PUBLIC WORKS TECHNICAL BULLETIN 200-1-92
31 MARCH 2011

GUIDANCE AND DEMONSTRATION OF MOTION DETECTION SYSTEMS FOR MONITORING SPECIES OF CONCERN

Public Works Technical Bulletins are published by the U.S. Army Corps of Engineers, 411 G Street NW, Washington, DC 20314-1000. They are intended to provide information on specific topics in areas of Facilities Engineering and Public Works. They are not intended to establish new Department of the Army policy.

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

CECW-CE

Public Works Technical Bulletin 28 February 2011

No. 200-1-92

Facilities Engineering
Environmental

GUIDANCE AND DEMONSTRATION OF MOTION DETECTION SYSTEMS FOR MONITORING OF SPECIES OF CONCERN

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) describes the use and effectiveness of motion detection camera systems for monitoring animal species of concern on military installations and/or Corps of Engineers (COE) facilities in the United States.

b. This PWTB provides guidance to natural resource managers on the potential benefits and/or limitations of using alternative non-invasive methods (e.g., motion detection camera systems) to survey for the presence of species of concern on their lands.

c. All PWTBs are available electronically (in Adobe® Acrobat® portable document format [PDF]) through the World Wide Web (WWW) at the U.S. Army Engineering and Support Center's Technical Information – Facility Design ("TechInfo") web page, which is accessible through URL:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability. This PWTB applies to U.S. Army facilities in the United States where wildlife species of concern reside.

3. References.

a. Army Regulation (AR) 200-1, "Environmental Protection and Enhancement," 13 December 2007. This Regulation "Implements Federal, State, and local environmental laws and Department of Defense (DoD) policies for preserving, protecting, conserving, and restoring the quality of the environment."

b. AR 200-3, "Natural Resources - Land, Forest, and Wildlife Management," 28 February 1995, as modified 20 March 2000. This Regulation requires that installations be good stewards of land resources.

4. Discussion.

a. In order to effectively recover and manage species of concern on Department of Defense (DoD) lands, it is important that natural resource managers have tools to accurately and effectively survey and monitor species of concern. Current survey methods, like live-trapping, provide good information on Mohave ground squirrel (MGS) presence, distribution, and density; however, cost, logistical issues (i.e., permit requirements), and availability of permitted personnel can be prohibitive and may hinder the collection of such information. With the MGS currently listed as a Priority 1 Species-At-Risk candidate within the Army and a candidate for federal listing, it is especially important that current population and distribution information be collected.

b. Appendix A provides background information on MGS which was the test subject for this project.

c. Appendix B provides information about the study area, equipment, and methods used. This project was conducted within the West Mojave Desert at the National Training Center (NTC) at Fort Irwin, California, and on the National Aeronautics and Space Administration's (NASA's) Goldstone Deep Space Communications Complex. Camera traps were tested to demonstrate if they effectively documented ground squirrel presence at feeding stations and differentiated between the various ground squirrel species of interest.

d. Appendix C details project results and conclusions. A total of 14 sites were monitored to test the functionality and effectiveness of camera traps during different activity periods during the year and across different habitat types. Ground squirrels readily visited feed stations monitored by camera traps. Camera traps were found to be very effective in distinguishing between the three ground squirrel species of interest, MGS, antelope ground squirrel (AGS), and round-tailed ground squirrel (RGS). Ground squirrels readily visited feeding stations monitored by camera traps and did not appear to be impacted by the presence of the monitoring equipment.

e. Appendix D describes the major benefits associated with using automated motion detection systems. Examples of these benefits include: definitive identification between ground squirrel species; a non-invasive method for species detection and behavioral observation; and no requirement for permits when working with non-federally listed species.

f. Appendix E describes the limitations or caveats associated with using automated motion detection systems. Even though cameras traps were effective, there were some limitations with their use, namely the inability to positively distinguish between individuals or determine an exact number of animals apart from using age, sex, pelage, or simultaneous visitations.

g. Appendix F provides information on lessons learned, recommendations, and possible future field tests utilizing motion detection systems to further study MGS.

h. Appendix G contains references used in the appendices. A short list of abbreviations is also included.

5. Points of Contact (POCs). Headquarters, U.S. Army Corps of Engineers (HQUSACE) is the proponent for this document. The HQUSACE POC is Mr. Malcolm E. McLeod, CEMP-CEP, 202-761-5696, or E-mail: Malcolm.E.Mcleod@usace.army.mil.

Questions and/or comments regarding this subject should be directed to the technical POC:

U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory
ATTN: CEERD-CN-N (David K. Delaney)
2902 Newmark Drive
Champaign, IL 61822-1076
Tel. (217) 373-6744
FAX: (217) 373-7266
e-mail: David.Delaney@usace.army.mil

FOR THE COMMANDER:

JAMES C. DALTON, P.E., SES
Chief, Engineering and Construction
Directorate of Civil Works

Appendix A

INTRODUCTION

The Mohave ground squirrel (MGS; *Xerospermophilus mohavensis;* Figure A-1) is a small herbivorous endemic rodent found in desert-scrub habitat of the western Mojave Desert in California. This species is believed to have the smallest geographic range of *Xerospermophilus* ground squirrels in California, about 2 million hectares (nearly 5 million acres), of which approximately 34.5% is on Department of Defense (DoD) lands (i.e., the Naval Air Weapons Station [NAWS] at China Lake, National Training Center [NTC] on Fort Irwin, Edwards Air Force Base [EAFB], Marine Corps Auxiliary Air Station, Barstow, and Air Force Plant 42, Palmdale; Figure A-2). The remaining MGS range is owned by the Bureau of Land Management (BLM; ~ 31.8%), private land owners (~ 31.0%), and within state and federal protected lands (~ 2.7%; Stewart 2005). The historic range of the MGS is confined to the northwestern corner of the Mojave Desert; bounded by the San Gabriel, Techachapi, and Sierra Nevada Mountains to the south and west, and by Owens Lake and various small mountain ranges to the northeast (Leitner 2008).

