DECLINE OF KANGAROO RATS DURING A WET WINTER IN THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

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ABSTRACT: During and following the 1994-1995 winter, biologists noted a decline in abundance of kangaroo rats (*Dipodomys* spp.) in the southern San Joaquin Valley. On 5 widely separated study areas, total captures and trap response were substantially reduced in comparison with 1994 and earlier results. Declines were noted in short-nosed (*Dipodomys nitratoides brevinasus*), Tipton (*D. n. nitratoides*), and Heermann's (*D. heermanni*) kangaroo rats, although only modest reductions were noted for giant kangaroo rat (*D. ingens*) populations on the valley floor. The 1994-95 winter was cooler and wetter than typical. Causes of the observed population decline in the San Joaquin Valley are speculative. Widespread flooding and short-term habitat degradation were not observed on the study sites, and are probably not factors. Thermal stress, reduced caloric value of seeds, disease, and mycotoxic factors could be involved. Interactions among several factors are likely. Conditions similar to the 1994-1995 winter have a historic probability of occurrence of 11%, and are widely dispersed over the last 45 years. Anthropogenic impacts to kangaroo rat populations could be more significant during cool wet winters; changes in conservation and protection strategies during these winters may be warranted. Consideration of the effects of catastrophic winter population declines, in addition to the effects of drought on kangaroo rat numbers, is merited in the long-term conservation planning for kangaroo rats in the San Joaquin Valley.

Key words: Heteromyidae, population ecology, *Dipodomys* sp., San Joaquin Valley, environmental fluctuation, regional population declines, weather, disease.

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Following the winter of 1994-1995, biologists working in the southern San Joaquin Valley noticed kangaroo rat (*Dipodomys*) tracks, droppings, and other sign were absent from sites where they were expected, and captures were low compared to previous experience. These observations indicated that kangaroo rat populations could have declined over a large portion of the range of 4 species. Precipitous population declines had not been reported from the San Joaquin Valley.

A similar decline of banner-tailed kangaroo rats (*Dipodomys spectabilis*) in Arizona may have been caused by a tropical storm (Valone et al. 1995). The population decline in Arizona was followed by a long-term depression of that population, and persistent increases in populations of competing granivorous rodents. The unpredictability of community responses to rapid changes in species composition, and to rapid declines in keystone species was discussed by Valone et al. (1995). Regional population declines or long-term population depressions of kangaroo rats in the San Joaquin Valley could be significant to the management and recovery actions planned for 4 of the 5 local species of kangaroo rats, and also have implications for our understanding of interspecific interactions and community ecology in the southern San Joaquin Valley. Here, we present a summary of population trends and site conditions for 5 separate study areas and 4 species of kangaroo rat in the southern San Joaquin Valley. We also discuss possible causal factors, and implications for the management of the affected kangaroo rat species.

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STUDY AREA AND METHODS

Information on species abundance was available for the short-nosed kangaroo rat (*Dipodomys nitratoides brevinasus*; a California Species of Concern, and former Federal List 2 Candidate), Tipton kangaroo rat (*D. n. nitratoides*; a California and Federal Endangered species); the giant kangaroo rat (*D. ingens*; a California and Federal Endangered species), and Heermann's kangaroo rat (*D. heermanni*) in the San Joaquin Valley. The climate of the San Joaquin Valley is mediterranean, with cool, wet winters and hot, dry summers. On the valley floor and adjacent low hills, where the study areas discussed herein are located, summer high temperatures reach over 38° C, and winter lows are generally above -1° C. Average annual rainfall is about 125-250 mm. Most precipitation falls as rain during winter and early spring (Twisselmann 1967).

Information was synthesized from studies being conducted at 5 study sites, spread over about 3150 km^2 (Fig. 1). The sites had been live-trapped for 1 or more years prior to the 1995 trapping period. Each site included from 1-20 independent trapping grids or lines. Trapping was generally conducted for 4 consecutive nights, using Sherman kangaroo rat traps or Sherman small mammal traps with doors modified to avoid injuring kangaroo rat tails. Traps were baited with birdseed, and there was usually 1 night of pre-baiting. For our purposes the results from these independent trapping locales were combined, and kangaroo rat species captured in low numbers (6 individuals or less) are not discussed. Study area vegetation is described after Holland (1986).

