre area which was burned on 3 October, 1985. Stakes marking the trapping stations were protected from fire by clearing dead litter away from the base of the stakes and then enclosing them in 3' lengths of galvanized metal downspout material. Plot AA—EE, located in the southern half of the study area, represents the control plot because habitat on the southern half of the study area was left undisturbed. Over the years, a number of new stakes have been placed on the plots to replace ones that have disappeared or rotted. In 1989, each station was marked with a heavy plastic flag attached to an 18" length of wire.

TRAPPING METHODS

All trapping was conducted under provisions of Federal Fish and Wildlife Permit No. PRT—702631—GAMBRD, Joint State of California Department of Fish and Game / Federal Scientific Collector's Permit, and a Memorandum of Understanding by and between California Polytechnic State University and California Department of Fish and Game. Field work in 1989 was conducted by the author and Mr. Eric Trevena.

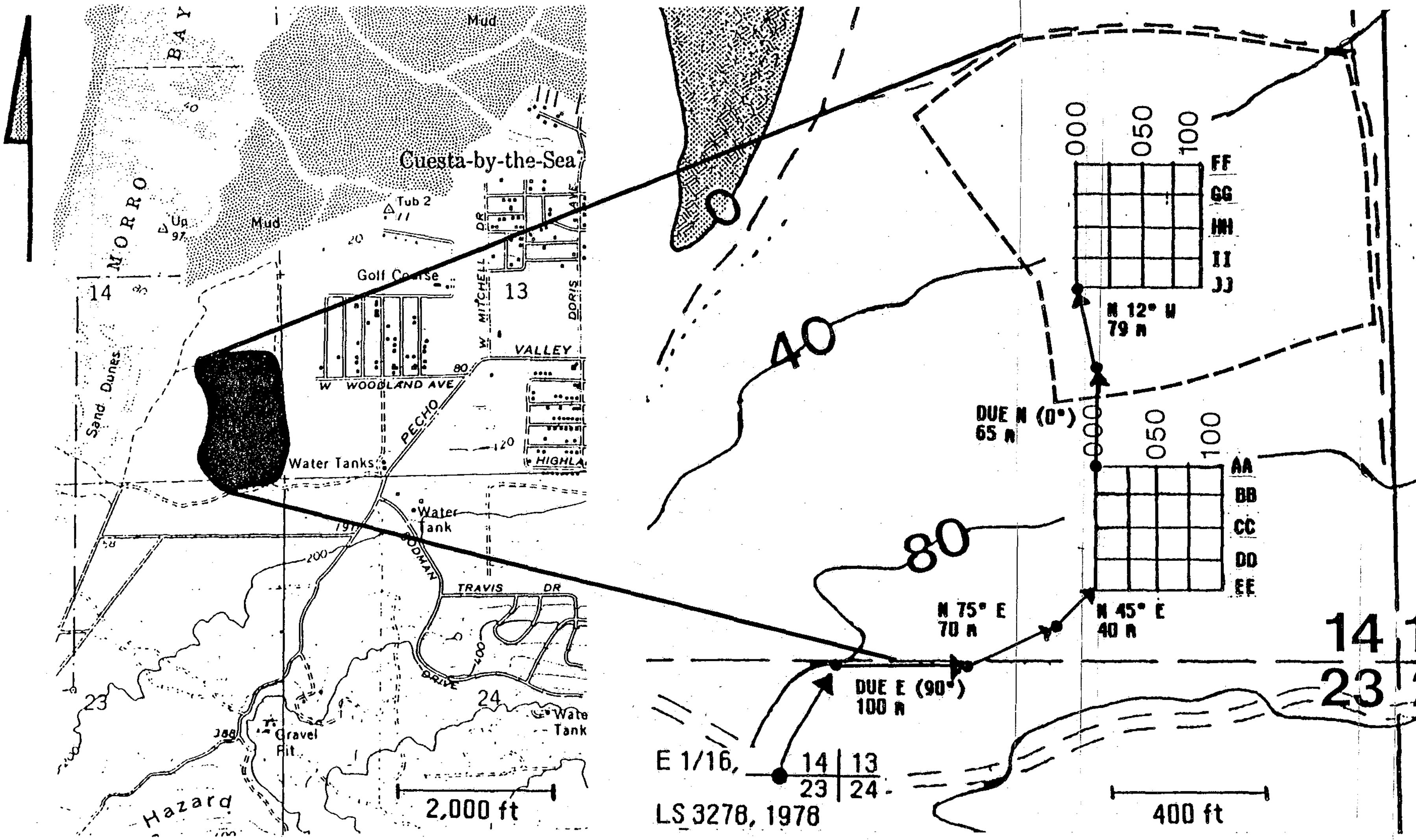

Figure 1. Location of study area, near the southern end of Morro Bay, in Montana de Oro State Park. The control plot is designated by lines AA—EE and the experimental plot is designated by lines FF—JJ. Notes from the traverse survey used to reference the two plots to a legal landmark are indicated in the enlarged view. The dashed line around plot FF—JJ indicates the perimeter of the area which was burned on October 3, 1985.

Two, folding, aluminum, Sherman XLK live traps were placed within 5 m of each trapping station. Traps were set during daylight on one day and then checked and rebaited in the early morning hours for 5 subsequent days (July 15 – July 19, 1989). A 3-5 cm diameter ball of cotton was placed in each trap and a small handful of Quaker, old–fashioned, rolled oats (bait) was divided between the interior of the trap and the ground in front of the trap. All loose debris was removed from traps before each trapping session, but the traps were not brushed out or washed.

FIELD DATA

All data were recorded in pencil in a weatherproof field book at the time of capture. Field data, arranged to facilitate population estimates, are included in Appendix A. Copies of the raw field data are included in Appendix B. Unless otherwise indicated, the following data were gathered for each small mammal trapped during the study:

1. Date of capture
2. General weather: wind, cloud cover, moisture, and temperature
3. The station and plot where the animal was captured.
4. Identification to species using external characteristics
5. Sex of the individual
6. Age class and signs of molting
7. General reproductive condition
8. Body weight to the nearest 0.5 g.

INDIVIDUAL MARKING AND RELEASE

Every small mammal was marked with a numbered, stainless steel fingerling tag (Salt Lake Stamp Co.) which was clamped on one of its ears. Thus each individual was identified with a unique number followed by an L or R indicating the ear holding the tag. All animals were released at their site of capture after all necessary data had been recorded.

TRAPPING INTENSITY AND EASE OF CAPTURE

Trapping intensity during any trapping session is expressed as number of trap nights (TN) which is equal to the sum of the number of traps set each night minus the number of tripped traps, the number of stolen or missing traps, and the number of other animals (birds, reptiles, rabbits, and insects) captured. A total of 488 trap nights were exerted during the 1988 study.

Ease of capture is expressed as the ratio of the trapping intensity (TN) to the number of individuals captured. As an example, if 5 deer mice were caught (# CAP) during a trapping session with 50 TN, then the ease of capture for deer mice during that session would be 10 TN / CAP. The ease of capture for 1 deer mouse caught during another trapping session with 50 TN would be 50 TN / CAP.

RELATIVE ABUNDANCE

Relative abundance is expressed as the number of individuals captured per 100 TN (#/100 TN). Relative abundance is equal to the reciprocal of the ease of capture multiplied by 100 [1 / (#TN / CAP) X 100]. As an example, the relative abundance of 5 deer mice captured during 50 TN = 1 / 10.0 X 100 = 10.0 individuals / 100 TN. The relative abundance of 1 deer mouse caught during 50 TN = 1 / 50 X 100 = 2.0 individuals / 100 TN. Although relative abundance cannot be used to compare absolute differences between populations occurring on different plots, it does provide a means of expressing animal abundance (in terms of trapping success) for months when standard population estimates could not be computed. The average annual relative abundance was derived by applying the above formula to the $\sum$ of TN and the $\sum$ of CAP over the trapping session.

POPULATION ESTIMATION TECHNIQUES

Capture/recapture data from the 5-day trapping session were used to calculate population estimates for each session using the Schnabel Method (Davis and Winstead 1980). The first time an individual was captured it was counted as a newly captured individual, regardless of whether or not it had been captured during the previous field season.

DENSITY ESTIMATION TECHNIQUES

Density was expressed as the population estimate derived from the Schnabel method divided by the area trapped. The area trapped was obtained by assuming that each trapping station "trapped" a 25 m X 25 m (625 m^2) area. Thus, plots AA-EE and FF-JJ, containing 25 trapping stations, were each considered to trap an area of 25 X 625 m^2 = 15,625 m^2 = 1.5625 ha. The average density estimate for each species was obtained by simply taking the average of the separate, non-zero, density estimates for the trapping session.

RESULTS

The results of the present study are based upon trapping data gathered from 37 different individuals belonging to 4 different species which were captured over a total trapping effort of 488 trap nights from 15 July to 19 July, 1989. Detailed information on capture locations, age, sex, breeding condition, and body weight are included in Appendix A and the raw field notes are presented in Appendix B. Eleven different small mammals were captured on the control plot, whereas twenty-six different individuals were caught on the experimental (burned) plot. Deer mice (15 individuals) were the most common species followed by western harvest mice (14 individuals), California pocket mice (6 individuals), and California mice (2 individuals).

No Morro Bay kangaroo rats *(Dipodomys heermanni morroensis)* were found on either of the study plots during the present study. California ground squirrels *(Spermophilus beecheyi)* were not captured during the study, however their burrows were observed in the vicinity of both plots.