Figure A-1. Two adult MGS arrive at a camera trap station at the same time.

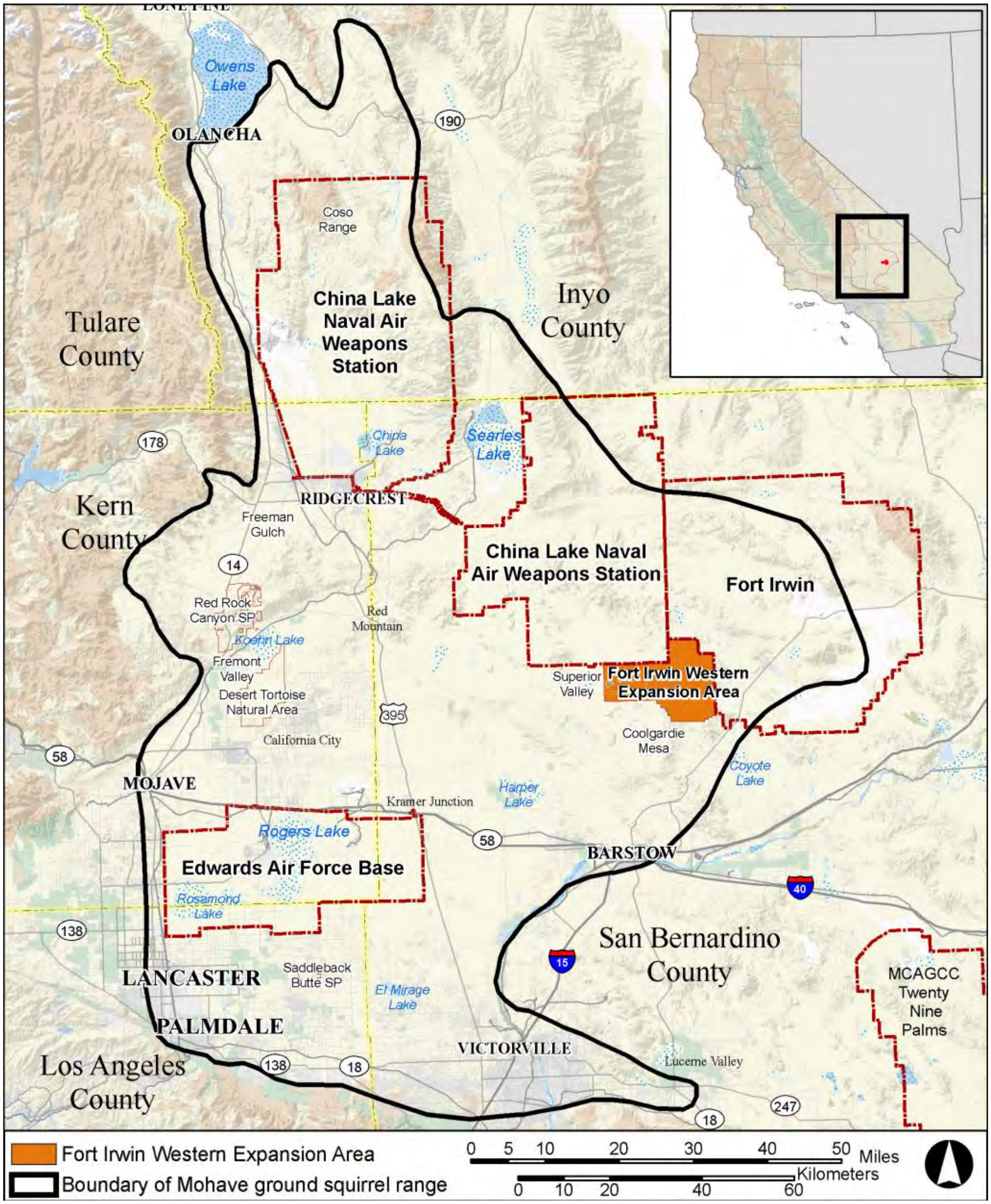

Figure A-2. Location of the NTC at Fort Irwin, California, within the Western Mojave Desert. The black line represents the current known boundary of the MGS range. (Map created by personnel at California State University [CSU]-Stanislaus.)

The MGS is currently listed as threatened under the California Endangered Species Act and is a Priority 1 Species-At-Risk candidate within the Army. Additionally, there is a current petition to federally list this species as Endangered with critical habitat (Stewart 2005). The U.S. Fish and Wildlife Service (USFWS) recently released its 90-day finding, in which it determined that the listing of the species may be warranted. The USFWS has initiated a status review of the species to determine if listing is warranted. The primary threats to this species have been habitat loss, fragmentation, and degradation on federal and private lands from urbanization, agricultural development, military activities, energy development, roads, off-highway vehicle use, and grazing. Natural factors, such as drought, may impact MGS breeding behavior and could affect this species' ability to persist in areas with extended periods of drought from global climate change. The MGS was chosen to be the test species for this project.

