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The Mohave Ground Squirrel at Fort Irwin, California

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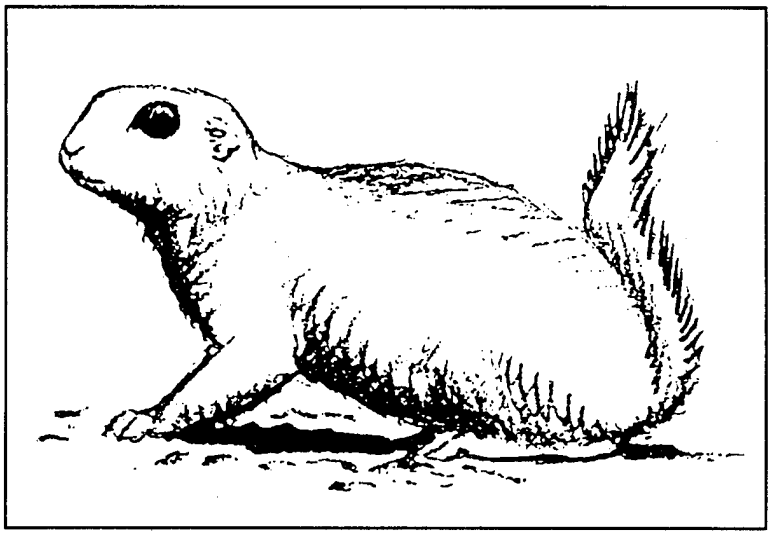
A State Threatened Species

by
Anthony J. Krzysik



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This report discusses the ecology and biology of the Mohave Ground Squirrel—a State threatened species—summarizes the geophysical characteristics and environment of Fort Irwin, and describes the Army training mission at the NTC. Priorities are discussed for environmental management and mitigation, based on sound ecological principles and the author's cumulative research on the Mojave Desert ecosystem.

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Foreword

This study was conducted for Headquarters, U.S. Army Forces Command (FORSCOM) under Military Interdepartmental Purchase Request (MIPR) No. FE017-91, dated 30 September 1991; Reimbursable Work Unit "Army Training Activities at the National Training Center and Their Effects on Wildlife and Their Habitats." The technical monitor is Stuart Cannon, FCEN-RDF.

The work was performed by Environmental Natural Resources Division (EN) of the Environmental Sustainment Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. William Severinghaus is Chief, CECER-EN, and Dr. William Goran is Chief, CECER-EL. Thomas Clark, Bureau of Land Management, Barstow (CA) Resource Area Office, is acknowledged for his work as installation technical monitor on this project in his previous position as Ecologist for Fort Irwin. The cover drawing of a Mohave Ground Squirrel was taken from an illustration published by the Naval Air Warfare Center Weapons Division, China Lake, CA, in 1987. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

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Distribution

1 Introduction

Background

The U.S. Department of Defense (DOD) has the legal responsibility for managing the natural resources on its training lands, and the Department of the Army (DA) has made a commitment to become exemplary in issues of environmental compliance. Strongly pertinent environmental mandates and documents include the *National Environmental Policy Act (NEPA)*, *Endangered Species Act*, *Clean Water Act*, *Migratory Bird Conservation Act*, Executive Orders 11990 (Protection of Wetlands) and 11988 (Floodplain Management), and Army Regulations (AR) 200-2, AR 420-74, and AR 420-76.

Important components of Army environmental compliance programs are properly designed and implemented inventory, assessment, and monitoring programs. In earlier work the author researched and developed a statistically rigorous quantitative assessment and monitoring program for arid and semiarid ecosystems (Krzysik 1984, 1985, 1987). The program was implemented in March 1983 at Fort Irwin, CA, the Army's National Training Center (NTC) to monitor woody perennial vegetation and vertebrate populations. Data from that program and ongoing research and development by the author have developed analytical capabilities to quantitatively assess the effects of military training activities on ecological communities and ecosystems at landscape scales.

The Mohave* Ground Squirrel (Spermophilus mohavensis) is currently listed as a State threatened species (John Gustafson, Nongame Biologist, California Department of Fish and Game, 1990) and a Federal Candidate 2 species (Ray Bransfield, Endangered Species Biologist, U.S. Fish and Wildlife Service, 1990). The reason for the listing is the rarity and patchy distribution of the species within its already limited geographical distribution, combined with habitat loss and degradation. Urbanization and agricultural development on private lands has been responsible for a significant loss of habitat (Aardahl and Roush 1985). Habitat loss and degradation on Bureau of Land Management (BLM) public lands continues, with leading causes attributed to development of energy projects and facilities, mining, recreational and off-road

* Although the name of the desert is spelled with *j*, the name of the ground squirrel is correctly spelled with an *h*.

vehicles, and sheep and cattle grazing (California Department of Fish and Game 1987). An additional loss and degradation of habitat of unknown magnitude has undoubtedly occurred on the DOD installations present in the Mohave Ground Squirrel's range: Fort Irwin; Naval Air Weapons Station, China Lake; and Edwards Air Force Base.

A petition was filed in 1993 with the California Department of Fish and Game to delist the Mohave Ground Squirrel from its State threatened status. The petition was filed by a coalition of land developers and resource extractors. In the summer of 1994 the Fish and Game department denied the petition, recommending additional field research and population monitoring.

Objectives

The objectives of this report are to:

1. describe geophysical, biological, and environmental parameters affecting the Mohave Ground Squirrel at Fort Irwin
2. discuss the impact of Army training activities on the Mohave Ground Squirrel and its habitat
3. summarize the threatened status of the Mohave Ground Squirrel at Fort Irwin
4. discuss priorities for mitigation, management, research, and monitoring, based both on the research reported here and the author's cumulative work.

Approach

The author summarized pertinent observations and published findings from his previous research on the plant and animal communities of Fort Irwin. To support those observations and findings, the author conducted a comprehensive literature survey pertaining to plant and animal communities naturally occurring within desert environments in the vicinity of Fort Irwin, including migratory species that may use any part of the installation during part of their life cycle (Krzysik 1994a).

Training activities at Fort Irwin were described and quantified, with special attention to the force-on-force battle exercises conducted regularly at Fort Irwin's National Training Center. The author's previous research and all other pertinent literature were surveyed to compile a summary of both the known and potential effects of training activities on Fort Irwin's Mohave Ground Squirrel populations.

Scope

Although the assessment and monitoring program was developed for arid ecosystems and initially implemented in the Mojave Desert, the overall concept, approach, experimental and sampling design, and statistical analyses are directly applicable to any ecosystem. Of course, details of sampling design and field methods will differ because these directly depend on ecosystem type and the specific objectives of assessment and monitoring (including desired accuracy and precision).

This report, and companion reports on (1) biodiversity and threatened/endangered/ sensitive species at Fort Irwin (Krzysik 1994a) and (2) the Federal threatened Desert Tortoise (Krzysik 1994b) were motivated by extensive biological (Krzysik 1990a) and ecological (Krzysik 1991) assessments conducted by the author at Fort Irwin for the NTC and U.S. Army Forces Command (FORSCOM).

2 Site and Setting

Geography and Physiography

Fort Irwin is located in San Bernardino county in southeastern California, about 65 km northeast of Barstow CA. Most of the land surrounding the fort is public land managed by BLM. The western boundary is adjacent to Naval Air Weapons Station, China Lake (Mojave B Ranges). The southern boundary of Death Valley National Monument is close to the northeast boundary of the fort. Fort Irwin is in the Basin and Range geologic province. Structural features of the landscape formed in the Cenozoic Era, about 40 million years ago from movements related to the San Andreas and Garlock faults.

Physiographically, Fort Irwin is located in the central Mojave Desert. This region is characterized by rugged block-faulted mountain ranges separated by alluvium filled basins. The basins consist of broad valley plains, gentle sloping bajadas (ancient coalesced alluvial fans), and rolling hills with low relief. The lowest basins form playas (dry lake beds). The eroding mountains produce talus slopes, boulder fields, and rocky or gravelly alluvial fans (pediments) that merge into the sandy soils and fine gravels of bajadas and plains. A dominant visual feature of the landscape, especially impressive from an aerial view, are the extensive and complex dendritic networks of canyons, arroyos, and washes. Washes often form extensive networks of braided channels on bajadas with low relief. Other common features of the landscape include rolling hills with gravelly or rocky substrates, highly fractured boulder ridges, rugged boulder/rock outcrops of granite or volcanic basalt, desert pavement, and sand dunes. Springs and seeps are uncommon occasional features of the Mojave Desert landscape.

Five mountain ranges (or portions of them) are located within the boundaries of Fort Irwin: Granite, Tiefort, Avawatz, Quail, and Paradise. The foothills of three additional mountain ranges fall along the fort's boundaries: Alvord, Soda, and Owlshead. Approximately 60 percent of Fort Irwin consists of bedrock at or near the surface. The remaining 40 percent is underlain by alluvial and lacustrine deposits.

