

CURRENT STATUS OF THE MOHAVE GROUND SQUIRREL

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ABSTRACT: The Mohave ground squirrel (*Spermophilus mohavensis*) is found only in the western Mojave Desert of California. Although it is listed as Threatened by the State of California, there is little published information regarding its current distribution and status. I have assembled a comprehensive database covering unpublished field studies, surveys, and incidental observations conducted over the 10-year period from 1998-2007. This database contains records of 1140 trapping sessions, only 102 of which were successful in capturing ≥ 1 Mohave ground squirrels. In addition, there are 96 incidental observations in which the species was detected. An analysis of these 198 positive records identifies 4 core areas that continue to support relatively abundant Mohave ground squirrel populations and 4 other areas in which there are multiple recent records of the species. Although the southern portion of the range has been most intensively sampled, the only recent occurrences there are from a single core population on Edwards Air Force Base plus an additional 4 detections from Victor Valley. There are extensive areas within the geographic range where the status of the species is unknown, especially on the China Lake Naval Air Weapons Station and Fort Irwin. I present recommendations for surveys in areas where no recent studies have been carried out. I also identify potential corridors between known populations and recommend studies to determine if these connections are actually occupied by the species. Finally, I indicate conservation measures needed to ensure that known populations and corridors are adequately protected from habitat loss and degradation.

TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 44:11-29

Key words: Mohave ground squirrel, *Spermophilus mohavensis*, California, Mojave Desert, threatened species, core populations, corridors, conservation

The Mohave ground squirrel (*Spermophilus mohavensis*) is found only in the western Mojave Desert of California (Best 1995). Its historic range (Figure 1) totaled about 20,000 km² (Gustafson 1993). It has been found from the area of Palmdale and Victorville in the south to Owens Lake in the north. The eastern escarpment of the Sierra Nevada forms much of the western boundary of its range, while in the east its distribution extends to the Mojave River Valley and to the Fort Irwin military reservation. This region has experienced rapid growth over the past few decades. Urban development in the Antelope Valley, Indian Wells Valley, and along the Mojave River from Victorville to Barstow has resulted in a human population in excess of 700,000. Three large military bases conduct extensive training and testing operations. Much of the western Mojave Desert is used for motorized outdoor recreation, mining, and livestock grazing. There is an expanding transportation infrastructure, including highways, railroads, airports, pipelines, and electric transmission lines. Recent government policies have stimulated great interest in siting renewable energy facilities in this region, especially wind farms and solar installations.

Because of these multiple development pressures, there has been significant and on-going loss of wildlife habitat in the western Mojave Desert as well as widespread habitat degradation and fragmentation.

There has been concern about the conservation status of the Mohave ground squirrel since 1971, when it was first listed as Rare under the California Endangered Species Act (CESA). After the reauthorization of CESA in 1984, the species was classified as Threatened. Its subsequent regulatory history has been highly controversial. In 1993, the California Fish and Game Commission acted to remove it from the list of threatened species, a decision that was set aside in 1997 following judicial review. A petition to list the Mohave ground squirrel under the federal Endangered Species Act (ESA) was rejected by the US Fish and Wildlife Service in 1995. The US Fish and Wildlife Service is currently (2008) reviewing a new petition to list the species as endangered under the ESA.

In 2006, the US Bureau of Land Management (BLM) approved the West Mojave Plan, which was designed to conserve a number of sensitive species throughout the western Mojave Desert, with special emphasis on the desert tortoise (*Gopherus agassizii*) and Mohave ground squirrel (Bureau of Land Management 2006). The alternative version of the plan as adopted established a Mohave Ground Squirrel Conservation Area consisting of 6,988 km² of public lands managed by the BLM. (Fig. 1) These conservation measures do not apply to private and military lands within the historic range of the species.

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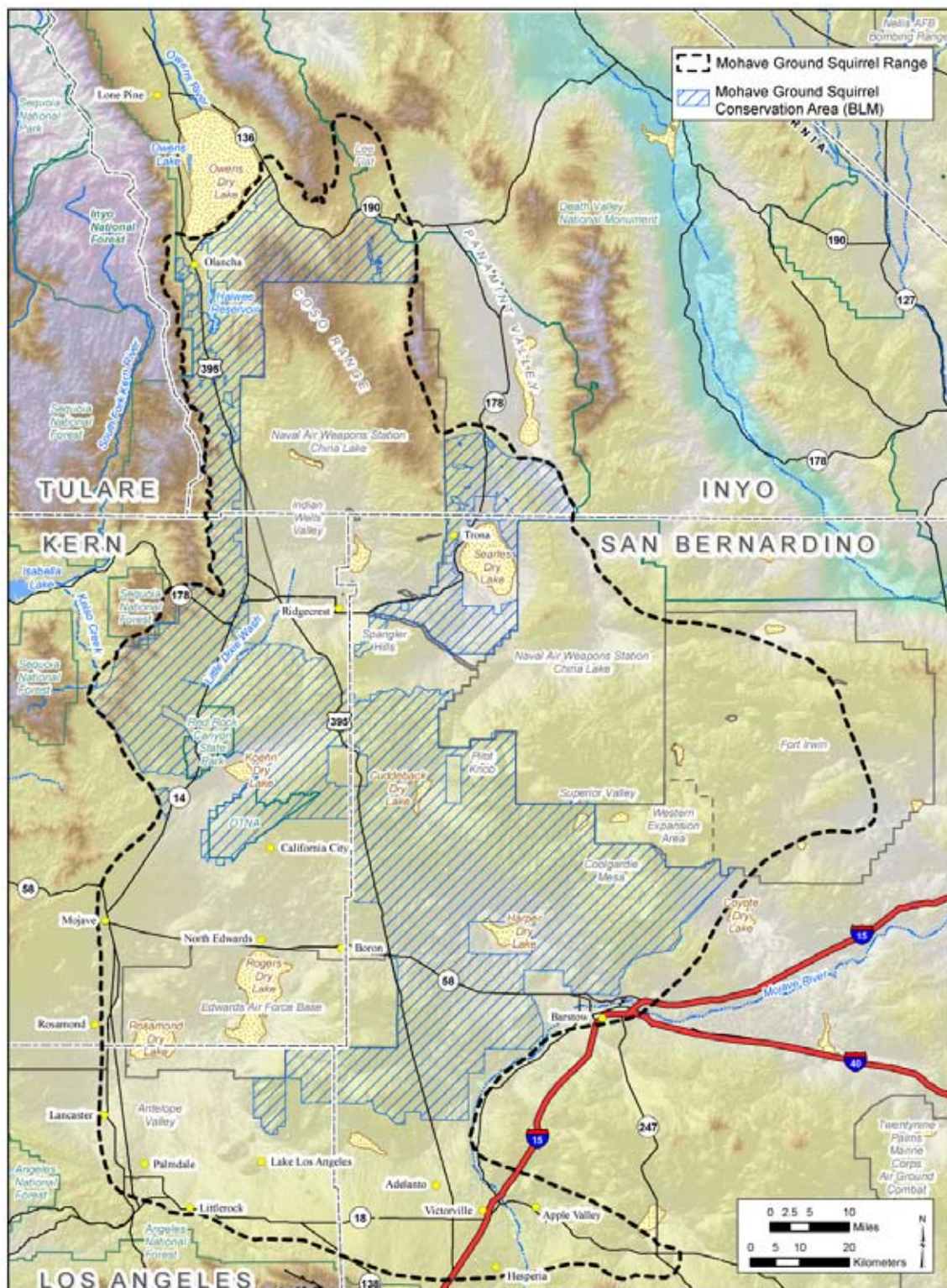


Figure 1. The historic range of the Mohave ground squirrel in the western Mojave Desert of California, with important place names indicated. The Mohave Ground Squirrel Conservation Area is shown as established in the West Mojave Plan (U.S. Bureau of Land Management (2005).