Land managers currently survey for some wildlife species of concern (e.g., MGS) by setting up live-trapping grids based on expert knowledge of habitat use. The limited number of permitted individuals authorized to survey for some threatened, endangered, and at-risk species can greatly increase the costs of surveying for animal populations and substantially reduces the number of transects/land area that can be surveyed.

Alternative survey, inventory, and monitoring techniques (e.g., motion detection systems, also referred to herein as camera traps) are needed to examine large parcels of potentially suitable land for priority species of concern. Camera traps have been used to investigate a variety of wildlife species (e.g., Rowcliffe et al. 2008; Tobler et al. 2008), but have not been comprehensively field tested on MGS to date. Such techniques have the potential to greatly reduce the overall costs of animal surveys and provide important information on where more expensive/labor-intensive trapping surveys should be concentrated, which should improve the efficiency of live-trapping surveys, while increasing our knowledge on species distribution, relative density, and habitat use.

Appendix B

STUDY AREA AND DATA COLLECTION METHODS

Study Area

This project was conducted at the NTC on Fort Irwin, California, (which includes WEA) and NASA's Goldstone Deep Space Communication Complex (within Fort Irwin along the southwestern border between the installation and WEA). The project timeline was between February and June 2010, which is during the known activity period of the MGS. These locations were chosen because they contain known populations of MGS or suitable habitat. Secondly, Fort Irwin is interested in learning more about the distribution of MGS within the WEA. Lastly, the Army is interested in finding cost-effective, non-invasive alternatives to conventional trapping surveys for detecting MGS presence on DoD and other federal and state lands.

Methods

Site Selection

To test the use and effectiveness of camera traps to detect MGS, sites were selected where squirrels had been detected recently (Leitner 2007; Figure B-1) or based on the presence of suitable habitat according to expert opinion[1]. It is important that camera traps are able to identify between different ground squirrel species of interest within the MGS range. Therefore, sites also were selected to the east within the NTC in an attempt to detect round-tailed ground squirrels (RTGS; *X. tereticaudus*) for comparative purposes. It was anticipated that white-tailed antelope ground squirrels (AGS, *Ammospermophilus leucurus;* Figure B-2), which are quite common throughout the MGS range, would also be detected by camera traps.

[1] Personal communication between PWTB author David Delaney (ERDC-CERL) and P. Leitner (CSU-Stanislaus) on 15 January 2010.

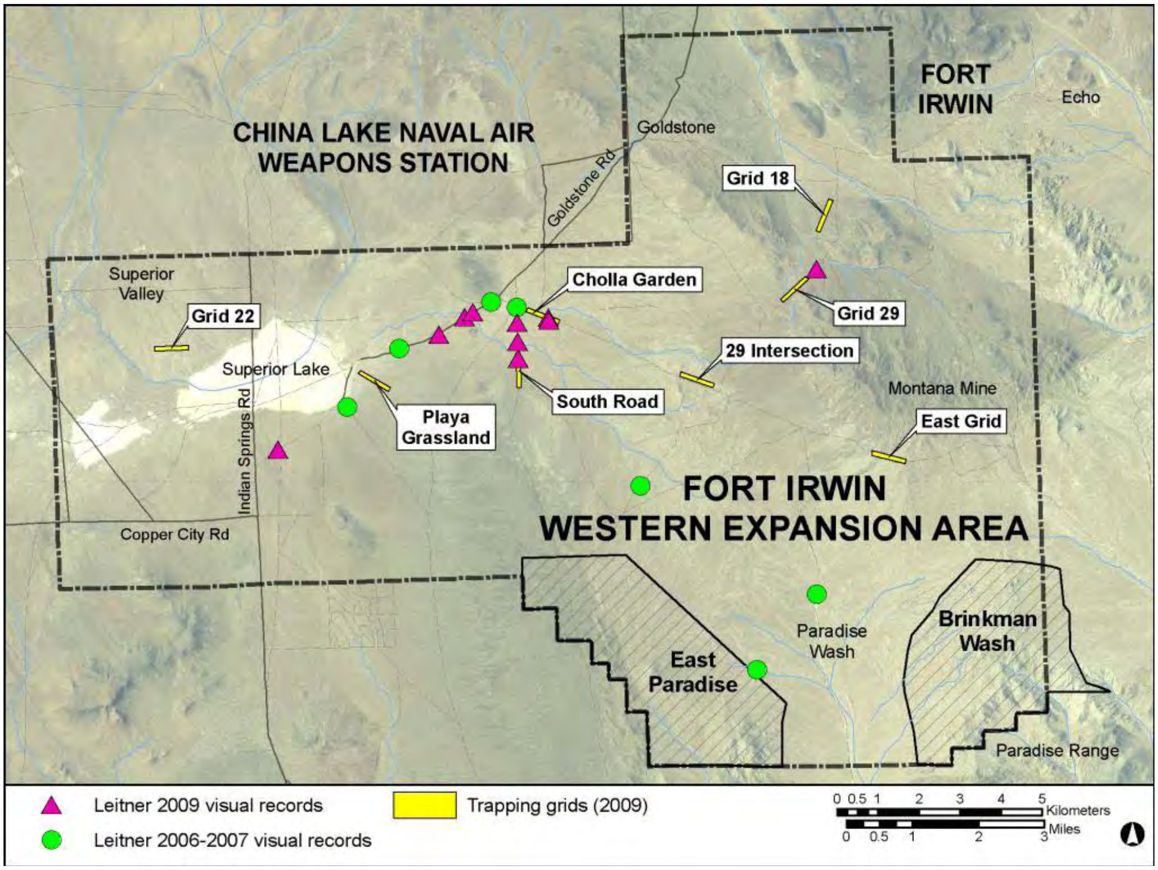

Figure B-1. Locations of MGS visual records and recent trapping locations within the WEA, 2006-2007 and 2009 (Leitner 2007, 2009). (Map created by personnel at CSU-Stanislaus.)

