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Workshop to Improve Inter-Agency Cooperation and Collaboration for Managing Sustainable Populations of Mohave Ground Squirrels

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Workshop to Improve Inter-Agency Cooperation and Collaboration for Managing Sustainable Populations of Mohave Ground Squirrels

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1. BACKGROUND

The Mohave ground squirrel (MGS; *Xerospermophilus mohavensis*) is a small herbivorous endemic rodent found in desert-scrub habitat of the western Mojave Desert. This species is believed to have the smallest geographic range of any California ground squirrels, about 2 million hectares, of which approximately 34.5% is on DoD lands (i.e., Naval Air Weapons Station (NAWS) at China Lake, National Training Center on Fort Irwin, Edwards Air Force Base [EAFB]). The remaining MGS range is managed 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, Tehachapi, and Sierra Nevada Mountains to the south and west, and by Owens Lake and various small mountain ranges to the north (Fig. 1; Leitner 2008). 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. The primary threats to the MGS are habitat loss, fragmentation, and degradation from urbanization, agricultural development, military activities, energy development, roads, off-highway vehicle use, and livestock 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. It is important that facilitated workshops is conducted to help identify the most effective methods for detecting and monitoring MGS populations throughout its range. Improvements in conservation protocols for this species are needed in order to evaluate the effectiveness of management and regulatory actions.

Objectives

The objectives of this workshop were to: 1) improve inter-agency cooperation, collaboration, and understanding of various management and regulatory actions; 2) review and summarize the current literature for MGS and similar ground squirrel species; 3) bring together recognized experts on MGS and similar species and on relevant topic areas so there could be an exchange of ideas; 4) increase the standardization and quality of field data collection so more informed, adaptive management, and regulatory decisions can be made; 5) seek the input of workshop participants on how to enhance conservation efforts for MGS through improvements in field methodologies, protocols, and management strategies and to map a course to implement these ideas through a conservation strategy; 6) distribute information from the workshop to natural resource managers and regulatory personnel and other interested parties involved in the conservation of MGS through

website posting(s) (e.g., Mojave Desert Ecosystem Program [MDEP], Desert Manager's Group [DMG]); 7) provide a base from which other future discussions, meetings, and information exchanges will happen; and 8) develop a technical report that discusses the viewpoints of workshop participants on how best to standardize field protocols to survey and detect MGS and to monitor population trends, and a number of other topic areas.

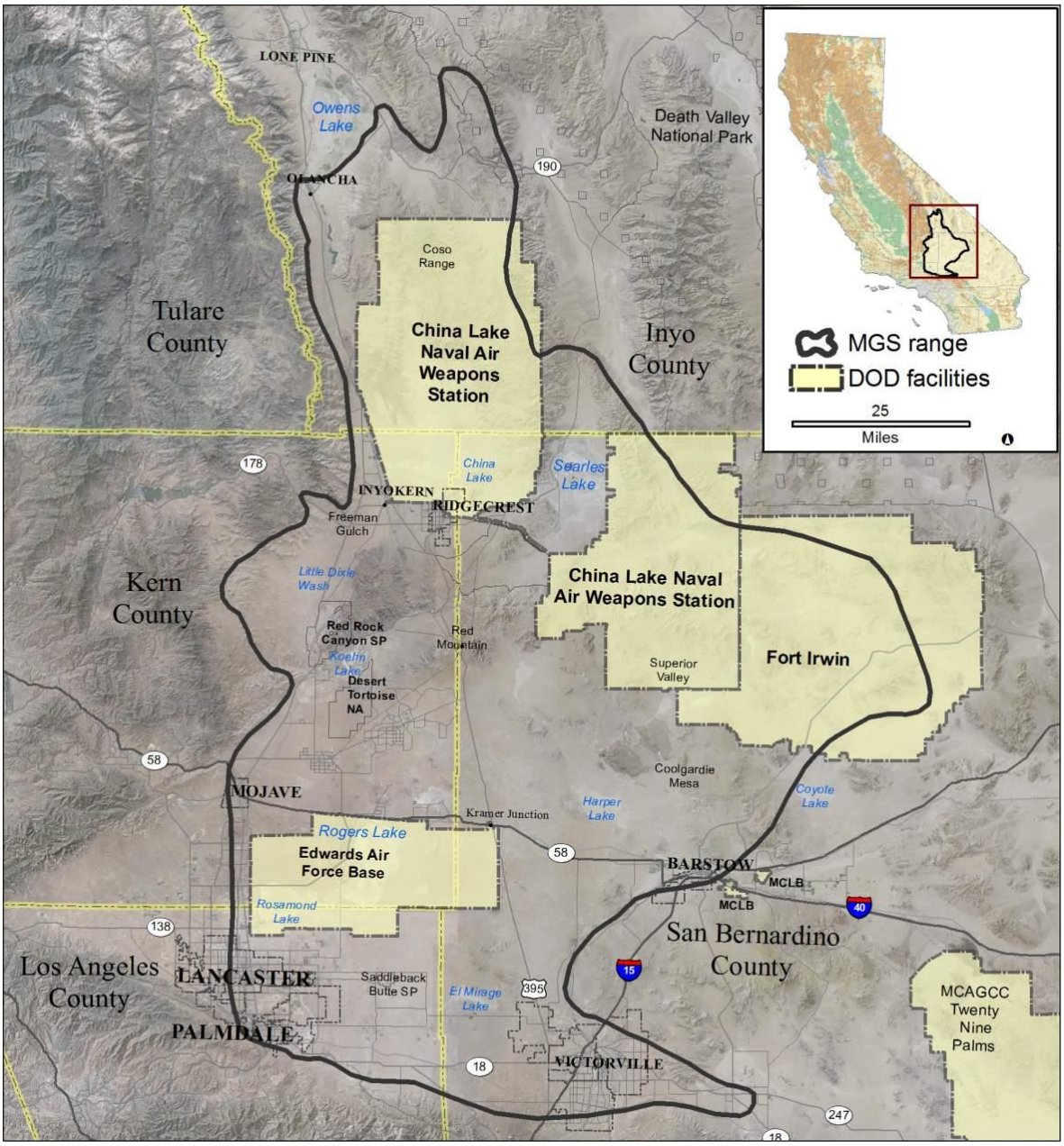

Figure 1. Map showing the boundary of the Mohave ground squirrel's range within the western Mojave Desert (ESRP 2010).

2. DAY 1

The Mohave ground squirrel workshop was held at the Mojave National Preserve Office in Barstow, CA on July 24-27, 2012. The first half day of the MGS workshop provided workshop participants with background material on MGS, Washington ground squirrel (WGS), and southern Idaho ground squirrel (SIGS) as a way to provide everyone with a good base of knowledge for our upcoming discussions during the workshop. Dr. Leitner, from California State University, Stanislaus and the Endangered Species Recovery Program, started the workshop with two presentations that provided background information on MGS life history, home range, distribution, and geographic connectivity. Mr. Mach (with the Oregon Military Department), a Natural Resource Specialist working on the Naval Weapon Systems Training Center, Boardman in Oregon, followed by providing an overview of the Washington ground squirrel's (WGS; (*Urocitellus washingtoni*) life history traits that showed some similarities to MGS, and providing insight into WGS issues they are dealing with on base. Dr. Yensen, from the College of Idaho, spoke about his work on southern Idaho ground squirrels (SIGS; *Urocitellus brunneus endemicus*) and compared the life history of SIGS with MGS. Dr. Matocq, from the University of Nevada, Reno, spoke next about her work with genetic variation in MGS. Her research showed patterns of connectivity between MGS populations, and identifies three genetic groups (north, central, and south) within the MGS range, based on strong separation in MtDNA. Ms. Hogan, who works for the U.S. Fish and Wildlife Service and works closely with the Desert Renewable Energy Conservation Plan (DRECP) Renewable Energy Action Team (REAT), provided an update on the DRECP alternatives, which will affect future renewable energy development projects and conservation within the western Mojave Desert. The final presentation of the day was given by Mr. Scofield, who works for the Bureau of Land Management and is the Co-Chair and Department of the Interior Representative of the Desert Manager's Group. He provided information on the political landscape affecting MGS.

3. DAY 2

The second day of the MGS Workshop started with two presentations by Dr. Reinke, a biologist with the Natural Resources Program on EAFB. Dr. Reinke described the installation's "soft footprint" approach for the development of large-scale solar energy on EAFB. He followed with descriptions of the ongoing Small Business Innovation Research (SBIR) Program-funded projects that are on the base. The installation has been very successful in getting SBIR grants awarded.

State/Federal Agency Discussion: Data Gaps and Agency Needs

State and Federal personnel made a number of suggestions/comments in relation to data gaps and agency needs during a round robin discussion:

1) How well do habitat models reflect animal distribution, abundance, occupancy rates, important linkages (i.e., USGS model, but also Penrod et al. {2012} for discussion on linkage network for California Deserts) between suitable habitat areas, quality versus marginal habitat, etc?
2) What constitutes good habitat and where is it located within the MGS range?
3) What size buffers are adequate/appropriate to protect MGS habitat? Are there areas that should be protected from any disturbance, that are in essence are unmitigable?
4) Need to outline what the ultimate goal is for habitat conservation.
5) What amount and location of preserve or other natural habitat needed to preserve the species for the long-term (including effects of climate change)?
6) Need to assess habitat quality from a squirrel's point of view based on important biologically meaningful variables.
7) What are the pluses and minuses to acquiring mitigation lands?
8) Why is the range of MGS so restricted and their population size limited, given the high dispersal rate, relatively low competition with other squirrels, and its generalist-type nature?
9) There is a need to better understand MGS nutrition. What are their food preferences and how does nutrition influence MGS dormancy?
10) Need for robust statistically-based survey approaches/protocols.
11) Long-term data are needed on range wide distribution and population trend data for MGS populations.
12) Importance of connectivity between populations of MGS; need for better understanding of how many linkages are necessary, where should linkages be located, how large should linkages be to be effective?
13) What linkage areas are crucial to the species for its long-term survival?
14) What constitutes a viable MGS population?
15) Need to define what constitutes a core MGS population with boundaries that are acceptable to the MGS community. How many core populations are needed to recover the species?
16) What are the limiting factors impacting MGS population growth and sustainability?
17) Need density estimates on MGS populations throughout their range.
18) Need to know where populations are located and at what density.
19) Need to better understand of the relationship of MGS population density across different habitat types.
20) Are invasive species an issue for MGS?

21) Need to share information.
22) Need to collaborate/cooperate more effectively.
23) Need for greater resolution on genetics.
24) Need more information on mortality factors versus reproductive effects.
25) Policy and land planning decisions are being made ahead of the science.
26) How does development around military installations affect MGS populations on base?
27) Information is needed on how to conduct a demographic study on MGS, and understand how demographics are tied to habitat use.
28) Need for more work on MGS burrows, especially through an improved understanding of burrow configuration, artificial burrow construction, and burrow use.
29) Need to look into alternative funding opportunities to conduct MGS work on military lands.

Participant List of Prioritized Needs

Workshop participants then rated the different topic areas of data gaps based on what they thought was the most important to least important as listed below.

1) Range wide distribution/population trend data for specific areas throughout the MGS range.
2) Demographic data
3) Identification of habitat characteristics associated with MGS density.
4) Statistically robust survey protocols based on needs
5) Amount and type/configuration of habitat needed for the long-term sustainability of MGS populations
6) Resolution of MGS genetics
7) Nutrition/diet studies to help define habitat requirements
8) Clarification of factors limiting the growth of MGS populations
9) Identification of what constitutes a viable or core MGS population
10) Clear, valid models that represent the reality on the landscape
11) How to address data calls when there is limited information
12) Focus efforts on geographic gap areas
13) Population viability study

Field Surveys Techniques and Protocols

The purpose of this session was to provide workshop participants an overview and real-world examples of the types of field techniques/technology and protocols being used to survey for MGS. Dr. Leitner provided an overview of MGS live-trapping in the western Mojave Desert, as well as examples from his long-term survey work in the Coso Range. Mr. Delaney followed with an overview of the direct-funded U.S. Army CERL project that he and Dr. Leitner worked on that compared the effectiveness of live-trapping with camera trapping within the Western Expansion Area on Fort Irwin in 2009-2010. He continued by describing their current follow-on camera trap project funded in 2011-2012 by Fort Irwin and the California Department of Fish and Wildlife (CDFW), in which they are surveying for MGS using camera traps at random sites ranging from Ridgecrest to Lucerne Valley.

Mary Kotschwar, from the Desert Tortoise Preserve Committee, presented some recent data her organization collected at the Desert Tortoise Research Natural Area near California City, while surveying for MGS using direct and auditory observation. She also described some preliminary estimates on occupancy and detection probability based on their work.

CDFW Survey Protocol: overview and discussion of possible ways to revise

Scott Osborn, the statewide Coordinator for small mammal conservation for the California Department of Fish and Wildlife, presented an overview on the state's MGS survey protocol. The purpose of the CDFW MGS live-trapping protocol is to determine if the MGS is present in the proposed project area. To implement the survey proposal, the CDFW issues state permits to trained biologists to conduct pre-project surveys for projects (<180 ac, and to linear projects 5 mi long) that would remove or degrade habitat. Biologists need to be permitted to handle MGS. The current established CDFW MGS protocol specifies: 1) conduct visual surveys between Mar 15 – Apr 15 prior to live-trapping; 2) use 100 traps in either a 4 x 25 or 10 x 10 grid pattern, with 35 m spacing between traps; 3) traps should be placed within the best habitat on-site; 4) survey reports are reviewed by CDFW staff; 5) during diurnal hours traps will have shade covers and biologists should avoid putting out traps during inclement weather and when temperatures are too high; 6) three trapping sessions of 5 days each should be held per season, or until the 1st MGS detection - Session 1: between Mar 15 to Apr 15; Session 2 - at least 2 weeks between May 1-31; and Session 3: at least 2 weeks later, Jun 15 to July 15.

There are a number of limitations with the current CDFW trapping protocol, namely: 1) negative survey data is only valid for 1 year. This can be problematic for developers, but does provide important year-to-year variation in presence data; 2) the expense of conducting live-trapping surveys may encourage project proponents to assume MGS presence and go straight into permit application and associated MGS mitigation, which reduces the amount of data being collected on MGS distribution; 3) results are not statistically based, therefore it is not possible to conduct a detection probability analysis on the results; 4) data need to be updated on a regular basis, which can prove difficult if funding/willingness is not there; 5) currently there is no provision for the use of camera traps within the CDFW trapping protocol, but this technology/technique could be used on a case-by-case basis; and 6) there is an assumption that all sites within the MGS' range are occupied and thus require surveys.

Workshop participants suggested the following ways to improve the CAFW trapping protocol: 1) make requirements specific to geographic areas where the data were collected; 2) make mitigation standard; 3) require more trapping beyond 1st MGS detection to improve our base knowledge on MGS distribution and population trend data; 4) understand the significance of the impact and if it can be fully mitigated for, *e.g.*, quality of the mitigation land may not be good enough to account for the loss, or do not know the importance of the loss (both habitat and number of MGS); 5) incorporate camera trapping into survey protocol trapping, either partially or fully depending on the location (camera trap use is limited by the threat of theft or vandalism in areas with high human use); 6) allow negative results to be good for 2 years or more during drought years; 7) trapping results should be driven by weather/drought, such that there must be adequate precipitation during biologically important times of the year (*i.e.*, winter) for there to be valid data, otherwise development cannot occur or would automatically require full mitigation; 8) assess habitat impact, treat models as hypotheses that needs to be validated through intensive surveying; 9) ensure grid design (*i.e.*, grid size and trap spacing and configuration) has a strong statistical basis for validation; 10) change purpose of protocol trapping from just detection to significance of population; 11) base protocol trapping on female home range; 12) specify most effective trap type (Tomahawk versus Sherman); may need to systematically compare trap types to determine this; 13) specify the most efficient bait type; may need to systematically test different types of bait first to determine this; 14) specify that taking tissue samples is required when live-trapping; 15) consider requiring the collection of demographic and habitat data to better assess project impacts; 16) consider collecting the types of data listed in Brooks and Matchett (2002); and 17) include negative data in the MGS database on survey location data.

Survey Efforts on Fort Irwin

Ms. Liana Aker, the lead wildlife biologist on Fort Irwin, provided an overview of their current and future MGS survey program. She stressed that they do not have a fully structured survey and monitoring program for MGS, but are using existing data and reestablishing species presence on the installation. She mentioned that they are using camera traps to document the presence of a number of species of interest on base, and are interested in expanding the work. The USGS recently donated some professional grade weather stations that they will use in conjuction with their trapping efforts. Both U.S. Army CERL and California State University, Stanislaus are assisting Fort Irwin with their MGS program.

Occupancy Models

Dr. Roemer, a professor at New Mexico State University, provided an overview of occupancy modeling. He emphasized the importance of incorporating covariate analysis in occupancy models to better understand factors that affect animal presence at each site. He provided some examples (Fig. 2) of covariates and subcategories within each covariate that might be important for understanding detection probability, occupancy rates, and demographic information. Important covariates can include weather (temperature, annual rain fall, wind), soils (e.g., structure, depth, rock, slope), vegetation (e.g., structure, seed bank, species composition, annual vs. perennial), time (e.g., time of day, season, phenology).

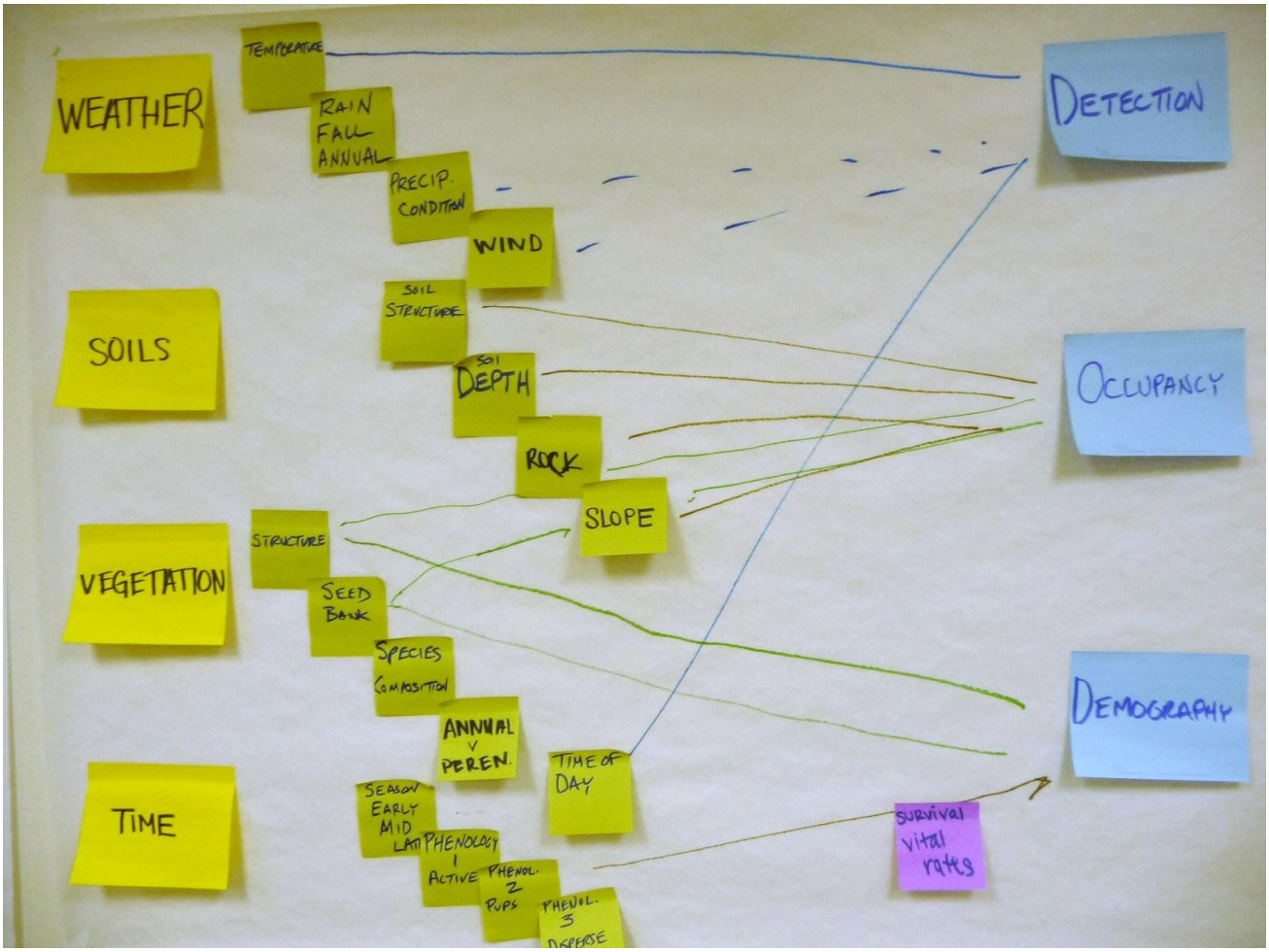

Figure 2. Examples of covariates and subcategories of variables that could be used in occupancy models.

Kit Fox Study

Dr. Roemer presented some of his work on kit fox on White Sands National Monument, NM from 2011-2012. He was studying kit fox occupancy, population dynamics, distribution, and abundance. His group addressed occupancy before investigating population dynamics. They also studied the general mesocarnivore community to assess the impact of carnivores on the ecosystem and the ecological role of carnivores. The study objectives were to document carnivore distribution patterns and measure ecological covariates. Some of the main covariates they investigated were prey abundance (e.g., rabbits), predator distribution (e.g., coyotes, which can kill foxes), environmental temperatures (kit foxes adapt to extreme temperature regimes better than coyotes), and bait type. They subdivided the study area into different habitat types and located random camera sites based on the proportion of habitat types and home range of kit foxes. Cameras were moved for different sampling sessions.

Matrix of MGS Survey Techniques

A number of different tools/techniques have been used to survey and monitor for the presence of MGS (Table 1). It is important for resource managers/researchers to understand the potential benefits and limitations of these survey techniques before deciding which technique is best for the land they manage or their research project. Table 1 provides a list of important distinguishing factors that people should consider as they decide which survey method(s) to use for their specific need/application. The ratings and the importance of the variables listed in Table 1 are subjective, and depend greatly on a number of factors, such as research/management question, funding level, experience, permit status, etc.

Determination of Rangewide Distribution

Discussion on this topic was primarily based on detection for distribution purposes. Participants discussed the importance of having the appropriate grid size, sample size, and sample technique based on the specific research question being asked. A range-wide sampling framework was suggested that would be made up of 10 x 10 km sampling units. Participants stressed the importance of prioritizing or randomizing within such a range-wide sampling grid, while taking into account where and when areas had already been sampled. It is not only important to fill in data gaps for areas that have never been sampled, but to collect information in areas that have not been sampled recently. Participants agreed that it is important to do occupancy analysis on the existing presence data that

have been collected (i.e., Edwards AFB and the Delaney and Leitner camera data). It was also pointed out that habitat modeling and occupancy estimates may help to identify those areas that should be sampled using more detailed demographic protocols. Edwards AFB has very detailed MGS presence data, and is interested in collecting demographic data on its MGS population.

Population Estimates and Habitat Quality

Workshop participants suggested the following ways to improve population estimates and habitat quality data, namely: 1) multi-year studies need to follow detection studies; 2) data need to be collected through a series of wet and dry years; 3) determine what factors (e.g., weather, vegetation, predation, etc.) drive distribution patterns (i.e., why are MGS found in some areas, but not others); 4) for demographic data, separate 5-day grid trapping sessions by 2 weeks throughout the active season to get all offspring and family lineage information; 5) collect more genetic information to better understand how MGS populations are linked; 6) need to conduct population viability analysis using grid-based mark-recapture study timed just before aestivation; 7) need to collect survival rate data by marking immigrants and emigrants within populations; 8) estimate population density using a closed-population model, e.g., estimate how many total marked individuals there are based on recaptures; 9) use individual fecundity estimates to estimate reproduction in a population; and 10) use survival and fertility rates to investigate population dynamics. A number of additional variables were identified as important when investigating population dynamics, such as: a) survival and fertility; b) use of a 2-stage model which measures the number of juveniles and adults at time t; c) measure of fecundity by calculating female annual survivorship x mean number of pups/litter; d) the annual survival of juveniles and adults determined by using a matrix; e) population size estimated at t + 1; and f) parameters factored in that are important for MGS survival, such as precipitation, vegetation, etc. A grid size of 500 x 500 m with 25 m spacing was suggested for population estimation and to assess habitat quality, though subdividing to subgrids to get the best data for parameter estimates was also suggested.

Table 1. Qualitative and quantitative matrix of variables for different surveying methods used for monitoring the presence of Mohave ground squirrels in the Mojave Desert, CA.

Variables	**Live trapping**	**Camera trapping**	**Audio surveillance**	**Visual surveillance**	**Track plates**
Quantity of data	Limited	Very large	Moderate	Low-moderate	Low-moderate
Quality of data	Very high	Very high	Moderate	Very high	Fair-poor
Possible number of MGS detections per day	Low-moderate	Low-high	Low-moderate	Low-moderate	Low-moderate
Chance that earlier data are compromised by more recent data	No	No	Unlikely, but possible masking by other sounds at the time of recording	No	Possible
Permits required	Yes	No	No	No	No
Environmental impacts on trapping success	High	Limited	Limited	Limited	Possible
Potential impact on MGS health/behavior	Moderate/high	Minor	Minor	Minor/moderate	Minor
Potential for disease transmission	High	None	None	None	None
Ability to individually identify squirrels	Yes	Limited	Limited	Limited	Limited
Data adequate to establish density estimates	Possible	Possible	Possible	Possible	Unlikely
Data adequate to establish occupancy rates	Possible	Possible	Possible	Possible	Unlikely
Time to setup/monitor/operate equipment	Fast-slow	Moderate	Moderate	Fast	Moderate
Time to reduce data	Fast	Moderate-long	Moderate-long	Fast	Moderate
Repeatability of results	Likely	Likely	Likely	Likely	Unknown
Ability to collect genetic samples	Yes	No	No	No	No

Table 1. cont.

Detection of non-target species/ social interactions	Likely/very limited	High/high	High/possible	High/possible	Likely/very limited
Threat of theft/vandalism	Possible	Possible	Possible	Possible	Unlikely
Cost	Expensive	Moderate	Expensive	Low-moderate	Moderate
Data collection in areas with reduced access	Limited	Few restrictions	Few restrictions	Limited	Limited
Consistency of data output	Moderate-high	High	Moderate-high	Moderate-high	Low
Ability to determine exact timing and duration of detections	Limited	High	High	High	Limited
Ability to document morphometric data	High	Not possible	Not possible	Limited	Limited
Confidence in target species identification	High	High	Moderate	High	Limited
Ability to draw in potential predators	Yes	Yes	Unlikely	Unlikely	Yes
Habituation of target animals to detection method possible	Yes	Yes	Not likely	Not likely	Yes
Distinguishes animal species	Yes	Yes	Likely	Yes	Possible
Technique requires specialized training/knowledge	Yes	No	Yes	No	Yes

4. DAY 3

Best Methods for MGS Detection

A number of different field techniques were discussed to detect MGS presence, including live-trapping, camera traps, auditory and visual surveys, track plates, and pit fall traps. Workshop participants discussed benefits and limitations for some of the more common field techniques that have been used in recent years (Table 1). Few studies have attempted to compare the detection rates between different techniques, though Delaney and Leitner (Delaney 2009, Leitner 2009) have collected some preliminary data comparing live-trapping with camera traps as part of a study within the Western Expansion Area on Fort Irwin in 2009-2010. These data suggest that camera traps are at least as effective as live-traps (Delaney 2009, Leitner 2009), but further analysis is needed before firm conclusions can be reached. The participants' discussion analyzed the different field techniques as follows:

Live-traps – Live-trapping is the predominant method for surveying MGS and other ground squirrel species in the western Mojave Desert. This method is known to be effective in detecting MGS presence, and is the only viable way to collect detailed morphometric and genetic data, but live-trapping can be costly and requires state permits. A variety of live-traps have been used for ground squirrels, including Tomahawk, Pymatuning, and Sherman traps. It does not appear that trapping success varies based on the trap type used, but there has not been a study done to specifically address this question relative to MGS survey use.

Camera traps - Workshop participants agreed that camera trap technology appears to be an effective, non-invasive method for detecting ground squirrel presence. In addition to randomly placing camera traps on the landscape to detect MGS presence, it was suggested that camera traps could be used to monitor animal behavior and collect demographic data at natal burrows. Further investigation is needed to determine what the optimal number of camera traps/grid is and what the best placement configuration is for this technology. Camera traps should be effective for determining occupancy rates.

Auditory/Visual Surveys – Auditory and visual surveys have been shown to be effective in detecting MGS and other ground squirrel species. These techniques can be cost effective for surveying small to moderate sized areas, although cryptic behavior of MGS sometimes makes auditory or visual detection problematic.

Track plates – Track plates have been used to a limited degree to detect MGS. There is a question as to the overall accuracy and consistency of this technique for identifying ground squirrels, especially between different species and age classes (but see Table 1 for more details). There does not appear to be any interest across land management agencies for the wide use of this technique.

Use of canines – The use of canines to detect MGS and other ground squirrels has had limited use (Leitner 2009). Canines can be trained to detect MGS presence, but at times it can be difficult to interpret their signals. In particular, it can be uncertain as to how long ago the target animal was present. This technique could possibly be used as an initial screening tool to locate areas that may be occupied by MGS, followed by use of live-trapping or cameras as confirmation. Researchers might want to also consider placing acoustic and/or video recording equipment on search dogs. Canine detectors could possibly be used to find MGS scat for genetic analysis, as it has for other desert species like desert tortoise (Clark and Heaton 2006), but more testing needs to be done, especially because of concern that canines may attract potential predators.

Sampling Design

The participants discussed an interest in establishing a range-wide sampling design that has consistent protocols across the range. The size of the sampling frame would depend on the areas of interest. Large sampling frames (e.g., 10 x 10 km) could be used to survey larger areas. The sampling frames could be based on UTM coordinates to make it easier to randomly subdivide larger sampling blocks into smaller areas. An advantage of this method is that it would allow for a comparison of detection data across the range and would make it easier to monitor ongoing/future survey work on MGS based on the same grid pattern. Use of a universal grid pattern would assist land managers/ researchers in identifying priority areas for sampling or for possible development, or where survey work has not been done, while also possibly helping to prioritize potentially suitable habitat. To date, most of the live-trap sampling for MGS presence has occurred in relation to project clearance surveys. Management/ research based sampling for MGS has occurred on Edwards AFB (Dan Reinke, pers. comm.), Fort Irwin (Liana Aker, pers. comm.; Delaney {2009}, Leitner {2009}), within the Coso Range (Leitner 1980), and at a number of random locations throughout the western Mojave Desert (Delaney and Leitner, pers. comm.). It is important to also resample areas with historic MGS records to update the status of the species in these areas.

Model Covariates

The United States Geological Survey (USGS) developed a habitat suitablility model based on occurrence data from 440 data points, all these occurances since 1975. The workshop participants were very interested in this model, particularly when it would be available to the public, and what variables were used in creaing the model. No one from the USGS that worked on the model was present, but Dr. Leitner, who collaborated on the project, provided some background material. The USGS used multiple Maxent models with custom layers for 14 environmental variables to model the data. Some of the model variables used in the USGS model included surface texture, surface albedo, precipitation, and winter climatic water deficit. Winter climatic water deficit was found to be the biggest predictor of MGS habitat suitability, while vegetation was not used because it could not project habitat suitability into the future under climate change scenarios. It was pointed out that the vegetation layers that were available for use by the USGS are not fine-scale or up-to-date. Todd Keeler-Wolfe, and others from the CDFW, are working on collecting additional vegetation plot data which should help to improve habitat information within much of the MGS range.

Workshop participants discussed model covariates that could influence detection, occupancy, demography, and habitat suitability for predicting MGS presence. They identified a number of variables that can impact the detection rate of MGS, including timing during the active season and time of day. Identifying the seasonal period and time of day when detection probability is the highest should be helpful in making future surveys more effective. Other important variables are weather (temperature, rain, wind, etc.), soil temperature, presence of predators (e.g., ravens, kit fox, badgers), bait type, and trap type. For determining occupancy rates, factors such as soil depth and texture, surface texture (e.g., rock, sandy soil, etc.), slope, and seed bank, could greatly influence model predictive power.

Capture and Survival Probability

Dr. Roemer presented some of his work on the banner-tailed kangaroo rat in the Chihuahuan Desert of New Mexico from 2004-2007. The study objective was to evaluate whether environmental drivers affect the survival of the banner-tailed kangaroo rat. They examined 15 environmental variables as possible drivers of kangaroo rat survival (e.g., precipitation, land surface temperature, vegetation, dew point, density, percent scrub cover, habitat saturation). They found that summer, diurnal land surface temperatures were the most important driver, and was negatively correlated with

banner-tailed kangaroo rat survival. The point of the study was to use models of factors influencing survival to determine probability of survival, and thus probability of recapture.

Statistical Analysis

Participants briefly discussed the importance of sample size, sample timing, and sample period when it comes to documenting variation in MGS populations across years. For example, factors such as weather and fecundity will greatly influence how stable populations are, and how long they can persist in a specific area or across a larger region. It was pointed out that few land managers within the western Mojave Desert have a good understanding of where MGS occur on their lands. However, EAFB does have good information on the spatial occurance of MGS populations on base. This installation is well-positioned to investigate habitat associations with MGS presence/occupancy data by comparing areas with and without MGS presence.

Conservation Strategies

Workshop participants started by listing some other conservation strategy examples, such as the Flat-tailed Horned Lizard Management Strategy for minimizing habitat loss and the BLM conservation strategy which was incorporated into the West Mojave Plan. The Desert Managers Group has sponsored the development of an MGS Conservation Strategy Plan. Previous editions of this conservation plan were incorporated into the most recent version. It is important that this Conservation Strategy Plan be incorporated into the Desert Renewable Energy Conservation Plan (DRECP). The BLM is also working on a set of rules for maintaining, altering, or expanding conservation allocations across the western Mojave Desert. It is important that any conservation strategy incorporative adaptive management of the resource and identify areas that are critical for MGS recovery. Participants discussed the function of a conservation strategy and how it compared with a recovery plan. An effective conservation strategy should provide adequate conservation measures so that federal listing of a species is not necessary. There was interest from the group in reestablishment of the MGS Working Group and associated information resources. The group determined it is important that the conservation strategy be updated as more information becomes available, in order to be effective long-term.

Participants discussed the importance of developing recovery goals for the MGS that would remove this species from listing under the California Endangered Species Act (CESA) list and preclude federal listing as well. Participants raised several questions associated with recovery goals

for the MGS, namely: 1) what conservation measures would meet both goals of removing the species from CESA and precluding federal listing; 2) what should the delisting criteria be for this species; 3) how many core populations are necessary to recover this species and where are they located; 4) how stable is the population, which expresses the need for population trend data; 5) what actions are necessary to sustain the population; 6) how best to monitor the species and determine the population trend/trajectory over time; 7) what are the opportunities for conservation; 8) how best to restore MGS habitat; and 9) how best to conserve what remains.

Participants discussed the process of adopting a conservation strategy, namely: getting people involved that are interested, folding in the MGS Technical Advisory Group, and securing agency involvement for input, effective implementation, and development of conservation priorities. It is important that future research inform land management actions to benefit the MGS. A key component of conserving this species is identifying core areas and linkage areas and maintaining the connectivity between them. To provide for the long-term survival of the MGS, and to preclude the need for federal listing, there needs to be more research across a variety of life history topic areas for the species. The USFWS makes its listing determinations on the best available scientific information, but there are limitations on what is available. There is an important need for functional and effective groups working on the conservation strategy for this species and the need for tools to help focus needed research and improve ways to find new funding sources. Ms. Logsdon announced CDFW's plan to lead the update and completion of the current draft Conservation Strategy to fold into the DRECP, with the participation of the Desert Management Group, and an interagency working team was developed during the course of the workshop.

Map Review

Workshop participants reviewed maps showing MGS distribution and discussed which areas they thought were critical to conserve the species, which areas were desirable to conserve, and which areas need more research due to a lack of information on MGS occurance. The discussion included the terminology of "core area" where MGS are know to persist and "corridors" which represent occupied linkages where MGS may be moving currently and in the future, especially in response to climate change. The map also provided for discussions of known MGS populations, known areas of MGS concentration, and of MGS populations thought to be genetically connected. Participants discussed the effects of topography on occurrence and what factors that may create barriers for MGS movement. Areas were identified where participants thought more information was needed on MGS

populations (e.g., South of EAFB to El Mirage Valley, NAWS at China Lake, Fort Irwin, California City area north of EAFB, and the Kramer-Fremont Desert Wildlife Management Areas. It was suggested that the USGS habitat suitability model should be utilized to review prospective areas for MGS presence to help focus research questions and prioritize where work should be done.

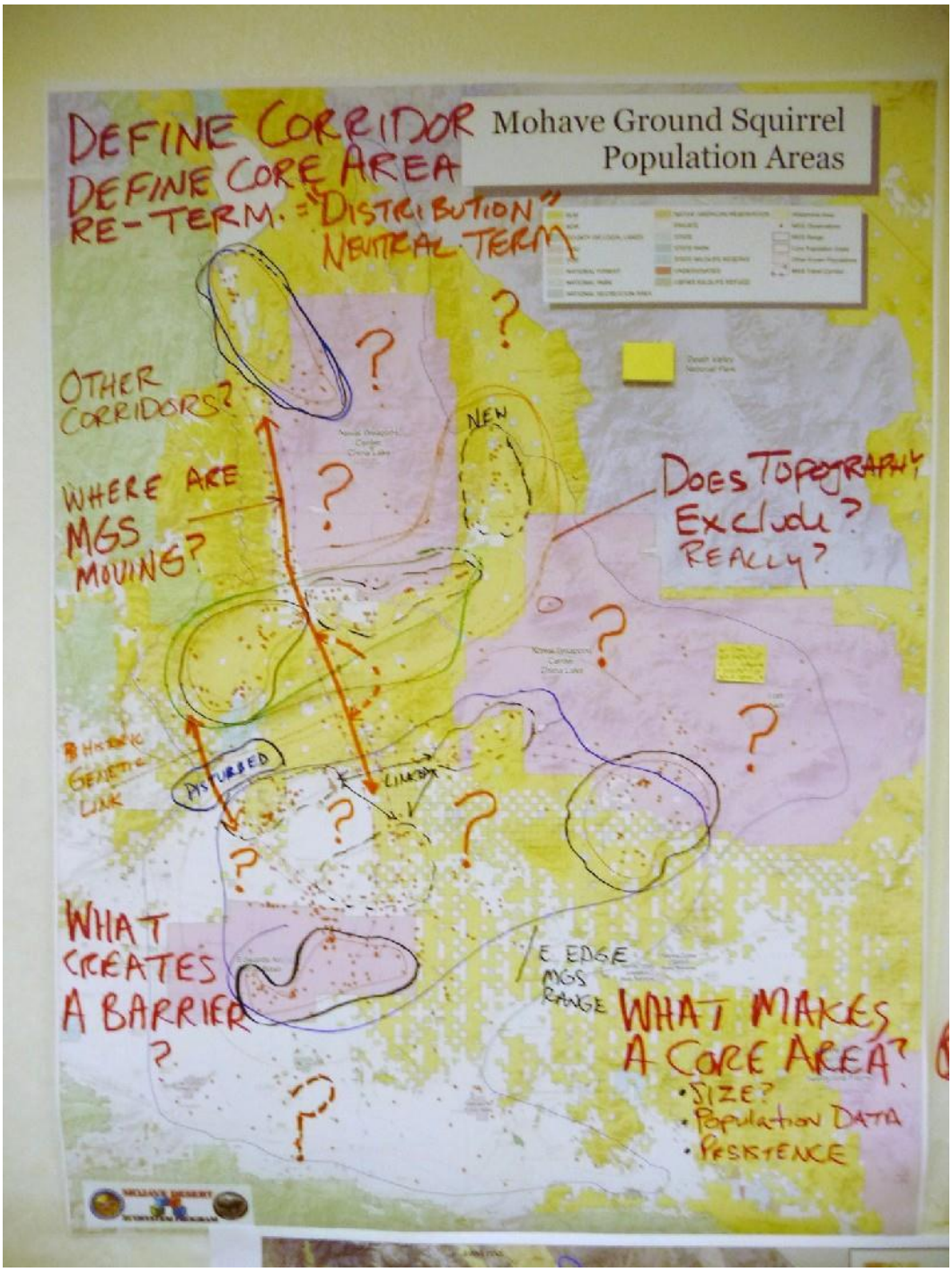

Figure 3. Distribution map of the Mohave ground squirrel. Participants used the map to discuss topics such as core area, corridors, and possible changes in distribution relative to climate change.

DRECP Maps

Ms. Hogan attended the DRECP REAT meeting in Ontario, CA the same week as the MGS workshop. She presented maps to workshop participants showing alternative locations (which will be analyzed under the California Environmental Quality Act) that might be reserved for the siting of renewable energy projects across the landscape of the western Mojave Desert development focus areas (DFA). It was explained that in addition to DFAs, the DRECP alternatives provide potential arrangements for a reserve design, with conservation priorities based on the level of biological sensitivity. The participants discussed that conservation of MGS should not be driven by potential development scenarios, but by the biology of the species. See http://www.drecp.org/ for more information.

Southern Idaho Ground Squirrel

Dr. Yensen presented overview material on northern Great Basin ecology, including how human use and ecological impacts have changed the landscape. He followed with a discussion of the life history of the southern subspecies of Idaho ground squirrel and identified the species as an important component of the local ecosystem. He then provided some detailed examples of his team's research, including studies of reproduction, survival, food abundance, burrow configuration and use, and population growth as components of a population viability model for the southern Idaho ground squirrel. He discussed how his work related to MGS diet studies and suggested that a similar population viability model could also be applied to MGS. He recommended trying to determine the historical conditions of the West Mojave Desert to better determine how MGS have adapted to changes on the landscape.

Climate Change

Participants discussed how climate predictions appear to show that the Mojave Desert will get hotter and drier in the future. The University of California, Los Angeles Climate Study Center is projecting that the number of "extreme heat events" in southern California will increase by 30-40% by mid-century (Hall et al. 2012). Some studies indicate that vegetation composition within the MGS range appear to be changing over time due to increasing temperatures. The group expressed concern that increasing temperature and decreasing precipitation in the Mojave Desert will particularly affect the growth and viability of certain plant species with Great Basin affinities, many of which are important MGS forage species. The MGS does not appear to be physiologically well-adapted to its

desert existence, but uses behavioral mechanisms as its primary adaptation. If overall temperatures rise and warmer conditions expand during the year, such changes could cause MGS to shift their daily and seasonal activity patterns. Based on their postulated climate envelope, it is likely that MGS will move to north in response to climate change.

5. DAY 4

Terminology Discussion

The group discussed the concept of "core areas" and its variety of definitions and criteria associated with it depending on the species being discussed. The concept of core areas is sound, but there appears to issues with its use, how it is applied, and the semantics of the phase. The use of certain terminology (e.g., core area, core population, and corridors) can cause difficulties in communication between resource managers/researchers and other stakeholder groups (*e.g.,* general public, contractors, business community, County Supervisors, etc.). It important that resource managers/researchers are aware that other stakeholder groups may have different perspectives on what specific terms mean and that this can lead to misinterpretation or confusion of the message that resource managers/researchers are trying to convey to the other groups. Two prime examples of terms for which there has been some confusion, include "core population/area" and "corridors". The concern about the use of these terms has to do with the restrictive use that some stakeholders have put on these terms based on their own impressions/biases. Some stakeholder groups have the impression that the terms core area and corridor only refer to specific areas on the landscape, and that the land areas covered by these terms do not change over time (*e.g.,* expansion or contraction) due to possible extrinsic or intrinsic factors such as drought, anthropogenic effects, climate change, etc.

Several participants at the MGS workshop expressed caution in the use of these terms when communicating with stakeholders because some stakeholder groups assume that the protection of some initial core areas identified by Leitner (2008) will be adequate to sustain MGS populations over the long-term. Leitner (2008) did not suggest that the core areas that were identified in his paper were the only such areas within the historic range of the MGS, but that those were the areas that met his definition at that time based on the available distribution data. Resource managers look to expert opinion and empirical data to help them identify important animal populations, but it important to understand that such information is not static, and that it should be considered more dynamic in

nature. It is important to identify and describe areas that will allow populations to expand, remain, and persist over time.

The group also expressed concerns that there is increasing pressure to identify important population areas and migration pathways that MGS use relative to the siting of renewable energy DFAs within the western Mojave Desert. It is important that all stakeholders groups recognize that additional "core" areas may be identified as new information on MGS distribution becomes available. There has been a substantial increase in the amount of data on MGS distribution since Leitner (2008) was published. Work is being done to update the historic/known distribution of MGS using newly available survey data (Leitner, pers. comm.). His definition of MGS core area was based on three factors that were generated from historic/current live-trapping data. It is important that resource managers, researchers, and others convene to discuss what the definition of "core area" means for the MGS and to agree on the criteria used to define such areas.

Concept of "Core Areas"

Participants thought that the concept of core area/population was sound, but that they are issues with how people use the term and a general lack of consistency with its use. It was suggested that the term "known" precede the word "core" so people do not emphasize core areas as the only areas that need protection. The group thought that persistence of a population over time and across one or more drought cycles was a good indictor of a core population. The group agreed that more areas need to be surveyed to better understand where populations occur across the landscape. It was suggested that populations that are genetically linked could be defined as a "core" area or "population center", without defining blocks of habitat. It is important to understand that populations expand when habitat is healthy, and can contract when habitat degrades. There need to be good descriptions of habitats where MGS populations have been found to expand, remain, and persist over time. The relationship between habitat characteristics and MGS presence, density, and reproductive fitness needs to be much better understood. With the growth of human population centers and activities within the western Mojave Desert, it is crucial that we are able to identify currently occupied areas that MGS populations may be capable of expanding into, especially when considering the effects of climate change on the MGS. It was suggested that instead of core populations that the term "source population" could be used. Associated with the earlier group discussion of climate change, it is anticipated, based on USGS and University of Nevada, Reno modeling efforts, that MGS will move in a more northerly direction in future years. The group brought up the question of how to address areas

without data, and how to determine additonal “source” areas, if new populations are detected after non-drought years (i.e, recolonization).

Concept of “Corridors”

As with “core population”, the participants were also concerned about how the term “corridor” has been misused as well. It was suggested that a better term might be linkage. Regardless of the term, the participants agreed that the concept and importance of conserving land for MGS to move between important population areas is crucial to the long-term survival and sustainability of this species. The group noted that there are different types of corridors depending on the linkage being discussed, such as genetic or demographic linkages. Detailed vegetation and habitat suitability models could indicate where demographic linkages could exist. The University of Nevada, Reno is working on a connectivity model for MGS based on the USGS habitat suitability model. The UNR model takes into account potential barriers (e.g., fallowed agriculture land in Fremont Valley, or developed areas in Indian Wells Valley), but it is not clear how permeable these barriers are to MGS movement. It is important to determine the best paths across the landscape for MGS in different parts of the range. Research on genetic linkages will be very helpful in identifying these important areas. The collaboration between volunteer trappers and researchers has provided tissue samples from MGS that will help ground-truth the UNR connectivity model and help with questions concerning potential hybridization between MGS and the closely-related round-tailed ground squirrels (*Xerospermophilus tereticaudus*). The BLM, South Coast Wildlands, and Northern Arizona University are also working on the topic of linkages, and have developed a linkage network for the California deserts (Penrod et al. 2012). It was pointed out that a modeled corridor is a planning mechanism, not a design. The model can show how landscape patterns affect species movements, which can be used for land use planning. However, whether or not a “corridor” is used as a linkage depends largely on habitat, and the discussion pointed out that habitat models need to be validated before a “corridor” model can be relied upon.

Translocation/Captive Breeding

Workshop participants discussed the concept and application of translocation/captive breeding programs in relation to MGS. There was agreement that in most cases the use of translocation/captive breeding programs should be a last resort, and not a substitute for real recovery actions. The majority of ground squirrel translocations have failed (E. Yensen, pers. comm.), emphasizing the need for

careful planning prior to any such attempt. The participants stressed the importance of having detailed information (sink/source population, territorialism of species of interest, habitat, genetics, etc.) about the potential translocation site prior to any action. They also discussed the importance of having detailed data on the receiving population and other important biological factors, such as predation pressure. Animals with a strong homing response have been documented to travel many miles in search of their original home territory, which exposes them to increased risk from predation and anthropogenic impacts outside of the project activity. Prior to any translocations, it is essential to clearly define how it will be determined if the translocation was successful and what data will be collected to evaluate success? It was pointed out that ground squirrels in general have not been propagated in captivity on a large scale. Some ground squirrels have been propagated for research purposes, but not for the purpose of recovering a population. More investigation is needed to determine what other ground squirrel species have been raised in captive breeding programs and how successful those programs were. It is important to take into account differences in life history characteristics between ground squirrel species when developing a captive breeding/release program. The participants agreed that it is important to collect information on existing translocation/captive breeding programs in case of catastrophic events that could force resource managers to consider such actions. Information on the success and failures from zoos would be helpful in developing a proof of concept MGS program. One major concern of captive breeding/release programs is the effect that these reintroduced animals have on the receiving population and the surrounding resources.

Improved Communication/Cooperation

The group discussed recent examples of cooperation within the MGS community, such as volunteer live-trapping surveys to collect genetic tissue samples for ongoing speciation research between MGS and round-tailed ground squirrels. Participants discussed the importance of collecting, analyzing, and reporting MGS data in a more uniform manner. The group discussed ways to improve communication within the MGS community, as well as how to distribute information to other groups using MGS web sites (DMG, MDEP, MGS Working Group, etc.). The discussion identified the importance of establishing ways to improve communication and more readily include other interested groups in the MGS community.

