MORRO BAY KANGAROO RAT

Recovery Plan

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RECOVERY PLAN

Published by

U.S. Fish and Wildlife Service
Portland, Oregon

Approved: Robert A. Jantzen
Director, U.S. Fish and Wildlife Service

8/18/82
Date

THIS IS THE COMPLETED MORRO BAY KANGAROO RAT RECOVERY PLAN. IT HAS BEEN APPROVED BY THE U.S. FISH AND WILDLIFE SERVICE. THE PLAN WAS PREPARED BY DR. ARYAN I. ROEST (DEPARTMENT OF BIOLOGICAL SCIENCES, CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO, CALIFORNIA 93407) IN COOPERATION WITH THE SACRAMENTO ENDANGERED SPECIES OFFICE OF THE U.S. FISH AND WILDLIFE SERVICE. IT DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF COOPERATING AGENCIES AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED KEY ROLES IN PREPARING THIS PLAN. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS AND CHANGES IN SPECIES STATUS AND COMPLETION OF TASKS DESCRIBED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER BUDGETARY CONSTRAINTS.

ACKNOWLEDGEMENTS SHOULD READ AS FOLLOWS:

THE MORRO BAY KANGAROO RAT RECOVERY PLAN, DATED AUGUST 18, 1982, PREPARED BY THE U.S. FISH AND WILDLIFE SERVICE IN COOPERATION WITH DR. ARYAN I. ROEST, CALIFORNIA POLYTECHNIC STATE UNIVERSITY, SAN LUIS OBISPO, CALIFORNIA 93407.

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PART I

INTRODUCTION

The Morro Bay kangaroo rat (*Dipodomys heermanni morroensis*) occurs within a restricted range on the south side of Morro Bay, in San Luis Obispo County, California. Its survival is endangered by the continuing destruction and modification of its habitat. The problem of the continued survival of this geographic race was first recognized by Stewart (1958), and has been re-emphasized by subsequent investigators (Congdon 1971; Congdon and Roest 1975; Roest 1973, 1977; Toyoshima 1979, 1980). It was placed on the Federal list of endangered species in 1970 (*Federal Register* 35(199):16047), and was recognized as an endangered species by the State of California in 1971. In the same year it was listed in the International Red Data Book for Mammals (Int. Union Cons. Nat. 1971).

This recovery plan provides background information on the Morro Bay kangaroo rat, and outlines a program which would enable this currently endangered animal to be reclassified to threatened status.

TAXONOMY

The Morro Bay kangaroo rat differs from other kangaroo rats in its smaller size and darker coloration (Table 1). Merriam (1907) felt

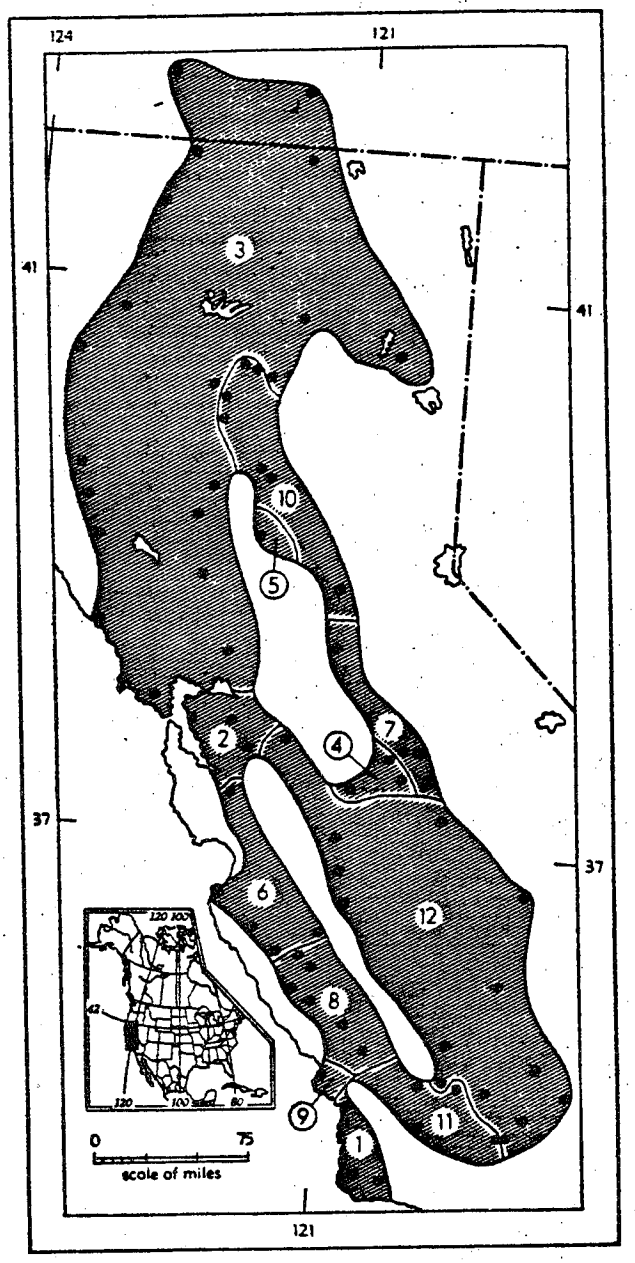
Table 1. Average morphometric values and coloration which distinguish *Dipodomys heermanni morroensis* from its closest neighbors (geographically and taxonomically). Source: Grinnell 1922; Roest, unpublished data.

Subspecies:	*D. h. jolonensis*	*D. h. swarthi*	*D. h. arenae*	*D. h. morroensis*
Features:				
Total mean length:	304 mm	297 mm	305 mm	290 mm
Tail mean length:	188 mm	175 mm	179 mm	174 mm
Mean weight:	87.7 gm	87.0 gm	70.7 gm	66.6 gm
Skull length:	41.0 mm	41.1 mm	39.6 mm	38.6 mm
Dorsal color:	light	pale	medium	dark
Hip stripe:	present in all specimens	present in all specimens	present in 95% of specimens	present in less than 25% of specimens

these features were sufficient to warrant full species status, and described the Morro Bay animals as Perodipus morroensis. Grinnell (1922) supported this recognition, but revised the name to Dipodomys morroensis. Boulware (1943) however, noted its resemblance to Heermann's kangaroo rat, and considered it to be a subspecies of that species: Dipodomys heermanni morroensis. Since then other studies have confirmed its distinctive features and its relationship to D. heermanni (Roest 1964; Risser 1975, 1976).

There are nine subspecies of Dipodomys heermanni (D. h. arenae, berkeleyensis, dixoni, goldmani, heermanni, jolonensis, morroensis, swarthi, and tularensis). They inhabit the inland valleys and coastal plains of California, from San Francisco Bay and Amador County south to Point Conception and the Tehachapi Mountains (Figure 1).

The isolation of the Morro Bay kangaroo rat from other subspecies of D. heermanni is complete. Souza (1958a, 1958b) found the nearest populations of D. h. arenae about 14 miles (22.5 km) southeast, and 1 mile (1.61 km) west of Edna, where an isolated colony occupies about 350 acres (141.7 ha). The Edna population is a range extension for arenae, which is otherwise found south from Arroyo Grande to Point Conception (Boulware 1943). D. h. jolonensis, which occurs from approximately Atascadero northward, ranges to within roughly 17 miles (27.4 km) of the range of morroensis. D. h. swarthi only occurs in the eastern part of San Luis Obispo County and is separated from D. h. morroensis by over 40 miles (64.4 km).



Dipodomys heermanni.

1. *D. h. arenae*
2. *D. h. berkeleyensis*
3. *D. h. californicus*
4. *D. h. dixoni*
5. *D. h. eximius*
6. *D. h. goldmani*
7. *D. h. heermanni*
8. *D. h. jolonensis*
9. *D. h. morroensis*
10. *D. h. saxatilis*
11. *D. h. swarthi*
12. *D. h. tularensis*

Figure 1. Distribution of Heerman's kangaroo rat (Dipodomys heermanni). Taken from Hall and Kelson (1959).

ECOLOGY AND BEHAVIOR

Distribution and Abundance

The first effort to define the range of the Morro Bay kangaroo rat was that of Grinnell (1922) (Figure 2) who indicated that the species' range was an area "less than four miles square" near Morro Bay. This phrase suggests an occupied area of nearly 16 square miles (25.7 km), and he probably meant "less than four square miles." Grinnell indicated a vertical distribution from sea level to an elevation of about 250 feet (76.2 m).

Stewart (1958) made a careful study to determine the distributional limits of morroensis. He found kangaroo rats over a total area of 4.8 square miles (12.4 square km), of which only 2.2 square miles (5.7 square km) were actually occupied by the animals.

The rest of the area was unsuitable habitat (oak and eucalyptus groves, thick chaparral, riparian vegetation, etc.) or was urbanized. He also found kangaroo rats near the 1,000 foot (305 meter) summit of a nearby hill.

