# MOHAVE GROUND SQUIRREL RESEARCH AND MONITORING PROGRAM

# MONITORING MOHAVE GROUND SQUIRREL POPULATIONS IN THE COSO REGION 2001-2010

PREPARED FOR THE CALIFORNIA DEPARTMENT OF FISH AND GAME
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Prepared by Philip Leitner

*California State University, Stanislaus*
*Endangered Species Recovery Program*
*One University Circle*
*Turlock, CA 95382*

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## ABSTRACT

Mohave ground squirrel (*Xerospermophilus* [=*Spermophilus*] *mohavensis*) populations were monitored from 2001-2010 at 2 study sites in the Coso Range of southwestern Inyo County, California. These sites have been protected from human impacts since 1990, so population trends here should result from natural environmental influences only. Live-trapping was carried out for 5 days on 25-hectare grids in the spring (March-April) each year. The number of adult individuals captured in each annual trapping session was used as an index of abundance. The number of captures was low over this 10-year period, averaging 4.6 per year at the Coso Basin site and 7.3 per year at the Cactus Peak site. Trends in abundance did not move in synchrony at the 2 study sites. While number of adults captured at Cactus Peak tended to increase as expected with a lag time of 1 year following high winter rainfall, this was not the case at Coso Basin. There appeared to be poor survival and recruitment of females at Coso Basin. The superior demographic performance at Cactus Peak was most likely due to higher winter rainfall, perhaps resulting from its higher elevation (1470 m vs. 1085 m) and its position closer to the Sierra Nevada escarpment. Both Mohave ground squirrels and white-tailed antelope squirrels failed to reproduce at either site in 2002 and 2007, following winters with very low rainfall. A review of longer-term trends in adult Mohave ground squirrel captures at these 2 sites shows that numbers have been relatively low since 2001 as compared to the 1993-96 period. The much greater Mohave ground squirrel abundance during this earlier period was clearly related to a prolonged El Niño episode characterized by unusually high winter precipitation and plant productivity. The monitoring results for 2001-2010 help to extend the only long-term record of population trends for the Mohave ground squirrel and demonstrate the great importance of winter rainfall to sustaining viable populations in this species. It is recommended that funding be provided to continue this unique record.

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## ACKNOWLEDGMENTS

I very much appreciate the enthusiasm and hard work of the field crews. Field workers included students and alumnae of Mills College and many volunteers. J. Harris of Mills College generously provided his expertise as crew leader every year. The Environmental Office and Geothermal Program Office at China Lake NAWS granted access to the Coso study area, obtained badges for project personnel, and provided Coso Basin rainfall data, while C. Brock of Coso Operating Company, LLC greatly facilitated our work in many ways. The Los Angeles Department of Water and Power provided precipitation data collected by their personnel at the Haiwee Power Plant. The DFG provided funding for this study through an agreement with California State University Stanislaus. Coso Operating Company, LLC has also provided significant funding. Trapping and marking Mohave ground squirrels was conducted under authority of a Memorandum of Understanding with DFG.

# INTRODUCTION AND BACKGROUND

This report presents the results from 10 years of a long-term monitoring study of Mohave ground squirrel (*Xerospermophilus* [=*Spermophilus*] *mohavensis*) populations at study sites in the Coso Range, Inyo County, California. This study is a component of the Mohave Ground Squirrel Research and Monitoring Program that has been funded by California Department of Fish and Game (DFG) through contracts with the Endangered Species Recovery Program (ESRP) at California State University Stanislaus. The operator of the Coso geothermal power plants, Coso Operating Company, LLC, has also contributed to this effort by funding the monitoring studies in 2001 and 2006.

The Coso Range is located in southwestern Inyo County on military lands managed as part of the China Lake Naval Air Weapons Station (China Lake NAWS). It has been known for 30 years that this area supports relatively abundant and widespread populations of the Mohave ground squirrel (Leitner 1980; Zembal and Gall 1980). During the 1980s, development of geothermal resources in the Coso Range for electric power generation raised concerns about potential impacts to this State-listed species. In 1988, geothermal developers, China Lake NAWS, U.S. Bureau of Land Management (BLM), and DFG adopted a comprehensive mitigation plan to address these impacts.

The Coso Mohave Ground Squirrel Mitigation Program consisted of several elements, including establishment of a livestock exclosure covering about 165 $km^2$ (64 $mi^2$) of the Coso Range. Cattle grazing was eliminated from this area in December 1990 to benefit wildlife and particularly Mohave ground squirrel populations. The program also called for monitoring (Coso Grazing Exclosure Study) to evaluate the effects of the grazing exclosure on Mohave ground squirrel abundance. Four study sites were selected and trapping studies initiated in May and June 1988. Monitoring efforts continued in early summer at these 4 sites through 1996. In 1990, a spring sampling period (15 March-15 April) was added and spring trapping was also conducted from 1992-1996. Major findings of this 9-year program are summarized in Leitner and Leitner (1998).

During the period from 1997 through 2000, no funding was available to continue systematic monitoring of Mohave ground squirrel abundance on the 4 original study sites. However, a radio-telemetry study of adult and juvenile Mohave ground squirrel movements was carried out at the Cactus Peak study site (Study Site 3) from February through August 1997, along with trapping and marking for estimation of population size. Live trapping was also conducted in March-April 1998 and again in April and June 2000 (Leitner 2001b) to determine Mohave ground squirrel abundance at the Cactus Peak study site. There are no data for 1999.

Regulatory requirements on the operator of the Coso geothermal power plants were modified in 1997. The geothermal operator is now required to monitor the status of Mohave ground squirrel populations every 5 years at 2 of the Coso Grazing Exclosure sites. Coso Basin (Study Site 2) and Cactus Peak (Study Site 3) were chosen because they appeared to have the best quality habitat and generally supported the most abundant Mohave ground squirrel populations during the 9 years of the Coso Grazing Exclosure Study (1988-1996). The first monitoring effort under this new program was conducted in March-April 2001 (Leitner 2001a). Monitoring was carried out again in March 2006 (Leitner 2006).

The study described in this report was designed to complement the monitoring effort conducted every fifth year by the Coso geothermal operator. Such continued monitoring was first recommended in December 1999 by the Mohave Ground Squirrel Technical Advisory Group (TAG), an organization made up of scientists and agency staff that advises DFG on conservation and management of the Mohave ground squirrel. In late 2001, DFG provided funds for spring monitoring of Mohave ground squirrel populations at the Coso Basin and Cactus Peak study sites. This work was conducted from 2002-2005 and again from 2007-2010 through DFG contracts with ESRP.

The purpose of this monitoring effort is to maintain the only long-term record of abundance for the Mohave ground squirrel. The Coso study sites are in relatively undisturbed habitat protected from urban development, livestock grazing, and OHV recreation. The data from long-term monitoring at these sites can show the response of Mohave ground squirrel populations to natural environmental changes. In particular, these data can be used to test the hypothesis that annual variation in winter rainfall is an important factor in driving changes in Mohave ground squirrel abundance (Leitner and Leitner 1998). The results of monitoring at the 2 Coso sites can serve as an indicator of the health and viability of other Mohave ground squirrel populations in the northern part of the range. Finally, they can provide a reference point for evaluating population trends at future long-term study sites in other parts of the Mohave ground squirrel range.

# METHODS

## *DESCRIPTION OF STUDY SITES*

The locations of the 2 study sites at which monitoring was carried out from 2001 through 2010 are shown in Figure 1. Both the Coso Basin (Study Site 2) and Cactus Peak (Study Site 3) monitoring plots are within the Coso Grazing Exclosure established in December 1990. They have not been grazed by domestic livestock since 1990. These sites are within the military reservation managed by China Lake NAWS for weapons testing activities, but have been reserved exclusively for biological monitoring and research since 1990. The legal description of each site is as follows:

- **Coso Basin**: T22S R39E, SE ¼ Sec. 3 and NE ¼ Sec. 10, MDB&M
- **Cactus Peak**: T21S R39E, SE ¼ Sec. 30, MDB&M

The Coso Basin study site is southeast of Coso Hot Springs at an elevation of 1085 meters (3580 feet). The natural community is Mojave Mixed Woody Scrub, a diverse mixture of shrubs including shadscale (*Atriplex confertifolia*), goldenhead (*Acamptopappus sphaerocephalus*), and Mormon-tea (*Ephedra nevadensis*), among others. The western edge of this site contains a narrow strip of Mojave Desert Wash Scrub, a rich mixture of deep-rooted perennials.

The Cactus Peak study site is located southeast of Cactus Peak in a large upland basin at an elevation of 1470 m (4840 ft). The vegetation consists of the bajada phase Mojave Mixed Woody Scrub grading into Desert Saltbush Scrub in the lowest portions of the basin. Important shrub species are spiny hopsage (*Grayia spinosa*), fourwing saltbush (*Atriplex canescens*), and shadscale with scattered Joshua trees (*Yucca brevifolia*).