Post-Workshop Plan to Move Forward

Participants listed a number of actions they were interested in taking to move forward with the information discussed at the workshop, namely: 1) use information and discussion from the workshop as a springboard for future meetings/discussions; 2) establish additional working groups to address specific topic areas; 3) re-invigorate the Desert Manager's Group by reaching out to other groups/organizations (i.e., non-governmental organizations, consultants, biologists, academic scientists, etc.); 4) move forward with the parties involved in developing the MGS conservation strategy; 5) invent new pathways to get information out to other interested parties and get them more involved; and 6) establish new ways to improve and foster ongoing communication/collaboration among groups/individuals.

Post-Workshop Follow Up Topics

There were a number of topics/issues that participants were interested in following up on after the workshop:

1) Develop a draft summary report of the MGS workshop.
2) Submit a draft report to the DoD Legacy Program for their review (12/31/12).
3) Secure additional funds to analyze existing data MGS data (e.g., occupancy data analysis).
4) Work with desert counties to advocate the use of "soft foot prints" for energy/human development projects, MGS monitoring plans, BMPs, and CDFW policy.
5) Revise the MGS protocol trapping procedures (CDFW).
6) Invite the USGS authors of the MGS Habitat Suitability Model to the next MGS Technical Advisory Group meeting to present their work, as well as a CEC research briefing.
7) Develop a demographic protocol based on the best survey methodology to collect MGS demographic data. There is interest across multiple agencies, but EAFB is in position to mobilize data collection on this topic.
8) Develop the concept of "core area" and distributed to the group for input by 12/31/12.
9) Complete an update to the Leitner (2008) paper by 12/31/12.
10) Continue the process of organizing and coordinating the MGS conservation strategy efforts.
11) Learn about captive breeding program for MGS;
12) Educate the public through new exhibit on MGS at regional zoos.
12) Learn more about the CDFW's policy direction associated with MGS.

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APPENDIX A

Workshop Participants/Facilitation Team

Participant	Organization
Judy Hohman*	U.S. Fish and Wildlife Service
Bronwyn Hogan*	U.S. Fish and Wildlife Service
Scott Osborn*	California Department of Fish and Wildlife
Randi Logsdon	California Department of Fish and Wildlife
Becky Jones*	California Department of Fish and Wildlife
Lisa Gymer	California Department of Fish and Wildlife
Eric Weiss	California Department of Fish and Wildlife
Clarence Everly	Fort Irwin
Liana Aker*	Fort Irwin
David Delaney*	U.S. Army CERL
Danny Reinke	Edwards Air Force Base
Thomas Mull	Edwards Air Force Base
Fon Allan Duke*	MDEP, DoD Coordinator for DMG
Russell Scofield*	BLM, DoI Coordinator for DMG
Larry LaPre	Bureau of Land Management
Jeff Mach	Oregon Army National Guard/Military Department
William Vagt	Oregon Army National Guard/Military Department
Philip Leitner*	California State University at Stanislaus, ESRP
Eric Yensen	The College of Idaho
Jeff Aardahl	Defenders of Wildlife
Mary Logan	Desert Tortoise Preserve Committee
Marjorie Matocq	University of Nevada, Reno
Gary Roemer	New Mexico State University
Debra Hughson	National Park Service, Mojave National Preserve
Jim Nelson*	Nelson Facilitation
Soren Nelson	Workshop assistant
Julia Gonzales	Workshop assistant (CDFW)

* Planning Committee Members

Figure 1. Photograph of the participants of the DoD Legacy funded Mohave Ground Squirrel Workshop held at the Mojave National Preserve Office in Barstow, CA 24-27 July 2012.

APPENDIX B

Summary of Workshop Evaluation
Mohave Ground Squirrel Working Group
July 24-27, 2012

1. . Please tell us who you represent:
   Total evaluations: 21
   Military: 5
   Federal Agency: 6
   State Agency: 5
   Other: 5
   -Desert Tortoise Preserve Committee
   -NGO
   -Academia x3

2. In general the meeting was:
   Great: 14
   Very Good: 7
   Good: 0
   Fair: 0
   Poor: 0

3. Something I liked about this meeting was...
   - Facilitator kept on track and moving
   - Good discussion, density and distribution discussion
   - Participation of outside researchers. Presentations on new techniques – camera trapping.
   - Bringing in people from outside the MGS world, bringing in academia
   - Interest in data, models, and natural history
   - Weaving of non-MGS topics into the agenda. Good presentations by Eric, Gary and others – helped inspire the MGS-centric discussions
   - Learn what is happening in other states – ideas on how to improve protocols – modeling
   - The opportunity to coordinate and learn and feel confident about moving forward with being part of the group that conserves and recovers MGS
   - The wealth of knowledge out there and willing to share research work, genetic results, conservation thoughts – all very useful.
   - The length of time which stressed the focus to the species w/o being distracted w/ daily grind
   - Everyone's willingness to share so much information the facilitation that kept the meeting running so well and the extensive reading list sent out before the meeting
   - Outstanding facilitator and impressive participation by leading experts. Key was devoting time for active participation by all.
   - Collaboration and dedication by the participants, good people, good meeting
   - Participation
   - Energy, interaction, data sharing, new ideas. Facilitation!
   - The collection of attendees I thought was nearly perfect. I would have loved a bit more background and current approaches for WA ground squirrel but Eric Yensen was awesome w/ Idaho g.s.

- Very good folks – the right folks – the non-MGS folk helped – generated good life for new projects
- Expansion of knowledge related to professionals dedicated to MGS conservation. Ability to see future projects for EAFB.
- Participation by all members of the workshop.
- Great contributions from everyone – discussions provided ideas for future work
- Very interactive; passionate ecologists and land managers

4. Something that I think could have been improved is...
    - More lunches in
    - Too cold
    - Fewer acronyms. Less emphasis on DRECP
    - Temperature of the room. After first day not going around room asking what they got out of the day's discussion
    - Integration into planning
    - I wish I had done more of the pre-meeting reading, and that DFG generally was better prepared. How can you ensure prior preparation?
    - More on future needs for climate change
    - Not much – very well facilitated – got everything I had hoped for.
    - Keep room temp more moderate! In summer 75 lowest
    - Still need to keep the focus tight (although it was VERY good/tight) still might have resulted in more deliverables.
    - I think a little more time could have been spent developing the list of study covariates affecting detection and occupancy, but I appreciate the facilitator keeping things moving to cover all the topics.
    - None!
    - Hard to improve upon.
    - More goals to be set.
    - Well if I HAD to complain, things we couldn't do anything about: the presentation screen could have been bigger and the climate in the room w/ fluctuating temperature hot/cold.
    - Well done – not really.
    - Having CD available w/ data before meeting on presentations
    - Seasonal timing to afford a field trip
    - More info about fund – (just kidding!)
    - The meeting was very smooth – I don't think anything needed to be changed

5a. Do you see this workshop being a catalyst for future MGS meetings/discussions? If so, in what ways (in person, e-meetings, regular comm., etc.)? Involving what specific topics?

- Yes – DMG
- Communication down to the Technical Advisory Group. Use of camera trapping.
- Yes.
- Yes – e-meeting – regular communication
- I hope this will be a catalyst for MGS and basic biology of MGS, which is sorely needed to inform conservation decisions.
- Yes, e-meeting mostly. Conservation strategies, trapping protocols.
- Yes – helped launch conservation strategy

- Yes. As new info comes in would love to discuss results and implications.
- Certainly I think it will be a variety at forums. Processing existing data – modeling, policy reform etc.
- Yes! I foresee a lot of telephone and email conversations about data analysis and study design with several of the people here.
- Yes, mix of telecom/webex and occasionally in person as needed to allow for personal interactions
- Meetings like this are always beneficial.
- Yes, web and in person. Modeling and data analysis.
- Yes! In form appropriate to the need!
- I think the most important role of this meeting was to be a catalyst for participation and collaboration in general, in any form – be it future meetings and conference calls.
- Yes – in person cooperation
- Yes – following modeling / validation, demographic studies
- Yes. In all possible way. All pertinent topics
- Yes – good opportunities for future communications thru DMG and MGS TAG
- Yes; all of the above. Another meeting would be prudent after another round of data analysis.

5b. How often should a workshop such as this take place, if at all, in the future?

- Within the next year
- Every couple of years
- ~2 years
- After some demographic input
- This scale 1st every 2 years
- As needed, and it almost certainly will be needed again at some point
- 1 a year or as needed
- Every year or two
- Every 2 years or so
- Every other year
- Another year or so – maybe smaller groups on specific topics (i.e DFG survey protocol)
- Every few years we should all try to meet again
- If a stronger research and conservation effort can be started, the once per 5 yrs would be a good interval
- Once /year
- Perhaps in 5 yrs to see where we are. Future sooner workshops would focus on a particular topic.
- Every 5 years

6. Other comments:

- Really enjoyed Dave's organizing dinner together
- It would be good to have a group like this meet every four years to review how we are doing in our progress to conserve the species and recommendations on how to improve what we are doing
- I appreciate having a facilitator w/ a science background
- Would love to have a meeting that allows a field trip to see MGS
- Enjoyed your style of facilitation, Jim. I hope we meet again.

- Very good presentation provided new way for EAFB to more towards MGS conservation
- Far exceeded my expectations
- Thanks! A+ kudos to Dave for organizing the workshop and Jim's outstanding facilitation.
- Thanks for inviting me and allowing me to participate and contribute ideas.
- Thanks so much for everything
- Great info. Great ideas. Great discussions. Great facilitation.
- Sorry I missed the 2 middle days
- Still very hard to integrate military conservation with conservation on other federal lands and private lands.

APPENDIX

WORKSHOP PRESENTATIONS

IMPACT OF HABITAT DEGRADATION ON SOUTHERN IDAHO GROUND SQUIRREL (*Urocitellus endemicus*) DEMOGRAPHY

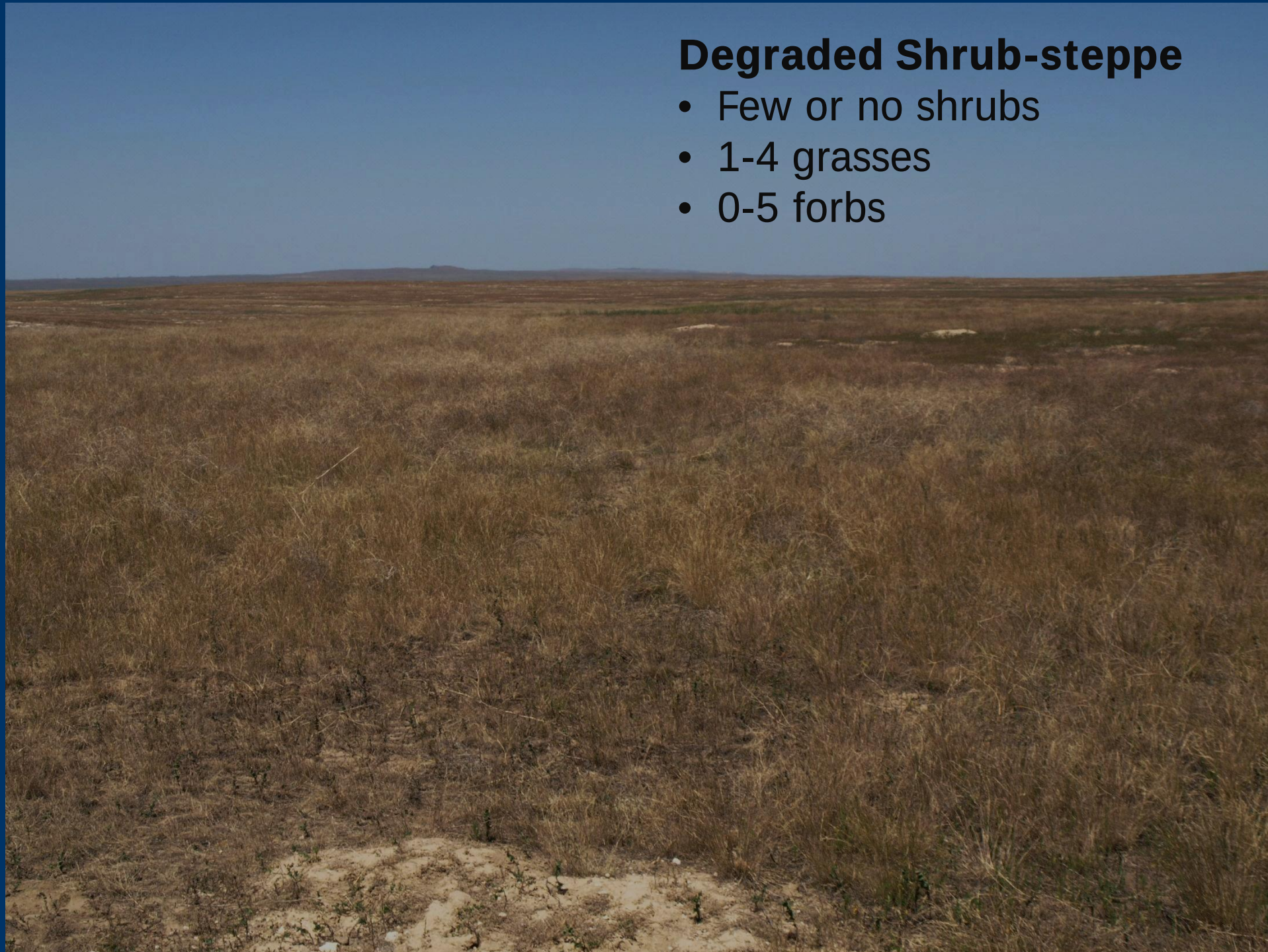
Justin S. Barrett[1,2], Eric Yensen[3], James Munger[1], and Teresa Tarifa[4]

[1]Department of Biological Science, Boise State University, 1910 University Drive, Boise, ID 83705, [2]Present address: Idaho Department of Fish and Game, 3316 16th St., Lewiston, ID 83501; [3]Department of Biology, The College of Idaho, 2112 Cleveland Blvd., Caldwell, ID 83605, and [4]Museum of Natural History, The College of Idaho, 2112 Cleveland Blvd., Caldwell, ID 83605.

Shrub-Steppe History

- Abusive grazing in 1870s-1880s
- Agricultural conversion of best sites; degradation of rest
- Invasive plant species replace natives
  - e.g., cheatgrass (*Bromus tectorum*), medusahead rye (*Taeniatherum capit-medusae*), various mustards, etc.
  - Nearly all invasives are annuals; natives are nearly all perennials.
- Alteration of ecosystem processes
  - Changes in fire cycles, nutrient cycling
  - Reduction in native species abundance, including keystone species and ecosystem engineers
- Negative effects on most native animals:
  - sage grouse, sage sparrows, sage thrashers, brewer's sparrows, pygmy rabbits, horned lizards, harvester ants, etc.

Pre-settlement Shrub-Steppe
• Open-canopy shrub overstory
• 6-8 spp. perennial bunchgrasses
• 20-30 spp. forbs

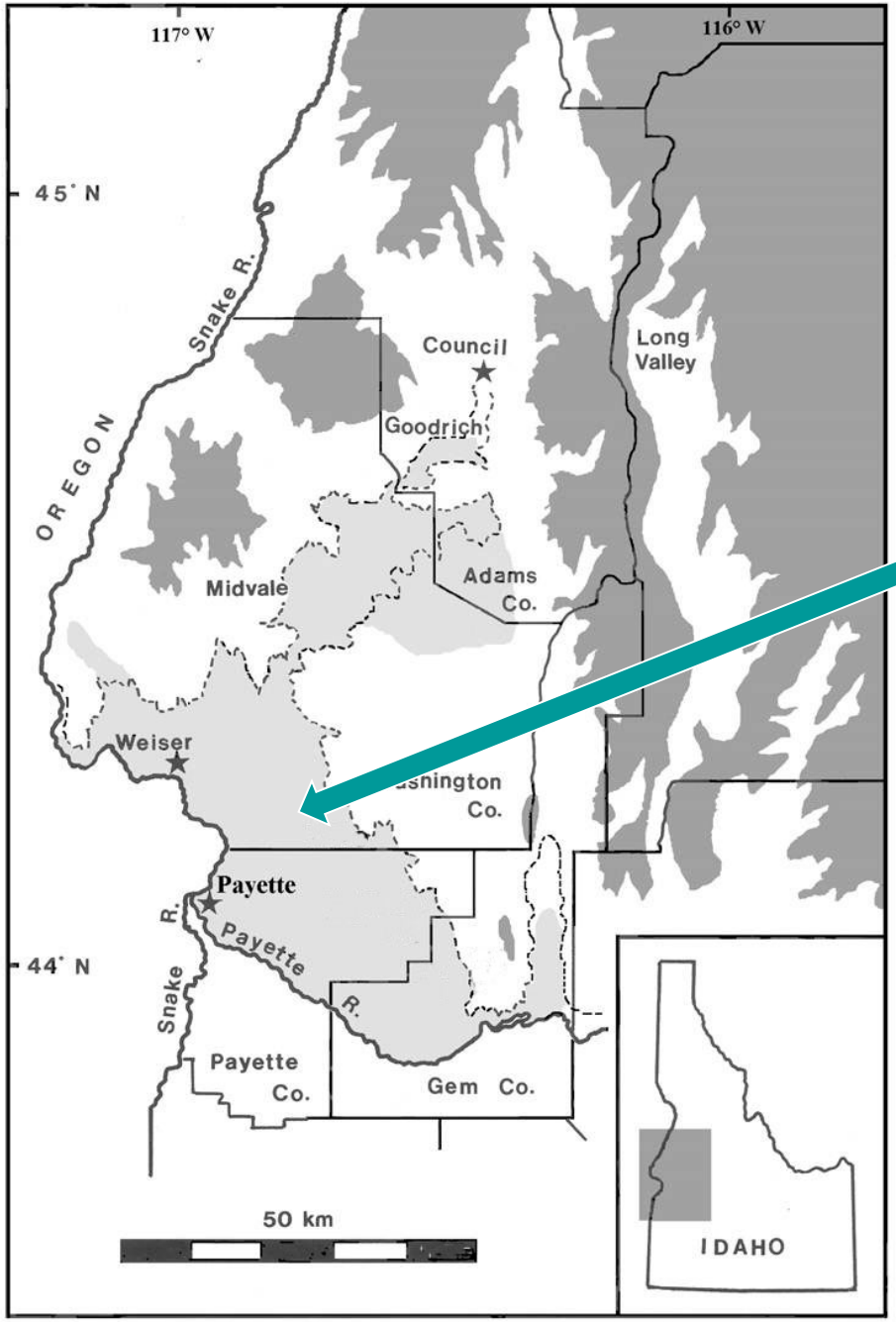

Degraded Shrub-steppe
• Few or no shrubs
• 1-4 grasses
• 0-5 forbs

Cheatgrass
Bromus tectorum

medusahead

Southern Idaho Ground Squirrel
Urocitellus endemicus

- Emerge from hibernation in late January-early February
- One litter per year
- Re-enter torpor in May-June when shrub-steppe dries out.
- Folivorous/granivorous: feed on forb and grass seeds, leaves, flowers, etc.
- Live in burrows they dig themselves



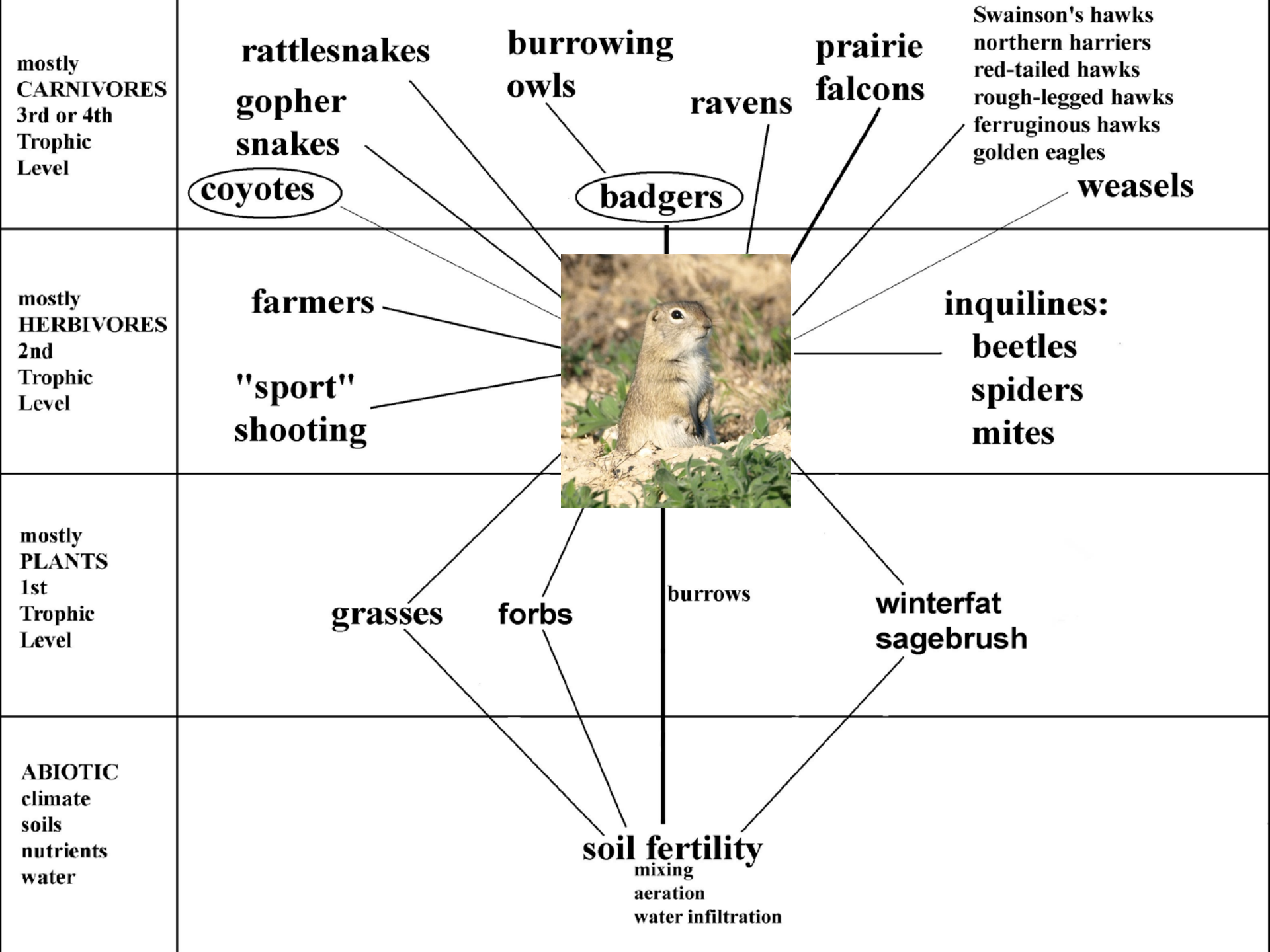
Geographic Distribution of *Urocitellus endemicus*

(light gray)

- Range <20 x 80 km
- Patchy distribution within limited range

Southern Idaho Ground Squirrel

- Population Trends
  - Fluctuates erratically
    - high in early 1980s, crash in late 1980s, recovery in 1990s, crashed in 1998-2003, now high again
  - Loss of sites, connectivity
  - Extinction prone
- Status
  - Candidate Species, 30 October 2001, Federal Register 66:54807-54832
  - Vulnerable (IUCN 1998: Rodent Action Plan)
  - “Species of Greatest Conservation Need” Idaho Department of Fish and Game


mostly CARNIVORES 3rd or 4th Trophic Level
rattlesnakes
gopher snakes
coyotes
burrowing owls
badgers
ravens
prairie falcons
Swainson's hawks
northern harriers
red-tailed hawks
rough-legged hawks
ferruginous hawks
golden eagles
weasels
mostly HERBIVORES 2nd Trophic Level
farmers
"sport" shooting
inquilines:
beetles
spiders
mites
mostly PLANTS 1st Trophic Level
grasses
forbs
burrows
winterfat
sagebrush
ABIOTIC
climate
soils
nutrients
water
soil fertility
mixing
aeration
water infiltration

Food Limitation in Ground Squirrels

Food supplementation resulted in...

- Increased population density
- Increased fecundity
- Increased growth rates
- Increased survival

Food restriction resulted in...

- Decreased population density
- Decreased mass
- Delayed immergence
- Decreased survival

Bachman (1993); Dobson and Kjelgaard (1985); Dobson and Oli (2001); Karels et al. (2000); Nunes and Holekamp (1996); Nunes et al. (2000); Pulawa and Florant (2000) + others

Southern Idaho Ground Squirrel Diets

- Forbs and forb seeds
  - Composites, lupine and other legumes, *Amsinckia* and other borages, *Lomatium, etc.*
- Grasses and grass seeds
  - *Poa* spp., *Elymus elymoides*, some *Stipa*s
- Native plants generally preferred
- Native perennial species more dependable than exotic annuals

Hypothesis

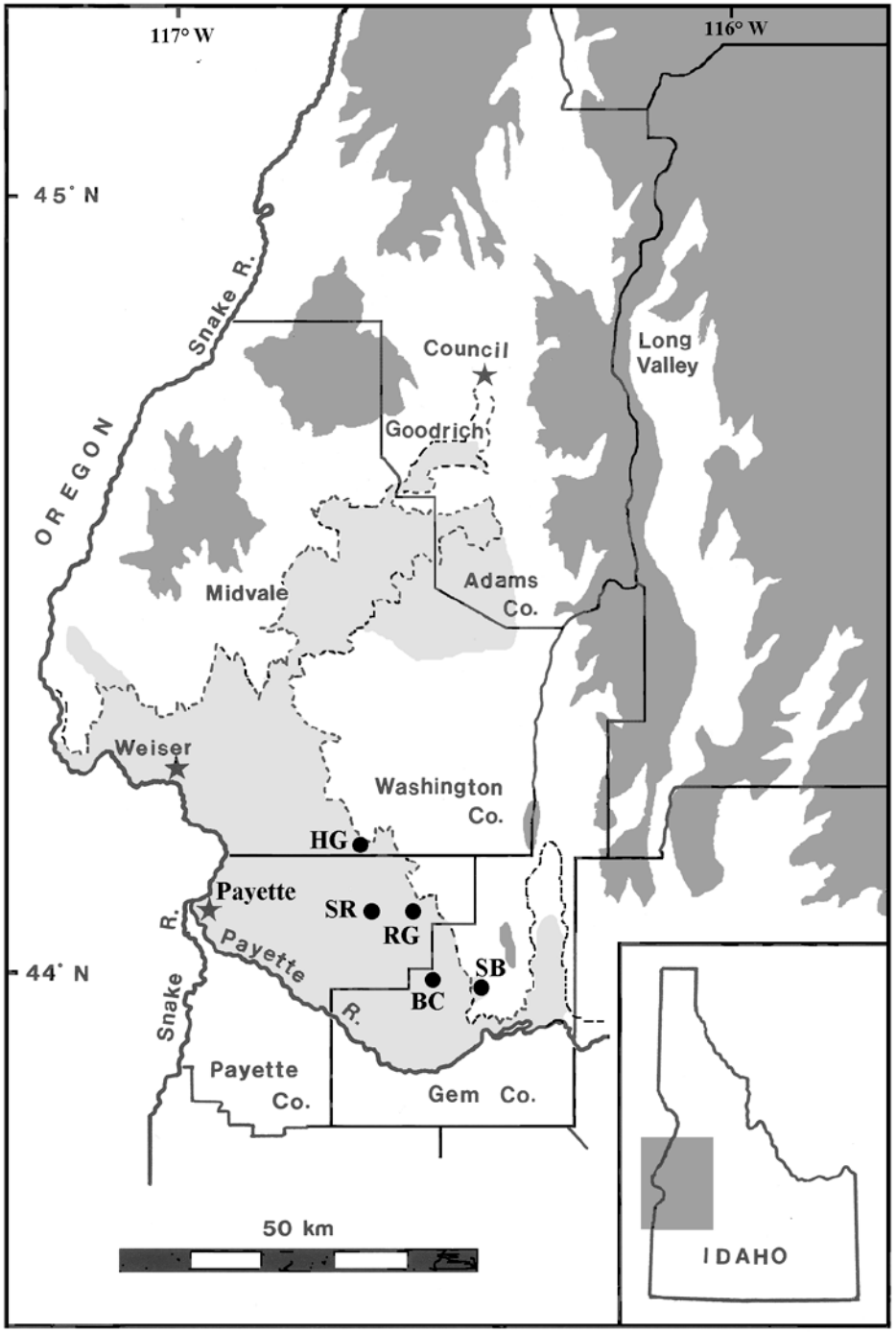
- Food abundance should drive fat deposition
- Body fat in late active season should predict overwinter survival
- Body fat at emergence should correlate with reproductive success, survivorship
- Reproductive success, survivorship should drive population trends

Food Plants [habitat degradation]

Body Condition

Demographics [Age-specific Survival & Reproduction]

Population Trends



Study Sites

- 7 sites selected to encompass a range of habitat conditions
- All were grazed
- None were dominated by native species

METHODS

Vegetation Analyses

- Daubenmire plots
  Plant species, cover,
  frequency
- Site characterization
  Richness, diversity (H'), dominance
  (Simpson's index)
- Importance Values
  I.V. = (Cover + Freq.)/2
  - Ten most dominant grasses
  - Ten most dominant forbs

Trapping

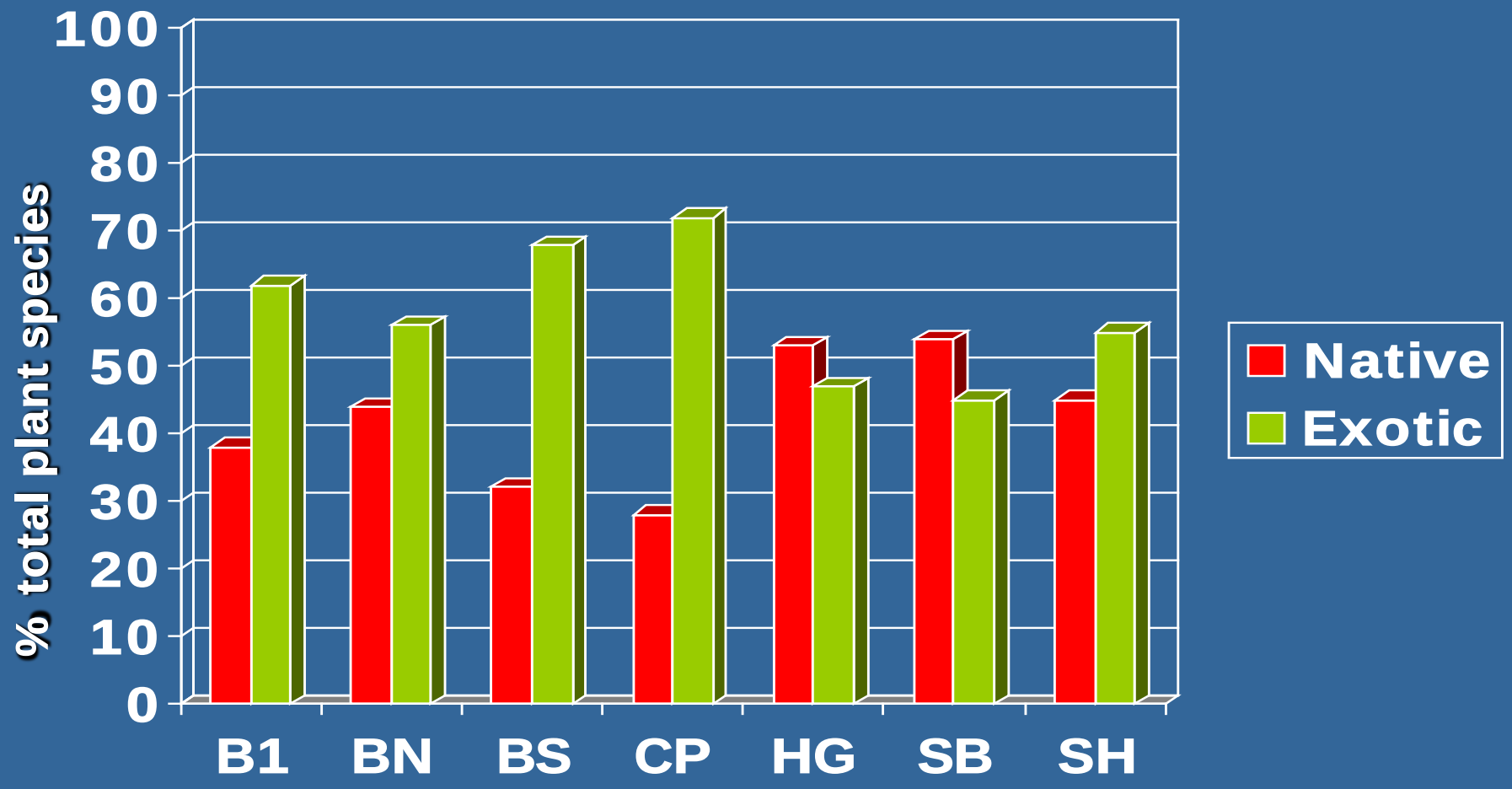
- Focal Animal Trapping
  - Attempted to trap every animal at site
- Processing
  - Identified to age/sex
  - Numbered ear-tags
- Site visits
  - Each site was trapped every two weeks

Body Condition

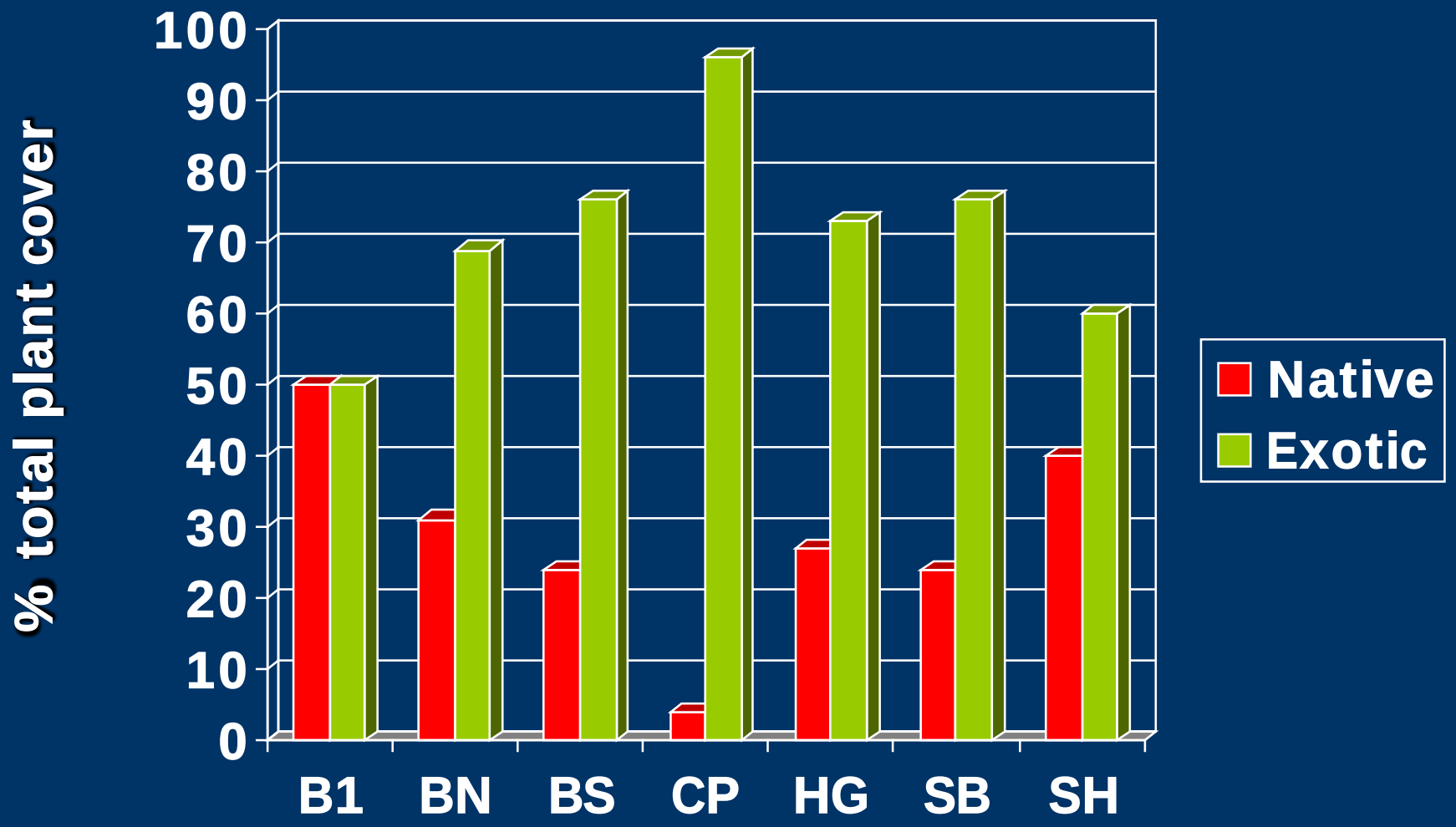
- Mass
  - Each individual weighed at each trapping event
- Fat
  - Total Body Electrical Conductivity (TOBEC) using an EMSCAN Model SA-2000; EM-SCAN Inc., Springfield, IL, USA

RESULTS

Native vs. Exotic Plant Species by Study Site



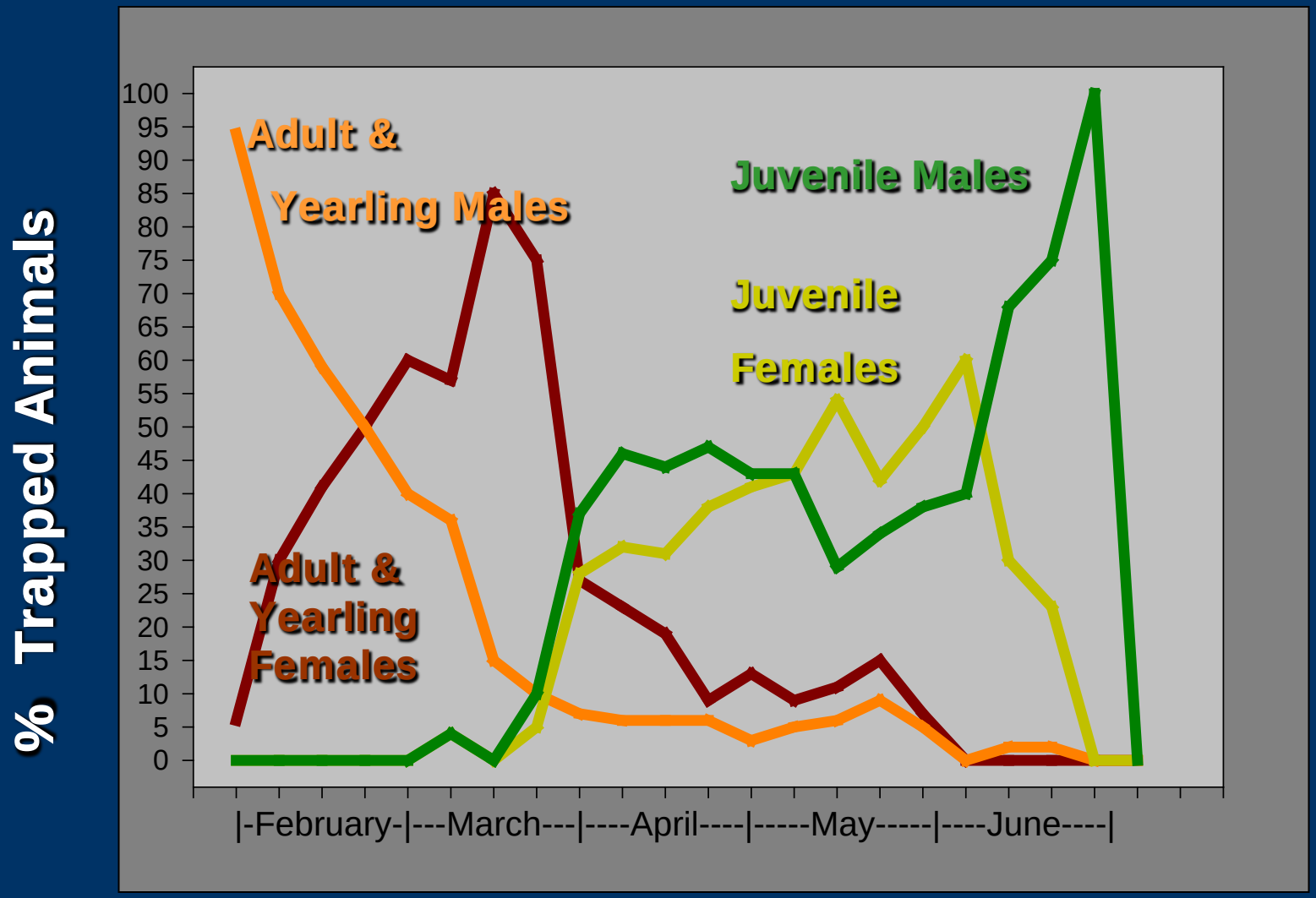
Exotic vs. Native Plant Cover



Trapping Results

- Total captures: 2,667
  - First trap events = 1,993 (74.3%)
  - Re-trap events = 674 (25.3%)
- Sex ratios
  - Juveniles: 46.1% Female
  - Adults: 62.7% Female
- Age ratios
  - 30.5% Adult

Seasonal Activity



Reproduction

(# Juveniles / Female)

Year	Juv. Males	Juv. Females	Breeding Females	Ratio
2002	349	505	155	5.51
2003	419	612	207	4.98

Ratios varied widely across sites

Site-specific ratios:

2002: 3.58 – 9.82

2003: 3.63 – 6.59

Comparison to Reproductive Rates in Related *Urocitellus*

Species	Rate (jv/litter)	Based on:	Source
U. endemicus	4.98-5.51	Pop. estimates-trapping	**Present study**
U. brunneus	5.46-5.54	Trapping of emerging litters	**Sherman and Runge, 2002**
U. endemicus	5-10	Placental scars	**Yensen and Sherman, 1997**
U. mollis	7.2-9.1	Embryo counts & placental scars	**Smith and Johnson, 1985**
U. mollis	9.2-10.0	Placental scars	**Steenhof et al., 2004**

Survival
Urocitellus juveniles

	Mean (%)			
Species	Males	Females	Years	Source
U. endemicus	10.9	21.6	2	Present study
U. mollis	15.0	30.0	5	Smith and Johnson, 1985
U. beldingii	31.0	35.0	11	Sherman and Morton, 1984
U. armatus	30.0	39.0	4	Rieger, 1996
U. armatus	50.0		4	Slade and Balph, 1974
U. columbianus	66.8		7	Dobson and Oli, 2001

Survival rates 2002-2003; 2003-2004

	Adult/Yearlings	Juveniles
Females	37.8 %	21.6 %
Males	16.0 %	10.9 %

Comparison to other *Urocitellus* juvenile survival rates during drought years

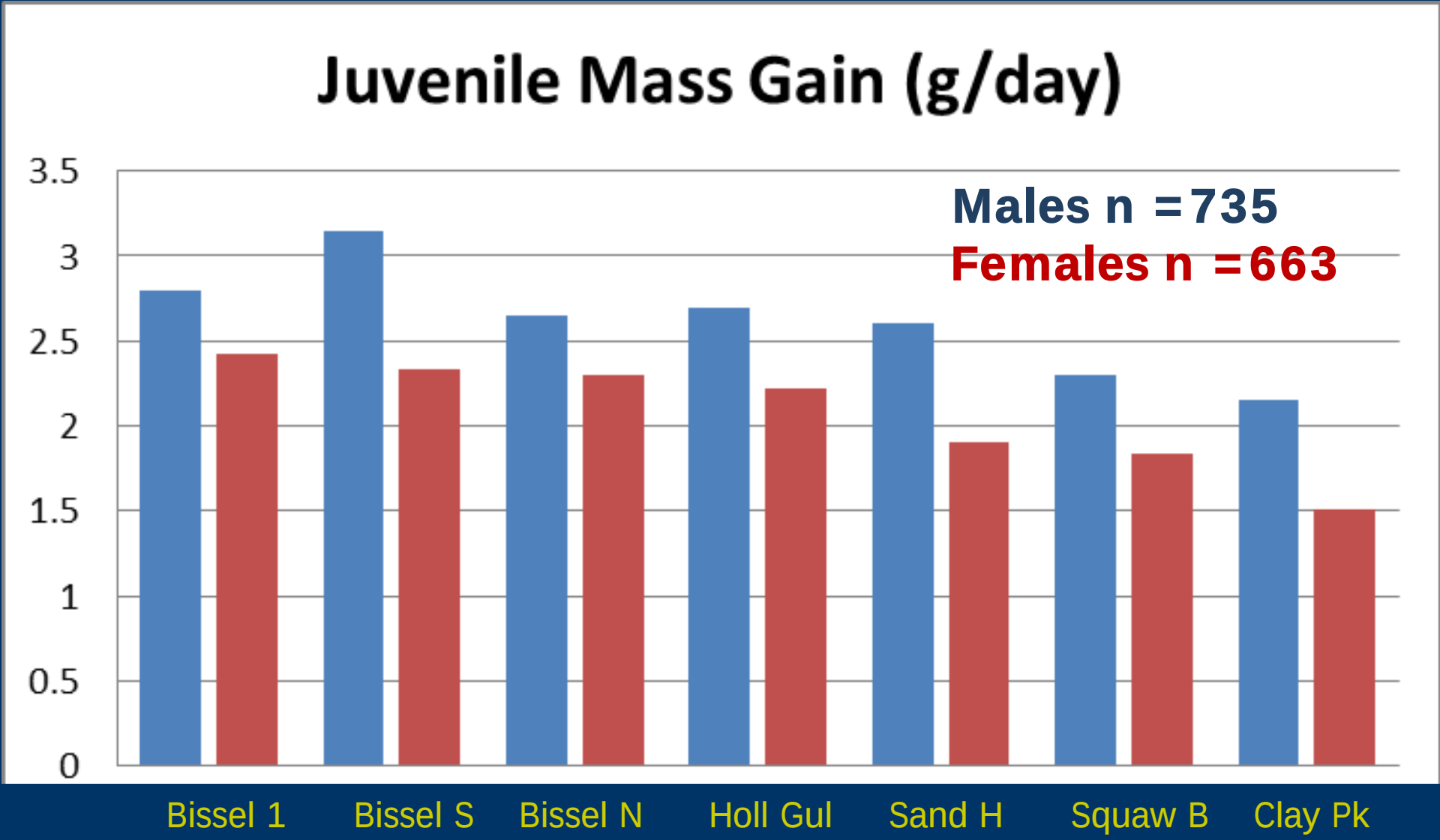
Species	Mean (%) Males	Mean (%) Females	Time	Source
U. endemicus	10.9	21.6	2-years	Present study
U. brunneus	6.6	20.6	5-years (pop decline)	Sherman and Runge, 2002
U. mollis	11.0	23.0	drought year	Smith and Johnson, 1985
U. mollis	10.7	21.3	3-years (drought year)	Van Horne et al., 1997

Our survival rates are characteristic of drought years, but precipitation during study was only slightly below normal not a drought.