In 1979, the total occupied range for the Morro Bay kangaroo rat consisted of approximately 640-650 acres (259-263 ha) distributed within six disjunct localities (Table 2). However, development is planned for approximately 150 acres (61 ha) in the Bayview area. Of

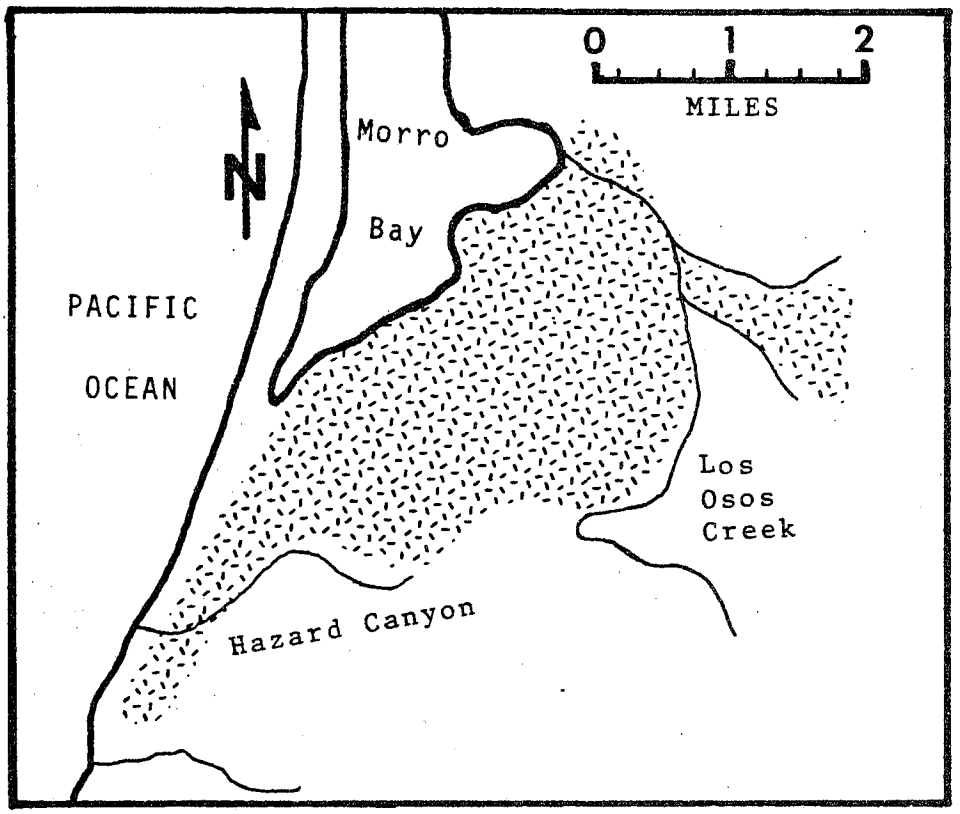


Figure 2. Historical distribution of the Morro Bay kangaroo rat (Dipodomys heermanni morroensis).

Table 2. Current land ownership and present and potential population numbers of Morro Bay kangaroo rat.

Site	Total acres (approx.)	Potentially Occupiable acres (approx.)	Public acres (approx.)	Private acres (approx.)	1979 population estimate	1983 population estimate	Potential[1] population estimate
Pecho	160 (65 ha)	160 (65 ha)	120 (48 ha)	40 (16 ha)	20-25	?	800
Bayview	200 (81 ha)	175[2] (71 ha)		200 (81 ha)	(170-175)	(50-100?)	875
Hazard	100 (40 ha)	100 (40 ha)	100 (40 ha)	---	?	?	500
Buckskin	50 (20 ha)	50 (20 ha)		50 (20 ha)	50-65	?	250
Eastern	50 (20 ha)	50 (20 ha)		50 (20 ha)	80-85	?	250
Turri	50 (20 ha)	50 (20 ha)		50 (20 ha)	?	?	250
	640-650 (259-263 ha)	580-590 (236-240 ha)	210-230 (85-93 ha)	380-400 (154-163 ha)	320-340	(50-100?)	2925 (2500-3000)

[1] estimate based on the conservative average of 5 kangaroo rats per acre.
[2] includes approximately 50 acres of presently occupied habitat.

the 160 acres (65 ha) in the Pecho area, only 20 acres (8 ha) were occupied by kangaroo rats in 1978-79. Other sites, such as the Hazard Canyon area, sustain relatively heavy recreational use and, hence, are not ideal kangaroo rat habitat as presently managed.

In 1979 kangaroo rats were known to exist in only four localities (Toyoshima 1979, 1980) (Figure 3). Current land ownership, area sizes, and current and potential* estimates of kangaroo rat populations appear in Table 2. Kangaroo rats formerly occurred in the area west of Pecho Road, between the road and the base of the active sand dunes. The Pecho area consists of 160 acres (65 ha) of which 50 (20 ha) comprise the Morro Dunes Ecological Reserve, and the rest is under the ownership of the California Department of Parks and Recreation or is privately owned. Within the Pecho area in 1979, Morro Bay kangaroo rats were located within a 20-acre (8 ha) site known as the Dunes, which lies within the ecological reserve. The Dunes area is actually only a small portion of the larger Pecho area at the south end of Morro Bay. The Pecho area formerly was excellent kangaroo rat habitat (Stewart 1958, Stewart and Roest 1960) and is entirely within the critical habitat designated for the Morro Bay kangaroo rat in 1977 (Federal Register 42(184):47840-47845 and Federal Register 42(155): 40685-40690).

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* Estimate of the number of animals that a given site could support if the habitat were in optimal condition.

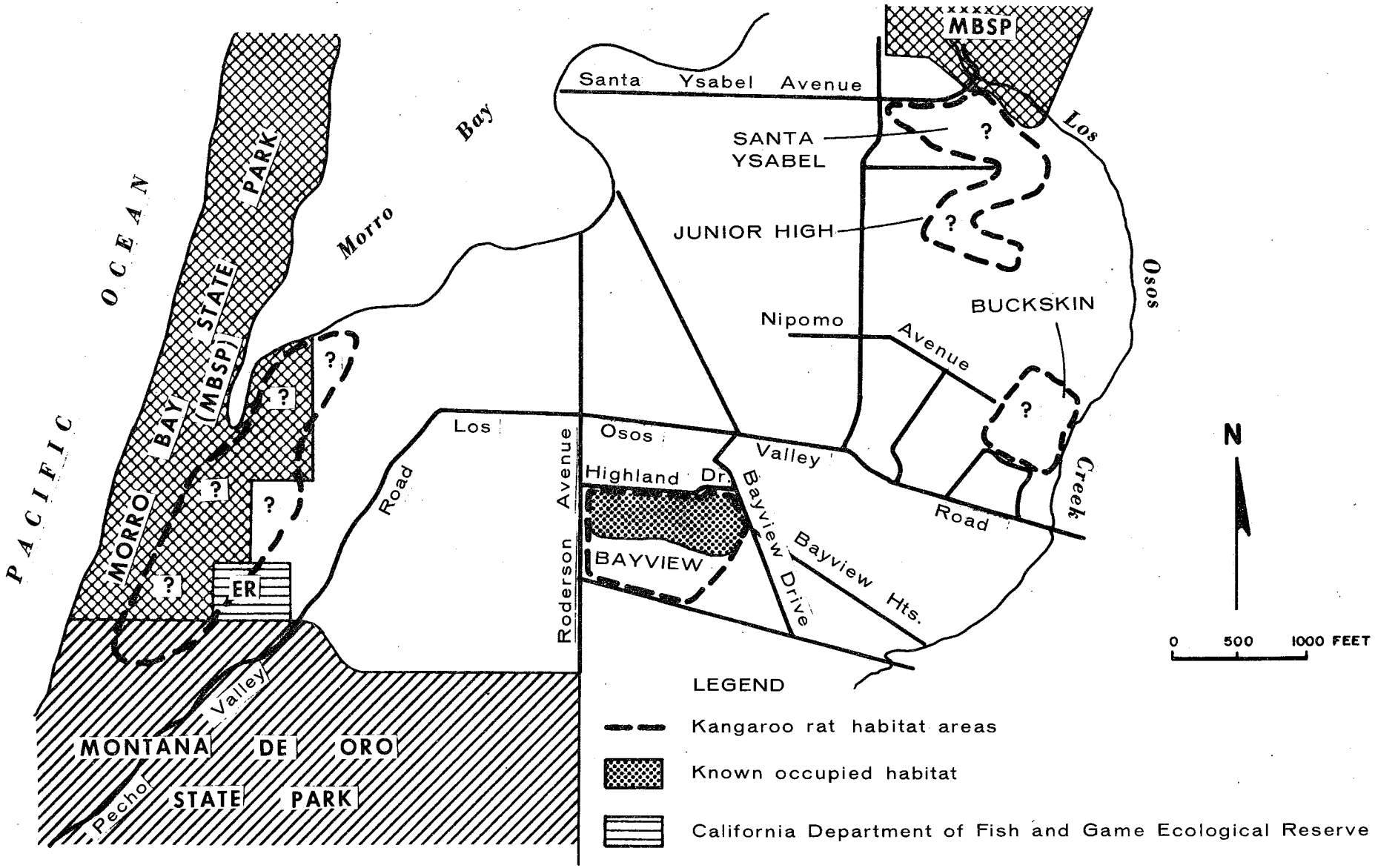

Figure 3. Current available habitat and known occurrence of the Morro Bay kangaroo rat (Dipodomys heermanni morroensis). Taken from Toyoshima (1980).

In 1979, the Dunes area had a very low kangaroo rat population, estimated at only 20-25 animals (Toyoshima 1980). Much of the southeastern portion of the reserve is unsuitable for kangaroo rats, and has probably never supported them because of steep slopes and unsuitable vegetation (Stewart 1958, Toyoshima 1980). Recent trapping efforts (1982-1983) in this area have been unable to confirm the presence of kangaroo rats (Gambs[1], pers. comm.).