Additional details about the geophysical setting, biological environment, and ecology of Fort Irwin can be found in Krzysik (1994a).

Military Training Activities

Fort Irwin consists of three management units: the National Training Center (NTC), the Goldstone Deep Space Communications Complex, and Leach Lake Bombing Range (Figure 1). Fort Irwin is 2600 sq km in area (1004 sq mi), about the size of Rhode Island. The Goldstone complex (135 sq km) is leased and operated by the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL). The Leach Lake Bombing Range (369 sq km) is leased to George Air Force Base.

Before the NTC was established, the Fort Irwin landscape was subjected to a cumulative total of 35 years of military training activities. The War Department withdrew public lands in 1940 and established the Mojave Army Antiaircraft Range. The installation was renamed Camp Irwin in 1942. During this period General George

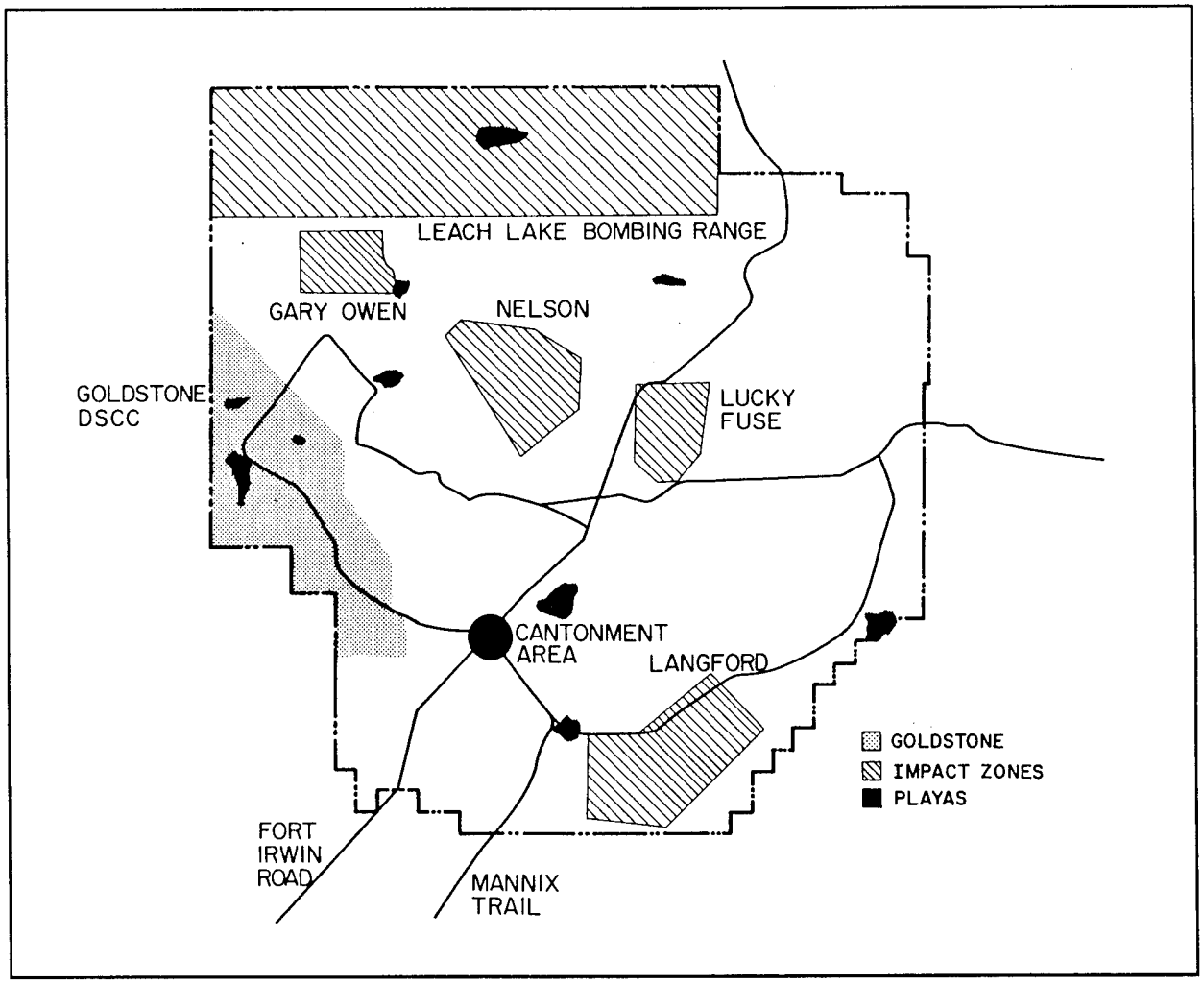

Figure 1. Schematic drawing of Fort Irwin, CA, showing the three management units and the four former impact areas and 10 playas.

S. Patton's armored division of the Third Army trained at the installation and elsewhere in the California Desert. The post was placed on surplus status in 1947, but was reactivated in 1951 for training troops during the Korean conflict. Camp Irwin was redesignated 1 August 1961 as the Fort Irwin Armor and Desert Training Center. Between 1972 and 1980 it was used as a training area for the California Army National Guard. Fort Irwin was selected as the Army's National Training Center in August 1979. The first NTC training exercise took place 13 April 1981, while the official reactivation ceremony was held 1 July 1981. NTC's massive force-on-force training exercises did not begin until 17 January 1982. At present the California National Guard occasionally trains on weekends between scheduled NTC training rotations.

Goldstone is off limits to Army training activities, but a tank trail constructed in 1985 bisects most of the installation. Vehicle use by Goldstone personnel is confined to paved and maintenance roads. Off-road vehicle use is minimal since public access is denied. However, Army tactical vehicles occasionally stray off the Goldstone tank trail. The Leach Lake Bombing Range is continually used for Air Force live-bomb practice, and is therefore off limits for ground use because of the high risk of unexploded ordnance. Military and civilian personnel working near the bombing range have reported detonations induced by rapid temperature changes.

Typical NTC rotational training exercises consist of realistic war games and battle scenarios where American forces, represented by visiting rotational units, engage enemy forces (NTC personnel), with both sides using eye-safe computer encoded laser beams to simulate bullets, missiles, and artillery projectiles. All tactical vehicles and soldiers are equipped with multiple sensors to count laser hits. All components of the exercises, including laser fire and hits, are directly incorporated into an extensive computer network that analyzes in detail tactical strategies and results. Another major component of a rotational group's training responsibilities is the live-fire exercises, which employ stationary, moving, and pop-up targets. All weapons systems are used: small arms fire, armored vehicle cannons and automatic weapons, mortars, grenades, and antitank missiles. Two books are available describing actual battles and the rotational training exercises at the NTC (Bolger 1986; Halberstadt 1989).

Figure 2 shows the intensity of Army training activities at Fort Irwin, based on the number of annual tracked vehicle days since the initiation of NTC training scenarios. Note the large increase in training intensity since 1985. Tracked vehicles include tanks, armored personnel carriers, and armored fighting vehicles like the Bradley. The ratio of wheeled to tracked vehicles is approximately 3:1. Figure 3 shows the cumulative increase in the number of tracked vehicles used at the fort. Note the geometric increase in training intensity between 1981 and 1989.

