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WILDLIFE MANAGEMENT DIVISION
NONGAME BIRD AND MAMMAL SECTION

INTRODUCTION OF CAPTIVE MORRO BAY KANGAROO RATS *(Dipodomys heermanni morroensis)* INTO AN ENCLOSURE ON CRITICAL HABITAT AT MONTANA DE ORO STATE PARK

by

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INTRODUCTION

Background

Morro Bay Kangaroo Rats *(Dipodomys heermanni morroensis)* were once common on the stabilized sand dunes south of Morro Bay (Figure 1) (Dixon 1918, Grinnell 1922, Stewart 1958, Stewart and Roest 1960). Over the years, both their numbers and their distribution have steadily decreased to a point where about 50 individuals inhabited about 13 ha at the Bayview site (Figure 1) in 1986 (Congdon 1971, Congdon and Roest 1975, Roest 1977, Toyoshima 1983, Roest 1984, Gambs 1986a, 1986b, 1986d, Villablanca 1987, and Gambs and Holland 1988). Factors contributing to this decline include direct loss of habitat, changes in the remaining habitat, predation by cats and dogs, destruction of burrows by vehicle, livestock, and pedestrian traffic, competition with other burrowing rodents, fragmentation of large populations into small sub–populations, and perhaps inbreeding (Roest 1982, Gambs 1986b, Gambs and Holland 1988).

In response to the negative population growth observed in the subspecies since 1957, the Morro Bay Kangaroo Rat (MBKR) was listed as an Endangered species by the U.S. Fish and Wildlife Service (USFWS) in 1970 and the California Fish and Game Commission in 1971. In 1977, the USFWS (USFWS 1977) designated the Pecho area as Critical Habitat for the MBKR. In 1978, the California Department of Fish and Game (DFG) purchased a 50-acre parcel of land adjacent to Montana de Oro State Park and established the Morro Dunes Ecological Reserve (Lidberg 1982). The USFWS completed a recovery plan for the MBKR in 1982, which summarized the status of the subspecies and outlined the steps necessary for its recovery. The long–term goal of the recovery plan USFWS 1982) is to establish a population of at least 2500 animals located on at least two different sites in the vicinity of Los Osos/Baywood Park, CA (Figure 1). The Pecho site (Figure 1) represents one of these two sites and most of the efforts to manage the MBKR and it's habitat have been focused there. Although no rats have been trapped at Pecho since 1979, efforts to improve habitat there by manual brush clearing (1983) and prescribed burns (1984, 1985, 1986) have been conducted in anticipation of subsequent re–introduction attempts.

The first introduction of captive MBKR into the field occurred in May 1988. We documented the techniques used and our observations on the rats during their first year inside a protective enclosure (Gambs and Nelson 1989). The present report documents the second year of this project, 1989.

Original Proposal for the Present Project

The work elements in the original proposal for this project included the following: (a) monitoring MBKR and other small mammals in the enclosure through live-trapping and observation; (b) monitoring MBKR outside the enclosure through live-trapping and observation; (c) releasing MBKR from the enclosure to

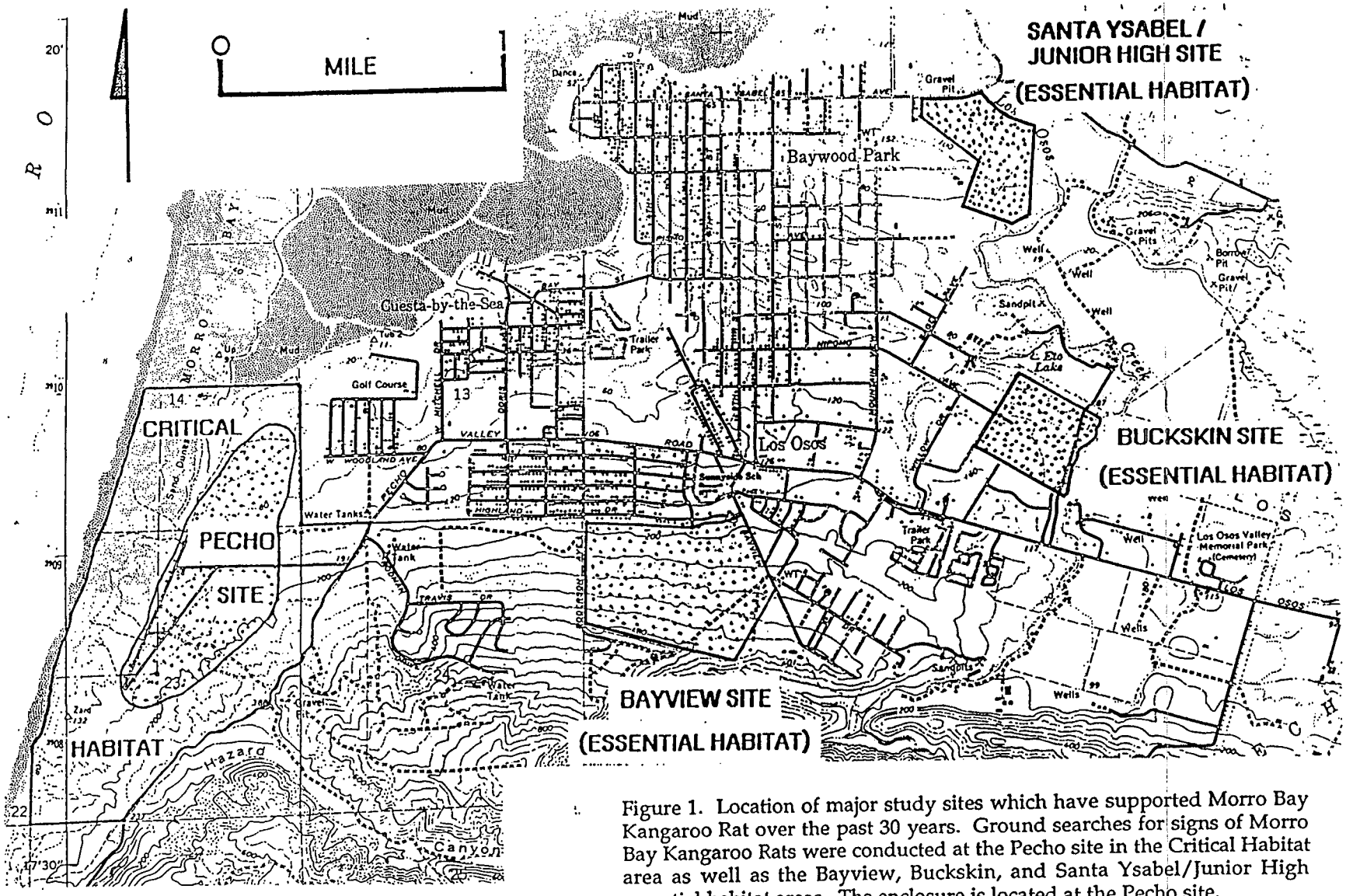

Figure 1. Location of major study sites which have supported Morro Bay Kangaroo Rat over the past 30 years. Ground searches for signs of Morro Bay Kangaroo Rats were conducted at the Pecho site in the Critical Habitat area as well as the Bayview, Buckskin, and Santa Ysabel/Junior High essential habitat areas. The enclosure is located at the Pecho site.

the area outside the enclosure; (d) translocating new MBKR from other sites to the enclosure; (e) conducting a population census of MBKR at other sites; and (f) conducting night observations of MBKR in and around the enclosure.

Unfortunately, we were unable to conduct some of the original work elements (above) because of the following, unforeseen, circumstances: 1.) We were forced to conclude that none of the animals released last year were still residing in or near the enclosure in 1989. This conclusion was reached after two trapping sessions in the enclosure, one trapping session in the area surrounding the enclosure, and repeated searches for signs of MBKR activity both in and around the enclosure. 2.) The original authorization to translocate more animals from the captive colony to the enclosure was reversed by the USFWS at a meeting held on 27 June 1989. This decision was based on the fact that several of the captive animals had died and no young had been born in 1988-89. 3.) We were not granted permission from the landowner to trap at the Bayview site. Thus, our plan to obtain a current census of the last remaining wild kangaroo rat population was rendered inoperable and we were effectively prevented from translocating any kangaroo rats from Bayview to the enclosure.

We contacted our DFG Project Manager, John Gustafson, as soon as we learned of these three confounding developments. We mutually agreed that, to compensate for those work elements which could not be completed, we would conduct small mammal census projects on four, 1 ha study plots at Pecho which have not been trapped for two to three years. Two of the plots (DEF and GHI) were subjected to manual brush clearing in 1982/83 and the other two (ABC and JKL) served as control plots. These new work elements allowed us to continue assessing the long term effects of brush removal on small mammal populations in the Critical Habitat area.

Revised Proposal for the Present Project

After various deletions, revisions, or substitutions in the original work plan (above), the revised set of work elements undertaken for this project are summarized as follows:

1. Continued monitoring of soil temperature in the enclosure using the three-probe, recording thermograph installed last year.
2. Continued monitoring of small mammals (other than MBKR) in the enclosure using capture/recapture techniques.
3. Systematic ground surveys aimed at detecting signs of MBKR activity at the Bayview, Buckskin, and Jr. High/ Santa Ysabel Essential Habitat sites and on portions of the Pecho Critical Habitat site.
4. Excavation and mapping of the underground layout of several MBKR burrows that were constructed in 1988 and abandoned in 1989.
5. Conducting population censuses of small mammals occurring on two cleared and two control study plots at Pecho.
6. Trapping and removal of pocket gophers that appear in the enclosure.
7. Removal of any ground squirrels or snakes that appear in the enclosure.
8. Removal of any exotic vegetation that appears in the enclosure.

9. Repairing minor damage to the enclosure and notifying the proper authorities of any signs of vandalism or major repair requirements.
10. Summarizing progress and submitting two progress reports to DFG.
11. Summarizing data and submitting a draft final report and a final report to DFG.

METHODS AND MATERIALS

Study Area

The Pecho site is located west of the village of Los Osos, CA; on Sections 14 and 23, T30S, R10E, Morro Bay South Quadrangle; Longitude 120° 52', Latitude 35° 18' (Gambs and Holland 1988). The site is roughly bordered by Morro Bay to the north, Pecho Valley Road to the east, Hazard Creek to the south, and the Pacific Ocean to the west (Figure 1). Refer to Holland (1986) and Gambs and Holland (1988) for details on the physiography, soil types, and plant communities of the area.

Construction of the 150 ft X 150 ft (.212 ha) MBKR enclosure was completed on 13 April 1988 at Pecho. It is located approximately in the center of a 13-ha parcel of coastal dune scrub habitat that has been recovering from an experimental burn since October 1984. Refer to Holland (1986), Nelson (1987), Souza (1989), and Gambs and Holland (1988) for details on the effects of the fire on vegetation and small mammal communities in the area. Details on the construction of the enclosure as well as qualitative and quantitative descriptions of the vegetation within the enclosure were summarized in Gambs and Nelson (1989).