The second area lies south of Highland Drive and west of Bayview Drive, and is referred to as the Bayview area. Although it is subject to considerable disturbance from nearby residents, at present it supports the only confirmed population of kangaroo rats [(in 1979 there were about 170-175 animals (Toyoshima 1980)]. The area is used by hikers, dog walkers, horseback riders, and off-road vehicle drivers. Field investigators funded by the Service and co-sponsored by the California Department of Fish and Game have recently (1983) been granted access to this site to conduct surveys. The contemporary status of the animals there has not been fully evaluated.

The third area lies just north of the dead end of Buckskin Drive, and is referred to as the Buckskin area. About 50-55 rats were present in 1979 (Toyoshima 1980), but there is heavy use of the area by hikers, joggers, cyclists, horseback riders, and others. This area also has not been evaluated by the Service because access has not been granted.

[1] Dr. Roger Gambs, Professor of Biology, California Polytechnic State University, San Luis Obispo, California 93407

The fourth area lies east of South Bay Boulevard (a newly completed road not shown on earlier maps) and north of Eto Lake, and is referred to as the Eastern area. The northern part of this area, near the east end of Santa Ysabel Avenue, had a kangaroo rat population of about 80-85 animals in 1979 (Toyoshima 1980). Disturbance near the Santa Ysabel part of the area is minimal, but from the junior high school southward and eastward the area is subject to considerable human use.

The northern edge of the Eastern area apparently abuts the Baptista Ranch, public land that was recently purchased as an addition to Morro Bay State Park. Actual boundary lines of this purchase are not clear from available maps (Baxter 1979, Toyoshima 1980).

Two other areas supported kangaroo rats in the past, but animals have not been trapped at these sites in recent years. One area lies between Hazard Canyon and Spooner's Cove, west of Pecho Road, on a bluff just above the Pacific Ocean. The Hazard area (identified as Spooners' Cove area in Roest 1977) lies entirely within the boundaries of Montana de Oro State Park. Stewart (1958) trapped kangaroo rats there, and both Congdon (1971) and Roest (1977) noted typical burrows in the area. In March 1980 Roest found a single open burrow near the north end of this area, suggesting that a few kangaroo rats were still present. Gambs (1983 pers. comm.) found no evidence of kangaroo rats in this area during his surveys (fall 1982 - summer of 1983).

The other area which supported kangaroo rats in the past lies just south of Turri Road, and is the only area located east of Los Osos

Creek. Stewart (1958) captured five animals there, but the area now appears unoccupied (Congdon 1971, Roest 1977). No tracks or burrows were found by Roest in March, 1980. The western portion of this area has been partially developed, much of it as a waste disposal site. Intensive efforts here by Gambs in 1982-83 also failed to locate any evidence of kangaroo rats.

If Morro Bay kangaroo rats occupied the entire 4.8 square miles (12.4 km^2) of their original range at a density of 15 rats per acre (37/ha)--considered an average density by Stewart (1958)--the total population could not have been more than about 46,000 animals. However, because some of the habitat within their historical range was not suitable (i.e., dense chaparral), it is doubtful that the population was ever that high.

During recent years, consistently lower populations than noted in 1958 have been estimated in several studies (Table 3). Both the occupied range and the total population estimate have dropped more than 80% in the past 20 years, while the human population has increased dramatically.

Roest (1977) and Toyoshima (1980) both added a factor to their population estimates to include kangaroo rats which might be present in areas which were not well trapped, or which presumably had no rats because none were trapped in such areas. Both assumed an additional 100 acres (40 ha), supporting perhaps 500 animals, might still be

Table 3. Population estimates and occupied range for Morro Bay kangaroo rats, compared with human population estimates in the same area.

Source	Year	Morro Bay kangaroo rat Population Estimate	Square Miles of Occupied Range mi^2 (Km^2)	Baywood-Los Osos Human Population[2]
Stewart	1958[1]	8,000	2.2 (5.6)	1,500
Congdon	1971	3,000	1.75 (4.5)	4,700
Roest	1977	1,700-2,000	0.52 (1.3)	8,500
Toyoshima	1980	830-1,700	0.49 (1.25)	10,000

[1] as quoted in Congdon (1971).

[2] estimates from San Luis Obispo County Planning Department.

present in the general area. On the basis of their actual trapping results, their population estimates should be reduced to about 1,200-1,500 (Roest 1977) and 330-1,200 rats (Toyoshima 1980). Whatever the estimates may be, it is clear that the Morro Bay kangaroo rat population is at a very low level for a small mammal.

Habitat

Two primary factors are of importance in defining the habitat of the Morro Bay kangaroo rat--suitable soil type and suitable plant cover. Sandy soil (but not active dunes) is essential, because the animals can not construct their burrows in hard, rocky, or heavy clay soils. Grinnell (1922) referred to their range as being "sandy ground", and Stewart (1958) found them inhabiting only dry sandy areas. Stewart (1958) noted that the Turri area was apparently marginal habitat for kangaroo rats because, although sandy, the soil is considerably more compact than that in the rest of their range. Kangaroo rats have not been found on the more typical clay or adobe soils in this part of California. Other subspecies of Heermann's kangaroo rat are also found only on sandy valley floors or coastal plains. Most areas of sandy soil have rather low relief, and these kangaroo rats are rarely found on slopes with more than a 15 percent grade. Steeper slopes in this part of California are usually much more rocky, and support a dense chaparral vegetation.

The vegetation which grows on sandy soil near Morro Bay can be described as Southern Coastal Scrub (Mooney 1977), Coastal Sage Scrub

(Munz and Keck 1959), or as Coastal Sand Plains and Stabilized Dunes (Hoover 1970). Characteristically, a variety of low, dominant, shrub species, scattered over the area are the most obvious feature of the landscape and include bush lupine (Lupinus arboreus), dune lupine (Lupinus chamissonis), mock heather (Haplopappus ericoides), coyote bush (Baccharis pilularis), and California sagebrush (Artemisia californica) (Table 4).

In the best kangaroo rat habitat these shrubs rarely exceed three feet in height. Less noticeable are a number of smaller, herbaceous plants such as croton (Croton californicus), buckwheat (Eriogonum parvifolium), phlox (Eriastrum densifolium), dudleya (Dudleya caespitosa), and deerweed (Lotus scoparius), which grow in the spaces between the dominants. The kangaroo rats use the leaves, stems, and seeds of most of these plants for food (Stewart 1958, Roest 1973), and their roots provide support for kangaroo rat burrows.

The plant community described above constitutes an early seral stage in a natural succession toward the mature coastal scrub vegetation of the region. The twigs and stems of shrubs of the Coastal Sage Scrub community are soft and flexible, and the community is sometimes described as "soft chaparral." The vegetation becomes taller as the community matures, and begins to occupy all open space, thus crowding out the smaller herbaceous species which are an important food supply for the kangaroo rats. Still later, more woody species begin to establish themselves, particularly chamise (Adenostoma fasciculatum),

Table 4. Plant species composition within the range of the Morro Bay kangaroo rat. An asterisk (*) indicates species known to be used for food by the kangaroo rat. Modified from Stewart (1958) and Roest (1973).

Coastal Sage Scrub - Soft Chaparral elements		
Shrubs:	*Black Sage	Salvia mellifera
	Sand Almond	Prunus punctata
	*Bush Lupine	Lupinus arboreus
	*Dune Lupine	Lupinus chamissonis
	*Mock Heather	Haplopappus ericoides
	Coyote Brush	Baccharis pilularis
	Sagebrush	Artemisia californica
Herbs:	*Filaree	Erodium cicutarium
	*Croton	Croton californicus
	Rockrose	Helianthemum scoparium
	Indian Pink	Silene laciniata
	Sand Mat	Cardionema ramosissimum
	*Spineflower	Chorizanthe californica
	*Buckwheat	Eriogonum parvifolium

*Sand Verbena	Abronia umbellata
*Phlox	Eriastrum densifolium
*Popcorn Plant	Cryptantha clevelandei
*Monkey Flower	Mimulus aurantiacus
*Dudleya	Dudleya caespitosa
*Cinquefoil	Potentilla lindleyi
*Deerweed	Lotus scoparius
*Tarweed	Hemizonia sp.
Golden Yarrow	Eriophyllum confertiflorum
*Cudweed Aster	Corethrogyne filaginifolia
*Yarrow	Achillea millefolium
*Thistle	Cirsium occidentale
*Wreath Plant	Stephanomeria virgata
*Red Brome	Bromus rubens

Chaparral - Hard Chaparral elements

Shrubs:	Morro Manzanita	Arctostaphylos morroensis
	Chamise	Adenostoma fasciculatum
	Chokecherry	Prunus fasciculata
	Holly-leaf Cherry	Prunus ilicifolia
	Buckbrush	Ceanothus cuneatus
	Poison Oak	Toxicodendron diversiloba

Trees:	Live oak	Quercus agrifolia

buckbrush (Ceanothus cuneatus), and sometimes Morro manzanita (Arctostaphylos morroensis).