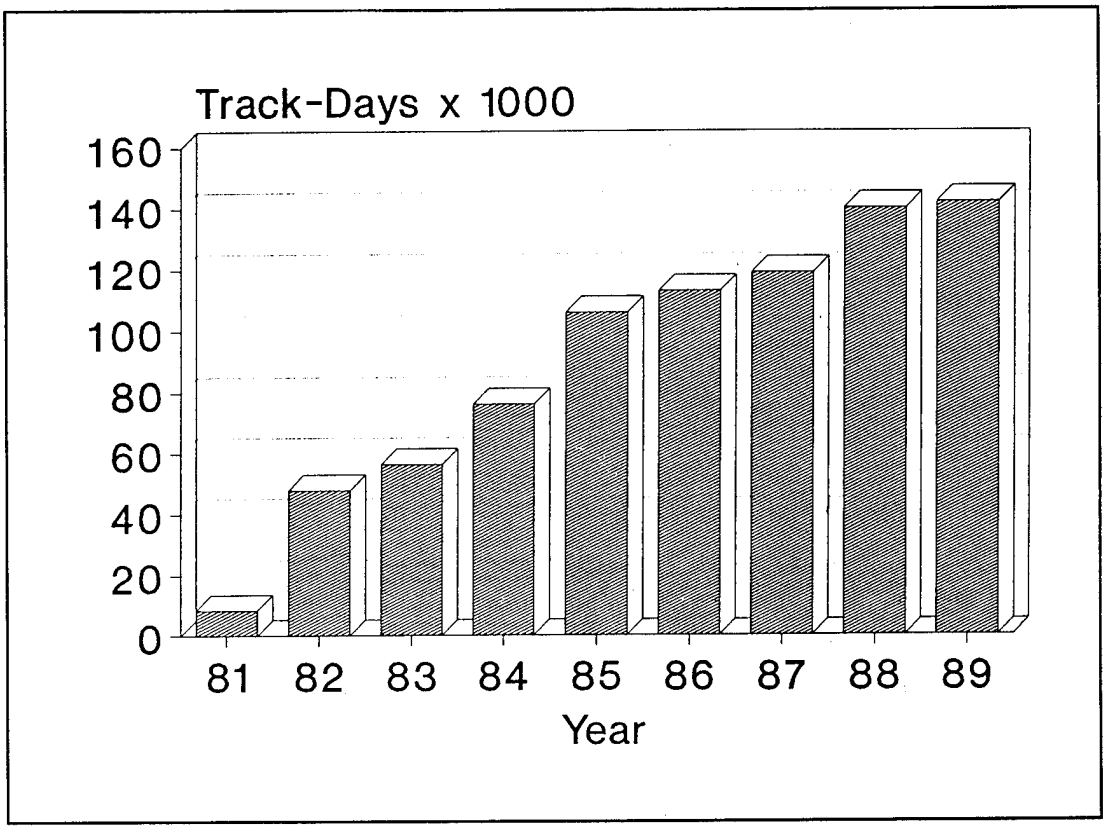

Figure 2. Annual tracked vehicle days at the NTC.

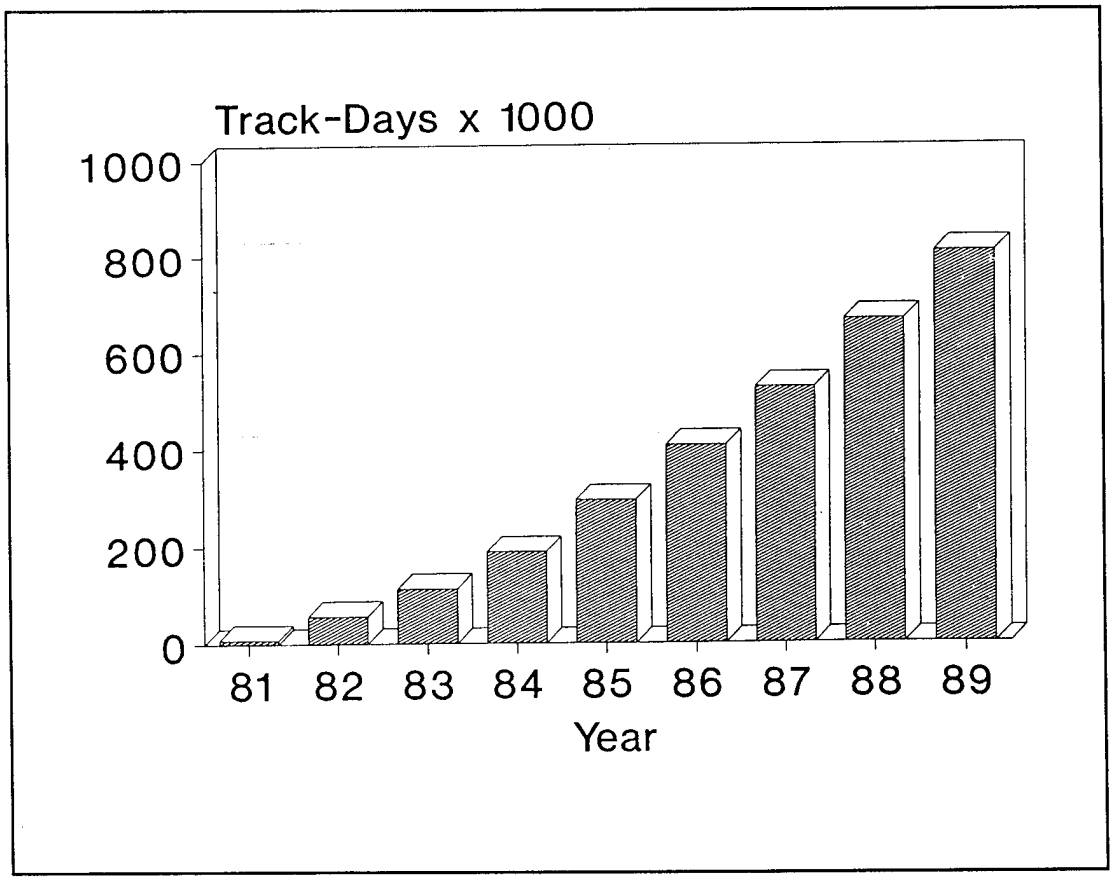

Figure 3. Cumulative tracked vehicle days at the NTC.

Additional details about the NTC military mission and its effects on biological resources can be found in Krzysik (1994a). An analytical assessment of the effects of Army training activities on the central Mojave Desert ecosystem at Fort Irwin can be found in Krzysik (1984, 1985).

3 Parameters Affecting Mohave Ground Squirrel Populations

Three members of the squirrel family (Sciuridae) are found at Fort Irwin: Mohave Ground Squirrel (Spermophilus mohavensis), Round-tailed Ground Squirrel (Spermophilus tereticaudus), and White-tailed Antelope Ground Squirrel (Ammospermophilus leucurus). Unlike other desert rodents, ground squirrels are diurnal, spending their nights in burrows. During the day, ground squirrels retreat to their burrows when air temperatures in the shade rise above their thermal neutral zone (see "Estivation and Hibernation" later in this chapter). The Antelope Ground Squirrel is common and widely distributed at Fort Irwin. It occupies a broad geographical range, being found in all of the Mojave Desert, the California and Baja portions of the Sonoran Desert, and possessing an extensive range in the Great Basin shrub steppe as well as the short grass steppe. The Round-tailed Ground Squirrel is uncommon and limited in its distribution at Fort Irwin, but has a widespread distribution in the Mojave Desert east and south of Fort Irwin, and in the Sonoran Desert (except most of Baja). The Mohave Ground Squirrel is found only in the western Mojave Desert (see Figure 4). This species occurs in extreme southwestern Inyo, eastern Kern, extreme northeastern Los Angeles, and western San Bernardino counties.

The Mohave and Round-tailed Ground Squirrels are morphologically similar, possessing a light tan or pale cinnamon to cinnamon-gray coat color, and they are closely related genetically (Hafner and Yates 1983). Despite their similarities, these species are easily distinguished by their tails. The Round-tailed Ground Squirrel (116–133 g) has a long tail (6–10.7 cm) that is slender and round, not much more than 0.5 cm in diameter. The upper and lower portions of the tail are the same light tan or cinnamon color. The Mohave Ground Squirrel (85–130 g) has a shorter (5.7–7.2 cm) flattened tail that is over 1 cm wide, dusky or dark above, and white beneath. The smaller Antelope Ground Squirrel (74–103 g) is easily identified by the white stripe on each side of its body—the species resembles a pale chipmunk. When running, it curls its tail over its body, boldly exposing the white underside. (The body weights are from Jameson and Peeters [1988] and the tail lengths are from Hall [1981].)