Plant cover on the site before the fire was mainly shrubs dominated by California Sagebrush *(Artemisia californica)*, Mock Heather *(Ericameria ericoides)*, California Aster *(Corethrogyne filaginifolia)*, Sand Almond *(Prunus fasciculata* var. *punctata)*, and Holly-leaf Cherry *(Prunus ilicifolia)*. The dominant shrubs and subshrubs inside the enclosure in 1988 were Deerweed *(Lotus scoparius)*, Mock Heather, California Aster, and Croton *(Croton californicus)*. Some of the shrubs reached heights of 1 m, but most were 0.5 to 0.75 m tall in 1988. By 1989 there had been little change in species composition, but the tallest shrubs, most notably Black Sage *(Salvia mellifera)*, reached the roof netting of the enclosure (1.07 m to 1.7 m). Many of the small pathways and open areas used by kangaroo rats in 1988 were completely obscured by new plant growth in 1989.

Soil Temperature

In order to document the magnitude of soil temperature fluctuation over the possible range of kangaroo rat burrow depths, a Weathertronics (Model 4030) three-probe, recording thermograph was installed at station F6 on 2 May 1988. Except for minor interruptions, soil temperature data at depths of 10 cm, 30 cm, and 60 cm have been collected continuously through the fall of 1989.

MBKR Burrow Excavation

After finding no signs of the 4 MBKR released in 1988, we decided to examine two of their old burrow sites in an attempt to resolve several unanswered questions from last year.

We lost track of male MBKR # 2601R shortly after he was released in the enclosure on 27 May 1988. This animal was presumed dead or escaped at the close of the 1988 field season. To rule out the possibility that he had died shortly after being released in artificial burrow A, we excavated and screened the soil in the vicinity of burrow A on 25 April 1989. No signs of old burrows were found nor were any animal remains found in the screen.

We also excavated two burrow sites outside the enclosure which were known to be used by male MBKR # 2702R. Because of time restraints and the extent of the two burrow systems, we did not screen the sand taken out during these excavations. The burrow that was located adjacent to station G1 (see Gambs and Nelson 1989, pp 49-51) was excavated on 25 April and 15 June. The other burrow, located approximately 7 m due east of station D1, was excavated on 15 June and 4 July. In both cases, we began digging at the main burrow entrances and immediately intersected tunnels in the soil profile. Then we shaved the soil profile one inch at a time with a shovel, mapping the burrow as we progressed. The tunnels were roughly oval in cross section and were completely filled in with plant debris and loose sand which made them easy to follow. The material filling the tunnels was darker and softer than the surrounding soil and appeared to have been moved down from the surface layer.

Ground Surveys

The soil surface of the enclosure was searched for signs of MBKR once each week. Any signs (burrows, tail drags, digs) were recorded in a field notebook and directly onto vegetation maps.

Similar ground searches were conducted on the Bayview, Junior High / Santa Ysabel, and Buckskin Essential Habitat sites (Figure 1), as well as those portions of the Pecho site designated as suitable MBKR habitat (Villablanca 1987). These surveys began in mid-May and were completed in mid-July 1989. All signs of MBKR activity were plotted directly onto either an aerial photo or a topographic map of the areas surveyed.

Three different signs of activity were recorded:

1. Burrow entrance open and/or showing signs of recent use
2. Small, shallow dig in the soil surface
3. Shallow tail drag in the soil surface

Trapping Methods

All field work was conducted under provisions of USFWS, permit no. PRT-702631, subpermit no. GAMBRD-1; DFG scientific collector's permit; and a Memorandum of Understanding by and between California Polytechnic State University and the DFG.

Folding, aluminum Sherman XLK live traps and/or folding Tomahawk No. 201 live traps were used to trap small mammals. A small ball of cotton was placed in each Sherman trap to reduce the risk of hypothermia to animals inside. No cotton was used in the Tomahawk traps, but two wooden shingles (9 cm x 45.7 cm = 3.5 in x 18 in) were placed on top of each trap to provide overhead cover for animals inside. A small handful of bait was divided between the inside of the trap and the ground outside the door. Sherman traps were baited with Quaker old-fashioned rolled oats and Tomahawk traps were baited with a mix of 4 parts hamster chow (rat/mouse): 1 part sunflower seeds: 1 part wild bird seed: 1 part old-fashioned rolled oats. All trapped animals were released at the site of capture.

Trapping sessions were conducted inside the enclosure on 11-15 April, 3-7 July, 14-18 August, and 28 September - 3 October 1989. The times of the 1989 trapping periods were approximately the same as those conducted in 1988. Two Sherman XLK live traps and one Tomahawk live trap were placed at each of 30 stations spaced evenly throughout the enclosure (intersections of lines B, D, F, H, J and lines 1, 3, 5, 7, 9, 11). All traps were set within 2 m of the station markers. Traps were closed on the last day of each trapping session but left in place for the next session.

One trapping session was conducted outside the enclosure in search of MBKR that may have been residing nearby after escaping from the enclosure. Fifteen Sherman XLK live traps were set in a 30-m zone outside the eastern, southern, and western sides of the enclosure on 20-24 April 1989. No traps were set along the northern side of the enclosure because this area (plot TUVWX) was being trapped by a Cal Poly senior project student.

Small mammal trapping was conducted on Pecho study plots ABC and DEF on 15-17 August and on plots GHI and JKL on 22-24 August. Two Sherman XLK live traps were placed within 3 m of each station for a total of 54 traps on each plot. Plots ABC, GHI, and JKL were last trapped in 1986 (Gambs and Holland 1988). Plot DEF was last trapped in 1987 (Schneider 1988).

Field Data

The following data were recorded for each small mammal at the time of capture:

1. Date of capture
2. General weather; cloud cover, fog, moisture, wind, temperature.
3. Capture station
4. Identification to species
5. Sex
6. Age class and signs of molting

7. General reproductive condition
8. Weight
9. Tag number

Individual Marking

Each new small mammal caught was marked with a numbered, stainless-steel, fingerling tag (Salt Lake Stamp Co.) clamped to one of its ears. The tag number recorded for each individual included a four-digit number followed by an L or R, indicating the ear carrying the tag.

Removal of Potential Competitors and Predators

As in 1988, we were prepared to remove any California Ground Squirrels *(Spermophilus beecheyi)* which appeared in the enclosure by using Tomahawk traps. We also were prepared to remove any snakes found in the enclosure by using a snake stick or by means of funnel traps.

Botta Pocket Gopher *(Thomomys bottae)* burrows became quite dense around the perimeter of the enclosure in early March 1989. On 19 April 1989 the first pocket gopher mounds were confirmed inside the enclosure. Since we were quite certain that there were no MBKR in the enclosure and we were preparing to introduce two new MBKR in June, we set seven pocket gopher traps on June 1. We dug into recently active gopher mounds and located open tunnels. Traps were placed inside the tunnels and secured to shrubs or stakes with twine. Wooden shingles were placed over the opened tunnels to shield them from light.

Trapping Intensity, Ease of Capture, and Relative Abundance

The trapping intensity of any trapping session is expressed as the number of trap nights (TN), which is equal to the total number of traps set minus the number of tripped traps and traps containing other animals (e.g., birds, California Ground Squirrels, or lizards).

Ease of capture is expressed as the ratio of trapping intensity to the number of individuals captured (TN/CAP). As an example, if a trapping session consisted of 225 TN and 9 Deer Mice *(Peromyscus maniculatus)* were captured, then the ease of capture for Deer Mice during this session would be 225/9, or 25 TN/CAP.

Relative abundance is expressed as the number of animals that would be expected to be caught per 100 TN (#/100 TN), given the actual number of animals caught and the actual number of trap nights exerted during any trapping session. As an example, if the trapping session consisted of 225 TN and 9 Deer Mice were captured, then the relative abundance for Deer Mice during this session would be (100/225 TN) X 9 animals, or 4 Deer Mice /100 TN.

Population Estimation

Capture and recapture data for each trapping session were used to calculate population estimates according to the Schnabel method (Davis and Winstead 1980). The first time an individual was caught during each separate trapping session it was counted as a new capture. Each subsequent capture of this animal was counted as a recapture during that particular trapping session.

Density Estimation

Density is expressed as the number of animals per ha, and is calculated by dividing the Schnabel population estimate by the area "trapped". Since traps were spaced evenly throughout the enclosure and the enclosure has a surrounding barrier (aviary fence and aluminum flashing), the area trapped is assumed to be the area of the enclosure, 0.212 ha. We suspect that this assumed area trapped is too small for mice because we have seen them crawl through the aviary wire.

The assumed area trapped for the Pecho study plots (ABC, DEF, GHI, JKL) was obtained by assuming that each station "trapped" a 25 m X 25 m (625 m^2) area (Gambs and Holland 1988). Since each plots has 27 stations, the assumed area trapped on each plot was 1.6875 ha (27 X 625 m^2 = 16,875 m^2).

RESULTS AND DISCUSSION

Soil Temperature

The monthly thermal regimes at soil depths of 10, 30, and 60 cm in the enclosure are presented in Table 1 and Figure 2. The mechanisms involved in upward and downward heat flow at different times of the year were summarized in our previous annual report (Gambs and Nelson 1989). From April through August, median monthly soil temperatures at 10 cm exceeded these at 60 cm. Conversely, soil temperatures at 60 cm exceeded those at 10 cm from September through February. Thermal "turnovers" separating these two soil temperature regimes occurred between March and April and again between August and September.

MBKR and other burrowing animals probably take advantage of the annual as well as diurnal oscillations of soil temperature (Figure 2). The "damping" effects on temperature oscillations with increasing depth creates a more stable thermal environment in deeper burrows. This relationship combined with the turnover phenomena should reduce the risks from summer heat stress and dehydration as well as winter cold stress when animals are at depths of about 60 cm. This year the authors discovered that MBKR burrow substantially deeper than 60 cm (see burrow construction, below) which would place them in even a more favorable thermal regime than the one we measured at 60 cm.

Table 1. Minimum and maximum soil temperatures (° F) taken inside the enclosure at soil depths of 10 cm, 30 cm, and 60 cm. Minimum and maximum temperatures were read directly from weekly temperature charts from a recording, 3-probe thermograph.