Mass and Fat Gain Juveniles

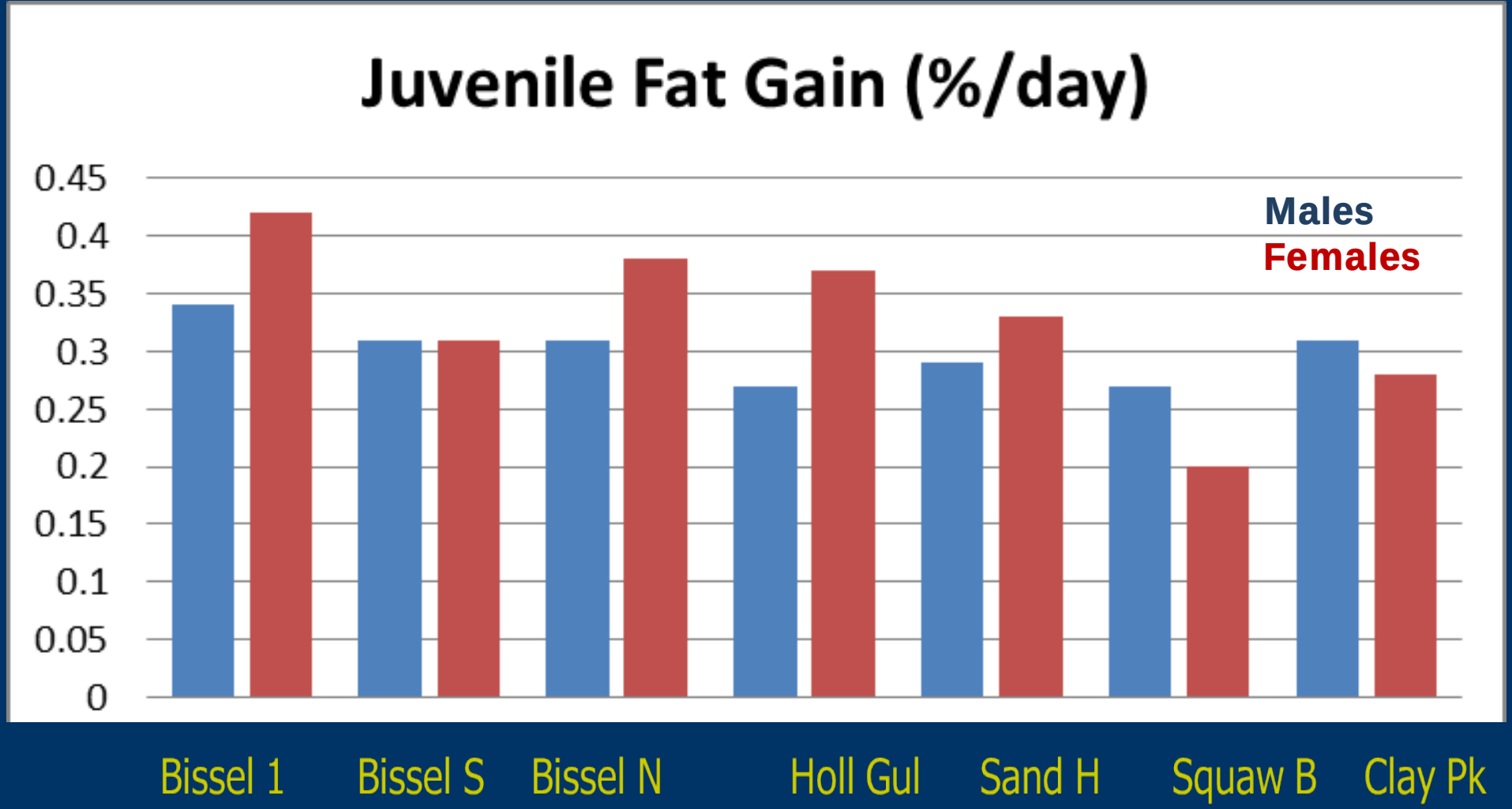
- Mass gain
  - Males: 2.72 g/day (± 0.05 [n = 735])
  - Females: 2.15 g/day (± 0.05 [n = 663])

- Fat gain
  - Males: 0.29 %/day (± 0.01 [n = 459])
  - Females: 0.32 %/day (± 0.01 [n = 354])



Study Sites

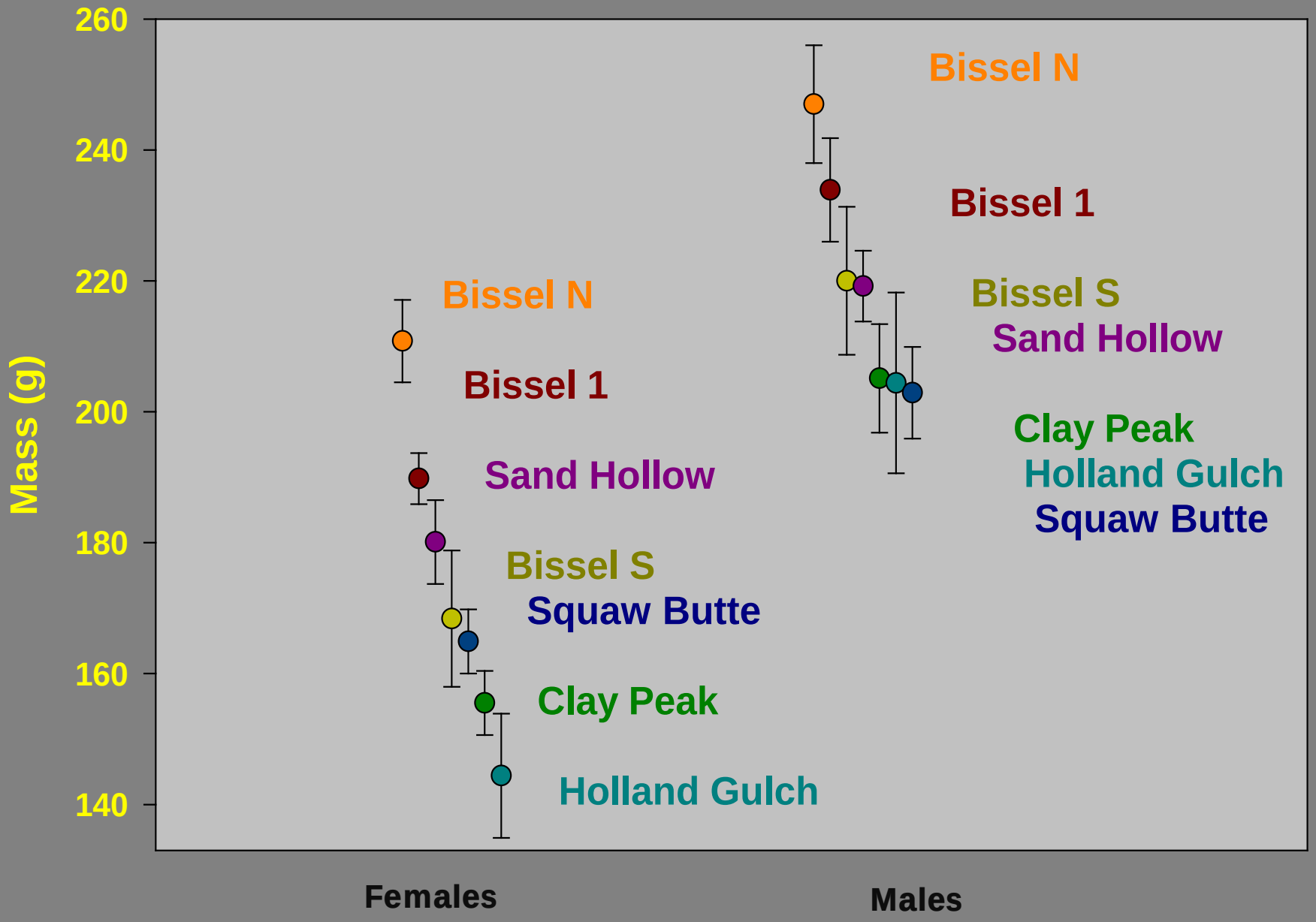
Highly significant differences among sites

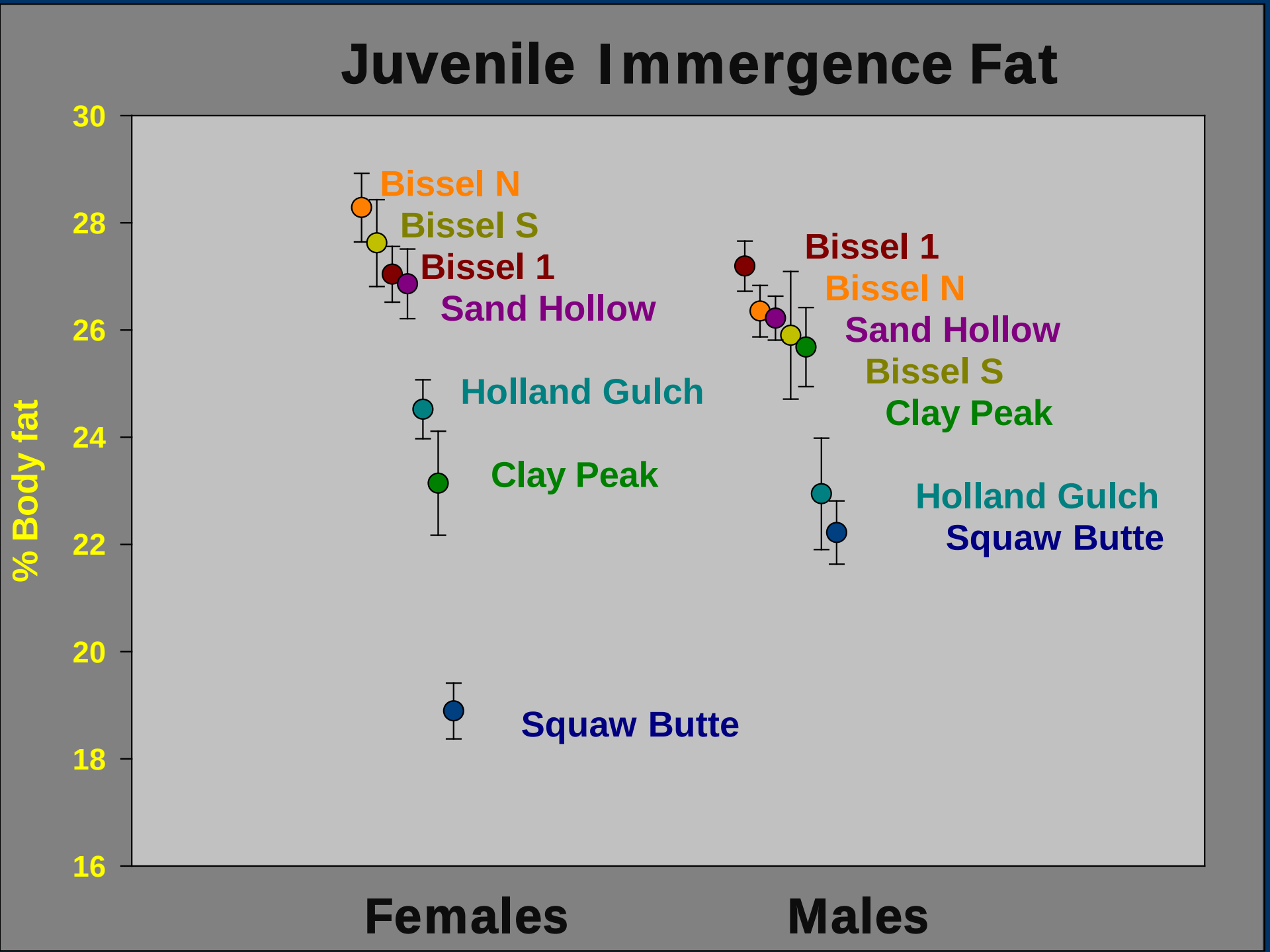


Study Sites

> 2 x difference among sites among females

Juvenile Immergence Mass




Juvenile Immergence Fat
% Body fat
30
28
26
24
22
20
18
16
Bissel N
Bissel S
Bissel 1
Sand Hollow
Holland Gulch
Clay Peak
Squaw Butte
Bissel 1
Bissel N
Sand Hollow
Bissel S
Clay Peak
Holland Gulch
Squaw Butte
Females
Males

Vegetation and Late-season Body Condition

- Juvenile Females
  - Negatively correlated with invasive grasses ($r = -0.83$; $p = 0.02$)
  - Positively correlated with plant species diversity ($r = -0.87$; $p = 0.01$) and perennial species diversity ($r = 0.74$; $p = 0.07$)
- Juvenile Males
  - Negatively correlated with invasive grasses ($r = -0.72$; $p = 0.07$)

Inter-year Stability in Adult Emergence Body Condition

- Negatively correlated with **invasive grasses** ($r = 0.68$; $p = 0.09$)
- Positively correlated with **bunchgrasses** ($r = 0.70$; $p = 0.08$) and **forbs** ($r = 0.77$; $p = 0.05$)

Sites with the most bunchgrasses and forbs had the most consistent body condition at spring emergence.

Vegetation and Reproductive and Survival Rates

- Reproductive rates were positively correlated with forb importance values

  ($r = 0.73$; $p = 0.06$)

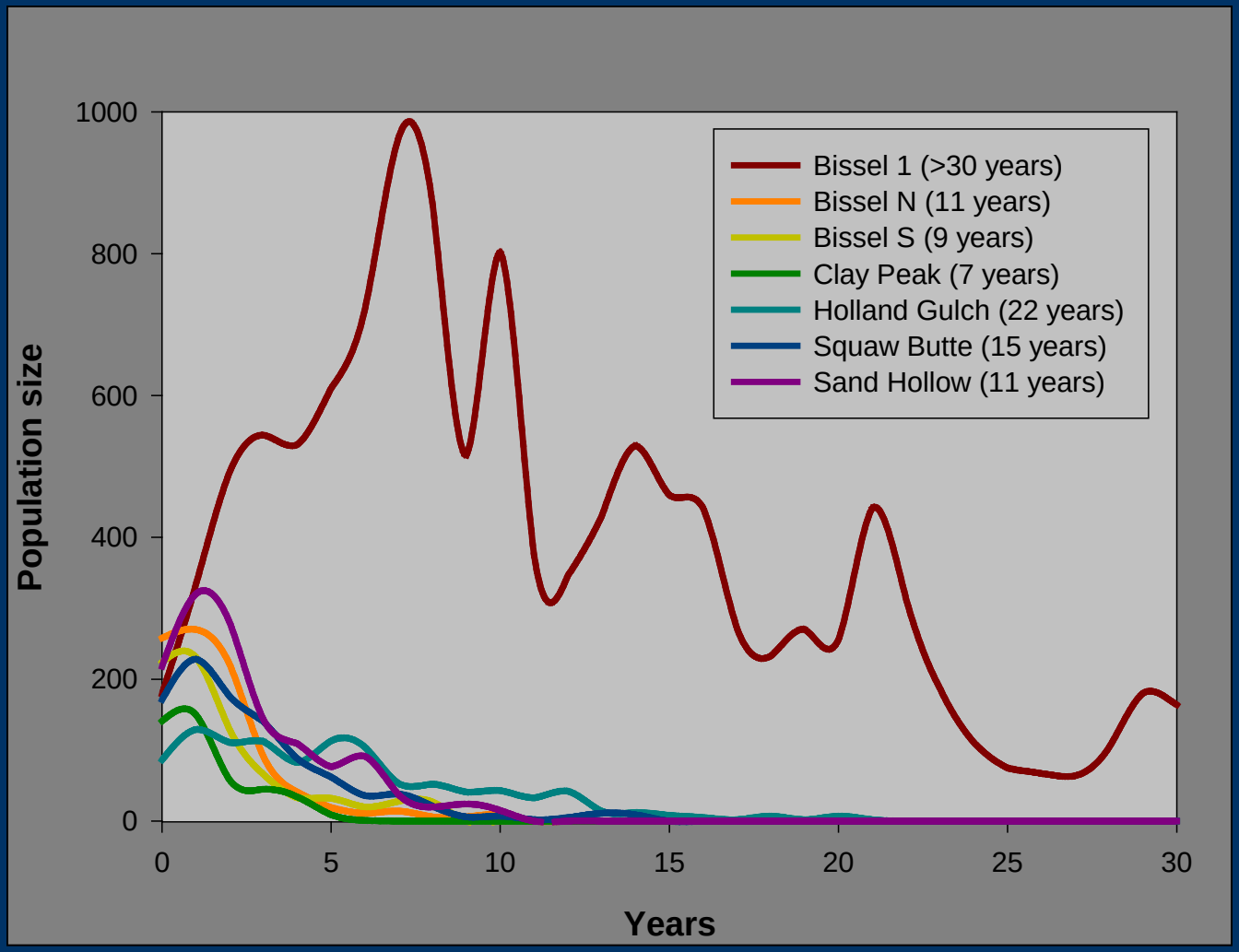
- Juvenile male survival was positively correlated with Forb Importance Values

  ($r = 0.85$; $p = 0.02$)

Population Viability Model

- Leslie-matrix model
  - Northern Idaho ground squirrel (Runge, 1999)
- 30-year projection based on:
  - population sizes
  - reproductive rates
  - survival rates
  - 100 iterations
- Sensitivity Analysis

Runge Population Model
Southern Idaho Ground Squirrel



Sensitivity Analysis

- Increasing survival rates of **juvenile females** had the largest impact on population persistence
- Male survival rates had little impact on population persistence
- Reproductive rate did little to increase population persistence until it reached 10-13 pups/female

Correlations
Population Modeling

Years until population extinction was negatively correlated with importance values of invasive grasses

($r = -0.74$; $p = 0.06$)

Conclusions

- Survival of juvenile females appears to be most critical to improving the status of the species.
- Native forbs are highly correlated with body condition in *U. endemicus*
- Body condition is highly correlated with reproductive success and overwinter survival.
- Population trajectories in *U. endemicus* ultimately determined by vegetation degradation
- Management actions needed to restore forbs to rangeland.

Acknowledgments

- Land owners / managers – Jim Little and Aggie Bradford, Bureau of Land Management for site access
- Field assistants – Kevin Werner, Karen Panek, Kristin Lohr
- Funding – U.S. Fish and Wildlife Service, Idaho Department of Fish and Game, Bureau of Land Management

Use of Camera Traps to Survey and Monitor Mohave Ground Squirrels

David Delaney

Philip Leitner

MGS Workshop

California State University Stanislaus

Background 2009-2012

- Project initially funded through U.S. Army Corps ERDC/CERL (2009-2010) to investigate the effectiveness of alternative survey methods (camera traps) compared with conventional live-trapping techniques
- Subsequent work (2011-12) was done to demonstrate that camera traps are effective over large geographic areas and to fill in information gaps on MGS distribution patterns
- Surveys within the distributional range of MGS have been limited due to funding availability, survey costs, availability of trained personnel, etc.
- Important that resource managers/regulators have updated data on MGS presence and distribution throughout its range
- Improvements in survey methodology/data acquisition can potentially lessen the possibility of Federal listing of MGS

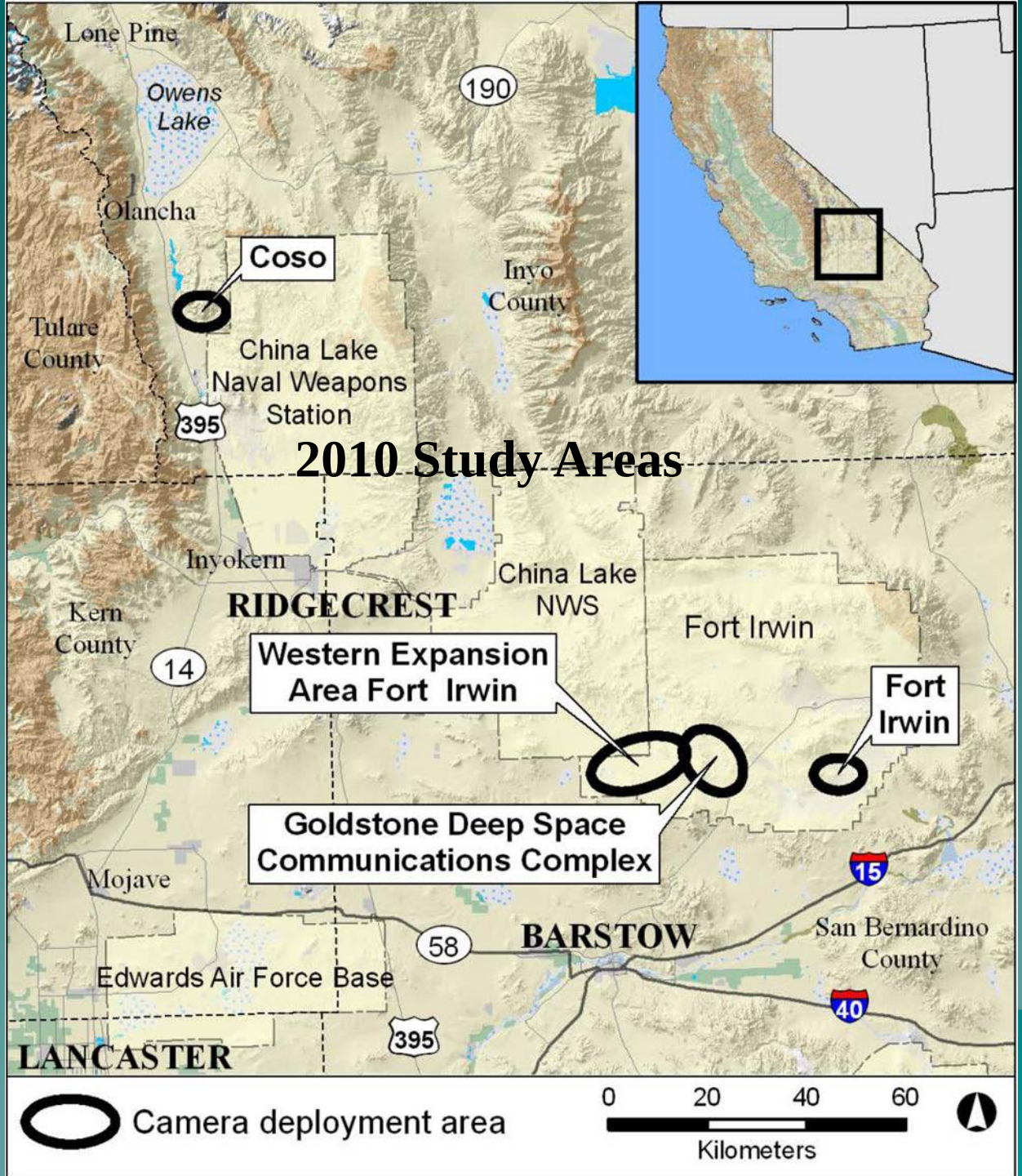
2009-10 Study Objectives

- Confirm that ground squirrels readily visit bait stations and are not bothered by camera trap equipment
- Compare the effectiveness of camera traps in detecting ground squirrel presence vs. live-trapping
- Determine if MGS and RTGS are readily distinguishable using camera traps?
- Determine if MGS marked with unique shave patterns were distinguishable using camera trap systems

Approach

- Survey 840 x 105 m grids using camera traps
- Record ground squirrel presence using camera trap systems (8-14 cameras per grid)
- Monitor for the presence of MGS from Feb-June (Coso, WEA, Goldstone, Fort Irwin)
- Use camera traps for 5 consecutive days (with 2 days pre-baiting)
- Compare trapping success rates between live-trapping vs. camera traps

2010 Study Areas



Results

- Documented MGS, AGS, and RTGS presence at one or more locations
- Documented general visitation times
- Documented multiple visitations/day for all ground squirrel species
- Documented intra- and interspecific interactions
- Documented individual/group behavior
- Documented non-target species

MGS Presence (2010)

- Coso – did not detect MGS at camera stations
- Ft Irwin WEA – MGS camera detections at five of eight study sites
- Goldstone DSCC – no MGS camera detections
- Ft Irwin proper – RTGS detections in both study sites

Mohave Ground Squirrel

White-Tailed Antelope Ground Squirrel

Round-Tailed Ground Squirrel

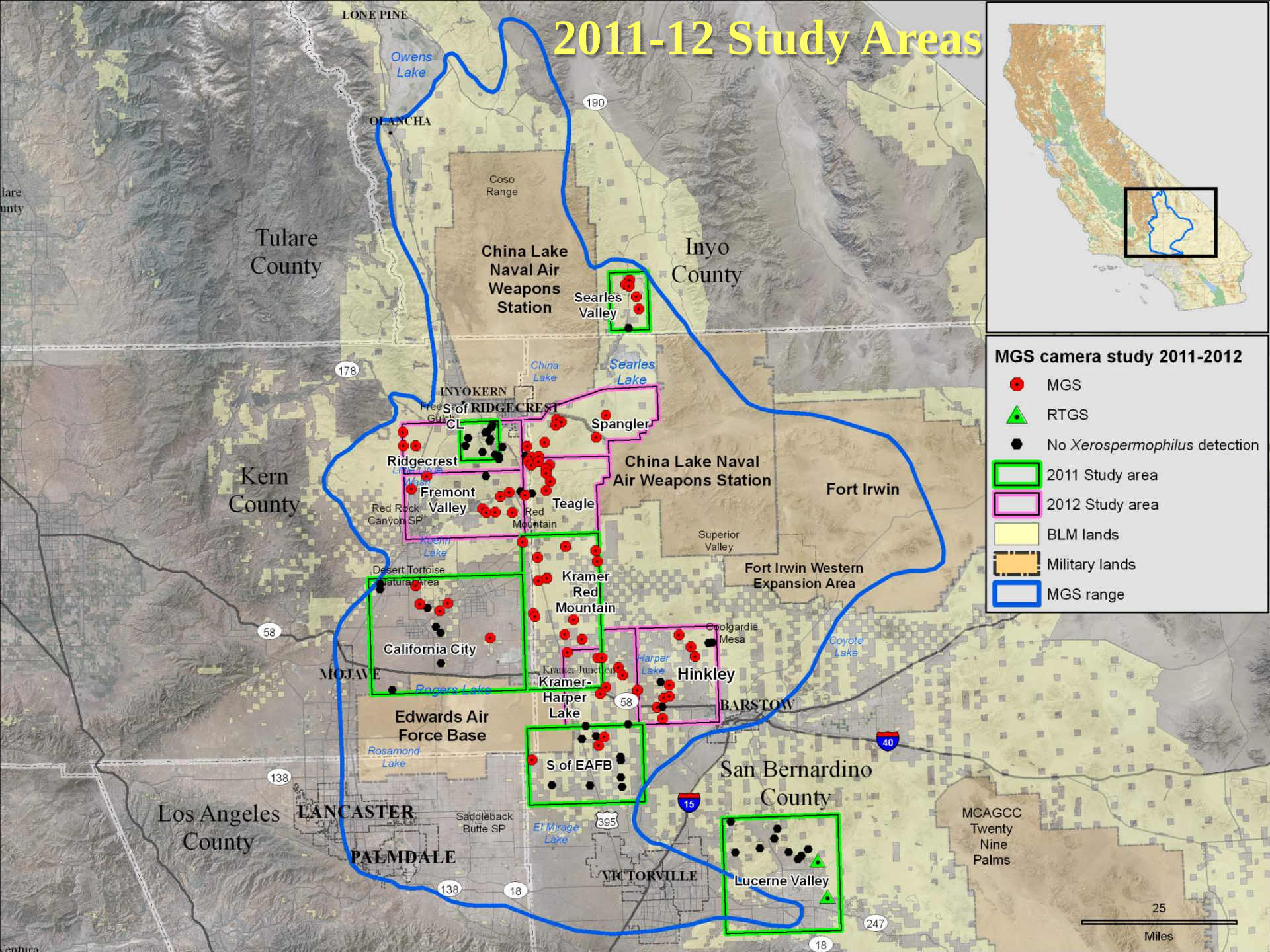
Camera Traps vs Live Trapping
2010 Results (April)

Grid Name	Live-Trap Detections (no. MGS) marked	Camera Detections (min. no. MGS) marked/unmarked	Camera Detections (min. no. MGS) unmarked
Grid 29	2F	1F / 3F	4F
Playa Road	1F, 1M	1F, 1M / 1F	2F, 1M
S. Road North	4F, 4M	4F, 3M / 1F, 1M	4F, 3M
Cholla Garden	2F	1F / 2F, 1M	2F, 1M
Total	9F, 5M 14 individuals	7F, 4M/ 7F, 2M 20 individuals	12F, 5M 17 individuals

Trapping Success Rates
2010

- Cameras with detections = 28/56
- Camera trap-days with detections = 76/280 (27.1%)
- Total visitations = 440 (95, 14, 174, 157)
- Live-traps with captures = 20/400
- Trap-days with captures = 24/2000 (1.2%)

2011-12 Study Areas

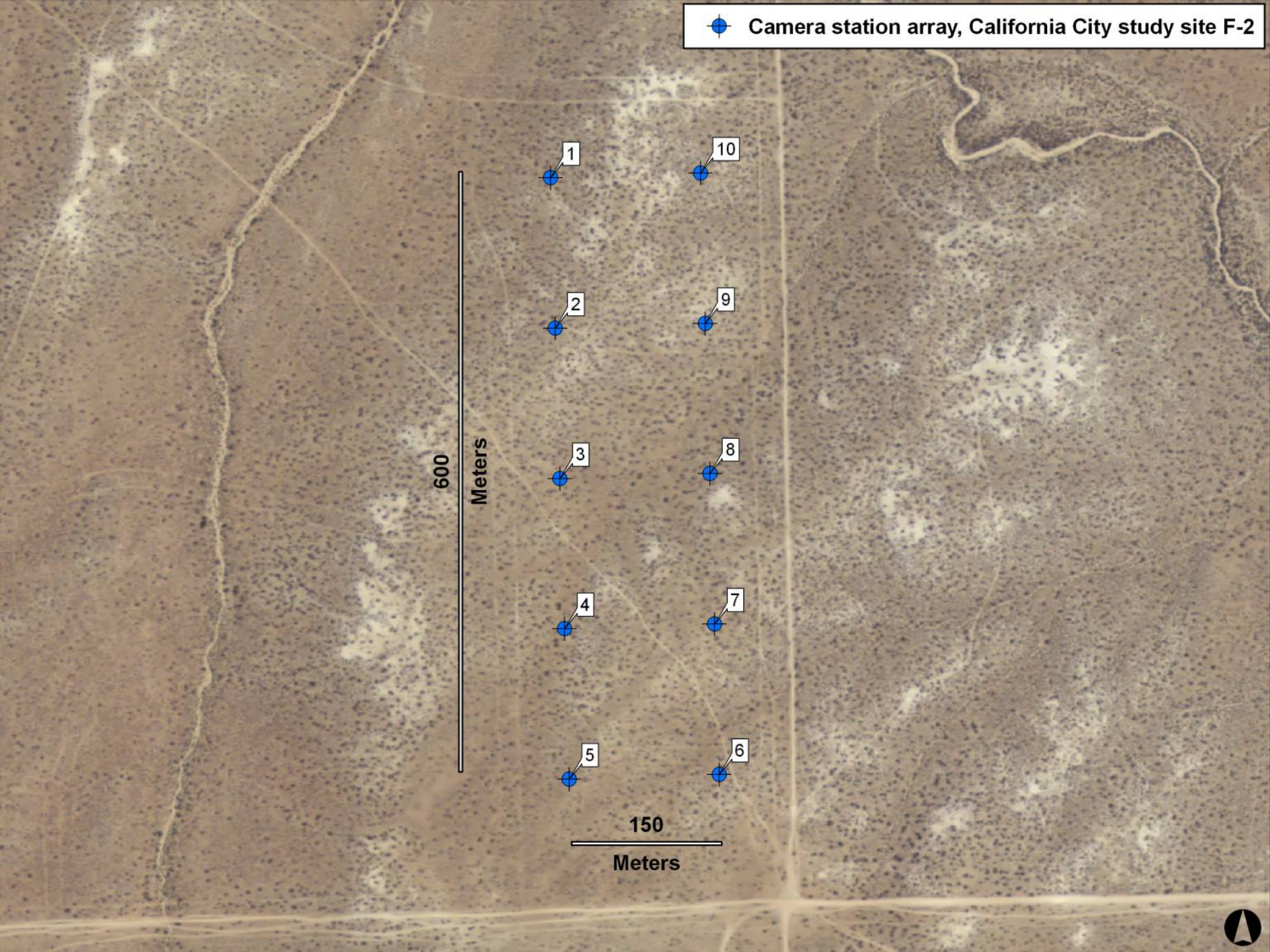


Project Goals/Objectives 2011-12

- Fort Irwin, BLM, CDFG, MDEP, DMG, CSU-Stanislaus/ESRP and CERL have provided resources and support to expand MGS surveys using camera traps on non-DoD lands
- Continue large scale field test of camera trap surveys
- Provide data to help validate the PACT model that the CEC PIER program is evaluating
- Help to field test the MGS habitat suitability model that the USGS is developing
- Vegetation sampling data will be directly applicable with ongoing CDFG vegetation mapping projects
- Research findings will be applicable across DoD and non-DoD lands
- Project results will improve our knowledge of MGS distribution

Approach

- Record ground squirrel presence using 2 x 5 grid pattern (10 cameras with 150 m spacing)
- Reconyx trail cameras: Models RC-60, HC500 and PC800 (0.2 trigger speed, no delay between HD photos)
- Record animal visitation 24 hours/day during weekdays
- Monitor potential MGS presence on non-DoD lands


Camera station array, California City study site F-2
1
2
3
4
5
6
7
8
9
10
600
Meters
150
Meters

2011 Study Results – 41.7% overall detection rate

Grid Name	MGS Detections	RTGS Detections
Searles Valley	83.3% (5 of 6)	0.0% (0 of 6)
S. of China Lake	0.0% (0 of 6)	0.0% (0 of 6)
California City	41.7% (5 of 12)	0.0% (0 of 12)
Kramer/Red Mtn	100.0% (12 of 12)	0.0% (0 of 12)
S. of EAFB	25.0% (3 of 12)	0.0% (0 of 12)
Lucerne Valley	0.0% (0 of 12)	16.7% (2 of 12)

2012 Study Results – 74.6% overall detection rate

Grid Name	MGS Detections	RTGS Detections
Ridgecrest	30.0% (3 of 10)	0.0% (0 of 10)
Fremont Valley	80.0% (8 of 10)	0.0% (0 of 10)
Spangler	90.0% (9 of 10)	0.0% (0 of 10)
Teagle	90.0% (9 of 10)	0.0% (0 of 10)
Kramer/Harper Lake	90.0% (9 of 10)	0.0% (0 of 10)
Hinkley	69.2% (9 of 13)	0.0% (0 of 13)

Summary of 2011-12 Camera Trap Results

- Surveyed 60 grids 3 times in 2011 (~600 camera sites) between Feb-June
- Surveyed 63 grids 2 times in 2012 (~630 camera sites) between Mar-June
- Documented MGS, AGS, and RTGS (2011 only) presence at one or more locations
- Documented general visitation times
- Documented multiple visitations/day usually for all ground squirrel species
- Documented intra- and interspecific interactions
- Documented individual/group behavior
- Documented multiple non-target species

Intra-/Interspecific Interactions

Examples of Nocturnal Non-Target Species Detections

Examples of Diurnal Non-Target Species Detections

Benefits of Camera Traps

- Detect MGS at similar or greater effectiveness as conventional live-trapping
- Non-invasive technique for surveying for MGS over large geographic areas
- Not limited by weather conditions
- Documents activity patterns of animals
- Records multiple visitations per day by animals
- Documents intra-/interspecific behavioral interactions
- Research findings from this project are applicable across DoD and non-DoD lands
- Unlike live-trapping, camera traps do not require federal permits to operate

Possible Future Uses of Camera Traps

- Determine the number of camera trap systems needed to fully sample conventional grid to directly compare with live-trapping surveys
- Utilize camera traps to locate future trapping sites to improve the cost effectiveness of live-trapping
- Investigate food preferences of MGS to possibly improve live-trapping success
- Investigate how MGS interact with live-traps to possibly improve trapping success
- Investigate if PIT tag reading devices can be effectively used in concert with camera traps/feeding stations
- Utilize camera traps to document burrow use/site fidelity by ground squirrels

Questions?

Matrix of Field Survey Techniques for Mohave Ground Squirrels

David Delaney

Philip Leitner

MGS Workshop

California State University Stanislaus

Variables	Live trapping	Camera trapping	Audio surveillance	Visual surveillance	Track plates
Quantity of data	Limited	Very large	Moderate	Low-moderate	Low-moderate
Quality of data	Very high	Very high	Moderate	Very high	Fair-poor
Possible number of MGS detections per day	Low-moderate	Low-high	Low-moderate	Low-moderate	Low-moderate
Chance that earlier data is compromised by more recent data	No	No	Unlikely, but possible masking	No	Possible
Permits required	Yes	No	No	No	No
Environmental impacts on trapping success	High	Limited	Limited	Limited	Possible
Potential impact on MGS health/behavior	Moderate/high	Minor	Minor	Minor/moderate	Minor
Ability to individually identify squirrels	Yes	Limited	Limited	Limited	Limited
Data adequate to establish density estimates	Possible	Possible	Possible	Possible	Unlikely
Data adequate to establish occupancy rates	Possible	Possible	Possible	Possible	Unlikely
Time to setup equipment	Fast-moderate	Moderate	Moderate	Fast	Moderate
Time to reduce data	Fast	Moderate-long	Moderate-long	Fast	Moderate
Repeatability of results	Likely	Likely	Likely	Likely	Unknown

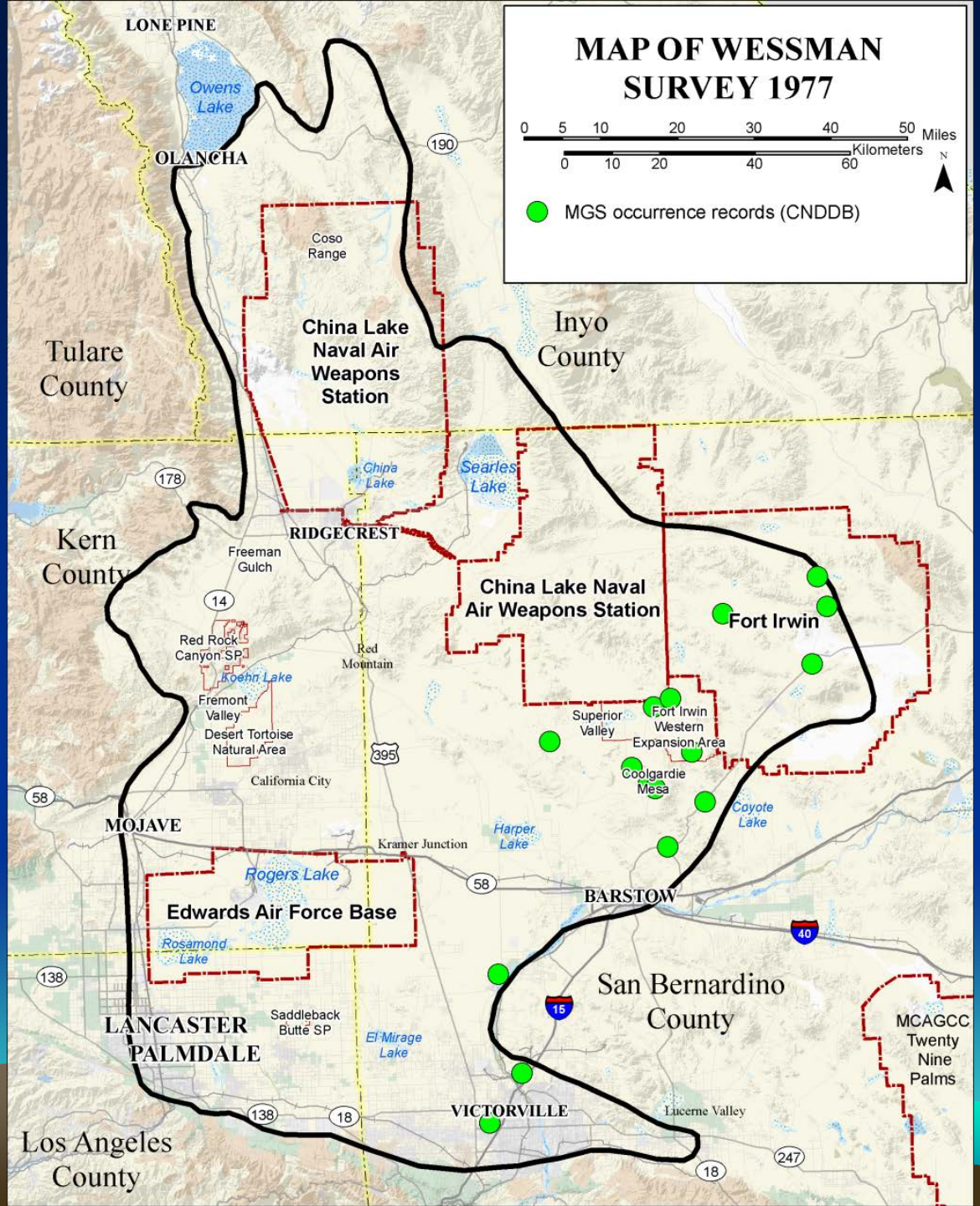
Variables	Live trapping	Camera trapping	Audio surveillance	Visual surveillance	Track plates
Detect non-target species/ social interactions	Likely/very limited	High/high	High/possible	High/possible	Likely/very limited
Threat of theft/vandalism	Possible	Possible	Possible	Possible	Unlikely
Cost	Expensive	Moderate	Expensive	Low-moderate	Moderate
Data collection in areas with reduced access	Limited	Few restrictions	Few restrictions	Limited	Limited
Ability to determine exact timing and duration of detections	Limited	High	High	High	Limited
Ability to document morphometric data	High	Not possible	Not possible	Limited	Limited
Confidence in species identification	High	High	Moderate	High	Limited
Ability to draw in potential predators	Yes	Yes	Unlikely	Unlikely	Yes
Habituation of target animals to detection method possible	Yes	Yes	Not likely	Not likely	Yes
Distinguishes animal species	Yes	Yes	Likely	Yes	Possible
Technique requires specialized training/knowledge	Yes	No	Yes	No	Yes

Live-trapping MGS

The Traditional Method for Detecting MGS

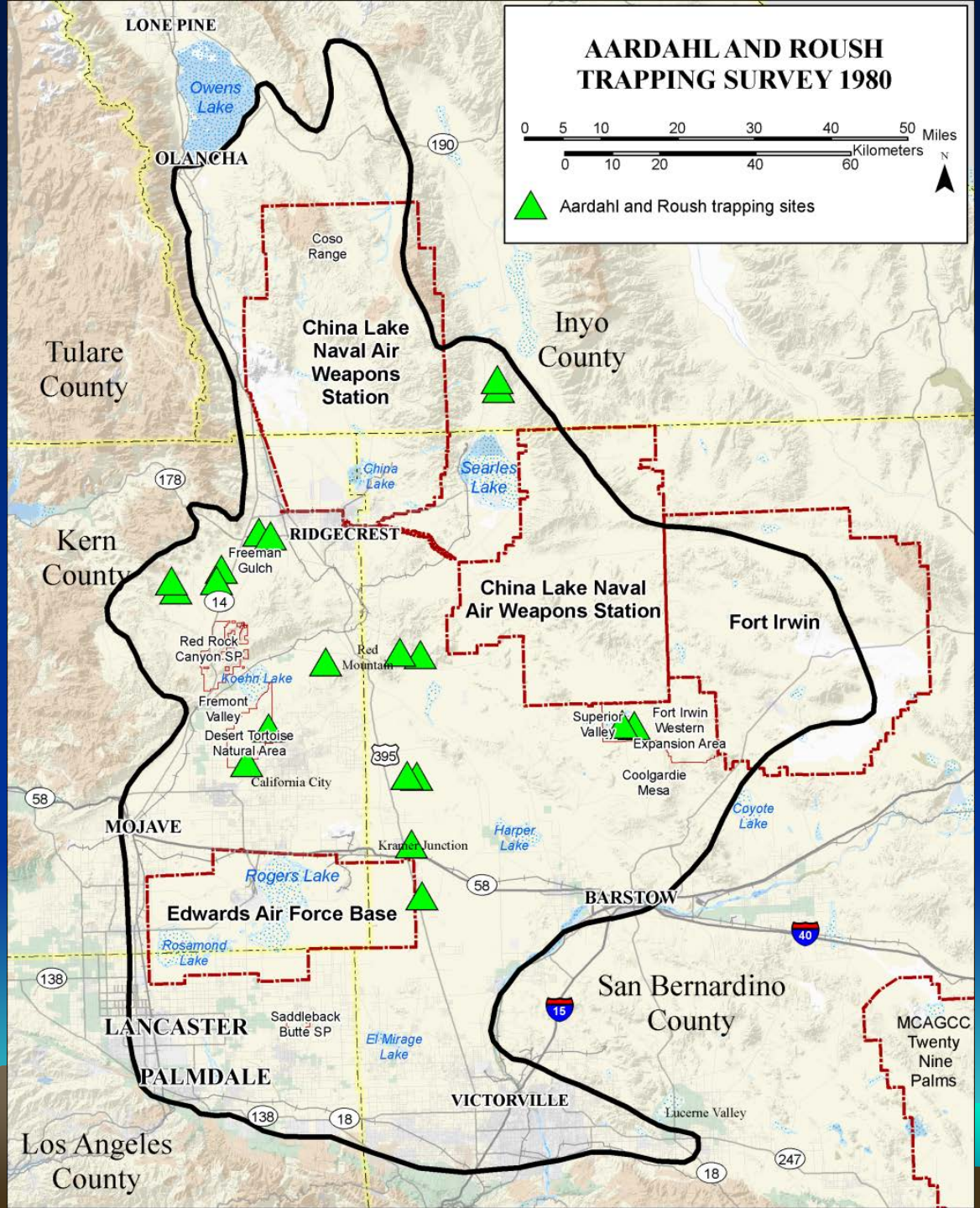
Documenting MGS Occurrence

- In the early days, collectors used snap-traps and shooting to collect specimens
- First large-scale live-trapping was by Wessman in 1977 along the eastern edge of the range
- He trapped 37 MGS in 16,000 trap-days of effort at 45 sites
- However, his captures wound up in museum cases


MAP OF WESSMAN SURVEY 1977
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
MGS occurrence records (CNDDB)
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Fremont Valley
Desert Tortoise Natural Area
Superior Valley
Fort Irwin Western Expansion Area
395
California City
Coolgardie Mesa
58
Coyote Lake
MOJAVE
Harper Lake
Kramer Junction
Rogers Lake
58
BARSTOW
Edwards Air Force Base
40
Rosamond Lake
138
San Bernardino County
15
LANCASTER
PALMDALE
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
138
18
VICTORVILLE
Lucerne Valley
Los Angeles County
18
247

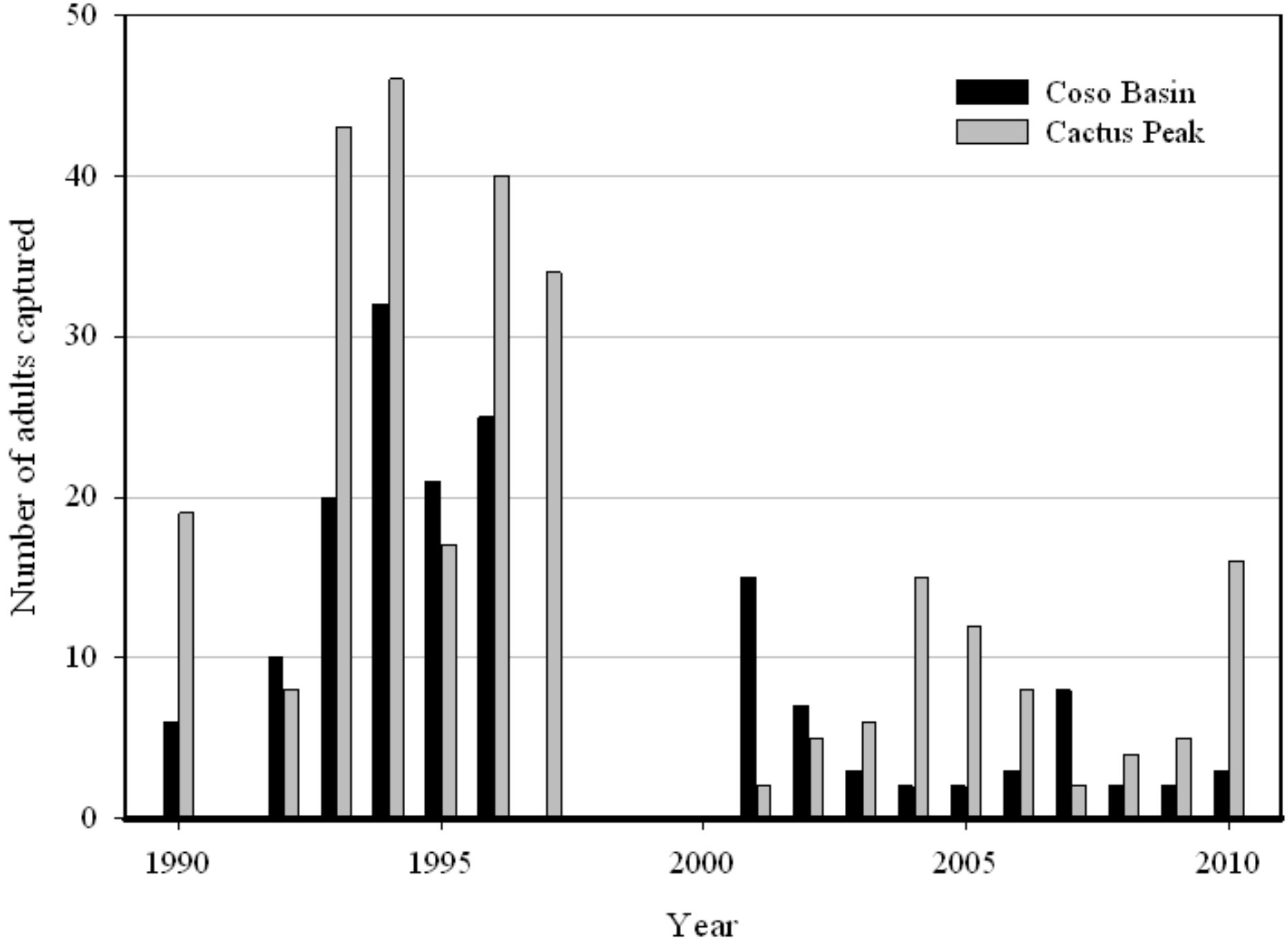
The Next Phase 1979-1987

- In 1979, trapping at 8 locations in Rose Valley and Coso Range yielded 124 MGS (Leitner 1980)
- Aardahl and Roush (1985) took up the challenge in 1980 with 22 sites widely distributed throughout the range, with 343 MGS
- In the mid-1980s, Tony Recht began trapping for Cal Trans projects with a 4x25 trap array
- Recht started the first project-related presence/absence surveys


AARDAHL AND ROUSH
TRAPPING SURVEY 1980
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Aardahl and Roush trapping sites
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Koehn Lake
Red Mountain
Fremont Valley
Desert Tortoise Natural Area
California City
395
Superior Valley
Fort Irwin Western Expansion Area
Coolgardie Mesa
Coyote Lake
58
MOJAVE
Kramer Junction
Harper Lake
Rogers Lake
Edwards Air Force Base
Rosamond Lake
BARSTOW
40
138
San Bernardino County
15
LANCASTER
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
18
247
Los Angeles County

Coso Grazing Exclosure Study

- From 1988-1996 trapping carried out at 4 sites in Coso region of Inyo County to evaluate a large grazing exclosure
- Trapping grids were 500 x 500 m with 441 trap stations at 25 m centers
- Goal was to estimate and monitor population size/density over multiple years
- This was actually accomplished several times!