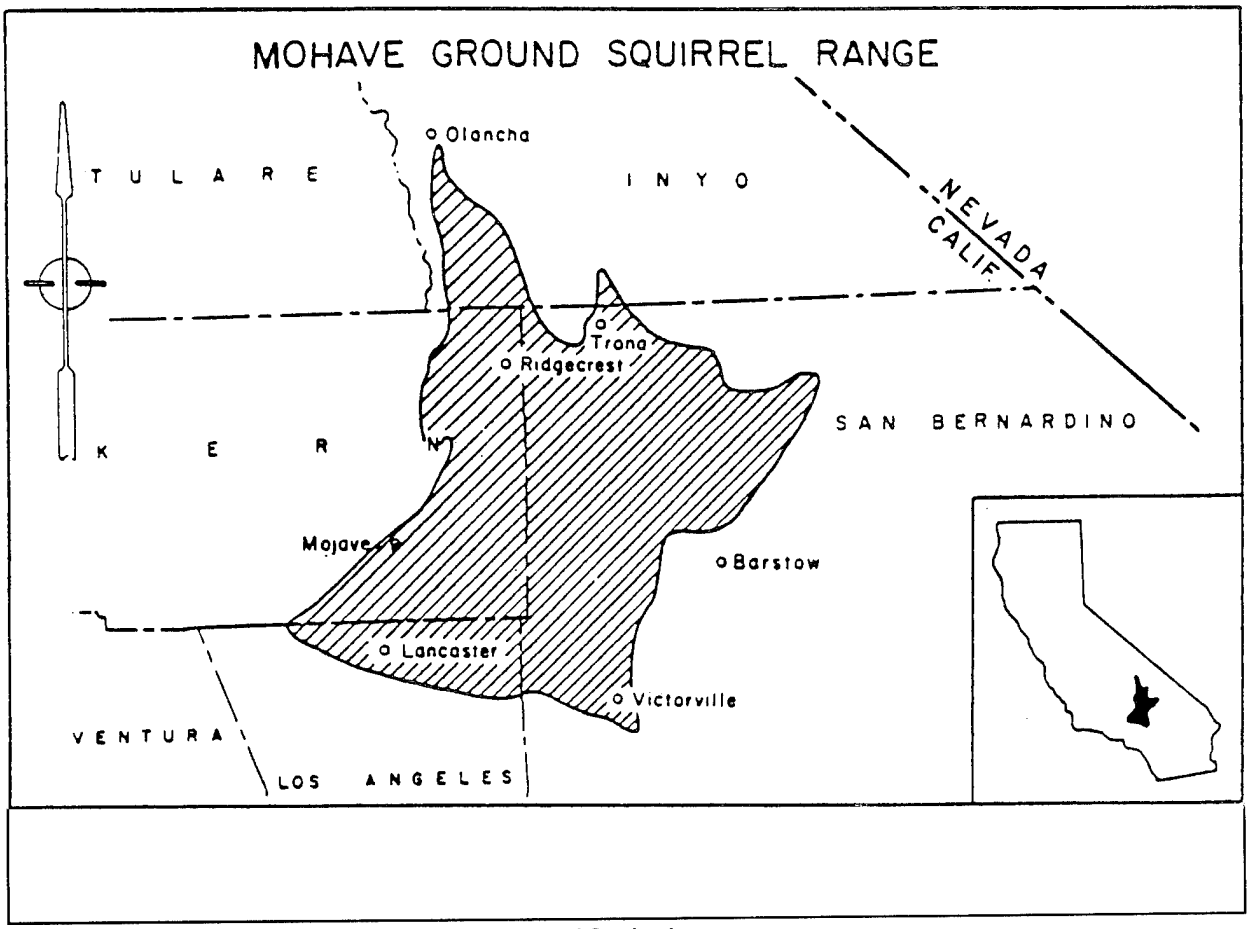

Figure 4. Geographical range of the Mohave Ground Squirrel.

Biological Parameters

Food Habits

Recht (1977) observed approximately 2400 foraging bouts with the Mohave Ground Squirrel, and reported that they fed predominantly and extensively on four genera of plants: desert thorn, coreopsis, fiddleneck, and Russian thistle (exotic) (scientific names for these and other species are given in the Appendix). These taxa possessed the highest measured water content in the plant community, and, with the exception of desert thorn were also the most abundant vegetation. Desert thorn comprised about 10 percent of the vegetation, while the other three taxa provided 60 to 90 percent of the vegetation cover. Mohave Ground Squirrels preferentially foraged on these four taxa sequentially, on a seasonal basis. Their selected seasonal forage contained the highest water content available in the plant community during that specific time-frame. The sequential order of the taxa listed above parallels increasing water content and seasonal use. Desert thorn was used in early spring while Russian thorn was used in the summer.

Zembal and Gall (1980) reported preferential, concentrated, and extensive foraging on a bumper crop of Joshua tree seeds. Spiny hopsage may also be a preferred food item. Mohave Ground Squirrels require succulent vegetation to obtain water. In laboratory studies, when Round-tailed Ground Squirrels were fed dry grain they died from hemoconcentration (Schmidt-Nielsen 1979). Vorhies (1945) reported that the average water content of the natural vegetation consumed by Round-tailed Ground Squirrels may be 60 to 80 percent.

Reproduction

Mohave Ground Squirrel males establish and defend territories after they emerge from hibernation. In prime habitat, two or three—sometimes as many as five—females will construct burrows near a territorial male. With good food availability, each female will produce 6 to 8 young (Anthony Recht, Professor, California State University at Dominquez Hills, personal communication, 1990). In a drought year Mohave Ground Squirrels may not reproduce.

Reproductive output in populations would be particularly low if there were two or more drought years in a row. However, although there was a drought in the western Mojave Desert in the mid- to late 1980s, a pregnant female was captured in May 1990 near Ridgecrest, CA (Debbie Clark, Consultant Biologist, California Department of Fish and Game, personal communication, 1990).

Estivation and Hibernation

A serious difficulty with studying Mohave Ground Squirrels is that their seasonal activity period is shorter than their estivation-hibernation period. Hibernation is the winter period of dormancy for an animal—an adaptation to avoid hypothermia, food shortages, or both. Estivation is the summer dormancy period—an adaptation to avoid heat, drought, or food scarcity. Homeotherms (essentially mammals and birds) possess a thermal neutral zone, which is defined as the range of temperature where oxygen consumption by a given species reaches its minimum and is independent of temperature (Bartholomew 1977). When environmental temperatures are within this zone, the animal maintains its core temperature without the need to expend any metabolic energy or resort to behavioral adaptations. Below the thermal neutral zone, an animal must resort to chemical regulation to produce metabolic heat, absorb heat from the sun, or seek the insulation of a burrow. Above this zone of thermal neutrality is a narrow zone of physical regulation, where the animal reduces core temperatures by sweating or panting. Ground squirrels do not possess physiological mechanisms to reduce their body temperatures below ambient (Schmidt-Nielsen 1979). Therefore, they must retreat to their burrows. The thermal neutral zone for Mohave Ground

Squirrels is 31–36.25 °C (A. Recht, personal communication). Body temperatures only a few degrees above this are lethal. Even at air temperatures below their body temperature, ground squirrels spend a great deal of time foraging in the shade. Burrows are effective shelters from desert temperature extremes. Vorhies (1945) reported that in June in southern Arizona, Round-tailed Ground Squirrel burrows were 27 °C when the air temperature was 40 °C and the soil surface was 70 °C. In the summer soil temperatures reached 75 °C, but burrows remained below 29 °C. Mohave Ground Squirrel burrows are typically 1 meter deep and several meters in length (A. Recht, personal communication). During cool weather, ground squirrels can be observed basking in the sun. Mohave Ground Squirrel hairs are multi-banded at their tips and, along with their dark skin, assist in thermoregulation.

Zembal and Gall (1980) reported that Mohave Ground Squirrels were not observed before mid-June at a site near their northernmost geographical range (1025–1300 meters elevation). In the southern part of their range, males come out of their burrows and establish territories as early as mid-January to late February, with females following about two weeks later (A. Recht, personal communication, 1990). Bartholomew and Hudson (1960) reported that Mohave Ground Squirrels were active from early March to August in Antelope Valley, the southwestern portion of their range. Estivation occurs in the summer and continues into hibernation without the animal coming above ground. Estivation usually occurs in July or August, but may occur as early as mid-May in a drought year (Phil Leitner, St. Mary's College of California [Moraga], personal communication, 1990). Recht believes estivation begins from July to September, with August or September being typical. At Fort Irwin, Mohave Ground Squirrels have been captured from 5 April to 29 May (Table 1), 30 May and 21 June (Lee and Ro 1986), and 19, 20, 29 July (Wessman 1977). Under laboratory conditions, even with abundant food, dormancy in the Mohave Ground Squirrel can occur between 10 °C and 27 °C. They typically enter torpor at room temperature and spend much of the summer, fall, and winter in a dormant state (Bartholomew and Hudson 1960). Apparently, the primary determinant affecting estivation, hibernation, and above-ground activity is the availability of succulent forage. The spring activity period for the Mohave Ground Squirrel coincides with both optimal thermal regimes and succulent food availability in the Mojave Desert.

Ecological Parameters

Population Dynamics

Populations of Mohave Ground Squirrels are usually highly patchy in distribution, occupy small areas, and possess low densities (Burt 1936; Hoyt 1972; Wessman 1977;

Leitner 1980; Krzysik [personal observation]). These population characteristics make the species difficult to study. However, Aardahl and Roush (1985) reported that the species was common at 22 sites they studied in portions of Inyo, Kern, and San Bernardino counties. Zembal and Gall (1980) reported observing at least 35 different individuals in a localized area on China Lake, where they were foraging on Joshua tree seeds. Ray Bransfield (personal communication) also indicated that the species may be common at some localities.

Phil Leitner has been studying Mohave Ground Squirrels for over a decade in highest-quality habitat on permanently established plots at Naval Air Weapons Station, China Lake. Leitner's plots are located in a 39 km^2 area known as Coso Hot Springs, just southwest of the northernmost recorded locality of the Mohave Ground Squirrel at Haiwee Meadow, Inyo County (Hall 1981). The hot springs are the site of a geothermal study area. During the drought years (mid- to late 1980s) a typical population of ground squirrels on Leitner's 500 m x 500 m plots was approximately six individuals. Precipitation in the Mohave Desert—particularly in western portions—primarily occurs in the winter (Krzysik 1985). The winters of 1991–1992 and 1992–1993 provided above-average precipitation, and the number of ground squirrels on Leitner's plots rose to more than 50 individuals (Tom Clark, Ecologist, BLM, personal communication, 1994).