	SOIL DEPTH					
	10 cm		30 cm		60 cm	
Month	Min.	Max.	Min.	Max.	Min.	Max.
1988						
June	66	80	68	73	69	70
July	66	80	68	76	69	73
August	67	82	71	76	71	73
September	62	74	67	72	69	72
October	56	68	62	69	65	70
November	47	64	55	66	61	66
December	41	56	48	59	52	61
1989						
January	42	53	48	53	52	56
February	41	59	48	58	53	58
March	46	68	51	62	56	63
April	61	79	61	69	60	67
May	63	77	64	68	64	68
June	67	84	66	73	66	72
July	70	84	71	74	70	72
August	68	82	68	72	69	72
September	66	78	67	71	67	71

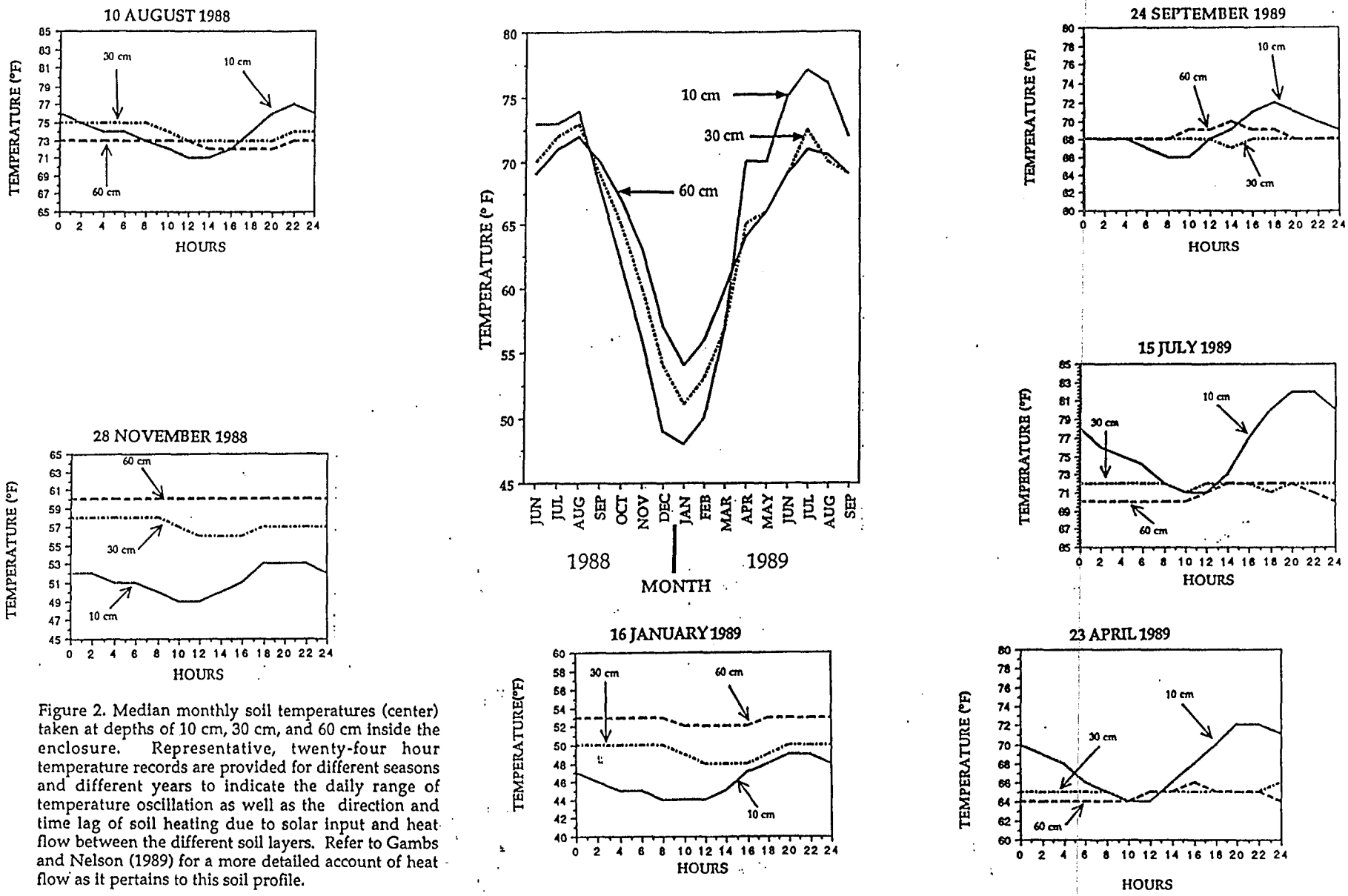

Figure 2. Median monthly soil temperatures (center) taken at depths of 10 cm, 30 cm, and 60 cm inside the enclosure. Representative, twenty-four hour temperature records are provided for different seasons and different years to indicate the daily range of temperature oscillation as well as the direction and time lag of soil heating due to solar input and heat flow between the different soil layers. Refer to Gambs and Nelson (1989) for a more detailed account of heat flow as it pertains to this soil profile.

MBKR Burrow Construction

At the close of the 1988 field season, we had accounted for three of the four animals released in the enclosure (Females #2602L and #2603L and Male #2702R). Male #2601R was never caught and we suspected that he had either escaped or died in the artificial burrow we provided for him. Male #2702R was last caught outside the eastern fence of the enclosure. In our report last year we speculated that Male #2702R may have climbed over the top of the enclosure or burrowed under the aviary wire fence which was buried 61 - 92 cm (24 - 36 in.) below the surface.

We were reluctant to dig out any burrow systems during the winter months for fear of injuring or disrupting animals still using their burrows. However, after our 1989 ground searches and trapping sessions failed to reveal any evidence that rats still were using sites they had used in 1988, we decided to excavate the last known burrows of Males #2601R and #2702R.

We excavated and screened the soil from the last known location of Male #2601R (artificial burrow A) on 25 April 1989. Since it had been nearly a year since this burrow was last used, we were not particularly surprised to find that no underground tunnels or chambers remained visible in the soil profile. We found scattered sunflower seed hulls in the soil, but no ear tag or MBKR remains were found on the 0.25 in. mesh screen. Unfortunately, we can only conclude that Male #2601R either escaped outside or died elsewhere in the enclosure. It's more likely that Male # 2601R died inside because we did not detect any signs of MBKR activity in the 3–m zone of bare ground surrounding the enclosure during the time when he might have escaped.

Excavation of Male #2702R's burrow systems on 25 April, 15 June, and 4 July 1989, provided several new insights into the burrowing capabilities of MBKR. The first burrow system we excavated was located along the eastern side of the enclosure, between the aviary wire and barbless wire fences (Figure 3). The main tunnel of this system ran immediately below the buried aviary wire at a depth of 82 cm and terminated in a surface entrance about 6 m from the aviary fence. A nest chamber about 15 cm in diameter at a depth of 90 cm was located at the end of one side tunnel. One side tunnel ended in a second surface entrance and another side branch was a dead end. Although we did not continue the excavation inside the enclosure, we believe that this outside burrow system was continuous with additional tunnels and entrances (e.g., burrow JJ) inside the enclosure.

It is possible that kangaroo rats only dig deep when confronted with an underground obstacle. To evaluate this hypothesis and also learn more about burrow construction, we excavated a second burrow system constructed by Male #2702R which was further away from the enclosure (Figure 4). Although there were no underground obstructions in the vicinity of the second burrow system, many of the tunnels and chambers were still more than 70 cm below the surface. The second burrow system was considerably more complex than the first one and, in addition to a large chamber (perhaps a nest), it had a seed cache containing sunflower and millet seeds and numerous, blind, side tunnels. The seeds in the cache had to come from

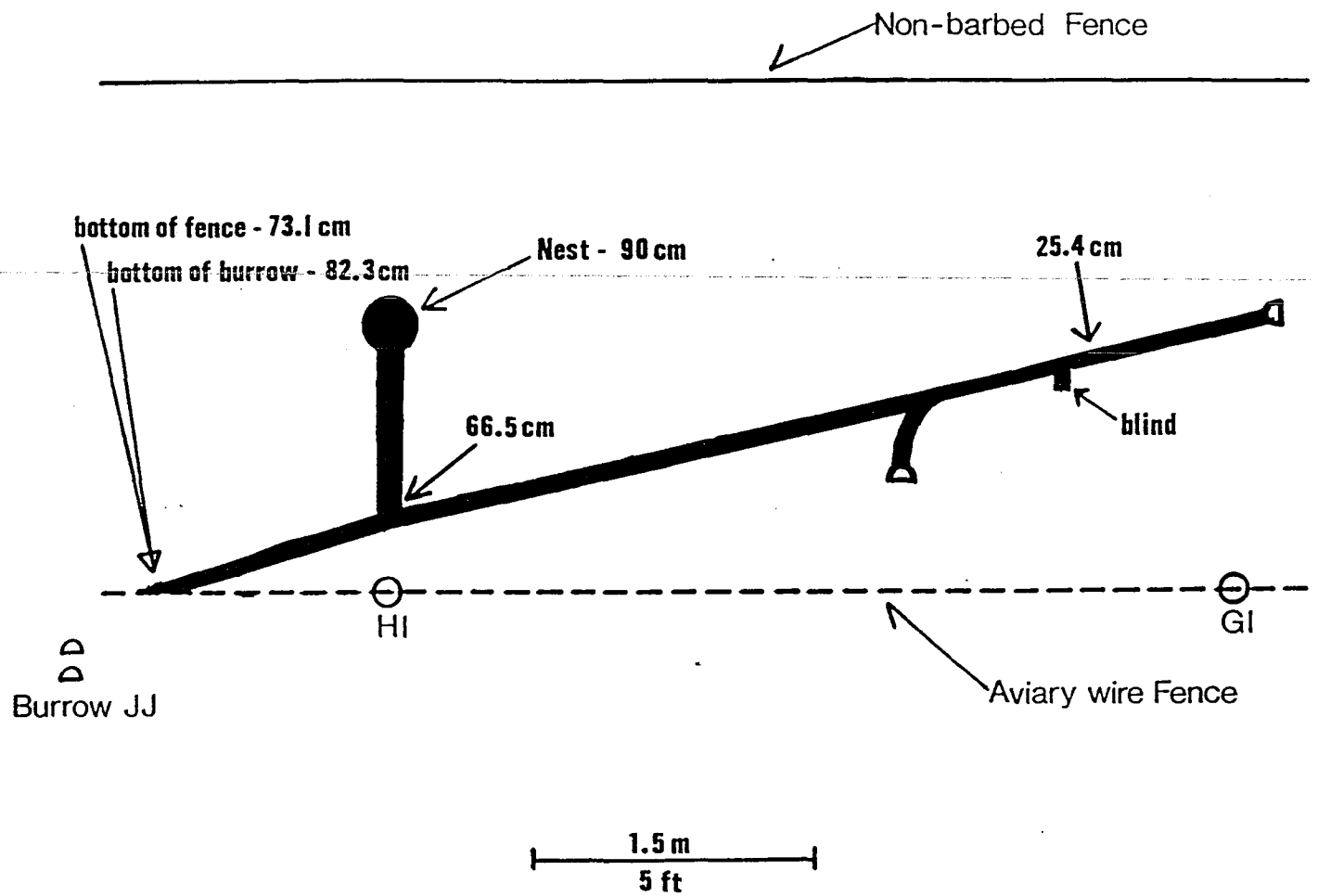

Figure 3. Diagram of the burrow system constructed by male #2702R which enabled him to escape from the enclosure. The burrow below the aviary wire fencing continued inside the enclosure and undoubtedly connected with other burrow systems made by the same animal prior to his escape. Male # 2702R was last caught on the surface between the aviary wire and barbless wire fences, opposite stations G1-H1 in the fall of 1988. Depths (cm) were measured vertically from the surface to the bottom of the tunnel or nest.