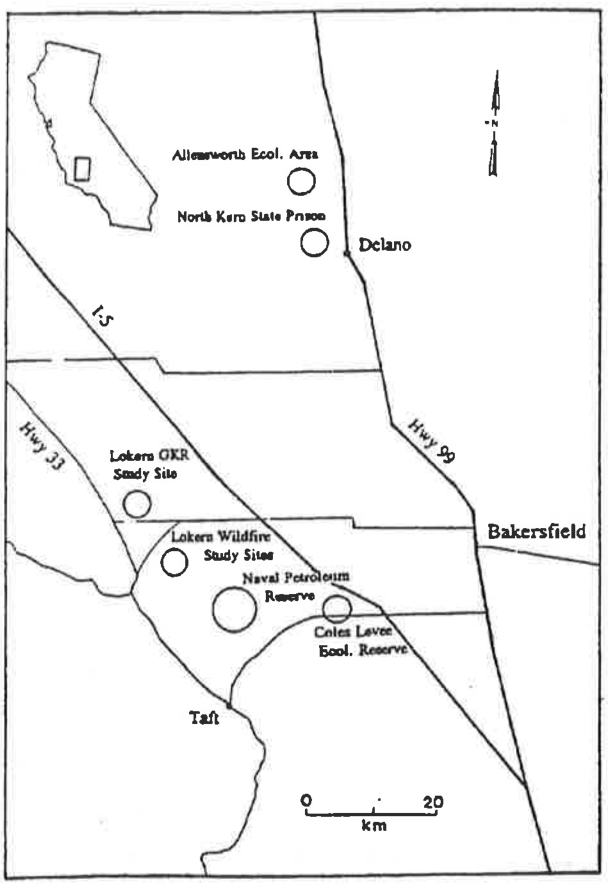


Fig. 1. Sites of rodent studies in the southern San Joaquin Valley, California, 1990-1995.

The wide distribution of affected populations suggests that any causative factor would be regionally pervasive. The basic characteristics of potential causes, plus the hypothesis regarding the effects of weather on the decline of banner-tailed kangaroo rats in Arizona (Valone et al. 1995), prompted a comparison of 1994-1995 winter temperature and precipitation in the southern San Joaquin Valley to data from previous years. Rainfall and air temperature data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Bakersfield weather station. Soil temperature data were obtained from the California Irrigation Management Information System (CIMIS) operated by the California Department of Water Resources.

Allensworth Ecological Area

Located about 8 km west of the town of Earlimart, Tulare County, the Allensworth Ecological Area was a mosaic of natural alkali sink, valley saltbush (*Atriplex*) scrub, and non-native grassland vegetation, as well as fallowed agricultural fields and active agriculture. Elevation is about 77 m. Live-trapping was conducted on 4 separate 100-trap (10 x 10, 10-m spacing) grids. Grids were 0.8-1.6 km apart. Trapping on each grid occurred over 5 consecutive nights in June 1993, 1994, and 1995 (M. Potter, unpubl. report, California Department of Fish and Game, Fresno, 1995).

North Kern State Prison

The grounds of the North Kern State Prison, about 3.2 km west of Delano, Kern County, included an undeveloped area of natural alkali sink, non-native grassland, and fallowed agriculture. Elevation is about 77 m. As part of a study of revegetation of the site and the reintroduction of Tipton kangaroo rats, live-trapping was conducted at 3 sites representing various revegetation treatments and at 1 control site (C. Uptain, unpubl. report, California Department of Corrections, Sacramento, 1995). At each site, trapping was conducted for 6 consecutive nights in September 1990 and 1991, and April-May 1991, 1993, 1994, and 1995. At each site live-traps were arranged in 2 primary parallel lines 53 m apart, each line containing 20 traps spaced 15 m apart.

Coles Levee Ecosystem Preserve

The Coles Levee Ecosystem Preserve is located along State Highway 119, approximately 24 km southwest of Bakersfield. The preserve, operated by Arco Western Energy as a conservation and mitigation bank, contained a variety of vegetation types, primarily non-native grassland, alkali sink, and valley saltbush scrub. Kangaroo rat trapping was initiated in 1994 and is to be conducted annually to establish population trends on portions of the preserve designated for conservation management.