Local population densities are probably closely correlated with winter rainfall, which directly influences vegetation productivity. During drought years the Mohave Ground Squirrel estivates early, and may not reproduce. The occurrence of Multiple consecutive drought years, as during the 1980s in the western Mojave Desert, may contribute significantly to local population extinctions. Reproduction—and hence population recruitment—has undoubtedly been low. Animals may be in poor nutritional condition and may have difficulty maintaining water homeostasis. Populations in these conditions are very susceptible to parasites, disease, and predation. These agents commonly cause local extinctions when population levels are low. Outright starvation, or death from osmoregulatory breakdown, is also possible. Populations existing at low numbers also face extinction from genetic drift, demographic or environmental/ecological stochasticity (random conditions), natural catastrophes, and anthropogenic impacts. See Krzysik (1994a) for additional information on habitat fragmentation and extinction risks to small populations.

Populations that widely fluctuate in numbers, occur at low densities, occupy small areas, and possess highly patchy distributions make it difficult to inventory, construct range maps, develop management guidelines, and design monitoring programs. Another important difficulty, as noted earlier, is that this species is only active during a short period of the year; sometimes this window of activity may be very narrow.

Habitat Requirements

The Mohave Ground Squirrel is found in creosote bush and shadscale scrub communities, and in Joshua tree woodland. The species rarely occurs in rugged, rocky terrain. Aardahl and Roush (1985) reported that the preferred habitat is large alluvial filled valleys possessing deep fine- or medium-textured soils and the absence of desert pavement. The associated vegetation communities were creosote bush, shadscale, or alkali sink (saltbrush) scrub.

Biogeography

The range of the Mohave Ground Squirrel is shown in Figure 4. The type specimens of the Mohave Ground Squirrel were collected near Rabbit Springs, 15 miles east of Hesperia in the Lucerne Valley, in 1889 (Merriam 1889). Hall and Kelson in 1959 (Hall 1981) gave records for Hesperia and Palmdale. Bartholomew and Hudson's (1960) physiological research was conducted on animals caught in Antelope Valley, 3 miles east of Palmdale. Undoubtedly, this ground squirrel's range extended south to the San Bernardino Mountains, and west to the Tehachapi and Sierra Nevada Mountains. Extensive urbanization and the spread of alfalfa fields in Antelope Valley and throughout its southern range have directly destroyed prime Mohave Ground Squirrel habitat, and have fragmented populations. Agricultural development, particularly alfalfa, has been extensive along the Mojave River, and habitat loss is substantial between Barstow and Victorville (Krzysik, personal observation). Wessman (1977) concluded from the results of his surveys that this species is no longer found in Lucerne Valley, Apple Valley, and the Victorville area. Following Wessman's study, urbanization in the southern Mojave Desert has been explosive. The species is no longer found in the vicinity of Palmdale and Hesperia, and probably has disappeared from most, if not all, of its former southern range. Other heavily impacted areas include western Fremont Valley, Rose Valley, and Harper Lake Basin (Aardahl and Roush 1985). However, after the wet winters of 1991–1992 and 1992–1993, Mohave Ground Squirrels were relatively abundant in Rose Valley during the subsequent springs (T. Clark, personal communication, 1994).

Before Wessman's (1977) survey, the distribution of the Mohave and Round-tailed Ground Squirrels were believed to be allopatric: the Mohave Ground Squirrel occurring west of Barstow, while the Round-tailed Ground Squirrel's western boundary was located just east of Barstow. However, Wessman found three areas where the two species came in contact:

1. in Fort Irwin, about 3 km north of the Tiefort Mountains (UTM coordinate 3709)
2. near the Fort Irwin road, about 10 km southwest of the fort

3. near Helendale, about 32 km southwest of Barstow.

Twelve hybrids of the two species were also captured near Helendale (see section on competition). Mohave Ground Squirrels were not found in the sandy soils of the Mojave River Wash, while Round-tailed Ground Squirrels were common. Wessman recorded 13 Mohave Ground Squirrel localities, 5 to 20 km southwest of Fort Irwin. On the basis of his study, and habitat suitability he proposed that the eastern boundary of the Mohave Ground Squirrel be extended such that Searles Dry Lake, the Owlshead Mountains, and Death Valley form the northern boundary; the Avawatz and Soda Mountains form the eastern boundary; and Red Pass, Coyote, and Langford Dry Lakes form the southern boundary. Wessman captured 6 Round-tailed Ground Squirrels at two trapping plots 15 km south of Fort Irwin, and beside the individual captured 3 km north of the Tieforts, he trapped another round-tail within the installation, 14 km east of the Tiefort Mountains. The author has recorded 59 captures of Round-tailed Ground Squirrels (1984-1989—the actual number of different individuals is less because some individuals were captured more than once) in the valley and bajada 1 to 4 km south of the Tieforts, and a single individual captured twice (1990) 13 km south of these mountains. A hybrid between the two ground squirrels was captured in 1989 on the Tiefort bajada 2 km south of the mountains. Clearly, a contact zone between these two species of ground squirrels exists at Fort Irwin.

Competition With Other Ground Squirrels

The Mohave Ground Squirrel is commonly associated with the Antelope Ground Squirrel throughout its range (Wessman 1977; Zembal and Gall 1980). Adest (1972) studied interspecific aggression in these two species, and reported that the Mohave Ground Squirrel was interspecifically as well as intraspecifically more aggressive than the Antelope Ground Squirrel. Recht (1977) confirmed that the Mohave Ground Squirrel aggressively formed and defended territories. Zembal and Gall (1980) observed the two species in the field foraging for seeds in Joshua trees. They reported that they only observed a single Mohave Ground Squirrel at a time foraging in an individual tree, while there could be up to 7 Antelope Ground Squirrels foraging in a given tree. They recorded 27 agonistic* encounters between the two species in Joshua trees. In all encounters, the Antelope Ground Squirrel was subordinate to the Mohave

* agonistic: aggressive behavior among individuals.

Ground Squirrel. The Antelope Ground Squirrel neither estivates nor hibernates (Bartholomew and Hudson 1960), so this species can forage over a long period with no interference from its larger and more aggressive competitor. Also, in the spring, when they are both competing for similar food resources, productivity in the Mojave Desert is at its peak.

Wessman (1977) and the author have found localities where the Mohave and Round-tailed Ground Squirrels are sympatric, and assumed hybrids have been found by both investigators. Although the two species possess different chromosome numbers (MGS, 2N=38; RTGS, 2N=36), they also exhibit a moderate level of genetic similarity (S=0.78) (Hafner and Yates 1983). These investigators have recommended full species recognition for each of the ground squirrels. They have suggested that, based on the genetic similarity between these taxa, the two species may be in the process of evolutionary divergence, with ecological factors serving as prereproductive isolating mechanisms. The area around Helendale where the hybrids have been collected is environmentally severely disturbed, so ecological (and perhaps behavioral) isolating mechanisms have broken down. Hafner and Yates collected their two Helendale specimens "immediately adjacent to fields of alfalfa and wheatgrass; despite extensive searching, we found no Spermophilus away from these fields" (Hafner and Yates 1983). The extensive ecological disturbance and agricultural development along the Mojave River wash may therefore provide a broad hybrid zone. Since possible hybrids have been seen in the ecologically disturbed training areas at Fort Irwin, and the Coyote Lake basin has also been impacted, the hybrid zone may be more extensive than previously thought. However, it must be emphasized that the disturbance-hybridization theory is just a hypothesis and not documented fact. It may be a coincidence that the contact hybridization zone has become ecologically degraded. Possibly, environmental disturbances have created more extensive areas of loose sandy soils. The Round-tailed Ground Squirrel favors this substrate, and may have expanded its former range.