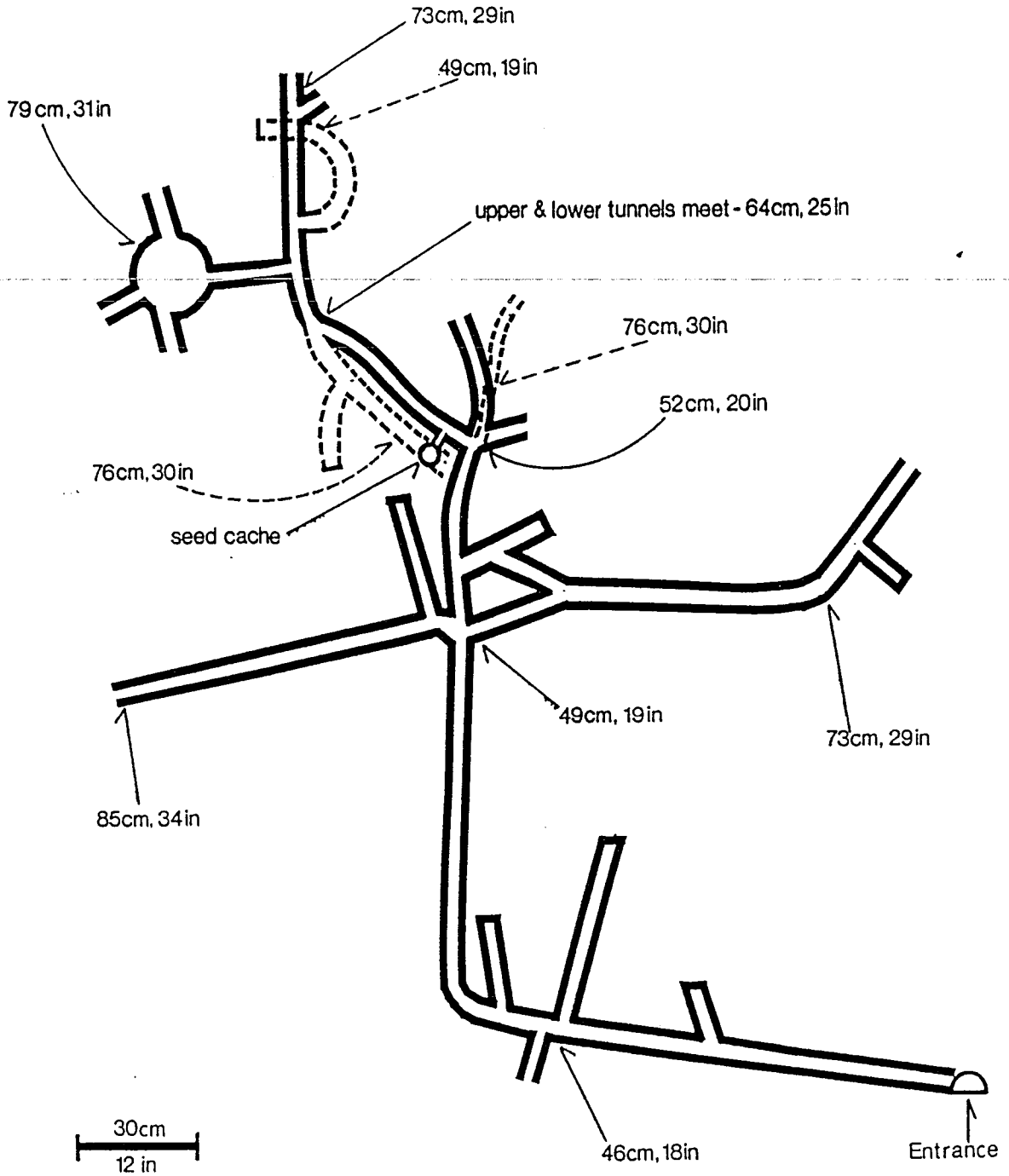

Figure 4. Diagram of a second burrow system constructed by male #2702R in the fall of 1988, after he had escaped from the enclosure using the burrow system shown in Fig. 2. This second burrow system was located approximately 7 m due East of station D1 in the enclosure. Depths (cm and in) were measured vertically from the surface to the bottom of the tunnel or nest. Where tunnels occurred at different depths in the same location, the deeper tunnel is shown in broken lines. Tunnels ending with a solid line were dead end tunnels. Tunnels not ending with a solid line continued through the soil, but were not excavated. Most of the tunnels were 8-10 cm (3-4 in) in diameter and filled with debris from the surface.

the feed mix we distributed inside the enclosure from May through July 1988. Male #2702R may have been able to collect these seeds from the upper soil layer of the enclosure, but it seems more likely that he moved the contents of an earlier seed cache to his new location outside.

In contrast to last year, we now have conclusive evidence that at least one MBKR readily dug under the aviary wire fence buried 76 - 91 cm (2.5 - 3 ft) below the surface. It is even possible that once Male #2702R tunneled under the fence, the two females used his burrow to escape; however, the only evidence supporting such a scenario is the disappearance of the females between fall 1988 and spring 1989.

The depth of the tunnel running below the fence (82 cm) and the depth of one nest (90 cm) indicate that future fencing should be buried much deeper to prevent MBKR escape. We think that a 0.5 in. mesh fence buried to a depth of about 152 cm (5 ft) would probably discourage most kangaroo rats from digging out.

At least some free-ranging kangaroo rats may regularly burrow to depths of 70 - 80 cm in the fall months. This finding indicates that MBKR are capable of moving to soil depths where diurnal temperature oscillations are nearly constant and minimum winter temperatures are much warmer (10 - 12 °F) than they are closer to the surface.

Ground Surveys for Signs of MBKR in Remaining, Suitable Habitat Sites

Ground reconnaissance surveys aimed at locating signs of MBKR at the Bayview, Junior High / Santa Ysabel, and Buckskin sites, as well as those portions of the Pecho site designated as suitable habitat by Villablanca (1987) were conducted from mid-May to mid-July. The areas searched are shown on Figure 5.

The only signs of MBKR found during this comprehensive search were at the Bayview site (Figure 6). The combined area of habitat occupied by rats at Bayview in 1989 was 14.8 ha. The smallest occupied area was .08 ha, the largest occupied area was 10.2 ha, and the remaining occupied areas ranged from .8 - 1.1 ha. Earlier estimates of the area occupied by rats at Bayview ranged from about 12 ha (Villablanca 1987) to 15 ha (Gambs and Holland 1988). Results of our 1989 ground survey indicate that the Bayview population presently occupies about the same amount of habitat as it did in 1986. Since we were not permitted to sample the population size at Bayview, we cannot comment on the numbers of rats present there this year or on any population changes that might have taken place since 1986.

Small Mammal Population, Density, and Relative Abundance Estimates Inside the Enclosure

Deer Mice *(Peromyscus maniculatus)*

Deer Mouse density last year (1988) was 49.4 mice/ha in April, 18.8 in May, 0 in August, and 13.2 in September/October (Gambs and Nelson 1989).

The density of Deer Mice in 1989 also fluctuated, but the magnitude and the

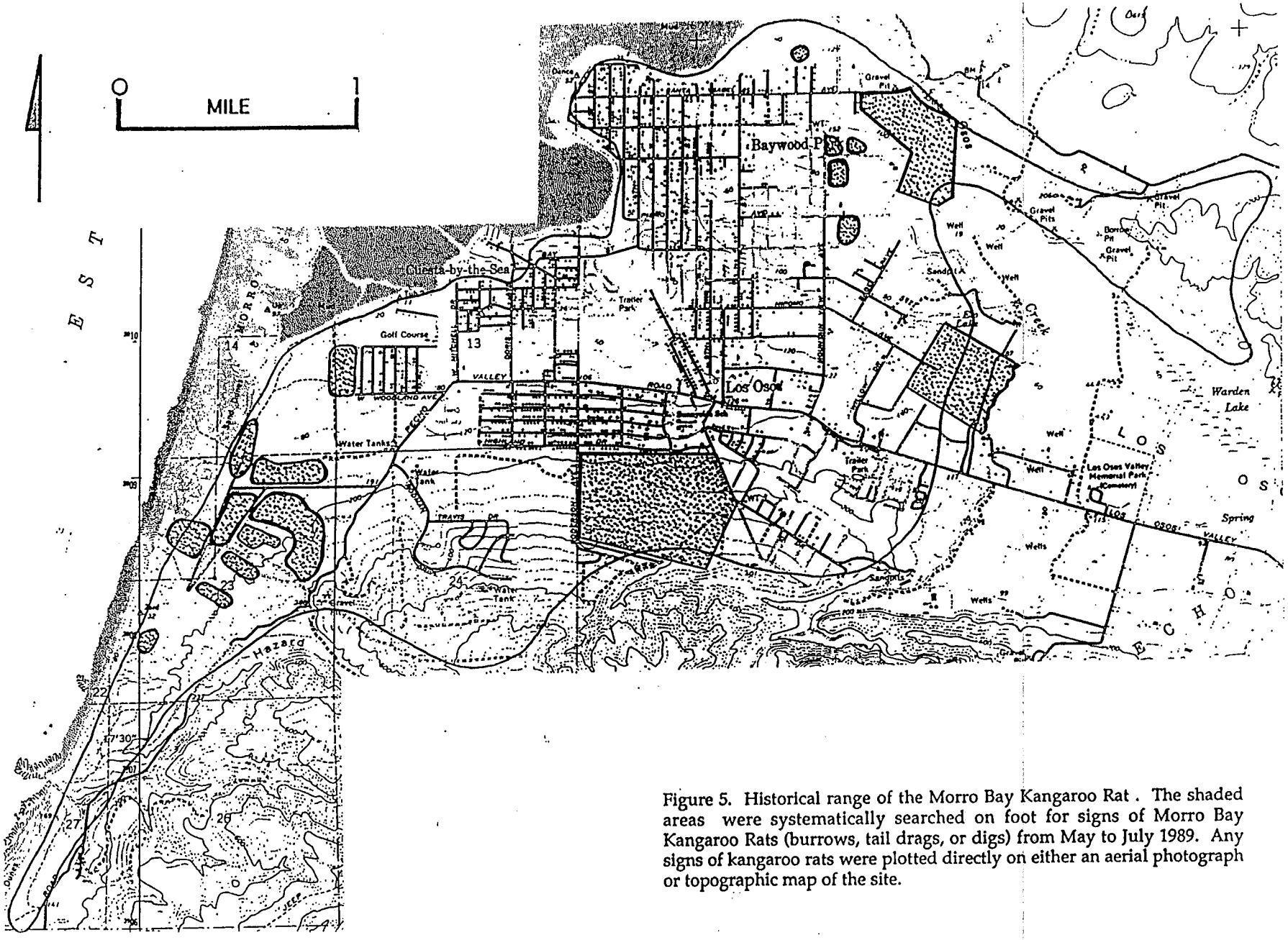

Figure 5. Historical range of the Morro Bay Kangaroo Rat . The shaded areas were systematically searched on foot for signs of Morro Bay Kangaroo Rats (burrows, tail drags, or digs) from May to July 1989. Any signs of kangaroo rats were plotted directly on either an aerial photograph or topographic map of the site.