Although the Mohave ground squirrel has been designated as a state-listed species since 1971 and has been the focus of a major conservation planning effort by the BLM, there is still little published information on its distribution, abundance, and population trends. Brooks and Matchett (2002) reviewed 19 reported studies of the species, covering the period from 1918 to 2001. Only 2 of these studies were published in scientific journals. Since this review by Brooks and Matchett, a great deal of new information has become available, most of it unpublished. Two radiotelemetry studies describing home range dynamics and juvenile dispersal were recently published in peer-reviewed journals (Harris and Leitner 2004, 2005). Several state and federal agencies, as well as private conservation groups, have sponsored field research designed to determine the status of the species in particular areas. In addition, the California Department of Fish and Game (CDFG) requires trapping surveys at proposed development sites according to a prescribed protocol (CDGF 2003).

This paper brings together the data from unpublished field studies and surveys conducted during the 10-year period from 1998-2007. I have obtained reports for all sponsored research surveys and have received information on protocol trapping surveys from many consulting biologists. The information presented here includes both positive records documenting Mohave ground squirrel occurrence and negative results from trapping surveys in which the species was not detected. The objectives of this review are to:

1. Document the geographic distribution of Mohave ground squirrel occurrences,
2. Summarize the distribution and relative intensity of survey efforts,
3. Identify important areas and corridors for conservation based on available occurrence data, and
4. Recommend areas where additional survey effort is needed.

METHODS

I utilized 4 sources of information regarding the distribution and occurrence of the Mohave ground squirrel during the period 1998-2007: the California Natural Diversity Database, regional field studies, protocol trapping at proposed development sites, and incidental observations as reported by field biologists.

The California Natural Diversity Database (CNDDDB) is a state-wide inventory of the status and locations of rare species and natural communities. The CDFG produces and regularly updates this computerized catalog, which contains records of occurrence submitted by state and federal agencies, consulting firms, and individual biologists. It contains positive records of

occurrence only and generally does not include data documenting the absence of a species from a particular locality.

The CNDDDB contained a total of 293 occurrence records for the Mohave ground squirrel as of August 4, 2007 (CNDDDB 2007). Twenty-eight new occurrences were submitted during the period from 1998-2007 and there were also 2 new records at previously known locations for the species. These records were obtained from regional field studies, protocol trapping, and incidental observations. I incorporated these 30 records into the data base used in this analysis.

A number of regional field studies have been conducted during the past 10 years, many of them funded by public agencies and private conservation groups. I have reviewed 19 unpublished reports that describe the results of such trapping surveys and have also obtained data from several biologists whose surveys have not been documented in formal reports (Appendix A).

The third source of data was trapping surveys carried out at proposed development sites, as required by the CDFG (CDFG 2003). The CDFG guidelines specify that surveys be conducted on proposed project sites that support desert scrub vegetation and are within or adjacent to the Mohave ground squirrel geographic range. The surveys must be carried out by a qualified biologist operating under authority of a Memorandum of Understanding (MOU) with CDFG. The protocol mandates an initial visual survey of the project site. If no Mohave ground squirrel is detected visually, live-trapping is required for up to 3 sessions of 5 consecutive days each. The trapping sessions must be conducted during the periods March 15-April 30, May 1-31, and June 15-July 15. Trapping grids normally consist of 100 traps arranged in a 4x25 array (linear projects) or in a 10x10 array (other projects).

If a Mohave ground squirrel is detected on the site, the project proponent must apply to CDFG for an Incidental Take Permit and provide compensation, usually in the form of mitigation lands. If no Mohave ground squirrel is observed or captured, it is not necessarily evidence that the site is unoccupied or is not potential habitat. Nonetheless, CDFG will stipulate for a period of 1 year that the project site harbors no Mohave ground squirrels. Most protocol surveys carried out in recent years have not resulted in detection of the species.

In order to obtain the results of protocol trapping surveys for the period 1998-2007, I contacted all biologists who were known to possess an MOU authorizing take of Mohave ground squirrels. The great majority responded by providing their survey data, including dates of trapping sessions, coordinates of grid centers, number of trap-days of sampling effort, and

whether or not Mohave ground squirrels were detected. Although I have not obtained data for all protocol trapping efforts, I have collected a total of 943 records that represent 426,615 trap-days of sampling. I estimate that I obtained records for >95% of the total protocol trapping effort for the period 1998-2007.

I have classified as incidental observations all reports by biologists who observed or captured Mohave ground squirrels incidental to other field studies. This category includes visual and auditory detections, captures made while trapping for other species, and highway mortalities.

For regional and protocol surveys, a record is defined as a single trapping session, usually consisting of 5 successive days. Records from trapping surveys can be negative, with no Mohave ground squirrel captures, or positive, indicating a session with at least 1 capture. On the other hand, records from incidental observations were always positive, indicating the detection of at least 1 Mohave ground squirrel at a specific location. Table 1 lists the number of records obtained for this review from regional surveys, protocol trapping, and incidental observations. The regional and protocol trapping surveys provided a total of 1,038 negative records, as compared to only 102 trapping sessions in which at least 1 Mohave ground squirrel was captured. Although the regional studies involved only 21.6% of the total trapping effort, they accounted for 69.6% of the positive records. On

Table 1. A summary of the data sources used for this review. For regional and protocol surveys, a record is defined as a single trapping session (usually 5 days) at a specific grid location. If no Mohave ground squirrels were detected, such records were considered negative, while a positive record was a trapping session in which >1 Mohave ground squirrels were captured. For incidental observations, all records are positive. Each record indicates the detection of >1 Mohave ground squirrels at a particular location. The sampling effort for regional and protocol surveys is calculated as the number of traps operated per day times the number of days per trapping session summed over all trapping sessions.

Type of Data	Total	Positive Records	Trap-days
Regional Surveys	197	71	111,710
Protocol Surveys	943	31	426,615
Incidental Observations	96	96	N/A
Totals	1,236	198	538,325

the other hand, the protocol surveys made up 78.4% of trapping effort, but contributed only 30.4% of Mohave ground squirrel detections.

I entered data from all sources into an Excel spreadsheet and then imported that into an Access database. This permitted data to be manipulated and extracted through the query process. A series of base maps covering the geographic range of the Mohave ground squirrel was developed using Geographic Information System (GIS) techniques. All records, both positive and negative, were plotted on these digital maps for visual analysis. In this way, the distribution of Mohave ground squirrel occurrences for the last 10 years could be visualized in relation to the distribution of sampling effort.

RESULTS

General Distribution of Mohave Ground Squirrel Records

The geographic distribution of both positive and negative Mohave ground squirrel records over the period 1998-2007 is shown in Figure 2. There has been no attempt at either systematic or random range-wide sampling and the records tend to be concentrated in certain well-defined regions. The great majority of trapping effort has been conducted in the southern part of the geographic range, south of State Route 58. In spite of this very intensive sampling, Mohave ground squirrels have been detected in only 2 areas south of State Route 58, one on Edwards Air Force Base and the other in the vicinity of Victorville. The northern part of the geographic range is in Inyo County, where almost all trapping has been conducted in the Coso region on China Lake Naval Air Weapons Stations (China Lake NAWS) and in the vicinity of Olancho and Haiwee Reservoir. Outside of these 2 areas, there have been only 5 widely scattered detections in the entire northern part of the range over the past 10 years. In the central part of the range, from Ridgecrest south to State Route 58, most positive records have been concentrated in 6 distinct regions. Trapping in the vicinity of Ridgecrest has resulted in the capture of a number of Mohave ground squirrels and there are abundant records for the extensive valley (Little Dixie Wash) between Inyokern and Red Rock Canyon State Park. To the south, there is a cluster of detections associated with the Desert Tortoise Natural Area (DTNA) and another in the Pilot Knob region east of Cuddeback Dry Lake. There are many records from the broad plateau that lies north of Barstow (Coolgardie Mesa and Superior Valley) and there are also several detections in the area just north of Boron.