An extensive literature search produced no citations for studies of agonistic behavior between these two species. Wessman (1977) noted that Round-tailed Ground Squirrels have replaced Mohave Ground Squirrels in Lucerne Valley, including Rabbit Springs. However, Round-tailed Ground Squirrels are often associated with alfalfa fields because of their concentrated forage, and agricultural conversion rather than competition may be the primary factor responsible for the extirpation of Mohave Ground Squirrels. Agricultural development with alfalfa and wheatgrass is extensive along the Mojave River between Barstow and Victorville, and the southern end of Coyote Lake. Round-tailed Ground Squirrels are common in these fields and in the sandy soils of the Mojave River wash (Wessman 1977). South of Helendale, Round-

tailed Ground Squirrels disappear, and Mohave Ground Squirrels and California Ground Squirrels have been found in alfalfa fields (Wessman 1977). Round-tailed Ground Squirrels (s. beecheyi) (300–650 g) appear to be strongly associated with sandy substrates (Wessman 1977; Krzysik, personal observation). Wessman (1977) believed that Round-tailed Ground Squirrels are expanding their range into former Mohave Ground Squirrel areas. Five hypotheses (or some combination) are possible:

1. Round-tailed Ground Squirrels are simply expanding into localities where Mohave Ground Squirrels have undergone local extinctions.
2. Round-tailed Ground Squirrels are outcompeting Mohave Ground Squirrel when food resources are limited. During drought years, food resources for species in need of succulent vegetation are certainly limited. Round-tailed Ground Squirrels may be more efficient harvesters of food items (for reasons including thermoregulation, stress, or predator escape during foraging), or they are more efficient at turning primary production into biomass or reproductive tissues.
3. Round-tailed Ground Squirrels are physiologically better adapted to thermal and/or osmoregulatory stresses.
4. Round-tailed Ground Squirrels, through agonistic territoriality or interference competition, directly exclude Mohave Ground Squirrels.
5. The two species are hybridizing, and the resulting F1 hybrids are sterile or less fertile, or the smaller gene pool of the Mohave Ground Squirrel is being swamped out.

Hypothesis 4 seems unlikely because the Mohave Ground Squirrel is apparently the more aggressive species. Detailed experiments are needed to elucidate the relative importance of hypotheses 2 and 3. Round-tailed Ground Squirrels are more widely distributed than Mohaves, but their population densities are not particularly high—at least not at Fort Irwin. Jaeger (1961) reports that in appropriate habitat 10 to 15 individuals per square mile are typical (4–6/sq km). The role of genetic dilution—hypothesis 5—is unknown. Extinctions of local demes or populations may be a common phenomenon in deserts, because of catastrophic and unpredictable environmental events: drought, excessive heat, and flash floods. The more extensive and widespread distribution of the Round-tailed Ground Squirrel by chance alone makes this species a more effective or consistent colonizer.

California Ground Squirrels have followed the spread of alfalfa fields and agriculture into the Mojave Desert. This large bushy-tailed ground squirrel's native habitat is all of California and Oregon with the exception of deserts and steppe. This species follows California's chaparral shrubland into northwest Baja. The spread of California Ground Squirrels, a much larger and aggressive competitor, may be a contributing

factor to recent range reductions of Mohave Ground Squirrels, especially in the southern portions of its former range where agricultural development has been particularly intensive. California Ground Squirrels are common around alfalfa fields west of Lucerne Valley, and they have spread into surrounding natural habitats (Wessman 1977). This species has not been recorded at Fort Irwin, but the author has observed it on a number of occasions within the city limits of Barstow.

4 Mohave Ground Squirrel Surveys at Fort Irwin

The author conducted a number of small-mammal surveys on Fort Irwin between 1983 and 1991. A general summary of the results are presented in Krzysik (1994a). The Mohave Ground Squirrel captures discussed in that report are the result of the small-mammal surveys. However, the author has never attempted to sample exclusively for the Mohave Ground Squirrel.

The presence of Mohave Ground Squirrels has been recorded at 12 sites on Fort Irwin by three groups of investigators (Tables 1 and 2). A total of 51 different sites have been trapped for rodents on Fort Irwin. The trapping effort has varied enormously among these sites. Most of these sites have only been trapped for a brief period in a single year: 38 sites were sampled in only a single year, 7 were sampled in two different years, 1 site for 3 years, 1 site for 4 years, 2 sites for 5 years, and 2 sites for 6 years. This trapping effort (27,399 trap-days) was made during the optimal season for Mohave Ground Squirrel above-ground activity. Over 95 percent of the author's trapping was conducted in April and May (the remainder having been conducted in March and June). The Lee and Ro study was conducted in May and June. Although Wessman's trapping period at Fort Irwin was late July, he did capture Mohave Ground Squirrels.

Although the first year of the author's ecological monitoring program followed an exceptionally wet winter (1982–1983), the remainder of the monitoring years were conducted during a prolonged drought in southern California, including the Mojave Desert. The low number of Mohave Ground Squirrel captures at Fort Irwin during the monitoring program—even in the undisturbed habitats at Goldstone—clearly reflected their sensitivity to drought years.

Mohave Ground Squirrels have been captured in a relatively wide range of habitats at Fort Irwin (Table 1). The location and UTM coordinates of these sites are available in Table 2. The most typical habitat has been valley or bajada creosote/burroweed scrub, which is also the most extensive available habitat. Shrub cover has ranged from 2000–3000 sq m/ha at Goldstone, to 100-300 sq m/ha in the heavily used southern training corridor of the NTC. Vegetation composition has varied from almost pure stands of creosote bush and burroweed (with creosote bush usually dominant), to

Table 1. Habitat characteristics of Mohave Ground Squirrel capture sites at Fort Irwin.

Investigator	Captures	Site Code	Year	Topography	Community	Soils	Plant Diversity	Habitat Condition
Krzysik	7	VC	1984-1987	Valley	Creosote/ Burroweed	Fine Granite Gravel (0.3-1cm) Silty-Sandy	Low	Good
	1	AC	1986	Bajada	Creosote/ Burroweed	Gravel (1-8cm) Silty	High	Good
	2	S	1983-1984	Valley	Creosote/ Burroweed	Sandy	Low	Very Poor
	1*	M	1989	Bajada	Creosote/ Burroweed	Sandy-Gravel	Moderate	Poor
	2	AN	1984	Alkali Sink	Shadscale	Silty Surface pebbles	Low	High
	2	SD	1984	Sand Dunes	Shadscale	Sandy	Low	High
	1	Roadkill	1983	Alkali Sink	Shadscale/ Allscale	Silty Surface pebbles	Low	High
	* Mohave Ground Squirrel and Round-tailed Ground Squirrel hybrid							
	Trap Days = 23,219				Total Sites Trapped = 27			
Wessman	1	41	1977	Bajada	Creosote/ Burroweed	50% Small Rocks (0.3-8cm)	Low	**
	1	42	1977	Valley	Creosote/ Burroweed	Sandy-10% Small Rocks	Low	**
	1	43	1977	Bajada	Creosote Bush	50% Small Rocks	High	**
	2	50	1977	Valley	Creosote/ Burroweed	58% Small Rocks	High	**
	**Poor to very poor habitat quality at present. The sites were in better condition in 1977.							
	Trap Days = 2900				Total Sites Trapped = 10			
O'Farrell, Woodman, and Bagley	1	2	1985	Wessman Site 41				Some Disturbance
	1	5	1985	Krzysik Site AN				High
	1	8	1985	Bajada	Creosote/ Burroweed	Course Sandy Gravel (Granitic)	High	Little Disturbance
	Trap Days = 1280				Total Sites Trapped = 16			

Table 1. (Cont'd) Dates of Mohave Ground Squirrel captures.

Investigator	Year	Site	Date	Number
Wessman	1977	41	19 July	1
		42	20 July	1
		43	20 July	1
		50	29 July	2
Krzysik	1983	S	5 April	1
		RK	10 April	1
	1984	S	12 April	1
		VC	25 April	1
		AN	5 May	1
		AN	6 May	1
		SD	6 May	1
		SD	7 May	1
O'Farrell, Woodman, and Bagley	1985	2	30 May	1
		5	30 May	1
		8	21 June	1
Krzysik	1986	AC	17 April	2
	1987	VC	16 April	2
		VC	18 May	1
		VC	21 May	1
		VC	22 May	1
		VC	23 May	1
	1989	M	29 May	1 (hybrid)

highly diverse areas where 20 to 60 percent of the shrub cover represent other species. These other species typically include desert tomato, Mormon tea, cheesebush, spiny hopsage, goldenhead, shadscale, bladder sage, California buckwheat, turpentine broom, Cooper's goldenbush, winter fat, and cotton-thorn. (See Appendix for scientific nomenclature of plants.)

The Mohave Ground Squirrel has also been captured in saltbush scrub and sand dunes. The saltbush community consisted of almost a pure stand of shadscale, with some budsage and occasional allscale and spiny hopsage. The sand dune habitat was dominated by shadscale. At this site Russian thistle, a persistent annual exotic whose growth is strongly influenced by rainfall, was common. Traces of allscale and inkweed were also present.

The substrates/soils varied a great deal among the sites where Mohave Ground Squirrels were captured. A common substrate in creosote/burroweed scrub was a fine granitic gravel with particle sizes of 3–10 mm. Sandy, but especially silty soils were

Table 2. Location and UTM coordinates for Mohave Ground Squirrel captures at Fort Irwin.