The 1 monitoring site trapped in 1994 and 1995 was primarily non-native grassland. Elevation is 92 m. A 100-trap (10 x 10, 10-m spacing) grid was live-trapped for 4 consecutive nights in May 1994, and a 144-trap (12 x 12, 10-m spacing) grid was trapped for 6 consecutive nights in 1995 (M. Wolfe, unpubl. reports, Arco Western Energy, Bakersfield, 1994, 1995; S. Geddes, pers. comm.).

Lokern Natural Area: Wildfire Study Site

The Lokern Natural Area is a mosaic of state, federal, and private lands in western Kern County. Primary vegetation types were valley saltbush scrub, alkali sink, and non-native grassland. Elevation is about 245-275 m. Following a wildfire of approximately 815 ha in 1993, an interagency study of the impacts of that fire was undertaken by the Bureau of Land Management, California Energy Commission, U.S. Department of Energy, and California State University, Bakersfield. As part of the study, live-trapping was conducted on 10 independent trap-lines in saltbush scrub and grassland vegetation (5 lines in burned areas, 5 in unburned areas). Each trap-line consisted of 25 stations spaced 10 m apart, and each station had 2 Sherman live-traps (50 traps/line). Trap-lines were 0.2-0.4 km apart. Trapping was conducted for 3 consecutive nights in July 1993, February and October 1994, and April and October 1995 (Germano et al., unpubl. data).

Lokern Natural Area: Giant Kangaroo Rat Study Site

At a site on the eastern periphery of the Lokern Natural Area, there is an ongoing study of what is possibly the lowest elevation population of giant kangaroo rats (Germano and Saslaw, unpubl. data). The site elevation is about 92 m; the primary vegetation type was valley saltbush scrub. The site contained 1 12 x 12 grid (144 traps at 10-m spacing). Trapping was conducted for 6 consecutive nights in August 1993, April and August 1994, and April and September 1995.

Naval Petroleum Reserve Number 1, Elk Hills

The Naval Petroleum Reserve Number 1 is located in the Elk Hills of western Kern County, northeast of the city of Taft. The Reserve is a mixture of public and private lands encompassing about 184 km^2 and is administered by the U.S. Department of Energy for oil and gas production. Research and management on a variety of special status plants and animals is conducted on the Reserve as a consequence of consultation between the Department of Energy and the U.S. Fish and Wildlife Service under section 7 of the Federal Endangered Species Act. Elevations ranged from 92 to 462 m. Vegetation types included non-native grasslands and valley saltbush scrub. Live-trapping was conducted at 20 independent sites $\geq$0.8 km apart. Each site was trapped with a 50-trap, 25-station (7.5-m spacing) transect for 5 consecutive nights in September 1993, 1994, and 1995 (Cypher 1995)

RESULTS

Several sites showed substantial declines ($\geq$90 %) in numbers of individuals captured and rates of capture. At the 4 Allensworth sites, Tipton kangaroo rats comprised the majority of captures. A few Heermann's kangaroo rats also were present in some years and on some trap-grids. There was a declining trend in Tipton kangaroo rats from 1993 to 1995 (Fig. 2A). Tipton kangaroo rats also were the only kangaroo rat species captured at the North Kern State Prison site, but at that site there was an increase from 1993 to 1994, and a steep decline from 1994 to 1995 (Fig. 2B). Only results from the control plot are discussed here, but the other 3 plots showed a similar trend (Uptain, unpubl. data).

At the Coles Levee monitoring site, Heermann's kangaroo rats constituted almost all animals captured and their numbers also declined from 1994 to 1995 (Fig. 2C). At the Lokern Natural Area Wildfire Study Site, short-nosed, Heermann's, and giant kangaroo rats were captured. All species apparently increased in abundance from 1993 to 1994, and declined from 1994 to 1995 (Figs. 2D, 2E, 2F). In contrast, the giant kangaroo rat population at the lower elevation Lokern Giant Kangaroo Rat Study Site increased from 1993 to 1994, and remained relatively stable from 1994 to 1995 (Fig. 2G). Giant kangaroo rats constituted >99 % of captures at that site (Germano and Saslaw, unpubl. data). Although giant, Heermann's, and short-nosed kangaroo rats were present on the Naval Petroleum Reserve, almost no giant kangaroo rats were captured at the 20 study sites from 1993 to 1994 (Cypher 1995). Short-nosed and Heermann's kangaroo rats showed a stable or slightly increasing population from 1993 to 1994, and a decline from 1994 to 1995 (Figs. 2H, 2I).