The results presented below focus on species composition, ease of capture, and density of small mammals on the control plot (AA-EE) and the experimental plot (FF-JJ) at the Pecho site in July, 1989.

CONTROL PLOT (AA—EE)

SPECIES OCCURRENCE, TRAPPING INTENSITY, AND EASE OF CAPTURE

Four small mammal species were captured over a total of 245 trap nights on plot AA—EE in 1989. A total of 11 different individuals were captured during the 1989 field season, as follows: 2 (18 %) California pocket mice *(Perognathus californicus)*, 2 (18 %) California mice *(Peromyscus californicus)*, 2 (18 %) deer mice *(Peromyscus maniculatus)*, and 5 (46 %) western harvest mice *(Reithrodontomys megalotis)*.

Ease of capture and relative abundance of small mammals on the control plot are presented in Table 1. Western harvest mice and deer mice and were the two species that were "easiest" to catch (40.8 TN / CAP for both), followed by California mice (81.7 TN / CAP) and California pocket mice (122.5 TN / CAP). It should be emphasized that all 4 species were substantially more difficult to capture this year than last year.

POPULATION AND DENSITY ESTIMATES

<u>California pocket mice *(Perognathus californicus)*</u>

Although 2 individuals were caught, lack of recaptures prevented estimating the population size of California pocket mice during the 1989 field season (Table 2).

Table 1. Trapping intensity, ease of capture, and relative abundance for small mammals caught on control plot AA–EE in 1989. SPECIES abbreviations are as follows: Pg. cal. = California pocket mouse *(Perognathus californicus)*, Pm. cal. = California mouse *(Peromyscus californicus)*, Pm. man. = Deer mouse *(Peromyscus maniculatus)*, and Rd. meg. = Western harvest mouse *(Reithrodontomys megalotis)*. Other abbreviations are as follows: # TN (Trap Nights) = trapping intensity (1 trap night = 1 trap set for 1 night); # CAP = total number of animals caught (new captures + recaptures) each day; TN/CAP (ease of capture) = average number of trap nights required to capture one individual; and #/100TN (relative abundance) = average number of individuals caught for every 100 trap nights of trapping effort.

SPECIES	DATE	# TN	#CAP	TN/CAP	#/100 TN
Pg. cal.	7/15/89	49	0	.0	.0
	7/16/89	48	0	.0	.0
	7/17/89	50	0	.0	.0
	7/18/89	49	1	49.0	2.0
	7/19/89	49	1	49.0	2.0
Σ		245	2		
1989 AVG.				122.5	.8
Pm. cal.	7/15/89	49	0	.0	.0
	7/16/89	48	1	48.0	2.1
	7/17/89	50	2	25.0	4.0
	7/18/89	49	0	.0	.0
	7/19/89	49	0	.0	.0
Σ		245	3		
1989 AVG.				81.7	1.2
Pm. man.	7/15/89	49	1	49.0	2.0
	7/16/89	48	1	48.0	2.1
	7/17/89	50	1	50.0	2.0
	7/18/89	49	1	49.0	2.0
	7/19/89	49	2	24.5	4.1
Σ		245	6		
1989 AVG.				40.8	2.5
Rd. meg.	7/15/89	49	0	.0	.0
	7/16/89	48	0	.0	.0
	7/17/89	50	3	16.7	6.0
	7/18/89	49	1	49.0	2.0
	7/19/89	49	2	24.5	4.1
Σ		245	6		
1989 AVG.				40.8	2.5

Table 2. Summary of small mammal population data gathered from control plot AA–EE in 1989. SPECIES abbreviations are as follows: Pg. cal. = California pocket mouse *(Perognathus californicus)*, Pm. cal. = California mouse *(Peromyscus californicus)*, Pm. man. = Deer mouse *(Peromyscus maniculatus)*, and Rd. meg. = Western harvest mouse *(Reithrodontomys megalotis)*. The total number of animals captured (# CAP) = the number of newly captured animals (# NEW) + the number of recaptured animals (# RECAP). Schnabel population estimates [N¿ (POP)] represent the number of individuals estimated to occur on the plot after each day of trapping. The standard error (S.E.) of each population estimate is given for those days when estimates could be computed. Population density estimates (DENSITY = number of individuals / hectare) are based on daily population estimates and an assumed area trapped = 1.5625 ha. The average density (AVG. DEN.) for each species is provided as a single density estimate for each species in 1989.

SPECIES	DATE	#CAP	#NEW	#RECAP	N¿(POP)	S.E.	DENSITY	AVG. DEN.
Pg. cal.	7/15/89	0	0	0	.00	.00	.00	
	7/16/89	0	0	0	.00	.00	.00	
	7/17/89	0	0	0	.00	.00	.00	
	7/18/89	1	1	0	.00	.00	.00	
	7/19/89	1	1	0	.00	.00	.00	.00
Pm. cal.	7/15/89	0	0	0	.00	.00	.00	
	7/16/89	1	1	0	.00	.00	.00	
	7/17/89	2	1	1	2.00	2.65	1.28	
	7/18/89	0	0	0	2.00	2.65	1.28	
	7/19/89	0	0	0	2.00	2.65	1.28	1.28
Pm. man.	7/15/89	1	1	0	.00	.00	.00	
	7/16/89	1	0	1	1.00	1.32	.64	
	7/17/89	1	0	1	1.00	.88	.64	
	7/18/89	1	0	1	1.00	.69	.64	
	7/19/89	2	1	1	1.30	.72	.83	.69
Rd. meg.	7/15/89	0	0	0	.00	.00	.00	
	7/16/89	0	0	0	.00	.00	.00	
	7/17/89	3	3	0	.00	.00	.00	
	7/18/89	1	1	0	.00	.00	.00	
	7/19/89	2	1	1	11.00	14.55	7.04	7.04

California mice *(Peromyscus californicus)*

The population estimates of California mice over the 1989 field season ranged from 0 to 2.0 individuals (Table 2). These population estimates were equivalent to an average density of **1.3 California mice / ha.**

Deer mice *(Peromyscus maniculatus)*

The population estimates of deer mice over the 1989 field season ranged from 1.0 – 1.3 individuals (Table 2). These population estimates were equivalent to an average density of **0.7 deer mice / ha** (range: 0.6 – 0.8).

Western harvest mouse *(Reithrodontomys megalotis)*

The population estimates of western harvest mice over the 1989 field season ranged from 0 – 11.0 (Table 2). These population estimates were equivalent to an average density of **7.0 harvest mice / ha.**

Like 1988, western harvest mice were the easiest species to capture and had the highest density on the control plot in 1989. Deer mice were as easy to capture as harvest mice, however their density was only about 1/7 that of western harvest mice. Unlike 1988, California mice were somewhat easier to catch and had a slightly higher density than California pocket mice in 1989. In terms of density, western harvest mice were clearly the dominant species on the control plot; whereas deer mice, California mice, and California pocket mice were all subordinate species in 1989.

EXPERIMENTAL PLOT (FF—JJ)

SPECIES OCCURRENCE, TRAPPING INTENSITY, AND EASE OF CAPTURE

Three different small mammal species were captured over a total of 243 trap nights on plot FF—JJ in 1989. A total of 26 different individuals were captured during the 1989 field season, as follows: 4 (15 %) California pocket mice *(Perognathus californicus)*, 13 (50 %) deer mice *(Peromyscus maniculatus)*, and 9 (35 %) western harvest mice *(Reithrodontomys megalotis)*.

Ease of capture and relative abundance of small mammals on the control plot are presented in Table 3. Deer mice were the easiest species to catch (6.9 TN / CAP), followed by western harvest mice (20.3 TN / CAP), and California pocket mice (40.5 TN / CAP).

POPULATION AND DENSITY ESTIMATES

California pocket mice *(Perognathus californicus)*

The population estimates for California pocket mice over the 1989 field season ranged from 0 — 7.0 individuals (Table 4). These population estimates were equivalent to an average density of **3.3 pocket mice / ha** (range: 0 — 9.3).

Deer mice *(Peromyscus maniculatus)*

The population estimates for deer mice on the experimental plot during the 1989 field season ranged from 10.3 — 12.5 individuals (Table 4). These population estimates were equivalent to an average density of **7.4 deer mice / ha** (range: 6.6 — 8.0).

Western harvest mouse *(Reithrodontomys megalotis)*

The population estimates of western harvest mice over the 1989 field season ranged from 4.0 — 14.3 (Table 4). These population estimates were equivalent to an average density of **6.0 harvest mice / ha** (range: 2.6 — 9.2)).

Deer mice were easier to catch and had a higher density on the experimental plot than either harvest mice or pocket mice. Although California pocket mice were the most difficult to catch of the 3 species and had the lowest density on the experimental plot in 1989, they were far more abundant on the experimental plot than on the control plot this year. In terms of density, deer mice were the dominant species on the experimental plot in 1989. Western harvest mice and California pocket mice more or less shared a subordinate role, relatively close behind deer mice.

Table 3. Trapping intensity, ease of capture, and relative abundance for small mammals caught on experimental plot FF—JJ in 1989. SPECIES abbreviations are as follows: Pg. cal. = California pocket mouse *(Perognathus californicus)*, Pm. cal. = California mouse *(Peromyscus californicus)*, Pm. man. = Deer mouse *(Peromyscus maniculatus)*, and Rd. meg. = Western harvest mouse *(Reithrodontomys megalotis)*. Other abbreviations are as follows: # TN (Trap Nights) = trapping intensity (1 trap night = 1 trap set for 1 night); # CAP = total number of animals caught (new captures + recaptures) each day; TN/CAP (ease of capture) = average number of trap nights required to capture one individual; and #/100TN (relative abundance) = average number of individuals caught for every 100 trap nights of trapping effort.