It is clear that there are extensive areas within the range of the Mohave ground squirrel that have not been

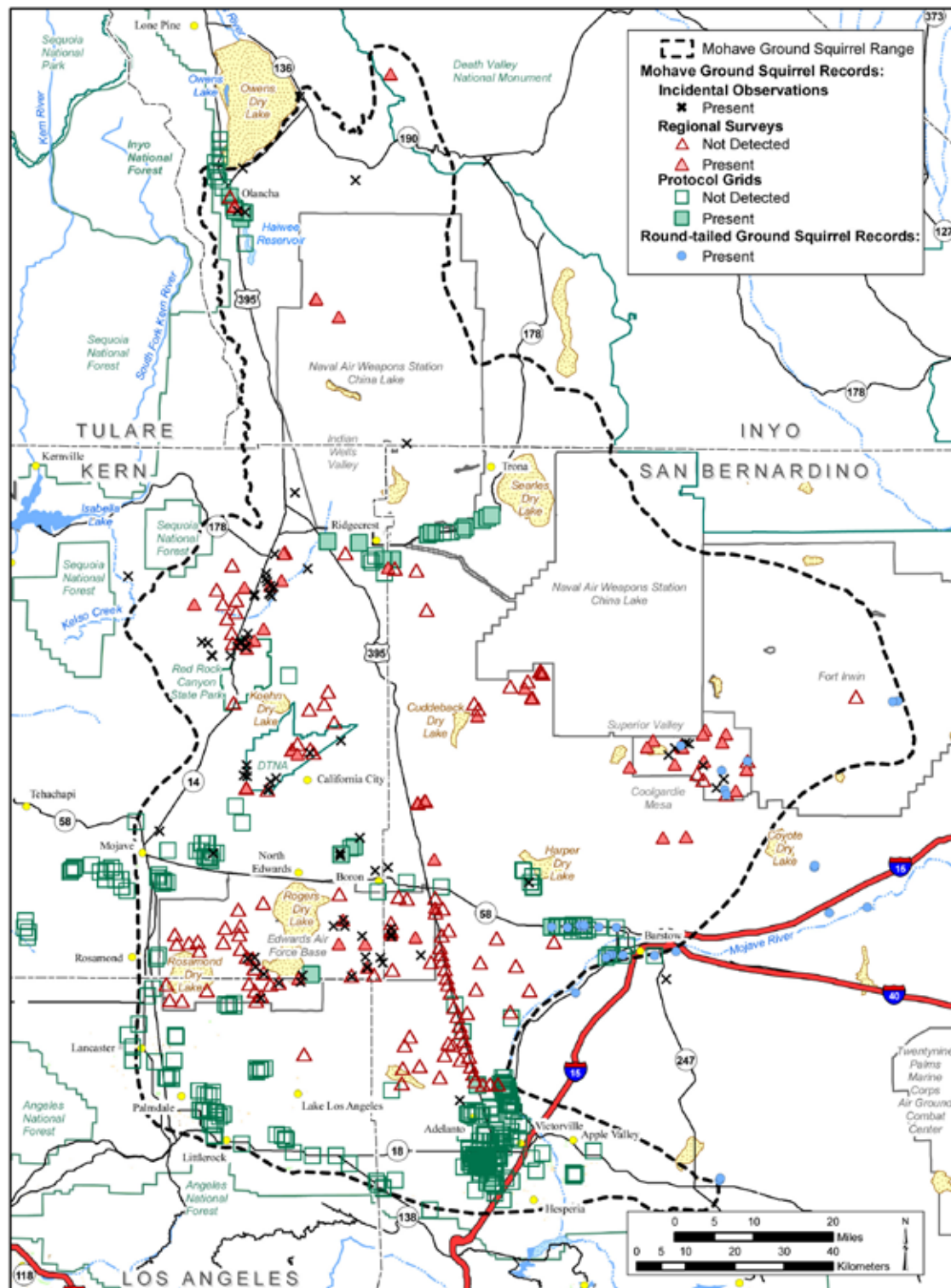


Figure 2. The geographic distribution of all Mohave ground squirrel records for the period 1998-2007. A total of 1,236 records are plotted, which include 1,140 trapping sessions conducted for regional and protocol surveys and 96 incidental observations. Solid triangles and squares represent locations of trapping grids at which >1 Mohave ground squirrels were captured. Crosses show sites of the 96 incidental observations at which >1 Mohave ground squirrels were detected.

effectively sampled. Figure 3 shows a 10x10 km sampling frame superimposed on the geographic range, with the sampling units color-coded to indicate the number of records (both positive and negative) for each unit during the period 1998-2007. It can be seen that sampling efforts have been heavily concentrated in the southern part of the range, especially to the west and north of Victorville, in the Palmdale-Lancaster area, around Barstow, and in the vicinity of the town of Mojave. Approximately 67% of all trapping efforts have been located in the region from State Route 58 south. The lack of recent data on Mohave ground squirrel occurrence in the northern part of the range is obvious, but there are also large gaps in our knowledge in the central part of the range. Except for the Coso area, there have been no surveys on either the north or south ranges of China Lake NAWS during the past 10 years. The Western Expansion Area of Fort Irwin has been well sampled using a randomized method of selecting trapping sites. However, only 1 trapping attempt has been recorded elsewhere on Fort Irwin over the period 1998-2007. In contrast, Edwards Air Force Base has sponsored extensive surveys on a randomized sampling basis, so that the distribution of the species is known there in great detail.

Regional Analysis of Mohave Ground Squirrel Records

In this section, I present detailed information on Mohave ground squirrel distribution and abundance during the period 1998-2007 for a number of regions within the geographic range. This regional analysis is supported by a series of 7 maps that are available as Supplemental Online Material at the website of The Western Section of The Wildlife Society: http://tws-west.org/transactions/TWSWS_Transactions_directory.htm

Inyo County.—Inyo County includes the northernmost region occupied by Mohave ground squirrels. Records are concentrated in the area between Olancha and Haiwee Reservoir and in the Coso Range, within the China Lake NAWS. The species has been detected at 5 protocol trapping grids to the south of Olancha, beginning in 2002. Mohave ground squirrel populations at 2 sites in the Coso Range have been monitored by regular spring trapping sessions. Animals have been captured on both grids at every trapping occasion. In 2007, a Mohave ground squirrel was captured at Lee Flat just inside the boundary of Death Valley National Park, which marks the northernmost record for the species. The other 4 records for Inyo County are incidental observations, including an individual that was stuck by a vehicle in northern Panamint Valley, several kilometers east of the generally-accepted limits of the range.

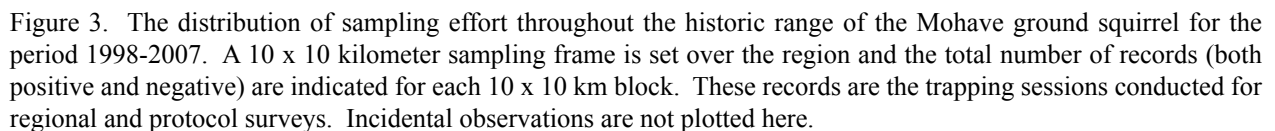
Ridgecrest Area.—Trapping has been conducted at 10 grids in the vicinity of Ridgecrest, with Mohave ground squirrels detected at 5 of these sites. In addition, protocol trapping at 10 grids along State Route 178 east of Ridgecrest in 2006 yielded captures at 6 locations. However, no Mohave ground squirrels were captured in 2002 at 2 sites in the Spangler Hills southeast of Ridgecrest.

Little Dixie Wash.—The Little Dixie Wash region is a broad valley extending from Inyokern southwest to Red Rock Canyon State Park. Two extensive trapping studies have detected Mohave ground squirrels throughout this region. In 2002, the species was captured at 6 of 7 grids widely scattered across this valley. There have been more than 20 incidental observations as well, suggesting that Mohave ground squirrels are widely distributed here. In 2007, a visual sighting established the first record to the west of the mountain crest in the Kelso Creek drainage.