Coso Basin
Cactus Peak
Number of adults captured
0
10
20
30
40
50
1990
1995
2000
2005
2010
Year

Development of Project-related Trapping

- In the late 1980's live-trapping was used to assess the impacts to MGS of project development
- Trapping was used to evaluate many highway projects
- Two large solar projects were located in MGS habitat and permitting required MGS trapping

The 1990s

- In 1993 a petition to de-list the MGS was approved by the CA Fish & Game Commission
- The CA Supreme Court invalidated the de-listing decision and the MGS was back in “Threatened” status in 1998

Present CDFG Survey Requirements

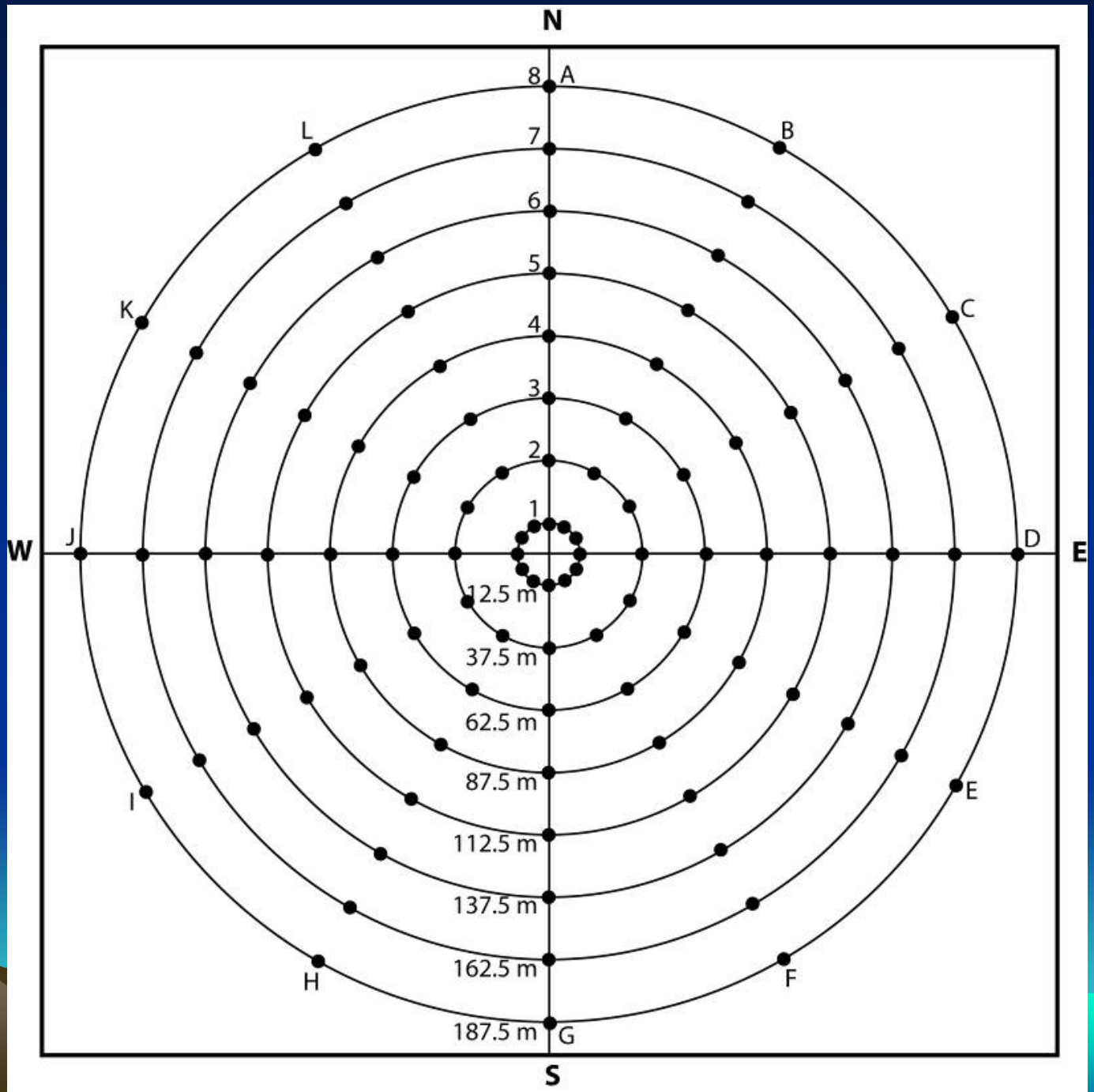
- Since the MGS has been restored to “Threatened” status, CDFG has required surveys to determine its presence or absence at project sites
- These surveys are carried out under detailed guidelines requiring visual and live-trapping efforts
- Only if MGS are determined to be present on a site can CDFG require mitigation for impacts
- Habitat cannot be protected under CA ESA

Live-trapping Methods

- Commonest arrangement is array of 100 traps either 4x25 or 10x10 with 35 m spacing – covers ~9-10 hectares
- Very unusual to capture more than 2 or 3 MGS
- The Coso grid with 441 traps in 21x21 array with 25 m spacing covers 25 hectares (500x500 m)

Trapping Web

- This method has been used at EAFB
- A total of 96 traps arranged at 25 m intervals along 12 radii
- A “spider web” covering 9.6 hectares
- Trapping effort is equivalent to that of a trapping grid
- Five days of trapping would be standard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7
8
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37.5 m
62.5 m
87.5 m
112.5 m
137.5 m
162.5 m
187.5 m

Application of Web Trapping Method

- Assume that probability of detection at center is 1.0
- Arrive at a detection function by looking at captures as you go out from center
- From this you can estimate density

What are the Applications of Live-trapping?

- Detect presence – but not absence
- Index of abundance – number captured
- Estimate density – but may be a big effort
- Longitudinal demographic study of marked individuals
- Collect samples for genetic analysis
- Capture animals for radio-tracking studies

Limitations of Live-trapping

- Trapping isn’t really practical to estimate MGS population densities
- Even using number of individual captures as index of abundance is problematic
- It requires well-trained permitted staff
- Weather conditions can be a limitation, especially with high temperatures in summer

MOHAVE GROUND SQUIRREL

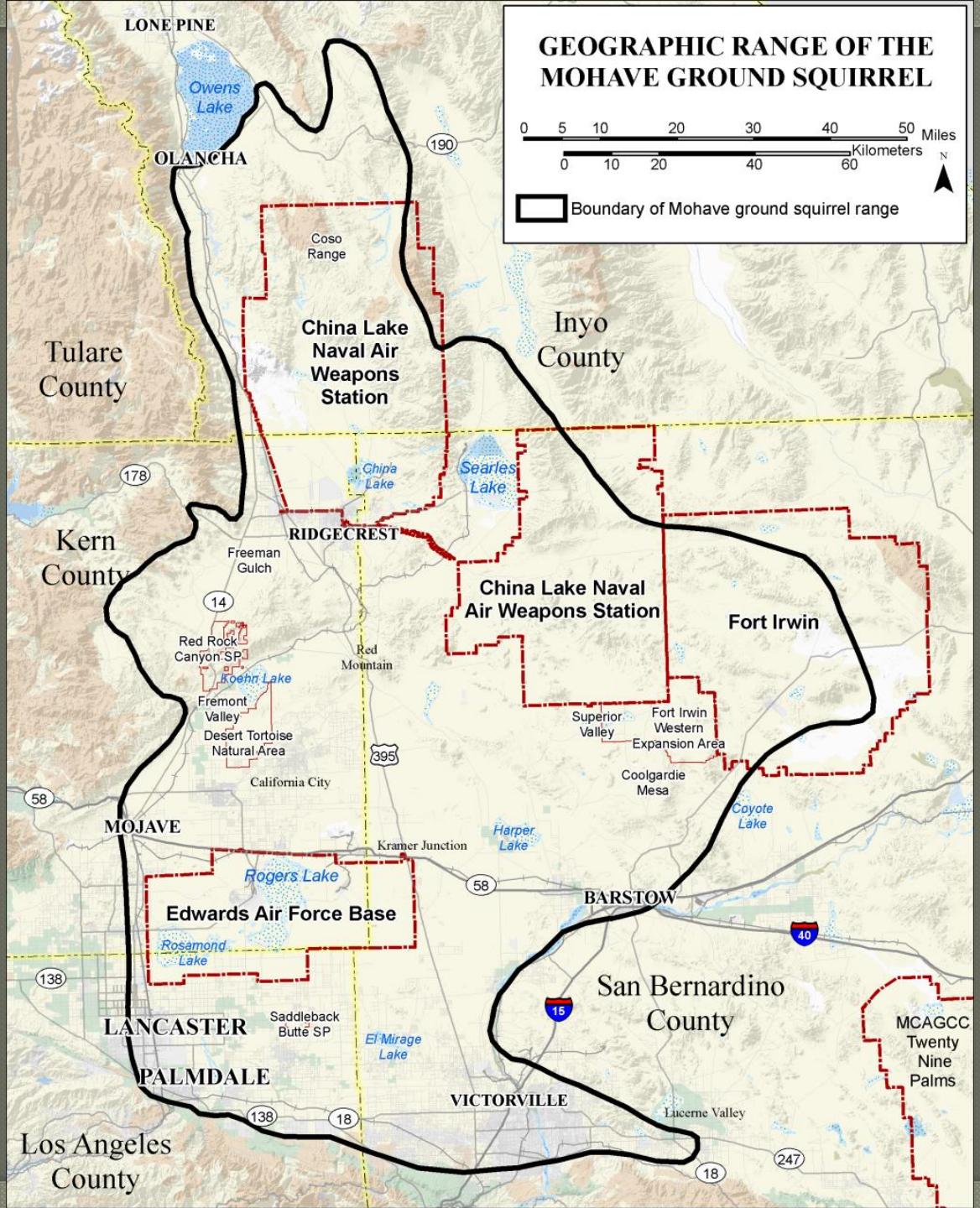
Distribution and Geographic Connectivity

Geographic Distribution

- MGS is endemic to western Mojave Desert of California
- Relatively small geographic range of about 20,000 km^2
- The closely-related round-tailed ground squirrel has a much more extensive geographic range

2011-03-31 1:54:54 PM M 2/5
95°F
PC800 HYPERFIRE PRO
RECONYX

Oregon
Idaho
Wyoming
Nevada
Utah
Colorado
United States
California
New Mexico
Arizona
Baja California
Mexico
Sonora
Chihuahua
Sinaloa
GEOGRAPHIC RANGE OF
MOHAVE GROUND SQUIRREL AND
ROUND-TAILED GROUND SQUIRREL
0 50 100 200 300 400 500 Miles
0 100 200 400 600 Kilometers
N
Mohave ground squirrel range
round-tailed ground squirrel range


GEOGRAPHIC RANGE OF THE MOHAVE GROUND SQUIRREL
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Boundary of Mohave ground squirrel range
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Fremont Valley
Desert Tortoise Natural Area
Superior Valley
Fort Irwin Western Expansion Area
395
California City
Coolgardie Mesa
58
Coyote Lake
MOJAVE
Harper Lake
Kramer Junction
Rogers Lake
58
BARSTOW
Edwards Air Force Base
40
Rosamond Lake
138
San Bernardino County
15
LANCASTER
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
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Los Angeles County
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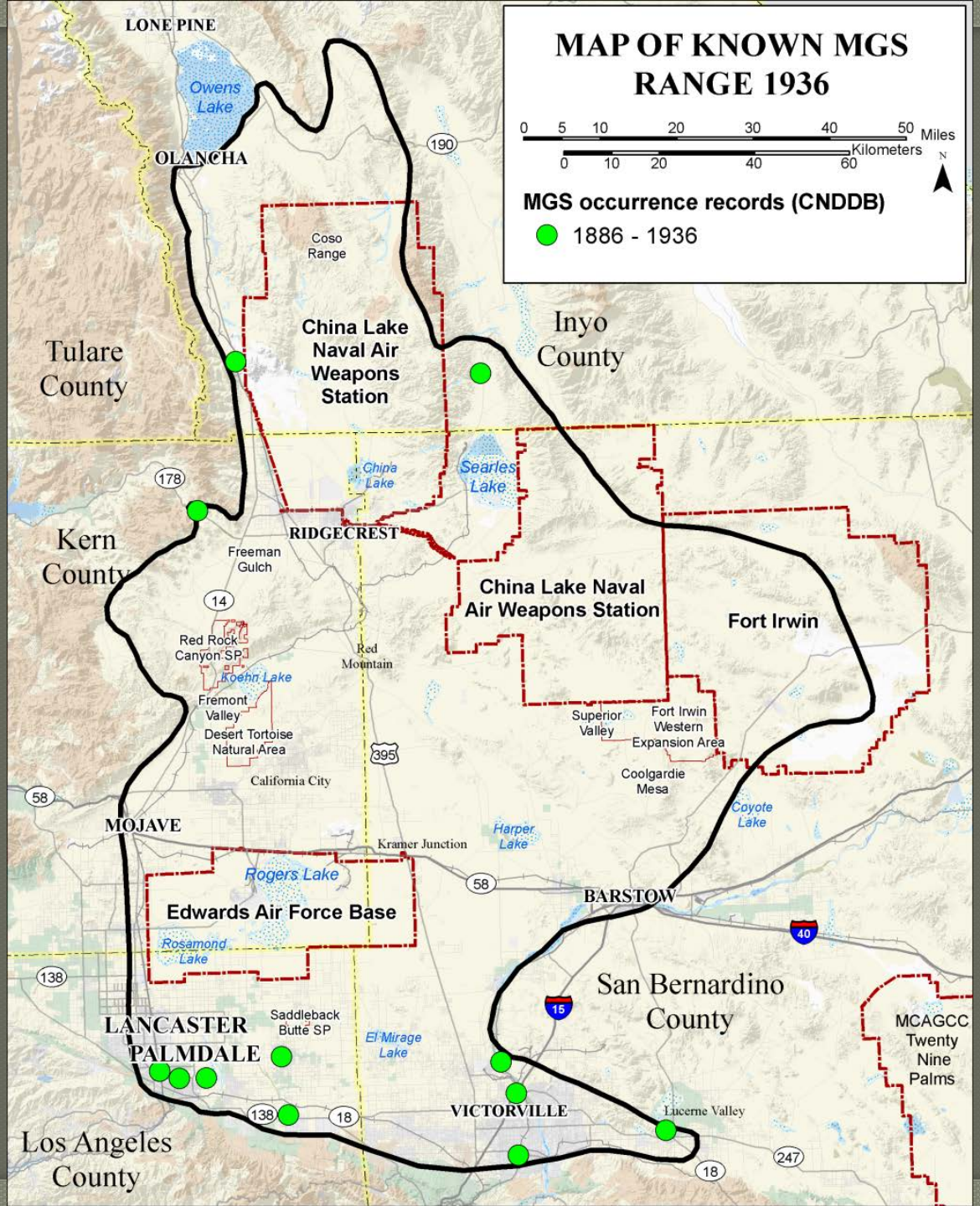
MAP OF KNOWN MGS RANGE 1936
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
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MGS occurrence records (CNDDB)
1886 - 1936
LONE PINE
Owens Lake
OLANCHA
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Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Fremont Valley
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Harper Lake
Kramer Junction
Rogers Lake
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BARSTOW
Edwards Air Force Base
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Rosamond Lake
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San Bernardino County
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LANCASTER
Saddleback Butte SP
El Mirage Lake
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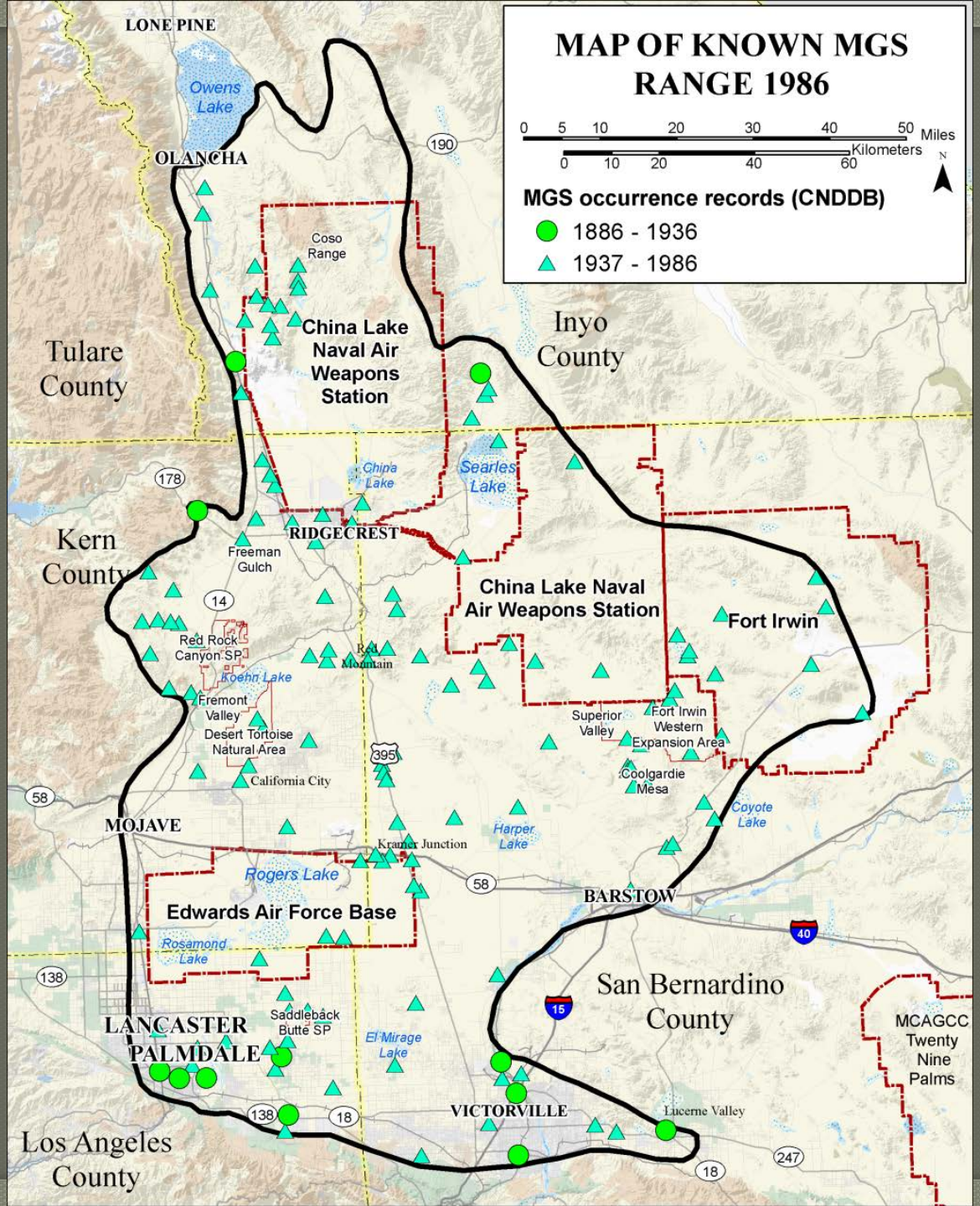
MAP OF KNOWN MGS RANGE 1986
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
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MGS occurrence records (CNDDB)
1886 - 1936
1937 - 1986
LONE PINE
Owens Lake
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Coso Range
China Lake Naval Air Weapons Station
Tulare County
Inyo County
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China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
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San Bernardino County
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Saddleback Butte SP
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MCAGCC Twenty Nine Palms
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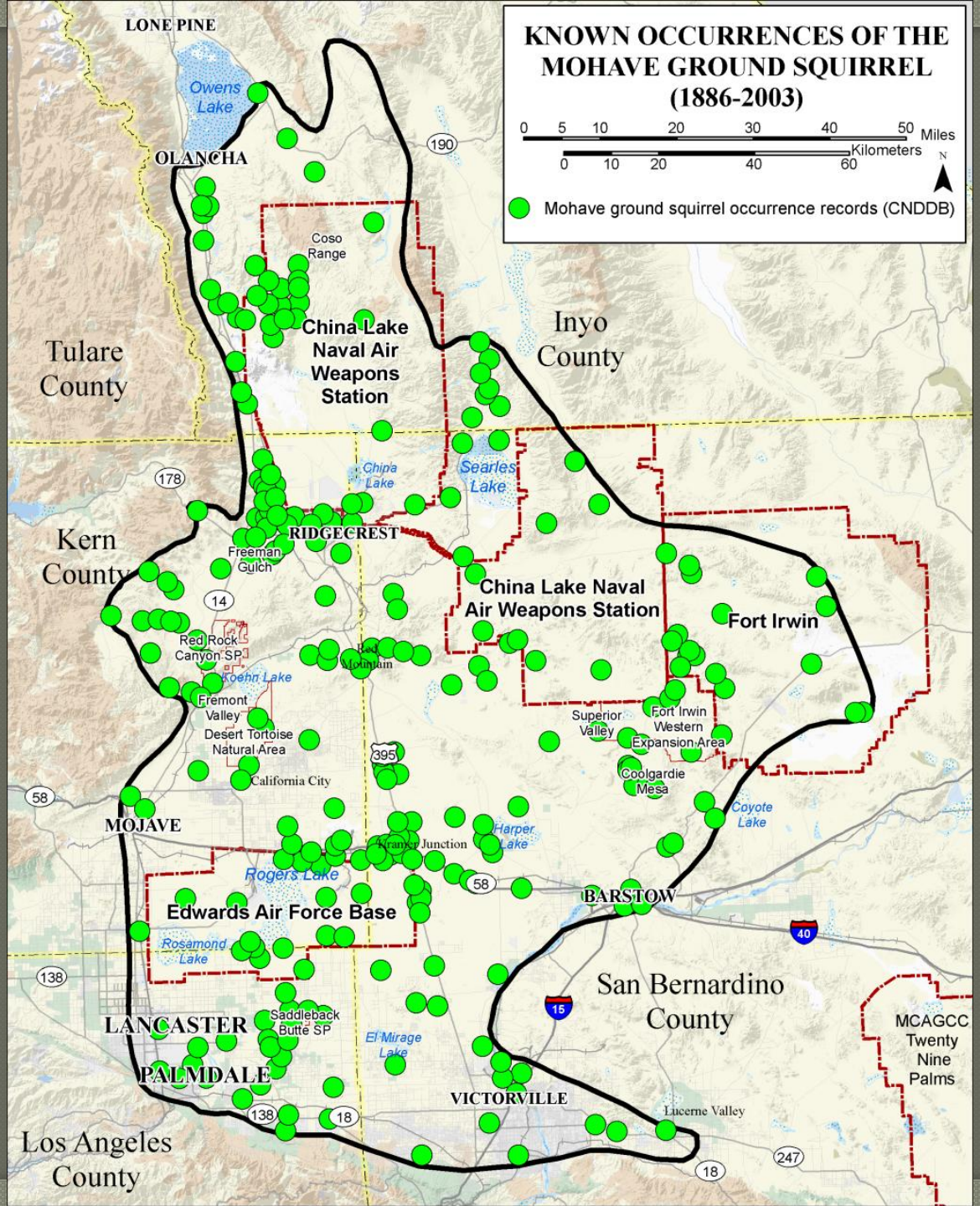
KNOWN OCCURRENCES OF THE MOHAVE GROUND SQUIRREL (1886-2003)
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Mohave ground squirrel occurrence records (CNDDB)
LONE PINE
Owens Lake
OLANCHA
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Coso Range
China Lake Naval Air Weapons Station
Tulare County
Inyo County
178
China Lake
Searles Lake
RIDGECREST
Freeman Gulch
Kern County
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Fremont Valley
Desert Tortoise Natural Area
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MOJAVE
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BARSTOW
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LANCASTER
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
138
18
Los Angeles County
18
247

Which Areas Are Most Important?

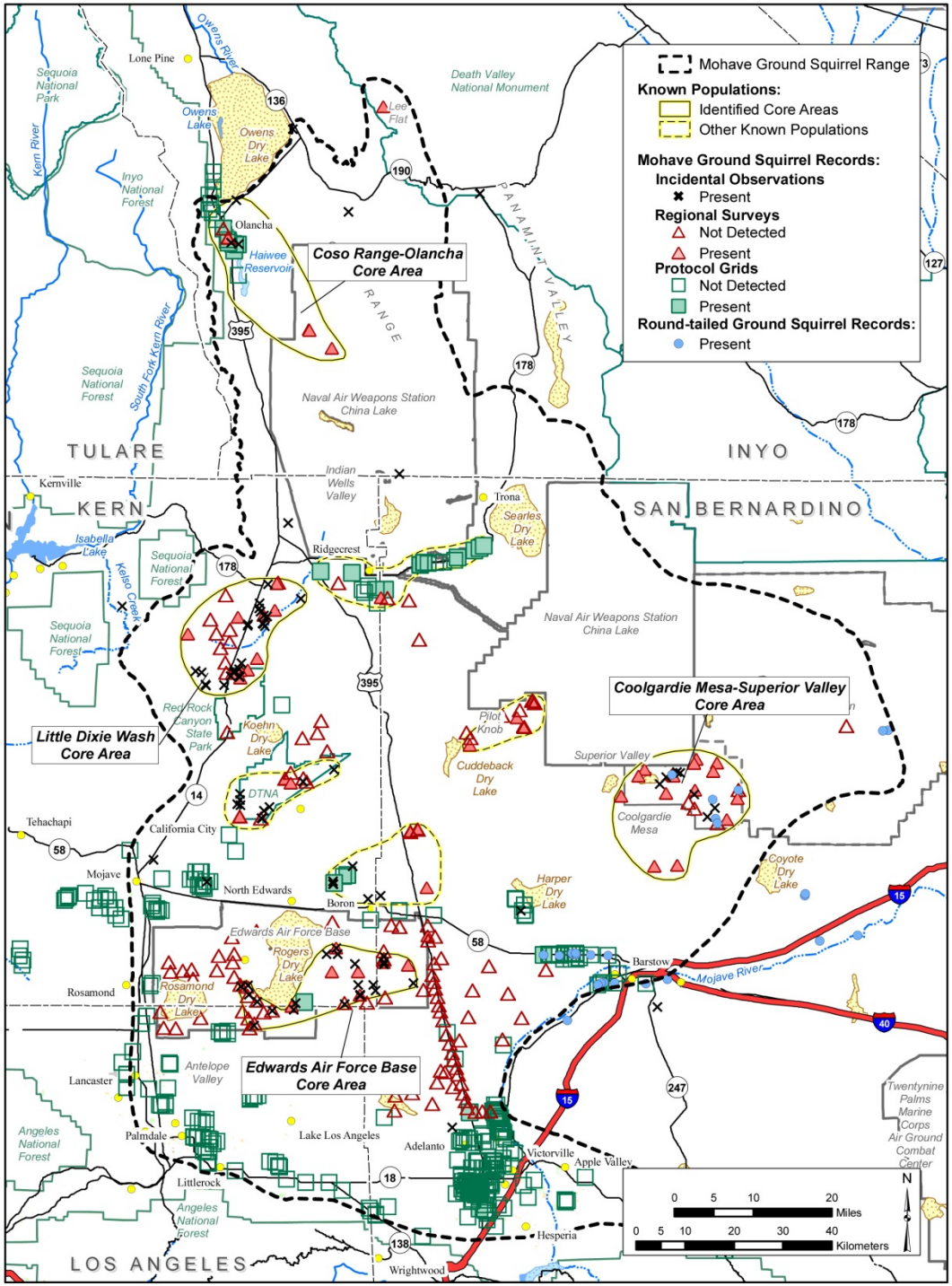
- Up to 2003, the records simply reflect where studies or incidental observations happened to be made
- There were no systematic or randomized range-wide surveys
- Areas with many detections were not necessarily excellent habitat and areas without detections may just not have been surveyed

Core Areas

- In a 2008 report on MGS status and distribution, I proposed 4 regions as important "core areas"
- Three criteria were used to define these core areas
  1) Evidence of persistence over time
  2) Presence at multiple locations
  3) Substantial numbers of adults

Four Proposed Core Areas

- Coso/Olancha – since 1978
- Little Dixie Wash – since 1931
- Coolgardie Mesa/Superior Valley – since 1977
- Edwards Air Force Base – since 1973
- Since 2000, MGS have been detected in each core area at 7-14 sites with total captures ranging from 33-241 individuals


Mohave Ground Squirrel Range
Known Populations:
Identified Core Areas
Other Known Populations
Mohave Ground Squirrel Records:
Incidental Observations
Present
Regional Surveys
Not Detected
Present
Protocol Grids
Not Detected
Present
Round-tailed Ground Squirrel Records:
Present
Coso Range-Olancha Core Area
Little Dixie Wash Core Area
Coolgardie Mesa-Superior Valley Core Area
Edwards Air Force Base Core Area
TULARE
KERN
INYO
SAN BERNARDINO
LOS ANGELES
Lone Pine
Owens Lake
Owens Dry Lake
Olancha
Haiwee Reservoir
Lee Flat
Death Valley National Monument
Sequoia National Park
Kern River
Inyo National Forest
Sequoia National Forest
South Fork Kern River
Naval Air Weapons Station China Lake
Indian Wells Valley
Kernville
Isabella Lake
Kelso Creek
Ridgecrest
Trona
Searles Dry Lake
Red Rock Canyon State Park
Koehn Dry Lake
DTNA
Pilot Knob
Cuddeback Dry Lake
Superior Valley
Coolgardie Mesa
Coyote Dry Lake
Tehachapi
California City
Mojave
North Edwards
Boron
Harper Dry Lake
Edwards Air Force Base
Rogers Dry Lake
Rosamond Dry Lake
Rosamond
Barstow
Mojave River
Lancaster
Antelope Valley
Palmdale
Lake Los Angeles
Adelanto
Victorville
Apple Valley
Hesperia
Littlerock
Wrightwood
Angeles National Forest
Twentynine Palms Marine Corps Air Ground Combat Center
Owens River
Death Valley National Monument
0 5 10 20 Miles
0 5 10 20 30 40 Kilometers
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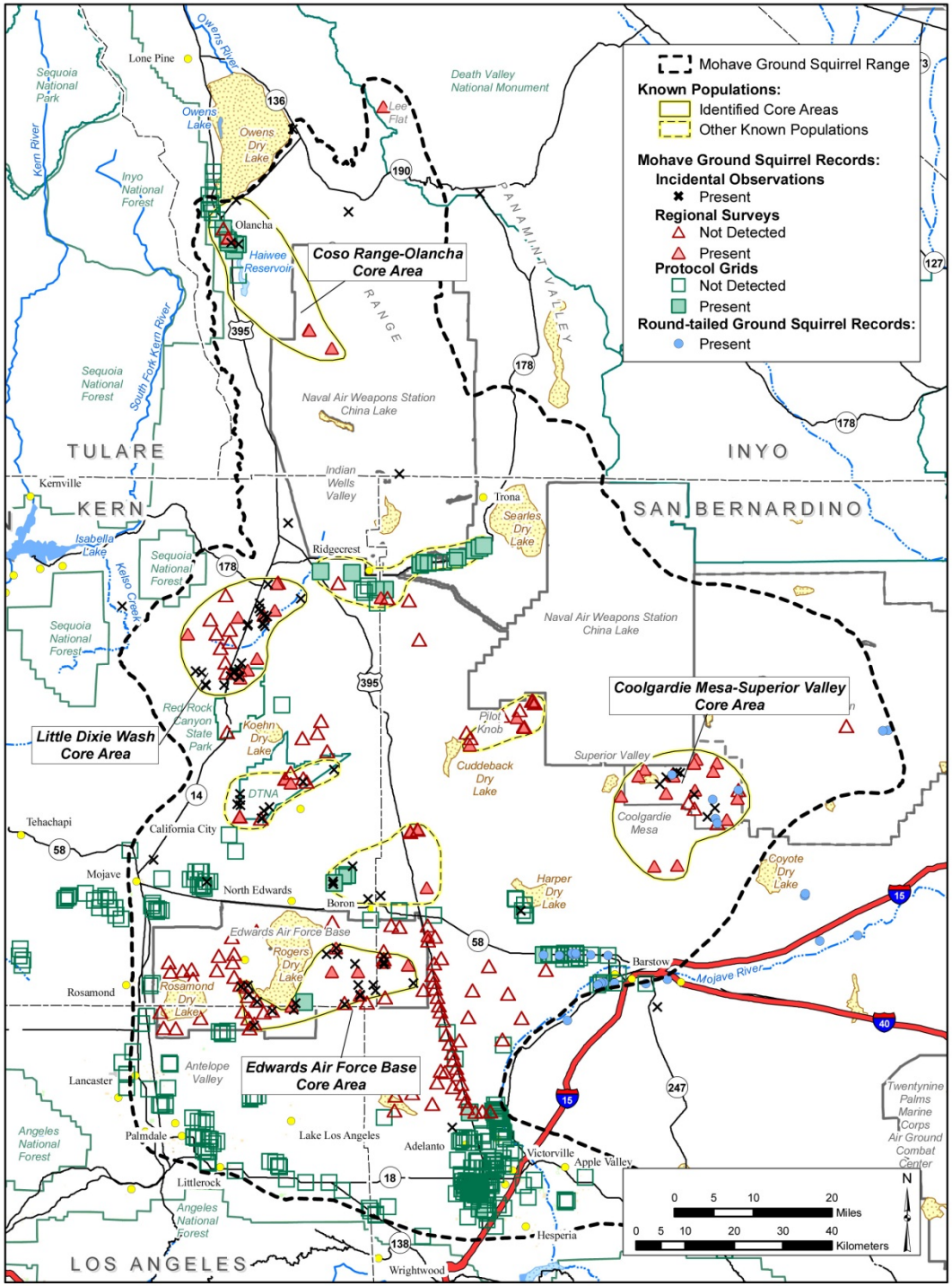
Other MGS Populations

- The 2008 status report also identified 4 other areas that recent data showed supported MGS populations
- However, they didn't meet all the criteria for core areas
- Since 2008, surveys have shown other areas within the range to be occupied
- At the same time, there are large areas with no evidence of recent MGS presence


Mohave Ground Squirrel Range
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Mohave Ground Squirrel Records:
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Not Detected
Present
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Round-tailed Ground Squirrel Records:
Present
Coso Range-Olancha Core Area
Little Dixie Wash Core Area
Coolgardie Mesa-Superior Valley Core Area
Edwards Air Force Base Core Area
TULARE
KERN
INYO
SAN BERNARDINO
LOS ANGELES
Lone Pine
Owens Lake
Owens Dry Lake
Olancha
Haiwee Reservoir
Lee Flat
Death Valley National Monument
Sequoia National Park
Kern River
Inyo National Forest
Sequoia National Forest
South Fork Kern River
Naval Air Weapons Station China Lake
Indian Wells Valley
Kernville
Isabella Lake
Kelso Creek
Ridgecrest
Trona
Searles Dry Lake
Red Rock Canyon State Park
Koehn Dry Lake
DTNA
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Superior Valley
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Coyote Dry Lake
Tehachapi
California City
Mojave
North Edwards
Boron
Harper Dry Lake
Edwards Air Force Base
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Rosamond Dry Lake
Rosamond
Barstow
Mojave River
Lancaster
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Littlerock
Wrightwood
Angeles National Forest
Twentynine Palms Marine Corps Air Ground Combat Center
Owens River
Death Valley National Monument
0 5 10 20 Miles
0 5 10 20 30 40 Kilometers
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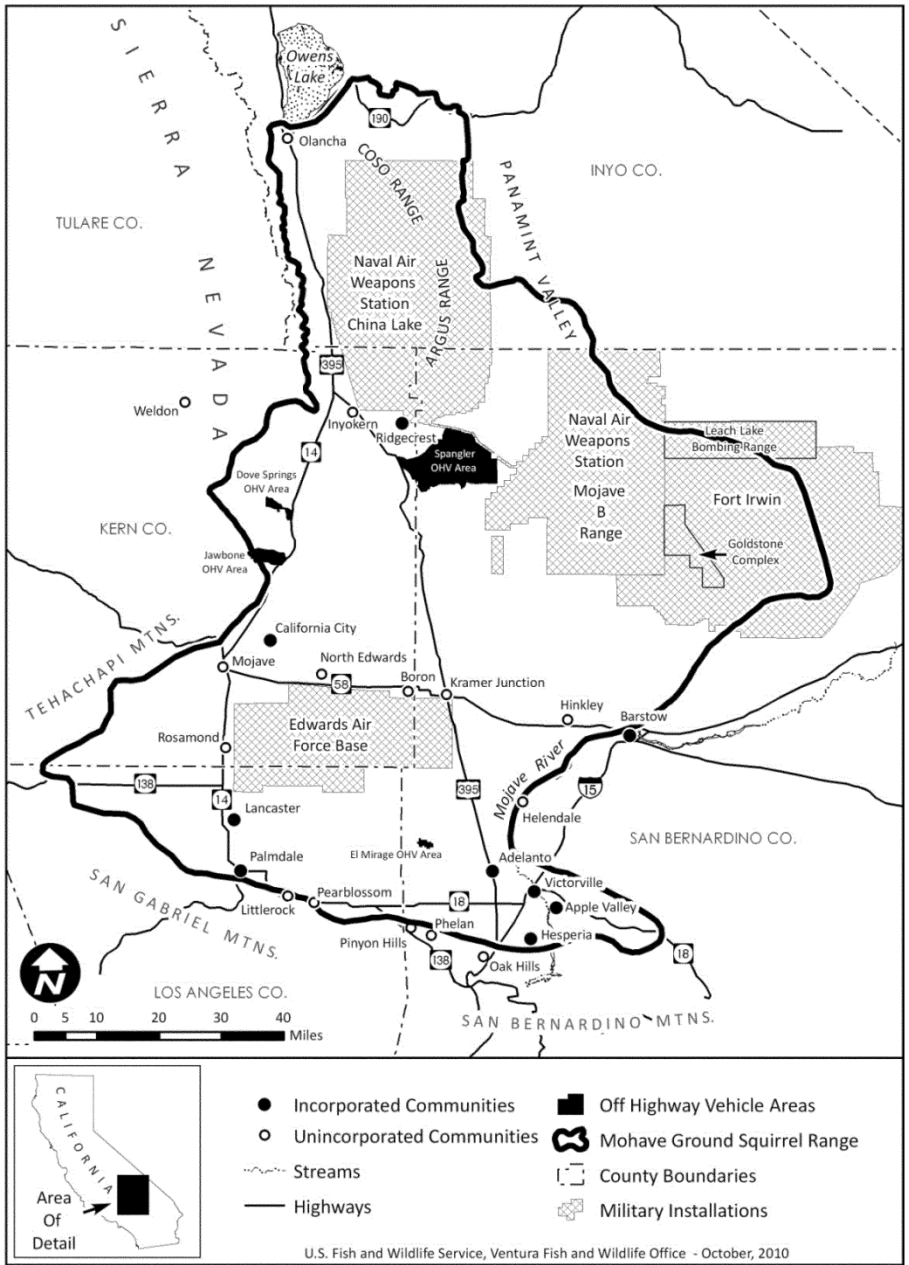
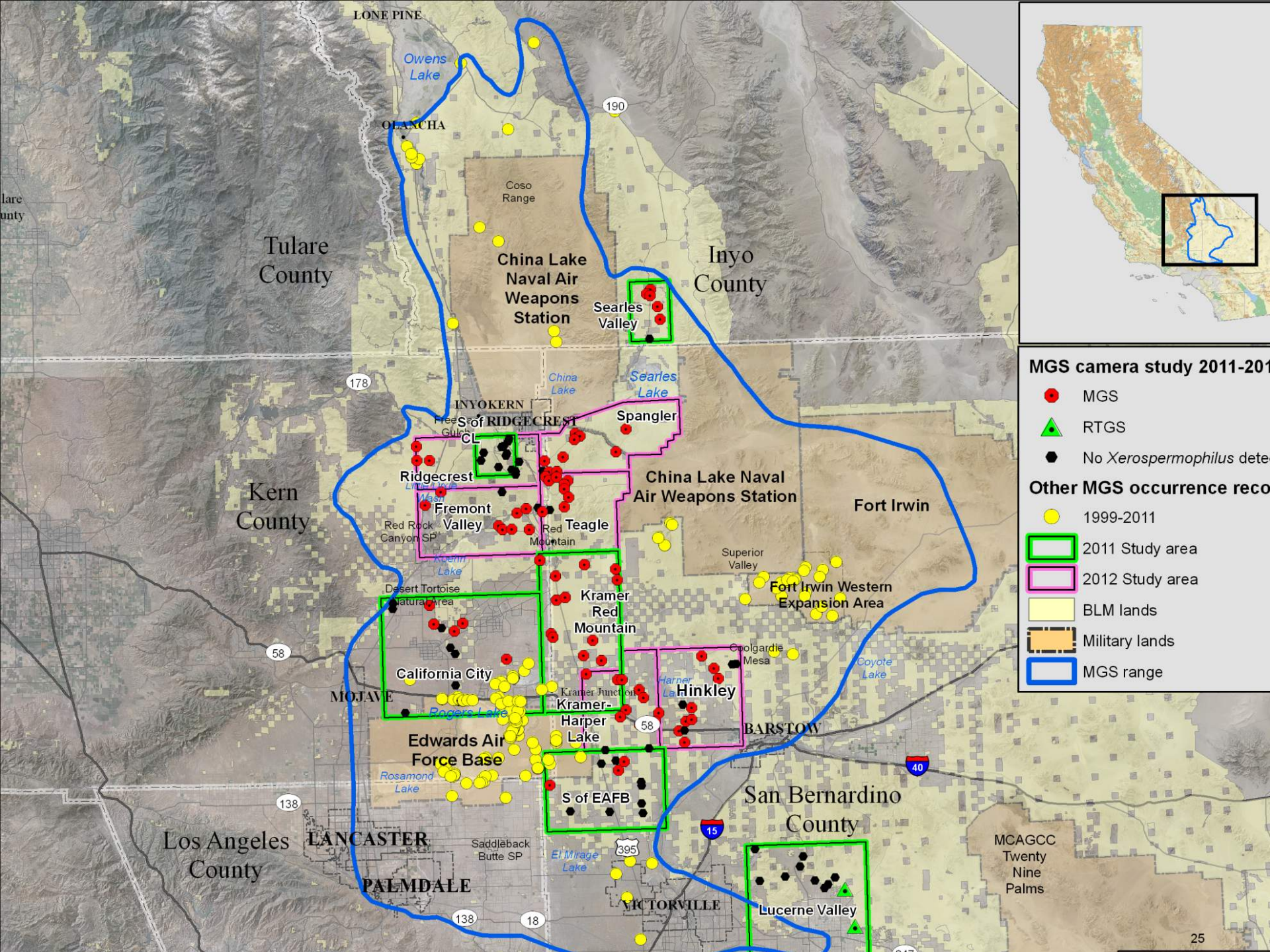
Map 1. Place names, major roads, military bases, and off-highway vehicle areas in the range of the Mohave ground squirrel (calculated by the Service).




MGS camera study 2011-201
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RTGS
No Xerospermophilus dete
Other MGS occurrence reco
1999-2011
2011 Study area
2012 Study area
BLM lands
Military lands
MGS range
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Owens Lake
OLANCHA
Coso Range
China Lake Naval Air Weapons Station
Searles Valley
Tulare County
Inyo County
Kern County
China Lake
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Ridgecrest
Fremont Valley
Red Rock Canyon SP
Teagle
Red Mountain
China Lake Naval Air Weapons Station
Fort Irwin
Superior Valley
Fort Irwin Western Expansion Area
Desert Tortoise Natural Area
Kramer Red Mountain
California City
MOJAVE
Rogers Lake
Kramer Junction
Kramer-Harper Lake
Harper Lake
Hinkley
Coolgardie Mesa
Coyote Lake
BARSTOW
Edwards Air Force Base
Rosamond Lake
S of EAFB
San Bernardino County
Los Angeles County
LANCASTER
Saddleback Butte SP
El Mirage Lake
PALMDALE
VICTORVILLE
Lucerne Valley
MCAGCC Twenty Nine Palms
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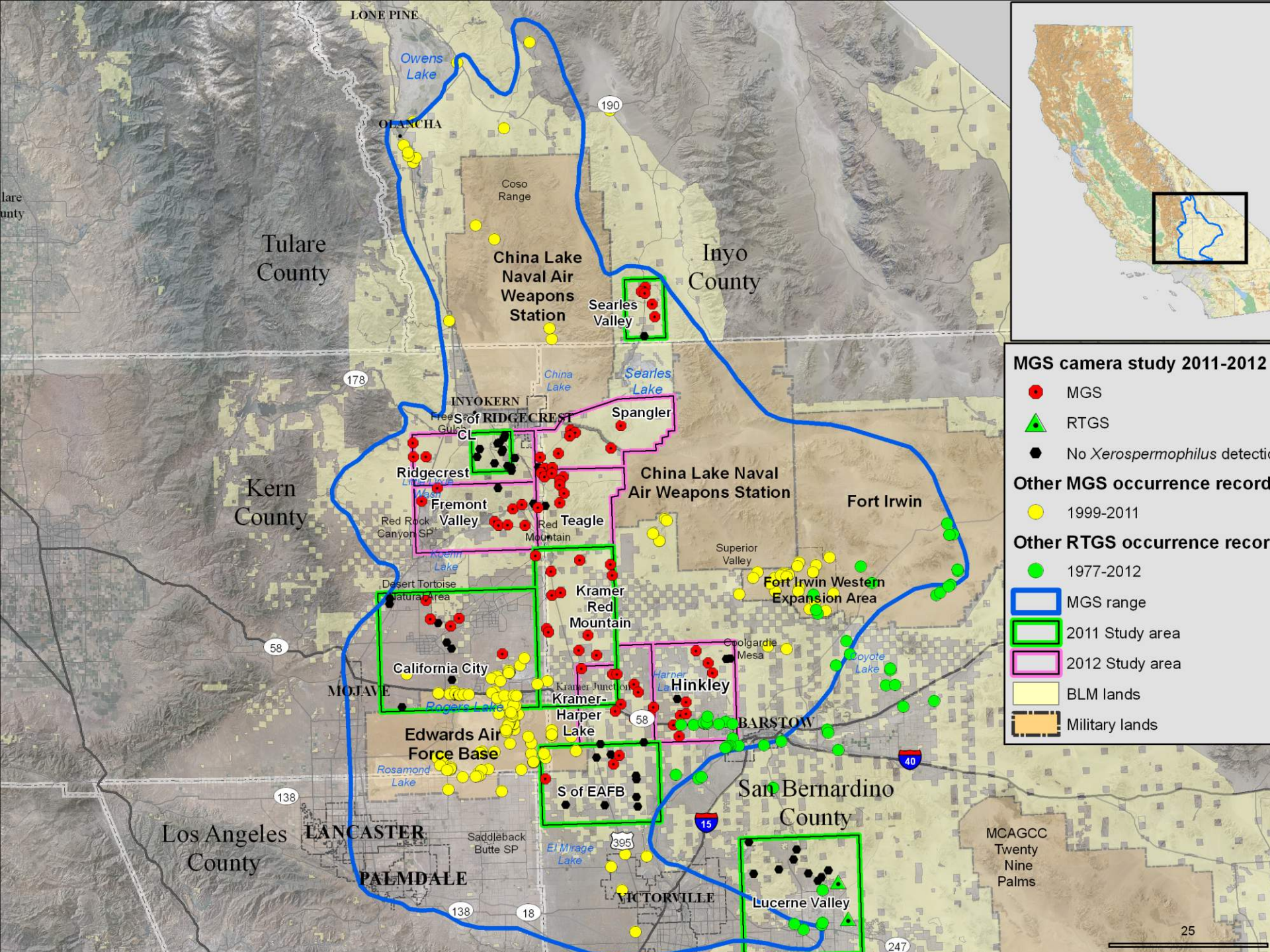
LONE PINE
Owens Lake
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Coso Range
Tulare County
China Lake Naval Air Weapons Station
Searles Valley
Inyo County
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China Lake
Searles Lake
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Fremont Valley
Red Rock Canyon SP
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Rogers Lake
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Rosamond Lake
S of EAFB
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138
Los Angeles County
LANCASTER
Saddleback Butte SP
El Mirage Lake
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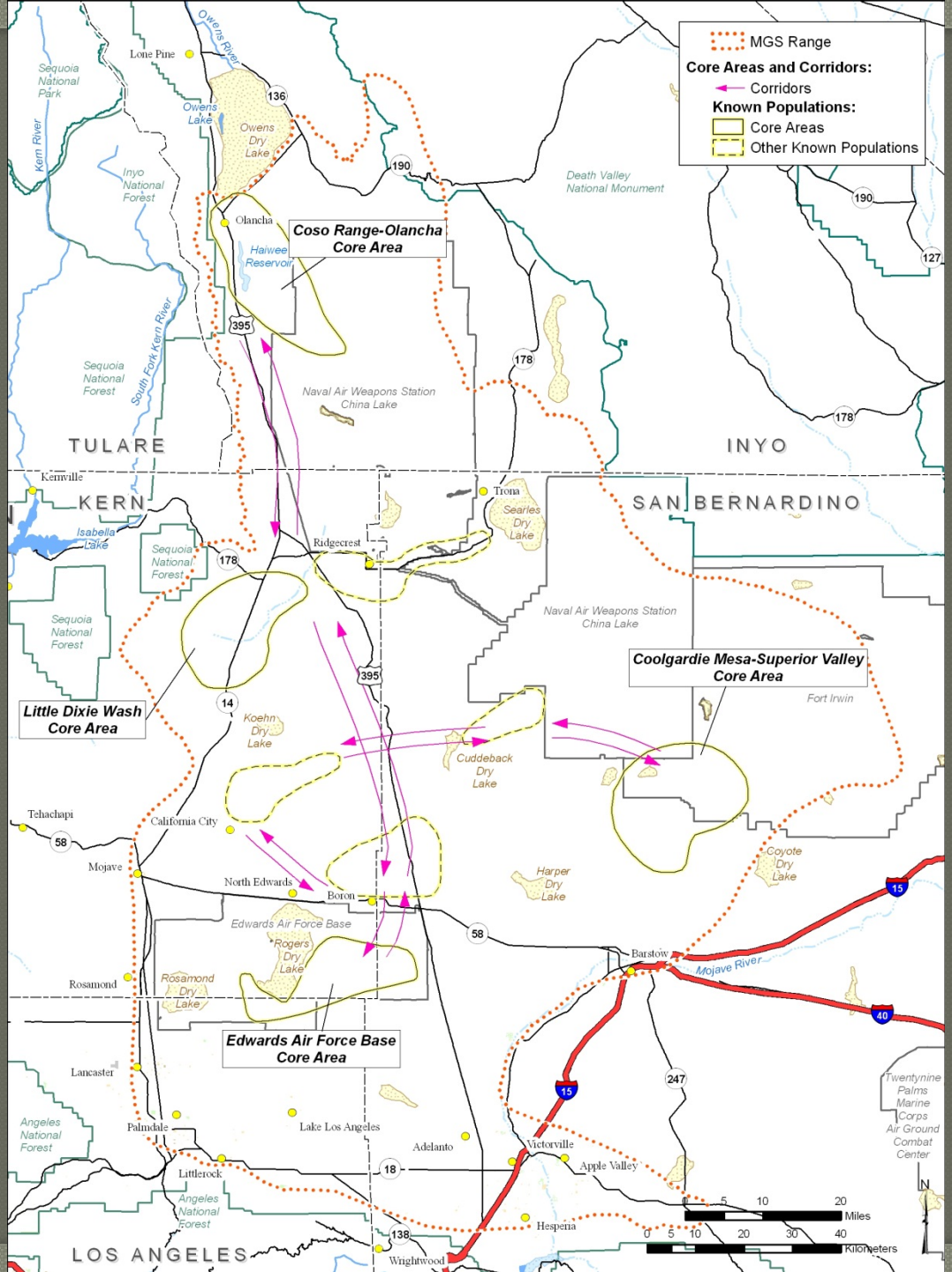
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
18
247
25
MGS camera study 2011-2012
MGS
RTGS
No Xerospermophilus detecti
Other MGS occurrence record
1999-2011
Other RTGS occurrence recor
1977-2012
MGS range
2011 Study area
2012 Study area
BLM lands
Military lands

Connections Between Known Populations

- The 8 populations recognized in 2008 are more or less separated
- An important conservation goal should be to avoid fragmentation and ensure connectivity
- Here is a hypothetical scheme for connectivity – does it match reality?