SPECIES	DATE	# TN	#CAP	TN/CAP	#/100 TN
Pg. cal.	7/15/89	49	1	49.0	2.0
	7/16/89	48	1	48.0	2.1
	7/17/89	49	1	49.0	2.0
	7/18/89	47	2	23.5	4.3
	7/19/89	50	1	50.0	2.0
∑		243	6		
1989 AVG.				40.5	2.5
Pm. man.	7/15/89	49	8	6.1	16.3
	7/16/89	48	9	5.3	18.8
	7/17/89	49	7	7.0	14.3
	7/18/89	47	6	7.8	12.8
	7/19/89	50	5	10.0	10.0
∑		243	35		
1989 AVG.				6.9	14.4
Rd. meg.	7/15/89	49	1	49.0	2.0
	7/16/89	48	4	12.0	8.3
	7/17/89	49	3	16.3	6.1
	7/18/89	47	1	47.0	2.1
	7/19/89	50	3	16.7	6.0
∑		243	12		
1989 AVG.				20.3	4.9

Table 4. Summary of small mammal population data gathered from experimental plot FF–JJ in 1989. SPECIES abbreviations are as follows: Pg. cal. = California pocket mouse *(Perognathus californicus)*, Pm. cal. = California mouse *(Peromyscus californicus)*, Pm. man. = Deer mouse *(Peromyscus maniculatus)*, and Rd. meg. = Western harvest mouse *(Reithrodontomys megalotis)*. The total number of animals captured (# CAP) = the number of newly captured animals (# NEW) + the number of recaptured animals (# RECAP). Schnabel population estimates [N¿ (POP)] represent the number of individuals estimated to occur on the plot after each day of trapping. The standard error (S.E.) of each population estimate is given for those days when estimates could be computed. Population density estimates (DENSITY = number of individuals / hectare) are based on daily population estimates and an assumed area trapped = 1.5625 ha. The average density (AVG. DEN.) for each species is provided as a single density estimate for each species in 1989.

SPECIES	DATE	#CAP	#NEW	#RECAP	N¿(POP)	S.E.	DENSITY	AVG. DEN.
Pg. cal.	7/15/89	1	1	0	.00	.00	.00	
	7/16/89	1	1	0	.00	.00	.00	
	7/17/89	1	0	1	3.00	3.97	1.92	
	7/18/89	2	2	0	7.00	9.26	4.48	
	7/19/89	1	0	1	5.50	4.85	3.52	3.31
Pm. man.	7/15/89	8	8	0	.00	.00	.00	
	7/16/89	9	2	7	10.30	4.22	6.59	
	7/17/89	7	2	5	11.80	3.58	7.55	
	7/18/89	6	0	6	11.90	2.89	7.62	
	7/19/89	5	1	4	12.50	2.72	8.00	7.44
Rd. meg.	7/15/89	1	1	0	.00	.00	.00	
	7/16/89	4	3	1	4.00	5.29	2.56	
	7/17/89	3	2	1	8.00	7.06	5.12	
	7/18/89	1	1	0	11.00	9.70	7.04	
	7/19/89	3	2	1	14.30	9.81	9.15	5.97

DISCUSSION

COMPARISON OF SMALL MAMMAL POPULATIONS ON THE TWO PLOTS BEFORE AND AFTER THE FIRE

1985

Prior to the 1985 burn, it was not clear whether the observed differences in species composition and density were attributable to low trapping intensity or real differences in the small mammal communities sampled by the two plots before the prescribed burn (Gambs 1985). The juxtaposition of the two plots suggested that the same species should have been found on both plots if the habitats of the two plots were at all similar. However, California mice were found only on the control plot and harvest mice were found only on the experimental plot in 1985. The deer mouse was the only species found on both plots, but deer mice were more abundant on the control plot than on the experimental plot (Fig. 2). Two other species (dusky — footed woodrats, *Neotoma fuscipes*, and California pocket mice), both typical inhabitants of Coastal Dune Scrub habitat similar to that covering the study plots (Gambs 1986d and 1986f), were not found on either of the plots in 1985.

1986

Results of the 1986 study (Gambs 1986e and 1986f) clarified several of the questions raised after the 1985 study. In addition to California mice and deer mice, California pocket mice and western harvest mice also were found on the control plot in 1986 Dusky-footed woodrats continued to be absent from the two plots (Fig. 2). Apparently pocket mice were extremely scarce on both plots before the burn, but their numbers increased between the 1985 and 1986 field seasons such that we were able to trap them during the second year of the study. The fact that pocket mice were over 4 times more abundant on the control plot than on the experimental plot the first year after the burn suggests that the recently burned habitat was actually less favorable for pocket mice. The disappearance of harvest mice from the experimental plot and their appearance on the control plot in 1986 indicates that the burned habitat was less favorable for this species than the pre—burn habitat (Fig. 2). Deer mice were more abundant on the control plot than on the experimental plot in 1985. However, by 1986, deer mouse abundance was essentially the same on the two plots. The greater increase in deer mouse abundance on the experimental plot suggests that the burned habitat may have been more favorable for deer mice.

1987

Results of the 1987 study (Gambs 1987) revealed that western harvest mice were beginning to re-invade the burned plot for the first time since the fire. Also, for the first time, pocket mice were more abundant on the burned plot than on the control plot. California mice were still absent from the burned plot, but deer mice were far more numerous on the burned plot than on the control plot. By 1987 (two years after the fire) deer mice were over three times more abundant on the burned plot than on the control plot. Furthermore, the suitability of burned habitat for pocket mice and

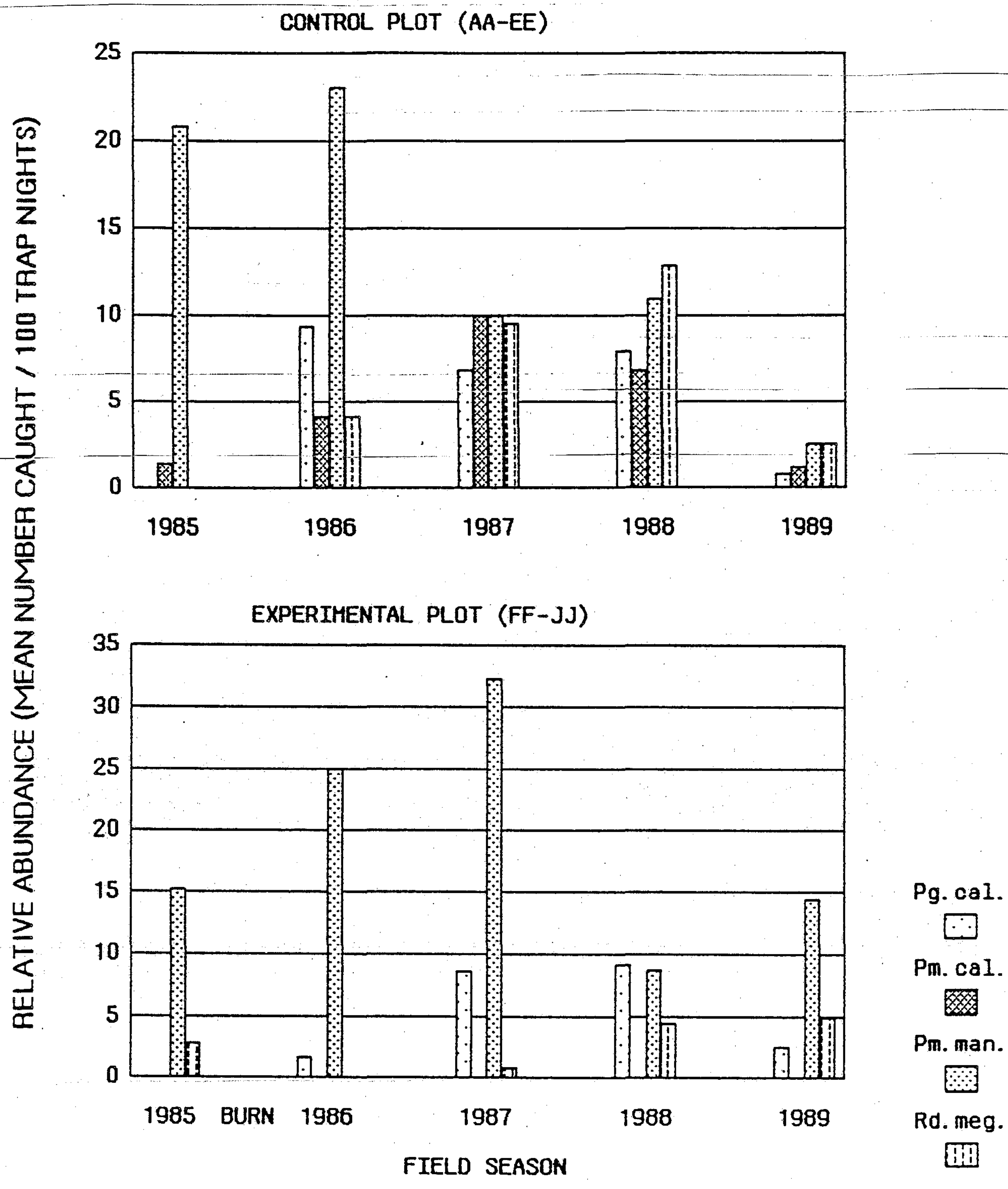

Figure 2. Comparison of average relative abundance values of small mammals captured on the control plot (AA—EE) to those on the experimental plot (FF—JJ). All 4 species have been included on each graph even though some species were not present on both plots each year. Species abbreviations are as follows: Pg. cal. = *Perognathus californicus*; Pm. cal. = *Peromyscus californicus*; Pm. man. = *Peromyscus maniculatus*; Rd. meg. = *Reithrodontomys megalotis*.

harvest mice appeared to have improved over what it had been the first year after the burn.