Figure B-2. An AGS (left) is being chased by an MGS (right).

Camera Trap Surveillance

Camera trap systems can differ in a number of ways, from the recording medium (still photo and/or video image), recording duration, color or black and white, detection range, time delay between images, field of view, setup procedures, trigger speed, detection sensitivity, cost, memory storage capacity, storage medium (i.e., compact flash, secure digital, jump drive), operating conditions, overall reliability, etc. Reconyx RC60 camera systems (Figure B-3) were selected for this demonstration project due to their low glow or no glow infrared motion detection, large storage capacity, long battery life, fast triggering time, no delay between pictures, and reported reliability.

Figure B-3. A Reconyx RC60 camera system is set up at a feeding station within the WEA on Fort Irwin.

Upwards of 14 camera trap systems, with 70-120 m spacing between cameras (~230-394 ft), were used to sample each conventional 840 x 105-m (~2756 x 344 feet) grid. Researchers regularly use 100 live traps with 25-m (~82 ft) spacing to cover trapping grids. Cameras were mounted onto 5-ft fence posts that were hammered into the ground at roughly a 50-degree angle, though other types of attachment setups using tripods, shovels, trees, etc. will work. It is important to consider the camera system's profile relative to surrounding vegetation when placing equipment onto the landscape to lessen the chance of theft or vandalism. In forested environments, cameras might need to be placed in elevated positions, from 3-4.6-m (~10-15 ft) up the tree, to lessen the potential of equipment theft.

Cameras were visited each day to monitor the equipment and refill feeding stations. Nocturnal food competitors like kangaroo rats (*Dipodomys deserti*) and desert pocket mice (*Chaetodipus penicillatus*) usually ate any food not eaten the previous day, so food needed to be replenished most days. Automated feeders could possibly be used to restock food at feeding stations in place of daily visits, but should be tested to confirm that this additional equipment will not impact ground squirrel visitation. Storage cards within cameras were swapped out every few days to safeguard against possible data loss, though the systems could run for a week to months at a time depending on the size of the storage card and the amount of animal activity present at the site.

Appendix C

SUMMARY

Results

A total of 14 sites were monitored within the WEA, Goldstone, and on Fort Irwin (Figures C-1 and C-2) to test the functionality and effectiveness of units during different activity periods and across different habitat types. Sites were surveyed for five consecutive days in February (mating period), April (when females are pregnant or lactating), and May (when young are born and starting to move from their natal burrows; Table C-1). Sites were also surveyed in June to attempt to record RTGS to confirm that cameras could distinguish between RTGS and MGS.

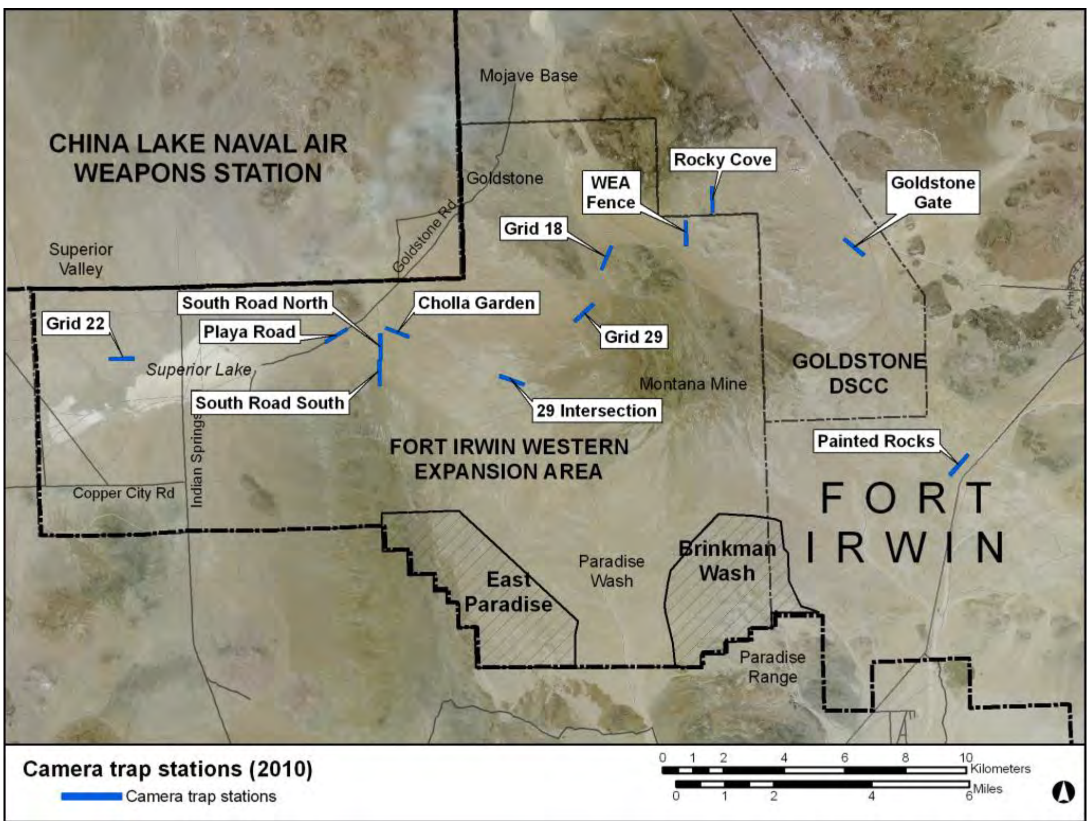

Figure C-1. Map showing the sites where camera trapping occurred within Fort Irwin, the WEA, and Goldstone in 2010. (Map created by personnel at CSU-Stanislaus.)