Mature coastal scrub vegetation in this area grows to a height of eight feet (2.4 m) or more in some places, and becomes so dense as to be nearly impenetrable to human beings. This dense cover completely shades the ground surface, eliminating the shade-intolerant, seed-producing species which provide food for kangaroo rats. In addition, in areas with a complete canopy, kangaroo rats might find it difficult to maneuver through dense woody stems and roots (Stewart[1], pers. comm.). The lack of suitable food sources and reduction in ease of mobility may account for the absence of kangaroo rats in mature coastal scrub. When fires or land-clearing activities destroy the vegetation growing on the sandy soils of the area, croton, buckwheat, deerweed and other herbaceous plants quickly colonize and soon produce an open, low-growing community of herbaceous plants (Hanes 1977), which presumably provide abundant kangaroo rat food. The animals quickly become established on such disturbed areas, usually within two or three years (Stewart 1958, Roest 1973). They can continue to inhabit these early successional areas until the vegetation matures to the point of dense, tall shrubs estimated to occur in 10 to 15 years (Roest, pers. obs.). The animals are nearly always found in relatively open areas with little or no shrubby vegetation and are

[1] Dr. Glen Stewart, Professor of Biology, California Polytechnic State University, Pomona, California 91768

only rarely found in thickly vegetated areas lacking herbaceous plants. The highest kangaroo rat populations have been found in open areas within the first few years after they have been cleared of vegetation, and the rats persist longest in areas which are the last to mature into dense, tall vegetation (Roest 1973). Morro Bay kangaroo rat habitat may perhaps best be maintained by vegetation clearing approximately every three to five years.

In prehistoric times the Indians regularly set fire to the vegetation to clear it for more successful hunting (Hanes 1977, Lewis 1973). Presently vegetation is being cleared for agriculture or for housing.

Heavy equipment was used in the Pecho area to eliminate unexploded (dud) shells in 1956 (the area was a mortar range during World War II), and by 1958 the kangaroo rat population was quite high (Stewart 1958). Since then the land has not been disturbed, and the resulting plant growth has eliminated kangaroo rats from most of it. Fires currently are rare, and those that do occur are quickly extinguished. There have been no fires in the chaparral of the kangaroo rat range since at least 1949 (Stewart 1958).

At present, it is clear that kangaroo rats are favored by the conditions and early successional plants found in disturbed areas. In the future it would be desirable to determine the specific seral stages preferred by the subspecies, and the time needed to establish such stages in this area.

Seasonal Activity Pattern

Morro Bay kangaroo rats are strictly nocturnal and are not seen on the surface during daylight hours. During the winter rainy season (late December to early March) Morro Bay kangaroo rats appear to be inactive on the surface. Trapping success at this time is very low, or completely unsuccessful. The animals stay in their burrows where they probably feed on supplies of stored seed. They are not known to hibernate. By early March the cold, wet weather is largely over, and the animals begin to appear above ground. Activity continues during the spring and summer months. This is the main period of plant growth, and food is abundant. The kangaroo rats gather food material each night, carrying much of it back to their burrows in their external cheek pouches. That which is not consumed is buried in small caches near the burrow entrances, or stored underground in the burrow.

The summer dry season begins in late June or early July, and most plant growth ceases as moisture is lost from the surface layers of the sandy soil. Judging from trapping results this is again a period of relative inactivity for kangaroo rats.

In late August or September the animals begin to become active on the surface again, coinciding with some plant growth which is perhaps associated with the heavy night and morning fogs which blanket the area.

Occasionally an early fall rainstorm also contributes to better plant growth. This period of kangaroo rat activity continues until the beginning of cold, wet weather in late December or early January.

Construction and Use of Burrows

Little is known about the behavior of the Morro Bay kangaroo rat, although in general it probably is much like that of other kangaroo rats. Each kangaroo rat lives in a burrow which it has constructed primarily with the aid of the hind feet, which kick excavated soil to the rear.

Kangaroo rat burrows are relatively simple in construction with few tunnel branches, and are usually less than a foot below the surface of the ground (Stewart, 1958). As a result, surface traffic by vehicles, people, or large animals frequently causes them to cave in, which may drive the animals out, exposing them to daylight predators and/or causing desertion of that particular area.

In favorable environments the burrows may be constructed fairly close to each other, so that the kangaroo rats share overlapping home ranges. However, they actively defend their individual burrows against entry by other kangaroo rats.

Home Range

In the course of their normal activities, kangaroo rats usually remain in the vicinity of their home burrows. Individuals are rarely retrapped over 100 feet (30 m) from where they were originally trapped, although a few have been recaptured at stations over 200 feet (60 m) apart (Roest, pers. obs.).

Stewart (1958) determined from trapping results that populations of Morro Bay kangaroo rats might reach densities as high as 60 rats/acre (148/ha), but considered a more representative density in good habitat to be about 15 rats/acre (37/ha). Where the kangaroo rat is abundant, trapping results suggest an absence of other small mammal species that normally live in the same habitat, such as the deer mouse (Peromyscus maniculatus), California pocket mouse (Perognathus californicus), and western harvest mouse (Reithrodontomys megalotis). Conversely, where kangaroo rats are scarce, these species are usually present. The reasons for this situation are not known, but perhaps result from the social dominance of kangaroo rats and/or from competitive interactions with them (Stewart, pers. comm.).

Locomotion

Most normal movement can best be described as a 'scurrying' form of locomotion, low to the ground and close to nearby cover. Only occasionally, when pursued by a predator, do kangaroo rats take to the air in a series of leaps.

Diet

The diet of the Morro Bay kangaroo rat consists primarily of the seeds, leaves, and young stems of a wide variety of local plants. The species taken by captive individuals are indicated in Table 4 with an asterisk, but no studies have been made of preferred foods in the wild. Stewart (1958) and Daniels (1979) (the latter study done on D. heermanni arenae) found that kangaroo rats would take animal food (grasshoppers, crickets, land snails) under captive conditions, and they probably do so in the wild.

Reproduction

The beginning of surface activity in the spring coincides with the beginning of plant growth, and breeding activity begins about the same time. Little is known about the details of reproductive behavior in the wild. The breeding season appears to be extended, and males may have descended testes even in June (Congdon 1971). Females can be quite resistant to advances from males during the breeding season before any copulation takes place. According to studies done on D. heermanni arenae, copulation in captive animals is brief, and requires only a few seconds (Kozik 1977, Studley 1978). Young are born after a gestation period of 30-32 days, and females will cycle every 18-20 days if not impregnated (Kozik 1977, Studley 1978). Litter size ranges from two to four, averaging three. By the age of four weeks the young are weaned, and at six or seven weeks (still with some grayish juvenile pelage) are beginning to live independently. Young

which were born in captivity stayed with their mother for a least 10 weeks without showing any aggressive behavior toward each other or their parent. Full adult size (about 60 grams in weight) and adult pelage are not reached until they are about 15 weeks old.

Mortality, Longevity, and Parasites

Mortality is mainly the result of predation by a number of local carnivorous species, including gray fox (*Urocyon cinereoargenteus*), long-tailed weasel (*Mustela frenata*), badger (*Taxidea taxus*), bobcat (*Lynx rufus*), great horned owl (*Bubo virginianus*), barn owl (*Tyto alba*), gopher snake (*Pituophis melanoleucus*), and western rattlesnake (*Crotalus viridis*). Of these predators the fox and the horned owl are probably the most important, since both are fairly common in the area. In situations close to human developments all these species may be reduced in numbers, or eliminated. However, their place is often taken by roving domestic cats, which hunt near the homes of their owners. Some kangaroo rats are also killed on roads by automobile traffic, and others may be killed or forced from their sheltering burrows by off-road vehicles or horses which break through into the burrows. Nothing is known about actual mortality rates in the wild.

Longevity in the wild is probably two to three years, as is true for most small rodents (Roest, pers. obs.). Toyoshima (1978) retrapped an individual which had been tagged 13½ months previously. An individual of the closely related *D. h. arenae*, trapped as an adult in August 1976, died in captivity 20 months later (Daniels 1979).

Stewart (1958) reported that 88.5 percent of the kangaroo rats he examined had external parasites. Of these parasitized animals, 73 percent had fleas, 37 percent had lice, and 35 percent had ticks. Usually only one or two fleas, or two or three ticks, were found on a single animal, but lice might be more abundant.

Nematodes were found in the gut of one of five individuals that were examined for internal parasites. None of these parasites were identified to species.

REASONS FOR DECLINE

The basic reason for the decline of the Morro Bay kangaroo rat population is the loss of suitable habitat, resulting from two main causes. First, the human population of the Baywood-Los Osos community on the south side of Morro Bay has increased 600 percent during the past 20 years (Table 3). Human population growth has been accompanied by a building boom which has replaced much of the original kangaroo rat habitat with homes, gardens, shopping centers, parking lots, and roads. These developments have completely destroyed major portions of the original kangaroo rat range (see Figure 1).

Second, areas which still remain in a natural state have not been disturbed by fire or any other factor for over 30 years. The resulting growth and maturation of the vegetation into mature coastal scrub has long passed the point at which kangaroo rats can easily move about and still find their natural foods. The shrubby vegetation has

replaced the low herbaceous vegetation which forms the optimum habitat for the animals.

The remaining small population of kangaroo rats is now restricted to a few local areas where plant growth has not occurred as rapidly as elsewhere (probably the result of slight differences in available water, wind exposure, etc.), or where vegetation has been cleared for agriculture in the past but now lies fallow. On such clearings, early successional stages of vegetation have become established, and are presently capable of supporting kangaroo rats.

Besides the loss of habitat, there probably are some additional factors which have complicated the problem of survival for the kangaroo rats. In the past, kangaroo rats occupied an essentially continuous range. Not only is this range now greatly reduced, but it is also subdivided into several small acreages which are isolated from each other by a distance of a mile or more. As a result, a drop in the population on one parcel can no longer be naturally restored by movement of animals from nearby areas. Each remaining population constitutes a small "island" of kangaroo rats, which is much more subject to minor local shifts in mortality rates than would be a larger population within a larger area. Factors such as burrow destruction, road traffic, or predation by domestic cats can affect a small, localized population seriously, even to the point of totally eliminating it. However, no actual data are available to support this supposition.