1988

Results of the 1988 study (Gambs (1988) showed that the relative abundance values obtained for the 4 species on the control plot in 1988 were fairly comparable to those obtained in 1987 (Fig. 2). Harvest mice were slightly more abundant on the control plot in 1988 than 1987 and California mice were slightly less abundant in 1988. Pocket mouse and deer mouse abundance on the control plot were quite similar in both 1987 and 1988. The relative abundances of two of the three species found on the experimental plot in both 1987 and 1988 changed dramatically between the two years. Deer mouse abundance decreased sharply and harvest mouse abundance increased moderately from 1987 to 1988. Pocket mouse abundance remained about the same in both years. Apparently favorable conditions for deer mice in 1987 were diminished substantially in 1988.

The change in densities of the four species on the control plot from 1987 to 1988 generally followed the same patterns as relative abundance (Table 5 and Fig. 3). The importance of western harvest mice on the control plot became more pronounced when densities are examined. Although western harvest mice have had high densities on the control plot in both 1986 and 1988, their density in 1988 was over twice that of any other species. As in previous years, California mice and California pocket mice were subordinate species on the control plot. The continuing pattern of decline in deer mouse density each year since 1985, finally reached a point in 1988 where deer mice shared a subordinate role with California mice and pocket mice on the control plot.

On the experimental plot, deer mice reached high densities during the first two years after the burn. In 1988, for the first time since the burn, the density of deer mice declined to the pre-burn level. Although the low populations of deer mice in 1988 may have been caused by botfly parasitism, it is more likely that other factors contributed to their decline. Unlike deer mice, the density of western harvest mice on the burned plot in 1988 increased to a measurable number for the first time since the study was initiated. Part of this increase may have been the result of individuals from the control plot moving to more favorable sites on the burned plot. The density of California pocket mice in 1988 remained at about the same level as 1987 which confirms last years idea that after a year or so the burned habitat may be more favorable for Heteromyid rodents (pocket mice and kangaroo rats).

1989

Results of the present study revealed a marked decline in the relative abundance values of all 4 species on the control plot in 1989 compared to 1987 and 1988 (Fig. 2). Harvest mice and deer mice were slightly more abundant than California mice and pocket mice in 1989; however all species were less than half as abundant as they had been the past 2 years. The diminished numbers of small mammals on the control plot in 1989 appear to be real and not due to normal population fluctuations characteristic of these species.

In contrast to the control plot, the relative abundances of two of the three species found on the experimental plot were somewhat higher in 1989 than in 1988 (Fig. 2). Deer

Table 5. Average annual densities of small mammals inhabiting the 1 ha control plot (AA-EE) and the 1 ha experimental plot (FF-JJ) at the Pecho site from 1985 — 1988. The experimental plot was burned between the 1985 and 1986 field seasons. Densities shown as "—" indicate that no animals were captured; whereas densities shown as 0(NA) indicate that too few animals were captured to calculate a Schnabel population estimate. Species abbreviations are as follows: Pg. cal. = *Perognathus californicus*, Pm. cal. = *Peromyscus californicus*; Pm. man. = *Peromyscus maniculatus*; Rd. meg. = *Reithrodontomys megalotis*.

				Pg.cal.	Pm.cal.	Pm.man.	Rd.meg.
PLOT	YR.	MN.	#OF T.N.	DEN. (#/ha)	DEN. (#/ha)	DEN. (#/ha)	DEN. (#/ha)
CONTROL PLOT							
AA—EE	1985	JUL	144	—	0(NA)	17.3	—
AA—EE	1986	JUL	143	5.8	4.6	15.2	17.9
AA—EE	1987	JUL	220	2.1	5.9	10.0	10.9
AA—EE	1988	JUN	266	3.5	7.3	5.6	16.3
AA—EE	1989	JUL	245	0(NA)	1.3	.7	7.0
EXPERIMENTAL PLOT							
FF—JJ	1985	JUL	145	—	—	7.9	0(NA)
FF—JJ	1986	JUL	150	.6	—	18.3	—
FF—JJ	1987	JUL	235	5.7	—	19.1	0(NA)
FF—JJ	1988	JUN	287	5.1	—	7.9	6.1
FF—JJ	1989	JUL	243	3.3	—	7.4	6.0

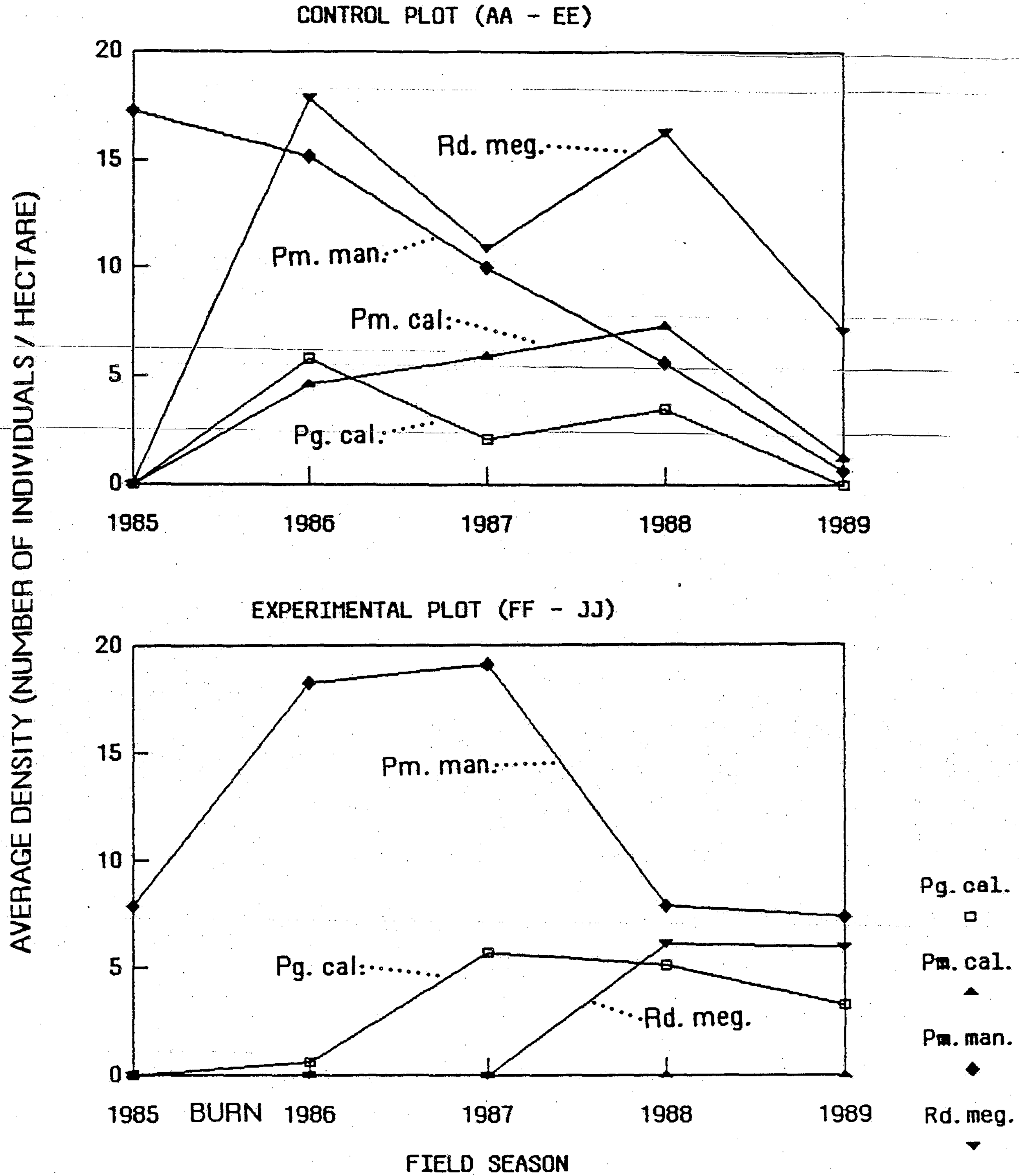

Figure 3. Comparison of average densities of small mammals captured on the control plot (AA—EE) to those on the experimental plot (FF—JJ). All 4 species have been included on each graph even though some species were not present on both plots each year. Species abbreviations are as follows: Pg. cal. = *Perognathus californicus*; Pm. cal. = *Peromyscus californicus*; Pm. man. = *Peromyscus maniculatus*; Rd. meg. = *Reithrodontomys megalotis*.

mice and harvest mice showed a moderate increase whereas pocket mice decreased by more than half. The differences in deer mouse and harvest mouse abundance between 1988 and 1989 are probably within the range of normal population fluctuations characteristic of these two species. However, the sharp drop in the abundance of pocket mice in 1989 to a level near that of 1986 probably represents a real decline this year.

The decline in densities of all four species on the control plot from 1988 to 1989 followed a pattern similar to that seen in their relative abundances (Table 5 and Fig. 3). The importance of western harvest mice on the control plot became more pronounced when densities are examined. Although western harvest mice were still the dominant species in 1989, their density was less than half that recorded in 1988. As in 1988, California mice, pocket mice, and deer mice were subordinate species. The continuing pattern of decline in deer mouse density each year since 1985 is unusual for the Pecho area and suggests that the small mammal community on the control plot may be undergoing a change in species relationships.