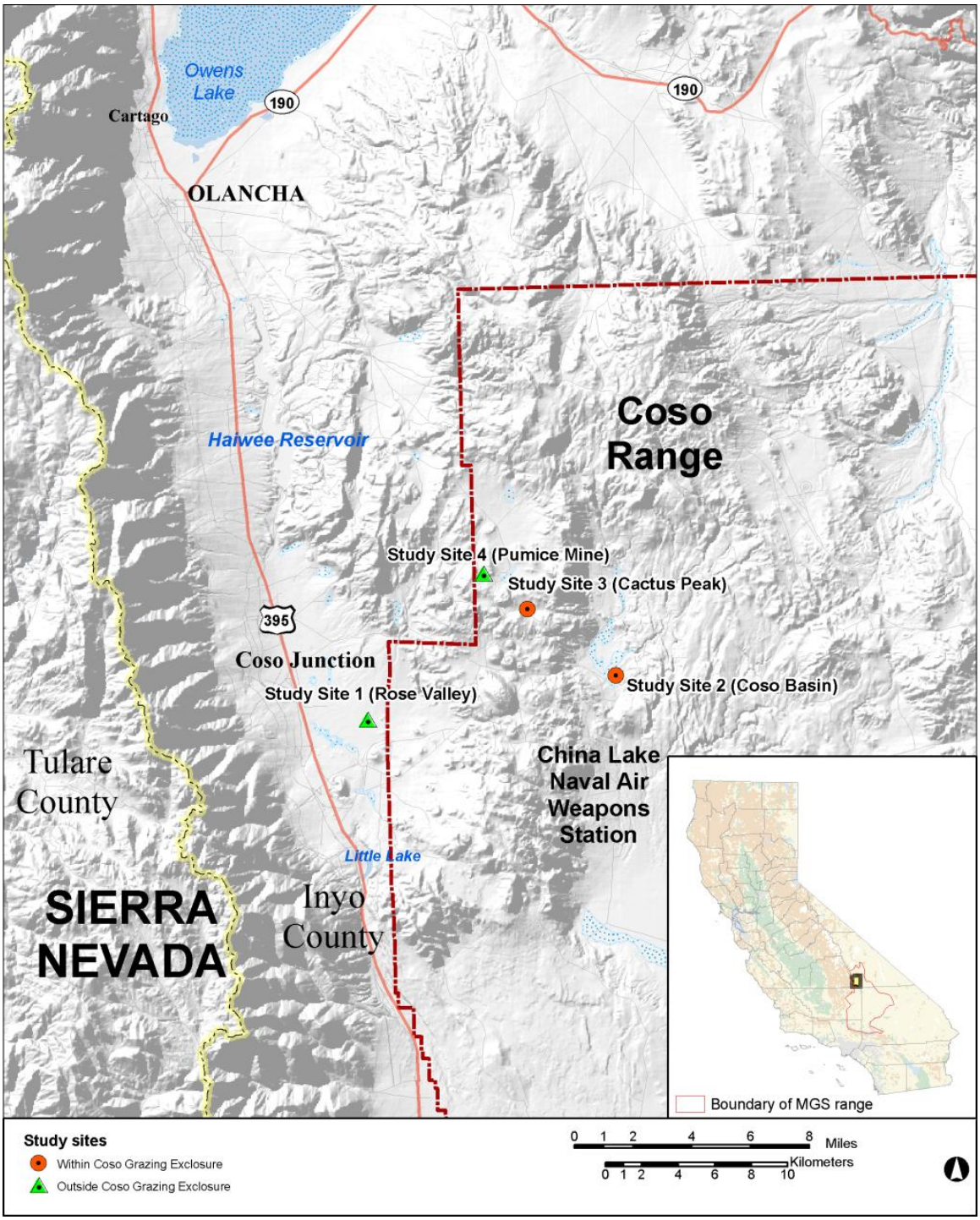


**Figure 1. Map of the Coso region in southwestern Inyo County, California, showing the locations of Mohave ground squirrel monitoring sites. Field studies were carried out at Rose Valley (Study Site 1) and Pumice Mine (Study Site 4) from 1988 through 1996, but no studies have been conducted at these sites in recent years except for Rose Valley in 2010.**

The location of a third study site at which monitoring was conducted only in March 2010 is also shown in Figure 1. The Rose Valley (Study Site 1) monitoring plot is located outside the Coso Grazing Exclosure on public land managed by BLM. It is within the Tunawee Common

Grazing Allotment which is open to livestock grazing in years when adequate forage is available. The legal description of the site is as follows:

- **Rose Valley**: T22S R38E, Sec. 17 (central portion)

The Rose Valley study site is located southeast of Coso Junction on the eastern side of a broad valley at an elevation of 1015 m (3350 ft). It is strongly dominated by Desert Saltbush Scrub, a low-growing, homogeneous mixture of 2 saltbush species, allscale (*Atriplex polycarpa*) and shadscale.

## *LIVE-TRAPPING PROCEDURES*

The abundance of Mohave ground squirrels on each of the study sites was determined using a standard live-trapping technique. The trapping grids established during the Coso Grazing Exclosure Study (1988-1996) were employed for this mark-recapture sampling procedure. Each grid measured 500 by 500 m (1640 x 1640 ft) and included an area of 25 hectares (62 acres). A total of 441 traps were placed at 25 m intervals on each grid in a 21 x 21 array. Two types of traps were employed at each grid. Pymatuning traps made up 81 percent (357 traps) of the total, while the remaining 19 percent consisted of Sherman traps. Pymatuning traps (10 x 10.5 x 39 cm) have wire mesh sides and back, while the tops, bottoms, and door are solid sheet metal. Sherman traps are smaller (8 x 9 x 23 cm) and are made entirely of sheet aluminum.

Monitoring was usually carried out during late March or early April (Table 1). This is the optimum time for assessing the adult population, since both males and females are active above ground at this time. However, in 2010 it was not possible to obtain access to the Cactus Peak site until early May because of military testing procedures in the vicinity. As a result, both adults and juveniles were captured at this site in 2010.

**Table 1. Trapping dates at the Coso study sites during spring monitoring from 2001- 2010. Trapping effort consisted of 2205 trap-days at each site over a 5-day period.**

| Year | Study Site | | |
|---|---|---|---|
| | Coso Basin | Cactus Peak | Rose Valley |
| 2001 | 19-23 March | 19-23 March | |
| 2002 | 19-23 March | 19-23 March | |
| 2003 | 1-5 April | 1-5 April | |
| 2004 | 30 March-3 April | 30 March-3 April | |
| 2005 | 22-25 & 27 March | 22-25 & 27 March | |
| 2006 | 21-25 March | 21-25 March | |
| 2007 | 20-24 March | 20-24 March | |
| 2008 | 25-29 March | 25-29 March | |
| 2009 | 24-28 March | 25-29 March | |
| 2010 | 23-27 March | 12-16 May | 23-27 March |

Traps were pre-baited for 2 days, followed by 5 days of trapping. The bait used was a commercial livestock feed that included rolled oats, rolled barley, cracked corn, and molasses. Traps were placed beside or under shrubs within 1-3 m (3-10 ft) of the wooden stakes that marked the trap stations. Traps were opened in the morning between 0800 and 1000 hours and

closed in the afternoon between 1600 and 1800 hours. They were checked twice each day on a regular schedule.

All captured ground squirrels were identified to species; both Mohave ground squirrels and white-tailed antelope squirrels (*Ammospermophilus leucurus*) were captured regularly on each grid. Sex, reproductive status, and age class (adult/juvenile) were recorded for both species. Males were considered to be reproductive if testes were descended into the scrotal sac, while females were judged to be reproductive if teats were enlarged, lactation was evident, or embryos could be detected by palpation. A 300 g (12 oz) capacity Pesola® spring scale was used to determine body mass of ground squirrels upon first capture. Mohave ground squirrels were permanently marked for individual identification with a passive integrated transponder (PIT) tag (BioSonics® 400 kHz). Some white-tailed antelope squirrels were also marked with PIT tags in order to train field personnel in this technique. The tags were implanted subcutaneously between the shoulder blades using a veterinary syringe and 12-gauge needle. Ground squirrels of both species were marked on the ventral surface with a colored felt marking pen so that they could be readily recognized as recaptures if trapped later in the same sampling period. All data were recorded on standard field data forms and the animal then released unharmed at the place of capture.

### *PRECIPITATION DATA*

Winter rainfall data for the region were obtained from weather stations maintained by the Los Angeles Department of Water and Power (LADWP) at the Haiwee Dam and Haiwee Power Plant. These 2 weather stations are about 16-19 km (10-12 mi) NW of the Coso Basin and Cactus Peak study sites (Figure 2). For many years, the Geothermal Program Office at China Lake NAWS operated 5 tipping bucket rain gauges in Coso Basin (Figure 2) and provided winter rainfall data for this study. Unfortunately, these rain gauges ceased operation during summer 2008 and no data are available for the 2008-09 or 2009-10 winter periods. Prior to the 2001 and 2006 sampling periods, winter rainfall data were also collected monthly at rain gauges located at the Coso Basin and Cactus Peak study sites. No precipitation data were collected at these two locations at other times during the 2001-2010 monitoring period.