The winter of 1994-1995 was relatively cool and wet. The pattern of precipitation and temperature was different from the previous 3 winters, of which 2 had an atypical distribution of precipitation, and 1 was near normal. Precipitation in winter of 1994-1995 was above normal for almost all months. Notably, October-December rainfall was at or above normal, which was not the pattern in the 3 previous winters (Fig. 3). Air temperatures also presented a different pattern in 1994-1995 than in the 3 previous winters. During 1994-1995, October-December air temperatures were below normal, but above normal in February and March (Fig. 3). Climatic water budget analysis for the Bakersfield region (S. Kruse, unpubl. report to California Department of Fish and Game, Fresno, 1996) predicted that available soil mois-

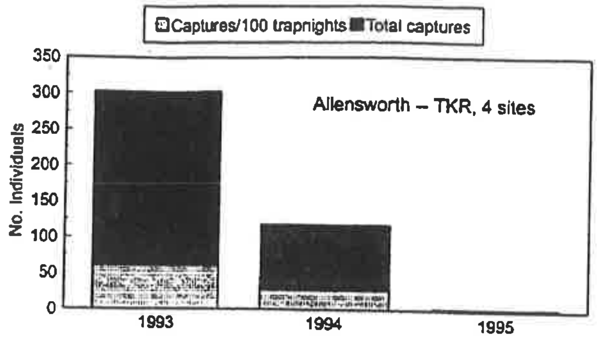


Fig. 2A

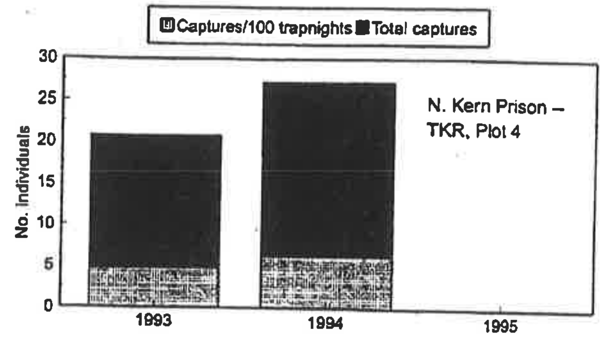


Fig. 2B

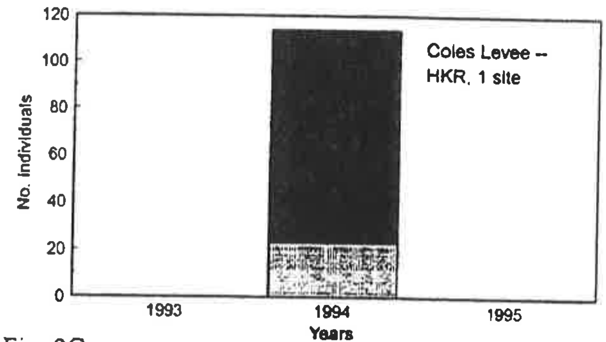


Fig. 2C

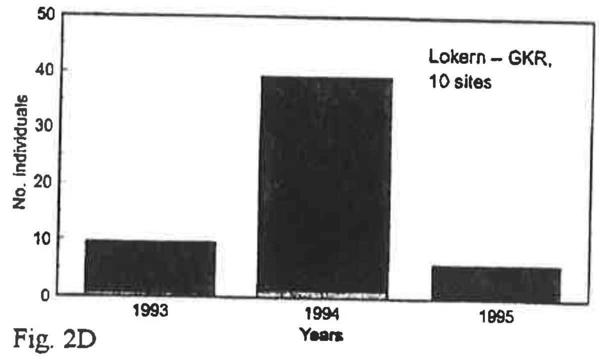


Fig. 2D

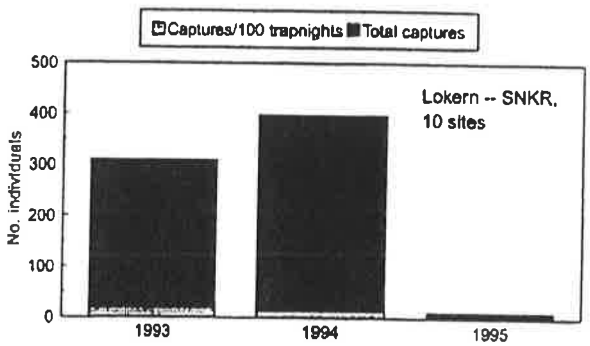
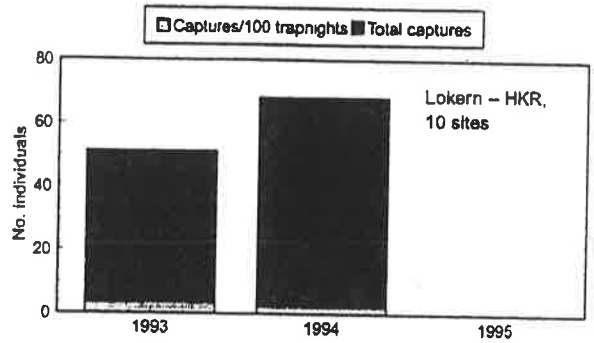


Fig. 2E



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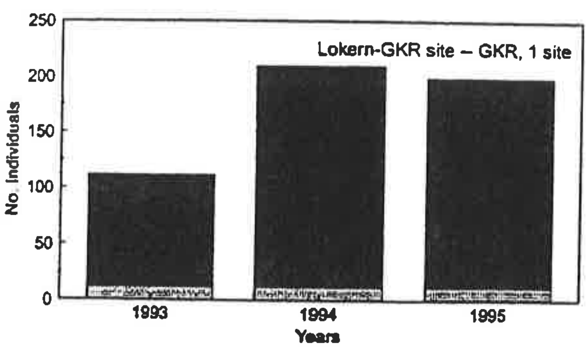

Fig. 2G

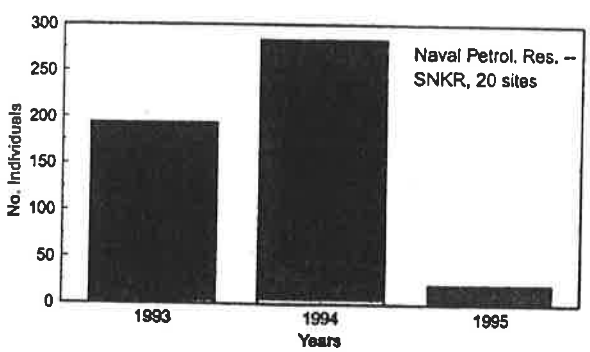

Fig. 2H

Fig. 2. Total number of kangaroo rats and number of kangaroo rats captured per 100 trap nights at study sites in the San Joaquin Valley, 1990-1995. GKR = giant kangaroo rat; HKR = Heermann's kangaroo rat; SKR = short-nosed kangaroo rat; TKR = Tipton kangaroo rat.