The 1989 densities of deer mice, harvest mice, and pocket mice on the experimental plot were quite similar to their densities in 1988. It appears that those conditions which favored very high densities of deer mice and very low densities of harvest mice and pocket mice immediately after the fire have changed such that the burned habitat now supports moderate densities of all 3 species. The fact that California mice have not yet invaded the experimental plot is undoubtedly explained by the absence of heavy brush in the burned area.

In summary, the main effects of the 1985 burn on the small mammal communities under investigation are as follows:

(1) Before the fire, no pocket mice were found on the experimental plot. During the first 4 years after the fire, the burned habitat has become slightly more favorable for pocket mice than the undisturbed (control) habitat. This effect may indicate that the burned habitat has been rendered slightly more suitable for Heteromyid rodents (pocket mice and kangaroo rats).

(2) Very few harvest mice were found on either plot in 1985, but in 1986 they became the dominant species on the control plot and this pattern has persisted through the current season. On the burned plot, harvest mice continued to occur at very low numbers through 1987. Their numbers first increased on the burn in 1988 and this pattern has continued through 1989. Apparently at least two years were required for the burned habitat to becoming favorable for harvest mice. Although they are not yet as common on the burn as on the control plot, harvest mice appear to be gaining a stronger position in the small mammal community of the burned plot.

(3) During the first 2 years after the fire, deer mice showed a dramatic rise in their population compared to their numbers on the plot before the fire. In 1988, their numbers dropped by over 50 % to the pre-burn level (1985) and this trend has continued through 1989. Those factors which were particularly favorable to deer mice during the first 2 years after the fire appear to have diminished to a level comparable to pre-burn conditions.

(4) Although California mice have been found on the control plot all 5 years of the study, none have appeared on the experimental plot. Clearly, the absence of substantial stands of tall, dense brush and the presence of low brush and herbaceous cover on the burned habitat continues to be unfavorable for California mice.

(5) California ground squirrels still occupy the burned area and have probably invaded the control area as well.

EVALUATION OF BURNING AS A METHOD OF IMPROVING HABITAT FOR MORRO BAY KANGAROO RATS

Past studies have shown that when Morro Bay kangaroo rats populated areas at moderate or high densities, the populations of other local species of small mammals (except California pocket mice) were generally quite low. Furthermore, past studies have at least implied that small mammal species which typically inhabit dense stands of Coastal Dune Scrub and Chaparral habitats (e.g. dusky-footed woodrats and California mice) rarely were found in habitat supporting Morro Bay kangaroo rats (Gambs 1986c). The small mammal data presented in this report suggest that burning has produced <u>some</u> of the conditions which have been associated with suitable Morro Bay kangaroo rat habitat. That is, the absence of dusky-footed woodrats and California mice and moderate (but not low) densities of other small mammal species in 1988 and 1989.

It is worth pointing out that successful habitat manipulation for Morro Bay kangaroo rats may not necessarily be restricted to just the manipulation (clearing, burning, etc.) of plant cover on an area. If one makes the extreme assumption that differences in small mammal communities occupying different habitats are completely dependent upon differences in the plant cover on these sites; it follows that a habitat manipulation procedure which suppressed or eliminated populations of other species (ie. dusky-footed woodrats, California Mice, deer mice, western harvest mice, and, to a lesser extent California pocket mice) might be considered to have successfully created potentially suitable habitat for Morro Bay kangaroo rats. That is, with the exception of Morro Bay kangaroo rats, such a procedure would have promoted a small mammal community similar to that found at the Bayview site. If habitat manipulation produced no noticeable effect on populations of other local small mammals, then factors other than the vegetative composition of the habitat might be involved in regulating populations of local small mammals (e.g. interspecific competition or differential rates of predation or parasitism). In reality, the population ecology of local small mammals (particularly Morro Bay kangaroo rats) probably depends upon a complex of botanical and zoological variables specific to a particular site.

Comparison of the results of the present study to the results of another, neighboring burn conducted in 1984 (Gambs 1986b, 1986f, and Gambs and Holland 1988) reveals more similarities than differences and serves to clarify several questions concerning the 1985 burn. Dusky-footed woodrats and California mice were both found on the other plot (TUVWX) before it was burned in 1984, however neither of these species inhabited that plot until 1988 (four years after the burn). This result suggests that burning was detrimental to woodrats and California mice for a period of about three years. By the fourth year, sufficient, dense, Coastal Dune Scrub habitat was available to again support these two species. The sharp decline in western harvest mice on both of the burned plots during the first two or three years after burning suggests that burning was definitely unfavorable for this species. Western harvest mice, like dusky-footed woodrats and California mice, also began to increase during the fourth year after the fire on plot TUVWX. The two species which continued to thrive on both of the burned plots were deer mice and California pocket mice. Since deer mice were numerically dominant to California pocket mice on both burned plots it appears that burning was more beneficial to deer mice than pocket mice. This is unfortunate because pocket mice, which belong to the same family (Heteromyidae) as Morro Bay kangaroo rats, appear to have habitat requirements which are more similar to those of the Morro Bay kangaroo rat than do deer mice. Thus, a manipulated Coastal Dune Scrub habitat which supported more California pocket mice than deer mice (or some other other rodent species) would probably represent a more favorable site for Morro Bay kangaroo rats than one in which deer mice or other species outnumbered California pocket mice.

It is important to note that burning has not produced depauperate small mammal communities (excluding Morro Bay kangaroo rats) which are comparable to those found at the Bayview site (Gambs 1986a, 1986f, and Gambs and Holland 1988). Despite this shortcoming, the burned areas appear to be more favorable for Morro Bay kangaroo rats than undisturbed or cleared areas because (a) the burns cover more area than the two cleared sites and (b) burning has been temporarily successful in reducing populations of dusky-footed woodrats and California mice.

California ground squirrels were seen foraging on plot FF-JJ the first year after it was burned and now they have established burrows there and in the surrounding area. California ground squirrels also have been seen and caught on plot TUVWX during all four years since it was burned. There is little doubt that burning has been beneficial to ground squirrels and their invasion into these sites represents a serious obstacle to the successful establishment of Morro Bay kangaroo rats at the Pecho site.

RECOMMENDATIONS FOR MORRO BAY KANGAROO RATS AND THEIR HABITAT

MANAGEMENT

1. Continue to pursue the goals of the Recovery Plan as vigorously as possible.

2. Before planning additional burns at the Pecho site, I strongly recommend that an experimental brush removal project be conducted. This is the one method of habitat manipulation that has been positively associated with a thriving population of Morro Bay kangaroo rats at the Pecho area in the past (Stewart 1958 and Roest personal communication). The method of brush removal that I am recommending involves the complete removal of all shrubs and their roots by means of a bulldozer equipped with ground breaking, "ripper", hooks. After the shrubs have been uprooted they could be piled and burned at a few sites within the area. A procedure similar to this was used by the U. S. Army when they decontaminated the Pecho area before turning it over to public and private ownership in about 1955. Such dramatic habitat manipulation should be completed before Morro Bay kangaroo rats are allowed to range freely at Pecho. News releases, signs explaining the purpose of the project, and other media efforts would at least provide concerned citizens with an explanation of what might appear to be an extreme method of habitat management.

3. Ground squirrel control requires immediate attention. The spread of California ground squirrels into manipulated habitat represents a serious obstacle to the future establishment of Morro Bay kangaroo rats at these sites because they are expected to behaviorally and ecologically dominate Morro Bay kangaroo rats. In 1988, it was recommended that ground squirrels be controlled in the general vicinity of both burned sites before Morro Bay kangaroo rats were released from their enclosure (Gambs 1988). The Morro Bay kangaroo rats introduced into the enclosure in 1988 probably escaped into the surrounding area (Gambs and Nelson 1988) and it is unknown whether any of these animals survived into the 1989 field season. Ground squirrel control initiated before the end of 1989 would carry some (probably low) risk to any Morro Bay kangaroo rats (and/or offspring) remaining in the area from the 1988 introduction. Ground squirrel control initiated after 1989 would be expected to carry a much greater risk to Morro Bay kangaroo rats because the U.S.F.W.S. is planning to release all or most of the captive breeding colony at the Piedras Blancas lab early in 1990.

4. A serious effort should be undertaken to identify parcels of "undeveloped", potentially suitable habitat which could be purchased by governmental agencies and then modified to support Morro Bay kangaroo rats. A suitable parcel would be circular or at least compact and cover about 90 ha. A 90 ha parcel would probably support a population of about 350 individuals. Parcels smaller than 90 ha might be feasible if a high level of management effort could be devoted to them. Obviously, a number of 90 ha parcels would be required to support the 2,500 animals prescribed in the recovery plan.

5. A long range program of experimental habitat manipulation and/or restoration should be instituted for the Critical Habitat area as well as other sites (e. g. the Buckskin, Bayview, Junior High, and Santa Ysabel Essential Habitat areas) where such activities would be feasible. Habitat management should be followed by successive introductions of Morro Bay kangaroo rats when sufficient rats become available and the

habitats are judged to be suitable. Assuming that Morro Bay kangaroo rats eventually become free ranging at Pecho or elsewhere, it will become increasingly more important to carefully weigh the benefits (vs) the risks to these animals of future habitat manipulation and/or restoration programs proposed for that site.

6. Experiments should be undertaken to evaluate the efficacy of supplemental feeding as means of increasing the future density of wild populations of Morro Bay kangaroo rats. "Before and after" experiments would be the designs most likely to reveal the effects of such a procedure.