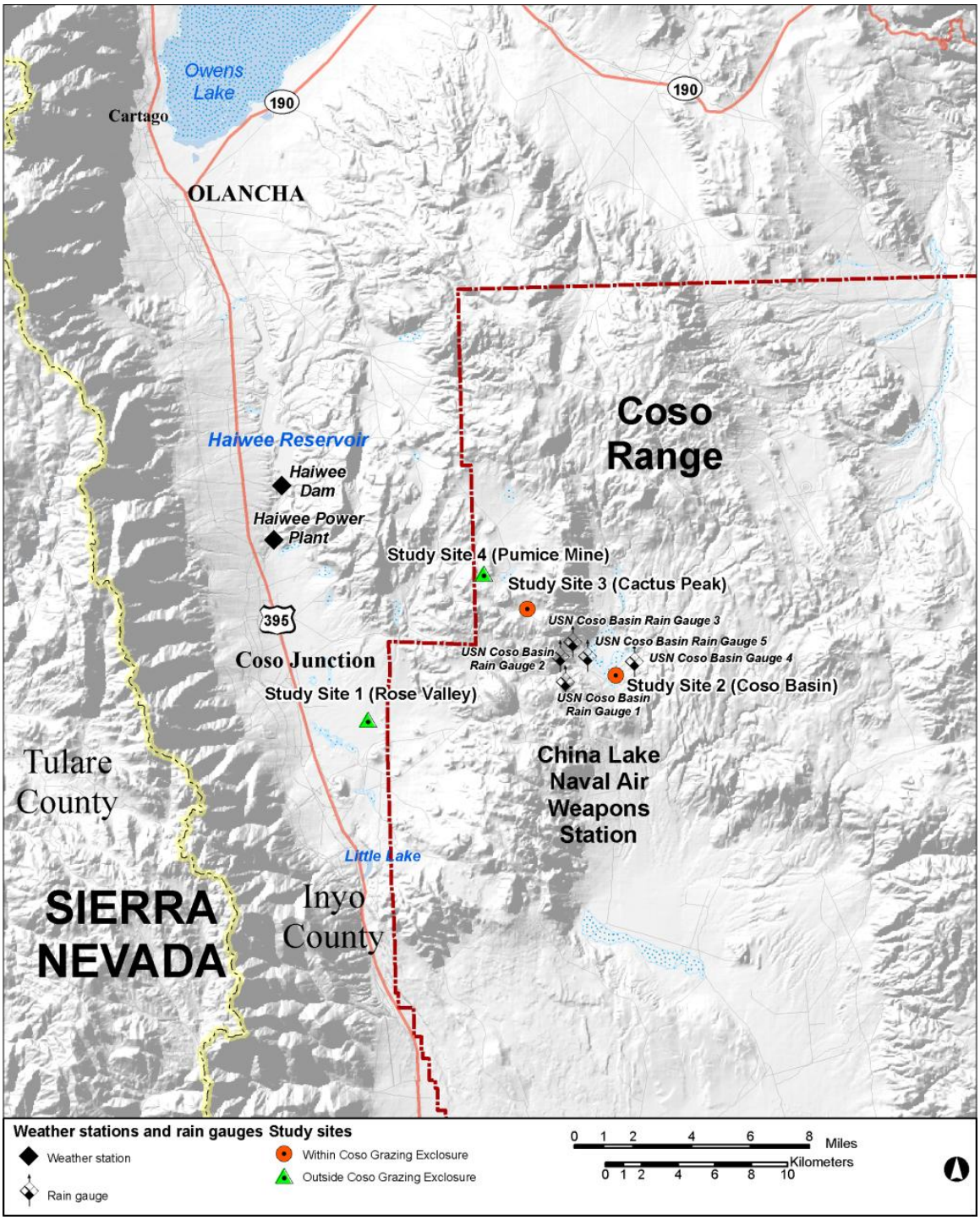


**Figure 2. Map of the Coso region in southwestern Inyo County, California, showing the locations of the Haiwee Dam and Haiwee Power Plant weather stations and the US Navy China Lake NAWS rain gauges in Coso Basin in relation to the Coso Basin and Cactus Peak study sites.**

# RESULTS

## *TRAPPING DATA*

### Coso Basin

Table 2 shows the capture results for Mohave ground squirrels at the Coso Basin study site by sex and age class (juvenile/adult) during the spring sampling period from 2001 through 2010. The total number of adults captured declined substantially after 2001, with a brief increase noted in 2007. The numbers of adult females followed the same pattern. No juveniles were trapped, as births usually occur during April. The sex ratio was strongly biased toward females in 2001 and 2002, but was more balanced in later years.

**Table 2. Summary of Mohave ground squirrel trapping results by sex and age class (juvenile/adult) at Coso Basin during the spring 2001-2010. Trapping effort totaled 2,205 trap-days on each occasion.**

| Year | Adults | | Juveniles | Total Individuals | Total Captures |
|---|---|---|---|---|---|
| | Males | Females | | | |
| 2001 | 5 | 10 | 0 | 15 | 24 |
| 2002 | 1 | 6 | 0 | 7 | 12 |
| 2003 | 2 | 1 | 0 | 3 | 4 |
| 2004 | 2 | 0 | 0 | 2 | 8 |
| 2005 | 1 | 1 | 0 | 2 | 3 |
| 2006 | 0 | 3 | 0 | 3 | 7 |
| 2007 | 4 | 4 | 0 | 8 | 13 |
| 2008 | 1 | 1 | 0 | 2 | 2 |
| 2009 | 1 | 1 | 0 | 2 | 4 |
| 2010 | 1 | 2 | 0 | 3 | 4 |

Detailed information on body mass, reproductive condition, and capture history of individual Mohave ground squirrels trapped at Coso Basin is shown in Appendix A. Data on reproductive condition are presented in Table 3. There was no evidence that females reproduced at this study site in 2002 or 2007, but females captured in other years were clearly in reproductive condition. Since no females were captured in 2004, there are no data on female reproduction for that year. The same was true for males in 2006.

Table 4 shows the capture results for white-tailed antelope squirrels at Coso Basin by sex and age class (juvenile/adult) during the period from 2001 through 2010. The total number of individuals captured was usually $\geq$10, with the highest abundance noted in 2002, 2004, and 2005. However, there was drastic decline from 51 in 2002 to just 1 in 2003. A similar, but less extreme decline was observed from 2008 to 2009. All animals captured were adults.

**Table 3. Reproductive condition of Mohave ground squirrels captured at Coso Basin during the spring from 2001-2010. Males were considered to be reproductive if testes were descended into the scrotal sac (testes scrotal), while those with undescended testes (testes non-scrotal) were considered non-reproductive. Females were judged to be reproductive if teats were enlarged, lactation was evident, or embryos could be detected by palpation.**

| Year | Males | | Females | |
|---|---|---|---|---|
| | Testes Scrotal | Testes Non-scrotal | Reproductive | Non-reproductive |
| 2001 | 5 | 0 | 10 | 0 |
| 2002 | 0 | 1 | 0 | 6 |
| 2003 | 2 | 0 | 1 | 0 |
| 2004 | 0 | 2 | -- | -- |
| 2005 | 1 | 0 | 1 | 0 |
| 2006 | -- | -- | 3 | 0 |
| 2007 | 0 | 4 | 0 | 4 |
| 2008 | 1 | 0 | 1 | 0 |
| 2009 | 1 | 0 | 1 | 0 |
| 2010 | 1 | 0 | 2 | 0 |

**Table 4. Summary of white-tailed antelope squirrel trapping results by sex and age class (juvenile/adult) at Coso Basin during the spring from 2001-2010. Trapping effort totaled 2,205 trap-days on each occasion.**

| Year | Adults | | Juveniles | Total Individuals | Total Captures |
|---|---|---|---|---|---|
| | Males | Females | | | |
| 2001 | 10 | 7 | 0 | 17 | 23 |
| 2002 | 17 | 34 | 0 | 51 | 60 |
| 2003 | 0 | 1 | 0 | 1 | 1 |
| 2004 | 12 | 18 | 0 | 30 | 100 |
| 2005 | 25 | 16 | 0 | 41 | 50 |
| 2006 | 2 | 16 | 0 | 18 | 46 |
| 2007 | 8 | 7 | 0 | 15 | 60 |
| 2008 | 6 | 4 | 0 | 10 | 15 |
| 2009 | 0 | 3 | 0 | 3 | 3 |
| 2010 | 9 | 2 | 0 | 11 | 19 |

Data on the reproductive condition of white-tailed antelope squirrels at Coso Basin are shown in Table 5. No reproductive data were taken for 2001 or for the single female captured in 2003. In other years, reproductive data were recorded for all or a substantial sample of individuals captured. With the exception of 2002, most males were found to be in reproductive condition, with scrotal testes. In most years, the great majority of females appeared to be pregnant or lactating. The notable exceptions were 2002 and 2007. The 2 females captured in 2010 did not appear reproductive, but may have been in early pregnancy.

**Table 5. Reproductive condition of white-tailed antelope squirrels captured at Coso Basin during the spring from 2001-2010. Males were considered to be reproductive if testes were descended into the scrotal sac (testes scrotal), while those with undescended testes (testes non-scrotal) were considered non-reproductive. Females were judged to be reproductive if teats were enlarged, lactation was evident, or embryos could be detected by palpation.**

| Year | Males | | Females | |
|---|---|---|---|---|
| | Testes Scrotal | Testes Non-scrotal | Reproductive | Non-reproductive |
| 2001 | -- | -- | -- | -- |
| 2002 | 3 | 7 | 2 | 23 |
| 2003 | -- | -- | -- | -- |
| 2004 | 10 | 1 | 16 | 1 |
| 2005 | 23 | 2 | 13 | 3 |
| 2006 | 2 | 0 | 13 | 2 |
| 2007 | 6 | 2 | 0 | 7 |
| 2008 | 5 | 1 | 2 | 1 |
| 2009 | -- | -- | 3 | 0 |
| 2010 | 7 | 0 | 0 | 2 |

## Cactus Peak

Table 6 shows the capture results for Mohave ground squirrels at Cactus Peak by sex and age class (juvenile/adult) during the spring sampling period from 2001 through 2010. The total number of adults captured increased from a low point of 2 in 2001 up to 15 individuals detected in 2004. This was followed by a decline to just 2 females in 2007. There was a sharp increase from 2009 to 2010, with 16 adults recorded. All animals captured during early spring from 2001 through 2009 were adults, while trapping in May 2010 resulted in the capture of 85 juveniles. The sex ratio was consistently biased toward females, with the exception of 2003 when a 1:1 ratio was recorded.