ture was greater during the 1994-1995 winter than during the previous 2 winters. We noted that the soil of kangaroo rat burrows excavated in April and May felt unusually damp, suggesting that soil moisture was retained for a longer period than normal in those sandy loams.

DISCUSSION

In addition to the trapping studies discussed above, incidental observations supported our idea that kangaroo rat populations in the southern San Joaquin Valley substantially declined in early 1995. The number of rodents captured at a site slightly above the valley floor northeast of Bakersfield was low in November-December 1994 (L. Saslaw, pers. comm.). At the Shafter-Wasco County landfill, a site centrally located on the valley floor, many Tipton and Heermann's kangaroo rats were captured in January 1995. Average levels of kangaroo rat sign were observed on the Kern Water Bank west of Bakersfield in January-February 1995, but no rodents were captured and there was little sign of activity in March-April 1995 (W. Rhodehamel, pers. comm.). At several sites in Kern County we observed average amounts of kangaroo rat sign in November and December 1995, but there was a noticeable absence of sign at the same or similar sites in February-March 1995. Kangaroo rat activity seemed average at the Naval Petroleum Reserve in December 1994 (B. Cypher, pers. comm.). Although there was a general lack of detailed information on kangaroo rat abundance covering the period from fall 1994 to spring 1995, our impression was that populations may have been at relatively average levels in fall and at least early winter. Lack of sign and a reduction in the number of animals trapped were noted in late winter and spring 1995.