7. Periodic ground reconnaissance trips should be made along the eastern boundary of public land in the Critical Habitat area. The purpose of this is to ensure early detection of erosion, invasion of weedy plants, runoff, and other adverse impacts to Critical Habitat originating from neighboring residential developments. As soon as additional rats are introduced at Pecho, it will be necessary to monitor domestic pets, vehicles, livestock, and foot traffic in the area to ensure that the rats, as well as their burrows and food sources remain undisturbed.

RESEARCH

1. Maintenance and expansion of the captive breeding facility are essential to ensure that animals will be available for future management projects. Preparations should be made for future reintroductions of Morro Bay kangaroo rats at Pecho and elsewhere. It may be necessary to employ artificial insemination, hormone or dietary supplements, reversed or altered photoperiods, and other procedures in order to promote maximum reproductive output of captive animals.

2. Controlled food discrimination experiments should be conducted on captive Morro Bay kangaroo rats. This information, when combined with field data on plant communities, would permit a more detailed evaluation of the importance of certain plants and it could suggest specific ways to restore or manipulate habitats. Results from these experiments also would provide valuable background information for a proposed supplemental feeding experiment.

3. Population estimates of the Morro Bay kangaroo rats at Bayview should be conducted every 1 – 2 years. This is particularly important because the Bayview population is the only viable wild population known to exist at the present time. Thorough ground searches for signs of Morro Bay kangaroo rats should be conducted at the Pecho, Bayview, Buckskin, and Junior High / Santa Ysabel sites every year.

4. At the present time, the Bayview site represents the best field site for assessing the population response of Morro Bay kangaroo rats to habitat manipulation. A set of "before and after" experiments would allow direct comparisons of rat responses to several types of habitat manipulation and/or restoration procedures.

5. Every effort should be made to monitor burrow system development, foraging activities, microhabitat preference, general physical condition, signs of agonistic interactions, reproductive success, and dispersal of adult and young Morro Bay kangaroo rats that have been introduced into protective enclosures at the Pecho site. Although difficult, it will be especially important to monitor the introduced animals after they have been allowed to leave the enclosures. These animals would be the logical subjects

for measurements on dispersal distance per generation and net lifetime production of female offspring per adult female. This latter monitoring work would be most efficiently done using biotelemetry and night vision equipment.

6. Continued monitoring of small mammal communities on the plots at Pecho will provide population baselines which can be used to assess possible competitive interactions between Morro Bay kangaroo rats and other small mammal species there. It would be particularly useful to design a set of field experiments which would directly measure the degree of actual competitive interactions.

7. Continued sampling of plant communities at all future reintroduction sites will become increasingly important as free ranging populations of Morro Bay kangaroo rats become established at these sites. Careful assessment of plant communities that are either used or unused by rats should provide a more precise evaluation of the importance of vegetation composition and structure as well as the efficacy of habitat manipulation techniques in providing optimal habitat for Morro Bay kangaroo rats.

8. A comprehensive examination of the genetic variance present in wild and lab animals using no risk, non-invasive genetic "fingerprinting" techniques should be conducted as soon as possible.

9. The preservation of Morro Bay kangaroo rat cellular and/or genetic specimens in a long-term "gene bank" should be initiated so that future scientific study may be conducted on properly preserved material. It may be possible to combine genetic preservation with genetic "fingerprinting" (above).

10. Field research biologists from various agencies and institutions could mount a more effective and expedient recovery effort on kangaroo rats if they worked through a local "research/recovery center" on a full time basis.

REFERENCES

Congdon, J. D. 1971. Population estimate and distribution of the Morro Bay kangaroo rat. California Dept. of Fish and Game, Wildlife Management Branch Administrative Report No. 71—11. 13 pp.

_____ and A. I. Roest. 1975. Status of the endangered Morro Bay kangaroo rat. J. Mamm., 56(3): 679—683.

Davis, D. E. and R. L. Winstead. 1980. Estimating the numbers of wildlife populations. in Wildlife Management Techniques Manual, S. D. Schemnitz (ed.), The Wildlife Society, Washington D. C.

Dixon, J. 1918. Field notes of Morro Bay trip, San Luis Obispo and Monterey Counties, California. Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Gambs, R. D. 1985. Small mammal census of two study plots on Montana de Oro State Park near Morro Bay, San Luis Obispo County, California. Interim Report, California Department of Parks and Recreation, Sacramento, CA. 23 pp.

_____. 1986a. Status of Morro Bay kangaroo rats on 3 study plots at the Bayview site in 1984 and 1985. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 29 pp.

_____. 1986b. Effects of a controlled burn (October 24, 1984) on small mammal populations on plot TUVWX at the Pecho site: comparison of 1984 (pre-burn) data to 1985 (post-burn) data. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 29 pp.

_____. 1986c. The effects of a proposed wastewater system in the communities of Los Osos and Baywood Park, California on the endangered Morro Bay kangaroo rat *(Dipodomys heermanni morroensis)*. Biological Assessment, San Luis Obispo County, CA. 26 pp.

_____. 1986d. Small mammal population studies at the Pecho, Hazard, and Turri sites and the effects of habitat manipulation on small mammals at the Pecho site: 1983—1984. Final Report, U. S. Fish and Wildlife Service, Sacramento CA. 165 pp.

_____. 1986e. The effects of a prescribed burn (October 3, 1985) on small mammal populations occupying critical, Morro Bay kangaroo rat habitat at Montana de Oro State Park: Comparison of pre-burn data (1985) to post-burn data (1986). Final Report, California Department of Parks and Recreation, Sacramento, CA. 44 pp.

_____. 1986f. I. Effects of habitat manipulation (brush clearing and prescribed burning) on small mammal populations at the Pecho site in 1985 and 1986: plots ABC, DEF, GHI, JKL, TUVWX, AABBCCDDEE, and FFGGHHIIJJ; II. Population studies of Morro Bay kangaroo rats and other small mammals at the Bayview site in 1986: plots NOP, QRS, and KKLLMM; III. Trends in small mammal populations on 7 study plots at the Pecho

_____. 1987. The effects of fire on small mammals occupying critical, Morro Bay kangaroo rat habitat at Montana de Oro State Park. First Annual Report. California Department of Parks and Recreation, Sacramento, CA. 36 pp.

_____. 1988. The effects of fire on small mammals occupying critical, Morro Bay kangaroo rat habitat at Montana de Oro State Park. Second Annual Report. California Department of Parks and Recreation, Sacramento, CA. 41 pp.

Gambs, R. D. and V. L. Holland. 1988. Ecology of the Morro Bay kangaroo rat *(Dipodomys heermanni morroensis).* Final Report, # 14-16-0001-85154 NR, U. S. Fish and Wildlife Service, Sacramento, CA.

Gambs, R. D. and A. R. Nelson. 1989. Introduction of captive Morro Bay kangaroo rats *(Dipodomys heermanni morroensis)* into an enclosure on critical habitat at Montana de Oro State Park. Final Report, # FG7568, California Department of Fish and Game, Sacramento, CA.

Grinnell, J. 1922. A geographical study of the kangaroo rats of California. Univ. Calif. Publ. Zool. 24(1): 1-124.

Lidberg, J. 1982. Morro dunes ecological reserve management plan. California Dept. of Fish and Game.

Roest, A. I. 1973. Morro Bay kangaroo rat habitat evaluation study. California Dept. of Fish and Game, Special Wildlife Investigations Prog. Rep., W-54-R. 25 pp.

_____ 1977. Distribution and population estimate of the Morro Bay kangaroo rat, 1977. Report for California Dept. of Fish and Game, Contract No. S1312, 19 pp.

_____ 1982a. Morro Bay kangaroo rats. in CRC Handbook of Census Methods for Terrestrial Vertebrates, D. E. Davis (ed.), CRC Press. Boca Raton, Florida. pp. 171-172.

_____ 1982b. Morro Bay kangaroo rat. in The IUCN Mammal Red Data Book, Part 1, J. Thornback and M. Jenkins (eds.), International Union for Conservation of Nature and Natural Resources, Gland, Switzerland, pp. 233-235.

_____. 1984. The Morro Bay kangaroo rat: A summary of current knowledge. Poster presented at the 64 th annual meeting of the American Society of Mammalogists, June 1984, Humboldt State Univ., Arcata CA.

Stewart, G. R. 1958. Notes on the Morro Bay kangaroo rat. Senior Project, California Polytechnic State University, San Luis Obispo. 49 pp.

_____. and A. I. Roest. 1960. Distribution and habits of kangaroo rats at Morro Bay. J. Mamm. 41(1): 126-129.

Toyoshima, J. M. 1983. Small mammal population in a coastal sage scrub community. M. S. Thesis, California Polytechnic State University, San Luis Obispo, 81 pp.

U. S. Fish and Wildlife Service. 1982. Morro Bay Kangaroo Rat Recovery Plan. Fish and Wildlife Reference Service. Rockville Md. 69 pp.

Villablanca, F. X. 1986. Morro Bay kangaroo rat distribution, status, population estimate and habitat evaluation throughout their original range: August to September 1984 and April to August 1985. Interim Report, U. S. Fish and Wildlife Service, Sacramento, CA. 57pp.

_____. 1987. Distribution, status, and ecology of Morro Bay kangaroo rats and their habitat. Senior Project. California Polytechnic State University, San Luis Obispo. 83 pp.