Fremont Valley to Edwards Air Force Base.—The Fremont Valley extends northeast from the vicinity of Cantil toward Garlock and Johannesburg. No Mohave ground squirrels have been detected here during the past 10 years, despite trapping efforts at 6 grids. There are 13 positive records around the periphery of the DTNA and out a few kilometers to the east. No trapping has been carried out in the interior of the DTNA, but it is likely that Mohave ground squirrels are present there as well. Two incidental records exist for the area just to the north and east of the town of Mojave, but repeated protocol trapping efforts here have been unsuccessful. Finally, there are 10 trapping records and incidental observations in the area to the north of Boron and Kramer Junction. These records suggest a fairly widespread population across this region.

Wind Farm Area Southwest of Mojave.—Protocol trapping surveys have been conducted at 24 grids located on wind energy development sites southwest of the town of Mojave. Although this area is outside the generally-accepted boundaries of the geographic range, much of the habitat here seems suitable for the species. To date, no Mohave ground squirrels have been detected during these trapping efforts. Two recent visual observations are listed in the CNDDDB, but confirmation through trapping is needed.

Edwards Air Force Base.—Edwards Air Force Base has been carrying out an extensive monitoring program to document the distribution of Mohave ground squirrels within the military reservation. From 2003 through 2007, trapping has been conducted at 40 randomly-located grids across the base, resulting in detection of the species at 6 of these sites. In combination with other trapping efforts and incidental observations, this program has clearly defined the area in which Mohave ground squirrel populations are present.



Los Angeles County.—Protocol trapping has been conducted at 52 grid locations in the desert portion of Los Angeles County during the period 1998-2007, but no Mohave ground squirrels have been detected by this method. The only positive records in Los Angeles County have been 4 detections in a small area near Rogers Dry Lake on Edwards Air Force Base.

Victor Valley to Barstow.—Intensive protocol trapping has been conducted in the Adelanto area and on the western outskirts of Victorville, resulting in the capture of Mohave ground squirrels at 3 separate locations. The 2 trapping records north of Adelanto plus a visual sighting just to the west suggest the presence of a residual population in this area. Capture of a juvenile female well to the south near the intersection of US 395 and I-15 indicates that another population may exist here as well. There have been no records east of the Mojave River since 1955 but, as shown in Figure 2, this area has not been effectively sampled in the last 10 years. Three major trapping studies have been conducted from El Mirage Dry Lake north and east toward Barstow. There have been no detections of Mohave ground squirrels over this extensive area.

Barstow Area.—There were only 3 Mohave ground squirrel records in the Barstow area during the period 1998-2007. In 2005, a Mohave ground squirrel was observed about 6 km south of Barstow near the city landfill, in an area outside the generally-accepted range boundary. Two other occurrences were documented in 2007 to the west of Barstow. Mohave ground squirrels were detected at the edge of an alfalfa field near Harper Dry Lake and 1 was trapped about 10 km west of Hinkley near State Route 58.

Coolgardie Mesa and Superior Valley.—To the north of Barstow is a broad, gently-sloping plateau that extends from Coolgardie Mesa in the south to Superior Valley in the north. Three trapping studies have been conducted in this region over the past 10 years and all have documented Mohave ground squirrel occurrences. There have also been at least 7 incidental observations.

Pilot Knob Area.—Trapping studies in the Pilot Knob area, from Cuddeback Dry Lake east to the boundary of China Lake NAWS, have detected Mohave ground squirrels at 5 different sites.

Contact Zone with Round-tailed Ground Squirrel

The Mohave ground squirrel and the round-tailed ground squirrel (*Spermophilus tereticaudus*) are closely related (Hafner and Yates 1983). The 2 species are very similar in general appearance, the most obvious difference being the much longer tail of the round-tailed ground squirrel. The round-tailed ground squirrel is found throughout the eastern Mojave Desert of California and its geographic range adjoins that of the Mohave

ground squirrel. The contact zone between the 2 species extends from Lucerne Valley along the Mojave River to Barstow and then northeast through Fort Irwin (Fig. 4). During the period 1998-2007, a total of 30 round-tailed ground squirrel occurrences have been recorded in this contact zone. Round-tailed ground squirrels are common in the area around Barstow, especially in disturbed habitats. The species has also been observed in Lucerne Valley, near Hodge on the Mojave River, near Coyote Dry Lake, and on the eastern side of Fort Irwin. In addition, round-tailed ground squirrels have been detected in 2 areas well within the historic range of the Mohave ground squirrel. There have been 5 reports from the Western Expansion Area of Fort Irwin, as much as 24 km inside the generally-accepted boundary of the Mohave ground squirrel range. The other area of interest is west of Barstow along State Route 58, where round-tailed ground squirrels were trapped at 8 sites in 2006 and 2007. Individuals of both species were captured on a grid about 20 km west of the range boundary. Lack of historical baseline data makes it impossible to determine if the round-tailed ground squirrel is actively extending its distribution at the expense of the Mohave ground squirrel.

DISCUSSION

General Distribution of Mohave Ground Squirrel Records

It is important to be clear about the significance of positive records that indicate Mohave ground squirrel presence during the past 10 years. These positive records are highly concentrated in just 8 distinct areas, in which 93.4% (185/198) of all Mohave ground squirrel occurrences have been documented (Fig. 5). It is of interest that there are at least some Mohave ground squirrel records prior to 1998 in each of these 8 areas, suggesting that recent trapping effort has focused on areas with historic records. However, much of the Mohave ground squirrel range has never been surveyed. This is especially true in Inyo County, which includes large areas where no surveys or protocol trapping have ever been carried out. The situation is similar, although not as extreme, in the central part of the range. There are 6 areas here where recent evidence indicates the presence of Mohave ground squirrel populations. However, little trapping has been conducted outside the areas that support these known populations. In the southern part of the range, south of State Route 58, there has been much greater trapping effort and the sampling has been much more widely distributed. Even here, there are still a few relatively restricted areas that have not been surveyed since 1998. In all 3 sections of the Mohave ground squirrel range, additional populations may well