Investigator	Site Code	Location	UTM Coordinates
Krzysik	VC	Goldstone - 1.5 km SE Echo Site	N 190060 E 196055 S 190046 W 178055
	AC	Goldstone - 2.5 km NNW Echo Site	170085
	S	NTC - 1.5 km N Whale	462994 478997
	M	NTC - 4 km N Whale	461023
	AN	Goldstone - 2 km NNW North end of Goldstone Lake	083158
	SD	Goldstone - SE Tip of Goldstone Lake	101111
	Roadkill	Goldstone - Road on E Side of Goldstone Lake	116145
Wessman	41	NTC - 0.5 km NW Nelson Lake	191210
	42	NTC - 4.5 km NE Bicycle Lake	372090
	43	NTC - 2 km NNE of NW tip of Lucky Fuse	406220
	50	NTC - 1 km W Drinkwater Lake	402283
O'Farrell, Woodman, and Bagley	2	See Wessman 41	
	5	See Krzysik AN	
	8	NTC-Lizard Gulch; 4 km SE Rio Hondo Mine	177956

often associated with this material. Gravelly substrates consisting of 10–80 mm particle sizes, were associated with about a third of Fort Irwin's Mohave Ground Squirrel sites. Sandy soils in creosote/burroweed scrub were also utilized. In the saltbush scrub, Mohave Ground Squirrels were associated with either silty soils overlain with a pebble veneer (10–30 mm), or sand (less than 4 mm) at the sand dunes site.

Most Mohave Ground Squirrels at Fort Irwin have been caught at the VC valley/bajada site, where visual sightings also occurred in May 1986 and 1987. However, this study site as well as site S (severely impacted site in the southern NTC training corridor) are the two Fort Irwin sites that have been monitored heavily for 6 years. The high number of captures at the VC site is a reflection of this concentrated effort. Despite the same trapping effort at the heavily used site S, only two animals have been captured, and none since 1984. Habitat characteristics at the VC site are given in Table 3. Sampling methods used can be found in Krzysik (1985). Note that the total shrub cover is 23.8 percent, with creosote bush and burroweed making up 98.6 percent

Table 3. Habitat characteristics of the Goldstone VC Mohave Ground Squirrel site.

Species	Cover (%)	Standard Error
Creosote Bush	17.3	2.0
Burroweed	6.2	0.5
Desert Tomato	0.2	0.1
Other Species	0.1	0.02
Total	23.8	1.9
Substrate Particle size (cm)	**Percent**	**Standard Error**
<0.3	24	4
0.3-<1	67	6
1-<8	9	4
>8	0.2	0.1

of the species composition. The remainder is desert tomato (Anderson's desert thorn), with smaller proportions of goldenhead and cheesebush.

Mohave Ground Squirrels have not been captured or observed on steep slopes, mountainous terrain, or in rocky or boulder habitats on Fort Irwin.

Detailed studies quantifying the habitat requirements of the Mohave Ground Squirrel have not been conducted. Aardahl and Roush (1985) reported that the preferred habitat of Mohave Ground Squirrels is large alluvial filled valleys with deep fine- to medium-textured soils in creosote/bursage, shadscale, or alkali sink scrub communities. Mohave Ground Squirrels were found to avoid areas of desert pavement and eroded shallow soils. Mohave Ground Squirrels also avoided steep slopes and rocky terrain at the Coso Hot Springs study area of the Naval Air Weapons Station, China Lake (Zembal and Gall 1980), but were relatively dense in an area of scattered Joshua trees. At China Lake, Mohave Ground Squirrels are typically found in creosote/bursage scrub and shadscale scrub (Zembal and Gall 1980; China Lake 1988).

Wessman (1977) extended the previous known range of the Mohave Ground Squirrel into Fort Irwin. He trapped at 10 sites in 1977 and captured five Mohave Ground Squirrels at four sites. The author has sampled 27 sites between 1983 and 1990, and has recorded 15 captures and a road kill at 7 additional sites. O'Farrell, Woodman, and Bagley (Lee and Ro 1986) sampled 16 sites in 1985 and captured three Mohave Ground Squirrels—one at a Wessman site, another at a Krzysik site, and the third at a new site. At the 13 sites where they did not capture a Mohave Ground Squirrel, three sites were several kilometers away from (and circled) their successful capture at the Wessman site; one was a Krzysik site (SD); and the other was located within 1 km of their new capture. Therefore, a total of 50 sites have been trapped at Fort Irwin.

Mohave Ground Squirrels are more abundant and more widely distributed on the Naval Air Weapons Station, China Lake, because this area is more within the geographical range of the species. Mohave Ground Squirrels have been trapped and seen at many localities at both the China Lake Complex and the Mojave B/Randsburg Wash Range (China Lake 1988, Exhibit 2). Management areas for Mohave Ground Squirrels have been identified and set aside on both complexes (China Lake 1988, Exhibits 6a and 6b).

5 Conclusion and Recommendations

Conclusion: Status of the Mohave Ground Squirrel at Fort Irwin

The northeastern boundary of the geographical range of the Mohave Ground Squirrel is located in central Fort Irwin. Species at the edges of their range generally do not occur at high densities. However, these areas are important evolutionary centers because small gene pools at range boundaries are subjected to strong environmental and ecological selective pressures. The Mohave Ground Squirrel probably always occurred in patchy low-density populations at Fort Irwin. Populations of this species currently possess such characteristics even in optimum habitat in the center of their range. The four Wessman sites and the two Krzysik sites located in NTC training ranges have been heavily impacted by tracked and conventional vehicular traffic. This has particularly been the case following Wessman's 1977 field work. Despite intensive field work and trapping at the S and M sites between 1983 and 1989, the author has never seen a free Mohave Ground Squirrel, and has captured only two (1983 and 1984). After 1984, the only capture was a hybrid in 1989. In this same period, 50 Round-tailed Ground Squirrel captures were recorded at these two sites. Since they were not marked, individuals were not discernible. Several of these round-tails may have been hybrids, since their tails, although long, appeared "bushier" than normal.

The S site was badly degraded as early as 1983 (Krzysik 1985), and deterioration has accelerated (Krzysik 1994a). The M site was only moderately degraded in 1983, but in the 7 years that followed it became seriously impacted. The degradation includes extensive loss of shrub cover. Burroweed appears to be more susceptible to vehicle collisions than creosote bush; the latter species readily sprouts new crown growth from its roots. Disturbance to soil layers and cryptogamic crusts occurs on all training areas, and soil compaction occurs where traffic concentration is heavy. Whenever the winter rains are adequate, these disturbed soils, if not compacted, exhibit a profuse bloom of annual forbs and Mediterranean grass. Perennial forbs and grasses also respond. It is not known if this profuse bloom "makes up" for the loss of long-lived woody vegetation destroyed by vehicles. During drought periods, when herbaceous vegetation is absent or scarce, woody vegetation would appear to be an essential food reserve.

It is unknown if Mohave Ground Squirrels are still present in localities S or M. Considering how degraded these habitats are, their subjection to several years of drought, the potential competition and genetic introgression with the Round-tailed Ground Squirrel, and the lack of captures after extensive trapping, it appears that the Mohave Ground Squirrel may be extinct at these localities. However, the capture of a hybrid at site M in 1989 indicates that the species may still be present. A possible locality for Mohave Ground Squirrels is located 5 km NNE of the M site. This area is a bowl- shaped bajada lying against the northeastern portion of the Tiefort Mountains. Surprisingly, the habitat is not severely impacted, and large creosote bush is still present. Most of the vehicle impacts have occurred in the late 1980s. The soils are sandy with some gravel, and 'ground-squirrel-sized' burrows are present. Small mammal trapping has never been conducted in this area.

No Mohave Ground Squirrels were captured at the VC locality despite extensive trapping in 1988–1989. This area supports preferred forage for Mohave Ground Squirrels: Lycium, Amsinckia, and Coreopsis, but productivity in annuals has been almost nonexistent because of the lack of rainfall. Although this area contains high-quality habitat and has not been impacted, it is possible that the prolonged drought has caused a local extinction in this species. However, researchers agree that the population dynamics of the species are exemplified by very low population densities or 'disappearance' during drought years, and explosive population growth during springs that follow a wet winter. The relative contributions of migration and dispersal from prime habitat patches, and the high fecundity of local rare residents to the overall dramatic population density increases at any given location remain unresearched and unknown.

The four localities at the NTC where Wessman captured Mohave Ground Squirrels in 1977 have been severely impacted by Army training activities. Shrub cover losses have not been quantified, but qualitative losses in the Wessman localities are visually extensive. Soils have correspondingly been disturbed. The status of the Mohave Ground Squirrel in these areas is unknown, but the 1985 field surveys contracted by Lee and Ro (1986) yielded a Mohave Ground Squirrel at one of the sites. The Lizard Gulch locality identified by Lee and Ro is gradually receiving more impacts each year. Foot traffic is growing appreciably, and the area is being used by Army airborne units. A large tactical vehicle staging area was developed in 1989 just east of the area.