APPENDIX A

Detailed trapping data collected from all animals captured on 2 study plots in 1989. The L or R following the number of the stainless steel ear tag number (TAG #) indicates whether the left or right ear was used to carry the tag. STA (trapping station) indicates where each individual was captured on the plot. SPECIES abbreviations are as follows: Pg. cal. = *Perognathus californicus*, Pm. cal. = *Peromyscus californicus*, Pm. man. = *Peromyscus maniculatus*, and Rd. meg. = *Reithrodontomys megalotis*. AGE abbreviations are: A = full—sized animals with bright, adult pelage, SUBA = animals weighing less than full adults with nearly adult pelage, J = animals with more or less uniform, dull pelage. SEX (M = male and F = female) is given for all animals that did not escape while being handled. REP. CND. (breeding condition) of males is designated as TD = testes scrotal or TND = testes abdominal. Breeding condition of females is designated as follows: NL = no external signs of present, past, or forthcoming reproductive activity as evidenced by examination of mammae and vulva, PLAC = minor development of mammae perhaps indicating either very early gestation or a post—weaning condition, PREG = distended abdomen and heavy body weight which were indicative of late gestation, LAC = enlarged mammae surrounded by a concentric zone of bare skin, VPLG = conspicuous, light—colored mass of tissue at the vaginal opening which may indicate early stages of gestation, or BLVG = blood present at the vaginal opening which may indicate recent parturition. In addition to general notes, body measurements (mm) of some individuals are given as tail (base to end of last vertebra) / hind foot (end of heel to end of longest toe pad) / ear (unstretched from notch to tip). (Wt g) indicates the live weight of the animal to the nearest 0.5 gram.

APPENDIX A. 1989 SORTED DATA FOR PLOT AA–EE (1)

	A	B	C	D	E	F	G	H	I
1	TAG #	DATE	SPECIES	STA.	AGE	SEX	REP.CND.	CAP. HIST.	WT.
2									
3	2938R	7/16/89	Pm. cal	EE100	A	F	PREG	new	48.0
4	2944R	7/17/89	Pm. cal	CC100	A	M	TND	new	35.0
5	2938R	7/17/89	Pm. cal	EE100	A	F	PLAC	Recap.	40.0
6	2950R	7/18/89	Pg. cal	AA100	A	F	NL	new	15.5
7	2955R	7/19/89	Pg. cal	AA100	A	F	NL	new	13.0
8	2931R	7/15/89	Pm. man	DD025	A	M	TND	new	15.0
9	2931R	7/16/89	Pm. man	BB050	A	M	TND	Recap.	16.0
10	2931R	7/17/89	Pm. man	BB050	A	M	TND	Recap.	15.5
11	2931R	7/18/89	Pm. man	BB075	A	M	TND	Recap.	15.0
12	2931R	7/19/89	Pm. man	BB050	A	F	TND	Recap.	14.5
13	2954L	7/19/89	Pm. man	DD100	A	M	TND	new	15.0
14	2943R	7/17/89	R. meg	CC050	A	M	TND	new	9.5
15	2945R	7/17/89	R. meg	DD025	A	M	TND	new	10.0
16	2946R	7/17/89	R. meg	EE050	A	F	PLAC	new	13.0
17	2949R	7/18/89	R. meg	AA000	A	M	TND	new	8.5
18	2945R	7/19/89	R. meg	CC025	A	M	TND	Recap.	10.0
19	2957R	7/19/89	R. meg	EE075	A	F	LAC	new	12.0

APPENDIX A. 1989 SORTED DATA FOR PLOT FF–JJ (1)

	A	B	C	D	E	F	G	H	I
1	TAG#	DATE	SPECIES	STA.	AGE	SEX	REP.CND.	CAP.HIST.	WT.
2									
3	2926R	7/15/89	Pg. cal	HH100	A	F	L	new	21
4	2936R	7/16/89	Pg. cal	II100	A	F	PLAC	new	34
5	2926R	7/17/89	Pg. cal	HH100	A	F	PLAC	Recap.	21.5
6	2485L	7/18/89	Pg. cal	JJ100	A	M	TD	Recap(new)	34.5
7	2948R	7/18/89	Pg. cal	JJ000	A	F	NL	new	19.5
8	2670R	7/19/89	Pg. cal	JJ075	A	F	LAC	Recap.	22.5
9	2921R	7/15/89	Pm. man	FF075	A	F	NL	new	12.5
10	2924R	7/15/89	Pm. man	GG025	A	M	TND	new	17.5
11	2925R	7/15/89	Pm. man	GG100	A	M	TND	new	16.5
12	2927R	7/15/89	Pm. man	II050	A	F	PLAC	new(escape)	
13	2928R	7/15/89	Pm. man	JJ100	A	M	TND	new	14.5
14	2929R	7/15/89	Pm. man	JJ050	A	M	TND	new	17.5
15	2930R	7/15/89	Pm. man	JJ025	A	M	TND	new	16.5
16	2921R	7/16/89	Pm. man	FF075	A	F	NL	Recap.	12
17	2925R	7/16/89	Pm. man	GG100	A	M	TND	Recap.	17.5
18	2933R	7/16/89	Pm. man	GG100	A	F	PLAC	new	16.5
19	2927R	7/16/89	Pm. man	II050	A	F	PLAC	Recap.	18
20	2928R	7/16/89	Pm. man	JJ100	A	M	TND	Recap.	14
21	2937R	7/16/89	Pm. man	JJ050	A	F	NL	new	14
22	2929R	7/16/89	Pm. man	JJ050	A	M	TND	Recap.	17.5
23	2924R	7/16/89	Pm. man	JJ025	A	M	TD	Recap.	17
24	2930R	7/16/89	Pm. man	JJ025	A	M	TND	Recap.	17
25	2925R	7/17/89	Pm. man	FF075	A	M	TND	Recap.	17
26	2921R	7/17/89	Pm. man	FF050	A	F	NL	Recap.	12
27	2940R	7/17/89	Pm. man	GG025	A	M	TND	new	16
28	2930R	7/17/89	Pm. man	II100	A	M	TND	Recap.	17
29	2942R	7/17/89	Pm. man	II075	A	M	TND	new	16.5
30	2928R	7/17/89	Pm. man	JJ075	A	M	TND	Recap.	14
31	2924R	7/17/89	Pm. man	JJ050	A	M	TND	Recap.	16
32	2921R	7/18/89	Pm. man	FF075	A	F	NL	Recap.	12
33	2933R	7/18/89	Pm. man	GG100	A	F	L	Recap.	15.5
34	2942R	7/18/89	Pm. man	II075	A	M	TND	Recap.	16.5
35	2927R	7/18/89	Pm. man	JJ050	A	F	PLAC	Recap.	18
36	2924R	7/18/89	Pm. man	JJ050	A	M	TND	Recap.	15.5
37	2930R	7/18/89	Pm. man	JJ025	A	M	TND	Recap.	17
38	2951R	7/19/89	Pm. man	FF075	A	M	TND	new	19
39	2940R	7/19/89	Pm. man	GG025	A	M	TD	Recap.	15.5
40	2930R	7/19/89	Pm. man	II025	A	M	TND	Recap.	17
41	2927R	7/19/89	Pm. man	II050	A	F	PLAC	Recap.	18
42	2929R	7/19/89	Pm. man	JJ050	A	M	TND	Recap.	

APPENDIX A. 1989 SORTED DATA FOR PLOT FF–JJ (2)

	A	B	C	D	E	F	G	H	I
43	2923R	7/15/89	R. meg	FF050	A	M	TND	new	8
44	2934R	7/16/89	R. meg	HH050	A	M	TND	new	10.5
45	2923R	7/16/89	R. meg	FF050	A	M	TND	Recap.	7.5
46	2932R	7/16/89	R. meg	GG075	A	M	TND	new	10
47	2935R	7/16/89	R. meg	HH075	A	M	TND	new	7.5
48	2939R	7/17/89	R. meg	FF025	A	M	TND	new	7
49	2932R	7/17/89	R. meg	GG075	A	M	TND	Recap.	10
50	2941R	7/17/89	R. meg	HH075	A	F	L	new	11
51	2947R	7/18/89	R. meg	II025	J	F	NL	new	5.5
52	2934R	7/19/89	R. meg	II075	A	M	TND	Recap.	12
53	2952R	7/19/89	R. meg	FF000	A	F	PLAC	new	8.5
54	2953R	7/19/89	R. meg	GG050	A	F	PREG	new	12

APPENDIX B

Copies of raw field data collected from all animals captured on 2 study plots in 1989. The L or R following the number of the stainless steel ear tag number (TAG #) indicates whether the left or right ear was used to carry the tag. STA (trapping station) indicates where each individual was captured on the plot. SPECIES abbreviations are as follows: Pg. cal. = *Perognathus californicus*, Pm. cal. = *Peromyscus californicus*, Pm. man. = *Peromyscus maniculatus*, and Rd. meg. = *Reithrodontomys megalotis*. AGE abbreviations are: A = full-sized animals with bright, adult pelage, SUBA = animals weighing less than full adults with nearly adult pelage, J = animals with more or less uniform, dull pelage. SEX (M = male and F = female) is given for all animals that did not escape while being handled. BR. CND. (breeding condition) of males is designated as TD = testes scrotal or TND = testes abdominal. Breeding condition of females is designated as follows: NL = no external signs of present, past, or forthcoming reproductive activity as evidenced by examination of mammae and vulva, PLAC = minor development of mammae perhaps indicating either very early gestation or a post-weaning condition, PREG = distended abdomen and heavy body weight which were indicative of late gestation, LAC = enlarged mammae surrounded by a concentric zone of bare skin, VPLG = conspicuous, light-colored mass of tissue at the vaginal opening which may indicate early stages of gestation, or BLVG = blood present at the vaginal opening which may indicate recent parturition. In addition to general notes, body measurements (mm) of some individuals are given as tail (base to end of last vertebra) / hind foot (end of heel to end of longest toe pad) / ear (unstretched from notch to tip). (Wt g) indicates the live weight of the animal to the nearest 0.5 gram.