**Table 6. Summary of Mohave ground squirrel trapping results by sex and age class (juvenile/adult) at Cactus Peak during the spring from 2001-2010. Trapping effort totaled 2,205 trap-days on each occasion.**

| Year | Adults | | Juveniles | Total Individuals | Total Captures |
|---|---|---|---|---|---|
| | Males | Females | | | |
| 2001 | 0 | 2 | 0 | 2 | 2 |
| 2002 | 2 | 3 | 0 | 5 | 11 |
| 2003 | 3 | 3 | 0 | 6 | 14 |
| 2004 | 5 | 10 | 0 | 15 | 30 |
| 2005 | 4 | 8 | 0 | 12 | 20 |
| 2006 | 1 | 7 | 0 | 8 | 11 |
| 2007 | 0 | 2 | 0 | 2 | 3 |
| 2008 | 0 | 4 | 0 | 4 | 4 |
| 2009 | 0 | 5 | 0 | 5 | 13 |
| 2010 | 3 | 13 | 85 | 101 | 219 |

Detailed information on body mass, reproductive condition, and capture history of individual Mohave ground squirrels trapped at Cactus Peak is shown in Appendix B. Data on

reproductive condition are presented in Table 7. There appeared to be no reproduction at this study site in 2002, 2006, or 2007 but pregnant females were captured in each of the other 7 years. The situation in 2004 was unusual; 6 females were clearly non-reproductive while 4 others were in late pregnancy. Three of the 4 pregnant females were recaptures from previous years (Appendix B), while none of the non-reproductive females were recaptures. This suggests that the non-reproductive individuals may have been yearlings born in 2003. Because of lack of male captures, there are no male reproductive data for 2001, 2007, 2008, or 2009.

**Table 7. Reproductive condition of Mohave ground squirrels captured at Cactus Peak during the spring from 2001-2010. Males were considered to be reproductive if testes were descended into the scrotal sac (testes scrotal), while those with undescended testes (testes non-scrotal) were considered non-reproductive. Females were judged to be reproductive if teats were enlarged, lactation was evident, or embryos could be detected by palpation.**

| Year | Males | | Females | |
|---|---|---|---|---|
| | Testes Scrotal | Testes Non-scrotal | Reproductive | Non-reproductive |
| 2001 | -- | -- | 2 | 0 |
| 2002 | 1 | 1 | 0 | 3 |
| 2003 | 3 | 0 | 3 | 0 |
| 2004 | 0 | 5 | 4 | 6 |
| 2005 | 3 | 1 | 8 | 0 |
| 2006 | 1 | 0 | 0 | 7 |
| 2007 | -- | -- | 0 | 2 |
| 2008 | -- | -- | 4 | 0 |
| 2009 | -- | -- | 5 | 0 |
| 2010 | 0 | 3 | 13 | 0 |

Table 8 shows the capture results for white-tailed antelope squirrels at Cactus Peak by sex and age class (juvenile/adult) during the spring sampling period from 2001 through 2010. The total number of individuals captured was >10 every year except for 2009, with the greatest abundances recorded early in the decade. There was a significant decline from 2002 to 2003 and again from 2008 to 2009. All animals captured were adults, except for single juveniles trapped in 2009 and 2010.

Data on the reproductive condition of white-tailed antelope squirrels at Cactus Peak are shown in Table 9. Reproductive data were recorded for just 3 males in 2001. In other years, reproductive data were taken for all or a substantial portion of individuals captured. The great majority of males had scrotal testes every year, with the exception of 2010 when only 2 out of 5 were reproductive. In 2002 and 2007, none of the females examined appeared to be in reproductive condition. At least some reproductive females were recorded in all other years. The large proportion of non-reproductive females noted in 2004 and 2005 was unusual and some may have been in early pregnancy.

**Table 8. Summary of white-tailed antelope squirrel trapping results by sex and age class (juvenile/adult) at Cactus Peak during the spring from 2001-2010. Trapping effort totaled 2,205 trap-days on each occasion.**

| Year | Adults | | Juveniles | Total Individuals | Total Captures |
|---|---|---|---|---|---|
| | Males | Females | | | |
| 2001 | 23 | 15 | 0 | 38 | 51 |
| 2002 | 14 | 20 | 0 | 34 | 44 |
| 2003 | 9 | 4 | 0 | 13 | 18 |
| 2004 | 30 | 23 | 0 | 53 | 81 |
| 2005 | 25 | 19 | 0 | 44 | 66 |
| 2006 | 10 | 8 | 0 | 18 | 38 |
| 2007 | 6 | 8 | 0 | 14 | 22 |
| 2008 | 7 | 4 | 0 | 11 | 15 |
| 2009 | 2 | 0 | 1 | 3 | 4 |
| 2010 | 5 | 6 | 1 | 12 | 13 |

**Table 9. Reproductive condition of white-tailed antelope squirrels captured at Cactus Peak during the spring from 2001-2010. Males were considered to be reproductive if testes were descended into the scrotal sac (testes scrotal), while those with undescended testes (testes non-scrotal) were considered non-reproductive. Females were judged to be reproductive if teats were enlarged, lactation was evident, or embryos could be detected by palpation.**

| Year | Males | | Females | |
|---|---|---|---|---|
| | Testes Scrotal | Testes Non-scrotal | Reproductive | Non-reproductive |
| 2001 | 3 | 0 | -- | -- |
| 2002 | 5 | 2 | 0 | 15 |
| 2003 | 7 | 0 | 4 | 0 |
| 2004 | 27 | 3 | 4 | 19 |
| 2005 | 24 | 1 | 7 | 12 |
| 2006 | 7 | 0 | 7 | 0 |
| 2007 | 4 | 1 | 0 | 8 |
| 2008 | 7 | 0 | 4 | 0 |
| 2009 | 2 | 0 | -- | -- |
| 2010 | 2 | 3 | 6 | 0 |

## Rose Valley

Table 10 shows the numbers of Mohave ground squirrels and white-tailed antelope squirrels trapped in 2010 on the Rose Valley study site during the March 23-27 sampling period. No Mohave ground squirrels were captured or observed during 5 days of trapping (2,205 trap--days). However, 6 adult white-tailed antelope squirrels were trapped and 3 recaptures brought the total number of captures to 9. The 3 males were in reproductive condition, with scrotal testes. The 3 females did not appear to be reproductive, but may have been in an early stage of pregnancy.

**Table 10. Summary of trapping results at Rose Valley (Study Site 1) by species, sex and age of animal during March 23-27, 2010. Trapping conducted with 441 traps at 25 meter spacing in a 21 x 21 trap array.**

| | | Male | Female | Total |
|---|---|---|---|---|
| Mohave Ground Squirrel | Juvenile | 0 | 0 | 0 |
| | Adult | 0 | 0 | 0 |
| | Total | 0 | 0 | 0 |
| White-tailed Antelope Squirrel | Juvenile | 0 | 0 | 0 |
| | Adult | 3 | 3 | 6 |
| | Total | 3 | 3 | 6 |

## *PRECIPITATION DATA*

Winter precipitation (Oct. 1 – Mar. 31) for the Coso region since the 1997-98 season is shown in Table 11. The data were recorded at the Haiwee Power Plant and Haiwee Dam weather stations, at rain gauges operated in Coso Basin by the China Lake NAWS Geothermal Program Office, and at rain gauges installed at the Coso Basin and Cactus Peak study sites during the 2000-01 and 2005-06 winters. The China Lake NAWS rainfall data were derived from 5 tipping bucket rain gauges that were located 1.8-3.0 km (1.1-1.9 mi) from the Coso Basin study site. The rainfall totals for China Lake NAWS Coso Basin represent data only from those gauges that operated successfully for the entire 6-month winter period. The highest value was used if one was substantially greater than the others since these gauges often malfunctioned; if 2 values were higher and roughly comparable, the mean was used. In 2 cases, all 5 values were comparable and the mean was used.

**Table 11. Winter precipitation (Oct. 1 – Mar. 31) as measured at Haiwee Power Plant, Haiwee Dam, China Lake NAWS Coso Basin rain gauges, and rain gauges at the Coso Basin and Cactus Peak study sites. Rainfall totals are presented in millimeters.**

| Winter Period | Haiwee Power Plant | Haiwee Dam | China Lake NAWS Coso Basin | Coso Basin study site | Cactus Peak study site |
|---|---|---|---|---|---|
| 1997-98 | 179 | 230 | -- | -- | -- |
| 1998-99 | 62 | 55 | 40 | -- | -- |
| 1999-00 | 81 | 105 | 34 | -- | -- |
| 2000-01 | 166 | 146 | 64 | 65 | 81 |
| 2001-02 | 42 | 33 | 17 | -- | -- |
| 2002-03 | 144 | 187 | 66 | -- | -- |
| 2003-04 | 92 | 105 | 28 | -- | -- |
| 2004-05 | 260 | 336 | 149 | -- | -- |
| 2005-06 | 112 | 130 | 62 | 52 | 75 |
| 2006-07 | 23 | 21 | 20 | -- | -- |
| 2007-08 | 96 | 138 | 254 | -- | -- |
| 2008-09 | 125 | -- | -- | -- | -- |
| 2009-10 | 136 | 193 | -- | -- | -- |

Total winter precipitation at the Haiwee Power Plant and Haiwee Dam weather stations was roughly similar for a given rainfall season, although the totals at the Haiwee Dam were often

somewhat higher. However, the Coso Basin totals as recorded at the China Lake NAWS rain gauges were almost always substantially lower than those at the 2 LADWP weather stations. Precipitation at the Coso Basin rain gauges in 8 of 10 years ranged from 30-65 percent of the totals recorded at the power plant 16 km (10 mi) to the NW in Rose Valley. The 2 exceptions to this pattern were the 2006-07 winter, when rainfall totals were extremely low across the entire region and the 2007-08 winter when a large rainfall event was recorded in March at Coso Basin but not at the power plant. Although data from rain gauges at the Mohave ground squirrel trapping grids are available for only 2 years, the results for the Coso Basin study site are quite consistent with those of the nearby China Lake NAWS rain gauges. It is noteworthy that both the 2000-01 and 2005-06 totals for the Cactus Peak study site are somewhat higher than those recorded in Coso Basin. This is probably due to the fact that the Cactus Peak study site is located almost 400 m (1260 ft) higher in elevation than the Coso Basin study site.