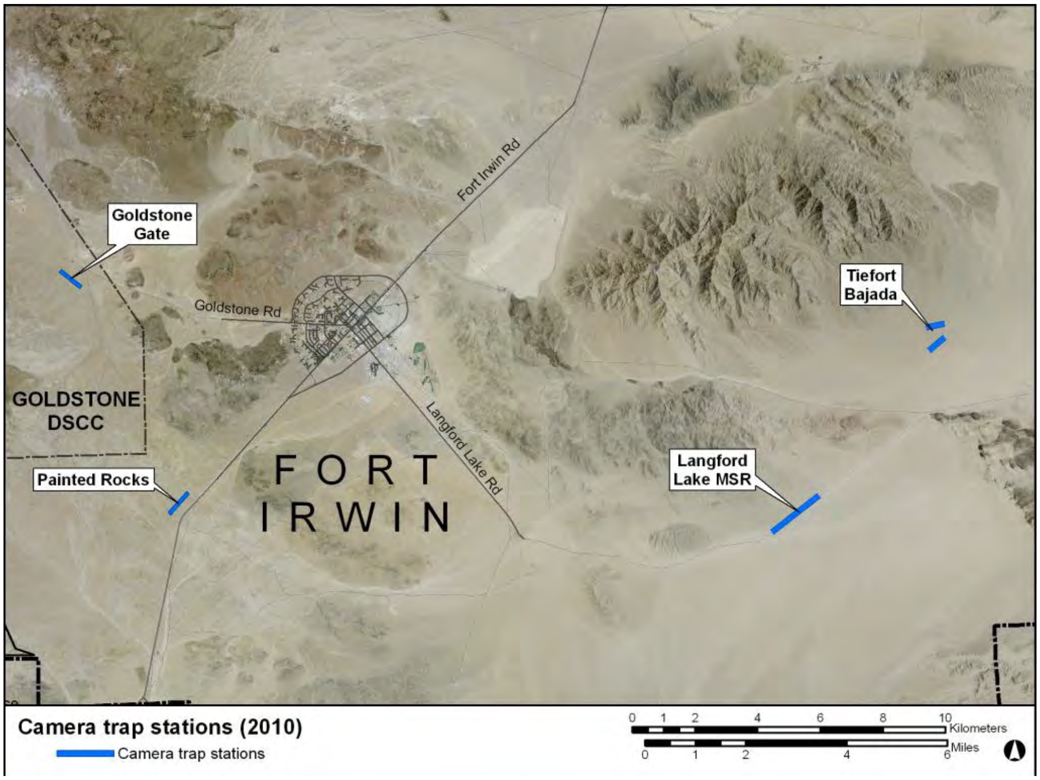

Figure C-2. Map showing additional sites where camera trapping occurred within Fort Irwin in 2010, east of the cantonment area. (Map created by personnel at CSU-Stanislaus.)

Table C-1. Months when sites were surveyed with camera traps in 2010 (see Figures C-1 and C-2 for site locations).

Sites	Date(s) Surveyed
Cholla Garden	FEB and APR
Grid 29	FEB and APR
South Road North	FEB and APR
Playa Road	FEB and APR
Grid 22	APR
Grid 18	APR
29 Intersection	APR
South Road South	APR
Painted Rocks	MAY
Goldstone Gate	MAY
Rocky Cove	MAY
WEA Fence	MAY
Langford Lake	JUNE
Tiefort Bajada	JUNE

Camera traps successfully detected all three ground squirrel species of interest (MGS, AGS, and RTGS) at one or more of the study locations. Camera traps recorded MGS at the same grids where this species was previously live trapped (Figure B-1). It took ground squirrels from a few hours to a few days to initially find feeding stations. Once feeding stations were found, all ground squirrel species readily visited feeding stations multiple times per day over consecutive days and did not appear to be bothered by the presence of the camera trap systems.

The three species of ground squirrels could clearly be differentiated by using camera trap equipment. The white lateral strip of the AGS could be clearly distinguished from the solid body colors of MGS (Figure B-2) and RTGS (Figure C-3). The RTGS also could be readily distinguished from the MGS based on the relative length, shape, and position of its tail during visits to feeding stations. The tail of the RTGS was usually positioned flat on the ground (Figure C-3), while MGS often held its tail up against its back, showing differences in coloration between dorsal and ventral surfaces of the tail (Figures A-1 and B-2).

Figure C-3. A juvenile RTGS feeds at a camera trap station.

Individual Mohave ground squirrels were distinguishable by using camera traps based on differences in age, sex, simultaneous detections at camera stations, and pelage/marking patterns. Differences in age were clearly identifiable based on variation in body size and tail length, while male and female squirrels were differentiated based on the presence/absence of external genitalia which were clearly visible during most squirrel visitations.