MGS Range
Core Areas and Corridors:
Corridors
Known Populations:
Core Areas
Other Known Populations
Coso Range-Olancha Core Area
Coolgardie Mesa-Superior Valley Core Area
Little Dixie Wash Core Area
Edwards Air Force Base Core Area
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Koehn Dry Lake
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Fort Irwin
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California City
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Adelanto
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Apple Valley
Hesperia
Littlerock
Angeles National Forest
Wrightwood
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Miles
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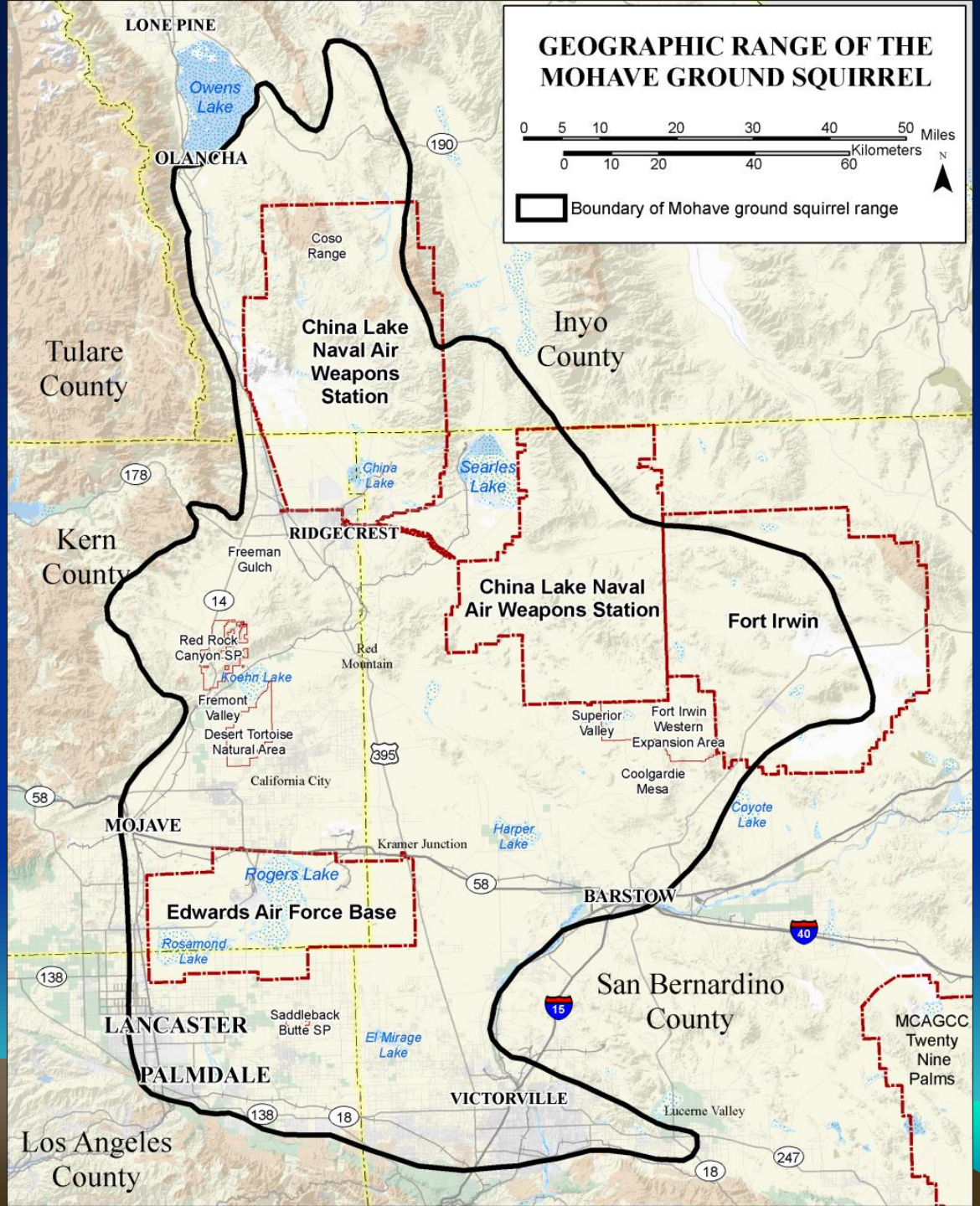
MOHAVE GROUND SQUIRREL

Natural History and Ecology


GEOGRAPHIC RANGE OF THE MOHAVE GROUND SQUIRREL
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0 10 20 40 60 Kilometers
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Boundary of Mohave ground squirrel range
LONE PINE
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Saddleback Butte SP
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MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
138
18
Los Angeles County
247
18

Habitat

- Fine-textured soils suitable for burrowing are found on alluvial surfaces
- MGS are typically found on alluvial fans, bajadas, and in basins and valleys
- They tend to avoid steep, rocky slopes
- MGS occur in all major plant communities of the Western Mojave Desert

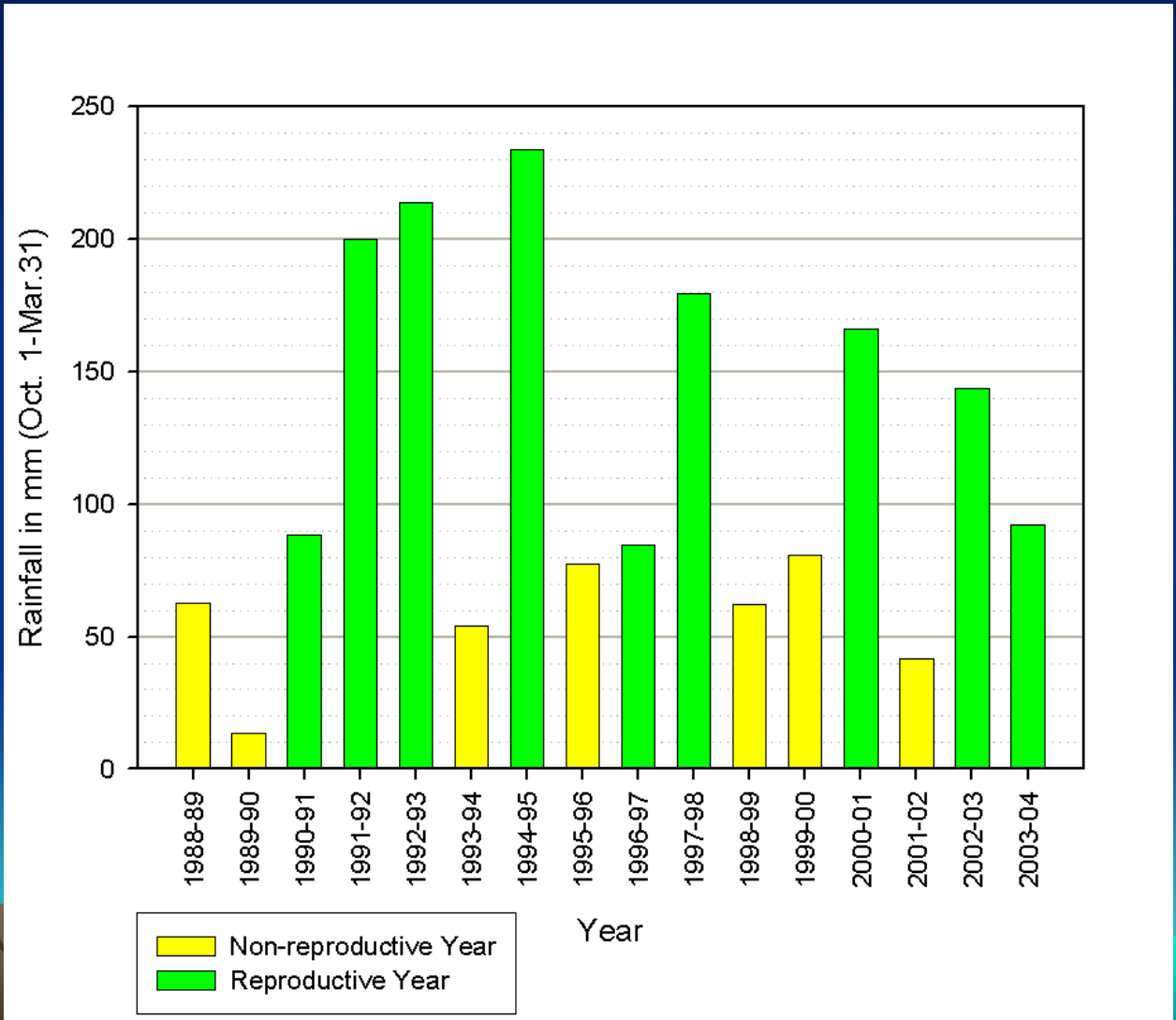
MGS And Major Plant Communities

Plant Community	Number and % MGS Occurrences	% Community Within MGS Range
Creosote Bush Scrub	136 / 54%	54%
Saltbush Scrub	50 / 20%	20%
Mixed Woody Scrub	22 / 9%	9%
Blackbrush Scrub	4 / 2%	2%

Winter Rainfall Desert

- Western Mojave Desert receives most of its rainfall in the winter
- The MGS depends on good production of spring forbs for reproduction
- If winter rainfall and forb production isn't sufficient, no reproduction
- Threshold for reproduction is ~75-80 mm of winter rain

Winter Rainfall And Reproduction At Coso Sites



Annual Cycle

- Mohave ground squirrels are typically active above ground from February to July
- In general, they spend 6 months per year underground in physiological dormancy
- This state has been called both estivation and hibernation, depending on what time of year is under discussion
- Dormancy is probably a good general term

The Timetable in a Reproductive Year

- Males emerge in first-half of February and females about 2 weeks later
- Mating occurs in late Feb-early Mar and young are born in late Mar-early Apr
- Young appear above-ground by late Apr-early May
- Then everyone tries to prepare for dormancy by getting fat

The Schedule in a Dry Year

- Males and females emerge on the normal schedule
- It’s not clear when or how the decision not to reproduce is made, but by late Mar it’s obvious
- At that point the adults try to put on as much fat as possible in preparation for dormancy
- Males may immerge in May and females in June

Diet

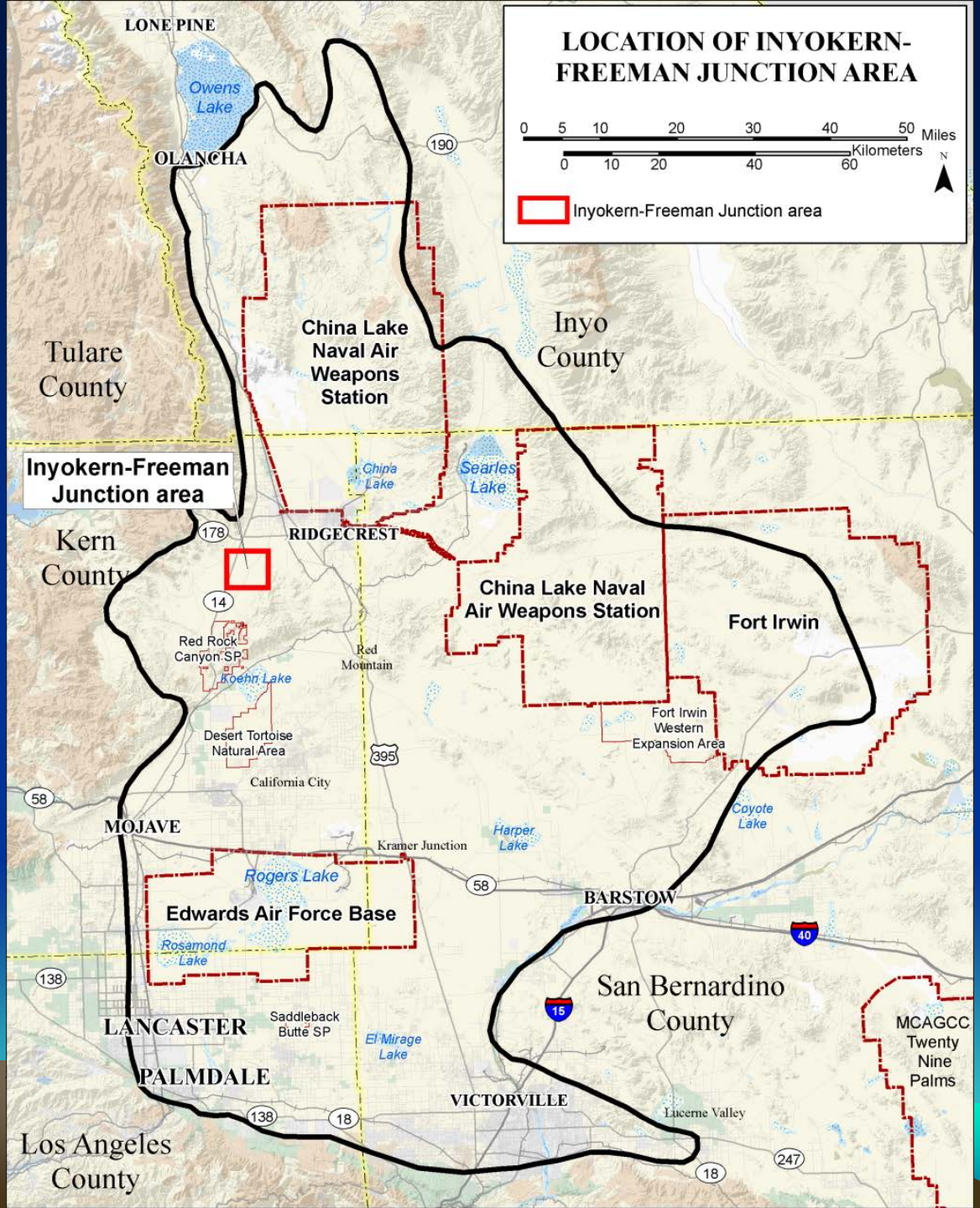
- Mohave ground squirrels feed almost entirely on plant material
- They utilize a number of species of herbaceous and perennial plants
- They feed on foliage, flowers, and seeds
- Diet shifts during the active season, as different resources become available

Coso Diet Results

- Samples from 4 sites, from spring and early summer, over 9 year period
- 77 identifiable food items recorded
- Plant materials made up >95% of diet
- Shrub leaf 45%, forbs 45%, grass 5%, insects <5%

Home Range and Dispersal

- HR for adult females is ~1-2 ha
- HR for adult males can be up to 100 ha in the breeding season (Feb-Mar)
- Juvenile dispersal occurs in late May-early June and is male-biased
- Although more young males move long distances, some females disperse up to 4-6 km


LOCATION OF INYOKERN-FREEMAN JUNCTION AREA
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Inyokern-Freeman Junction area
LONE PINE
Owens Lake
OLANCHA
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Tulare County
China Lake Naval Air Weapons Station
Inyo County
Inyokern-Freeman Junction area
China Lake
Searles Lake
178
RIDGECREST
Kern County
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China Lake Naval Air Weapons Station
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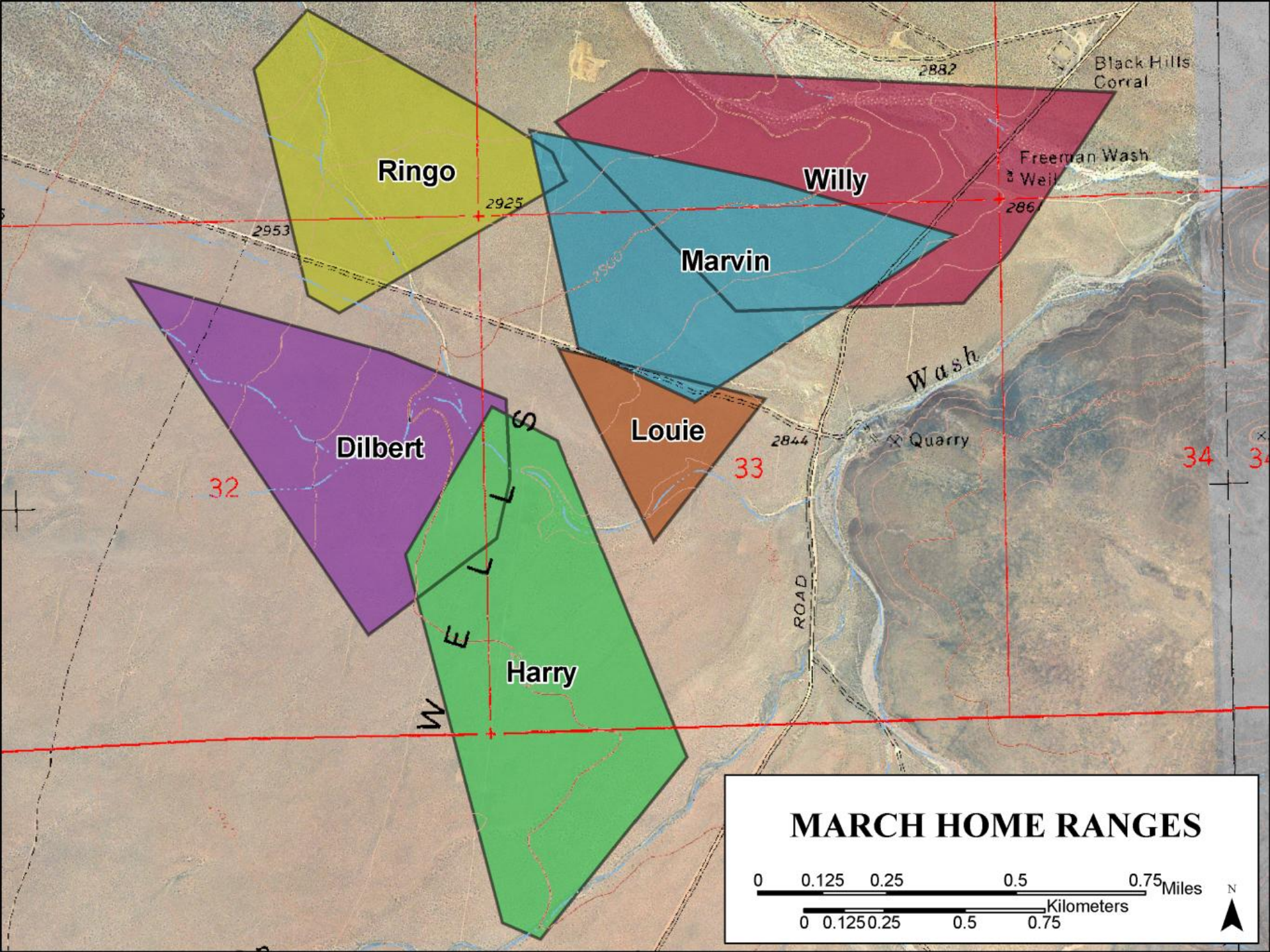
Ringo
Willy
Marvin
Dilbert
Louie
Harry
WELLS
Black Hills Corral
Freeman Wash
Wash
Quarry
ROAD
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MARCH HOME RANGES
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0 0.125 0.25 0.5 0.75 Kilometers
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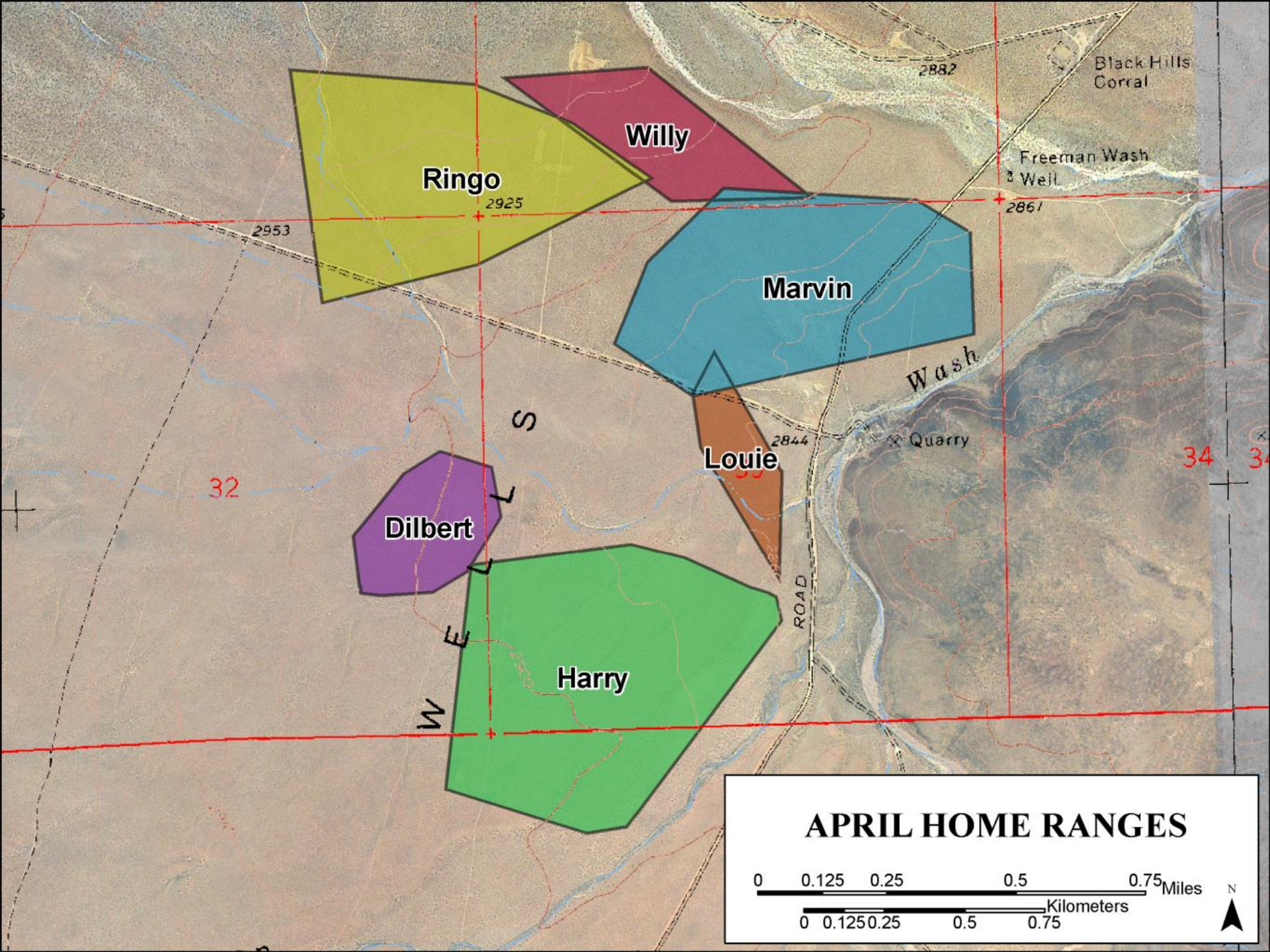
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Marvin
Louie
Dilbert
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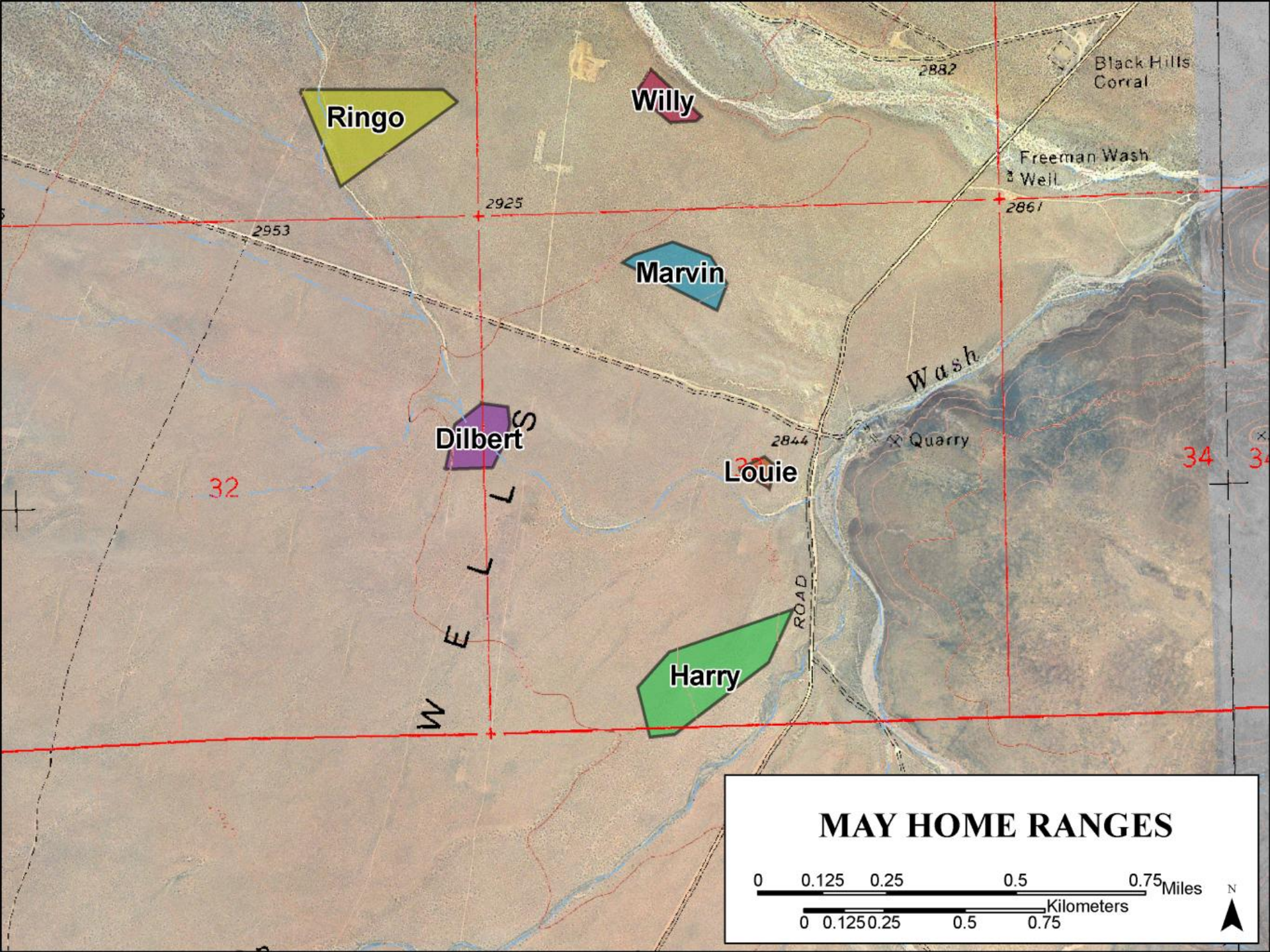
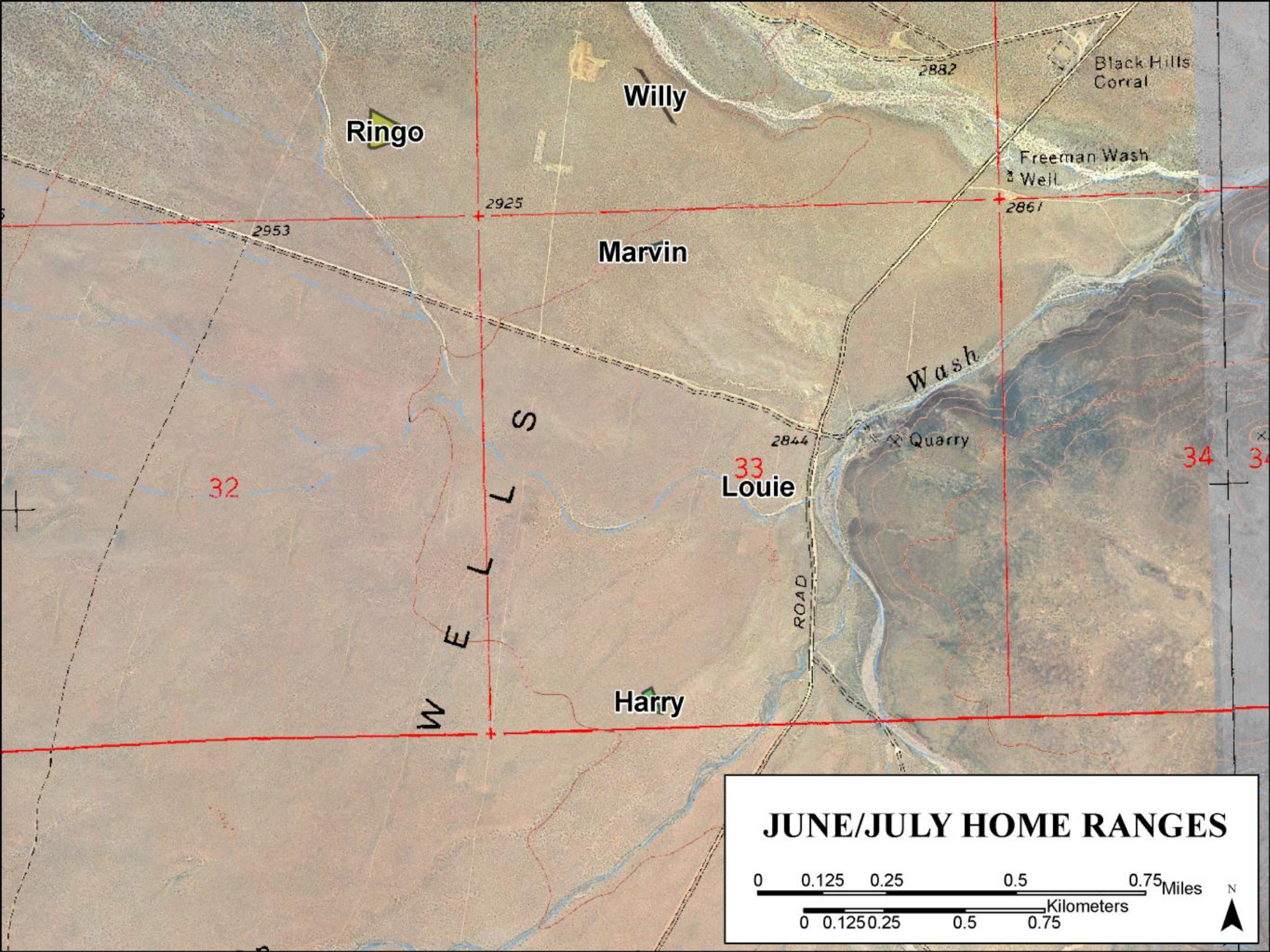
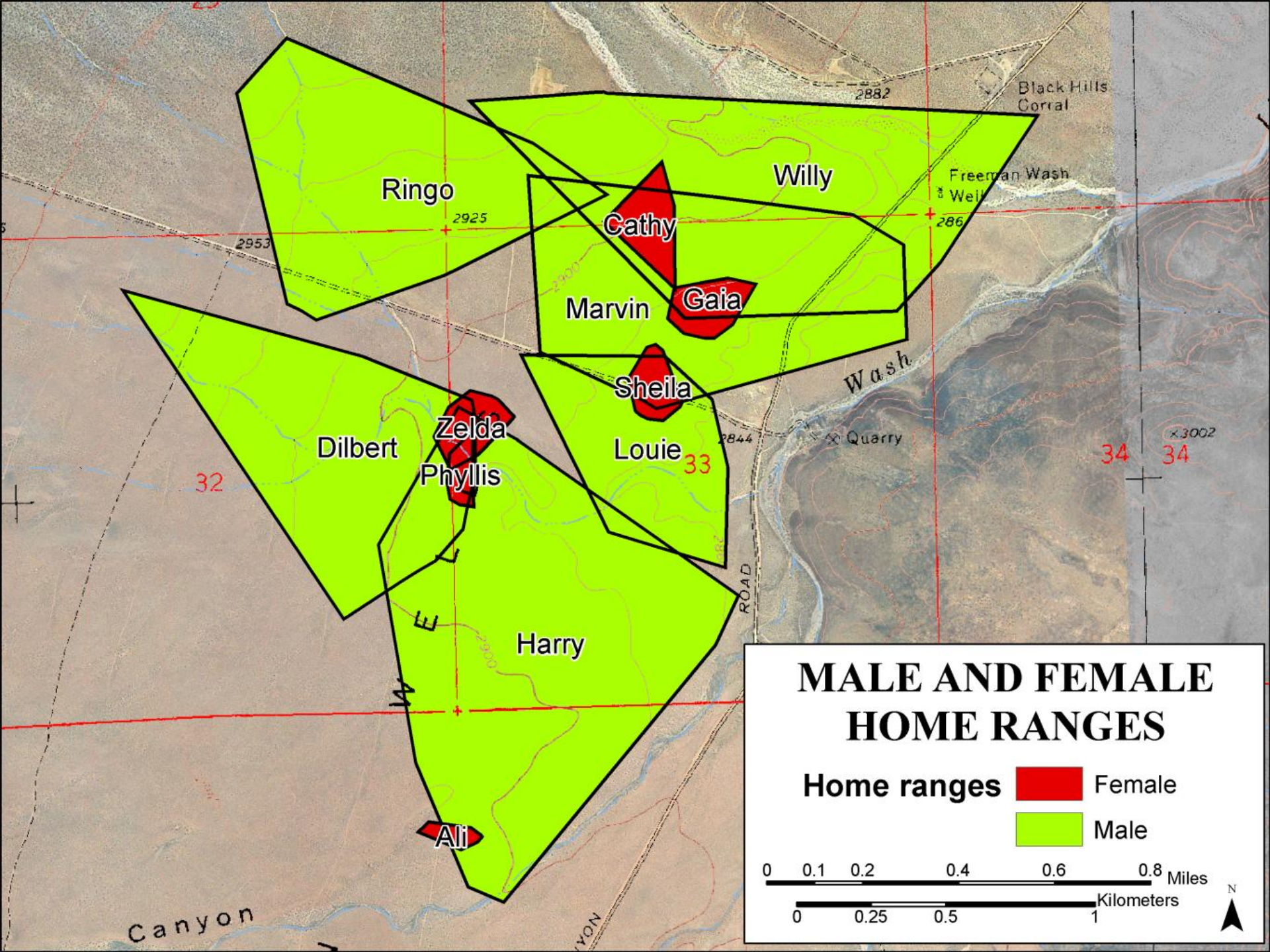
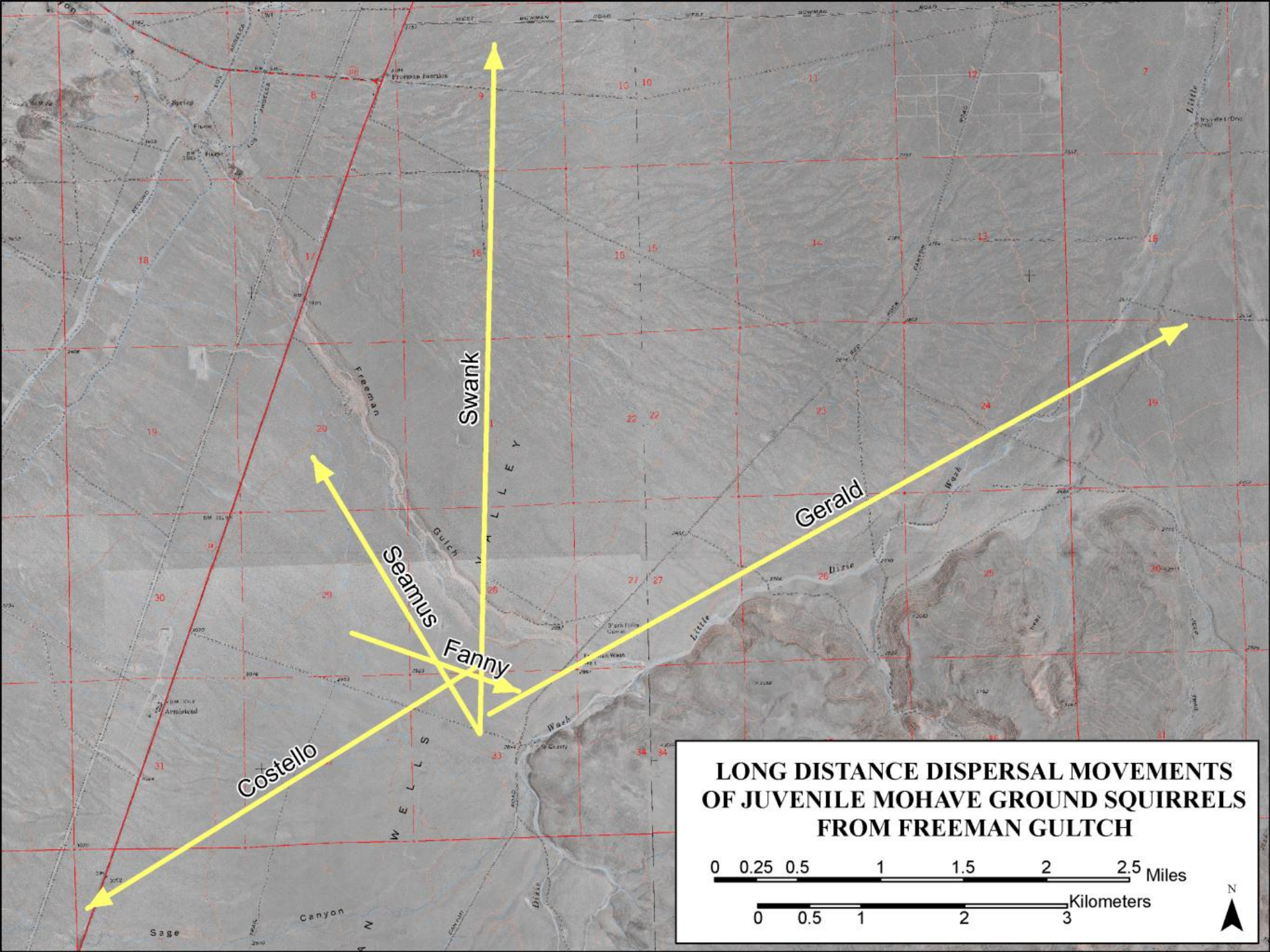
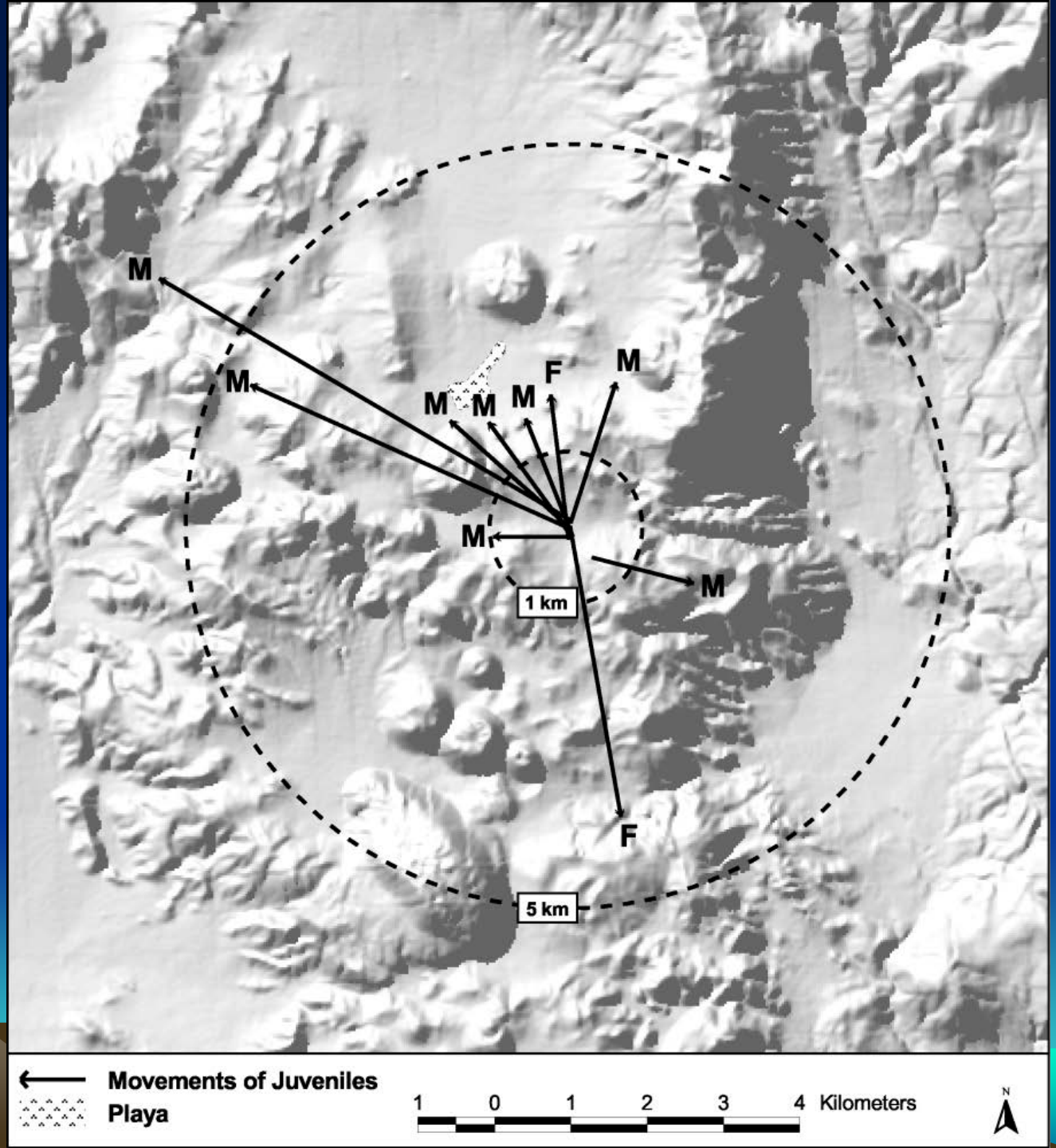
Black Hills Corral
Freeman Wash
Well
Wash
Quarry
ROAD
WELLS
32
34
APRIL HOME RANGES
0 0.125 0.25 0.5 0.75 Miles
0 0.125 0.25 0.5 0.75 Kilometers
N


Ringo
Willy
Marvin
Dilbert
Louie
Harry
Black Hills Corral
Freeman Wash
Well
Wash
Quarry
WELLS
ROAD
2882
2925
2953
2861
2844
32
34
MAY HOME RANGES
0 0.125 0.25 0.5 0.75 Miles
0 0.125 0.25 0.5 0.75 Kilometers
N


Ringo
Willy
Marvin
Louie
Harry
Black Hills Corral
Freeman Wash
Well
Quarry
Wash
WELLS
ROAD
2882
2925
2953
2861
2844
32
33
34
JUNE/JULY HOME RANGES
0 0.125 0.25 0.5 0.75 Miles
0 0.125 0.25 0.5 0.75 Kilometers
N


MALE AND FEMALE HOME RANGES
Home ranges
Female
Male
0 0.1 0.2 0.4 0.6 0.8 Miles
0 0.25 0.5 1 Kilometers
N
Ringo
Willy
Cathy
Gaia
Marvin
Sheila
Zelda
Phyllis
Dilbert
Louie
Harry
Ali
Black Hills Corral
Freeman Wash
Well
Quarry
Wash
ROAD
Canyon
2882
2925
2953
2844
3002
32
33
34
34

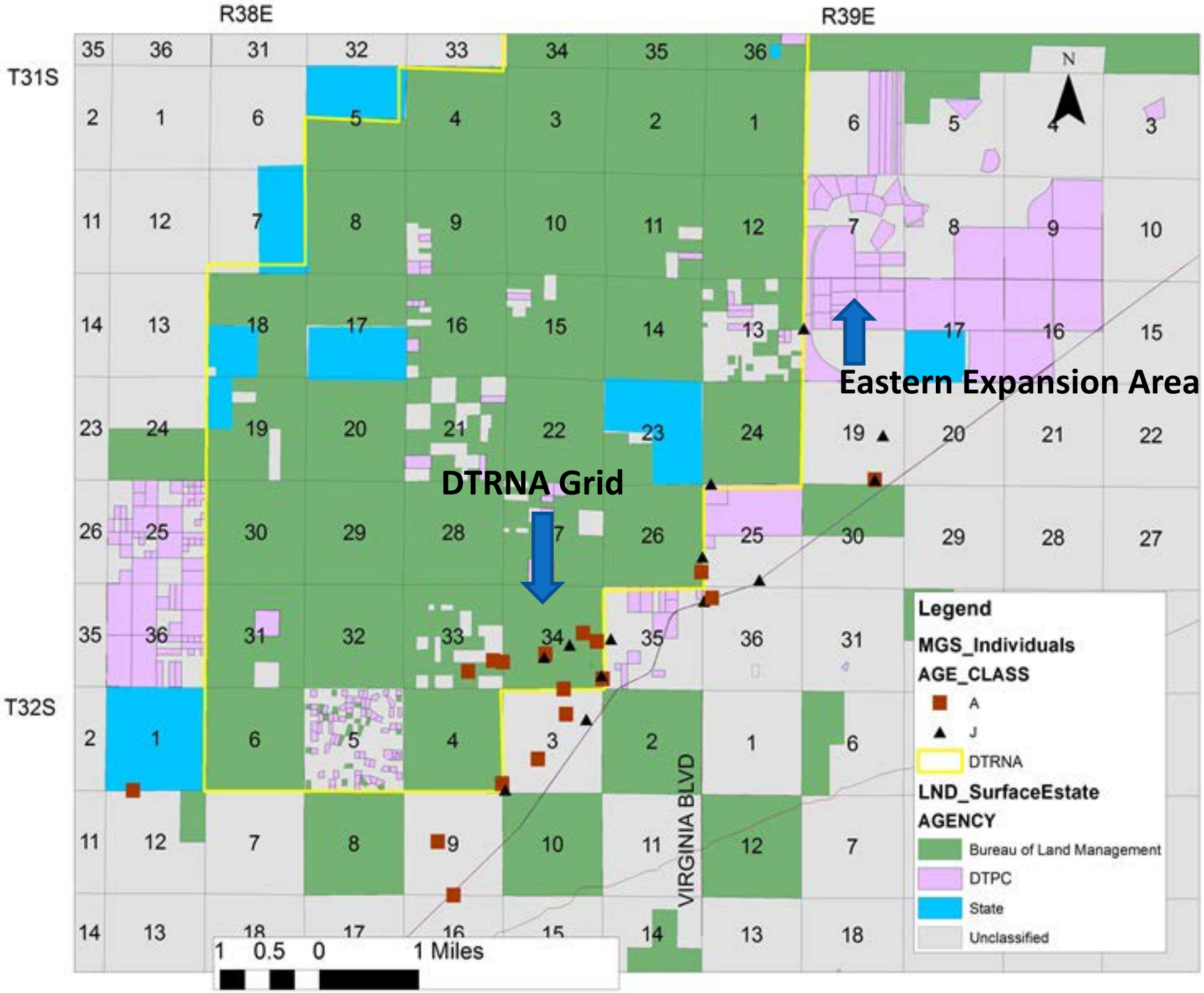

LONG DISTANCE DISPERSAL MOVEMENTS
OF JUVENILE MOHAVE GROUND SQUIRRELS
FROM FREEMAN GULTCH
0 0.25 0.5 1 1.5 2 2.5 Miles
0 0.5 1 2 3 Kilometers
N
Swank
Gerald
Seamus
Fanny
Costello
Freeman
Gulch
Dixie
Little
Wash
Canyon
Sage
WELLS
VALLEY


M
M
M
M
M
F
M
M
M
1 km
F
5 km
Movements of Juveniles
Playa
1 0 1 2 3 4 Kilometers
N

Mohave Ground Squirrel Occupancy Pilot Study: Spring 2012

2012 Study Objectives

- Preliminary estimates of occupancy and detection probability
- Comparison of different survey methods
- Relate occupancy to habitat characteristics


R38E
R39E
T31S
T32S
N
Eastern Expansion Area
DTRNA Grid
VIRGINIA BLVD
Legend
MGS_Individuals
AGE_CLASS
A
J
DTRNA
LND_SurfaceEstate
AGENCY
Bureau of Land Management
DTPC
State
Unclassified
1 0.5 0 1 Miles