A number of factors, singly or in combination, could have caused the observed wide-spread decline of kangaroo rats. Possible factors must be of regional scope, affect several species, and cause substantial mortality in a relatively short period, probably during late winter or early spring. Factors we considered as potential causes

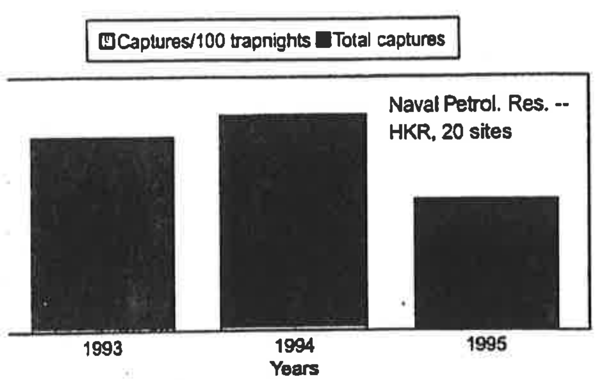

Fig. 2I

were short-term habitat degradation, flooding, thermal stress, diseases, fungal or microbial infections of seed, and pervasive dense groundcover.

Regionally synchronous short-term habitat degradation, occurring over 1-2 years, is 1 possible cause of the observed declines. However, habitat quality at the study sites was considered to have been relatively constant over the 2-3 years of trapping. At the North Kern Prison and Naval Petroleum Reserve, vegetation measurements confirmed these impressions of relatively minor changes in plant production or plant species composition across the years of record (Uptain, unpubl. data; B. Cypher, pers. comm.). Vegetative cover and productivity at the Coles Levee Ecosystem Preserve were equal to or greater than the previous year (M. Wolfe, unpubl. reports to ARCO Western Energy, Bakersfield, 1994, 1995).

Sustained flooding and short-duration sheet flooding occur in the region of the studies, and could cause population declines in affected areas. Sheet flooding may affect Stephens' kangaroo rat (*D. stephensi*) of southern California (P. Kelly, pers. comm.), and may have occurred on at least portions of the Allensworth and North Kern Prison sites (M. Potter, C. Uptain, pers. comm.). However, declines of similar magnitude were not noted at these sites in other wet years. Flooding could be an important stochastic mortality factor for local populations, but we think that it probably was not responsible for coordinated mortalities among the study areas. Flooding may have been significant to a greater segment of the populations of at least some species of kangaroo rats prior to extensive flood control now practiced in the San Joaquin Valley. Determining the relevance of flooding to regional populations would require characterization of both pre-flood control and current flood potentials, for a large number of sites and range of weather patterns, as well as detailed information on the direct and indirect effects of flooding on the species of interest.

A climate analysis by Kruse (unpubl. report to California Department of Fish and Game, 1996) using the 45 year record from the Bakersfield National Oceanic and Atmospheric Administration (NOAA) weather station, classified the 1994-1995 winter as relatively cool and wet, confirming our perceptions. The 1994-1995 winter weather conditions did not substantially exceed extremes of rain or cold that San Joaquin Valley kangaroo rats otherwise experience without noted widespread population declines. Soil temperatures recorded at 15 cm depth, from several stations of the California Irrigation Management Information System in the southern San Joaquin Valley, were almost identical over the 4 winters (1991-1994). Fifteen centimeters is near the shallow end of the range in depth of most burrows of Tipton and Heermann's kangaroo rats (Germano and

Rhodehamel 1995). At between 15-20 cm depth, diurnal soil fluctuations disappear (Fox and Hatfield 1983). However, the unusual combination of cool and wet conditions, possibly including unusually wet soil that may have increased thermal conductivity in burrows, might have stressed kangaroo rats more than normal. The available soil temperature and soil moisture records were not well suited to apply to this question. More focussed environmental measures in and around kangaroo rat burrows, plus direct physiological measurements, would be necessary to further investigate this topic.

There were some indications of diseased animals present from at least 1 site during the winter of 1994-1995. No samples from such animals were obtained and studied, but we found several Tipton kangaroo rats kept in captivity during February 1995 made raspy and wheezing sounds when breathing. This may have been caused by a respiratory infection, possibly due to the unusually wet weather.