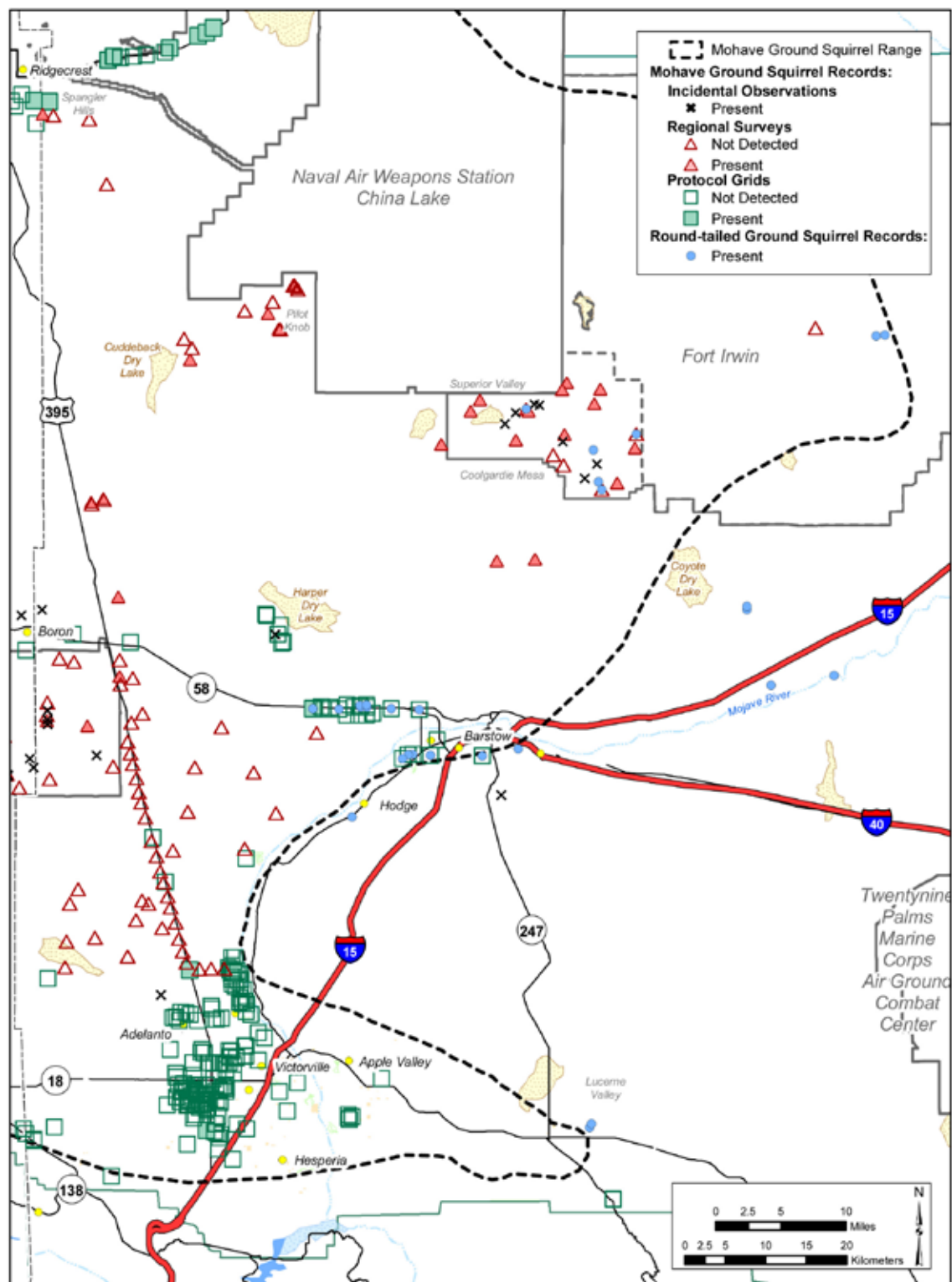


Figure 4. The contact zone between the Mohave ground squirrel and the round-tailed ground squirrel. This shows the distribution of trapping sessions conducted for regional and protocol surveys, as well as incidental observations of Mohave ground squirrels. Circles show sites where round-tailed ground squirrels have observed or captured. These data cover the period 1998-2007.



exist outside the 8 areas in which recent positive records are concentrated.

The significance of negative records must be interpreted carefully as well. When regional surveys or protocol trapping fail to detect Mohave ground squirrels, it is important to keep in mind that this in itself cannot be used as evidence that the species is absent or that the area does not provide habitat for the species. There are a number of other circumstances that could result in lack of captures, such as locating a trapping grid in a small patch of marginal or unsuitable habitat, abundance of natural foods that reduce the attractiveness of the bait, low population density due to a series of dry years, or trapping early in the season before juveniles begin their dispersal movements. If trapping grids are not randomly sited, it is not valid to infer from a lack of captures at the grid sites that Mohave ground squirrels are absent in the surrounding habitat. Any conclusions would apply only to the grid sites themselves. In general, the most that can be concluded from lack of captures is that the negative results provide no evidence that the species is present. However, if repeated trapping efforts over a period of several years fail to detect Mohave ground squirrels, it becomes more and more probable that the species is very rare, if not absent, from the study area.

The distribution of trapping effort among private, military, and public land ownerships has been distinctly uneven over the past 10 years. Almost all protocol trapping surveys have been conducted on private lands or on highway rights-of-way, because of the regulatory requirement to determine presence or absence of the Mohave ground squirrel on proposed project sites. Military lands make up about 37% of the land surface

within the range boundaries, but have been the locations for only 7.4% of all trapping records (Table 2). While Edwards Air Force Base and the Western Expansion Area of Fort Irwin have been sampled intensively, very little trapping effort has been expended on the remainder of Fort Irwin or on China Lake NAWS.

Core Areas

Data collected over the past 10 years has made it possible to identify 4 areas within the range of the Mohave ground squirrel that still support relatively abundant and widespread populations. These core areas are defined by 3 criteria. First, there must be evidence that Mohave ground squirrel populations have persisted for a substantial period of time, on the order of 2-3 decades. Second, the species must be currently found at a minimum of 6 locations throughout the area. Third, the total number of individuals detected since 1998 must be ≥ 30 . The 4 areas that are currently known to satisfy these criteria are Coso/Olancha, Little Dixie Wash, Coolgardie Mesa/Superior Valley, and Edwards Air Force Base (Fig. 5). These 4 core areas total about 1,672 km², or about 8.4% of the entire historic range (Table 3). During the period 1998-2007, there have been 135 positive records in core areas, accounting for 68.2% of the total 198 positive records. It is important to emphasize that these identified core areas are simply the only important population centers that have been identified thus far. There are very likely to be other core areas in parts of the geographic range that have not been adequately sampled in the last 10 years.

Coso/Olancha Core Area.—China Lake NAWS sponsored field studies of the Coso Hot Springs area

Table 2. An analysis of trapping effort on military lands within the range of the Mohave ground squirrel (MGS) during the period 1998-2007. The number of sites refers to the number of distinct trapping grid locations, while the number of records is the total number of trapping sessions at all sites, regardless of whether Mohave ground squirrels were captured.

Military Base	Area (km ²)	% MGS Range	No. Sites	No. Records	% Records
China Lake NAWS	4400	22%	2	20	1.8%
Fort Irwin	1800	9%	18	19	1.7%
Edwards AFB	1200	6%	43	43	3.9%
Totals	7400	37%	63	82	7.4%

in 1978 that detected 35 Mohave ground squirrels at a number of sites through trapping and visual observations (Zemba and Gall 1980). In the following year, trapping was carried out at 8 sites throughout the Coso Range and in Rose Valley to the west (Leitner 1980). A total of 124 individual Mohave ground squirrels were captured at 7 of the 8 trapping grids. A monitoring program in the Coso Range and Rose Valley from 1988 through 1996 resulted in the capture of over 1400 juvenile and adult Mohave ground squirrels (Leitner and Leitner 1998). Aardahl and Roush (1985) failed to trap the species at a site near Olancho in 1980, but did observe several individuals in the same general area.

During each of the past 7 years (2001-2007), Mohave ground squirrels have been trapped at 2 permanent grids in the Coso Range (Leitner 2001, 2006, 2008). A total of 89 adults have been captured over this period. The species has also been detected regularly in the Olancho area, where 29 adult captures were recorded at 5 sites from 2002 to 2005. The Coso/Olancho area clearly qualifies as an important core area, based upon the persistence of Mohave ground squirrel populations here for 30 years, the presence of the species at many sites, and the number of animals detected.

Little Dixie Wash Core Area.—Mohave ground squirrels were first recorded in the Little Dixie Wash region in 1931 and 1932, when specimens were collected at Freeman Junction and on the east side of Walker Pass (CNDDDB Occ. #21 and #52). Trapping surveys by the BLM in 1974 and 1975 resulted in 17 captures at 7 localities in Dove Springs Canyon and Bird Spring Canyon (CNDDDB Occ. #84, #174, #175, and #191-194). Aardahl and Roush (1985) reported capturing a total of 94 individuals (both adults and juveniles) at 6 grids in the Little Dixie Wash area from April-July 1980. Finally, trapping at 2 sites in 1994 yielded a total of 12 Mohave ground squirrels (Scarry et al. 1996). Additional occurrences were documented at 10 other locations in this region during the period 1974-

1990. Thus, Mohave ground squirrels were recorded at 27 locations in the Little Dixie Wash area from 1931 through 1996.

Recent field studies have been conducted in the Little Dixie Wash area during the period 2002-2007. In 2002, a total of 19 adult Mohave ground squirrels were captured at 6 of 7 grid locations (Leitner 2008). This was followed by more intensive studies at the Freeman Gulch site, with a total of 108 adults and 101 juveniles recorded from 2003 through 2007. Pit-fall trapping for reptiles in the Dove Springs Open Area resulted in the incidental capture of 6 Mohave ground squirrels at 4 different locations. Finally, a trapping survey in 2007 yielded 7 adults at 4 grids near the northern boundary of Red Rock Canyon State Park (Leitner 2008). The Little Dixie Wash core area has supported Mohave ground squirrel populations for over 70 years and recent records confirm that the species is abundant and widespread here.