# DISCUSSION

## *MONITORING MOHAVE GROUND SQUIRREL ABUNDANCE AT THE COSO STUDY SITES*

The results of the Coso monitoring study are of particular value because they indicate how Mohave ground squirrel abundance changes over time in response to natural environmental factors. Both the Coso Basin and Cactus Peak study sites have been free of human impacts since 1990, when livestock grazing was removed. Cattle grazing continued after 1990 to the north of the Coso Grazing Exclosure fence, but was completely eliminated throughout China Lake NAWS at the end of February 2000. There has been no surface disturbance or change in soils or vegetation due to human activity over the past 20 years at the 2 study sites. Although military testing in spring 2010 temporarily limited access to the Cactus Peak site, these activities were conducted >1.6 km (1 mi) away on the other side of a mountain ridge and there was no surface disturbance at or near the site. Any trends in abundance as shown by changes in number of captures over the past 10 years should therefore reflect natural environmental processes.

It should be emphasized that the number of individual Mohave ground squirrels captured in a 5-day trapping period provides an index of abundance, not an estimate of actual population size. During the 1988-96 monitoring period, it was usually possible to estimate population size with 95% confidence interval by using the Lincoln-Petersen and Schnabel mark-recapture methods (Seber 1982). However, it has not been possible to use these methods since 2001 because numbers of captures have been so low. It is also important to note that the probability of detecting Mohave ground squirrels by trapping could vary between years. For example, it is possible that Mohave ground squirrels are more likely to enter traps in search of bait in dry years when forage is scarce. If this were the case, it would tend to produce a positive bias in the number of individuals captured in a dry year. Capture probability could also be influenced by year to year variation in the number of white-tailed antelope squirrels competing for available traps. This seems unlikely to have had an effect during the period 2001-10, since the proportion of traps occupied by white-tailed antelope squirrels has never exceeded 6% in any trap check and in 87% of all cases has been <2%.

It is also important to note that the Coso Basin and Cactus Peak study sites are not closed to immigration or emigration. Although these 25-hectare sites are quite large in comparison to standard trapping grids, they are located in alluvial basins with large surrounding areas of similar habitat. Adult males make extensive movements during the mating season (Harris and Leitner 2004) and may range over areas as large as 100 hectares when searching for females (Leitner unpub. data). They can establish post-mating home ranges at widely-separated sites in successive years. Dispersing juveniles may undertake even longer movements (Harris and Leitner 2005), so that young males and females could readily enter or leave the study sites during their first summer. Thus, year to year changes in the number of individuals captured on these 25-hectare sites undoubtedly reflect demographic processes throughout the surrounding areas.

## *RECENT TRENDS IN MOHAVE GROUND SQUIRREL ABUNDANCE*

This monitoring effort has demonstrated that both the Coso Basin and Cactus Peak study sites have been continuously occupied by Mohave ground squirrels since 2001 (Table 12). However, the numbers of adults detected by trapping have been relatively low over this period, with total number of individuals captured $\geq$10 on only 4 occasions, in 2001 at Coso Basin and in 2004, 2005, and 2010 at Cactus Peak.

**Table 12. Mohave ground squirrel abundance at the Coso Basin and Cactus Peak study sites in March and April during the period from 2001 through 2010. Data presented are numbers of individual adult male and female Mohave ground squirrels captured during a 5-day trapping period preceded by 2 days of pre-baiting. In each case, a total of 441 traps were used with 25-meter spacing.**

| Year | Coso Basin | | | Cactus Peak | | |
|---|---|---|---|---|---|---|
| | Trapping Period | Number Captured | | Trapping Period | Number Captured | |
| | | Male | Female | | Male | Female |
| 2001 | March 19-23 | 5 | 9 | March 19-23 | 0 | 2 |
| 2002 | March 19-23 | 1 | 6 | March 19-23 | 2 | 3 |
| 2003 | April 1-5 | 2 | 1 | April 1-5 | 3 | 3 |
| 2004 | March 30-April 3 | 2 | 0 | March 30-April 3 | 5 | 10 |
| 2005 | March 22-25 & 27 | 1 | 1 | March 22-25 & 27 | 2 | 8 |
| 2006 | March 21-25 | 0 | 3 | March 21-25 | 1 | 7 |
| 2007 | March 20-24 | 4 | 4 | March 20-24 | 0 | 2 |
| 2008 | March 25-29 | 1 | 1 | March 25-29 | 0 | 4 |
| 2009 | March 24-28 | 1 | 1 | March 25-29 | 0 | 5 |
| 2010 | March 23-27 | 1 | 2 | May 12-16 | 3 | 13 |

As shown in Figure 3, trends in Mohave ground squirrel abundance at the Coso Basin and Cactus Peak study sites have not moved in synchrony since 2001. The number of adult individuals captured at Coso Basin was highest in 2001 at 14, fell sharply in 2002, and has generally remained at a very low level. The only exception was 2007, when 8 individuals were captured, 4 of them males. The number captured at Cactus Peak increased considerably from a low of 2 in 2001 to reach 15 in 2004. After a steady decline, the number of individuals captured reached another low point in 2007 and then rebounded to a total of 16 individuals in 2010.

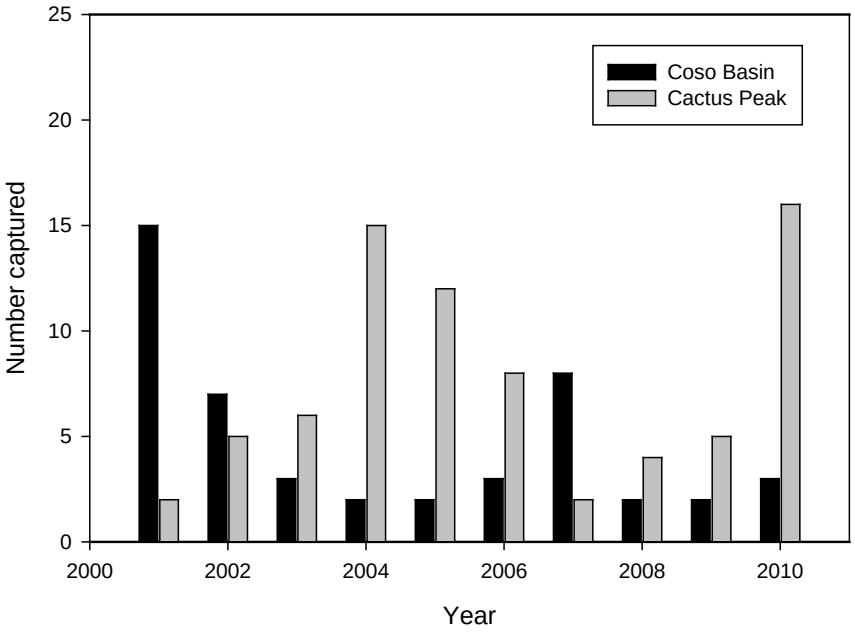


**Figure 3. Mohave ground squirrel captures at the Coso Basin and Cactus Peak study sites in March and April during the period 2001-2010. Data are numbers of individual adults captured over 5 days with 2 days of pre-baiting using 441 traps with 25-meter spacing.**

A detailed consideration of winter precipitation patterns and demographic trends at the 2 study sites may help to explain these contrasting results. Table 13 indicates that reproduction was documented in both Mohave ground squirrel populations in 6 of the 10 years between 2001 and 2010. The rainfall recorded at the 2 LADWP weather stations (Table 11) during the 6 preceding winters was well above the 65-80 mm range considered to be the minimum threshold for reproduction in this species (Leitner and Leitner 1998). No reproduction was recorded at either site in 2002 and 2007, both years with very low rainfall during the preceding winter. The Coso region received relatively low rainfall during the winter of 2003-04. Older females at the Cactus Peak study site were apparently able to reproduce in spring 2004, but it appeared that yearlings did not come into reproductive condition. No females were captured at the Coso Basin study site, so there are no reproductive data for that population. The only year in which the 2 study sites clearly differed was 2006, following a winter with moderate rainfall as measured at the LADWP weather stations. Winter precipitation in Coso Basin was comparable to that recorded in 2000-01 and 2002-03 when Mohave ground squirrel reproduction occurred. The lack of reproduction at Cactus Peak is puzzling because the rain gauge there recorded 75 mm of rain over the 2005-06 winter.

Although the occurrence of reproduction was generally similar at the 2 study sites, adult female survival and recruitment differed significantly (Table 13). At Coso Basin, mean female survival per year was 0.36 in comparison to 0.46 at Cactus Peak over the period 2001-2010. From 2001 to 2007, mean female survival per year was only 0.12 at Coso Basin, while at Cactus Peak it was 0.45. Over the entire period, only 12 new females were added to the population at Coso Basin, while 38 females were recruited at Cactus Peak starting from a much lower base number in 2001. The difference in female recruitment patterns between the 2 sites is particularly clear when the results for 2004, 2006, and 2010 are examined. In each

case, the preceding year was characterized by high winter rainfall and resulting good plant production, so excellent recruitment and survival of juveniles would be predicted. In fact, recruitment of adult females at Cactus Peak was highest in 2004, 2006, and 2010 as expected, with the addition of 7, 6, and 12 new individuals, respectively. At Coso Basin, recruitment of new females was much lower, at 0, 3, and 1 for those 3 years.