Another possible factor of significance to future kangaroo rat survival is genetic variability and drift. Small populations may be subject to the phenomenon of genetic drift whereby changes occur in the genetic variability because of a limited stock of parent animals. Conceivably, this could cause a change in the population so that it no longer would be representative of the original stock. Dr. William Stansfield[1] (pers. comm.) has studied computer simulations of inheritance patterns in theoretical populations. In his opinion, genetic drift is unlikely to occur in populations of 50 or more breeding animals. On a short-term basis, Franklin (1980) suggests that, in general, for a vertebrate population, the population size should be a minimum of 50 individuals and 500 individuals on a long-term basis. Whether this implication is true for Morro Bay kangaroo rats is not known; some populations are currently estimated to be at or below 50 individuals (Pecho area, Buckskin area, Hazard Area, Turri Road area). The possibility of a reduction in genetic diversity should be investigated as it relates to kangaroo rats, perhaps with a surrogate form closely related to the Morro Bay form. Until definite information is available, every effort should be made to maintain several populations each with at least 50 individuals.

PAST RESEARCH AND CONSERVATION EFFORTS

Several studies on the distribution and numbers of Morro Bay kangaroo rats have been conducted with financial support from the California

[1] Dr. William Stansfield, Professor of Biology, California Polytechnic State University, San Luis Obispo, California 93407

Department of Fish and Game (Congdon 1971; Roest 1973, 1977; Toyoshima 1979, 1980) and have documented the decline of the animals as well as the reasons for it. Other studies by students at nearby California Polytechnic State University (Cal Poly) in San Luis Obispo, have produced information on habits, distribution, and taxonomic relationships (Souza 1958a, 1958b; Stewart 1958; Helsel 1962; McMillan 1971; Rosner 1972; Risser 1975, 1976). A three year study at Cal Poly determined that D. h. arenae, a closely related subspecies used as a surrogate for morroensis, could be bred in captivity (Daniels 1979, Kozik 1977, Studley 1978).

The State of California (Department of Fish and Game) recently purchased 50 acres of undeveloped land in the Pecho area, adjacent to Montana de Oro State Park, as the Morro Dunes Ecological Reserve, partly to protect kangaroo rat habitat from development (Gustafson 1978). Although a few animals were present on the reserve in 1978 and 1979, recent surveys (Gambs unpubl.) failed to capture any kangaroo rats in 1982 or 1983. Much of the area is now covered with dense vegetation which is past the stage best suited to kangaroo rats (Toyoshima 1980).

In 1983, habitat enhancement efforts were initiated at the Pecho area by the California Department of Fish and Game, U.S. Fish and Wildlife Service, California Conservation Corps, California Department of Corrections, and California Department of Parks and Recreation. Two small test patches (50 x 200 m) on public land were partially cleared of dense vegetation by hand in an effort to enhance the kangaroo rat

population there. Unfortunately, contemporary trapping efforts since 1980 have been unable to confirm the presence of kangaroo rats in the Pecho area. Thus the suitability and effectiveness of brush removal as an appropriate habitat enhancement technique cannot be evaluated at this time.

Several rare plants (Table 5) also are found on the reserve. Their presence may require increased care during efforts to improve habitat conditions for the kangaroo rats. Rare plants were not observed in the areas cleared of dense brush.

The banded dune snail (Helminthoglypta walkeriana) may occur on the reserve but has not been observed by Department of Fish and Game personnel. It occurs elsewhere in the Pecho area, and on the sand spit which separates Morro Bay from the Pacific Ocean as well (Hill 1974, Roth 1972). Similarly, the rare plants are found throughout the area south of Morro Bay; but only a few specimens of each species actually grow on the reserve. Initial steps have been taken toward development of a vegetation management program which considers these several species and their requirement. (Lidberg 1979).

SUMMARY

The Morro Bay kangaroo rat is a unique subspecies occupying a small, isolated area in central California. In the past 23 years the population has been reduced to less than 350 individuals occupying several small parcels of suitable habitat which total approximately

Table 5. Rare plants of the Morro Dunes Ecological Reserve (Roest 1977).

Morro Manzanita (Arctostaphylos morroensis)*

Grows on old, established sand dune deposits.

Blochman's Leafy Daisy (Erigeron foliosis var. blochmanae)

Pholisma (Pholisma arenarium)

Parasitic on Mock Heather (Happlopappus ericoides).

Dune Shrubby Groundsel (Senecio blochmaniae)

Locally abundant.

Sand Almond (Prunus punctata)

Locally abundant.

Morro Dune Pennyroyal (Monardella undulata var. undulata)

Locally abundant.

Morro Dune Phlox (Eriastrum densifolium var. patens)

Needs taxonomic evaluation.

Dune Wallflower (Erysimum suffrutescens)

* Under Review by U.S.F.W.S.

320 acres (130 ha). The decline is the result of habitat loss. Much of the original range has been developed for housing, or now supports mature coastal scrub vegetation which is no longer suitable for the animal. The basic features of kangaroo rat habitat requirements are known, but additional details concerning several aspects of their life history are required to insure proper management of this subspecies and its habitat.

PART II

RECOVERY

OBJECTIVES

The Morro Bay kangaroo rat is endangered because the habitat it requires is rapidly disappearing. The loss of habitat has two primary causes: (1) human development has converted much of the original range to houses and streets; (2) on still undeveloped areas, maturation of the vegetation has produced conditions which are no longer suitable for kangaroo rats. To halt further losses of kangaroo rat habitat, land must be preserved from development, and the vegetation on such land must be managed to maintain optimum conditions for kangaroo rats. Good kangaroo rat habitat can be expected to support populations of at least 15 rats per acre (37/ha). The vegetation management program outlined below would maintain about half of any protected area in optimum habitat condition at any given time, and from 400 (162/ha) to possibly as much as 650 acres (263/ha) are presently available which could be so managed. However, because much of the habitat is in private ownership, it is doubtful the entire 650 acres (263/ha) would be managed to the benefit of the kangaroo rat. The objective of the plan is to preserve sufficient land, maintained at optimum habitat conditions, to assure a population of at least 2,500 kangaroo rats. Maintaining a minimum population of 2,500 Morro Bay kangaroo rats for each of three consecutive years will enable consideration of reclassification to threatened status. Because of the limited amount of habitat remaining for this kangaroo rat, the

necessity of regularly maintaining the habitat to assure optimum environmental conditions, and the small population size the probability of fully recovering this subspecies is remote.

MORRO BAY KANGAROO RAT

STEP-DOWN OUTLINE

Prime Objective: To preserve sufficient land and maintain optimum habitat conditions on that land, to assure a Morro Bay kangaroo rat population of at least 2,500 animals. Attainment of this goal for three consecutive years will enable consideration of reclassification to threatened status.

1. Protect, secure, and enhance existing Morro Bay kangaroo rat habitat.
    11. Protect additional essential kangaroo rat habitat (in priority order).
        111. Remaining portions of the Pecho area.
        112. Eastern area.
        113. Bayview area.
        114. Buckskin area.
        115. Turri area.
    12. Rehabilitate or create Morro Bay kangaroo rat habitat.
        121. Determine most effective and least disruptive means of restoring and maintaining appropriate habitat conditions.
            1211. Research to assess effectiveness of burning.
            1212. Research to assess effectiveness of mechanical brush removal.

1213. Research to assess effectiveness of other methods of habitat restoration.

122. Develop and implement habitat management plans for remaining kangaroo rat habitat.

1221. Hazard area, Montana de Oro State Park.

1222. Pecho site (the Morro Dunes Ecological Reserve and adjacent park lands)

1223. Pecho area (private lands).

1224. Eastern area.

1225. Bayview area.

1226. Buckskin area.

1227. Turri area.

13. Monitor existing habitat conditions.

131. Conduct detailed habitat surveys.

132. Maintain and regularly update habitat conditions on maps or aerial photographs.

2. Maintain and enhance Morro Bay kangaroo rat populations.

21. Determine environmental requirements of kangaroo rats.

211. Delineate precise usage of various seral stages of the habitat.

212. Obtain data on soil preferences.

22. Determine population dynamics of kangaroo rats.

221. Assess natural natality and longevity.

222. Assess mortality, both natural and man-induced (road kills, off-road vehicle effects, domestic cat predation, etc.).

23. Determine ecological and behavioral relationships of kangaroo rats.
    231. Disperal behavior and new habitat reoccupation rates.
    232. Establish life table and population replacement rates.
    233. Reproductive biology.
    234. Competitive interactions, both interspecific and intraspecific.
    235. Food preferences and relationships to plant seed production and reproduction.
24. Annually evaluate kangaroo rat population status.
    241. Hazard area.
    242. Pecho area.
    243. Eastern area.
    244. Bayview area.
    245. Buckskin area.
    246. Any rehabilitated or otherwise modified areas (i.e., Turri area).
25. Artificially increase Morro Bay kangaroo rat population.
    251. Determine feasibility and techniques for breeding and release of captive bred animals into the wild.
        2511. Continue research on captive breeding of D. h. arenae.
        2512. Establish captive reared D. h. arenae in Arroyo Grande-Point Conception area.
    252. Develop a Morro Bay kangaroo rat captive breeding program.