Recommendations: Management and Mitigation Issues

It is difficult to design management guidelines for the Mohave Ground Squirrel on Fort Irwin. This species probably always had a patchy distribution on the installation, with

each local population possessing low densities. With the present state of knowledge, the following management strategies are in order:

1. Preserve and manage as a natural area all of the undeveloped habitats within the 189 sq km area of Goldstone. The boundaries of Goldstone should be based on Fort Irwin Military Map Series V795S Edition 2-DMA.
2. Design and optimize survey techniques to specifically address this species at Fort Irwin. Optimal survey times are mid-March to late June. Technical foundations for survey techniques have been initiated by the author and California Fish and Game Department guidelines.
3. Resurvey all 12 sites where Mohave Ground Squirrels have been located on Fort Irwin.
4. Integrate Mohave Ground Squirrel localities and population parameters with vegetation, soil, geomorphological, geographical, and other identified environmental parameters into a geographic information system (GIS).
5. Identify and survey potential new localities on Fort Irwin. Field surveys guided by remotely sensed image analysis and a GIS should be used in the process. This technology is now being developed by the author's research group at the University of Illinois at Urbana-Champaign, which is conducting research in biodiversity, ecological modeling and risk assessment, and landscape ecology.
6. Protect all habitats in Goldstone from environmental impacts and degradation. The most serious impacts there are caused by unnecessary and unauthorized off-road travel of conventional and tracked tactical vehicles. The major access for these vehicles is the tank trail, constructed in 1985, which runs north-south and parallels the main blacktop road to Goldstone's Mars site. This road crosses through the Mohave Ground Squirrel VC site. Traffic using this road and all others on the Goldstone Complex should be authoritatively restricted from off-road travel. To ensure compliance, this restriction should include severe penalties for violators.

References

Aardahl, J. B., and P. Roush 1985. Distribution, relative density, habitat preference, and seasonal activity levels of the Mohave Ground Squirrel and White-tailed Antelope Squirrel in the Western Mojave Desert, California. U.S. Bur. Land Manage. Rep., Calif. Desert Dist., Riverside, CA.

Adest, G. A. 1972. Intraspecific and interspecific behavior of Ammospermophilus leucurus and Citellus mohavensis. M.S. Thesis. Calif. State Univ., Los Angeles, CA.

Bartholomew, G. A. 1977. Body temperature and energy metabolism. Pages 364-449 in Animal Physiology: Principles and Adaptation. M. J. Gordon, ed. McMillan. New York, NY.

Bartholomew, G. A., and J. W. Hudson 1960. Aestivation in the mohave ground squirrel, Citellus mohavensis. Bull. Mus. Comp. Zool. 124:193-208.

Bolger, D. P. 1986. Dragons at War: 2-34th Infantry in the Mojave. Presidio Press. Novato, CA.

Burt, W.H. 1936. Notes with habits of the Mohave Ground Squirrel. J. Mamm. 17:221-224.

California Department of Fish and Game 1987. Five-year status report: Mohave Ground Squirrel. Nongame Bird and Mammal Section, Calif. Dept. Fish and Game, Sacramento, CA.

China Lake 1988. China Lake Weapon Center Mohave Ground Squirrel and Management Plan. Envir. Resour. Mange. Branch, Naval Weapons Center, China Lake, CA.

Hafner, D. J., and T. L. Yates 1983. Systematic status of the Mohave Ground Squirrel, Spermophilus mohavensis (subgenus Xerospermophilus). J. Mamm. 64:397-404.

Halberstradt, H. 1989. NTC: A Primer of Modern Land Combat. Presidio Press. Novato, CA.

Hall, E. R. 1981. The Mammals of North America. John Wiley and Sons. New York, NY.

Hickman, J.C., ed. 1993. The Jepson Manual: Higher Plants of California. Univ. California Press. Berkeley, CA.

Hoyt, D. F. 1972. Mohave ground squirrel survey, 1972. Calif. Dept. Fish and Game, Special Wildlife Investigation, Final Rep., Project W-54-R.

Jaeger, E. C. 1961. Desert Wildlife. Standford Univ. Press, Stanford, CA.

Jameson, E.W., Jr., and H.J. Peeters. 1988. California Mammals. Univ. California Press. Berkeley, CA.

Krzysik, A. J. 1984. Habitat relationships and the effects of environmental impacts on the bird and small mammal communities of the central Mojave Desert. Pages 358-394 in Proceedings - Workshop On Management of Nongame Species and Ecological Communities. W. C. McComb, ed. University of Kentucky, Lexington, Kentucky.

Krzysik, A. J. 1985. Ecological assessment of the effects of Army training activities on a desert ecosystem: National Training Center, Fort Irwin, California. U.S. Army Corp of Engineers, Construction Engineering Research Laboratory, Tech. Rep. N-85/13, Champaign, IL. 139pp.

Krzysik, A. J. 1987. Environmental gradient analysis, ordination, and classification in environmental impact assessments. USA-CERL Technical Report N-87/19. 121pp.

Krzysik, A. J. 1990. Biological assessment of threatened, endangered, and sensitive animals and plants on Fort Irwin, California: National Training Center and Goldstone Deep Space Communications Complex. Report to Fort Irwin (NTC) and U.S. Army FORSCOM. 146pp.

Krzysik, A. J. 1991. Ecological assessment of military training effects on threatened, endangered, and sensitive animals and plants at Fort Irwin, California. Report to Fort Irwin (NTC) and U.S. Army FORSCOM. 171pp.

Krzysik, A. J. 1994a. Biodiversity and the threatened/endangered/sensitive species of Fort Irwin, California: The National Training Center mission, training effects, and options for natural resources management and mitigation. USACERL Technical Report EN-94/07. 114pp.

Krzysik, A. J. 1994b. The desert tortoise at Fort Irwin, California: A Federal threatened species. USACERL Technical Report EN-94/10. 99pp.

Lee and Ro. 1986. Endangered and sensitive species survey and deficiency tabulation for Fort Irwin National Training Center and Goldstone Space Communication Complex. Rep. to Fort Irwin DEH, Contract No. DACA09-84-C-0097.

Leitner, P. 1980. Survey of small mammals and carnivores in the Coso geothermal study area. Rep. IV in Field Ecology Technical Reprint on the Coso Geothermal Study Area, a Rockwell International, Environmental Monitoring and Services Center, Newbury Park, CA. Rep. to U.S. Bur. Land Manage., Bakersfield Dist., Bakersfield, CA, under contract no. YA-512-CT8-216.

Merriam, C. H. 1889. Description of a new spermophite from southern California. No. Amer. Fauna 2:15.

Recht, M. A. 1977. The biology of the Mohave Ground Squirrel, Spermophilus mohavensis: home range, daily activity, foraging and weight gain, and thermoregulatory behavior. Ph.D. Dissertation. Univ. Calif., Los Angeles, CA.

Schmidt-Nielsen, K. 1979. Desert Animals: Physiological Problems of Heat and Water. Dover Publ. New York, NY.

Vorhies, C. T. 1945. Water requirements of desert animals in the Southwest. Univ. Arizona Agric. Ext. Sta. Tech. Bull. No. 107, 487-525.

Wessman, E. V. 1977. The distribution and habitat preferences of the Mohave Ground Squirrel in the southeastern portion of its range. Calif. Dept. Fish Game, Wildl. Manage. Branch Admin. Rep. 77-5.

Zembal, R. and C. Gall 1980. Observations on Mohave Ground Squirrels, (Spermophilus mohavensis), in Ingo County, California. J. Mamm. 61:347-350.

Appendix: Scientific nomenclature of plant species discussed in report

Common plant name	After Hickman 1993
Allscale (Cattle Spinach)	Atriplex polycarpa
Bladder Sage (Paperbag-bush)	Salazaria mexicana
Budscale	Artemisia spinescens
Burroweed (Burrobush, White Bursage)	Ambrosia dumosa
California Buckwheat	Eriogonum fasciculatum
Cheesebush	Hymenoclea salsola
Cooper's Goldenbush	Ericameria cooperi (Haplopappus c.)
Coreopsis	Coreopsis sp.
Cotton-thorn	Tetradymia spinosa
Creosote Bush	Larrea tridentata
Desert Thorn	Lycium sp.
Desert Tomato (Anderson's Desert Thorn)	Lycium andersoni
Fiddlenecks	Amsinckia sp.
Goldenhead	Acamptopappus sphaerocephalus
Inkweed	Suaeda moquinii
Joshua Tree	Yucca brevifolia
Mediterranian Grass	Schismus arabicus/barbatus
Mormon Tea	Ephedra sp.
Russian Thistle (Tumbleweed)	Salsola tragus (also known incorrectly as S. kali, S. iberica, or S. australis)
Saltbush	Atriplex sp.

Shadscale	Atriplex confertifolia
Spiny Hopsage	Grayia spinosa
Turpentine-broom	Thamnosma montana
Winter Fat	Krascheninnikovia lanata (Ceratoides l., Eurotia l.)

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