**Table 13. Demographic patterns of the female Mohave ground squirrel populations at the Coso Basin and Cactus Peak study sites during the period from 2001 through 2010.**

| | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2001** | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** |
| **Coso Basin** | | | | | | | | | | |
| Reproduction | Yes | No | Yes | ?? | Yes | Yes | No | Yes | Yes | Yes |
| No. females | 9 | 6 | 1 | 0 | 1 | 3 | 4 | 2[a] | 1 | 2 |
| No. survivors from previous year | | 2 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 1 |
| Survival | | 0.22 | 0.17 | 0.0 | 0.0 | 0.0 | 0.33 | 0.50 | 0.50 | 1.0 |
| Recruitment | | 4 | 0 | 0 | 1 | 3 | 3 | 0 | 0 | 1 |
| **Cactus Peak** | | | | | | | | | | |
| Reproduction | Yes | No | Yes | Yes/No | Yes | No | No | Yes | Yes | Yes |
| No. females | 2 | 3 | 3 | 10 | 8[b] | 8 | 2 | 4 | 5 | 13 |
| No. survivors from previous year | | 1 | 1 | 3 | 6 | 2 | 0 | 1 | 3 | 1 |
| Survival | | 0.50 | 0.33 | 1.0 | 0.60 | 0.29 | 0.0 | 0.50 | 0.75 | 0.20 |
| Recruitment | | 2 | 2 | 7 | 2 | 6 | 2 | 3 | 2 | 12 |

[a] Includes one female captured in 2007 and 2009 that was likely present on this site in 2008.

[b] Includes one female captured in 2004 and 2006 that was likely present on this site in 2005

The superior demographic performance at Cactus Peak is most likely due to higher winter rainfall here. Its higher elevation (1470 m vs. 1085 m) and its position closer to the Sierra Nevada escarpment would be expected to result in more precipitation than at Coso Basin. While there were no rain gauge records for Cactus Peak during most of the 10-year period, data for the 2000-01 and 2005-06 winters show that rainfall totals there were higher than at Coso Basin (Table 11). If this pattern of greater winter precipitation at Cactus Peak has generally held since 2001, it could well explain the greater survival and recruitment and the upward trend in Mohave ground squirrel captures there.

## *LONG-TERM TRENDS IN MOHAVE GROUND SQUIRREL ABUNDANCE*

Monitoring of Mohave ground squirrel populations has been carried out in March and April at the Coso Basin and Cactus Peak study sites since 1990 (Table 14). Although there are gaps in the record (1991 and 1997-2000), these are the best long-term data available for the species at any location. They provide an indication of the size of the adult population in spring following emergence from dormancy and prior to the recruitment of young.

Adult Mohave ground squirrel captures in 1990 and 1992 were quite comparable to those recorded during the decade from 2001 to 2010 (Figure 4). However, the number of adults captured in March-April was unusually high during the mid-1990s. It seems reasonable to examine winter rainfall patterns during this period, since Mohave ground squirrel

reproduction is closely linked to winter rainfall and spring production of herbaceous forage (Leitner and Leitner 1998). Figure 5 shows the 23-year record of winter precipitation (Oct. 1-Mar. 31) as recorded at the Haiwee Dam and Haiwee Power Plant weather stations and at the China Lake NAWS Coso Basin rain gauges.

**Table 14 Mohave ground squirrel abundance at the Coso Basin and Cactus Peak study sites in March and April during the period from 1990 through 2010. Data presented are numbers of individual adult male and female Mohave ground squirrels captured during a 5-day trapping period preceded by 2 days of pre-baiting. In each case, a total of 441 traps were used with 25-meter spacing.**

| Year | Coso Basin | | | Cactus Peak | | |
|---|---|---|---|---|---|---|
| | Trapping Period | Number Captured | | Trapping Period | Number Captured | |
| | | Male | Female | | Male | Female |
| 1990 | March 20-24 | 1 | 5 | April 9-13 | 2 | 17 |
| 1992 | April 7-11 | 3 | 7 | April 15-19 | 2 | 6 |
| 1993 | March 30-April 3 | 5 | 15 | April 7-11 | 8 | 35 |
| 1994 | March 30-April 3 | 12 | 20 | April 6-10 | 6 | 40 |
| 1995 | March 28-April 1 | 5 | 16 | April 11-15 | 3 | 14 |
| 1996 | March 26-30 | 7 | 18 | April 2-6 | 12 | 28 |
| 1997 | | | | March 25-29 | 10 | 24 |
| 2001 | March 19-23 | 5 | 9 | March 19-23 | 0 | 2 |
| 2002 | March 19-23 | 1 | 6 | March 19-23 | 2 | 3 |
| 2003 | April 1-5 | 2 | 1 | April 1-5 | 3 | 3 |
| 2004 | March 30-April 3 | 2 | 0 | March 30-April 3 | 5 | 10 |
| 2005 | March 22-25 & 27 | 1 | 1 | March 22-25 & 27 | 2 | 8 |
| 2006 | March 21-25 | 0 | 3 | March 21-25 | 1 | 7 |
| 2007 | March 20-24 | 4 | 4 | March 20-24 | 0 | 2 |
| 2008 | March 25-29 | 1 | 1 | March 25-29 | 0 | 4 |
| 2009 | March 24-28 | 1 | 1 | March 25-29 | 0 | 5 |
| 2010 | March 23-27 | 1 | 2 | May 12-16 | 3 | 13 |

At the beginning of this winter rainfall record, severe drought conditions prevailed for almost 3 years, from summer 1988 to spring 1991, Although no monitoring was conducted in March or April 1991, trapping in May 1991 resulted in the capture of only 3 adults at the 2 study sites. Nevertheless, Mohave ground squirrel abundance recovered quickly after this low point and had already reached a combined total of 18 adults at the 2 sites in spring 1992. As indicated in Figure 5, the period from 1991 through 1993 was characterized by winter rainfall well above the Mohave ground squirrel reproductive threshold. There was relatively low precipitation during the 1993-94 winter and no Mohave ground squirrel reproduction in spring 1994. However, the next winter brought even higher rainfall totals and successful Mohave ground squirrel reproduction in spring 1995. This period of unusually high winter rainfall in the California deserts is attributed to a prolonged El Niño episode (Cayan et al. 1999).

There has been no other period during the past 20 years in which 4 out of 5 consecutive winters brought rainfall in the Coso region well above the threshold for Mohave ground squirrel reproduction. It seems clear that conditions in the mid-1990s were excellent for reproduction and survival, as reflected in the extremely high numbers of adults captured at the Coso Basin and Cactus Peak study sites from 1993 through 1996.

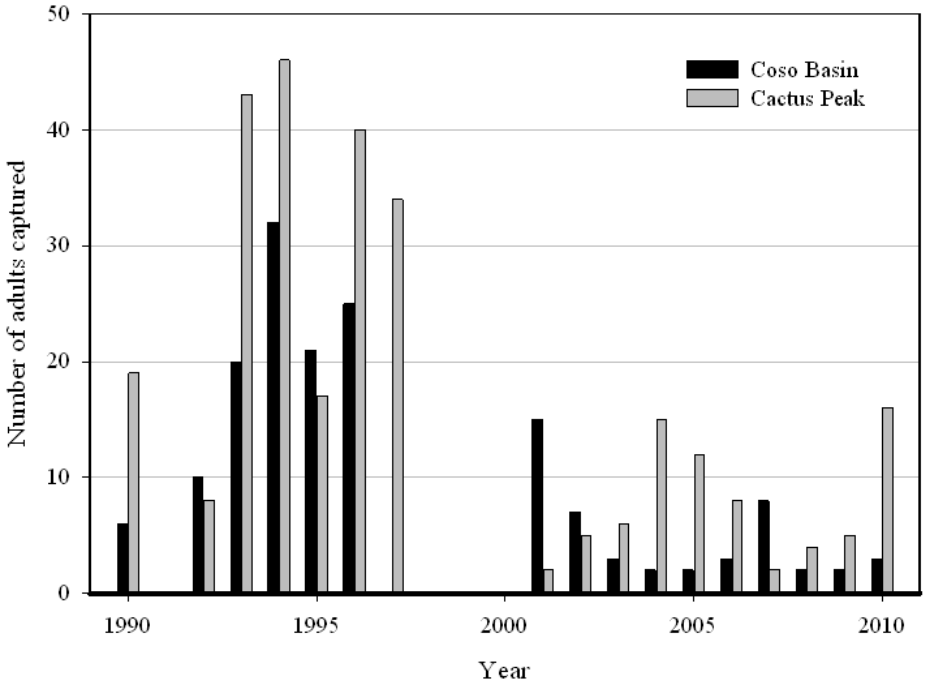


**Figure 4. Mohave ground squirrel captures at the Coso Basin and Cactus Peak study sites in March and April during the period 1990-2010. Data are numbers of adults captured over 5 days with 2 days of pre-baiting using 441 traps with 25-meter spacing. There are no comparable data available for 1991 and for 1998 through 2000; data for 1997 only for Cactus Peak.**