Coolgardie Mesa/Superior Valley Core Area.—Mohave ground squirrels were first discovered in 1977 north of Barstow on the plateau that stretches from Coolgardie Mesa north to Superior Valley (Wessman 1977). The species was detected at 9 locations, with 1-3 individuals reported at each site. In 1980, Aardahl and Roush (1985) trapped 2 grids in Superior Valley, capturing 24 individuals (both adults and juveniles). A total of 24 Mohave ground squirrels were subsequently recorded at 5 sites in 1981 and 1982 (CNDDDB Occ. #206-210). In 1994, 4 individuals were captured at 2 trapping grids in this area (Scarry et al. 1996).

Two recent surveys have been carried out in the Coolgardie Mesa/Superior Valley area. Trapping at 4 sites in 2002 yielded Mohave ground squirrel captures at each location for a total of 14 adults. A more extensive survey of the Western Expansion Area of Fort Irwin in 2006 and 2007 resulted in 36 individuals captured at 10 of 12 trapping grids. There is clear evidence that Mohave ground squirrels have persisted here for at

Table 3. The estimated sizes of the 4 identified core areas, as measured in square kilometers and in acres. The number of positive Mohave ground squirrel records for the period 1998-2007 is given for each core area.

Core Area Name	Area (km ²)	Area (acres)	Number of Positive Records
Coso / Olancho	452	111,690	33
Little Dixie Wash	393	97,172	44
Coolgardie Mesa / Superior Valley	516	127,450	23
Edwards Air Force Base	311	76,761	35

least 30 years. Recent surveys have documented that the species was present at 14 of 16 trapping sites and in several cases a substantial number of individuals was captured. This core area is at the eastern edge of the range and several captures or observations of animals that appear to be round-tailed ground squirrels have been recorded here. The potential for hybridization in this area between these 2 closely related species should be carefully investigated.

Edwards Air Force Base Core Area.—A number of surveys have documented the past occurrence of Mohave ground squirrels on Edwards Air Force Base, with most records located to the north, east, and south of Rogers Dry Lake. The earliest observations were made during the period 1973-1977 in the area south of Rogers Dry Lake (CNDDDB Occ. #265). Seventeen Mohave ground squirrels were trapped in 1988 at 3 sites northeast of Rogers Dry Lake (ERC Environmental and Energy Services Company 1989). Additional trapping in 1993 in this same area resulted in captures of many adults and juveniles (Deal et al. 1993, Mitchell et al. 1993). Surveys at Mt. Mesa to the southeast of Rogers Dry Lake yielded 9 Mohave ground squirrels in 1992 (U.S. Fish & Wildlife Service 1993) and over 30 individuals in 1993 (Deal et al. 1993, Mitchell et al. 1993). A total of 13 Mohave ground squirrels were trapped in 1994 at 4 sites in halophytic saltbush scrub to the south and southwest of Rogers Dry Lake (Buescher et al. 1995). The species was recorded at 4 additional locations to the east of Rogers Dry Lake during the period 1981-1991.

Recent field studies have clearly delineated a core area on Edwards Air Force Base, with all Mohave ground squirrel records since 2000 localized to the east and south of Rogers Dry Lake. Trapping surveys were conducted at 19 grids in this area during the period 2000-2005, with a total of 29 adults and 4 juveniles captured at 8 of the study sites (Vanherweg 2000, Leitner 2003, Air Force Field Test Center 2004 and 2005, Leitner 2008). Although no captures were recorded at the 8 grids south of Rogers Dry Lake in 2005, Mohave ground squirrels are known to be present here, based upon 6 incidental observations. Mohave ground squirrel populations have been known in this core area for over 30 years and the large numbers of recent records demonstrate that the species is still well-distributed here. To date, this is the only core area known to exist in the southern part of the range.

Connectivity between Core Areas

The 4 core areas are isolated from each other by distances ranging from 48-80 km. It will be an important conservation goal to ensure sufficient connectivity between them to allow gene flow. Figure 6 shows the

locations of the core areas with possible habitat corridors illustrated.

The potential corridor between the Coso/Olancha core area and Little Dixie Wash follows a narrow strip of public land between the Sierra escarpment and the boundary of China Lake NAWS. It is not clear that this corridor is effective because of its minimal width (1-4 km) and because there is no firm evidence that it is currently occupied. There may well be an alternative corridor through China Lake NAWS, but the U.S. Navy cannot guarantee permanent protection and, again, there is no proof that continuous Mohave ground squirrel populations exist here.

Connectivity between the Little Dixie Wash core area and Edwards Air Force Base is most likely to be achieved by protection of a north-south habitat corridor along US Highway 395. This linkage appears to provide the highest quality habitat connection between these 2 core areas. It would also help to provide connectivity among other known populations in the Ridgecrest area, the DTNA, Pilot Knob, and the Boron region. There are no recent Mohave ground squirrel records along much of this corridor, so it is not clear that it is currently occupied.

The most effective corridor linking the Coolgardie Mesa/Superior Valley core area with other populations is probably thorough the Pilot Knob region. This connection is relatively short and crosses apparently good quality habitat. Although the most direct route is across a corner of the China Lake NAWS, public lands just to the south could also provide connectivity. An alternative linkage would be to the southwest toward Edwards Air Force Base across the broad valley centered on Harper Dry Lake. However, this route is lower in elevation, receives less rainfall, and habitat here is of lesser quality.

The lack of data concerning the existence or status of Mohave ground squirrel populations in these potential corridors is a serious problem. While these routes may seem geographically appropriate in providing linkages between populations, it will be important to conduct field studies to determine whether or not they are actually occupied.

MANAGEMENT RECOMMENDATIONS

The database of Mohave ground squirrel records that has been assembled for this analysis should be maintained by CDFG or another suitable public agency and made available for on-line access by interested researchers, agency staff, consultants, and conservation organizations. An interactive mapping system should be developed in conjunction with the database, so that