A variety of different intraspecific and interspecific ground squirrel interactions were documented at feeding stations. It is important from a behavioral perspective to know under what circumstances different species and/or age classes visit feeding stations at the same time. The following types of ground squirrel visitations were recorded at feeding stations (occurred for all three squirrel species unless noted):

- single juvenile
- single adult
- multiple (2-4) juveniles of same species
- multiple adults of the same species (2-5; all but RTGS)
- adult and juvenile of same species
- multiple juveniles and one adult (all but RTGS)
- multiple adults and one juvenile of same species (AGS only)
- multiple juveniles and multiple adults of same species (AGS only)
- juvenile MGS and AGS
- adult MGS and AGS
- single adult MGS and multiple adults AGS
- multiple adult MGSs and single adult AGS
- single/multiple and/or adult/juvenile of another ground squirrel species and single/multiple adult or juvenile RTGS (none).

The largest number of individual adult MGS observed at feeding stations simultaneously was two. On every occasion, one adult would either leave the area immediately upon seeing the other adult MGS, or one would chase the other away. Adult MGS were not observed feeding in close proximity to one another at feeding stations, though juveniles were periodically seen feeding with adults or other juveniles. Under no circumstances did AGS act dominant towards MGS at feeding stations, regardless of age class. Both juvenile and adult MGS frequently made aggressive movements towards AGS though, chasing individuals away from feeding stations (Figure B-2). Camera traps also documented dominance behavior between AGS and conspecifics (same species), where one individual would attempt to defend the food source from other AGS (Figure C-4), often jumping at them or chasing them away (Figure C-5). Aggressive behavior can become serious, as individuals are wounded from bites or scratches (Figure C-6).

Figure C-4. Two adult AGS exhibiting aggressive behavior.

Figure C-5. One AGS chases another AGS away from food.

Figure C-6. An AGS (left) shows signs of injury (note blood marks around neck and upper arm), presumably suffered from an attack by a conspecific.

During instances when both juvenile and adult MGS or AGS were present, MGS were dominant over AGS. When MGS were present, AGS moved slowly along the periphery of the feeding station area and never fed directly from the tray itself. MGS frequently chased AGS away from the feeding station, though AGS often returned to continue feeding from the periphery of the feeding station. When MGS were not present at feeding stations, but present in the general area, AGS (both juvenile and adult) would usually quickly approach, grab some food, and quickly leave the area. MGS on the other hand would usually linger on or near the feeding station while feeding, regardless of age class.

Also detected at feeding stations were other non-target species, such as desert kangaroo rat (*Dipodomys deserti*), desert pocket mouse (*Chaetodipus penicillatus*), desert tortoise (*Gopherus agassizii*), raven (*Corvus corax*), coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), badger (*Taxidea taxus*), desert cottontail (*Sylvilagus auduboni*), blacktail jackrabbit (*Lepus californicus*), cactus wren (*Campylorhynchus brunneicapillus*), spotted towhee (*Pipilo maculatus*), horned lark (*Eremophila alpestris*), and western whiptail (*Cnemidophorus tigris tigris*).

Conclusions

Camera traps were effective in detecting and distinguishing between the three ground squirrel species examined during this project. Ground squirrels readily visited feeding stations monitored by camera traps and did not appear to be impacted by the presence of the monitoring equipment. Camera traps detected MGS at every one of the locations where MGS had been located during previous live-trapping sessions (Figure B-1). Based on the quality of the images examined during this project, there is 100% confidence in the ability of these systems to identify between all three ground squirrel species. It is important to note that MGS may hybridize with its sister species, RTGS (Hafner 1992; Bell and Matocq 2010). A number of ground squirrels captured recently in the contact zone between these species have exhibited morphometric attributes from both species. Camera traps could also be used to detect for possible hybrid individuals as well, especially in the contact zone.

These systems worked well for extended periods of time under a variety of harsh weather conditions and across a variety of desert environments. Camera traps should work well in other regions of the country on a variety of other animal species that installations or COE facilities might be interested in monitoring. It is important that alternative, non-invasive survey methods be examined and tested to find cost-effective ways to monitor species of concern, especially state or federally listed species.

Most MGS contractors currently charge $20,000-$25,000 to trap one grid 3 times per year to meet protocol trapping requirements[2], although costs can reach upwards of $40,000 for protocol trapping. Camera trap systems and associated field techniques, as tested, appear to be cost-effective in detecting MGS in comparison with current live-trapping cost estimates (Table C-2). Mohave ground squirrels were detected at all field sites where previous live-trapping studies had detected their presence. Multiple study sites of camera traps are able to be operated by a single field technician, unlike live-trapping (Table C-2). One main reason for the difference in cost has to do with the requirements that all personnel handling animals during live-trapping be permitted, which is not a requirement for camera trapping of the state-listed MGS. Also, camera trap equipment can be utilized over multiple years, increasing the overall cost effectiveness of this technology/technique. It is important to note that camera traps cannot replace live-trapping, but should help facilitate live-trapping by providing additional information on MGS presence to improve future live-trapping survey effectiveness.

[2] Personal communication between author David Delaney (ERDC-CERL) and P. Leitner (CSU-Stanislaus) on 20 December 2010.

Table C-2. Estimated cost comparison between protocol live-trapping (5 consecutive days of trapping, 3 times per year) of Mohave ground squirrels on conventional-sized grids for 1-2 years versus using camera traps. This estimate assumes equal travel time, vehicle expenses, and feed costs across sites. It is important to note that protocol live-trapping is the only currently approved survey method for clearing sites based on the presence/absence of MGS. This table is provided as a basic cost comparison and does not suggest that camera trapping with 14 cameras provides the amount of sampling coverage necessary for protocol live-trapping.