2521. Capture Morro Bay kangaroo rats from the wild.

2522. Breed Morro Bay kangaroo rats in captivity and produce young for release to the wild.

253. Reestablish wild populations of Morro Bay kangaroo rats.

2531. Select and prepare release sites.

2532. Release captive-reared Morro Bay kangaroo rats into selected habitats.

2533. Protect released animals.

2534. Monitor the released animals to assess the success of the program.

254. Translocate wild Morro Bay kangaroo rats to selected habitats on protected public lands, if necessary and appropriate.

2541. Capture wild Morro Bay kangaroo rats from unprotected private lands.

2542. Select and prepare release sites.

2543. Release wild animals on public lands.

2544. Protect released animals.

2545. Monitor released animals to assess the success of the translocation.

3. Foster interest in and support for, preservation of the Morro Bay kangaroo rat and its ecosystem.

31. Establish displays at the natural history museum at Morro Bay State Park.

32. Issue press releases on the natural history and status of kangaroo rats.

33. Develop displays and/or posters for public exhibit.

34. Make presentations about kangaroo rats available as programs for local schools, clubs, and similar groups.

4. Enforce laws and regulations protecting Morro Bay kangaroo rat and its habitat.

41. Protect Morro Bay kangaroo rat habitat; enforce trespass.

42. Enforce State and Federal regulations protecting Morro Bay kangaroo rat.

43. Coordinate action of enforcement personnel and others of Morro Bay kangaroo rat status and recovery effort.

NARRATIVE

The prime objective of the Morro Bay Kangaroo rat Recovery Plan is to preserve, protect and maintain sufficient habitat to support a Morro Bay kangaroo rat population of at least 2,500 individuals. Once this goal is maintained for three consecutive years, the taxon may be considered for reclassification to threatened status.

Perhaps the greatest problem in the protection and management of the Morro Bay kangaroo rat is the lack of precise data on the amount and specific features of the habitat necessary to achieve the prime objective. Several habitat characteristics, and not merely the successional stage of the vegetation, are critical to the design of viable reserves for the Morro Bay kangaroo rat. Important considerations include, but are not limited to, reserve size, the proximity to human developments, topographic features, occurrence and distribution of food plants, extent of appropriate sandy soils, potential for predation by wild and domestic animals (dogs and cats), and the extent or magnitude of human disturbance (e.g., off-road vehicles, and foot and equestrian traffic, etc.). The most critical need at this time, however, is to secure and maintain those areas with extant kangaroo rat populations.

Existing kangaroo rat habitat must be protected and enhanced (1). Protection of essential habitat for the Morro Bay kangaroo rat may be accomplished through acquisition, memoranda of understanding, or

conservation agreements (11). Morro Bay kangaroo rats are known to exist on only four undeveloped parcels of land within their original range. Three of these parcels are privately owned, as well as part of the fourth. Two other areas could provide suitable habitat if properly managed. A Land Protection Plan will be written for this task.

Protection of the Pecho area is essential to the kangaroo rat's conservation (111). The Pecho area consists of approximately 250 acres (101 ha) of which about 160 acres (65 ha) are within the original kangaroo rat range. The entire 160 acres (65 ha) lies within the critical habitat already designated for the animals (Sections 14 and 23, Township 30 S, Range 10 E; see Figure 3). The Morro Dunes Ecological Reserve occupies about 50 acres (20 ha) of this area, and State Park land accounts for about 70 acres (28 ha). The remaining land, approximately 40 acres (16 ha), is privately owned. Morro Bay kangaroo rats have been reported on only 20 acres (8 ha) within the ecological reserve boundaries. The vegetation throughout most of the area is past the stage considered optimum for kangaroo rats, and in 1979, less than 25 animals occupied the area, all on the reserve. The entire area, if protected from future development, would form a natural, defensible, and manageable extension of the reserve and state park. A vegetation control program throughout the Pecho area should produce conditions that could support over 800 kangaroo rats.

Essential kangaroo rat habitat within the Eastern area must also be secured (112). The Eastern area encompasses about 50 acres (20 ha) and supports vegetation that has matured to a point close to the limit

for optimum kangaroo rat habitat. Within a few years, if left undisturbed, the habitat will progress beyond the stage suitable for the kangaroo rat. Just east of the area an additional 30 to 40 acres (12-16 ha), formerly cultivated, has recently reached the proper stage for kangaroo rats, and in 1979 they were beginning to invade it. The Eastern area proper supported a population of about 85 rats in 1979, and a few were more on the new land to the east. With proper vegetation control at least 250 animals could exist on the area--more if the adjacent land is also protected.

The Bayview area, consisting of about 50 acres (20 ha) of occupied habitat, is part of a larger, 200-acre (81 ha) parcel for which development plans have already been prepared. About 175 acres (71 ha) of the Bayview site provides the largest contiguous area of potential Morro Bay kangaroo rat habitat within the original range. As such, if it were protected from development and properly managed, it could support a substantial population of kangaroo rats possibly as many as 850 (113).

Although vegetation growth over most of the neighboring portions of the tract has progressed beyond optimum habitat conditions, about 170 kangaroo rats occupied the Bayview portion in 1979. Proper vegetation management could restore this area to even greater productivity. Stewart (1958) estimated populations as high as 75 rats per acre (185/ha) on this area. A population of at least 250 animals could easily be supported on the existing 50 acres of suitable habitat if appropriate buffers are included.

An additional 50 acres (20 ha), known as the Buckskin area, is completely surrounded by developed land (114). Small parcels around the periphery of the area are regularly being sold and homes constructed on them. This does not appear to be the best habitat for kangaroo rats because there has been little change in the vegetation during the past 20 years, but the kangaroo rat population in 1979 was only about 65 animals. Human use of the area is fairly heavy. Protection of the area from development and excessive human activity, in conjunction with a vegetation control program, might result in a population of about 250 animals. Additional efforts to enhance the habitat might be needed to achieve this population figure.

A sixth area, along the south side of Turri Road, supported a small population of kangaroo rats 20 years ago. Although they do not occur there at present, if this area was protected and managed (115), the 50 additional acres (20 ha) of habitat there could support 250 more kangaroo rats.

In summary, the total area in which Morro Bay kangaroo rats either currently exist or could exist if managed to their advantage, is about 580 acres (236 ha). Of this, at least 220 (88 ha) acres [100 acres (40 ha) at Hazard and 120 acres (48 ha) at Pecho] are in public ownership.

Land values in the unincorporated area south of Morro Bay (the Baywood-Los Osos Community) are currently high and are increasing. Consequently, many land owners are reluctant to participate in any

agreement or contract which would restrict their ability to obtain a profit from the land. Nonetheless, if the kangaroo rat is to be saved, habitat must be protected from development.

Mere protection of kangaroo rat habitat, however, will not insure recovery. In most cases it will be necessary to rehabilitate habitat (12). The best kangaroo rat habitat is that of the earlier successional stages of vegetation which follow shortly after mature coastal scrub vegetation is removed. Over a period of years, the plant cover slowly matures toward dense coastal scrub vegetation, becoming less suitable for kangaroo rats as time passes. Consequently, to maintain optimum habitat on any protected area, a program of vegetation management is required.

The restoration program should consider that each area recommended for protection is isolated from the others, and will have to be managed as a self sustaining individual unit (121). In addition, each area should support a sufficient number of animals to insure that at least a few individuals would survive following some catastrophic event (total habitat destruction from fire, excessive predation by cats, contagious disease, etc.). It should also be large enough to avoid problems of inbreeding or genetic drift. A minimum of at least 50 animals is recommended although 500 would be preferable.

During restoration, an area should never be completely cleared of vegetation, because the resulting bare land would not support kangaroo rats. Some vegetative cover is required. Each cleared area should be

adjacent to an existing kangaroo rat population, so that animals could colonize the cleared areas as the vegetational cover becomes suitable. This would avoid any problems that may arise with efforts to transplant animals from elsewhere.

Clearing an area of vegetation could be accomplished several ways. Historically, fires modified vegetation patterns over large areas, and a controlled burn would be the most natural and cost-effective method of managing the vegetation. Use of fire as a tool in central California, noted for many destructive burns, may be controversial because of local concerns for safety and maintaining scenic values.

In this region, agricultural land and home sites are usually cleared with a bulldozer. The vegetation is broken up as the machine moves back and forth, then gathered into piles for burning, or simply shoved off the site. This method is effective, and well-known locally. However, such machinery will compact soils, and may perhaps crush burrows and animals.

The use of herbicides should be given more consideration. An integrated vegetation management program using selective, non-persistent herbicides in conjunction with hand and mechanical treatments and prescribed fire may provide the best results in maintaining optimum kangaroo rat habitat.

Lidberg (1979) suggested selective removal of vegetation by hand labor as a method for enhancing the habitat on the Morro Dunes Ecological

Reserve, so that cover would be reduced. However, plant and animal life in this region is well-adapted to periodic fires, and if small patch burns are used the rotational clearing recommended above should be no more destructive to the snail or the plants than it should be for the kangaroo rats. The plants would soon revegetate and some in fact, may do better after a burn. The surviving snails would find shelter in the oldest vegetation on each protected area. Total removal of the vegetation on limited sections of each area by fire (or if no other way is feasible, by bulldozer) would be similar to the natural conditions that existed in this region prior to the development that has occurred during the past 50 years. Therefore,, research on the most cost-effective methods of vegetation removal [i.e., burning (1211), mechanical removal (1212), or other means (1213)] should be undertaken.

A management plan for each protected area should be developed which would outline the methods to be used for vegetation management and the time sequence for such rehabilitation (122). A rotational pattern of vegetation clearing is suggested, duplicating on a small scale on each area what probably took place throughout the total range of the animals in the past.