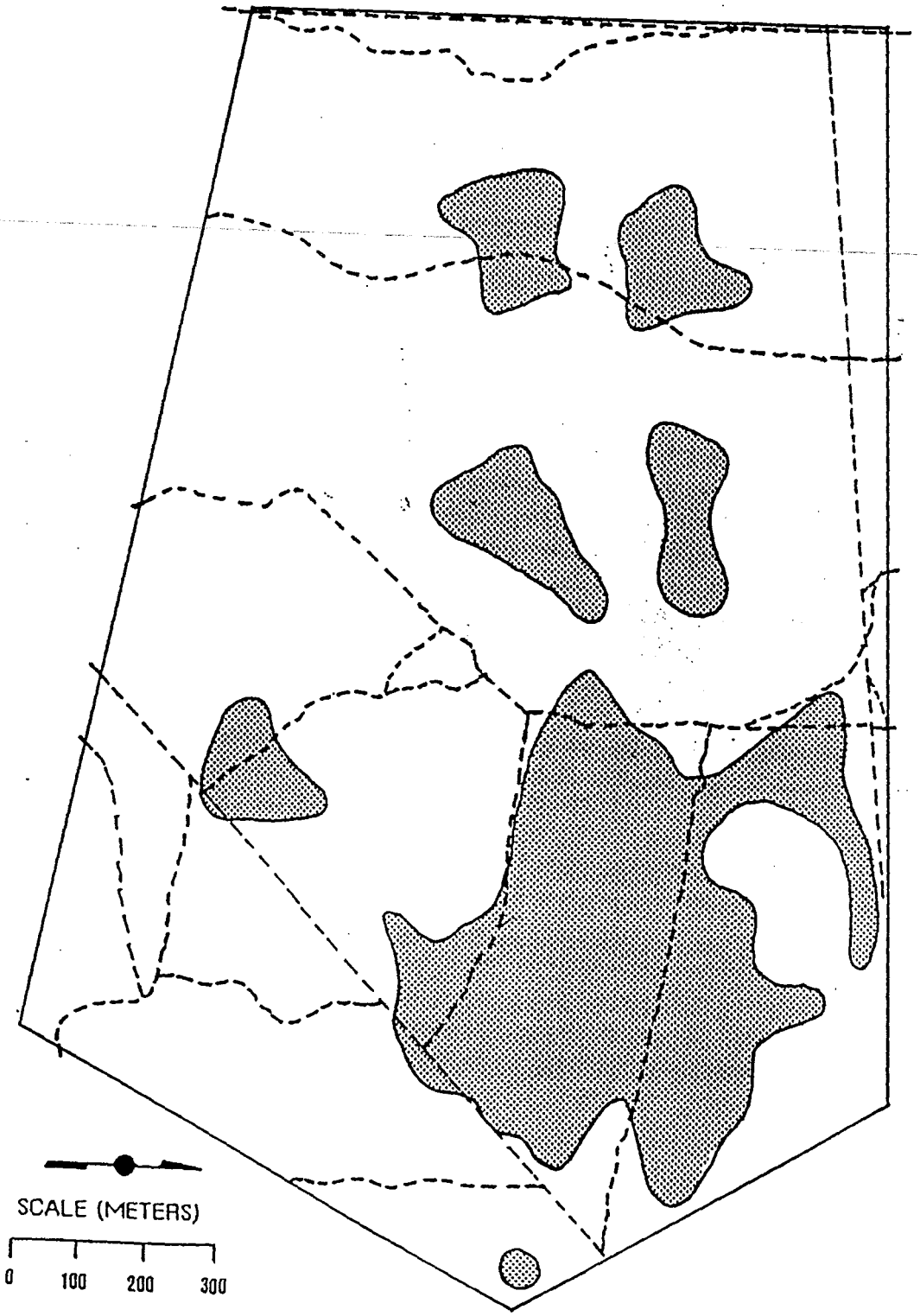

Figure 6. Outline map of the Bayview site. All of the site was searched on foot for signs of Morro Bay Kangaroo Rats. Those areas where signs (burrows, tail drags, or digs) of Morro Bay Kangaroo Rats were found are shown as shaded areas on the map.

periodicity were somewhat different from that observed in 1988. The density of Deer Mice in 1989 was 18.9 mice/ha in April, 0 in July, 4.7 in August, and 0 in September/ October (Table 2). Last year we thought that the sharp decline in Deer Mice in August might have been a consequence of newly introduced MBKR. The fact that the numbers of Deer Mice declined again in the summer of 1989, when no MBKR were present in the enclosure, contradicts our earlier speculation. At this point, it appears that the fluctuations in the Deer Mouse population in 1988 were independent of the four MBKR which shared the enclosure with them in 1988.

California Pocket Mice *(Perognathus californicus)*

California Pocket Mouse density last year (1988) was 0 mice/ha in both April and May, 93.4 in August, and 97.2 in September/October (Gambs and Nelson 1989). The absence of pocket mice in April and May of 1988 may have been a consequence of disturbance associated with construction of the enclosure earlier in the spring. The high densities of pocket mice recorded later in 1988 were a result of continued immigration of pocket mice into the enclosure at a time when at least three MBKR also resided there. While such immigration does not demonstrate that kangaroo rats somehow facilitated pocket mouse populations in the enclosure, it is clear that kangaroo rats did not deter immigrating pocket mice from sharing their habitat.

The density of pocket mice in 1989 was 28.3 mice/ha in April, 35.8 in July, 37.7 in August, and 46.7 in September/ October (Table 3). The sharp contrast in density fluctuations of pocket mice between 1988 and 1989 is difficult to explain. Obviously the large numbers of pocket mice present in the fall of 1988 did not persist to the spring of 1989. The winter decline could be explained by high mortality, dispersal, or a combination of both. Although pocket mouse densities in 1989 are still quite high, their numbers in the enclosure were substantially more stable this year than in 1988. It is possible that the pocket mouse population in the enclosure is gradually reaching an equilibrium condition after an initial period of perturbation following the construction of the enclosure.

Western Harvest Mice *(Reithrodontomys megalotis)*

Several Western Harvest Mice were caught, but none were recaptured last year (1988) so their density was 0 mice/ha in April, May, August, and September/October (Gambs and Nelson 1989).

As in 1988, several Western Harvest Mice were caught, but none were recaptured in 1989 so again their density was 0 mice/ha in April, July, August, September/October (Table 4). Last year we thought that a moderate decline in harvest mice in August might have been a consequence of newly introduced MBKR. However, the low numbers of harvest mice in 1989, when no MBKR were present in the enclosure, contradicts our earlier speculation. At this point, we conclude that the minor fluctuations in the numbers of harvest mice in the enclosure last year were independent of the four MBKR that shared their habitat in 1988.

Table 2. Trapping results, relative abundance, and density of deer mice *(Peromyscus maniculatus)* inside the enclosure in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN
11-Apr-89	59	4	4	0	6.78		
12-Apr-89	58	4	0	4	6.90	4.00	18.87
13-Apr-89	59	3	0	3	5.08	4.00	18.87
14-Apr-89	59	2	0	2	3.39	4.00	18.87
15-Apr-89	59	2	0	2	3.39	4.00	18.87
3-Jul-89	59	0					
4-Jul-89	59	0					
5-Jul-89	59	0					
6-Jul-89	59	0					
7-Jul-89	59	0					
14-Aug-89	57	1	1	0	1.75		
15-Aug-89	58	1	0	1	1.72	1.00	4.72
16-Aug-89	57	1	0	1	1.75	1.00	4.72
17-Aug-89	58	0	0	0	~	1.00	4.72
18-Aug-89	58	0	0	0	~	1.00	4.72
28-Sep-89	59	0					
29-Sep-89	46	0					
1-Oct-89	59	0					
2-Oct-89	58	0					
3-Oct-89	56	0					

Table 3. Trapping results, relative abundance, and density of California pocket mice *(Perognathus californicus)* inside the enclosure in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN
11-Apr-89	59	6	6	0	10.17		
12-Apr-89	58	4	0	4	6.90	6.00	28.30
13-Apr-89	59	3	0	3	5.08	6.00	28.30
14-Apr-89	59	3	0	3	5.08	6.00	28.30
15-Apr-89	59	1	0	1	1.69	6.00	28.30
3-Jul-89	59	7	7	0	11.86		
4-Jul-89	59	5	0	5	8.47	7.00	33.02
5-Jul-89	59	2	0	2	3.39	7.00	33.02
6-Jul-89	59	3	0	3	5.08	7.00	33.02
7-Jul-89	59	3	1	2	5.08	7.58	35.75
14-Aug-89	57	8	8	0	14.04		
15-Aug-89	58	5	0	5	8.62	8.00	37.74
16-Aug-89	57	1	0	1	1.75	8.00	37.74
17-Aug-89	58	1	0	1	1.72	8.00	37.74
18-Aug-89	58	1	0	1	1.72	8.00	37.74
28-Sep-89	59	9	9	0	15.25		
29-Sep-89	46	4	0	4	8.70	9.00	42.45
1-Oct-89	59	8	1	7	13.56	9.80	46.23
2-Oct-89	58	4	0	4	6.90	9.90	46.70
3-Oct-89	56	4	0	4	7.14	9.90	46.70

Table 4. Trapping results, relative abundance, and density of western harvest mice *(Reithrodontomys megalotis)* inside the enclosure in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN
11-Apr-89	59	0					
12-Apr-89	58	0					
13-Apr-89	59	0					
14-Apr-89	59	0					
15-Apr-89	59	0					
3-Jul-89	59	0					
4-Jul-89	59	0					
5-Jul-89	59	0					
6-Jul-89	59	0					
7-Jul-89	59	1	1	0	1.69	~	~
14-Aug-89	57	0	0	0	0.00		
15-Aug-89	58	1	1	0	1.72	~	~
16-Aug-89	57	0	0	0	0.00	~	~
17-Aug-89	58	0	0	0	0.00	~	~
18-Aug-89	58	1	1	0	1.72	~	~
28-Sep-89	59	0	0	0	0.00		
29-Sep-89	46	0	0	0	0.00		
1-Oct-89	59	1	1	0	1.70	~	~
2-Oct-89	58	0	0	0	0.00	~	~
3-Oct-89	56	1	1	0	1.79	~	~

Morro Bay Kangaroo Rats *(Dipodomys heermanni morroensis)*

We ended the 1988 field season with two females still in the enclosure and one male living about 10 m outside the enclosure.