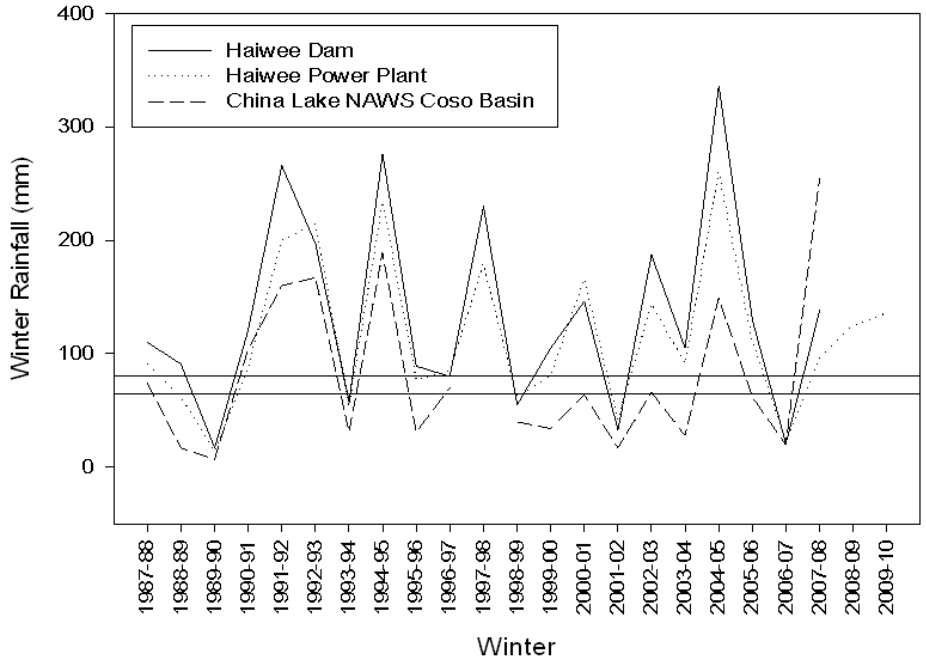


**Figure 5. Winter precipitation (Oct. 1 – Mar. 31) during the period 1987-88 through 2009-10 at Haiwee Dam and Haiwee Power Plant and at China Lake NAWS Coso Basin rain gauges. The 2 horizontal lines are placed at 65 mm and 80 mm, indicating the approximate range of the winter rainfall threshold for reproduction in the Mohave ground squirrel.**

An analysis of winter precipitation records going back to 1970 reveals another multi-year period of high rainfall throughout the western Mojave Desert (Hereford et al. 2004). In the Coso region, winter rainfall as recorded at the 2 LADWP weather stations was consistently >80 mm from 1977-78 through 1982-83. Moderate to strong El Niño conditions brought winter rainfall totals >300 mm at both the beginning and ending of this 6-year period, with less extreme but still high rainfall during the intervening years. Although Mohave ground squirrel populations were not systematically monitored at this time, 2 studies in the Coso region indicated that the species was easily observed there and trapped in significant numbers in 1978 and 1979 (Zembal and Gall 1980; Leitner 1980). Furthermore, a 1980 survey at 22 sites throughout the western Mojave Desert resulted in the capture of Mohave ground squirrels at every trapping grid, often in large numbers (Aardahl and Roush 1985). This suggests that Mohave ground squirrel populations can greatly increase in abundance in response to infrequent multi-year episodes of high rainfall. Under more usual conditions, with winter precipitation varying from year to year above and below the threshold for reproduction, the species persists in relatively low numbers in suitable habitat.

## *ROSE VALLEY STUDY SITE*

The Rose Valley study site was one of 4 locations at which Mohave ground squirrel populations were monitored from 1988 through 1996 during the Coso Grazing Exclosure Study (Figure 1). The vegetation on this site is strongly dominated by just 2 species of saltbush, in contrast to the highly diverse shrub communities found on the Coso Basin and Cactus Peak study sites. Table 15 shows all results of trapping at this site since 1988. No adults were captured during the entire 5 years from 1988 through 1992, which was marked by almost 3 years of very low winter rainfall. In contrast, adult Mohave ground squirrels were present throughout this period at the Coso Basin and Cactus Peak study sites. Although a few adults were recorded at the Rose Valley site from 1993 through 1996, almost all captures occurred in a small portion of the site with higher shrub diversity. Juveniles were documented in only 4 years and in many cases were obviously dispersing through the area. In 2010, just as during much of the 1988-1996 Coso Grazing Exclosure Study, no Mohave ground squirrels were detected at the Rose Valley site.

The Rose Valley study site, in contrast to the Coso Basin and Cactus Peak sites, does not support a permanent Mohave ground squirrel population. It appears to be an area of lower quality habitat where local extirpations occur periodically, followed by re-colonization by juveniles dispersing from adjoining more favorable habitat. Extirpations are very likely correlated with low winter rainfall, while periods of higher precipitation may lead to recruitment from more successful nearby populations. The Rose Valley site appears to differ significantly from the other 2 study locations in the properties of its shrub layer, which has much lower species diversity and lower live shrub cover. In particular, winterfat (*Krascheninnikovia lanata*) and spiny hopsage are almost entirely absent from the Rose Valley site, while they are relatively abundant at Coso Basin and Cactus Peak. Since the foliage of these 2 shrub species appears to be of great importance in the Mohave ground squirrel diet during drought periods, this may explain why the species is not able to persist at the Rose Valley site (Leitner and Leitner 1998). This pattern of local extirpation at lower quality sites followed by re-colonization from higher quality areas when environmental conditions become more favorable may be a general phenomenon in this species.

**Table 15. Summary of Mohave ground squirrel trapping results by sex and age class (juvenile/adult) at Rose Valley during the spring and early summer from 1988-2010. Trapping effort totaled 2,205 trap-days on each occasion.**

| Year | Adults | | Juveniles |
|---|---|---|---|
| | Males | Females | |
| May 1988 | 0 | 0 | 21 |
| May 1989 | 0 | 0 | 0 |
| March 1990 | 0 | 0 | 0 |
| May 1991 | 0 | 0 | 0 |
| April 1992 | 0 | 0 | 0 |
| May 1992 | 0 | 0 | 0 |
| March-April 1993 | 2 | 1 | 0 |
| May-June 1993 | 0 | 2 | 25 |
| March 1994 | 0 | 5 | 0 |
| June 1994 | 0 | 1 | 0 |
| March 1995 | 0 | 2 | 0 |
| May 1995 | 0 | 1 | 10 |
| March 1996 | 2 | 1 | 0 |
| May 1996 | 0 | 0 | 1 |
| March 2010 | 0 | 0 | 0 |

## *WHITE-TAILED ANTELOPE SQUIRREL ABUNDANCE AND REPRODUCTION*

While 10-year trends in Mohave ground squirrel abundance differed at the Coso Basin and Cactus Peak study sites, the numbers of individual white-tailed antelope squirrels captured followed a very similar pattern at both study sites (Figure 56).

The highest numbers of captures at both sites were recorded from 2001 through 2005, with abundances generally in excess of 20 individuals. Spring 2003 was the obvious exception with a major decline from the preceding year. This decline directly followed the severe drought conditions of 2002, when no reproduction occurred and survival may have been greatly impacted. After 2005, abundance declined precipitously at both sites, reaching a low point in 2009. However, the pattern from 2005 through 2010 does not appear to be closely linked to winter rainfall. Although rainfall was highest of the decade during the 2004-05 winter, white-tailed antelope squirrel captures were much reduced in 2006. Very low rainfall during the 2006-07 winter was followed by white-tailed antelope squirrel reproductive failure at both study sites in spring 2007. In spite of this, the numbers of captures in 2008 were only slightly lower. Finally, the greatly reduced white-tailed antelope squirrel abundance seen in 2009 was preceded by moderately high rainfall during the 2007-08 winter. Unlike Mohave ground squirrels, this species does not enter dormancy and is active throughout the year. It is possible that white-tailed antelope squirrel survival is significantly affected by food availability and severe weather during the fall and winter.

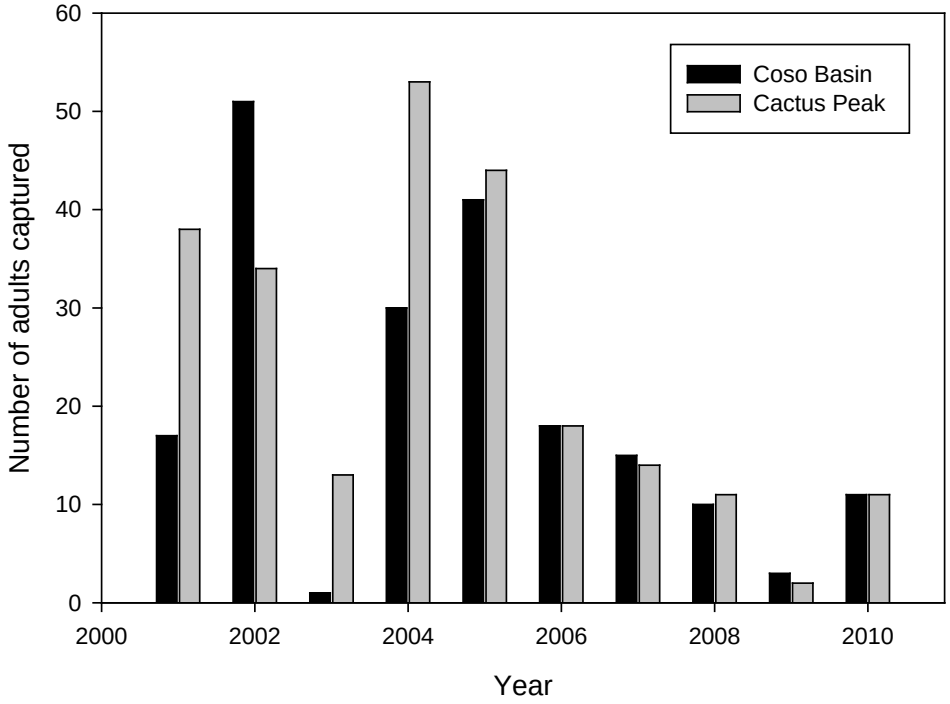


**Figure 6. White-tailed antelope squirrel captures at the Coso Basin and Cactus Peak study sites in March and April during the period 2001-2010. Data are numbers of individual adults captured over 5 days with 2 days of pre-baiting using 441 traps with 25-meter spacing.**

## RECOMMENDATIONS

The Coso monitoring study has been successful in demonstrating the importance of winter rainfall to reproduction and survival of Mohave ground squirrel populations. These results suggest that the protection of other areas within the range of the species that can support Mohave ground squirrel populations through low rainfall periods may be a critical conservation measure. This information will also be valuable for the interpretation of any temporal trends in the distribution and abundance of Mohave ground squirrels that may be revealed by future range-wide monitoring efforts. It is essential to maintain this unique long-term data base. It is recommended that DFG continue to fund this study at the 2 Coso sites at least through 2013.