Methods

- Grids composed of 100, 150 m x 150 m cells in the DTRNA and Eastern Expansion Area
- Camera-trapping and point counts conducted in 48 randomly selected cells in each grid
- 4 walking transects conducted through entire grids
- Habitat data collected at each sampled cell

- Cameras 5 inches above ground
- Bait enclosure 4 – 5 feet from camera
- Cameras checked every 3 – 5 days

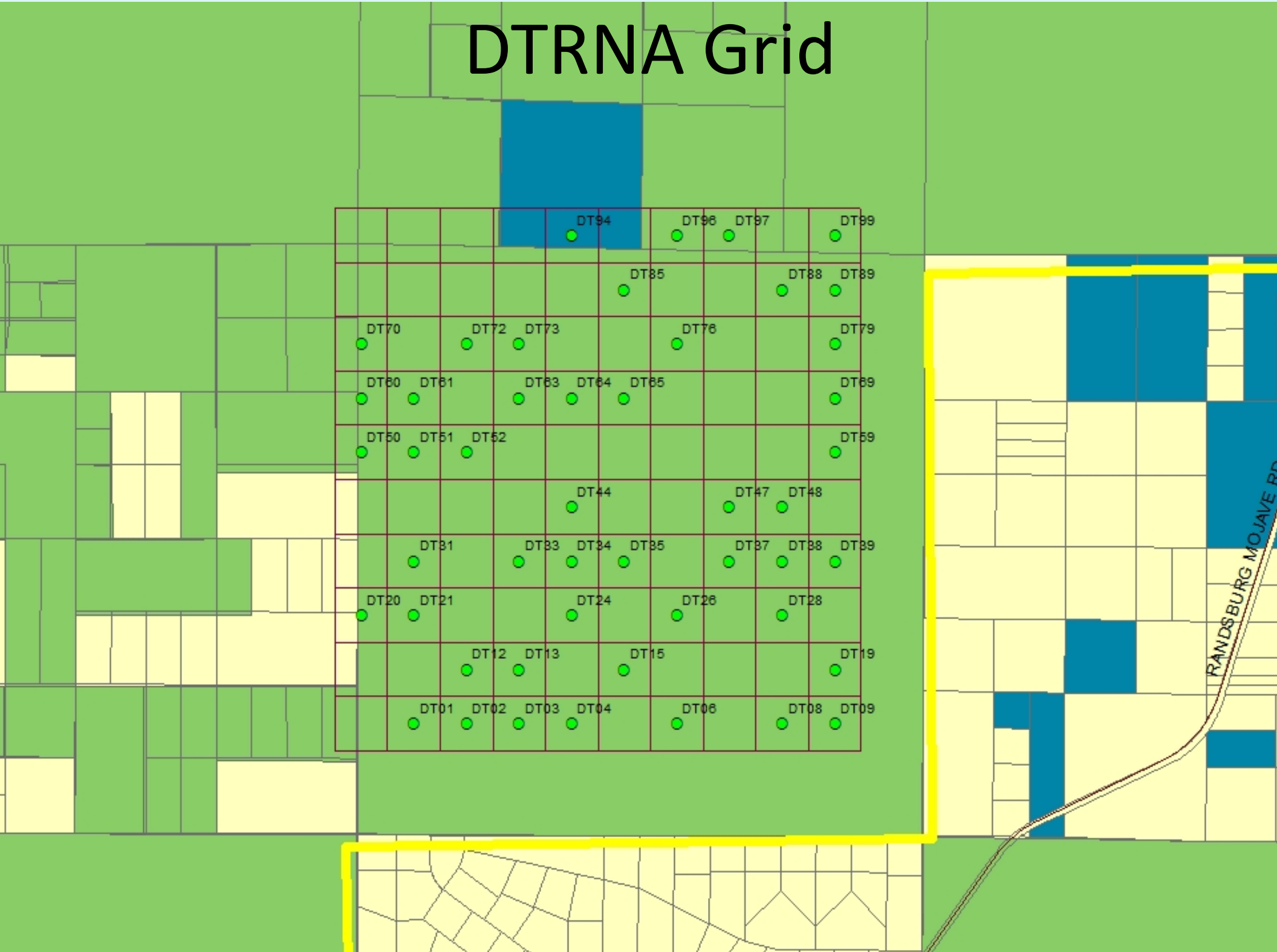
Summary of Effort

- 48 camera stations in DTRNA (3/14 – 5/8)
- 48 camera stations in EE Area (3/15 – 5/9)
- Point counts repeated 2 - 3x at each station
- Walking transects conducted 4x through both grids conducted by Freya Reder

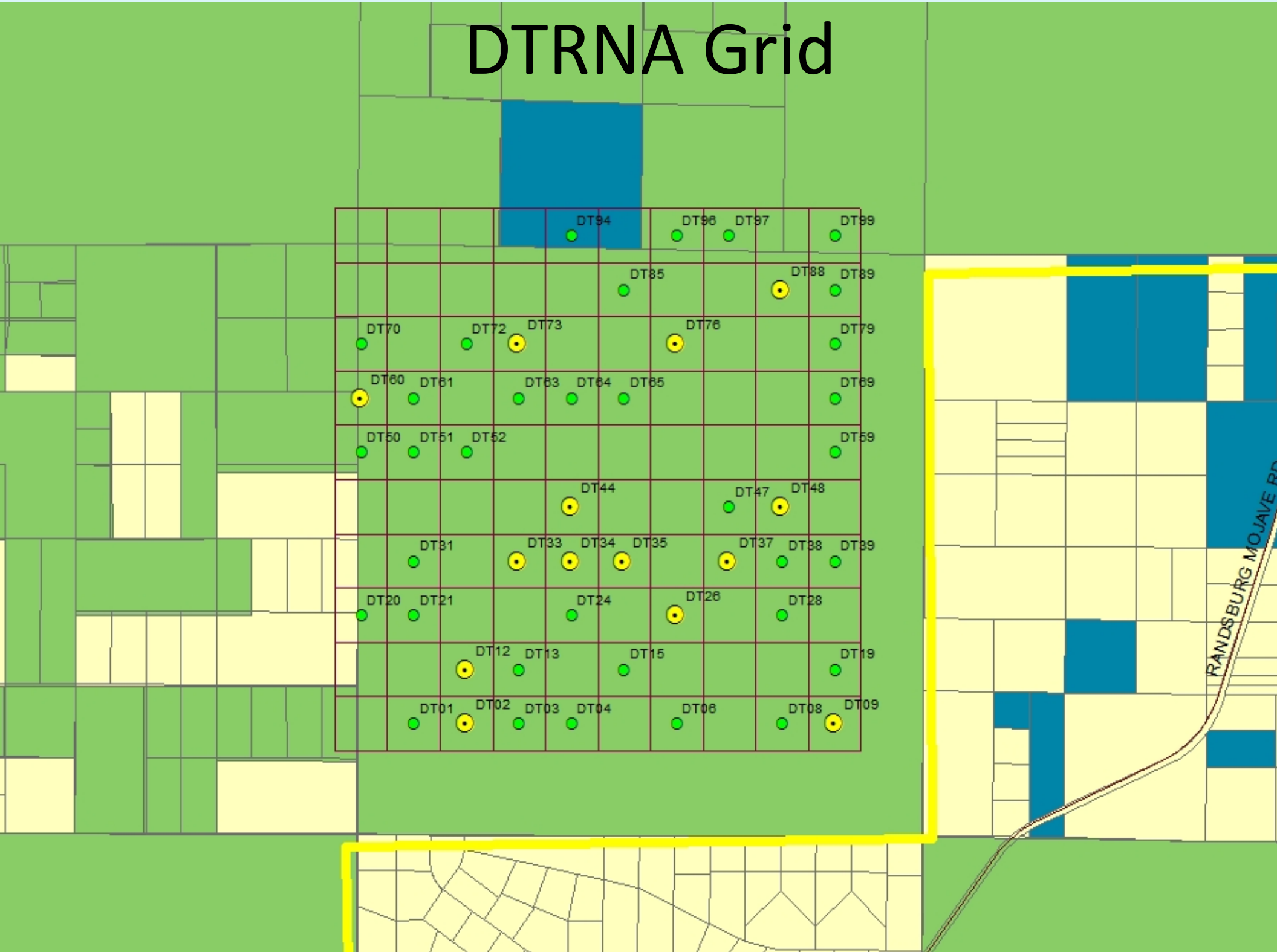
Summary of Results

- 137,336 photos taken over 960 trap-nights
- At least 18 vertebrate species detected:
  - 9 mammals
  - 6 birds
  - 3 reptiles
- MGS detected by all three methods in both study areas

DTRNA Grid


DT94
DT96
DT97
DT99
DT85
DT88
DT89
DT70
DT72
DT73
DT76
DT79
DT60
DT61
DT63
DT64
DT65
DT69
DT50
DT51
DT52
DT59
DT44
DT47
DT48
DT31
DT33
DT34
DT35
DT37
DT38
DT39
DT20
DT21
DT24
DT26
DT28
DT12
DT13
DT15
DT19
DT01
DT02
DT03
DT04
DT06
DT08
DT09
RANDSBURG MOJAVE RD

DTRNA Grid


DT94
DT96
DT97
DT99
DT85
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DT89
DT70
DT72
DT73
DT76
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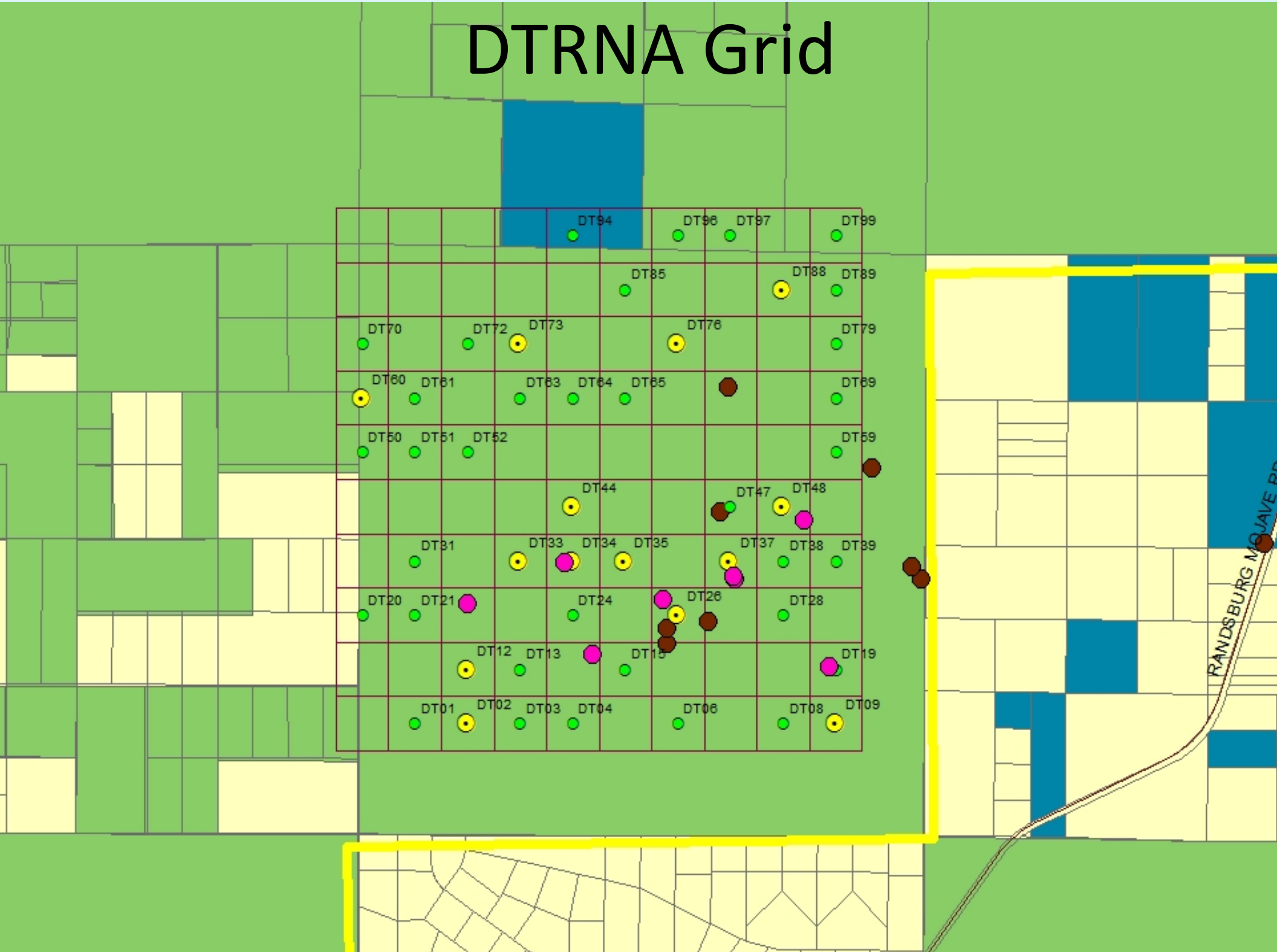
DT01
DT02
DT03
DT04
DT06
DT08
DT09
RANDSBURG MOJAVE RD

DTRNA Grid


DT94
DT96
DT97
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DT85
DT88
DT89
DT70
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DT73
DT76
DT79
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DT61
DT63
DT64
DT65
DT69
DT50
DT51
DT52
DT59
DT44
DT47
DT48
DT31
DT33
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DT12
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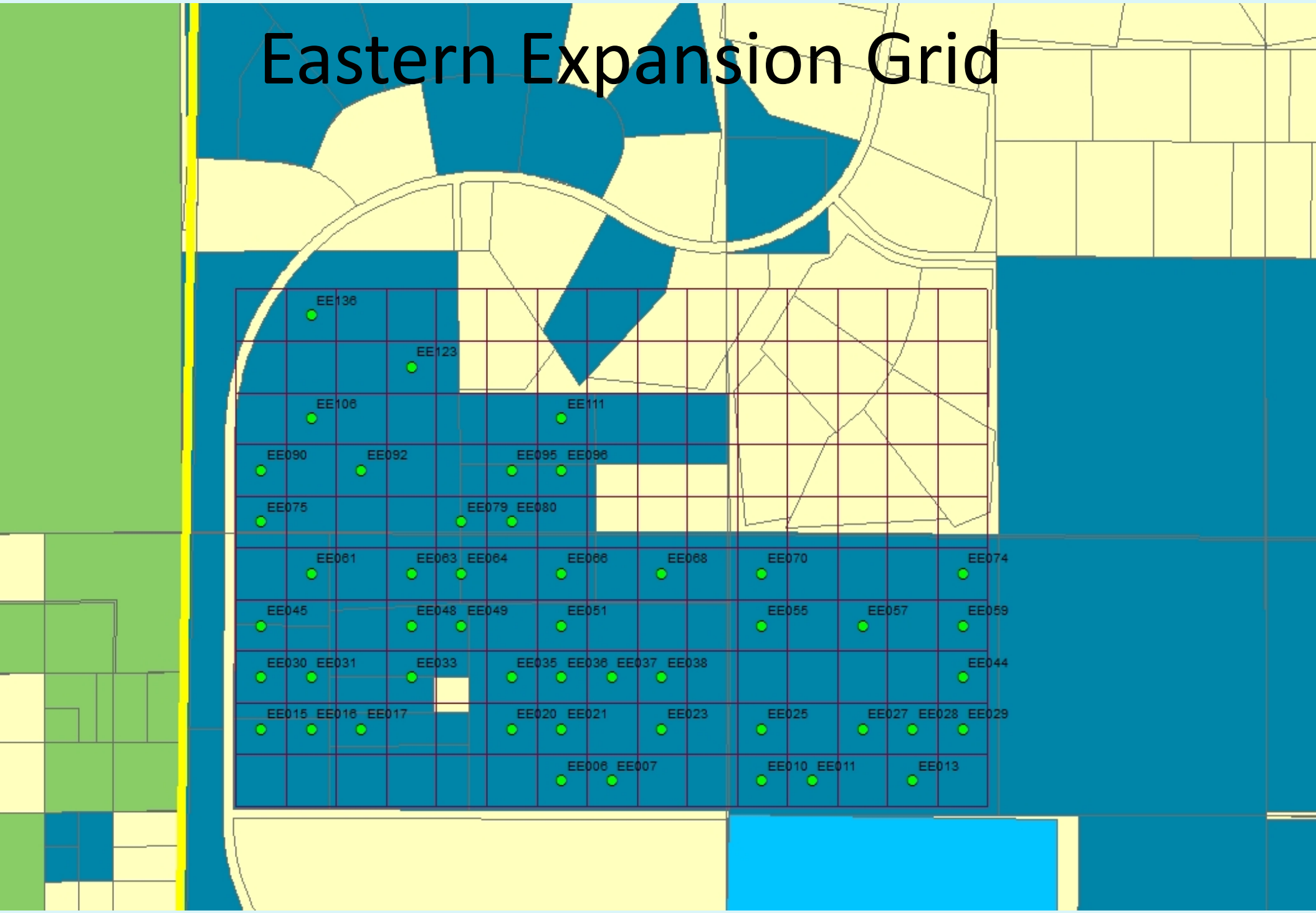
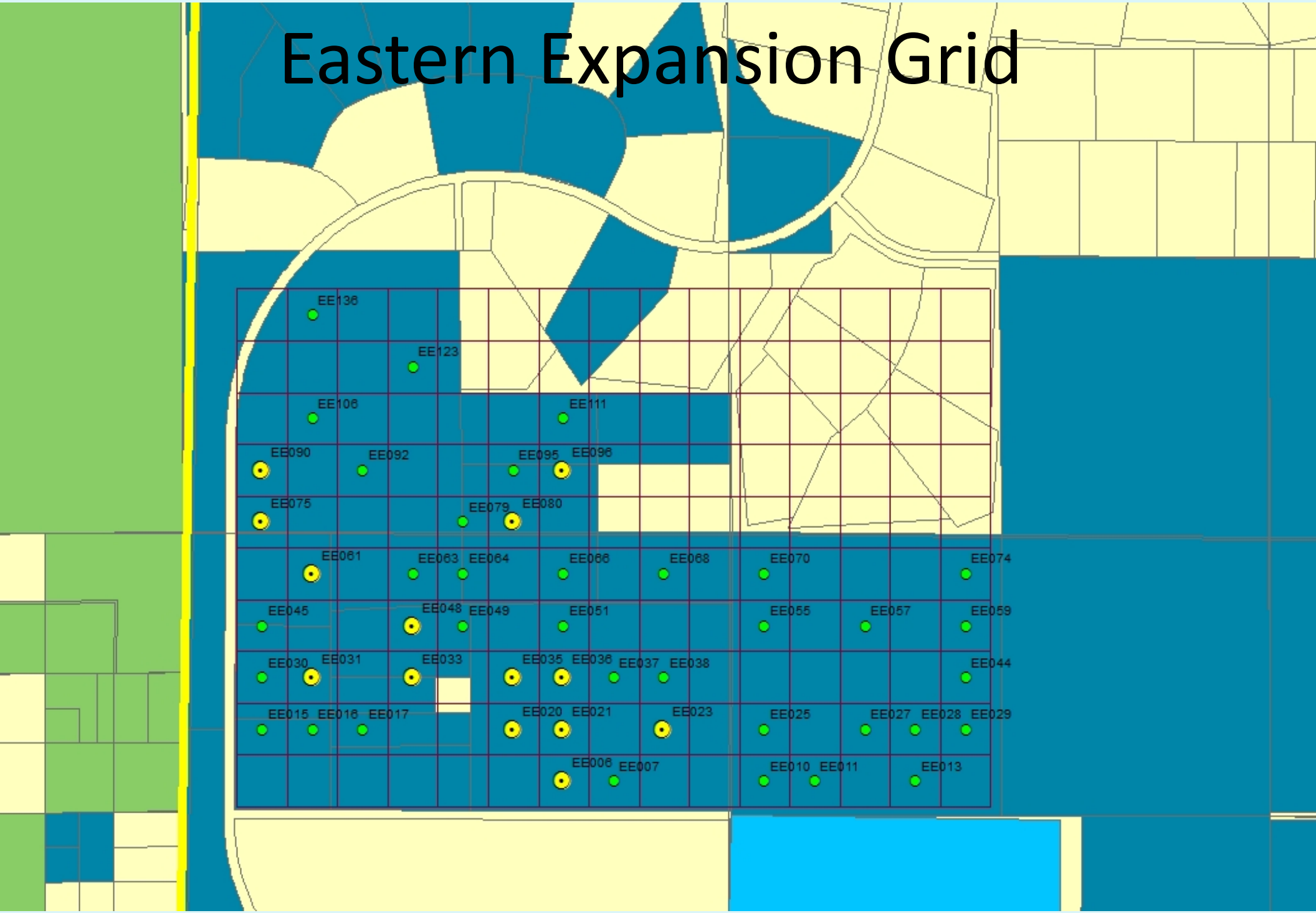
DT03
DT04
DT06
DT08
DT09
RANDSBURG MOJAVE RD

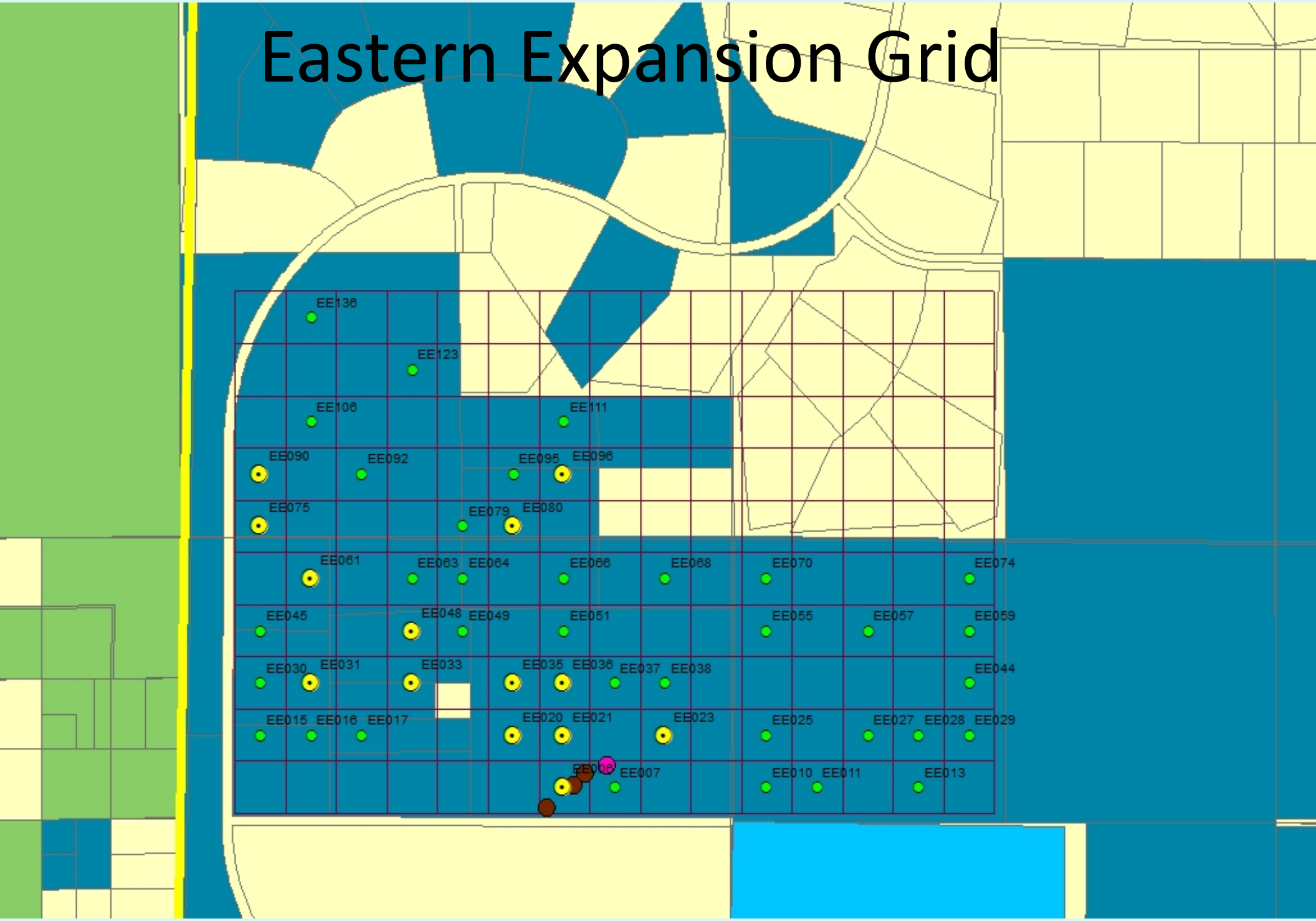
Eastern Expansion Grid



Eastern Expansion Grid



Eastern Expansion Grid



- 14 out of 48 camera stations with MGS detections at both sites
- Naïve occupancy of 0.29
- Probability of detecting MGS at a site < 1.0

	SESSION 1												
SITE	14-Mar-12	15-Mar-12	16-Mar-12	17-Mar-12	18-Mar-12	19-Mar-12	20-Mar-12	21-Mar-12	22-Mar-12	23-Mar-12	24-Mar-12	25-Mar-12	26-Mar-12
DT001	0	0	0	0	0	0	0	0	0	0	0	1	0
DT004	0	0	0	0	0	0	0	0	0	0	0	0	0
DT012	0	0	0	0	0	0	0	0	0	0	1	1	1
DT026	0	0	0	0	0	1	1	0	0	0	0	0	0
DT048	0	0	0	0	0	0	0	1	0	1	1	0	1
DT050	0	0	0	0	0	0	0	0	0	0	0	0	0
DT072	0	0	0	0	0	0	0	0	0	0	0	0	0
DT073	0	0	0	0	0	1	0	0	0	0	0	0	0
DT079	0	0	0	0	0	0	0	0	0	0	0	0	0
DT088	0	0	0	0	0	0	0	0	0	0	1	0	0
DT085	0	0	0	0	0	0	0	0	0	0	0	0	0
DT096	0	0	0	0	0	0	0	0	0	0	0	0	0

Walking Surveys & Incidental Observations

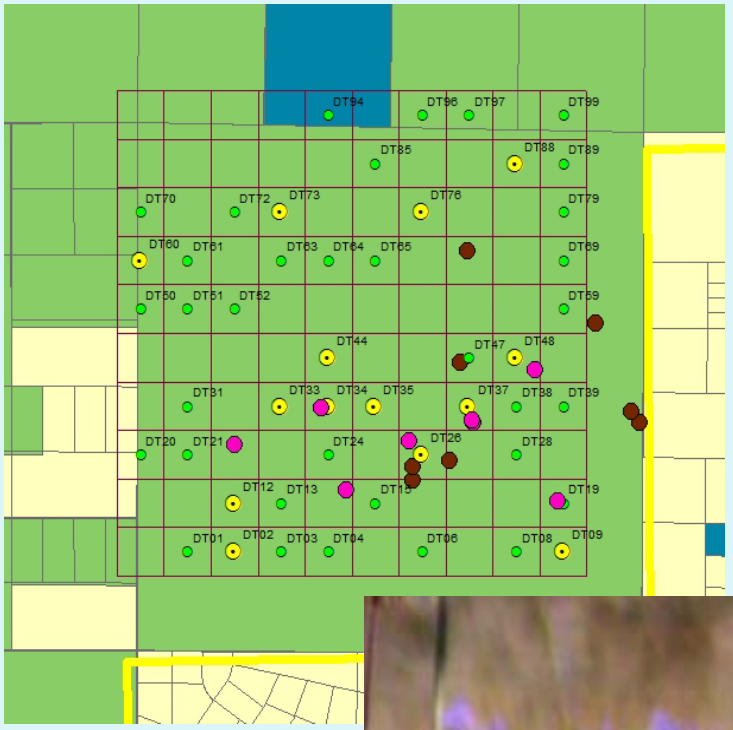
- 7 visual detections during walking transects in DTRNA
- 3 visual detections in Eastern Expansion Area during walking transects in DTRNA
- 2 MGS detected during camera station point counts
- 8 incidental detections of MGS in survey area
- Incidental observations of desert tortoises, burrowing owls, golden eagle, and many other species

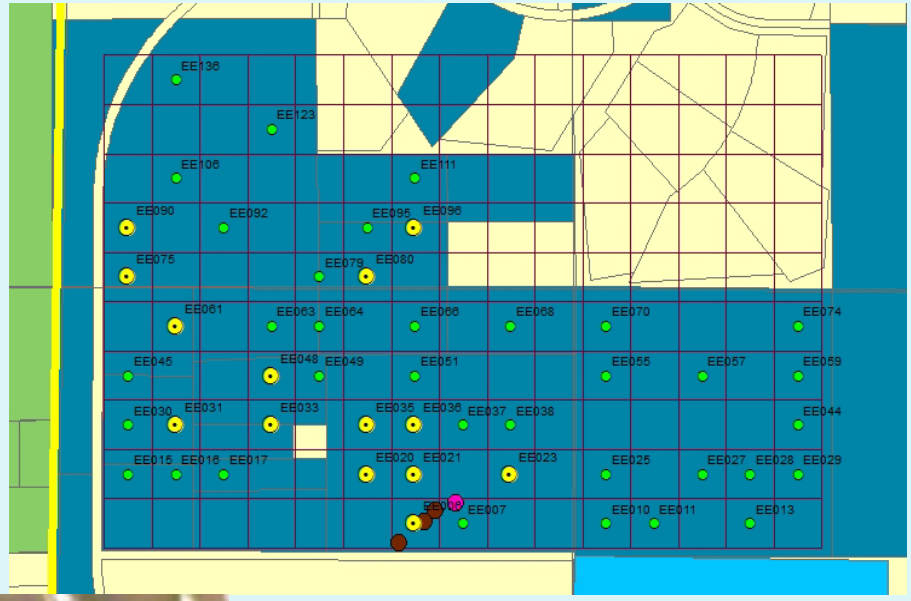
Auditory Detections

- 2011:
  - 3 observations included MGS alarm call
  - 1 detection of MGS alarm call without visual
  - More MGS alarm calls noted when juveniles present

- 2012:
  - 0 / 24 MGS detections by research crew included vocalizations
  - 9 / 94 detections of AGS with vocalizations

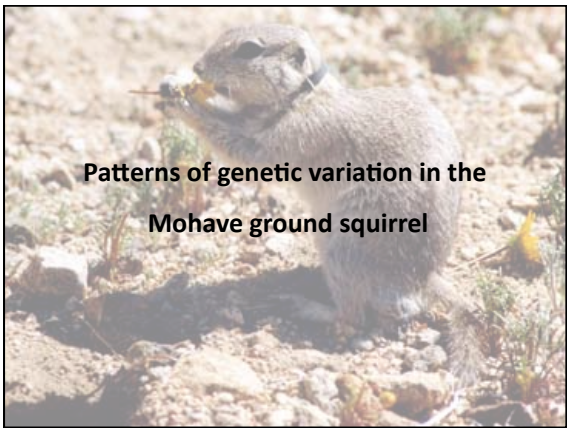
Summary





- Camera trapping resulted in detections of MGS at more sites
- Direct observation can provide complementary data and address different research questions

12-03-21 10:10:46 AM M 1/3



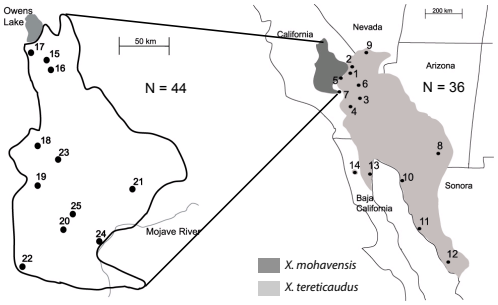
Ground Squirrels

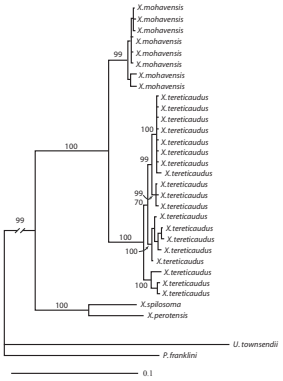
What is the history of *Xerospermophilus*?

(Hafner 1992, Hall 1981)

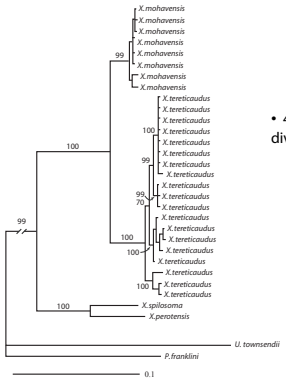
Biogeographic History

Mitochondrial cytochrome *b* gene



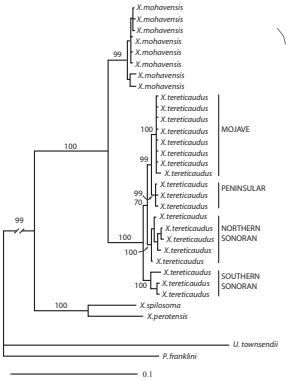


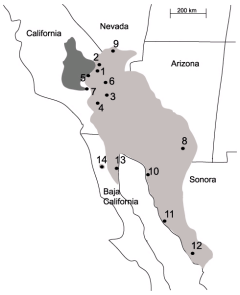
Bell *et al.* 2010
Journal of Biogeography

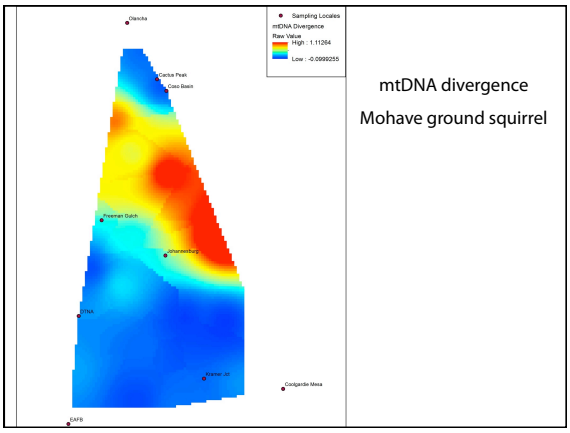


- 4% average pairwise sequence divergence ~ 1.6 million year

Bell *et al.* 2010
Journal of Biogeography





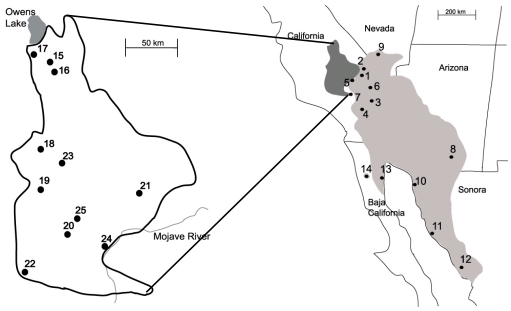


mtDNA divergence

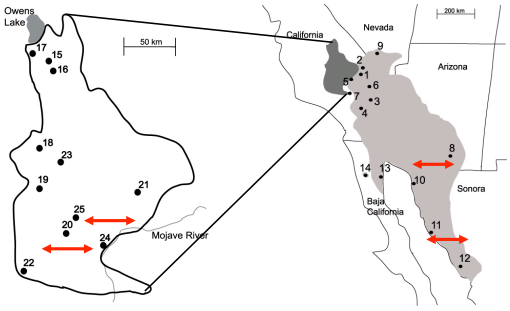
Mohave ground squirrel

Regional History

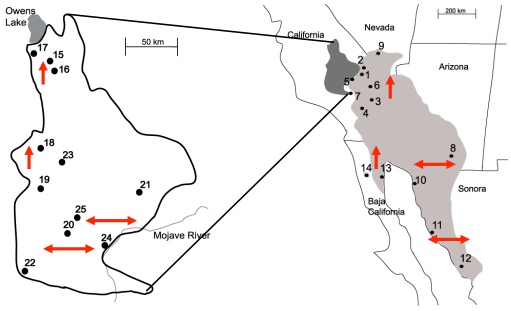
Areas of stability, areas of growth?



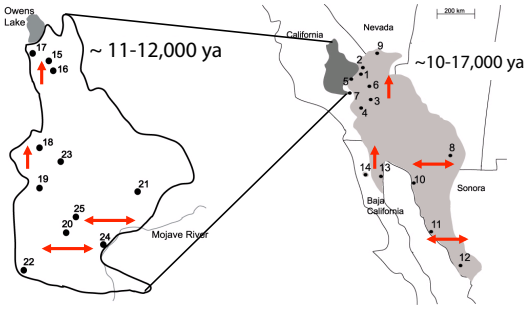
Regional History



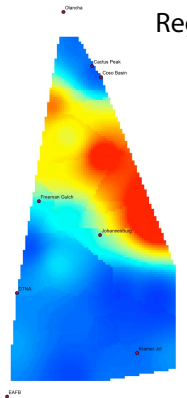
Regional History

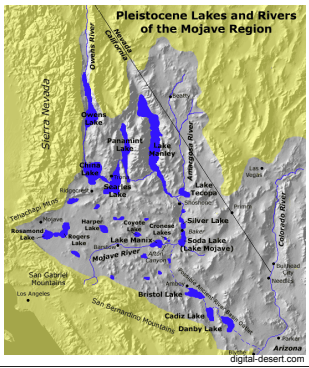


Regional History



Regional History



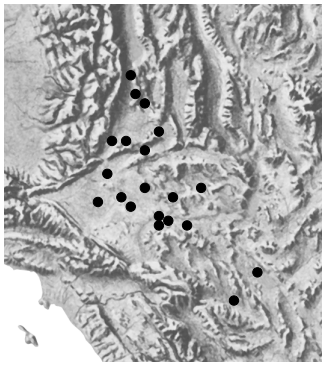


Nuclear Genetic Structure

256 MGS, 13 localities

64 RTGS, 7 localities

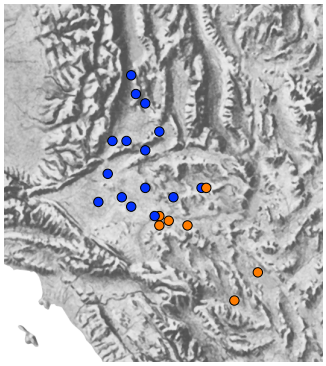
17 microsatellite loci



Distinct Species Signatures

MGS

RTGS

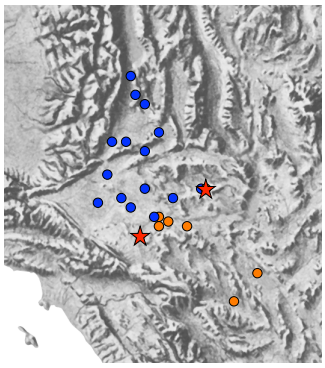


Hybridization

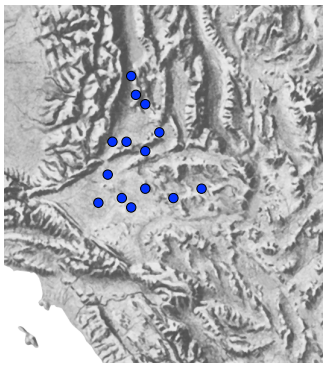
MGS

RTGS

★ – Two hybrid individuals

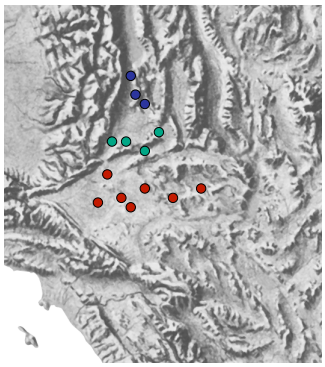


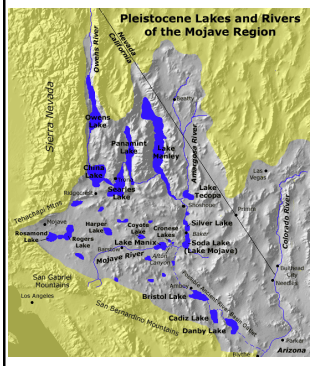
Population Genetic Structure

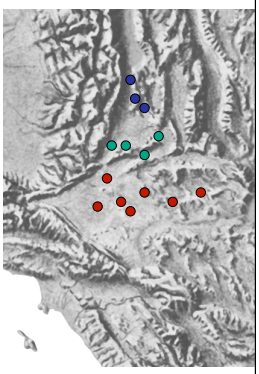


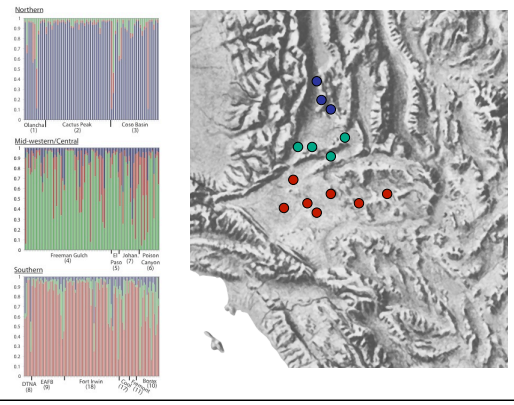
Population Genetic Structure

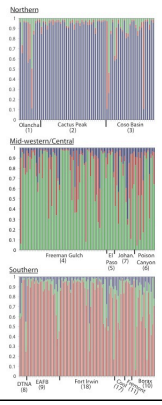
3 genetic groups within *X. mohavensis*

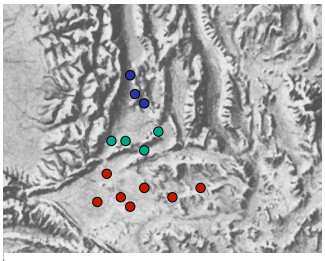




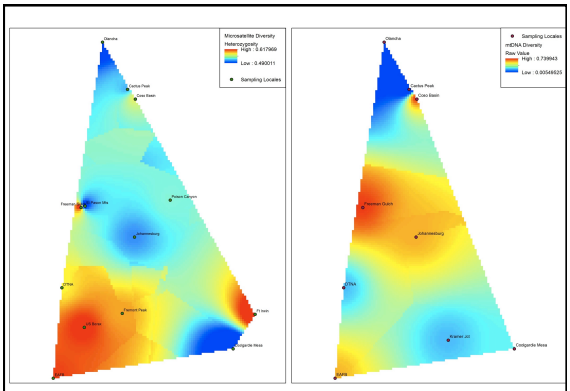


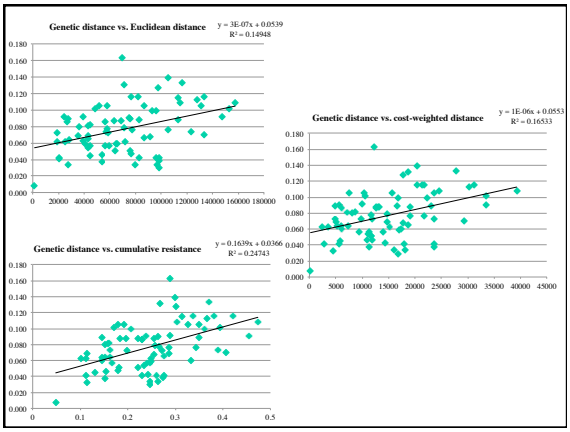






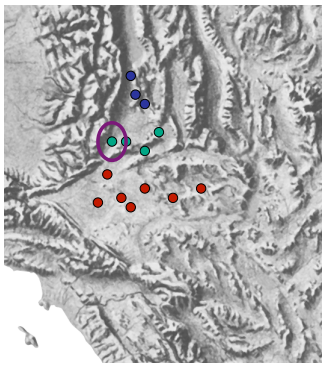
Identification of current key populations and areas of connectivity that maintain genetic variability and evolutionary potential of MGS.





Fine-scale genetic structure

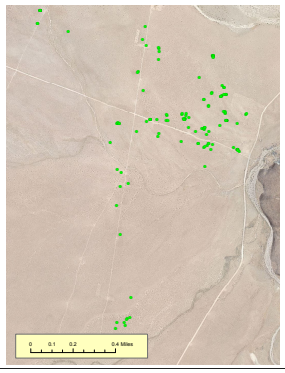
Freeman Gulch



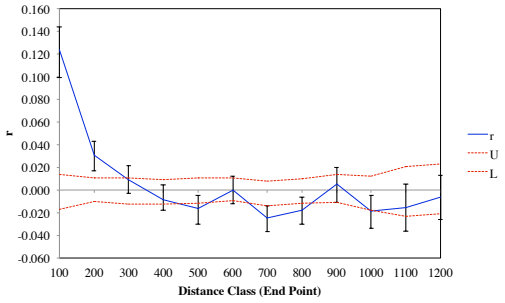
Fine-scale genetic structure

2002 – 2004

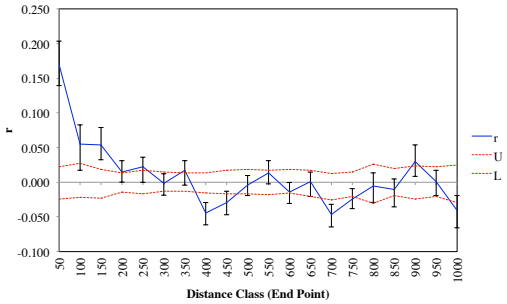
40 adults
97 juveniles



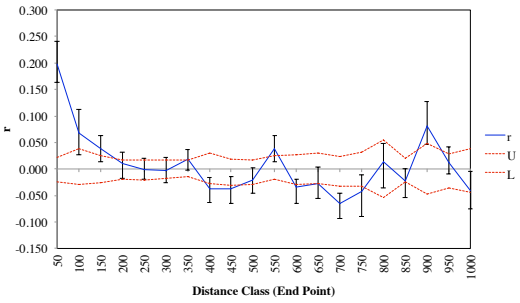
Genetic spatial autocorrelation
All Freeman Gulch individuals (N = 137)



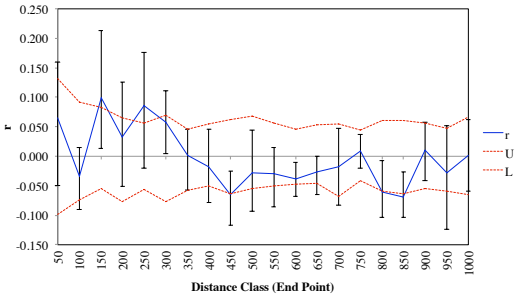
Genetic spatial autocorrelation
All Freeman Gulch individuals (N = 137)



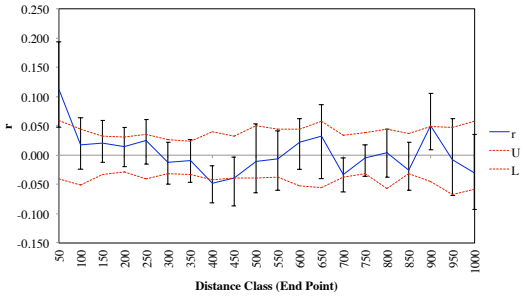
Genetic spatial autocorrelation
Freeman Gulch juveniles (N = 97)



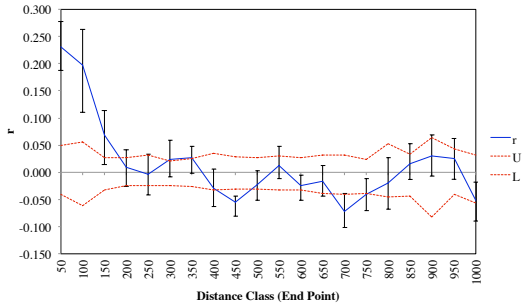
Genetic spatial autocorrelation
Freeman Gulch adults (N = 40)

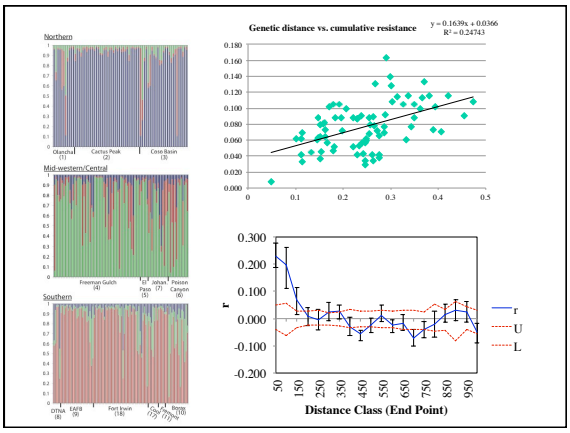


Genetic spatial autocorrelation
Freeman Gulch males (N = 57)



Genetic spatial autocorrelation
Freeman Gulch females (N = 80)





Integration with changes in connectivity

- EASYPOP for more simplistic, targeted simulations

- CDPOP to simulate actual changes in landscape

Estimates of how population and regional genetic diversity will be impacted by projected shifts in landscape connectivity.

Elevated surface temperature depresses survival of the banner-tailed kangaroo rat: Will climate change cook a desert icon?