No MBKR were trapped inside the enclosure in 1989. Likewise, trapping in the immediate vicinity of the enclosure, as well as on plots AA-EE, FF-JJ, TUVWX, ABC, DEF, GHI, and JKL failed to detect the presence of any live MBKR at Pecho. An extensive ground search for signs of MBKR in the Pecho area also failed to indicate their presence in the area. Although there is a remote chance that some of the animals from the enclosure (or their offspring) still inhabit isolated portions of Pecho, it is far more likely that none of these animals survived to the 1989 field season.

Although discouraging, these results are not completely unexpected. A surrogate project similar to the present one was conducted with Lompoc Kangaroo Rats *(Dipodomys heermanni arenae)* at "Dune Lakes" on the Nipomo Mesa in San Luis Obispo County, in 1986 (Gambs 1986c). Despite abundant supplemental food in the enclosures, no more than 50% of the Lompoc Kangaroo Rats survived longer than two weeks. Some of the introduced kangaroo rats escaped and resident small mammals (both Lompoc Kangaroo Rats and Deer Mice) entered the small portable enclosures. Captive born Lompoc Kangaroo Rats that were younger than one year of age appeared to adjust better to field conditions than the older animals. The one case of physiological stress observed in the Dune Lakes study involved a 3.5 year–old male that lost 20 g during his first six days in the enclosure. This animal had been expected to adapt better to field conditions than the others because it was the only wild-caught Lompoc Kangaroo Rat released during the study.

Compared to results from the Lompoc Kangaroo Rat study, the results from the present MBKR study are considerabely more promising. Three of the four MBKR released in 1988 survived at least five months in the enclosure and, unlike the Lompoc Kangaroo Rat study, none of the MBKR lost weight during their tenure in the enclosure. Although we lost track of the first two–year-old captive-born male we released, the second two–year-old captive-born male readily adjusted to field conditions. The 3+ year-old wild-caught female and the four–year-old captive born female both appeared to adjust quite well to field conditions.

Small Mammal Population, Density, and Relative Abundance Estimates for Pecho Plots ABC, DEF, GHI, AND JKL

The trapping program on these four plots was conducted as a substitute work element to compensate for our inability to gain permission to sample the MBKR population at Bayview. This trapping program also provided us with a current set of small mammal population data which could be compared to earlier (1983 - 1987) population data collected from the same plots. Plots ABC and JKL are plots located on relatively undisturbed stands of coastal dune scrub habitat. Plots DEF and GHI are located on coastal dune scrub habitat which has been recovering from a clearing experiment in which most of the dominant shrubs were cut at ground level and

removed by hand in the spring of 1983.

Plot ABC (undisturbed)

The only two small mammal species caught on plot ABC in 1989 during a three-night trapping session of 161 trap nights were Deer Mice and Western Harvest Mice (Table 5). Deer Mice were clearly the dominant species (relative abundance = 17 mice / 100 TN and density = 7 mice / ha). Lack of recaptures prevented population estimation for harvest mice.

The density of Deer Mice on plot ABC in 1989 was roughly comparable to densities found in 1983, 1984, and 1985, but substantially lower than 1986 (Table 6). Conversely, the density of harvest mice on plot ABC in 1989 was comparable to their densities in 1985 and 1986, but much lower than their densities in 1983 and 1984. The apparant absence of California Pocket Mice in 1989 was surprising because they had been a regular member of the small mammal community on ABC in previous studies. California Mice *(Peromyscus californicus)* were found on ABC in 1986, but, like earlier years, none were found in 1989.

Although there have been fluctuations in both the species diversity and population densities within the small mammal community inhabiting plot ABC over the past 7 years, the overall small mammal community generally has been dominated either by Western Harvest Mice (1983) or by Deer Mice (1984 - 1989). When present, pocket mice and California Mice have played a subordinate role (had lower densities) on plot ABC.

Plot JKL (undisturbed)

In contrast to undisturbed plot ABC, five small mammal species were found on undisturbed plot JKL in 1989 during a three-night trapping session of 160 trap nights: California Pocket Mice, Deer Mice, California Mice, Western Harvest Mice, and Dusky-footed Woodrats *(Neotoma fuscipes)*. Deer Mice were the dominant species (relative abundance = 30.2 mice / 100 TN and density = 9.9 mice / ha); however harvest mice (3.8 / 100 TN and 6.5 / ha) and pocket mice (3.8 / 100 TN and 4.0 / ha) were moderately abundant (Table 7). California Mice were present in low numbers (3.8 / 100 TN and 1.2 / ha) and lack of recaptures prevented population estimation of Dusky-footed Woodrats.

The density of Deer Mice on plot JKL in 1989 was roughly comparable to densities found from 1983 to 1986 (Table 6). The density of harvest mice in 1989 was lower than that found in 1983, but higher than their densities in 1984, 1985, and 1986. The density of pocket mice in 1989 was higher than 1983, 1984, and 1985, but not different from that in 1986. The density of woodrats was lower in 1989 than in previous years and, with the exception of 1985, the density of California Mice followed the same pattern as that of woodrats.

Unlike plot ABC, the species diversity on plot JKL has remained constant over the past seven years; however population densities within the small mammal community on JKL have exhibited fluctuations similar to those seen on plot ABC.

Table 5. Trapping results, relative abundance, and density of deer mice *(Pm. man. = Peromyscus maniculatus)* and western harvest mice *(Rd. meg. = Reithrodontomys megalotis)* on Pecho plot ABC (undisturbed Coastal Sage Scrub) in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

SPECIES	DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN.
Pm. man.	15-Aug-89	54	7	7	0	12.96		
(Deer	16-Aug-89	54	7	2	5	12.96	9.80	5.81
mouse)	17-Aug-89	53	9	3	6	16.98	11.80	6.99
Rd. meg.	15-Aug-89	54	0	0	0	0.00		
(W. harvest	16-Aug-89	54	1	1	0	1.85	~	~
mouse)	17-Aug-89	53	0	0	0	0.00	~	~

Table 6. Comparison of trapping intensity (# TN = trap nights) and average density estimates (# of individuals / hectare) of 6 small mammal species on two undisturbed plots (ABC and JKL) and two manually cleared plots (DEF and GHI) at Pecho from 1983 to 1989. Species abbreviations are as follows: Nt. fus. = *Neotoma fuscipes* (dusky-footed woodrat); Pg. cal. = *Perognathus californicus* (California pocket mouse); Pm. cal. = *Peromyscus californicus* (California mouse); Pm. man. = *Peromyscus maniculatus* (deer mouse); and Rd. meg. = *Reithrodontomys megalotis* (western harvest mouse).

				NT. FUS.	PG. CAL.	PM. CAL.	PM. MAN.	RD. MEG.	SP. BEC.
STUDY PLOT	MONTH/ YEAR	HABITAT MANIP.	# T.N.	AVG. DEN. (#/ha)	AVG. DEN. (#/ha)	AVG. DEN. (#/ha)	AVG. DEN. (#/ha)	AVG. DEN. (#/ha)	AVG. DEN. (#/ha)
ABC	JAN-FEB - 1983	NONE	532	0	0	0	4.4	10.4	0
ABC	MAY-AUG - 1983	NONE	735	0	1.0	0	3.8	13.0	0
ABC	MAY-AUG - 1984	NONE	399	0	1.5	0	7.5	3.6	0
ABC	JUL - 1985	NONE	155	0	0.6	0	10.8	0	0(NA)
ABC	AUG - 1986	NONE	158	0	6.3	1.2	30.2	0	0
ABC	AUG - 1989	NONE	161	0	0	0	7.0	0(NA)	0
JKL	JAN-FEB - 1983	NONE	328	0(NA)	0	1.8	4.1	3.3	0
JKL	MAY-AUG - 1983	NONE	691	2.1	0.4	2.2	7.7	13.3	0
JKL	MAY-AUG - 1984	NONE	421	0.4	2.2	1.6	8.7	4.1	0
JKL	AUG - 1985	NONE	149	2.4	0(NA)	0(NA)	8.7	0(NA)	0(NA)
JKL	JUL - 1986	NONE	156	0.6	4.1	2.7	7.6	0(NA)	0(NA)
JKL	AUG - 1989	NONE	160	0(NA)	4.0	1.2	9.9	6.5	0
DEF	JAN-FEB - 1983	NONE	534	1.5	0.6	1.1	4.2	5.4	0
DEF	MAY-AUG - 1983	CLEARED	726	0.1	2.1	0.9	3.1	8.4	0
DEF	MAY-AUG - 1984	CLEARED	406	0.1	1.0	0.6	8.4	6.5	0
DEF	AUG - 1985	CLEARED	151	0(NA)	5.8	0.6	11.4	0	0
DEF	AUG - 1986	CLEARED	154	0	16.2	2.2	16.7	0(NA)	0
DEF	OCT - 1987	CLEARED	462	0.2	4.6	2.4	9.6	8.2	0(NA)
DEF	AUG - 1989	CLEARED	161	0	0.6	0.6	7.9	0(NA)	0
GHI	JAN-FEB - 1983	NONE	424	1.2	0	0.3	6.2	5.6	0
GHI	MAY-AUG - 1983	CLEARED	725	0.1	0.9	0.6	5.4	10.9	0
GHI	MAY-AUG - 1984	CLEARED	414	0(NA)	0.9	0.3	9.3	3.1	0
GHI	AUG - 1985	CLEARED	153	0	3.9	0(NA)	12.7	0	0(NA)
GHI	JUL - 1986	CLEARED	156	0	7.7	0	7.8	0(NA)	0
GHI	AUG - 1989	CLEARED	160	0	4.7	1.8	10.0	0(NA)	0

Table 7. Trapping results, relative abundance, and density of California pocket mice *(Pg. cal. = Perognathus californicus)*, deer mice *(Pm. man. = Peromyscus maniculatus)*, California mice *(Pm. cal. = Peromyscus californicus)*, western harvest mice *(Rd. meg. = Reithrodontomys megalotis)*, and dusky-footed woodrats *(Nt. fus. = Neotoma fuscipes)* on Pecho plot JKL (undisturbed Coastal Sage Scrub) in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

SPECIES	DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN.
Pg. cal.	22-Aug-89	54	3	3	0	5.56		
(Ca. pocket	23-Aug-89	53	5	3	2	9.43	7.50	4.44
mouse)	24-Aug-89	53	2	0	2	3.77	6.75	4.00
Pm. man.	22-Aug-89	54	11	11	0	20.37		
(Deer	23-Aug-89	53	13	3	10	24.53	14.30	8.47
mouse)	24-Aug-89	53	16	4	12	30.19	16.68	9.88
Pm. cal.	22-Aug-89	54	0	0	0	0.00		
(California	23-Aug-89	53	1	1	0	1.89	~	~
mouse)	24-Aug-89	53	2	1	1	3.77	2.00	1.19
Rd. meg.	22-Aug-89	54	1	1	0	1.85		
(W. harvest	23-Aug-89	53	3	3	0	5.66	~	~
mouse)	24-Aug-89	53	2	1	1	3.77	11.00	6.52
Nt. fus.	22-Aug-89	54	0	0	0	0.00		
(Dusky-ft'd.	23-Aug-89	53	0	0	0	0.00	~	~
woodrat)	24-Aug-89	53	1	1	0	1.89	~	~

The overall small mammal community on plot JKL has been dominated by either harvest mice (1983), Deer Mice (1985), Deer Mice and pocket mice (1986), or Deer Mice, harvest mice, and pocket mice (1984 and 1989). Although woodrats and California Mice were more common on plot JKL than on plot ABC, they still played a subordinate role in the small mammal community inhabiting plot JKL. Differences in the overall coverage and dispersion of shrubs, changes in surrounding habitat conditions (e.g., controlled burns), and topography on plots ABC and JKL probably account for most of the differences in small-mammal species diversity seen on these two undisturbed plots. Plot JKL generally has more large shrubs (e.g. holly-leafed cherry) and is steeper than plot ABC.