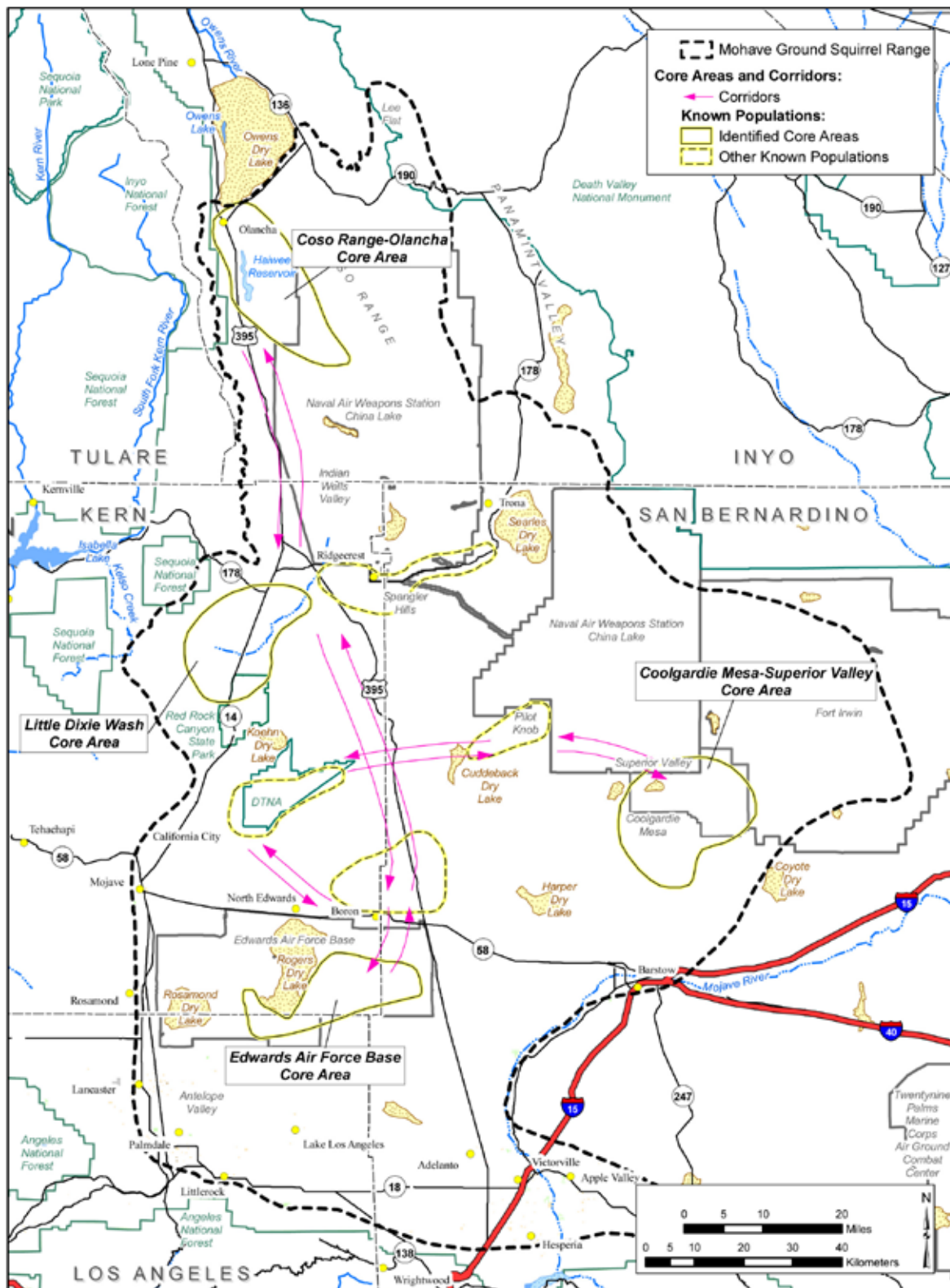


Figure 6. Map of potential habitat corridors that may provide connectivity between identified core areas and other known Mohave ground squirrel populations.

users could obtain map displays of areas of interest. As recommended by Brooks and Matchett (2002), a system should be developed to collect both positive and negative data on a continuing basis from biologists, agency staff, and consultants. It would be desirable to issue an annual report with appropriate maps to provide updated information on Mohave ground squirrel occurrences.

It is clear that additional field surveys are urgently needed to provide a more comprehensive picture of Mohave ground squirrel occurrence and status throughout its range. It is also clear that surveys to date have been seriously inadequate in documenting patterns of Mohave ground squirrel distribution because trapping sites have for the most part not been selected according to a randomized scheme. In the absence of a randomized sampling procedure, the results of such surveys apply only to the trapping site and cannot be extrapolated to the general region. It is recommended that a range-wide survey be conducted, with sampling locations determined on a randomized basis. Since this would be an expensive and logistically difficult undertaking, it

may be more realistic to develop a survey plan that could be implemented gradually over several years as funding becomes available. The first step could be to establish a sampling frame covering the entire Mohave ground squirrel range, with the area divided into sampling units, perhaps 10 x 10 km or smaller. When a survey is planned for a particular region, trapping grids could be sited in sampling units chosen at random. This system would be quite flexible, since it could be implemented at different scales as appropriate for the purposes of the sponsoring organization. It is recommended that the Mohave Ground Squirrel Technical Advisory Group develop such a range-wide randomized sampling plan and submit it to the CDFG, BLM, and military installations for consideration.

It appears to be of critical importance to acquire more data concerning the status of the species in the northern and central parts of its range (Fig. 7). Surveys should be carried out on both the north and south ranges of China Lake NAWS, on Fort Irwin, and along the corridor north from EAFB to Ridgecrest. There has

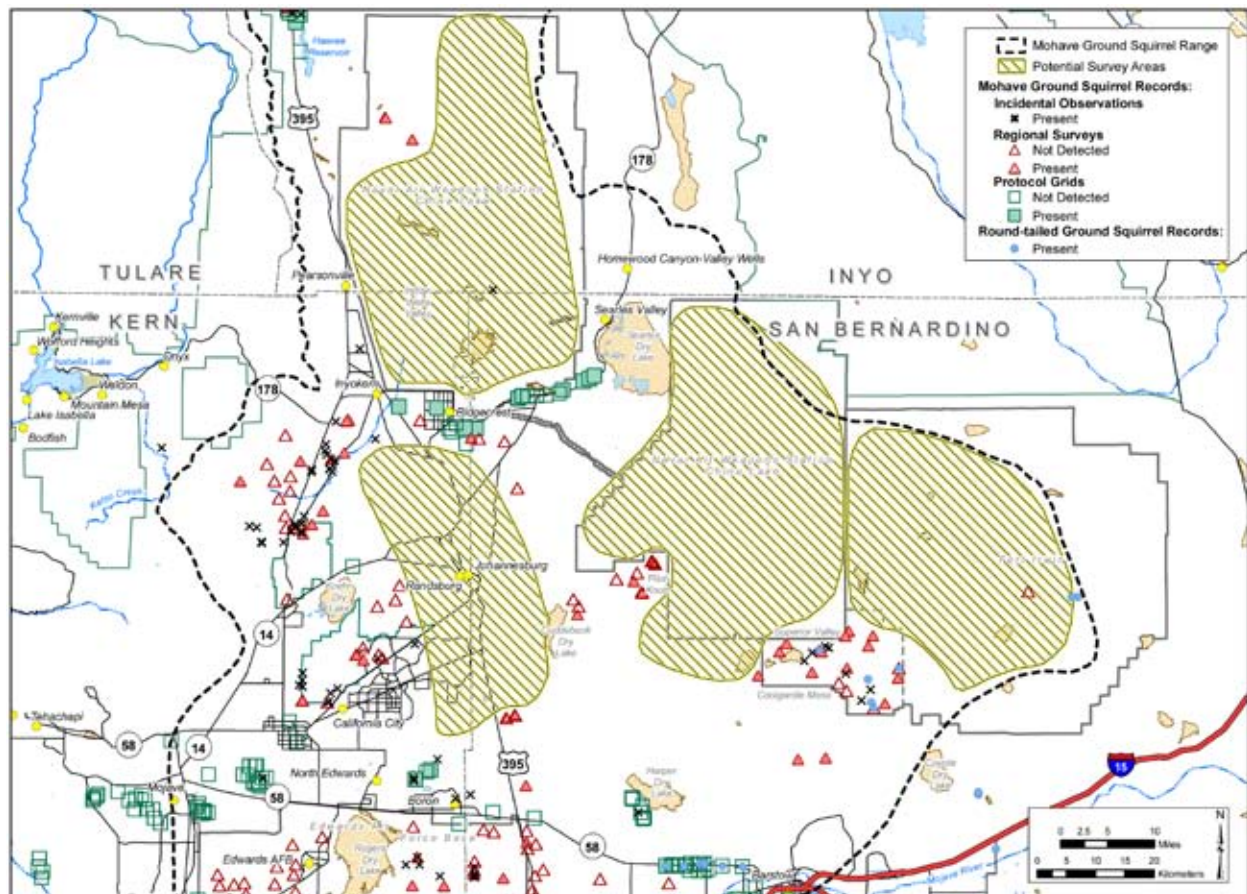


Figure 7. Potential survey areas in the northern and central portions of the Mohave ground squirrel range, showing their geographic relationship to survey efforts during the period 1998-2007.

been little or no sampling during the period 1998-2007 in these 4 extensive areas. A careful study plan should be developed to ensure adequate survey coverage within each area.