Martin R. Moses, Jennifer K. Frey
and
Gary W. Roemer

Martin kickin’ it

Climate Change

- There is general agreement that the earth has warmed ~0.74 ºC within the last 100 years

- Despite uncertainties, climate change models predict future extremes
  - Increasing air temperature, 2 to 6 ºC (Karl et al. 2009)
  - Increasing land surface temperature (Smith et al. 2007)
  - Decreasing available water (Seager et al. 2007, Karl et al. 2009)

Impacts of Climate Change to Flora & Fauna

- Impacts of change have focused on polar, montane, and tropical regions (Parmesan 2006)
  - Changes in phenology, range shifts, and population extirpations
- Species in deserts will likely experience harsher conditions as well, with increasing extreme events
- In Australia, 30,000 flying foxes perished in 19 extreme heat events in a 13 yr period (1994 – 2007) (Wellbergen et al. 2008)
- Only 3 such events were recorded between 1791 - 1913

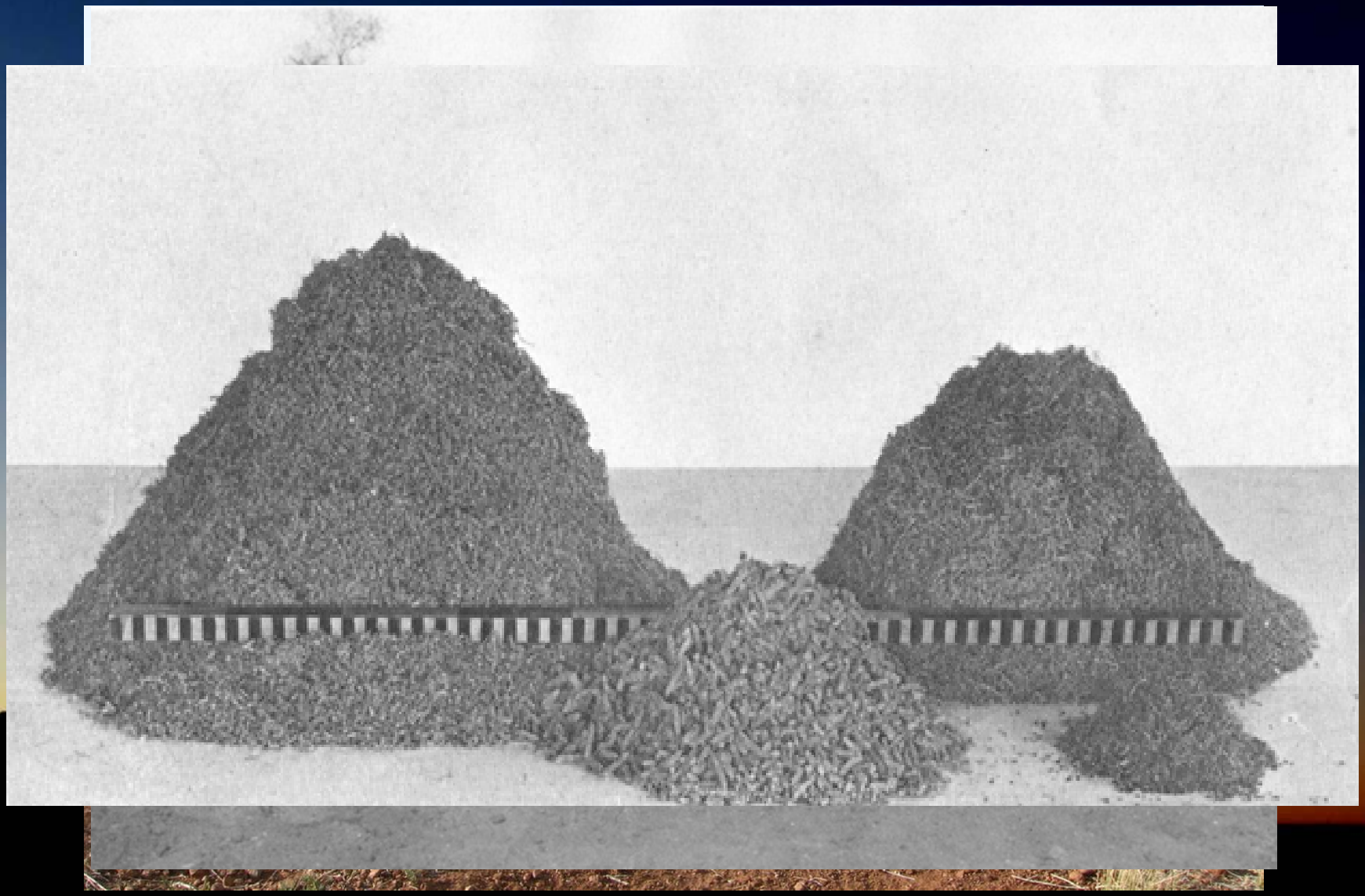
Dead Budgerigars killed in a heat wave in Australia in 2009

McKechnie & Wolf 2010

Study Objective

To evaluate if environmental drivers affect the survival of the arid-adapted, banner-tailed kangaroo rat; a model organism inhabiting the Chihuahuan Desert.

Banner-tailed Kangaroo Rat



15 Hypothesized Environmental Drivers of Survival

Winter: Dec-Mar, Spring: Apr-Jun, Summer: Jul-Sep, Fall: Oct-Nov

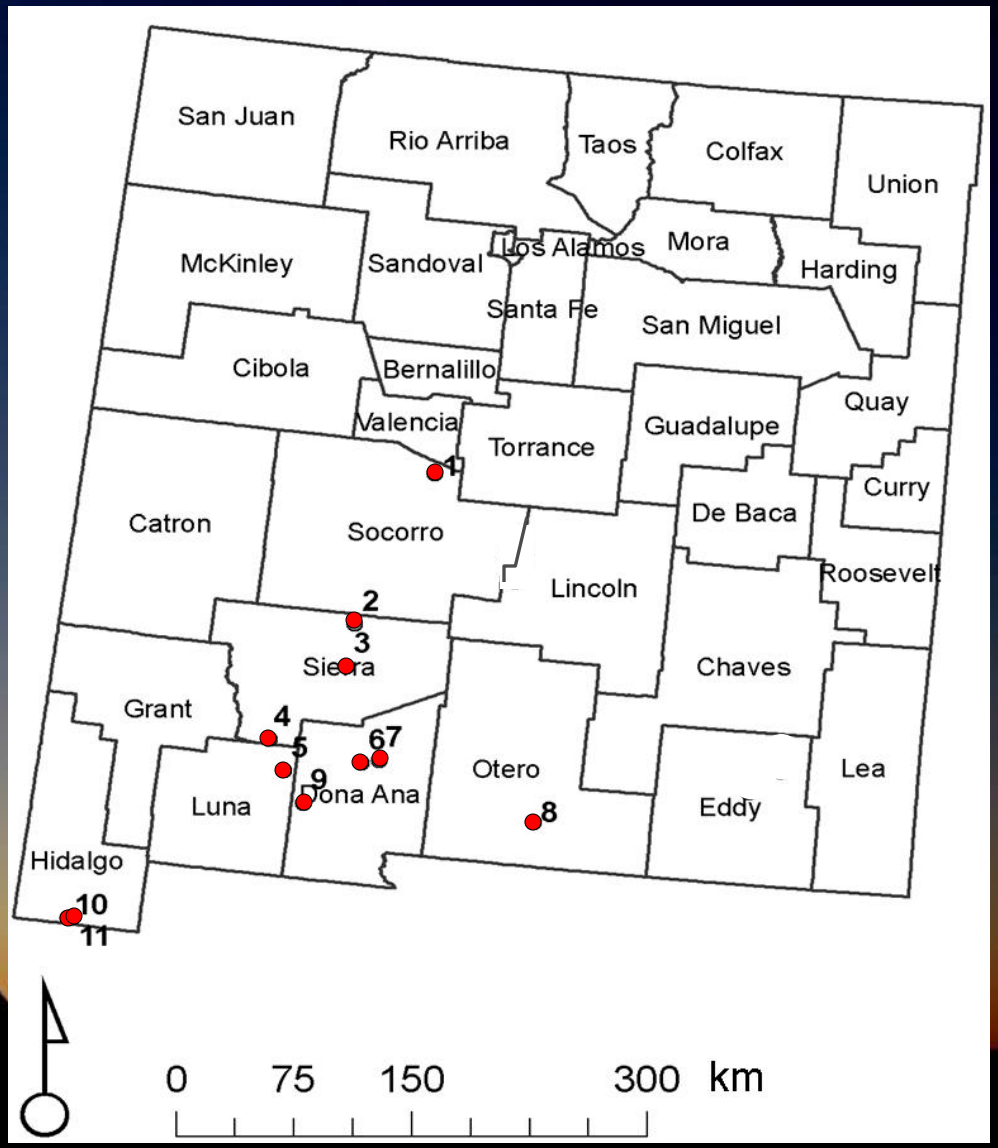
Winter Precip (Lag)	+	Summer-Fall Veg (Lag)	+	Density (Waser and Jones 1991)	+
Summer Precip (Lag)	+	Winter Nocturnal Land Surface Temp	+	Habitat Saturation	+ -
Total Precip (Lag)	+	Summer Diurnal Land Surface Temp	-	% Shrub Cover	-
Summer Dew Point	+	Summer Nocturnal Land Surface Temp	-		

Data from PRISM 4 km^2 MODIS 1 km^2 5.6 km^2

Moses et al. 2011. *Oecologia*

Study Sites

1. Sevilleta National Wildlife Refuge
2. Armendaris Ranch
3. Armendaris Ranch
4. Heritage Ranch
5. Las Uvas Valley
6. College Ranch
7. Jornada Experimental Range
8. Otero Mesa
9. Mason Draw
10. Diamond A Ranch
11. Diamond A Ranch



Information Theory – Hierarchical Analysis

I. Global model of survival and recapture probability
II. Single best model of recapture probability
III. Best categorical models of survival
IV. Best environmental driver models of survival
V. Examine environmental driver importance

I. Global Cormack-Jolly-Seber Model

Φ (Age*Sex*Time*Site) *p* (Sex*Time*Site)

- Goodness-of-fit (Program UCARE v.2.3)
  - ($\hat{c}$ = 1.37, $\chi^2_{7,\ 0.05}$ = 9.599, P = 0.212)

- Maximum likelihood estimates with a logit function (Program MARK v.5.1)

$$\Phi = e^{(\beta 0 + \beta 1(x1) + \beta 2(x2) + \ldots)} / 1 + e^{(\beta 0 + \beta 1(x1) + \beta 2(x2) + \ldots)}$$

- Models were ranked from low to high according to QAICc (Burnham and Anderson 2002)

Moses et al. 2011. *Oecologia*

II. Model of Recapture

- 10 candidate models of recapture
  - Sex, time, site
- Single best approximating model was constant (*p*. = 0.92)
  - Was used to build models of survival

Moses et al. 2011. *Oecologia*

III. Categorical Models of Survival (8/25)

(Waser and Jones 1991, Skvarla et al. 2004)

MODEL	Δ QAIC$_C$	QAIC$_C$ *w*	*K*
Φ A	0.000	0.256	3
Φ S*A	0.814	0.170	5
Φ A+SITE	0.927	0.161	13
Φ A*T	1.298	0.134	7
Φ A*T+SITE	1.785	0.105	17
Φ S*A+SITE	2.256	0.083	15
Φ A+T	3.087	0.055	5
Φ S*A+T	3.846	0.037	7

A (Σ *w* = 0.92)

Moses et al. 2011. *Oecologia*

IV. Environmental Driver Models of Survival

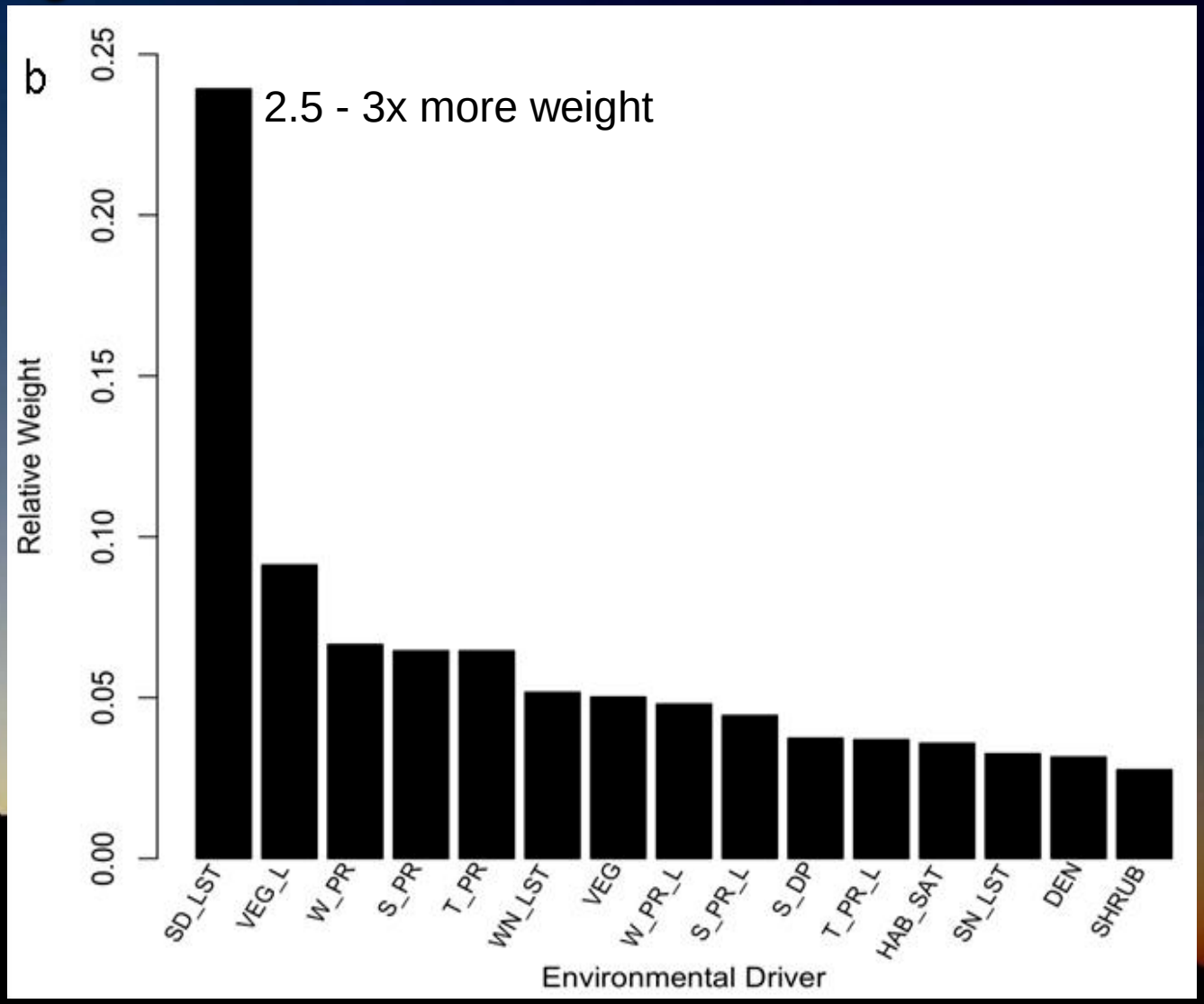
- Potential environmental drivers replaced either time or site in the categorical models
- 30 candidate models, where each potential environmental driver was represented twice w/ Age, either additively or multiplicatively
- Set of best approximating models
  - $\Delta QAICc \leq 2$

IV. Environmental Driver Models of Survival

MODEL	Δ QAIC$_C$	QAIC$_C$	*K*	β (SE)	w_i	% σ^2_P
Φ A+SD_LST	0.000	533.63	4	-0.14 (0.06)	0.24	83
Φ A+VEG_L	1.87	535.49	4	8.99 (4.86)	0.10	87
Φ A*SD_LST	1.97	535.59	5	-0.10 (0.17)	0.09	85

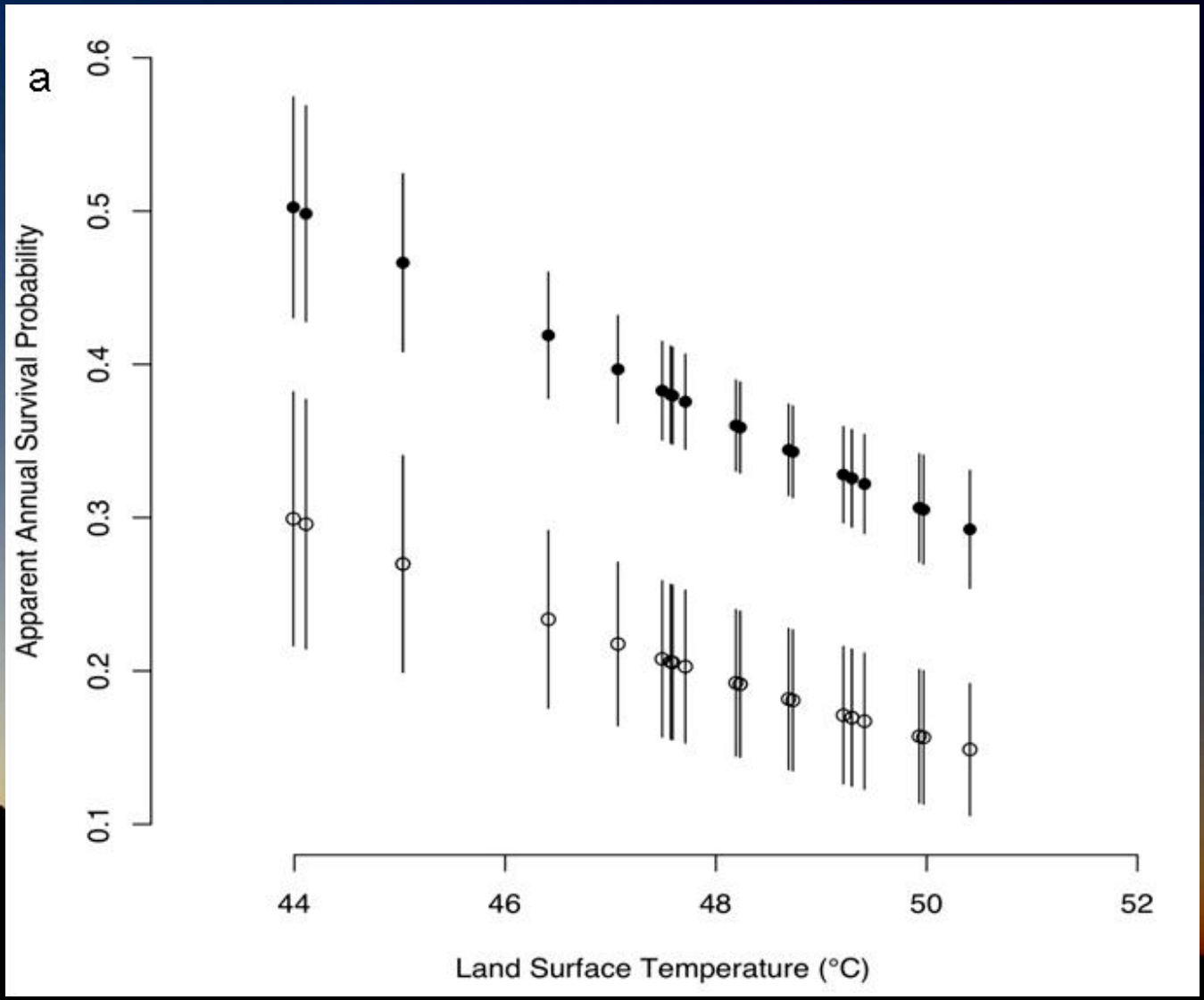
Moses et al. 2011. *Oecologia*

Strength of Evidence for each Environmental Driver



Moses et al. 2011. *Oecologia*

Summer Diurnal Land Surface Temperature



Moses et al. 2011. *Oecologia*

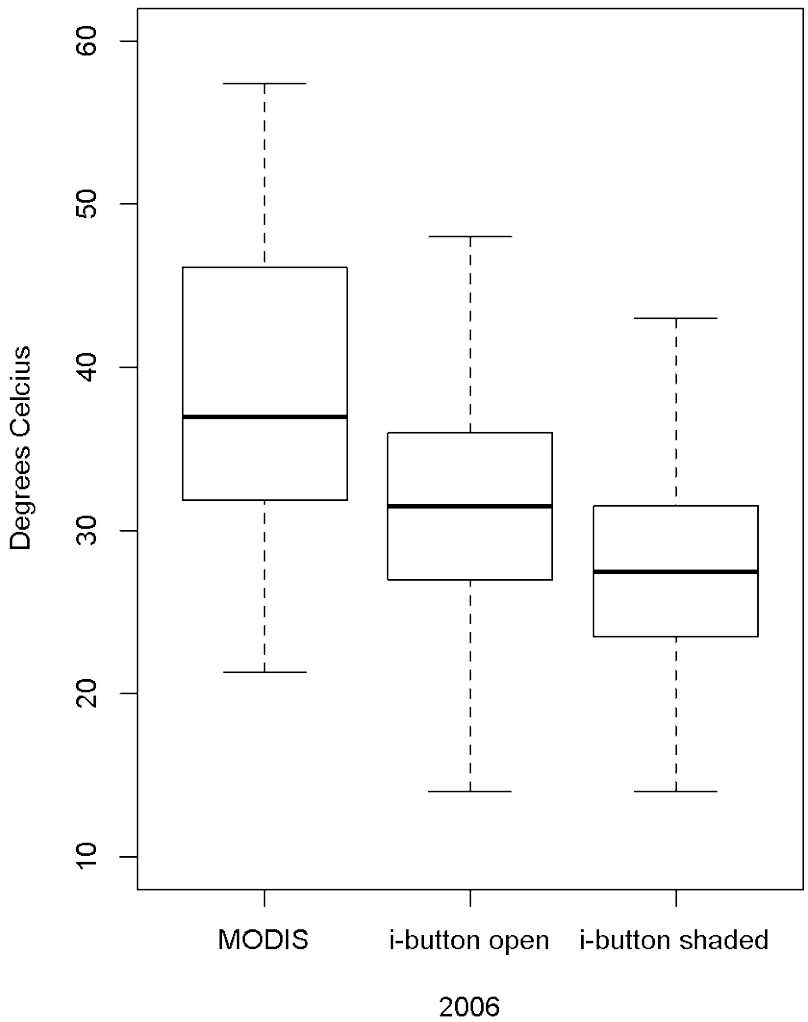
Possible Mechanisms of LST

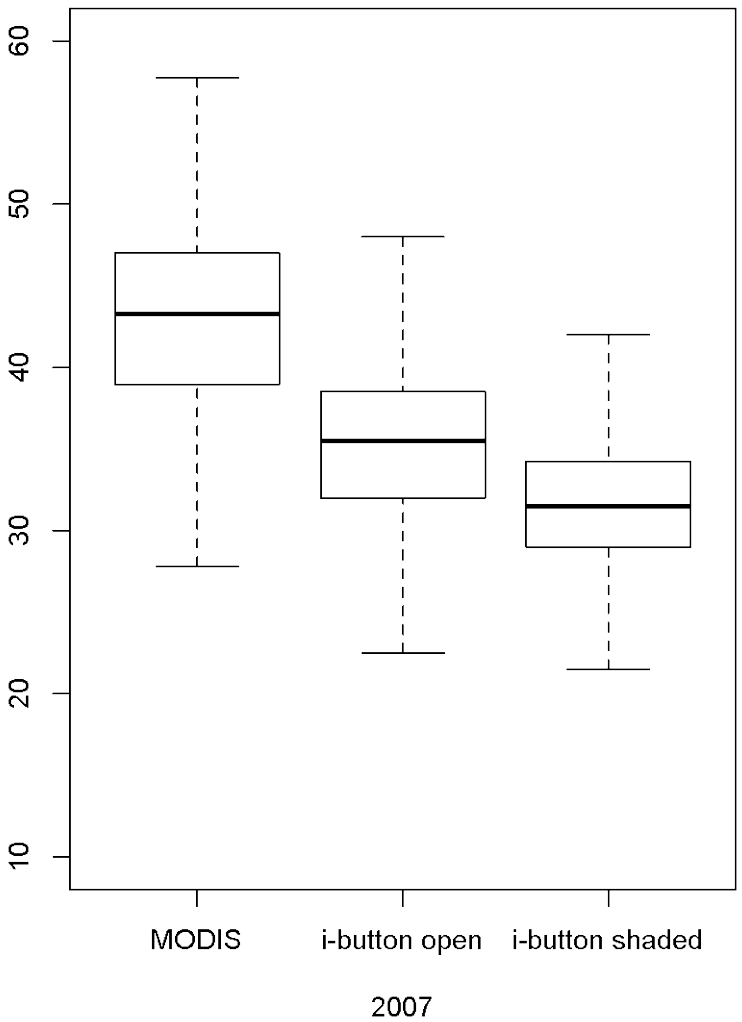
Negative Water Balance

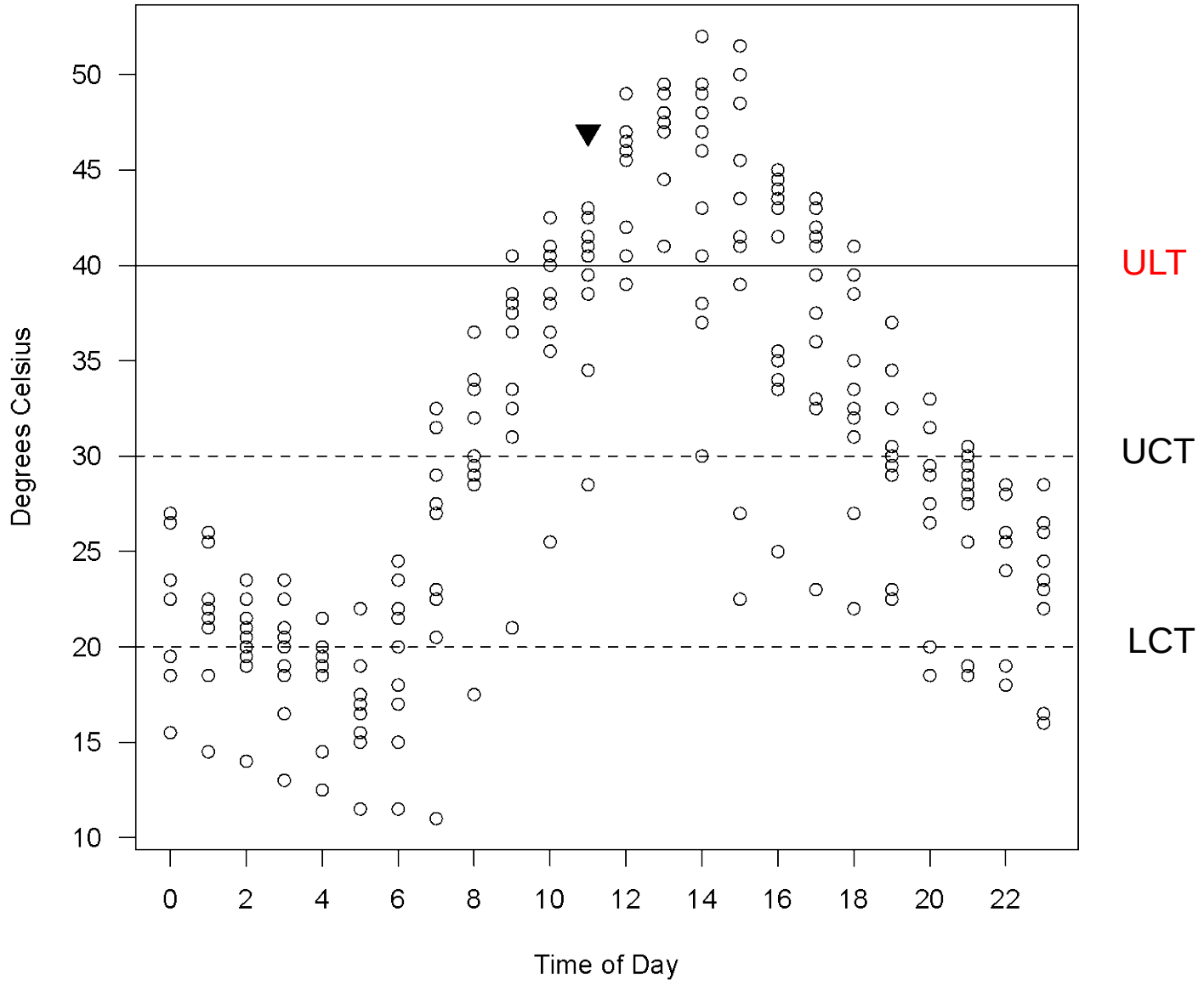
- Despite highly specialized water conservation mechanisms, evaporative water loss in Krats can be substantial (Schmidt-Nielsen 1964, Collins et al. 1971, Kay 1975, MacMillen and Hinds 1983)

- Desiccating environment (high temps, low humidity) could reduce available water, especially preformed water in food which is vital (Frank 1988, Alpert 2000, Tracy and Walsberg 2002)

Possible Mechanisms of LST






Degrees Celsius
50
45
40
35
30
25
20
15
10
0
2
4
6
8
10
12
14
16
18
20
22
Time of Day
ULT
UCT
LCT

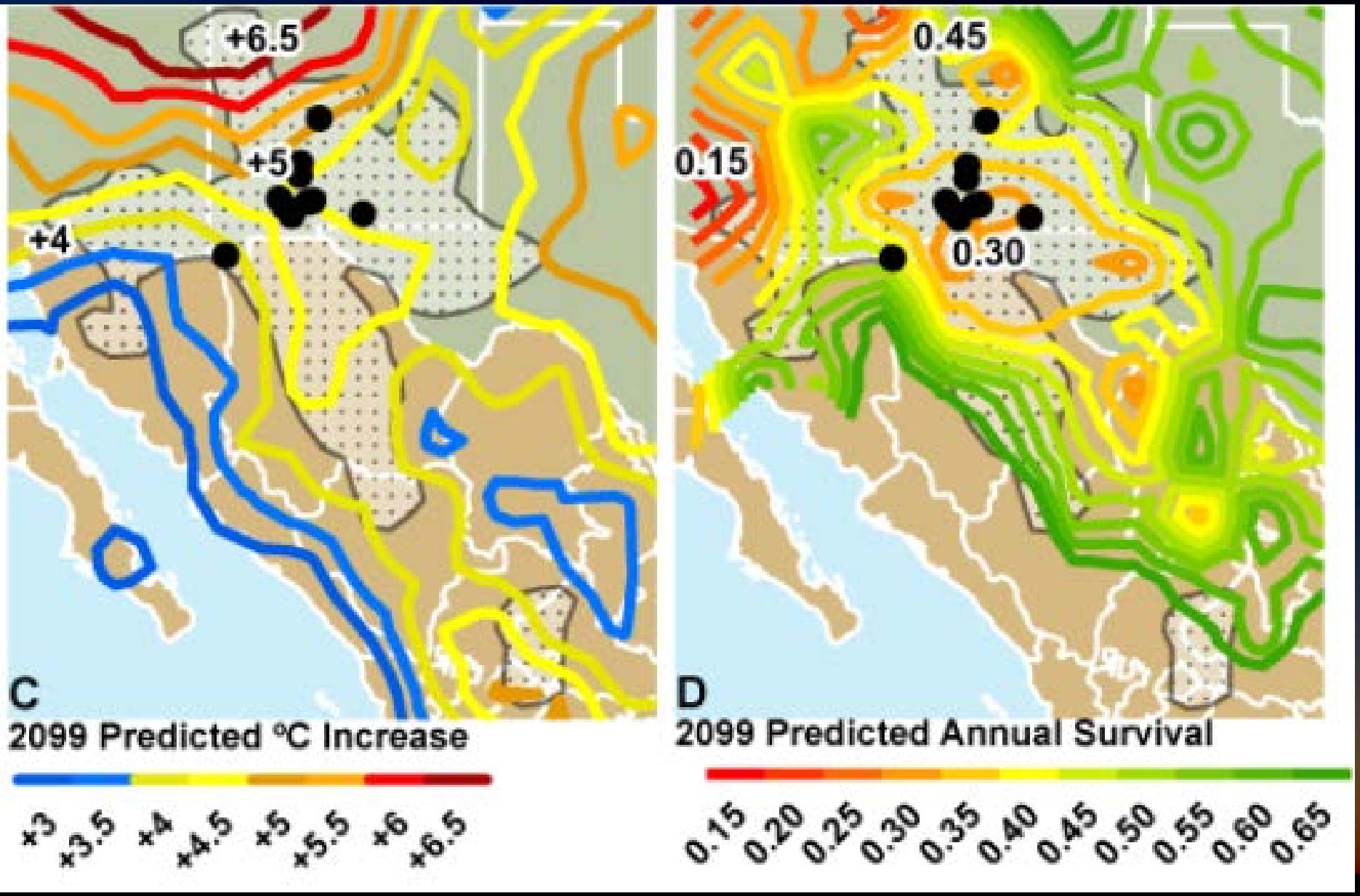
Enhanced Activity Period of Ectothermic Predators

Edelman 2010

Implications of Climate Change

Exploration into potential impact of climate change on range shifts

- Projected 2005 MODIS land surface temperature and modeled fitness surface
- Hindcast (2005) and forecast (2099) land surface temperature from CCSM
  - A2 carbon emission scenario



Moses et al. 2011. *Oecologia*

In Summary

Models revealed a relationship between land surface temperature and survival at a landscape scale

Robust process-based function that can be used in prediction

Exploratory analysis revealed potential consequences of climate change for the distribution of BTKRs

Sampling for MGS Surveys

How should sampling be done?

How Have Study Areas Been Selected?

* Define an area of interest based on an organization's interests and responsibilities
* DTPC, CDFG, CA State Parks, EAFB, and Ft. Irwin have conducted surveys of lands that they own and/or manage
* Many surveys have been done at the sites of public and private development projects
* In some cases, study areas were chosen based on the investigator's curiosity

Random Selection of Study Sites

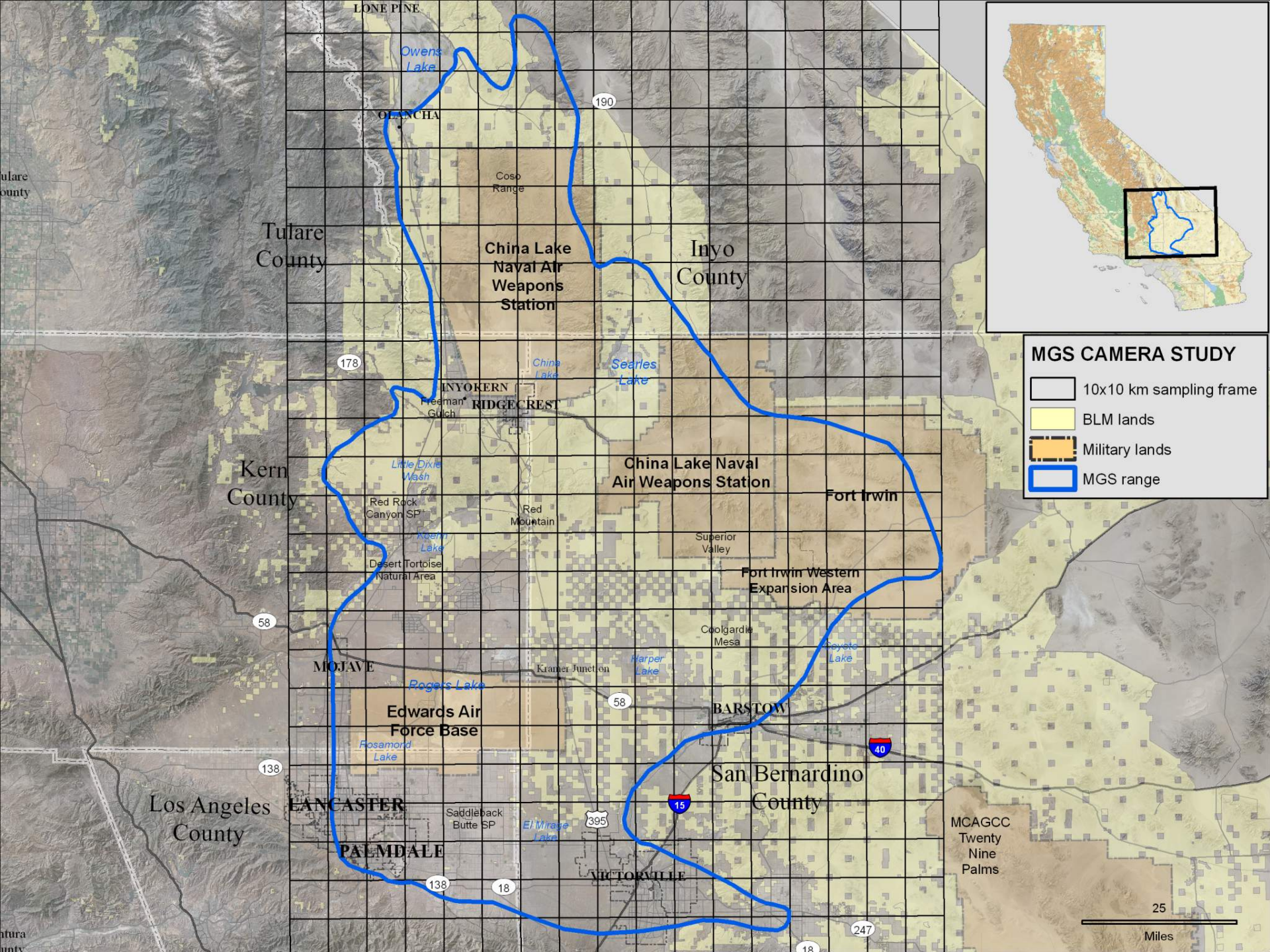
* On EAFB, 60 HQA sites were randomly selected across the base; each year MGS trapping has been carried out at 10-15 sites
* In Ft. Irwin's WEA, the landscape was divided into 2 x 2 km units and trapping grids were sited on random units (Leitner 2006 & 2007)
* In the 2011-12 camera study, 1 x 1 km study sites were randomly selected with larger study areas

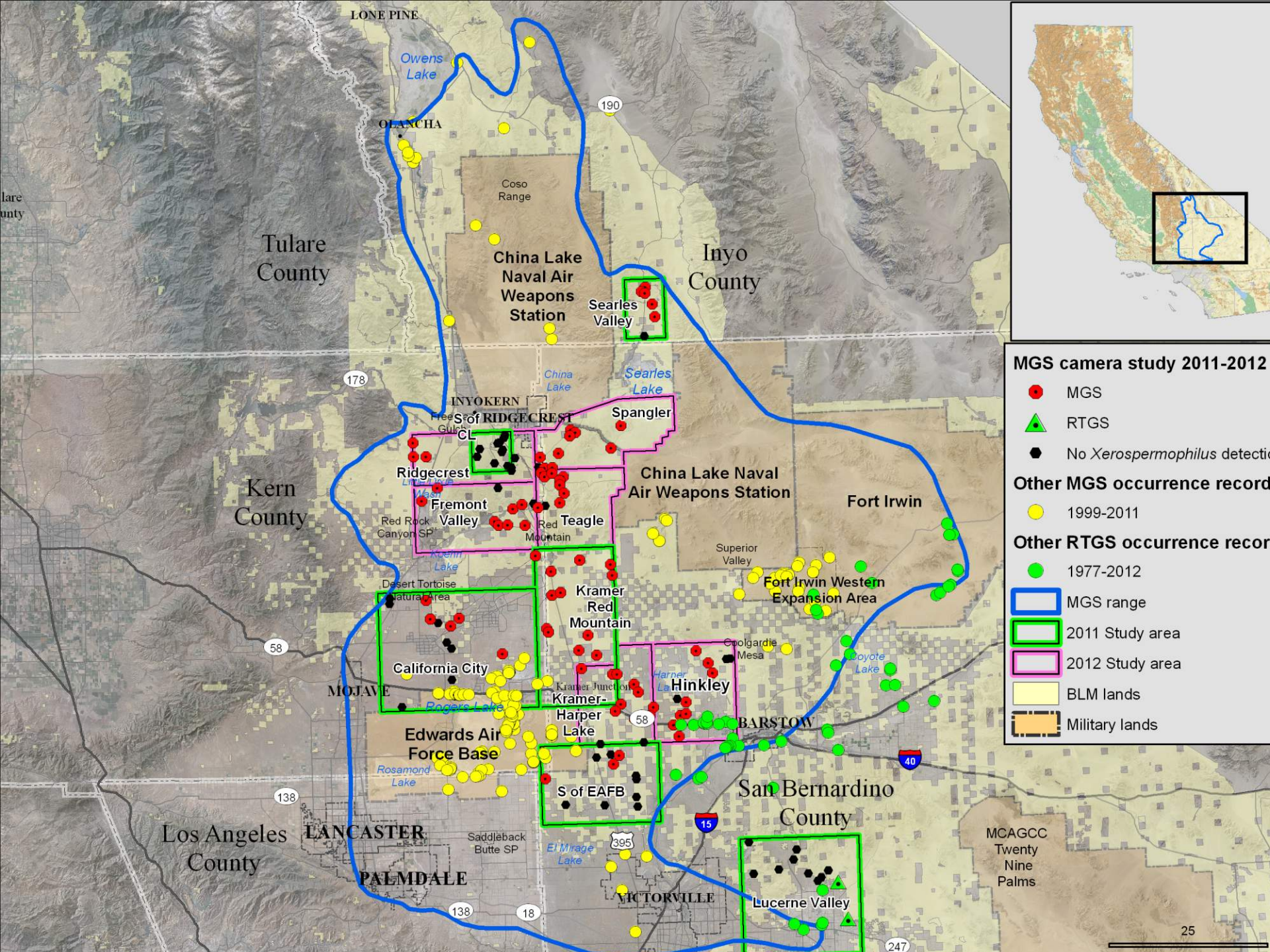
Sampling Frame

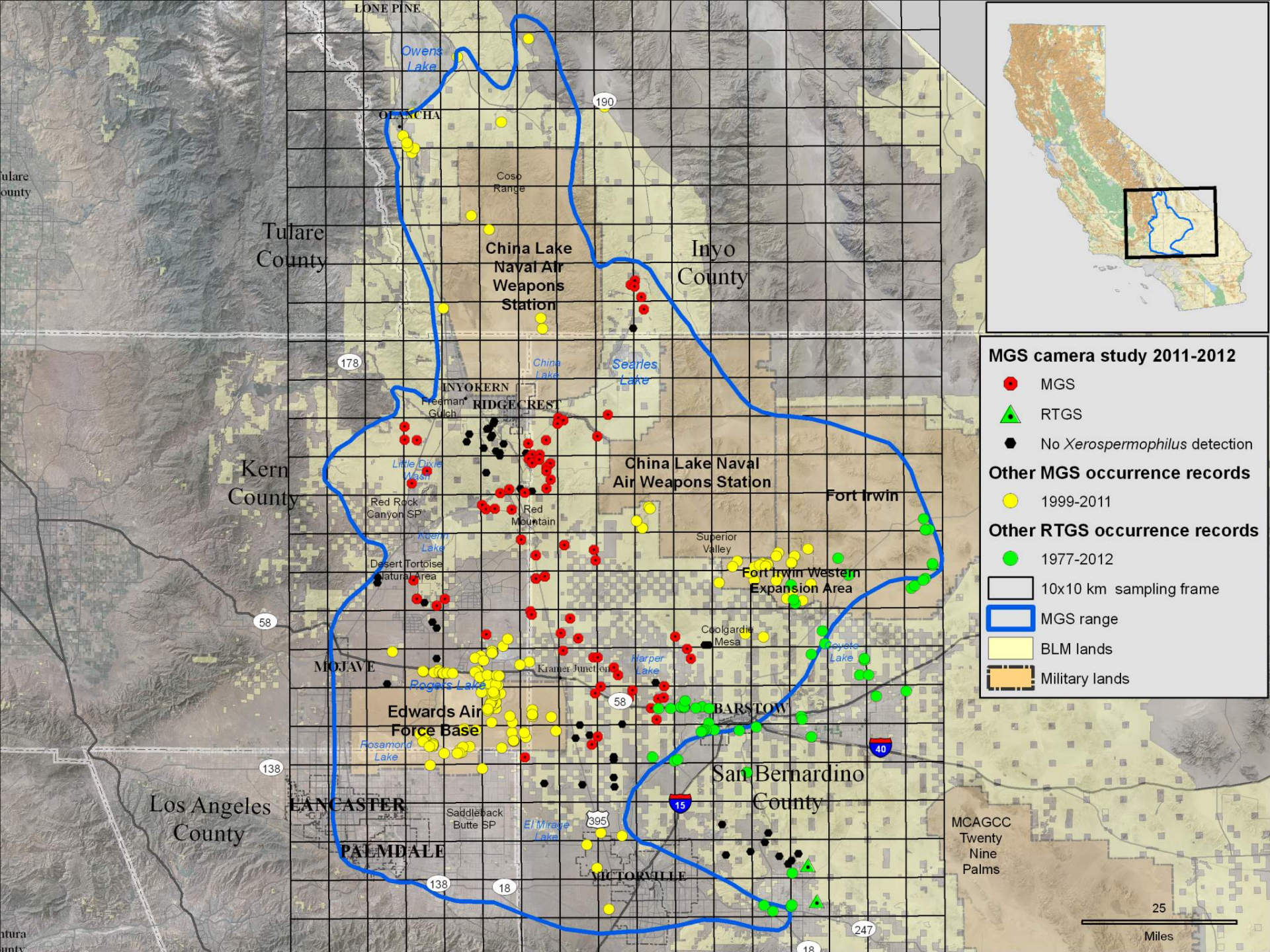
* It's pretty standard these days to set a sampling frame over an area of interest
* This grid provides the universe of sampling units
* A 10 x 10 km sampling frame is often used for large areas
* This frame is usually based on UTM coordinates and can be further subdivided if necessary – e.g., into 1 x 1 km units

Possible MGS Sampling Frame

* About 240 of the 10 x 10 km sampling units would cover the MGS range
* Various agencies and organizations could choose this as a standard for additional surveys
* It could also be used to evaluate the coverage achieved by previous surveys


MGS CAMERA STUDY
10x10 km sampling frame
BLM lands
Military lands
MGS range
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
Tulare County
China Lake Naval Air Weapons Station
Inyo County
178
China Lake
Searles Lake
INYOKERN
Freeman Gulch
RIDGECREST
Kern County
Little Dixie Wash
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Superior Valley
Desert Tortoise Natural Area
Fort Irwin Western Expansion Area
58
Coolgardie Mesa
Coyote Lake
MOJAVE
Kramer Junction
Harper Lake
Rogers Lake
Edwards Air Force Base
58
BARSTOW
Fosamond Lake
40
138
San Bernardino County
Los Angeles County
LANCASTER
Saddleback Butte SP
El Mirage Lake
395
15
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
138
18
247
18
25
Miles


LONE PINE
Owens Lake
OLANCHA
190
Coso Range
Tulare County
China Lake Naval Air Weapons Station
Searles Valley
Inyo County
178
China Lake
Searles Lake
INYOKERN
S of RIDGECREST
Spangler
CL
Ridgecrest
Fremont Valley
Red Rock Canyon SP
Red Mountain
Teagle
China Lake Naval Air Weapons Station
Fort Irwin
Kern County
Superior Valley
Fort Irwin Western Expansion Area
Desert Tortoise Natural Area
Kramer Red Mountain
Coolgardie Mesa
58
California City
MOJAVE
Kramer Junction
Kramer-Harper Lake
Harper Lake
Hinkley
Coyote Lake
Rogers Lake
Edwards Air Force Base
BARSTOW
40
Rosamond Lake
S of EAFB
San Bernardino County
138
Los Angeles County
LANCASTER
Saddleback Butte SP
El Mirage Lake
395
15
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
18
247
25
MGS camera study 2011-2012
MGS
RTGS
No Xerospermophilus detecti
Other MGS occurrence record
1999-2011
Other RTGS occurrence recor
1977-2012
MGS range
2011 Study area
2012 Study area
BLM lands
Military lands