Plot DEF (cleared in 1983)

Four small mammal species were found on cleared plot DEF in 1989 during a three-night trapping session of 161 trap nights: California Pocket Mice, Deer Mice, California Mice, and Western Harvest Mice. Deer Mice were the dominant species (relative abundance = 18.9 mice / 100 TN and density = 7.9 mice / ha); whereas California Mice (1.9 / 100 TN and .6 / ha) and pocket mice (1.9 / 100 TN and .6 / ha) were relatively uncommon and too few harvest mice were caught to estimate their population (Table 8).

The density of Deer Mice on plot DEF in 1989 was higher than in 1983, but lower than their densities in 1984 to 1987 (Table 6). The density of California Mice in 1989 was roughly comparable to their densities from 1983 to 1985, but lower than their densities in 1986 and 1987. The density of pocket mice in 1989 was lower than any previous census year since the plot was cleared. The density of harvest mice in 1989 was roughly comparable to their densities in 1985 and 1986, but much lower than densities found from 1983 to 1984 and 1987. No woodrats were caught in 1989; however low numbers of woodrats have been found during most years since the plot was cleared.

The species diversity on plot DEF has remained fairly constant over most years since the plot was cleared in 1983. Deer Mice, California Pocket Mice, and California Mice have been the regular residents; whereas woodrats and Western Harvest Mice have been less predictable during the past four years. During the years following brush removal, the overall small-mammal community on plot DEF generally has been dominated by Deer Mice with harvest mice and/or pocket mice playing a codominant role on certain years. Most of the differences in small-mammal species diversity and abundance observed on plot DEF are probably a consequence of ongoing changes in vegetation composition after clearing, differences in sampling time, and the changes in surrounding habitat conditions (e.g., controlled burns).

Plot GHI (cleared in 1983)

Like plot DEF, four small mammal species were found on cleared plot GHI in 1989 during a three-night trapping session of 160 trap nights: California Pocket Mice, Deer Mice, California Mice, and Western Harvest Mice. Deer Mice were the dominant species (relative abundance = 32.1 mice / 100 TN and density = 10.0 mice / ha); whereas California Mice (3.8 / 100 TN and 1.8 / ha) and pocket mice (1.9 / 100

Table 8. Trapping results, relative abundance, and density of California pocket mice *(Pg. cal. = Perognathus californicus)*, deer mice *(Pm. man. = Peromyscus maniculatus)*, California mice *(Pm. cal. = Peromyscus californicus)*, and western harvest mice *(Rd. meg. = Reithrodontomys megalotis)* on Pecho plot DEF (cleared Coastal Sage Scrub) in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

SPECIES	DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN.
Pg. cal.	15-Aug-89	54	1	1	0	1.85		
(Ca. pocket	16-Aug-89	54	1	0	1	1.85	1.00	0.59
mouse)	17-Aug-89	53	1	0	1	1.89	1.00	0.59
Pm. man.	15-Aug-89	54	7	7	0	12.96		
(Deer	16-Aug-89	54	9	4	5	16.67	12.60	7.47
mouse)	17-Aug-89	53	10	2	8	18.87	13.31	7.89
Pm. cal.	15-Aug-89	54	1	1	0	1.85		
(California	16-Aug-89	54	0	0	0	0.00	~	~
mouse)	17-Aug-89	53	1	0	1	1.89	1.00	0.59
Rd. meg.	15-Aug-89	54	0	0	0	0.00		
(W. harvest	16-Aug-89	54	1	1	0	1.85	~	~
mouse)	17-Aug-89	53	0	0	0	0.00	~	~

TN and 4.7 / ha) were less common and too few harvest mice were caught to estimate their population (Table 9).

The density of Deer Mice on plot GHI in 1989 was higher than all previous years except 1985 (Table 6). The density of California Mice in 1989 was slightly higher than all previous years. The density of pocket mice in 1989 was lower than in 1986 but higher than densities from 1983 to 1985. The density of harvest mice in 1989 was roughly comparable to densities in 1985 and 1986, but much lower than their densities in 1983 and 1984. Like 1985 and 1986, no woodrats were caught in 1989; however low numbers of woodrats were found on GHI in 1983 and 1984.

The species diversity on plot GHI has remained fairly constant over most years since the plot was cleared in 1983. Deer Mice and pocket mice have been the regular residents, whereas woodrats, California Mice, and harvest mice have been less predictable during the past four years. During the years following brush removal, the overall small-mammal community on plot GHI generally has been dominated by Deer Mice with harvest mice and/or pocket mice playing a codominant role on certain years. Like on plot DEF, most of the differences in small-mammal species diversity and abundance observed on plot GHI are probably a consequence of ongoing changes in vegetation composition after clearing, differences in sampling time, and the changes in surrounding habitat conditions (e.g., controlled burns).

At this point in time, the small mammal communities on the two cleared plots (DEF and GHI) are more diverse than the small mammal community on plot ABC, but slightly less diverse than the small mammal community on plot JKL. Plot ABC has always had low small mammal species diversity which is probably related to the somewhat unique combination of topography and plant cover on this particular plot. Prior to clearing, the small mammal communities on plots DEF, GHI, and JKL were quite similar; however, after clearing, species diversity dropped on the two cleared plots. The main difference between the two cleared plots and plot JKL this year is that harvest mice occurred in low numbers on the two cleared plots, whereas they were fairly abundant on JKL. Although Dusky-footed Woodrats have been caught on both cleared plots over the past five years, they have not reached densities comparable to those prior to clearing. We expect that in a few more years the small mammal communities on the two cleared plots will be no different from those occurring there prior to clearing.

Competitors and Predators

California Ground Squirrels *(Spermophilus beecheyi)*

Ground squirrels were seen regularly in the vicinity of the enclosure and their tracks were seen around the outside perimeter of the enclosure during the 1989 field season,but none entered the enclosure this year. The flashing around the base of the enclosure and on the outer surface of the wooden posts appears to have prevented them from entering the enclosure.

Table 9. Trapping results, relative abundance, and density of California pocket mice *(Pg. cal. = Perognathus californicus)*, deer mice *(Pm. man. = Peromyscus maniculatus)*, California mice *(Pm. cal. = Peromyscus californicus)*, and western harvest mice *(Rd. meg. = Reithrodontomys megalotis)* on Pecho plot GHI (cleared Coastal Sage Scrub) in 1989. Abbreviations are as follows: trapping intensity (# TN = # trap nights), total number of individuals captured (# CAP), number of unmarked individuals captured (# NEW), number of marked individuals that were recaptured (# RECAP), relative abundance (#/100 TN), schnabel population estimate for the enclosure (POP.EST.), and density (DEN. = #/hectare).

SPECIES	DATE	#TN	#CAP	#NEW	#RECAP	#/100TN	POP.EST.	DEN.
Pg. cal.	22-Aug-89	53	2	2	0	3.77		
(Ca. pocket	23-Aug-89	54	2	2	0	3.70	~	~
mouse)	24-Aug-89	53	1	0	1	1.89	8.00	4.74
Pm. man.	22-Aug-89	53	10	10	0	18.87		
(Deer	23-Aug-89	54	10	1	9	18.52	11.11	6.58
mouse)	24-Aug-89	53	17	9	8	32.08	16.88	10.00
Pm. cal.	22-Aug-89	53	1	1	0	1.89		
(California	23-Aug-89	54	2	1	1	3.70	2.00	1.19
mouse)	24-Aug-89	53	2	1	1	3.77	3.00	1.78
Rd. meg.	22-Aug-89	53	1	1	0	1.89		
(W. harvest	23-Aug-89	54	1	1	0	1.85	~	~
mouse)	24-Aug-89	53	4	4	0	7.55	~	~

Botta Pocket Gophers *(Thomomys bottae)*

Pocket gopher mounds appeared along the outer perimeter of the enclosure in March 1989, and by 19 April 1989 at least one pocket gopher had burrowed under the aviary fence and created mounds inside the enclosure. We set gopher traps in June, after we were confident that no MBKR were inside, but our trapping efforts were unsuccessful. Like MBKR, pocket gophers had no difficulty tunneling down 2.5 feet so that they could burrow under the aviary wire barrier.

Reptiles

Snake tracks were seen frequently in the Pecho area, but no signs of snakes were observed inside the enclosure or in the immediate vicinity of the enclosure in 1989. So far, the metal flashing placed at ground level around the perimeter of the enclosure last year continues to be an effective barrier to snakes.

No Southern Alligator Lizards *(Gerrhonotus multicarinatus)* have been seen in the enclosure this year, however a few Western Fence Lizards *(Scleropus occidentalis)* are resident inside the enclosure.

Other Animals in the Enclosure

Birds

White-crowned Sparrows *(Zonotrichia leucophrys)* continue to live inside the enclosure and on several occassions we have removed dead birds from the ground and from the plastic roof netting. To reduce bird mortality, we recommend using larger mesh size or other materials rather than the existing type of roof netting in any future enclosure. If the present enclosure is not used for MBKR releases in the near future, we recommend that the plastic roof netting be removed to prevent unnecessary mortality in resident populations of sparrow-sized birds.

Large mammals, domestic animals, and people

In addition to the tracks of Brush Rabbits *(Sylvilagus bachmani)*, Black-tailed Jackrabbits *(Lepus californicus)*, Raccoons *(Procyon lotor)*, Bobcats *(Felis rufus)*, and Black-tailed Deer *(Odocoileus hemionus)*, the tracks of domestic cats, domestic dogs, horses, and people were all observed around the perimeter of the enclosure. We found no evidence to indicate that any of these "visitors" had entered the enclosure in 1989. Other than small holes in the roof netting caused by birds and aerial fireworks, no other signs of damage or vandalism to the enclosure were found in 1989.

MAJOR FINDINGS AND RECOMMENDATIONS

Major Findings

1. Maximum and minimum soil temperatures inside the enclosure were, respectively, 84 and 41 °F at a depth of 10 cm, 76 and 48 °F at a depth of 30 cm, and 73 and 52 °F at a depth of 60 cm. As one might expect, there are temperature turnovers in the fall and spring such that the deepest layers are warmer than shallow layers in the winter and vice versa. Regardless of the season, soil temperature at 10 cm is warmest a few hours before midnight and coolest about noon. The depth of MBKR rat burrows probably varies throughout the year depending upon the depth at which animals find an optimal thermal regime in the soil profile.