A number of disease organisms, their antibodies, and known vectors have been reported from kangaroo rats in California, although little work has been conducted in the San Joaquin valley (Tabor and Thomas, unpubl. manuscript). Antibodies to viruses causing western equine encephalitis and St. Louis encephalitis (Togaviridae, Flaviviridae) have been found in San Joaquin (*D. nitratoides*) and Heermann's kangaroo rats (Hardy et al. 1972). Rickettsia are known from heteromyids: *Coxiella burnetii*, which causes Q fever, and *Rickettsia rickettsii*, which causes Rocky Mountain spotted fever. Seropositive responses to these, or the organisms themselves have been demonstrated in

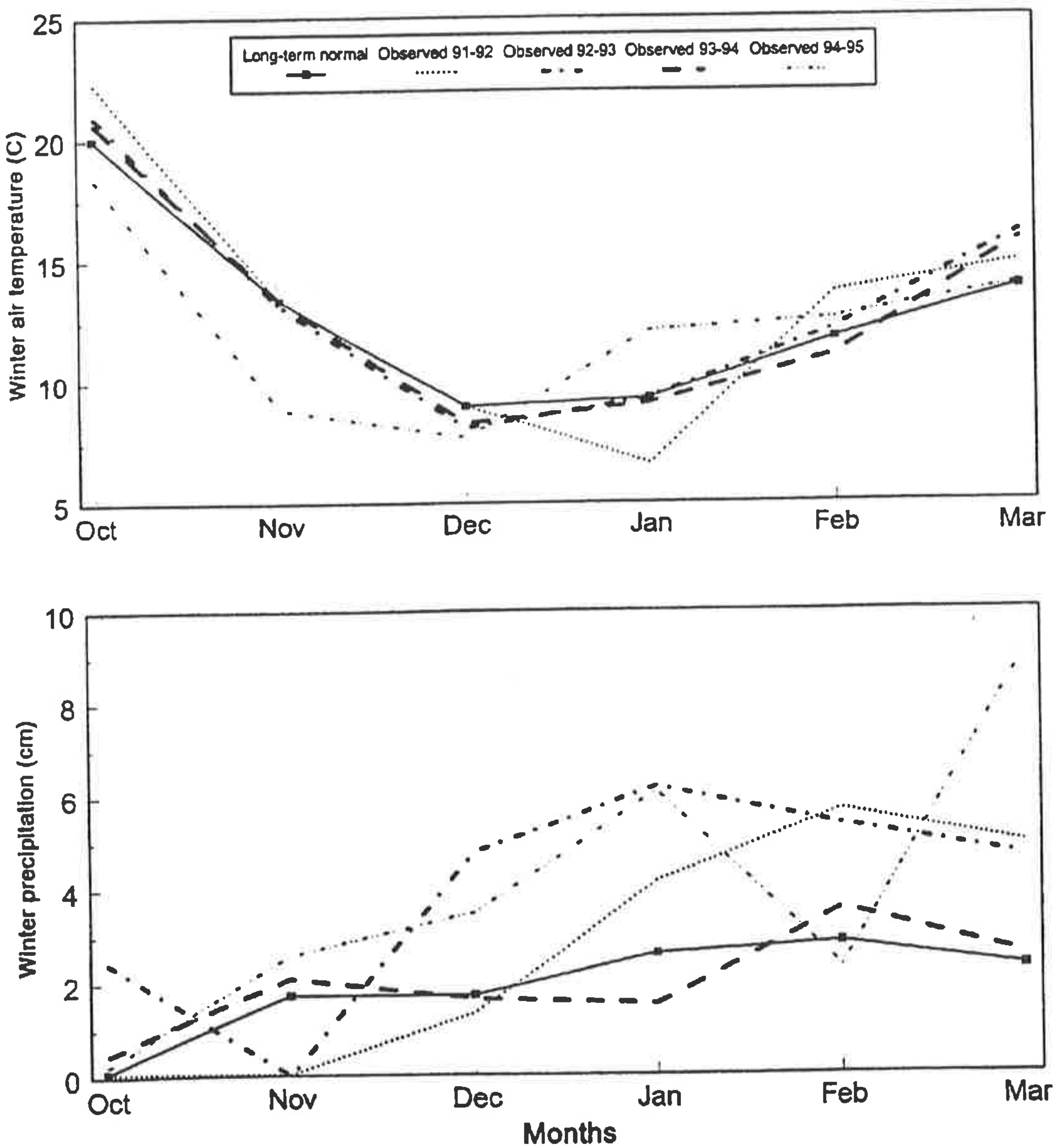

Fig. 3. Mean monthly winter rainfall and air temperature, 1991-1994, Bakersfield, California.