It is also recommended that field surveys be conducted in key areas within the southern range of the species in order to determine whether viable populations still remain outside of EAFB (Fig. 8). The trapping surveys could focus on public lands, but a serious attempt should be made to obtain permission for surveys on private lands as well. Because of the pace of development within the southern portion of the Mohave ground squirrel range, this exploratory work needs to be carried out with urgency.

The region southwest of the town of Mojave was identified in the West Mojave Plan (BLM 2003) as the Kern County Study Area. The West Mojave Plan recommended that Mohave ground squirrel trapping surveys be conducted here on public lands. The possibility was left open that the boundary of the Mohave

Ground Squirrel Conservation Area could be modified to include these public lands if justified by survey results. A number of protocol trapping surveys have recently been carried out on private land in this area in connection with proposed wind energy projects. Although no Mohave ground squirrels have been trapped thus far, there have been 2 reported visual detections. It is recommended that additional trapping surveys be authorized on both public and private property, especially in areas that have not yet been investigated.

More information is needed about the relationship between the Mohave ground squirrel and its sibling species, the round-tailed ground squirrel. There are recent reports of round-tailed ground squirrel occurrences well inside the historic Mohave ground squirrel range to the west of Barstow and in the Western Expansion Area of Fort Irwin. Round-tailed ground squirrels seem well-adapted to land disturbance in agricultural areas and on the outskirts of towns. It is possible that hybridization is occurring where the 2 species come in contact. It is

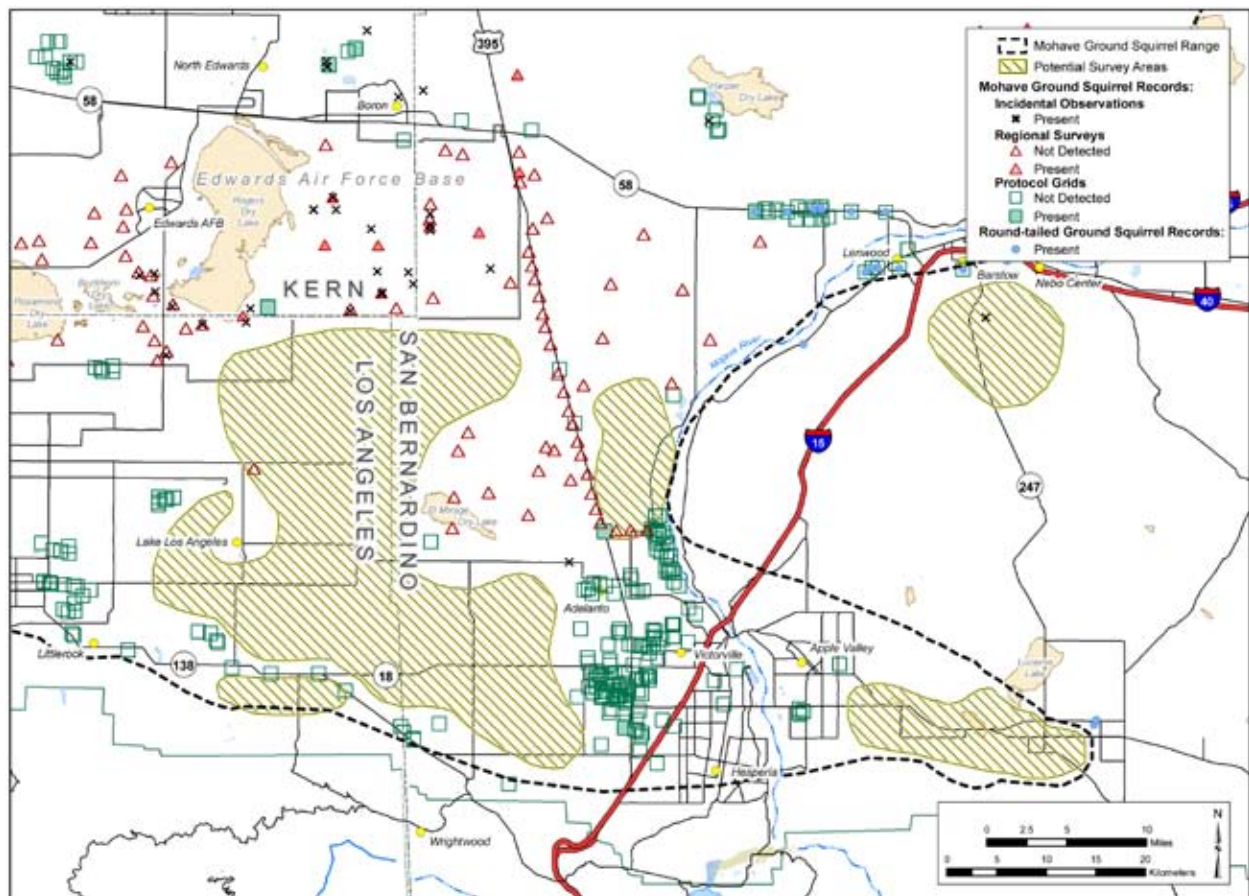


Figure 8. Potential survey areas in the southern portion of the Mohave ground squirrel range, showing their geographic relationship to survey efforts during the period 1998-2007.

recommended that surveys be carried out to determine the current eastern limits of the Mohave ground squirrel range and establish a baseline so that future westward movement of round-tailed ground squirrels could be detected. It is also recommended that genetic studies be undertaken in the contact zone to investigate the extent of hybridization where the 2 species co-occur.

Although trapping is the most effective method of identifying areas that support Mohave ground squirrel populations, it is recommended that certain modifications of current trapping procedures be tested. Trained wildlife dogs could be used to screen large areas and help focus trapping efforts on the most promising sites. Most trapping efforts to date have used large 100-trap grids. It would be of interest to try other trap configurations, such as more numerous small grids (for example, arrays of 20 traps) and long (>1000 meter) linear transects. Finally, such alternative trap configurations could be used in combination with adaptive cluster sampling (Thompson et al. 1998), which would allow for increased effort adjacent to a sampling unit where a Mohave ground squirrel is detected.

It is essential to protect BLM lands within the Mohave Ground Squirrel Conservation Area by enforcing the 1% limitation on ground disturbance (Fig. 1) called for under the West Mojave Plan (BLM 2005). In addition, acquisition of private lands that are included within the boundaries of the Conservation Area should be pursued aggressively, especially land that is included within known core areas. Finally, there may be important Mohave ground squirrel populations outside the Conservation Area that could be protected by acquisition of private lands and careful management of BLM lands. The area stretching from the DTNA southeast toward Boron may be a good example of such a conservation opportunity.

ACKNOWLEDGMENTS

This review was funded by Edwards Air Force Base through a subcontract with Tetra Tech, Inc. I am very grateful to Shannon Collis and Donald Clark for their support and guidance throughout this project. Carrie Munill provided outstanding assistance with the GIS mapping effort. A number of biologists generously contributed their data, including Mark Allaback, Patrick Kelly, Tom Kucera, David Laabs, Denise LaBerteaux, Steven Myers, Michael O'Farrell, William Vanherweg, and Ryan Young. The following agencies and organizations gave permission to include data collected in studies that they sponsored: California Department of Fish and Game, California Department of Parks and Recreation, California Department of Transportation, Desert Tortoise Preserve Committee, Edwards Air Force Base, Fort Irwin, and US Bureau of Land Management.

I greatly appreciate the helpful comments on the manuscript by B. Cypher, J. Harris, and 1 anonymous reviewer.

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APPENDIX 1
UNPUBLISHED REPORTS OF REGIONAL
TRAPPING STUDIES
CONDUCTED DURING THE PERIOD 1998-2007

- Air Force Flight Test Center. 2004. Inventory for Presence of Mohave Ground Squirrel at Edwards Air Force Base, California. 26 pp. + appendices.
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- Starr, Michael J. 2001. Population Distribution and Abundance of Antelope Ground Squirrels (*Ammospermophilus leucurus*) and Mohave Ground Squirrels (*Spermophilus mohavensis*), in the Western Mojave Desert, Spring 2001. 9 pp. + appendix.
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