2. One of three kangaroo rats known to inhabit the enclosure in 1988 (male #2702R) burrowed under the aviary wire barrier, 2.5 feet below the surface. The two remaining kangaroo rats (both females) disappeared from the enclosure sometime between fall 1988 and spring 1989. The fate of the two females is unknown; they may have died or they may have used the male's burrow to escape into surrounding habitat.

3. After male #2702R escaped from the enclosure in the fall of 1988, he regularly burrowed to depths of 70- 90 cm in his new burrow systems. The complexity of burrows constructed by this animal ranged from a fairly simple system (one main tunnel with several side branches and chambers) to a complex system (several main tunnels at different levels with numerous side branches and chambers).

4. Ground reconnaissance surveys over most of the critical habitat, all of the three essential habitat areas, and several other isolated areas within the historic range revealed that the Bayview site is still the only area supporting wild MBKR. The distribution of kangaroo rats at Bayview is patchy and covers a total area of about 14.8 ha. We were unable to estimate the size or density of the Bayview population.

5. Last year we concluded that the numbers of Deer Mice and Western Harvest Mice in the enclosure declined as a consequence of the MBKR introduction. Population results from these two species this year suggest that their declines last year were not related to rat introduction.

6. Last year California Pocket Mice reached extremely high densities (97 individuals / ha) in the enclosure several months after kangaroo rats were released. Clearly, the three kangaroo rats in the enclosure then did not deter the influx of subadult and juvenile pocket mice. This year the densities of pocket mice were lower (from about 30 / ha to 50 / ha) which suggests that pocket mice may be reaching a more stable population condition in the enclosure. It should be emphasized that a density of 30 / ha for pocket mice in

the Pecho area is still much higher than their typical densities on study plots located within 100 m of the enclosure. It is possible that residual feed mix in the enclosure last fall served to attract young pocket mice from the surrounding habitat, thereby contributing to their localized "explosion" in the enclosure. Residual feed mix should have been depleted if not exhausted by 1989 which may account for the somewhat lower numbers of pocket mice this year.

7. After considerable trapping and ground reconnaissance throughout the Pecho area this year, we are forced to conclude that none of the four MBKR released in the enclosure last year survived into the 1989 field season. Predation, disease, old age, competition, long-range dispersal, malnutrition, and destruction of burrow systems are some of the possible causes for the disappearance of these animals.

8. When compared to results from a surrogate study on Lompoc Kangaroo Rats, the results of the MBKR introduction are considerabely more encouraging. Unlike Lompoc Kangaroo Rats, more MBKR survived for a longer period of time, MBKR maintained or gained weight in the enclosure, and they appeared to adjust well to field conditions regardless of their age or place of birth.

9. The species composition of small mammals occurring on undisturbed plots ABC and JKL at Pecho were roughly comparable to results of previous studies; however the densities of some species this year were markedly different from densities observed in past years. Deer Mice were far more abundant than harvest mice on plot ABC this year. Deer Mice also were the most abundant species on plot JKL; however, harvest mice and pocket mice were moderately abundant, and California Mice and Dusky-footed Woodrats were present in low numbers on JKL.

10. The species composition of small mammals occurring on cleared plots DEF and GHI at Pecho were roughly comparable to results of past studies, but, like the two undisturbed plots, the densities of some species were much different from densities observed in previous years. Deer Mice were the most abundant species on both cleared plots this year; whereas California Mice and harvest mice were present in low numbers on both plots. Pocket mice were moderately abundant on plot GHI, but present in low numbers on plot DEF. We expect that in a few more years the small mammal communities on these two cleared plots will be no different from those present before the plots were cleared. When woodrat densities on the cleared plots approach densities recorded there prior to clearing or densities typical of plot JKL, then we would conclude that the influence of brush clearing was no longer playing a significant role in the ecology of resident small mammals.

11. California Ground Squirrels were present in the vicinity of the enclosure, but none were seen inside during the 1989 field season. Aluminum flashing installed over the wooden posts last year continues to be an effective barrier to ground squirrels this year.

12. Botta Pocket Gopher mounds have been abundant in the vicinity of the enclosure over the past few years. Early this year one or more gophers burrowed under the aviary wire barrier and created numerous mounds inside the enclosure. We set traps in the most recent burrows, but were unable to catch any gophers in the enclosure.

13. Signs of snakes were common in the Pecho area this year, but we found no evidence of snakes inside the enclosure. Aluminum flashing placed at ground level around the enclosure last year continues to be an effective barrier to snakes this year.

14. Live and dead White-crowned Sparrows again were found inside the enclosure this year. We recommend that the plastic roof netting be changed in future enclosures or removed when MBKR are absent from the enclosure. Replacement of the existing netting with a net having either a smaller or a larger mesh size should decrease the level of sparrow mortality.

15. Various wild mammals, domestic pets, horses, and people walked up to the perimeter of enclosure during the 1989 field season, however none entered the enclosure or caused any visible damage to the enclosure.

Management Recommendations

1. The primary management focus on the Critical Habitat area should be (a) to continue efforts to establish MBKR there and (b) to continue habitat improvement efforts there.

   Wild-caught kangaroo rats rather than captive kangaroo rats would be more likely to survive and reproduce on Critical Habitat. Before moving any wild animals from Bayview, it would be essential to know the estimated size of the existing wild population. Agents for USFWS, DFG, and San Luis Obispo county should undertake negotiations with the Bayview landowners to allow agency-authorized research on the MBKR population there and to obtain live animals to stock Pecho and other appropriate sites.

   The most logical vegetation improvement effort would be to plow a 10-15 acre experimental plot and then pile and burn or chip and remove all the plant debris. Ground squirrel and pocket gopher control measures constitute another significant set of habitat improvement actions.

2. A federal and/or state funded "management/research/recovery center" for MBKR should be developed as soon as possible. Such a center, staffed by federal, state, and/or private biologists, would greatly increase the efficiency of implementing all aspects of the recovery plan for this endangered species. At the present time the level of financial support, research, and management devoted to MBKR recovery is insufficient to accomplish any of the goals of the recovery plan. In our opinion, a high level of support should be directed toward at least four important actions: introduction, captive propogation, habitat restoration, and habitat aquisition.

3. Since private land surrounding Critical Habitat and essential habitat is rapidly being developed, it is mandatory that the Habitat Conservation Plan (HCP) for the MBKR be completed as soon as possible. Any element in the HCP which would ensure the maximum protection of available MBKR habitat among and within these developing parcels would certainly be beneficial to kangaroo rat recovery. An approved HCP also would clarify the limits of feasible management efforts and perhaps even enhance certain long-range aspects of the recovery plan for the MBKR. For example, aquisition of additional land which could be used or restored to a usable condition for future MBKR introductions would further improve the long-term prospects for recovery.

4. A long-range program of experimental habitat manipulation and/or restoration followed by successive introductions of MBKR should be initiated for the Critical Habitat area as well as other potential sites within the rat's historic range. This program should be undertaken immediately because of the serious condition of both the wild and captive populations of MBKR.

5. Last year we recommended that another enclosure should be built on Critical Habitat as soon as possible. At that time we assumed that more kangaroo rats would be available for release into the wild. The existing enclosure sat idle this year; therefore we are reluctant to recommend any further construction until a final decision is reached on future reintroduction attempts.

6. If another "kangaroo rat proof" enclosure is built in the future, the underground barrier should be buried to a depth of 4-5 ft below the surface to discourage kangaroo rats from escaping as one did in the fall of 1988. A barrier this deep might also deter pocket gophers from entering the enclosure from surrounding areas as they did this year.

7. Ground reconnaissance surveys of Critical Habitat, essential habitat, and land adjacent to these areas should be conducted every year to ensure early detection of adverse impacts to the habitat and/or MBKR on these areas. Close coordination between state, federal, county, and private individuals is mandatory if this effort is to succeed.

8. Local conservation and/or recovery activities for the MBKR might be facilitated by promotional efforts of such organizations as the Morro Bay Museum of Natural History, Small Area Wilderness Preserves, Coastal Land Conservancy, Sierra Club, or other private or public organizations involved in conservation activities.

Research Recommendations

1. Increased support to the captive breeding program should be pursued in an attempt to accelerate the production of new animals for future introductions. Attempts to breed them under more or less natural conditions have resulted in success rates too low to be useful for large-scale restocking purposes. Hormone therapy followed by artificial insemination should be considered as an alternate

approach to augmenting the captive stock.

2. Controlled food discrimination experiments on captive MBKR would provide a more comprehensive understanding of their preference for native plants in their historic range. This information could then be incorporated into more comprehensive habitat restoration procedures in the field.

3. Population estimation studies should be conducted on all wild populations of MBKR. The last estimate was in 1986 which was too long ago to provide reliable information on their status today. Assuming the wild population is still more or less replacing itself, an intensive program of research over at least 5 years would be required to collect enough data to unravel their reproductive and dispersal characteristics.

4. Field experiments designed to assess the utility of different types of habitat manipulation or restoration actions in enhancing wild populations of MBKR should be conducted when possible. Such experiments would incur risks because to be conclusive they would need to occur on sites presently occupied by MBKR. The type of habitat modification actions that seem to hold the most promise include (a) complete removal of existing plant cover (including roots), (b) selective removal of certain species of plants (e.g., eucalyptus, holly-leaf cherry, iceplant, or introduced grasses), (c) selective addition of certain species of plants (e.g., horkelia or deer weed), (d) supplemental feeding, (e) selective reduction of potential rodent competitors (e.g., ground squirrels and pocket gophers), and (e) selective reduction of predators (e.g., snakes, owls, cats, or dogs).

5. Assuming more MBKR might be released into Critical Habitat, careful consideration should be given to the type and intensity of monitoring efforts directed toward these animals (inside as well as outside the enclosure). The risks, costs, and benefits of each level of monitoring should be evaluated by all agencies involved.

   Monitoring inside the enclosure is required to assess survivorship, body weight and general condition of the animals. A weight loss of more than 10% should be taken as a sign of poor acclimation to field conditions. The benefits associated with monitoring animals inside the enclosure exceed the risks associated with proper live trapping because trap mortality is low and animals in poor condition can be detected, removed and treated.

   Monitoring outside the enclosure is the only way that immigration can be documented. The risks, costs, and benefits of this type of monitoring are more difficult to predict. For example, proper live trapping carries low risk, but has considerable equipment and field effort costs for a small expected recapture return (benefit) once animals leave the enclosure. Radiotelemetry may carry a slightly higher risk, has considerable equipment and field effort costs, but should produce a modest return until batteries or other components fail. Nocturnal observation has low risk, considerable equipment and field effort costs, and probably would yield a low to modest return.

6. The genetic variance of both wild and captive MBKR should be determined using no-risk genetic "fingerprinting" techniques as soon as possible. Cellular and/or genetic specimens of representative animals should be preserved in a long-term gene bank for future scientific research.

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