Following such a pattern, only a portion of each managed area would be optimum habitat at any given time. The optimum areas should be large enough to support at least 100 animals, preferably 500, which sets a minimum size required for each protected area. All the remaining areas that still support kangaroo rats are at least 50 acres (20 ha),

and this is recommended as a minimum size. Areas of this size will require carefully designed buffers and other protective measures such as regular, almost daily patrols. Larger areas may be more easily managed expecially if they are adjacent or close to existing public lands.

A 50 acre (20 ha) protected area could be subdivided into at least four sections of about 12 acres (4.9 ha) each. One of these sections should be cleared every few years, so that over a period of years all areas would be cleared. The resulting vegetation that develops on the area will represent four successional stages.

The time interval between clearings may differ on different areas as a result of the type of clearing, local differences in exposure, available water, and rates of plant growth. Specific clearing schedules, based on the observed local rates of plant succession, should be developed for each area. Initially, a three year interval is suggested between clearing each quarter of an area so that over a 12 year period the entire area would have been cleared and the first treated section would again be ready for clearing. Thus, at least half the area would always have a cover of three to six year old vegetation, probably optimum for kangaroo rats. Animals living on sections with older vegetation could readily move into sections with earlier successional stages, as suitable habitat conditions developed. Based on previous observations in the region, a section could be expected to support a population of about 10 rats per acre (25/ha) three years after being cleared. A longer interval between clearings

may be necessary if this density is not achieved in three years. After approximately 12 to 15 years, unmodified vegetation may be too dense to provide suitable habitat for the kangaroo rat.

A protected area of 50 acres (20 ha), managed as outlined above, would have 25 acres (10 ha) of optimum habitat available for kangaroo rats at any time. At a density of 10 rats per acre (25/ha) (a conservative estimate in good habitat), the area should support at least 250 animals, and might support more.

Prior to any vegetation clearing, each area should completely be trapped to determine the number of rats present, and their distribution on the area. Whenever possible the first clearing should be made in the section with the fewest animals, or where there are no kangaroo rats, and preferably adjacent to a good population to enhance immigration into the restored site. This will usually coincide with the area where the vegetation is thickest.

Each year additional live-trapping will be necessary to learn just when the animals begin to occupy a cleared section and what the condition of revegetation may be at that time. When the population increases to a density of 10 rats per acre (25/ha), vegetation clearing can proceed to the next uncleared section. Additional monitoring each year will permit further refinements to the clearing schedule for each protected area.

A management plan should be prepared and implemented for the Hazard area (1221). This area consists of approximately 100 acres (40 ha) within the boundaries of Montana de Oro State Park that is completely protected from development. The vegetation over much of this area is past the stage of optimum kangaroo rat habitat, and it is not known whether Morro Bay kangaroo rats are still extant there. Parts of the area are subjected to fairly heavy use by park visitors (hiking, horseback riding). California ground squirrels (Spermophilus beecheyi) are beginning to invade the southern part of the area, the only locality where this species may come into contact with the kangaroo rat. A vegetation control program should be developed for this area, in cooperation with the California Department of Parks and Recreation. Also, the competitive relationships between ground squirrels, and kangaroo rats should be investigated at the site (see 234). The area could support a population of about 500 kangaroo rats, although none have been verified in the area recently (Roest, pers. obs.).

A habitat management plan has been developed and is now being implemented for Morro Dunes Ecological Reserve (1222). Such a plan is also needed for the State Park land in the Pecho area. Plans for both the Ecological Reserve and State Park land at Pecho should be combined into a single plan. A management plan is also needed for the remaining private land in the Pecho area (1223). Management plans should also be developed for the Eastern area (1224), Bayview area (1225), Buckskin area (1226), and Turri area (1227). The above plans

should be implemented once the lands are under State or Federal management control.

Existing habitat conditions and distribution of the Morro Bay kangaroo rat should be evaluated periodically (13) by conducting detailed habitat surveys (131) and by maintaining and updating maps based on aerial photographs (132). Regular evaluations should also be made on the plant succession which follows clearing on each area. Vegetation varies from one area to the next and differences in specific successional patterns are expected.

To maintain and enhance kangaroo rat populations (2), it is necessary to define their environmental requirements precisely (21). This may be accomplished by examining kangaroo rat use of the various seral stages (211) and by determining soil preferences (212).

Morro Bay kangaroo rat population dynamics should be assessed (22) by analyzing natality and longevity (221) as well as mortality factors (222). The presence and abundance of other animal species, both potential predators and competitors, should be determined. The habits of local domestic cats, in particular, and their potential effect on kangaroo rats, should be evaluated. Examination of owl pellets for rat ear tags may contribute data on owl predation.

Ecological and behavioral relationships of kangaroo rats must be evaluated (23) by studying dispersal and recolonization rates (231), establishing a life table and population replacement rates (232) and

obtaining data on reproductive biology (233). These data will enhance our knowledge, specifically in regard to management; they will help determine how fast a restored area may be recolonized and possible optimum population sizes. Research on possible competitive relationships (234) as well as food selection versus availability (235), will aid in determining how best to manage and/or restore habitats for the kangaroo rat.

The kangaroo rat population on each protected, managed area should be censused at least once each year (24), to allow adjustments in the clearing schedule, and to evaluate the success of this plan. Because of the nocturnal, burrowing habits of the kangaroo rat, this information can be obtained by live-trapping. Each animal captured should be individually marked with a numbered ear tag. Standard Sherman live traps are effective, but the slightly longer [12" (30 cm)] design is preferred because they would reduce the number of tail tips lost in trap doors.

Trapping efforts conducted in the fall of 1982 and spring and summer of 1983 by Dr. Roger Gambs under contract to the FWS failed to locate any Morro Bay kangaroo rats on public land after more than 6,000 trap nights. The implication is that the Morro Bay kangaroo rat is now absent from the public lands. During this same time kangaroo rats were confirmed at only one area, the Bayview site. No specific details are available for any other private lands, however, because of problems with access.

Because the privately-owned Bayview site is now slated for development, it appears that artificial propagation will be necessary to prevent the extinction of the Morro Bay kangaroo rat (25) unless the site can be secured by other means. Even then there may be so few animals that captive breeding will still be required.

In anticipation of this contingency, research on captive propagation of the closely related Dipodomys heermanni arenae was initiated by Roest (unpubl.). As a consequence, some information on the feasibility and methods for captive propagation are available but additional information is needed (251, 2511). Specifically, methods for the release of captive-produced animals must be developed to assure successful reestablishment on the public land. This will be accomplished best by using the surrogate (2512) to test the methods and assess survival in the wild.

During the development of release methods a captive breeding program for the Morro Bay kangaroo rat should be initiated (252). This will entail the capture of breeding stock from the only known extant colony at Bayview (2521). Breeding facilities must therefore be established, preferably in the region of Morro Bay where conditions are similar to the natural environment (2522). It is anticipated that captive breeding for the Morro Bay kangaroo rat has a high chance of success, considering the past successes for other kangaroo rats including the closely related D. h. arenae.

Once methods and procedures have been developed for releasing captively-reared young, efforts should be initiated to reestablish the Morro Bay kangaroo rat on the public land at Pecho. The time schedule will, of course, be dependent upon the time required to develop appropriate release methods, the number of animals captured for breeding, their rate of production, and the time required to prepare appropriate habitat conditions. Once Tasks 2521 and 2522 have been accomplished, release of captive-bred animals back into the wild can proceed (2532) following the selection and preparation of appropriate release sites (2531), establishment of law enforcement and ranger patrols (2533) and initiation of a monitoring program (2534).

In addition to the release of captive bred individuals it may also be possible to translocate wild animals back to protected public lands (254). The opportunities for using translocation, however, will depend upon the number of animals available in the wild population. If only a few animals remain it may be necessary to take animals for captive breeding, thus effectively precluding translocation. It is highly desirable to retain a wild population at Bayview if at all possible.

If translocation is determined to be feasible and appropriate, release sites must be selected and prepared (2542). Animals must then be captured (2541). When animals are released protective law enforcement patrols must be initiated (2544) and a monitoring program established (2545).

Most local residents have at least heard of the Morro Bay kangaroo rat, but the vast majority have no idea what it looks like. The name itself--kangaroo rat--suggests to many a rather unpleasant and undesirable animal. Since the Morro Bay kangaroo rat was declared an endangered species and critical habitat designated, there has been more awareness of its existence. Construction plans for sites within historic habitat of the kangaroo rat will require an environmental impact report. For those sites with confirmed populations of the kangaroo rat, suitable conservation measures must be implemented. Moreover, any proposed conservation measures must be approved by the U.S. Fish and Wildlife Service.

At best, local concern about Morro Bay kangaroo rats is one of mild interest, with the exception of a minority of conservation oriented individuals. To achieve local support (3) for setting aside several areas for the animals, an educational program should be developed. Information about the Morro Bay kangaroo rat and the unusual coastal dune scrub ecosystem they inhabit should be made available to news media (32) and schools (34). Informative displays (33) should be prepared at appropriate locations, such as the Morro Bay Museum of Natural History (in Morro Bay State Park) (31).

Laws and regulations protecting the Morro Bay kangaroo rat and its ecosystem should be enforced (4) to provide for maximum conservation efforts for this subspecies. Habitat should be protected by enforcing trespass laws (41). Disturbance to individual kangaroo rats should be eliminated or minimized (42). Coordination among the Fish and

Wildlife Service, California Department of Parks and Recreation, and California Department of Fish and Game, and their respective law enforcement personnel is essential. Rangers and wardens should be kept informed of the status of the kangaroo rat and current recovery actions (43).