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# APPENDIX A. CHARACTERISTICS OF MOHAVE GROUND SQUIRRELS CAPTURED AT THE COSO BASIN STUDY SITE

| Capture Dates | PIT Tag No. | Sex | Body Mass (g) | Reproductive Condition | Previously Captured |
|---|---|---|---|---|---|
| March 19-23, 2001 | 1F6658683B | F | 92 | Teats enlarged | |
| | 1F640B076B | F | 138 | Teats enlarged | |
| | 1F62653A60 | F | 134 | Pregnant | |
| | 1F65317C4F | F | 140 | Teats enlarged | 1995 juvenile |
| | 1F0C784815 | F | 120 | Pregnant | |
| | 1F655A6B37 | F | 153 | Pregnant | |
| | 1F650B5F12 | F | 101 | Pregnant | |
| | 1F631C3131 | F | 124 | Teats enlarged | |
| | 1F5958032D | F | 138 | Pregnant | |
| | 1F645A564D | F | -- | Pregnant | |
| | 1F1F7D6560 | M | 123 | Testes scrotal | |
| | 1F685D0814 | M | 128 | Testes scrotal | |
| | 1F61167476 | M | 135 | Testes scrotal | |
| | 1F61527E30 | M | 135 | Testes scrotal | |
| | 1F631E1C44 | M | 121 | Testes scrotal | |
| March 19-23, 2002 | 1F631C3131 | F | 77 | Non-reproductive | 2001 |
| | 1F64757117 | F | 86 | Non-reproductive | |
| | 1F650B5F12 | F | 90 | Non-reproductive | 2001 |
| | 1F66657521 | F | 76 | Non-reproductive | |
| | 1F68250153 | F | 102 | Non-reproductive | |
| | Not PIT tagged | F | 118 | Non-reproductive | |
| | Not PIT tagged | M | 94 | Testes non-scrotal | |
| April 1-5, 2003 | 1F66657521 | F | 160 | Pregnant | 2002 |
| | 1F1F7D6560 | M | 155 | Testes scrotal | 2001 |
| | 1F6669533F | M | 154 | Testes scrotal | |
| March 30-April 3, 2004 | 1F570D106D | M | 153 | Testes non-scrotal | |
| | 1F63560028 | M | 147 | Testes non-scrotal | |
| March 22-25 & 27, 2005 | 1F645E6D32 | F | 159 | Pregnant | |
| | 1F1F7D6560 | M | 157 | Testes scrotal | 2001; 2003 |
| March 21-25, 2006 | 1F64445B5E | F | 144 | Teats enlarged | |
| | 1F644F0628 | F | 154 | Pregnant | |
| | 1F664F7438 | F | 143 | Teats enlarged | |
| March 20-24, 2007 | 1F67416158 | F | 90 | Non-reproductive | |
| | 1F63316568 | F | 89 | Non-reproductive | |
| | 1F64791173 | F | 86 | Non-reproductive | |
| | 1F644F0628 | F | 115 | Non-reproductive | 2006 |
| | 1F63243624 | M | 109 | Testes non-scrotal | |
| | 1F631D025F | M | 82 | Testes non-scrotal | |
| | 1F645B7032 | M | 108 | Testes non-scrotal | |
| | 1F647F126C | M | 102 | Testes non-scrotal | |
| March 25-29, 2008 | 1F67416158 | F | 166 | Pregnant | 2007 |
| | 1F64500D20 | M | 157 | Testes scrotal / regressing | |
| March 24-28, 2009 | 1F644F0628 | F | 154 | Pregnant | 2006; 2007 |
| | 1F642E420D | M | 130 | Testes scrotal | |
| March 23-27, 2010 | 1F65434D6C | F | 140 | Teats enlarged | |
| | 1F644F0628 | F | 185 | Pregnant | 2006; 2007; 2009 |
| | 1F5A622302 | M | 116 | Testes scrotal | |

# APPENDIX B. CHARACTERISTICS OF MOHAVE GROUND SQUIRRELS CAPTURED AT THE CACTUS PEAK STUDY SITE

| Capture Dates | PIT Tag No. | Sex | Body Mass (g) | Reproductive Condition | Previously Captured |
|---|---|---|---|---|---|
| March 19-23, 2001 | 1F637B671C | F | 135 | Pregnant | |
| | 1F60066417 | F | 152 | Pregnant | |
| March 19-23, 2002 | 1F60066417 | F | 132 | Non-reproductive | 2001 |
| | 1F62531319 | F | 89 | Non-reproductive | |
| | 1F660B244C | F | 107 | Non-reproductive | |
| | 1F6105215A | M | 98 | Testes non-scrotal | |
| | 1F653D457C | M | 126 | Testes scrotal | 2000 |
| April 1-5, 2003 | 1F60066417 | F | 170 | Pregnant | 2001; 2002 |
| | 1F633D122F | F | 129 | Pregnant | |
| | 1F730E045C | F | 168 | Pregnant | |
| | 1F6105215A | M | 138 | Testes scrotal / regressing | 2002 |
| | 1F620B6113 | M | 150 | Testes scrotal / regressing | |
| | 1F64142B3E | M | 156 | Testes scrotal / regressing | |
| March 30-April 3, 2004 | 1F60066417 | F | 230 | Pregnant | 2001; 2002; 2003 |
| | 1F62000976 | F | 135 | Non-reproductive | |
| | 1F63313F0E | F | 158 | Non-reproductive | |
| | 1F633D122F | F | 179 | Pregnant | 2003 |
| | 1F63414776 | F | 147 | Non-reproductive | |
| | 1F63677E19 | F | 120 | Non-reproductive | |
| | 1F665E5845 | F | 150 | Non-reproductive | |
| | 1F67344B7B | F | 151 | Non-reproductive | |
| | 1F730E045C | F | 199 | Pregnant | 2003 |
| | 2007401E7B | F | 160 | Pregnant | |
| | 1F6105215A | M | 169 | Testes non-scrotal | 2002; 2003 |
| | 1F620B6113 | M | 173 | Testes non-scrotal | 2003 |
| | 1F63351F2A | M | 195 | Testes non-scrotal | |
| | 1F64717616 | M | 164 | Testes non-scrotal | |
| | 1F650C412F | M | 147 | Testes non-scrotal | |
| March 22-25 & 27, 2005 | 1F604E3F74 | F | 128 | Pregnant | |
| | 1F615C3371 | F | 147 | Pregnant | |
| | 1F62000976 | F | 171 | Pregnant | 2004 |
| | 1F63414776 | F | 185 | Pregnant | 2004 |
| | 1F65650611 | F | 156 | Pregnant | |
| | 1F67344B7B | F | 182 | Pregnant | 2004 |
| | 1F730E045C | F | 178 | Pregnant | 2003; 2004 |
| | 2007401E7B | F | 197 | Pregnant | 2004 |
| | 1F6105215A | M | 166 | Testes scrotal | 2002; 2003; 2004 |
| | 1F635C3F63 | M | 184 | Testes non-scrotal | |
| | 1F64581411 | M | 166 | Testes scrotal | |
| | 1F64717616 | M | 174 | Testes scrotal / regressing | 2004 |
| March 21-25, 2006 | 1F665E5845 | F | 151 | Non-reproductive | 2004 |
| | 1F67344B7B | F | 151 | Non-reproductive | 2004; 2005 |
| | 1F67372122 | F | 122 | Non-reproductive | |
| | 1F6E2A1C2D | F | 118 | Non-reproductive | |
| | 1F65662D69 | F | 137 | Non-reproductive | |
| | 1F63742E5C | F | 129 | Non-reproductive | |
| | 1F611C677D | F | 161 | Non-reproductive | |
| | 1F651D7966 | M | 149 | Testes scrotal / regressing | |

| | | | | | |
|---|---|---|---|---|---|
| March 20-24, 2007 | 1F68206D6C | F | 112 | Non-reproductive | |
| | 1F664A4B66 | F | 137 | Non-reproductive | |
| March 25-29, 2008 | 1F666E0409 | F | 205 | Pregnant | |
| | 1F645F2A74 | F | 150 | Pregnant | |
| | 1F61145418 | F | 176 | Pregnant | |
| | 1F664A4B66 | F | 177 | Pregnant | 2007 |
| March 25-29, 2009 | 1F645F2A74 | F | 167 | Pregnant | 2008 |
| | 1F664A4B66 | F | 162 | Pregnant | 2007; 2008 |
| | 1F666E0409 | F | 155 | Pregnant | 2008 |
| | 1F63671B7C | F | 159 | Pregnant | |
| | 1F67431A1D | F | 178 | Pregnant | |
| May 12-16, 2010 | 1F6507482D | F | 164 | Post-lactating | |
| | 1F64295103 | F | 146 | Post-lactating | |
| | 1F6669050D | F | 166 | Post-lactating | |
| | 1F6461425A | F | 156 | Post-lactating | |
| | 1F657D5D22 | F | 166 | Post-lactating | |
| | 1F664E230A | F | 143 | Post-lactating | |
| | 1F645F2A74 | F | 179 | Post-lactating | 2008; 2009 |
| | 1F64334F7B | F | 140 | Post-lactating | |
| | 1F66542502 | F | 123 | Post-lactating | |
| | 1F65346464 | F | 149 | Post-lactating | |
| | 1F5F0A5325 | F | 152 | Post-lactating | |
| | 1F616E3A58 | F | 141 | Post-lactating | |
| | 2007501A6F | F | 149 | Post-lactating | |
| | 1F64012458 | M | 165 | Testes non-scrotal | |
| | 1F651D3B24 | M | 193 | Testes non-scrotal | |
| | 1F642F2A24 | M | 226 | Testes non-scrotal | |