Ord's kangaroo rat (*D. ordii*) (Vest et al. 1965, Lane et al. 1981). The etiologic agent of Lyme disease, *Borrelia burgdorferi*, was isolated from the California kangaroo rat (*D. californicus*) in northern California (Lane and Brown 1991). Several bacteria are known to infect heteromyids, and 2 are known to infect kangaroo rats: *Yersinia pestis*, the cause of plague, and *Francisella tularensis*, the cause of rabbit fever (tularemia). There is only 1 instance of a plague positive kangaroo rat in California, an Ord's kangaroo rat from northern California (Nelson 1980). *Francisella tularensis* has been documented in Ord's kangaroo rat and the chisel-toothed kangaroo rat (*D. microps*) in Utah (Vest et al. 1965). Two species of fungi have been documented in heteromyids. Of these, *Coccidioides immitis*, the cause of Valley fever, has been detected in Merriam's kangaroo rat (*D. merriami*) (Emmons and Ashburn 1942).

No widespread epizootics have been reported in kangaroo rats in the San Joaquin Valley. Information on diseases of kangaroo rats in California, and their context in the natural history of the genus, is scanty. It is possible that viral or bacterial respiratory disease could have been regionally promoted by cool wet weather, or that kangaroo rats could have been infected with *Coccidioides immitis*, the causative organism of Valley Fever, which is widespread in the southern San Joaquin Valley. Screening of a sample of kangaroo rats for diseases could help to determine the prevalence and role of diseases in these populations.

The weather conditions during the 1994-1995 winter seem favorable for fungus growth. Dense vegetation was observed decaying in the field (E. Cypher, pers. comm.), and local occurrence of the potato blight fungus (*Phytophthora infestans*) was markedly higher (Bakersfield Californian, November 15 1995). Fungal or microbial infection could decrease caloric value of seeds, or leave residual mycotoxins (Valone et al. 1995). Such conditions could be widespread, and have caused cause the observed population declines. Some investigations related to this factor have been conducted outside of the San Joaquin Valley (Valone et al. 1995) and with heteromyid species other than those discussed here (D. Grubbs, pers. comm.). The potential for this effect exists, but no assessment of its possible significance in the San Joaquin Valley is possible with current information. Local studies of seed contamination, and toxicological and physiological information on local kangaroo rats, would be necessary to address this topic.

Kangaroo rats in the San Joaquin Valley are most commonly found in settings with relatively sparse groundcover (pers. obs.). The persistence of dense litter from a few highly productive growing seasons, plus lush annual growth in 1994-1995, could have impeded movements, reducing the ability of individuals to efficiently forage, and escape predators (Germano and Saslaw, in prep.). In addition, dense groundcover could maintain higher surface humidity and soil moisture, interacting with some of the other possible causes that we discussed.

MANAGEMENT IMPLICATIONS

Based on the 45 years of available record from the Bakersfield station, a winter as cool and wet as 1994-1995 has an 11% chance of occurring (Kruse, unpubl. report, California Department of Fish and Game, Fresno, 1996). If a particular weather pattern is a factor that can trigger widespread population declines, then this effect is one that should be considered when modeling kangaroo rat populations, performing population viability analyses, designing preserves, managing populations, and regulating take of individual kangaroo rats. The observed population decline may have been the result of 1 winter of particular weather conditions. If so, the potential impacts of several such winters, either sequentially or closely spaced, might be of greater magnitude.

Currently, the U.S. Fish and Wildlife Service and California Department of Fish and Game authorize incidental take of kangaroo rats that are Threatened, Endangered, or of special concern. Although measures to reduce or avoid take of kangaroo rats are often required, loss of individuals to a particular project is often considered a recoverable impact under these circumstances. If there are identifiable conditions that could lead to a widespread decline in kangaroo rat abundance, the contribution of individuals to local populations could be more important than normal. In that case, avoiding take of individual kangaroo rats, or ensuring adequate measures to offset take, would be of much greater importance than normal.

Reduction of dense groundcover and litter (usually through grazing, but occasionally through fire or mowing) is emerging as a central issue in kangaroo rat management (Germano and Saslaw, in prep.). Sparse groundcover is expected to facilitate kangaroo rat movements, and increase efficiency of foraging and predator escape. However, management of soil moisture and soil-surface humidity to control kangaroo rat diseases, or contaminants of seed, could be additional benefits of groundcover management. This could be especially important prior to or following cool wet winters.

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