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PART III

IMPLEMENTATION SCHEDULE

The table that follows is a summary of scheduled actions and costs for the Morro Bay kangaroo rat recovery program. It is a guide to meet the objectives of the recovery plan for the Morro Bay kangaroo rat, as elaborated upon in Part II, the Narrative. This table indicates the general category for implementation schedule tasks, corresponding action outline numbers, task priority, duration of the tasks, which agencies are responsible to perform these tasks, and the estimated cost of implementation. Implementing Part III is the action of the recovery plan, that when accomplished, will bring about the protection of the Morro Bay kangaroo rat and its unique habitats.

GENERAL CATEGORIES FOR IMPLEMENTATION SCHEDULES

Information Gathering - I or R (research)

1. Population status
2. Habitat status
3. Habitat requirements
4. Management techniques
5. Taxonomic studies
6. Demographic studies
7. Propagation
8. Migration
9. Predation
10. Competition
11. Disease
12. Environmental contaminant
13. Reintroduction
14. Other information

Acquisition - A

1. Lease
2. Easement
3. Management agreement
4. Exchange
5. Withdrawal
6. Fee title
7. Other

Management - M

1. Propagation
2. Reintroduction
3. Habitat maintenance and manipulation
4. Predator and competitor control
5. Depredation control
6. Disease control
7. Other management

Other - O

1. Information and education
2. Law Enforcement
3. Regulations
4. Administration

RECOVERY ACTION PRIORITIES

1 = An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

2 = An action that must be taken to prevent a significant decline in the species population/habitat quality, or some other significant impact short of extinction.

3 = All other actions necessary to provide for full recovery of the species

PART III

Implementation Schedule - Morro Bay Kangaroo Rat

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
A7	Protect Pecho area	111	1	Continuous	1	SE	CDFG* CDPR		To Be Determined			
A7	Protect Eastern area	112	1	Continuous	1	SE	CDFG*		To Be Determined			
A7	Protect Bayview area	113	1	Continuous	1	SE	CDFG*		To Be Determined			

a/ Agency abbreviations:
CDFG = California Department of Fish and Game
CDPR = California Department of Parks and Recreation
FWS = U.S. Fish and Wildlife Service.
Other abbreviations: SE = endangered species
LE = law enforcement
PE = public affairs

* = Lead agency
Ongoing = Task currently underway and will continue from year to year
Continuous = When funding becomes available, task will continue from year to year

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
A7	Protect Buckskin area	114	1	Continuous	1	SE	CDFG*		To Be Determined			
A7	Protect Turri area	115	1	Continuous	1	SE	CDFG*		To Be Determined			
R4	Research to assess effectiveness of burning	1211	1	3	1	SE			2	2	2	
							CDFG		2	2	2	
							CDPR*		10	10	10	
R4	Research to assess effectiveness of mechanical vegetation removal	1212	1	3	1	SE*		8	8	2		Initiated in FY 83 AWPA #5e (8) #5e (13) FY 84
							CDFG	2	2	2		
							CDPR		2	2		
R4	Research to assess effectiveness of other methods of vegetation removal	1213	1	3	1	SE			2	2	2	
							CDFG		2	2	2	
							CDPR*		8	8	8	
M3	Hazard area management plan-Montana de Ora State Park	1221	1	1			CDFG	4				
							CDPR*	1				
M3	Management plan for public lands on Pecho site	1222	1	1			CDFG*	4				
							CDPR	1				
M3	Management plan for remaining Pecho area	1223	1	1			CDFG*		10			

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
M3	Eastern area management plan	1224	1	1			CDFG*		10			
M3	Bayview area management plan	1225	1	1			CDFG*				10	
M3	Buckskin area management plan	1226	1	1			CDFG*				10	
M3	Turri area management plan	1227	1	1			CDFG*			10		
I2	Conduct detailed habitat surveys	131	2	Ongoing	1	SE*	CDFG*	5 2	5 2	5 2	5 2	AWPA #5e (13)
I3	Maintain and regularly update habitat conditions on maps or aerial photographs	132	2	Ongoing	1	SE*	CDFG*	1 0.5	0.5 0.5	0.5 0.5	0.5 0.5	AWPA #5e (13)
R3	Delineate precise usage of various seral stages of the habitat	211	1	2	1	SE*	CDFG	2 1	2 1			
R3	Obtain data on soil preferences	212	2	1	1	SE*	CDFG		2 1			
R1	Assess natural natality and longevity	221	2	4			CDFG*	5	5	5	5	

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
R1	Assess mortality, both natural and human-induced	222	1	3			CDFG*		5	5	5	
R8	Dispersal behavior and new habitat reoccupation rates	231	1	3	1	SE			2	2	2	
							CDFG*		3	3	3	
R6	Establish life table and and population replacement rates	232	2	5	1	SE		2	2	2	2	
							CDFG*	3	3	3	3	
R1	Reproductive biology	233	2	3			CDFG*	2.5	2.5	2.5		
R10	Competitive interactions, both interspecific and intraspecific	234	2	3	1	SE				2	2	
							CDFG*			3	3	
R3	Food preferences and relationships to plant seed production and reproduction	235	2	3	1	SE			1	1		
							CDFG*	3.5	2	2		
R1	Evaluate Hazard area population	241	1	Ongoing			CDFG*	1	1	1	1	
R1	Evaluate Pecho area population	242	1	Ongoing			CDFG*	1	1	1	1	
R1	Evaluate Eastern area population	243	1	Ongoing			CDFG*	1	1	1	1	

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
R1	Evaluate Bayview area population	244	1	Ongoing			CDFG*	1	1	1	1	
R1	Evaluate Buckskin area population	245	1	Ongoing	1	SE*		2.0	2.0	2.0	2.0	AWPA #5e (13)
							CDFG	1.5	1.5	1.5	1.5	
R1	Evaluate any rehabilitated or otherwise modified areas	246	1	Ongoing	1	SE*		2.0	2.0	2.0	2.0	AWPA #5e (13)
							CDFG	1.5	1.5	1.5	1.5	
R7	Continue research on captive breeding of D. h. arenae	2511	1	3	1	SE*		2	2	2		
							CDFG	2	2	2		
R7	Reestablish captive reared D. h. arenae in the Arroyo Grande-Point Conception area	2512	1	5	1	SE			3	3	3	
							CDFG*		7	7	7	
M1	Capture Morro Bay kangaroo rats from wild	2521	1	3	1	SE*		5	2.5	2.5		
							CDFG		2.5	2.5		
M1	Produce young Morro Bay kangaroo rats for release into the wild	2522	1	8	1	SE*		20	15	15	15	
							CDFG	5	5	5	5	
M2	Select and prepare release sites	2531	1	8	1	SE			2	2	2	
							CDFG*		2	2	2	

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
M2	Release captive-reared Morro Bay kangaroo rats to selected habitats	2532	1	8	1	SE				5	5	
							CDFG*			5	5	
M7	Protect released animals	2533	1	Continuous	1	LE				5	5	
						SE				2	2	
							CDFG			5	5	
							CDPR*			10	10	
R14	Monitor released animals to assess success of program	2534	1	Continuous	1	SE				2	2	
							CDFG*			5	5	
							CDPR			5	5	
M2	Capture wild MBKR from unprotected private lands	2541	1	2	1	SE*			To be determined			
							CDFG					
M2	Select and prepare release sites	2542	1	3	1	SE				2	2	
							CDFG*			4	4	
							CDPR			2	2	
M2	Release wild animals on protected public lands	2543	1	3	1	SE			To be determined			
							CDFG*					
							CDPR					
R14	Monitor released animals	2545	1	10	1	SE			To be determined			
							CDFG					
							CDPR*					
M7	Protect released animals	2544	1	Continuous	1	LE				3	3	
						SE				3	3	
							CDFG			3	3	
							CDPR*			6	6	

General Category	Plan Task	Task Number	Task Priority	Duration of Task (Yrs.)	Responsible Agency FWS Region	FWS Program	Other Agencies	Estimated Fiscal Year Costs ($1,000's) FY84	FY85	FY86	FY87	Comments and Notes
01	Establish displays at the natural history museum at Morro Bay State Park	31	3	2			CDFG CDPR*	0.5 1.0	0.5 0.5			
01	Issue press releases on the natural history and status of kangaroo rats	32	3	Continuous	1	SE	CDPR CDFG*		To be determined			
01	Develop displays and/or posters for exhibit in local stores, etc.	33	3	1			CDFG*		0.5			
01	Make presentation about kangaroo rats available as programs for local schools, clubs, and similar groups	34	3	Ongoing	1	SE	CDFG* CDPR					
02	Protect Morro Bay kangaroo rat habitat; enforce tresspass	41	2	Ongoing	1	LE	CDFG* CDPR		To Be Determined			
02	Enforce State and Federal regulations protecting Morro Bay kangaroo rat	42	2	Ongoing	1	LE* SE	CDFG CDPR		To Be Determined			AWPA #3a
02	Coordinate action of enforcement personnel and others of Morro Bay kangaroo rat status and recovery effort	43	2	Ongoing	1	LE	CDFG*		To Be Determined			

APPENDIX:

LIST OF AGENCIES RESPONDING

DURING AGENCY REVIEW

U.S. Fish and Wildlife Service - Washington, D.C. and Portland, OR

California Department of Fish and Game - Sacramento, CA

California Department of Parks and Recreation - Sacramento, CA