APPENDIX B. RAW DATA: PLOTS AA—EE & FF—JJ; 1989 (1)

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	NEW RECAP	TAG
50 TRAPS @ FF-JJ July 15, 1989						COLD, BREEZE, FOG, SOIL DRY					
Full Moon July 18th '89											
	FF-JJ	FF075	July18	8:30	Pm.mam	A♂	NL		12.5	New	2921R
	"	FF050	"	"	R.meg	A♂	TND		8.0	New	2923R
		GG025	"	"	Pm.mam	A♂	TND		17.5	New	2924R
		GG100	"	"	Pm.mam	A♂	TND	Hole in head; Scar above rt eye	16.5	New	2925R
		HH100	"	"	Pg.cal	A♂	L		21.0	New	2926R
		HH075	—	TRIPPED		TRAP					
		II050	"	"	Pm.mam	A♂	PLAC	Bare patches around nipples	Escape	New	2927R
		JJ100	"	"	Pm.mam	A♂	TND		14.5	New	2928R
		JJ050	"	"	Pm.mam	A♂	TND		17.5	New	2929R
		JJ025	"	"	Pm.mam	A♂	TND		16.5	New	2930R

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	NEW RECAP	TAG
50 TRAPS @ AA-EE July 15, 1989						~~WARM, WINDY, CLEAR, DRY~~					
Full moon July 18th '89											
	AA-EE	CC100	July15	10:30	Pm.mam			Escape			~~[illegible]~~
		DD025	"	"	Pm.mam	A♂	TND		15.0	New	2931R
		~~DD050~~		TRIPPED			TRAP				
				11:30							

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	NEW RECAP	TAG
50 TRAPS @ FF-JJ July 16, 1989						COOL, BREEZE, CLEAR, DRY					
Full moon July 18, '89											
	FF-JJ	FF075	July16	7:50	Pm.mam	A♂	NL		12.0	—	2921R
		FF050	"	"	R.meg	A♂	TND		7.5	—	2923R
		GG025	— TRIPPED				TRAP				
		GG075	"	"	R.meg	A♂	TND	mean sucker	10.0	New	2932R
		GG100	"	"	Pm.mam	A♂	TND		17.5	—	2925R
		GG100	"	"	Pm.mam	A♂	PLAC	Bare spot nipples	16.5	New	2933R
		HH050	"	"	Per.cal	A♂	TND		10.5	New	2934R
		HH050	"	"	R.meg	A♂	TND		7.5	New	2935R
		II000	TRIPPED				TRAP				
		II050	"	"	Pm.mam	A♂	PLAC		18.0	—	2927R
		II100	"	"	Pg.cal	A♂	PLAC	very large	34.0	New	2936R
		JJ100	"	"	Pm.mam	A♂	TND		14.0	—	2928R
		JJ050	"	"	Pm.mam	A♂	NL		14.0	New	2937R
		JJ050	"	"	Pm.mam	A♂	TND		17.5	—	2924R
		JJ025	"	"	Pm.mam	A♂	TD		17.0	—	2924R
		JJ025	"	"	Pm.mam	A♂	TND		17.0	—	2930R

APPENDIX B. RAW DATA; PLOTS AA–EE & FF–JJ; 1989 (2)

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	New/Recap	TAG
50 TRAPS @ AA-EE July 16, 1989:						WARM, WINDY, CLEAR, DRY					
Full moon July 18th "89"											
	AA-EE	AA100	July 16	10:30	TRIPPED	TRAP					
		BB050	"	"	Pm. mam	A♂	TND		16.0	—	2931R
		CC100	"	"	TRIPPED	TRAP					
Cal mice		EE100	"	"	Pm. mam	A♂	PLAC	HF 25mm; Ear 18mm; Tail 12 cm; HB 8.0cm; Nipples enlarged; long whiskers	48.0	New	2938R
				11:45							

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	New/Recap	TAG
50 TRAPS @ FF-JJ, July 17, 1989						COOL, BREEZE, FOG, DRY					
Full moon July 18, "89"											
—	FF-JJ	FF075	July 17	8:00	Pm. mam	A♂	TND		17.0	—	2925R
		FF075	"	"	Pm. mam	A♂	NL		12.0	—	2921R
		FF050			TRIPPED	TRAP			7	New	2939R
		FF025	"	"	R. meg	A♂	TND		7.0	New	2959R
		GG025	"	"	Pm. mam	A♂	TND		16.0	New	2940R
		GG075	"	"	R. meg	A♂	TND		10.0	—	2932R
		HH100	"	"	Pg. cal	A♂	PLAC		21.5	—	2926R
		HH075	"	"	R. meg	A♂	L	Bare patches nipples	11.0	New	2941R
		II000	"	"	Pm. mam	A♂	TND		17.0	—	2930R
		II075	"	"	Pm. mam	A♂	TND		16.5	New	2942R
		JJ075	"	"	Pm. mam	A♂	TND		14.0	—	2928R
		JJ050	"	"	Pm. mam	A♂	TND		16.0	—	2924R

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	WT	New/Recap	TAG
50 TRAPS @ AA-EE July 17, 1989						COOL, BREEZE, PT FOG, DRY					
Full moon July 18th '89											
		BB050	July 17	10:00	Pm. mam	A♂	TND		15.5	—	2931R
		CC050	"	"	R. meg	A♂	TND		9.5	New	2943R
		CC100	"	"	Pm. mam	A♂	TND	HB 9.0cm E 2.5cm T 12.0cm	35.0	New	2944R
		DD025	"	"	R. meg	A♂	TND		10.0	New	2945R
		EE050	"	"	R. meg	A♂	[illegible]	Bare patches nipples around	13.0	New	2946R
		EE100	"	11:00	Per. cal	A♂	PLAC		40.0	—	2938R

2 TRAPS MISSING @ GG-000

SITE	PLOT	STA	DATE	TIME	SPECIES	AGE SEX	BRD COND	NOTES	wt	New / Recap	TAG
48 TRAPS @ FF-JJ July 18, 1989						COOL, BREEZE, FOG, DRY					
Full moon July 18th '89											
	FF-JJ	FF075	July 18	9:50	Pm. man	A♂	NL		12.0	—	2921R
	"	GG025	"	"				escape			
		GG100	"	"	Pm. mam	A♂	L		15.5	—	2933R
		HH100	"	"	TRIPPED	TRAP				[illegible]	[illegible]
		II025	"	"	R. meg	J♂			5.5	New	2947R
		II075	"	"	Pm. mam	A♂	TND		16.5	—	2942R
		JJ100	"	"	Pg. cal	A♂	TD		34.5	—	2485[illegible]
		JJ050	"	"	Pm. mam	A♂	PLAC		18.0	—	2927R
		JJ050	"	"	Pm. mam	A♂	TND		15.5	—	2924R
		JJ025	"	"	Pm. mam	A♂	TND		17.0	—	2930R
		JJ000	"	11:30	Pg. cal	A♂	NL		10.5	New	2948R
50 Traps @ AA-EE July 18, 1989						COOL, BREEZE, FOG, DRY					
Full moon July 18th 89											
	AA-EE	AA000	July 18	11:32	R. meg	A♂	TND		8.5	New	2949R
		AA100	"	"	Pg. cal	A♂	NL		15.5	New	2950R
		BB075	"	"	Pm. mam	A♂	TND		15.0	—	2951R
		CC025	"	12:00	BIRD						
50 traps at FF-JJ July 19, 1989						COOL, WINDY, CLEAR, DRY					
Full moon July 18th '89											
		FF075	July 19	8:00	Pm. mam	A♂	TND		19.0	New	2951R
		FF000	"	"	R. meg	A♂	PLAC	Bare patches around nipples	8.5	New	2952R
		GG025	"	"	Pm. mam	A♂	TD		15.5	—	2940R
		GG050	"	"	R. meg	A♂	PREG	[illegible]	12.0	New	2953R
		★ HH050	"	"	Pm. mam	A♂	TND		16.5	—	2946R
		II025	"	"	Pm. mam	A♂	TND		17.0	—	2930R
		II050	"	"	Pm. mam	A♂	PLAC		18.0	—	2927R
		II075	"	"	Per. cal	A♂	TND		12.0	—	2934R
		II100	"	"	R. meg	No	TAG	Escape		~~New~~	~~2954R~~
		JJ075	"	"	Pg. cal	A♂	LAC		22.5	—	2670R
		JJ050	"	9:45	Pm. mam	A♂	TND		18.0	—	2929R
50 TRAPS @ AA-EE July 19, 1989						WARM, BREEZE, CLEAR, DRY					
Full moon July 18th '89											
	AA-EE	AA100	July 19	10:00	Pg. cal	A♂	NL		13.0	New	2955R
		BB050	"	"	Pm. mam	A♂	TND		14.5	—	2931R
		CC025	"	"	R. meg	A♂	TND		10.0	—	2945R
		DD100	"	"	Pm. mam	A♂	TND		15.0	New	2[illegible]
		EE050	"	"	TRIPPED	TRAP					
		EE075	"	11:00	R. meg	A♂	LAC	Bare patches around nipple	12.0	New	2957R