Survey Effort	**Live-Trapping**		**Camera Trapping**	
	1 year	**2 year**	**1 year**	**2 year**
Number of grids	1/4	2/8	1/4	1/4
Number of traps	100/400	100/400	14/56	14/56
Number of days trapping	15	30	15	30
Number of total trap days	1500/6000	3000/12000	210/840	420/1680
Number of personnel	1/4	1/4	1/1	1/1
Estimated labor hours, including field work and/or data reduction	216/864	432/1728	45/90	90/180
Labor/Equipment costs	$24K/91.5K	$48K/183K	$10K/27K	$13K/30K

Appendix D

BENEFITS OF CAMERA TRAP SYSTEMS

The following is a list of the benefits of using camera trap systems:

1. Ground squirrels readily visit feeding stations and do not appear to be hindered by the presence of the camera equipment.
2. Ground squirrels (e.g., MGS, AGS and RTGS) are easily distinguishable using camera trap systems;
3. Camera trapping provides a non-invasive method for effectively detecting species of interest and will work across a variety of animals.
4. Camera trapping provides detailed intraspecific and interspecific behavioral information.
5. Camera trapping does not require specialized knowledge or training to set up, collect data, maintain equipment, or reduce data.
6. Camera trapping provides a high level of certainty in the identification of ground squirrel species within the range of MGS.
7. There is no need for state permits to use equipment, (though if a species is federally listed, there might be a need for a federal permit).
8. Use of camera trapping reduces human presence and impact on the landscape compared to other survey methods (e.g., live-trapping) because it is based on infrequent visits to the field and smaller field crews are required to run and maintain camera trapping systems.
9. Data reduction time for motion detection camera systems is greatly reduced compared with conventional video surveillance systems that record continuously (Delaney et al. 1999, Delaney et al. in press). Animal presence only registers when in proximity to units, so in-between times are eliminated, which lessens data reduction time and costs.
10. Motion detection systems are cost effective compared with other surveying methods. It is estimated that it would have cost about $266K ($19K per trapping session) to live-trap 14 grids, versus $95K for this camera trap project, including equipment costs. Also, because the

motion detection equipment can be used over multiple years, the cost-benefit increases over subsequent years.

11. Field deployment, data extraction, and data reduction are relatively quick compared to conventional video surveillance which involves more components and separate power sources.
12. Self-contained motion detection systems, like the one tested for this project, have a very low energy draw compared with conventional video surveillance systems that use digital video cameras/recorders and require large solar panels in concert with a deep-cycle battery in order to run.
13. Equipment upkeep and maintenance in the field is minimal.
14. System provides general age (juvenile/adult) and sex (male/female) information depending on the quality of the image and type of view for each animal.
15. Camera trapping enables the detection of non-target species that may also be of interest to the resource managers, regulators, or researchers.
16. Camera trapping provides a relative inventory of potential predators of the subject species of interest;
17. Camera trapping enables the detection of multiple animals (age classes and sexes) simultaneously at the same feeding station or at multiple stations while taking into account time synchronicity.
18. In comparison with live-trapping surveys, camera traps have the ability to record multiple animals/species and multiple visitations per day, while live-trapping surveys are limited by the number of trap checks per day and usually only record one animal/trap during each trap check.
19. Camera trapping surveys are not directly limited by weather conditions (e.g., strong winds, hot or cold temperatures); however, indirectly, weather conditions may limit above-ground animal activity, which can influence the amount of data collected;
20. Camera trapping provides general temporal and spatial data on ground squirrel presence across the landscape.
21. Using camera traps to survey areas prior to conventional live-trapping may increase the cost effectiveness of live-trapping by concentrating trapping in areas where

specific animals have been detected through camera surveillance.

22. Squirrels readily revisit camera traps over subsequent trapping days.

Appendix E

LIMITATIONS OR CAVEATS IN USING CAMERA TRAPS

The following are either limitations or issues to be aware of when using camera trapping methods.

1. Personnel are unable to distinguish between individuals, other than by general age/sex categories, unless animals are individually marked/tagged during trapping surveys or have unique markings/molting pattern that can be differentiated readily.
2. Exact numbers of MGS cannot be determined, though multiple squirrels can be identified based on simultaneous visitations to different feeding stations and differences in pelage color/patterning.
3. Start-up costs can be low-moderate (Table C-2), depending on the type of motion detection systems purchased and the size of the area to be surveyed according to project objectives. In addition, costs can be offset by use over multiple years with one person running multiple systems across multiple locations.
4. Feeding stations may draw in potential food competitors or predators, though this can also be said for other survey methods (i.e., live-trapping).
5. Theft or vandalism of equipment is a possible concern, as is the case for other survey methods, but measures can be taken to reduce visibility and access to the equipment.
6. The field of view for motion detection systems can be more limited than video surveillance systems. It is important when setting up motion detection systems to take advantage of wildlife travel corridors, water resources, etc. to improve detection rates.

Appendix F

LESSONS LEARNED AND RECOMMENDATIONS

Lessons Learned

1. Feeding stations and survey equipment should be placed in the field for use at least 1-2 days (i.e., pre-baiting) prior to formal surveying to allow animals time to find the feeding stations.
2. Feeding stations and survey equipment should be left in the field to collect data for a minimum of 5 days to determine presence of animal species of interest.
3. An adequate amount of food should be placed at feeding stations to cover the time period of interest to the investigator (i.e., nocturnal, diurnal or 24 hr). Field data should be reviewed to determine if the amount of dispensed food is adequate to fully cover the time frame of interest.
4. It is important to consider the profile of camera traps, relative to surrounding vegetation, when placing equipment out onto the landscape to lessen the chance of theft or vandalism. In forested environments, cameras might need to be placed in elevated positions of 3-4.6 m (10-15 ft) up a tree to lessen the potential of equipment theft or vandalism.
5. Marking MGS using different shave patterns is an effective, non-invasive way to temporarily distinguish between individual MGS if live-trapping is done in concert with camera trapping. These squirrels have dark skin under their fur that stands out and is clearly identified by camera traps.
6. Review data files after a couple of days to confirm that the storage card size will be adequate to cover the amount of time that systems will be left alone.
7. It is important to determine the optimum number of camera traps necessary to adequately sample conventional trapping grids 840 x 105 m (~2756 x 344 ft)to compare detection rates between conventional trapping surveys and camera traps, as well as assess relative ground squirrel density estimates for standard grids.

Recommendations

1. Utilize camera traps to monitor thermoregulatory behavior through identification of above/below ground activity for fossorial species like MGS.
2. Recommend using camera systems to attempt to document MGS presence during periods outside conventional trapping periods (i.e., mid-late winter and early- to mid-summer).
3. Recommend dispensing food at feeding stations (or setting automated feeders to allocate early in the day) during early morning hours (if diurnal species) to get best daily coverage. It should not be assumed that animals will come back later in the day to feed if food is not available earlier in the day. Animals that are transitioning through an area might be missed if food is not dispensed early.
4. Additional surveys are needed to demonstrate that camera traps can effectively detect MGS presence across the species distributional range under varying field conditions.
5. Field test automated feeding devices to reduce labor costs (i.e., daily trips to fill bait stations due to nocturnal rodent activity) and reduce human presence across the landscape, especially within sensitive desert environments.
6. Camera traps could be used to test if pit tag readers can be used effectively to identify tagged animals that visit feeding stations or traps (without being captured).
7. Utilize motion detection systems to monitor how animals address traps and attempt to secure food without being captured. Camera systems may provide researchers ideas for how to improve catch-ability through changes in trap setup procedures.
8. Recommend using camera traps to survey large areas of suitable MGS habitat that cannot be economically surveyed using live-trapping techniques. Areas with MGS can then be surveyed to collect detailed morphometric and reproductive information.
9. Animal visitation rates to feeding or trap stations may vary based on the type of bait used. It is important that food preferences be tested to determine if there is an ideal food that should be used to bait animals to improve chances of catching or detecting them.

Appendix G

REFERENCES AND ABBREVIATIONS

References

Bell, K.C., and M.D. Matocq. 2010. Development and characterization of polymorphic microsatellite loci in the Mohave ground squirrel (*Xerospermophilus mohavensis*). *Conservation Genetics Resources* 2(1)197–199. doi 10.1007/s12686-010-9229-y.

Delaney, David, K., T.G. Grubb, P. Beier, L.L. Pater, and M.H. Reiser. 1999. Effects of helicopter noise on Mexican spotted owls. *Journal of Wildlife Management* 63:60-76.

Delaney, David, K., L.L. Pater, L.D. Carlile, E.W. Spadgenske, T.A. Beaty, R.H. Melton. In press. Response of red-cockaded woodpeckers to military training operations. *Wildlife Monographs*.

Hafner, D.J. 1992. Speciation and persistence of a contact zone in Mohave Desert ground squirrels, subgenus *erospermophilus*. *Journal of Mammalogy* 73:770-778.

Leitner, P. 2007. Mohave ground squirrel surveys at the Western Expansion Area of the National Training Center and Fort Irwin, California. Prepared for ITS Corporation, San Bernardino, CA, by California State University-Stanislaus, Endangered Species Recovery Program, Fresno, CA.

Leitner, P. 2008. Current status of the Mohave ground squirrel. *Transactions of the Western Section of the Wildlife Society* 44:11-29.

Leitner, P. 2009. Testing alternative methods for the detection of Mohave ground squirrels at the Western Expansion Area of the National Training Center and Fort Irwin, California: Part II trapping and vegetation surveys. Prepared for ERDC-CERL, Champaign, IL, by California State University-Stanislaus, Endangered Species Recovery Program, Fresno, CA.

Rowcliffe, J.M., J. Field, S.T. Turvey, and C. Carbone. 2008. Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology* 45:1228-1236.

Stewart, G.R. 2005. Petition to list the Mohave ground squirrel (*Spermophilus mohavensis*) as a federally endangered species. Defenders of Wildlife, Sacramento, CA.

Tobler, M.W., S.E. Carrillo-Percastegui, R. Leite Pitman, R. Mares, and G. Powell. 2008. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation* 11:169-178.

Abbreviations

AGS	antelope ground squirrel
BLM	Bureau of Land Management
COE	Corps of Engineers
CSU	California State University
DoD	Department of Defense
EAFB	Edwards Air Force Base
HQUSACE	Headquarters, United States Army Corps of Engineers
MGS	Mohave ground squirrel
NAWS	Naval Air Weapons Station (China Lake)
NASA	National Aeronautics and Space Administration
NTC	National Training Center (Fort Irwin, CA)
POC	point of contact
PWTB	Public Works Technical Bulletin
RTGS	round-tailed ground squirrels
URL	universal resource locator
USFWS	United States Fish and Wildlife Service
WBDG	Whole Building Design Guide
WEA	Western Expansion Area
WWW	World Wide Web