MGS camera study 2011-2012
MGS
RTGS
No Xerospermophilus detection
Other MGS occurrence records
1999-2011
Other RTGS occurrence records
1977-2012
10x10 km sampling frame
MGS range
BLM lands
Military lands
LONE PINE
Owens Lake
OLANCHA
Coso Range
Tulare County
China Lake Naval Air Weapons Station
Inyo County
China Lake
Searles Lake
INYOKERN
Freeman Gulch
RIDGECREST
Kern County
Little Dixie Wash
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Superior Valley
Desert Tortoise Natural Area
Fort Irwin Western Expansion Area
Coolgardie Mesa
Coyote Lake
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Kramer Junction
Harper Lake
Rogers Lake
Edwards Air Force Base
BARSTOW
Rosamond Lake
San Bernardino County
Los Angeles County
LANCASTER
Saddleback Butte SP
El Mirage Lake
PALMDALE
VICTORVILLE
MCAGCC Twenty Nine Palms
25
Miles
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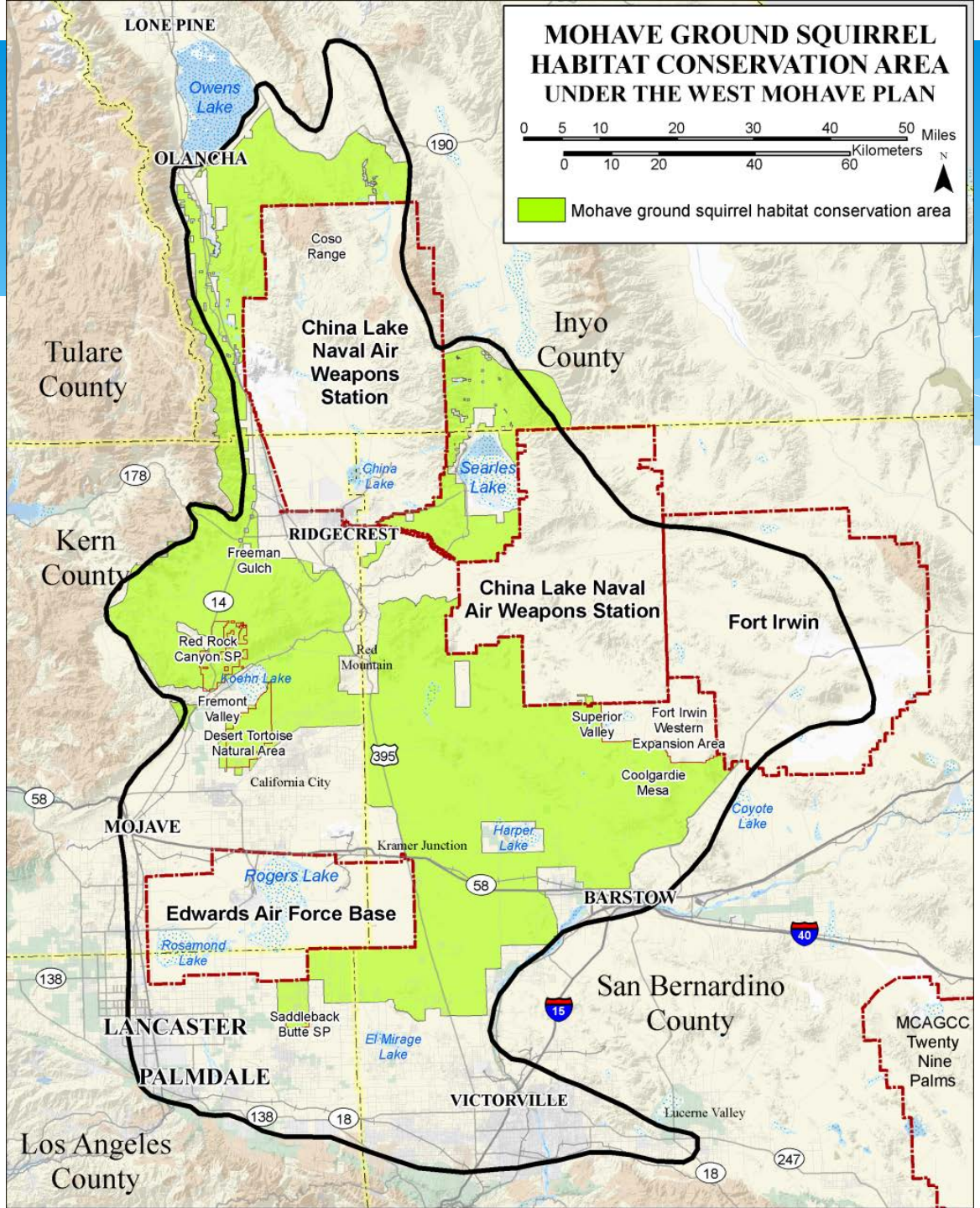
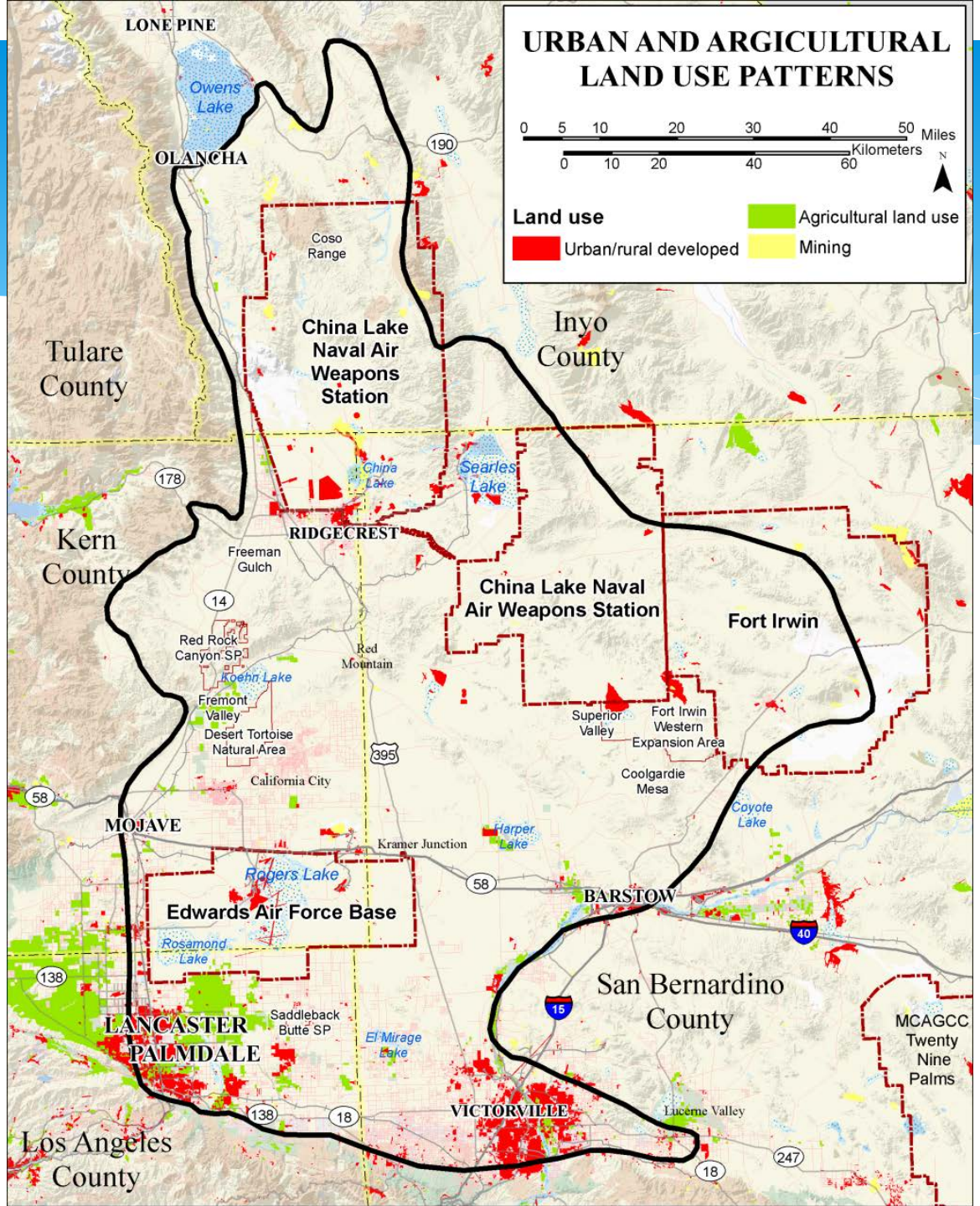

MOHAVE GROUND SQUIRREL
HABITAT CONSERVATION AREA
UNDER THE WEST MOHAVE PLAN
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Mohave ground squirrel habitat conservation area
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
Fort Irwin
Red Rock Canyon SP
Red Mountain
Koehn Lake
Fremont Valley
Desert Tortoise Natural Area
Superior Valley
Fort Irwin Western Expansion Area
395
California City
Coolgardie Mesa
58
Coyote Lake
MOJAVE
Harper Lake
Kramer Junction
Rogers Lake
58
BARSTOW
Edwards Air Force Base
40
Rosamond Lake
138
San Bernardino County
15
LANCASTER
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
PALMDALE
VICTORVILLE
Lucerne Valley
138
18
Los Angeles County
247
18


URBAN AND ARGICULTURAL LAND USE PATTERNS
0 5 10 20 30 40 50 Miles
0 10 20 40 60 Kilometers
N
Land use
Urban/rural developed
Agricultural land use
Mining
LONE PINE
Owens Lake
OLANCHA
190
Coso Range
China Lake Naval Air Weapons Station
Inyo County
Tulare County
178
China Lake
Searles Lake
RIDGECREST
Kern County
Freeman Gulch
14
China Lake Naval Air Weapons Station
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San Bernardino County
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LANCASTER
PALMDALE
Saddleback Butte SP
El Mirage Lake
MCAGCC Twenty Nine Palms
VICTORVILLE
Lucerne Valley
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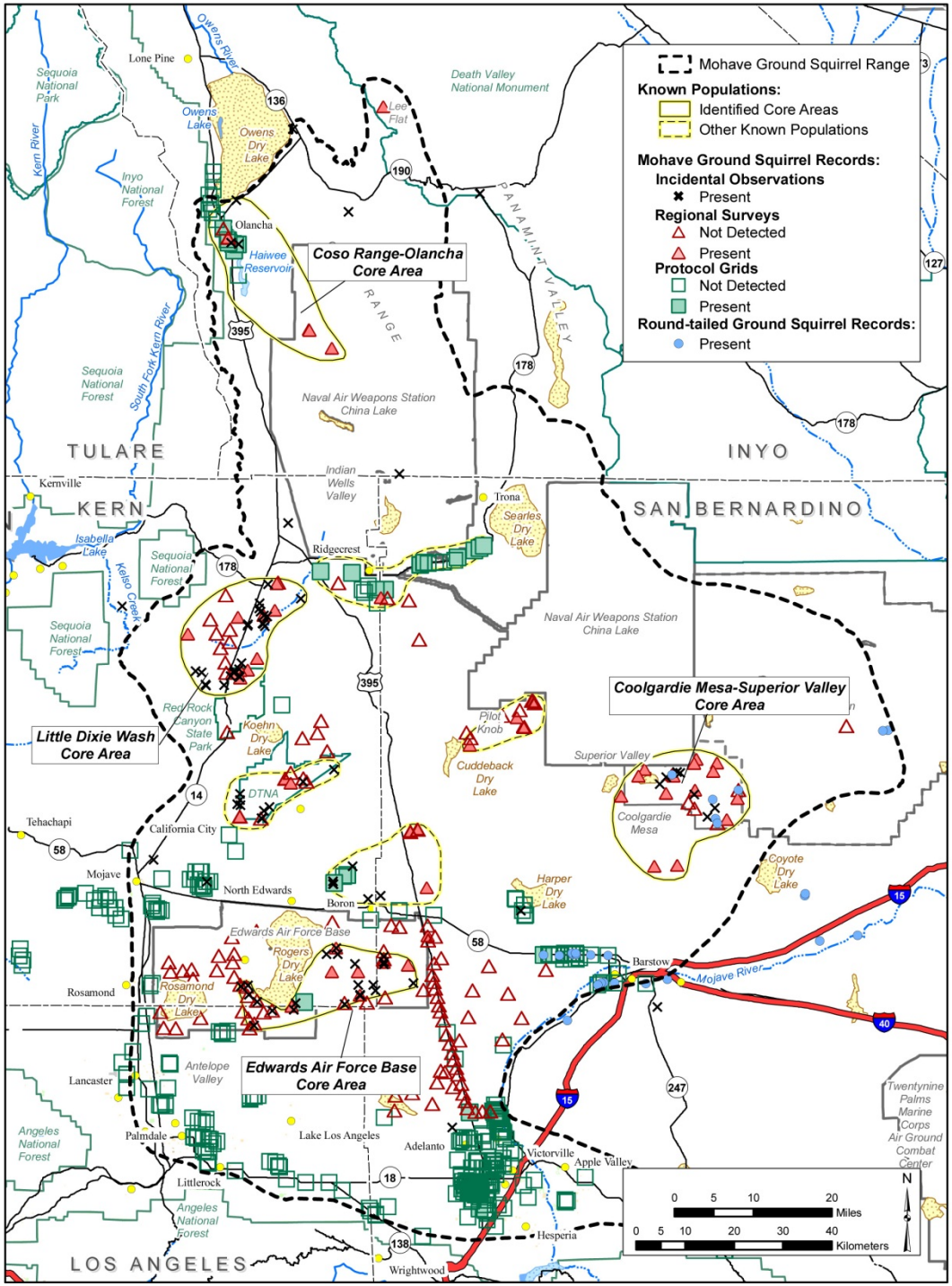
Los Angeles County


Mohave Ground Squirrel Range
Known Populations:
Identified Core Areas
Other Known Populations
Mohave Ground Squirrel Records:
Incidental Observations
Present
Regional Surveys
Not Detected
Present
Protocol Grids
Not Detected
Present
Round-tailed Ground Squirrel Records:
Present
Coso Range-Olancha Core Area
Little Dixie Wash Core Area
Coolgardie Mesa-Superior Valley Core Area
Edwards Air Force Base Core Area
TULARE
KERN
INYO
SAN BERNARDINO
LOS ANGELES
Lone Pine
Owens Lake
Owens Dry Lake
Olancha
Haiwee Reservoir
Sequoia National Park
Kern River
Inyo National Forest
South Fork Kern River
Sequoia National Forest
Death Valley National Monument
Lee Flat
PANAMINT VALLEY
RANGE
Naval Air Weapons Station China Lake
Indian Wells Valley
Trona
Searles Dry Lake
Kernville
Isabella Lake
Kelso Creek
Ridgecrest
Red Rock Canyon State Park
Koehn Dry Lake
DTNA
Pilot Knob
Cuddeback Dry Lake
Superior Valley
Coolgardie Mesa
Coyote Dry Lake
Tehachapi
California City
Mojave
North Edwards
Boron
Harper Dry Lake
Edwards Air Force Base
Rogers Dry Lake
Rosamond Dry Lake
Rosamond
Barstow
Mojave River
Lancaster
Antelope Valley
Palmdale
Lake Los Angeles
Adelanto
Victorville
Apple Valley
Hesperia
Littlerock
Angeles National Forest
Wrightwood
Twentynine Palms Marine Corps Air Ground Combat Center
0 5 10 20 Miles
0 5 10 20 30 40 Kilometers
N

Edwards Air Force Base

EDWARDS AIR FORCE BASE

AFTC/CEV
SBIR PROJECTS

Environmental Management

Integrity - Service - Excellence

SBIR Basics

- The Small Business Innovative Research (SBIR) program is a highly competitive program that encourages small business to explore their technological potential and provide the incentive to profit from its commercialization.
- SBIR targets the entrepreneurial sector because that is where most innovation and innovators thrive.
- Since its enactment in 1982 as part of the Small Business Innovation Development Act, SBIR has helped thousands of small businesses to compete for federal research and development awards.
- The SBIR program is a three-phase program. Phase I is the startup phase, awards of up to $100,000 for approximately 9 months support to explore the technical merit or feasibility of an idea or technology (*increase to $150,000 beginning FY11*).
- Phase II awards of up to $750,000 over a 2 years period expands Phase I results to the prototype stage (*increase to $1,000,000 beginning FY11*).
- Phase III is the period during which Phase II innovation moves from the laboratory into the marketplace. No AF SBIR funds support this phase.

Phase II
Multispectral Desert Fauna Surveillance and Recognition System

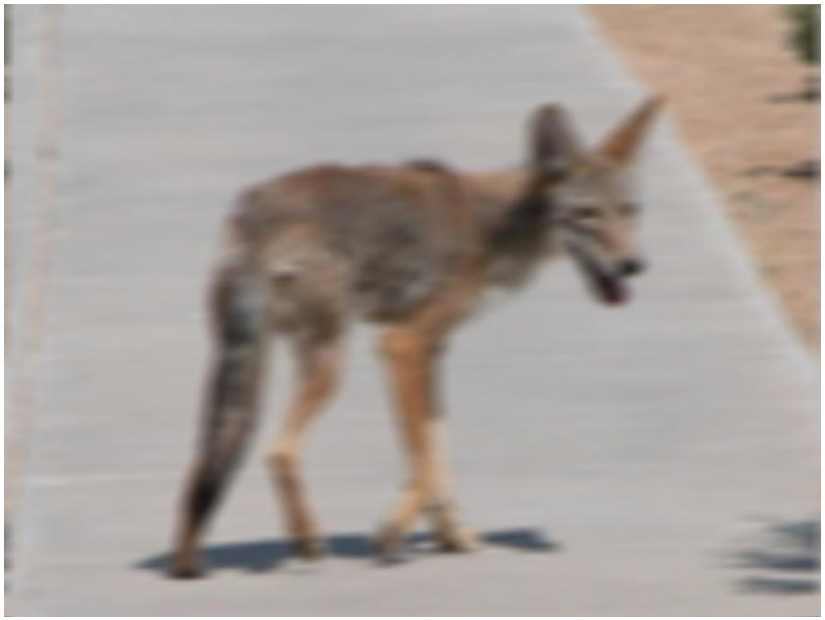
Danny C. Reinke
Paul Mattson

Topic Overview

- Uses adaptive ecosystem management strategies to protect the properties and values of the base's natural environment in concert with the military mission
- Data collection system to integrate with a sensor suite for the purpose for observing and recognizing wildlife 24/7
- Uses a standard suite of digital video sensors that are multi-spectral (i.e. visual, color, infrared, etc.)

De-blurring Algorithms and Analysis

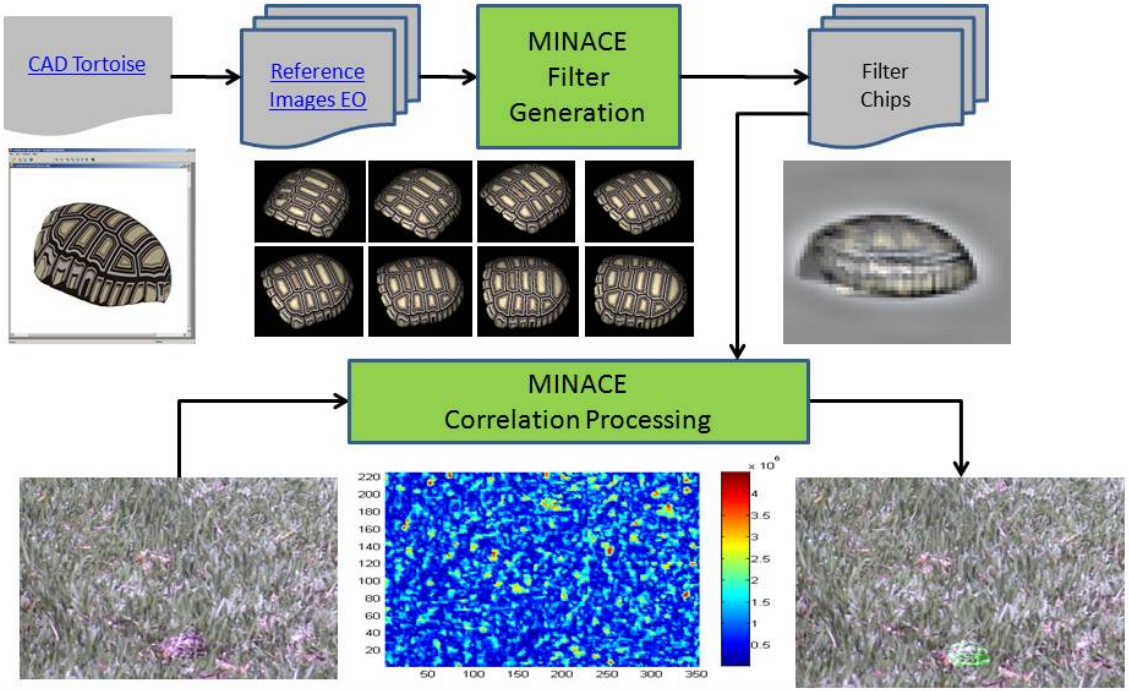
Goal is to Develop Algorithms that Can Run in a Real Time System to Estimate and Compensate for the Effects of Motion Blur and Atmospheric Blur from a Single Image



Motion Blurred Image

Atmospheric Blurred Image

Correlation - Color



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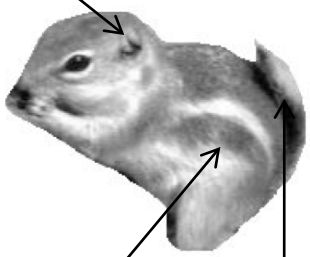
Benefits to the AFFTC

- Uses new technology to satisfy legal and Air Force regulations to manage natural resources, including wildlife
- Saves manpower that would be used to perform these tasks manually
- Saves significant cost of outside consultants licensed to handle the wildlife during manual data collection
- Avoids the use of traps

Squirrel Species Identification

White-tailed Antelope Squirrel

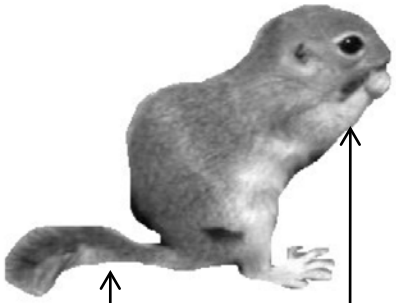
Ears stick up a bit higher than those of the others



White lateral stripe on each side of body

Tufts of white hair on backside of tail

Mohave Ground Squirrel



Uniformly Brown

Light fur on back of tail

Round-tailed Ground Squirrel

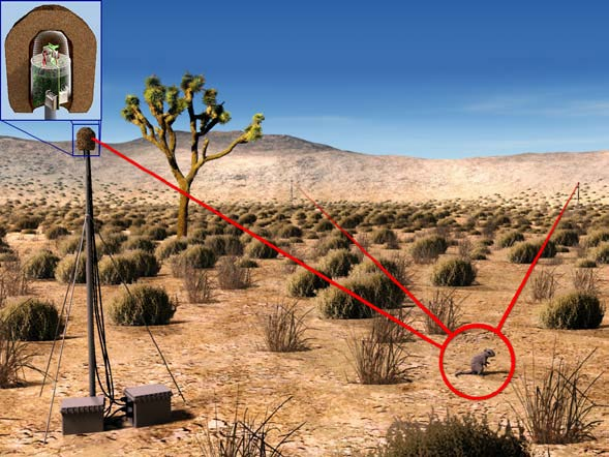
Longer thinner tail compared to MGS

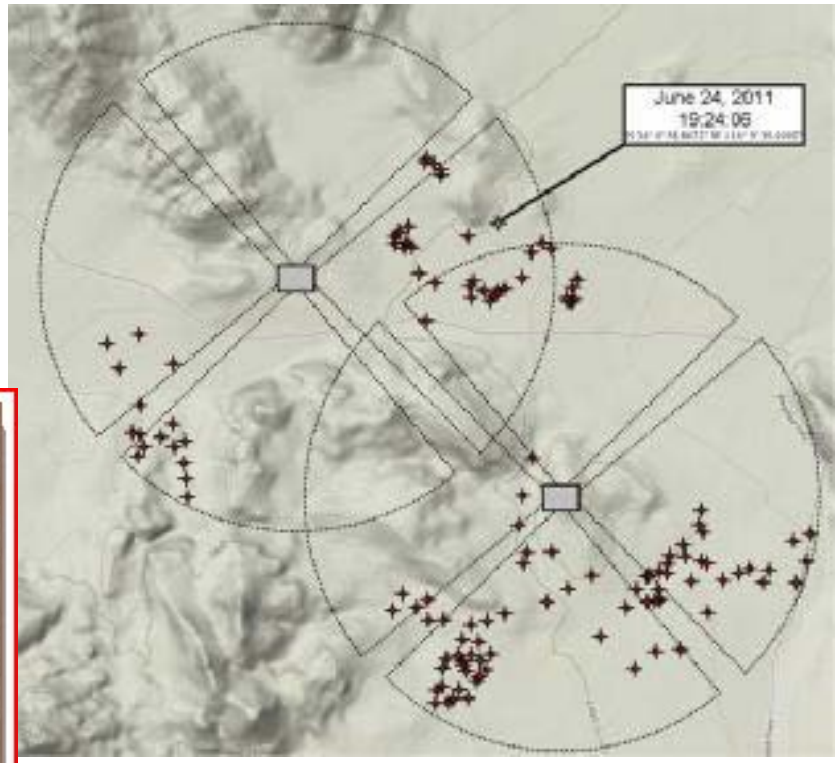
Phase I - Dr. Danny Reinke
Floral Disruptor - Directed-Energy Weed Abatement and Prevention

OBJECTIVE: Research and develop a device that uses electromagnetic radiation emissions as a form of prevention and abatement to kill, at long distances, unwanted plants (weeds) in and around areas that require control or defoliation. The primary purpose of this system will be to kill unwanted seedlings to mature plants. A secondary purpose for this technology would be to prevent unwanted plant seeds from germinating growing in areas of concern.

Phase I - Dr. Danny Reinke Acoustic Detection and Tracking System

OBJECTIVE: Research and develop a system that uses a ruggedized field-portable unit to detect and track desert fauna in remote areas. The primary purpose of this system is a drastic reduction of costs/manpower and field time required to determine the presence/absence of sensitive species. A secondary purpose is to produce species specific activity maps (similar to lighting strike maps) with frequency and location (+/- 2 meters), thereby enabling researchers to develop follow-up studies in an efficient manner. Most animal have at least two calls or songs, many have more and may have other detectable marks. The Activity map should document at least “alert or danger” calls and “mating” signals.

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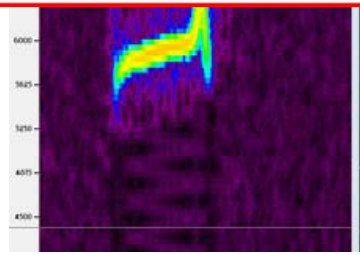
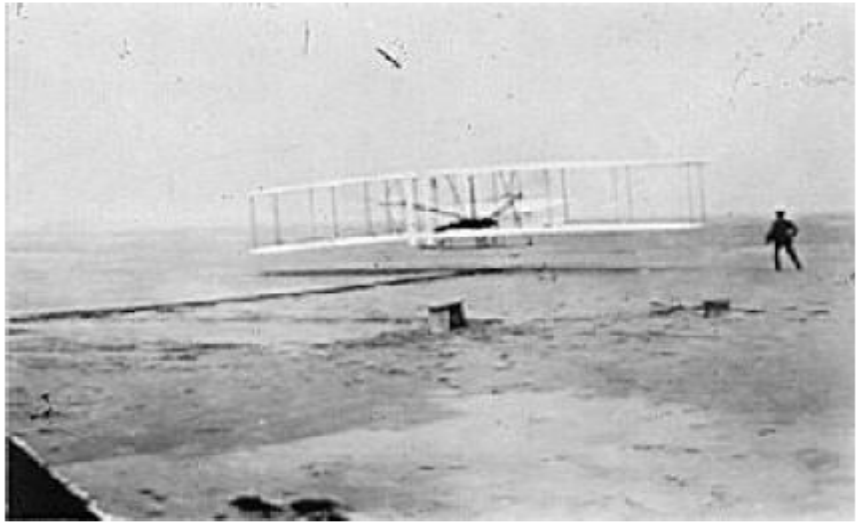


Phase II
Non-Lethal Avian
Active Denial System
Utilizing Directed Energy

Danny C. Reinke, PhD
Paul Mattson

No-lethal Avian ADS



This is the #1 engine of the MD-80 after ingesting at least 1 double-crested cormorant on 16 September

Cost the civil aviation industry in the USA at least $500 million in direct damage and associated costs and over 500,000 hours of aircraft down time.

Cost $1.2 billion to commercial aircraft worldwide.

Topic Overview

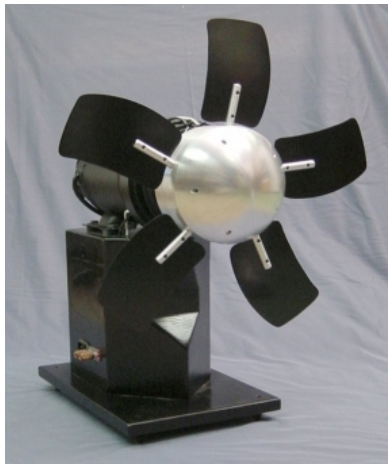
- Directed Energy Spin off
  - Builds on developments of military systems designed for use in non-lethal crowd control systems
  - Adapted for appropriate use to move birds off of active runways and out of the flight path of aircraft near the ground
  - Could use microwave, acoustic, ultrasonic, etc.
  - Designed to make birds uncomfortable in a particular area, but not harm them

Project Progress

NP Photonics teaming with
Bird Detection Radar company

XADS Green Laser Device

TII of Virginia Infrasound Device



EUL Solar Project

(a minimal impact/environmentally conscience project)

Considerations

Soft Footprint Approach

“Design in the Mitigation” - Avoid

- **Minimize plant removal & study the impact**
- **Maximize the potential for tortoise, squirrels and rare plants to improve**
- **Design in islands of undisturbed habitat**
  - **Monitor & compare to HQA baselines**

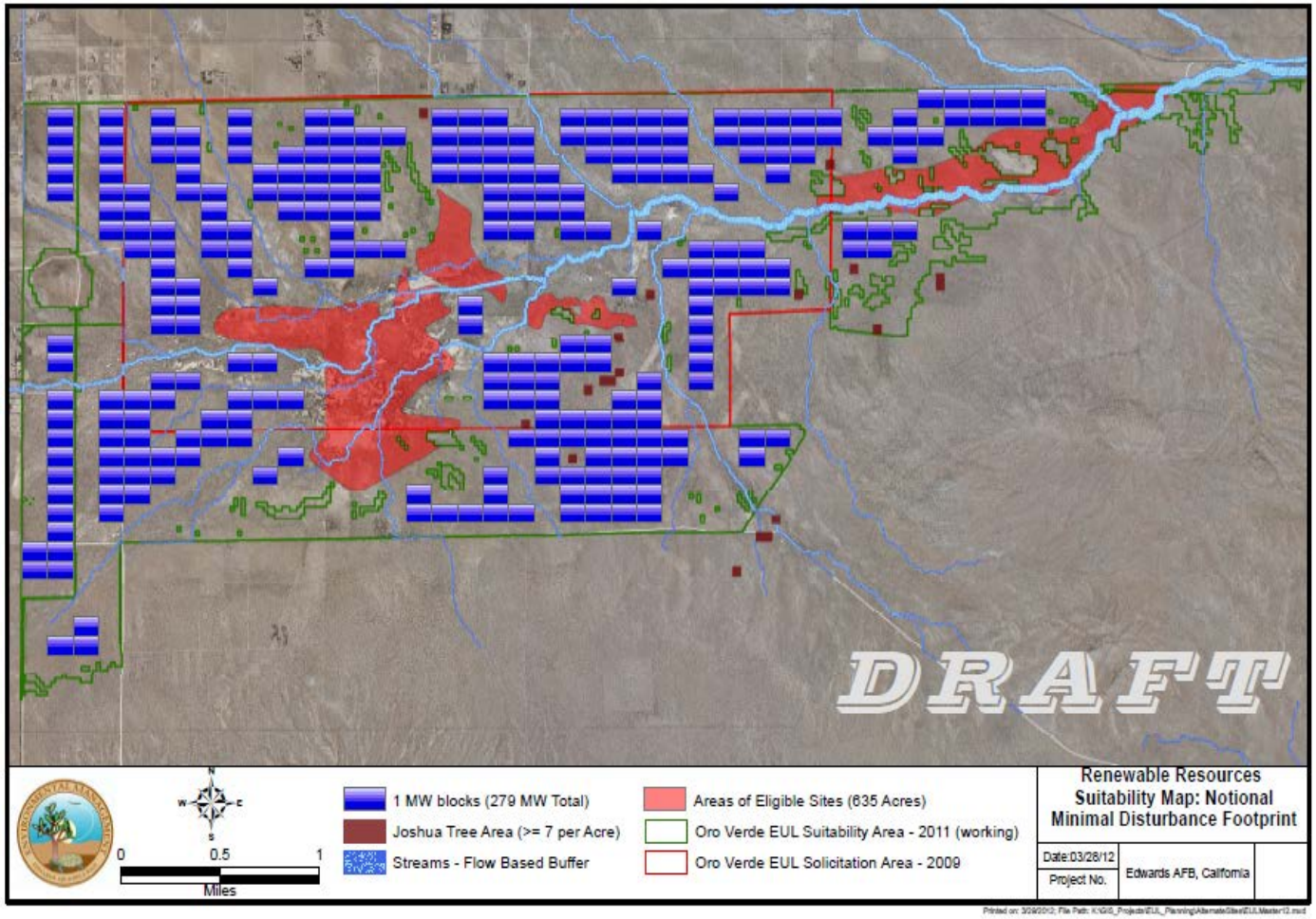
Smart (Military) Planning

- **Know what issues are important**
- **Know where the “hotspots” are and avoid**
- **Ensure the plan is followed**
- **Update as new issues develop - adapt**

Ground disturbance

- **Limited to maximum extent possible**
- **Avoid and/or limit impacts to Natural and Cultural resources**
- **Reduces impact to environment, avoids some mitigation that has to be done off-site**

Notional Footprint – Alternative 1



Buffers Around:

-Wash/gullies (also functions as wildlife corridors thru site)

-known CR sites

-known NR clusters

LIMITED:

-Vegetation removal (no mowing)

-ground disturbance (only if technically required)

Ground disturbance

Cultural sites

- Leave in place as much as possible
- Faster and much less impacts/costs

Site prep /construction

- **No "blade to grade"** – grading limited – trim plants
- **Soil density** -Limit vehicles to road after construction, limit construction activities as much as possible
  - use of large over-sized tires with low PSI
- **Stability of crypto-biotic soil crust**

  -Leave in place, limit disturbance

Drainage

- Erosion (drainage patterns, channeling run-off)
  - Don’t develop the drainages
- Maintain natural infiltration, reduces run-off, need less drainage structures
- Limits the need for erosion control activities/structures, - Not channeling runoff away from plant communities avoids what can be dramatic negative effects

Edge Effect

Edge Effect

- Find ways to make an asset. (impervious surfaces, roads, panels-light, etc)
- Disperses the “edge effect” typically produced by construction

Exotic plant invasion

- Clean equipment for seeds, limit disturbance
- Less opportunity for exotic plants to become established

Species Harassment

Temp Removal/Replace – long term monitoring

- Move out of the way – return to site
- No translocation issues, study “compatibility” issues
  - Recommended in the desert tortoise Recovery Plan
- Project design adjustments for impact avoidance
- Ideally will reduce the need for off-site mitigation

Worker Training

(During Construction)

Training – Required by Edwards Biological Opinions

Monitors & Monitoring

More than most projects, full-time environmental monitors, monitoring all aspects of the projects

Avoids take – Required by Edwards Biological Opinions

Direct Mortality

Roads, fire, construction

-Salvage selected biologically important specimens

-Plants prep for teaching and research institutions

-Seeds collected, storage and possible use in restoration of sites

-Animals send to research institutions

-Both have tissues for genetic studies

Nothing wasted, supports education and provide resource material for scientific research

Roads

Limited as much as possible

Vehicles

- use oversize tires with low PSI
-drivers trained
-speed limits strictly enforced

Limits “take”

Dust & Dust Suppressants

Limited disturbance

- Leave native plants/biotic crust as a natural dust suppressant

- **Prohibit commonly used suppressants**

– brines and salts

-Most of these damage native plants, and can migrate off site

Design In Habitat Preservation

Density of Panel Arrays

- Determine if PV projects are compatible with native wildlife

Corridor “habitat” strips

- Design project area to include different levels of density and corridors (e.g. green space along wash/stream beds)
- Provide free movement for “migration” corridors for wildlife, strips allow wildlife to pass thru the project without impediments
- Maintains migration patterns, gene flow, habitat for on-site wildlife to use

Minimize Habitat loss

- **Co-located project in wildlife habitat**
  - The Grand Experiment
- **Determine if solar projects can be located in wildlife habitat without “loss” of wildlife values – NEPA’s “Productive Harmony”**
- **The studies & monitoring may reduce or eliminate mitigation on future EAFB developments**

Light Pollution

Ecological Light pollution

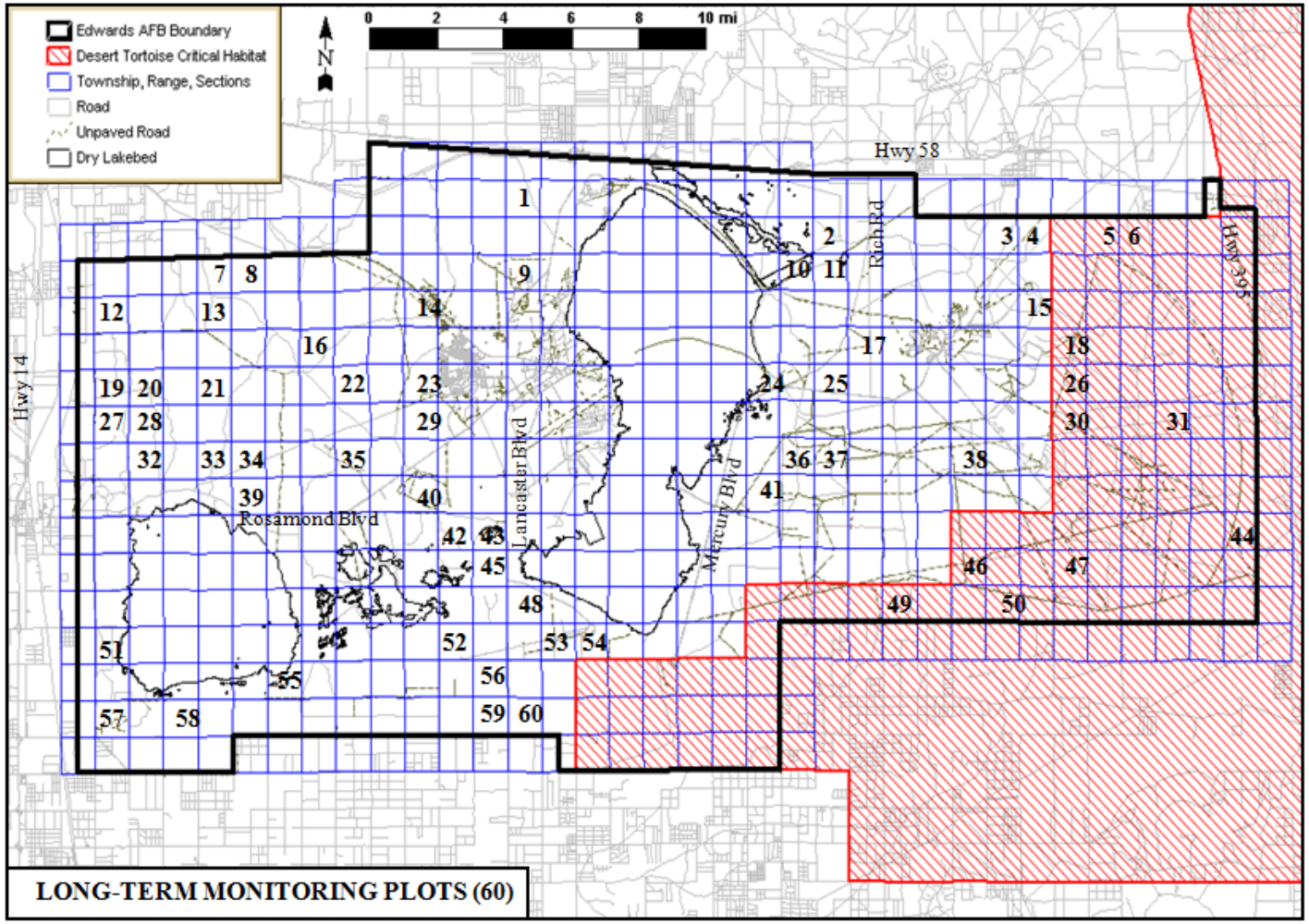
-Use uni-directional lights, limit lighting to essential areas

Polarized light Pollution (all large dark bodies)

-Emerging issue

-Study areas around panels

Habitat Quality Assessment Sites



-Random site selected in 1993

-Species specific IDs (plant & animals) and relative abundance measurements

-Repeated 3-4 times at some sites over the years

-Standardized approach to limit variability

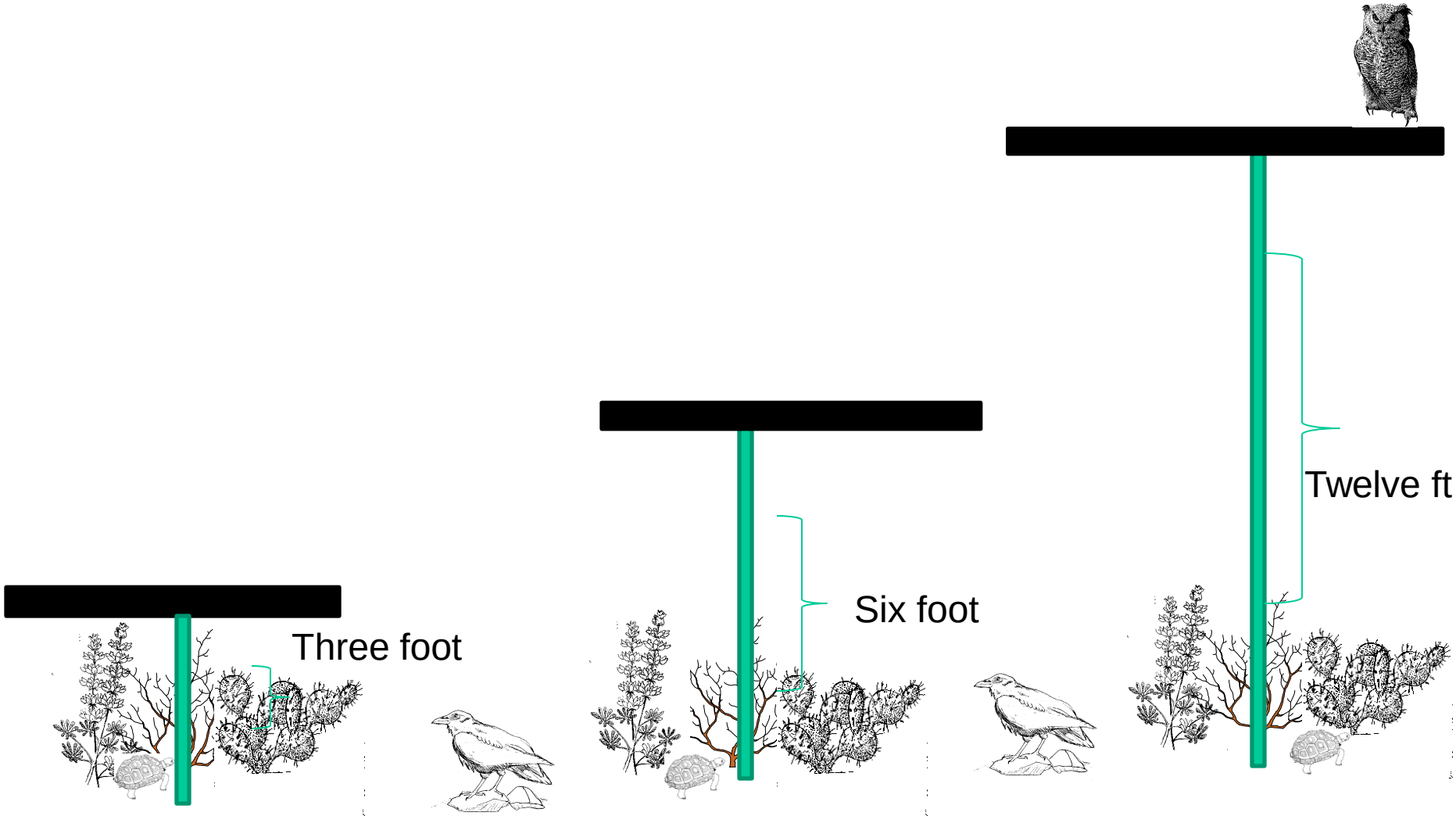
Monitoring/Studies After Construction

- **Long-term monitoring of vegetation and listed/sensitive species**
  - funding for expanded data collection at the 60 HQA sites - Continues the HQA monitoring sites

“ground-truths” the whole approach

- **Can Not “prove” the “effect” without scientifically valid data**

Refugium – Protected Areas

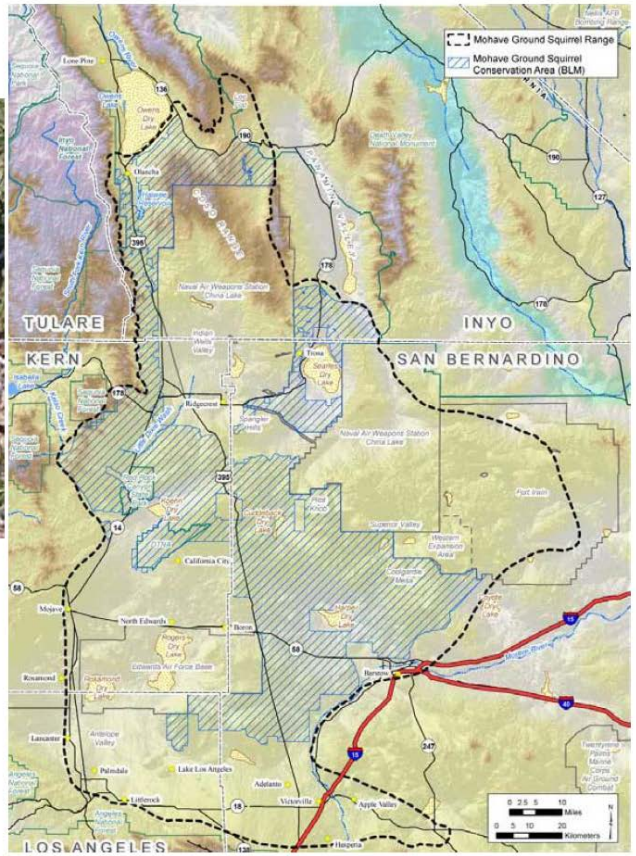


MGS Indexed Disk

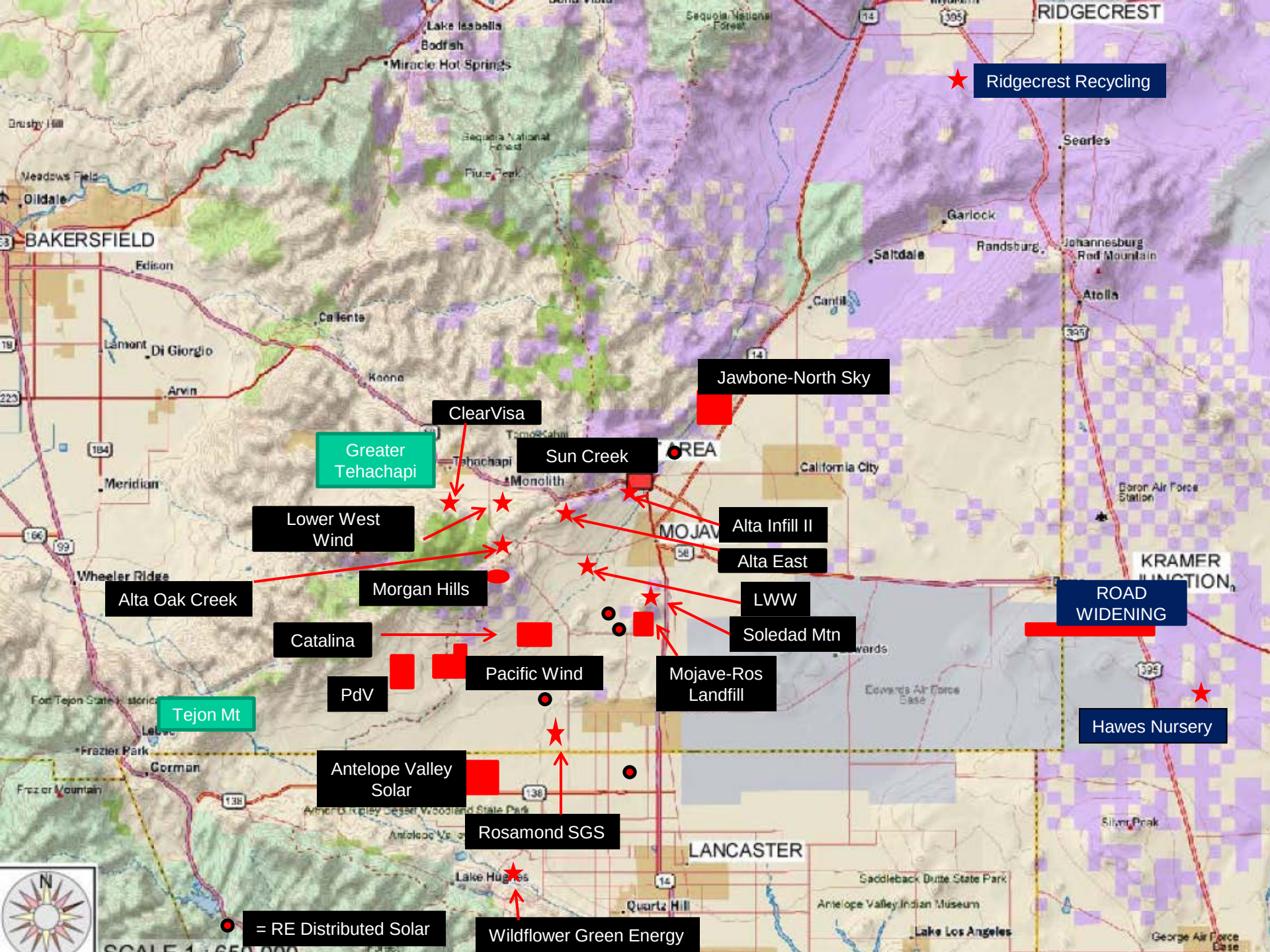
Mohave Ground Squirrel

Search All MGS focused publications

July 2012 V.3.5



- 323 files
- 2.76 GB
- Publications
- Gray Reports
- NEPA Documents
- CEQA Documents


Ridgecrest Recycling
RIDGECREST
Searles
Garlock
Randsburg
Johannesburg
Red Mountain
Saltdale
Atolia
Cantil
BAKERSFIELD
Edison
Oildale
Lamont
Di Giorgio
Arvin
Caliente
Keene
Tehachapi
Monolith
California City
Meridian
Wheeler Ridge
Jawbone-North Sky
ClearVisa
Greater Tehachapi
Sun Creek
Lower West Wind
Alta Infill II
Alta East
Alta Oak Creek
Morgan Hills
LWW
Soledad Mtn
Catalina
Pacific Wind
Mojave-Ros Landfill
PdV
Tejon Mt
ROAD WIDENING
KRAMER JUNCTION
Hawes Nursery
Frazier Park
Corman
Antelope Valley Solar
Rosamond SGS
LANCASTER
Lake Hughes
Quartz Hill
Wildflower Green Energy
= RE Distributed Solar
Edwards Air Force Base
Saddleback Butte State Park
Antelope Valley Indian Museum
Lake Los Angeles
Silver Peak
Baron Air Force Station
George Air Force Base
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The Ecology and Conservation of Mesocarnivores at White Sands National Monument, New Mexico

Quinn H. Robinson[1], David Bustos[2], Gary W. Roemer[1]

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[2] White Sands National Monument, PO Box 1086, Holloman AFB, NM 88330

11WHSAOCCU RECONYX

Research Background

- The community ecology of the White Sands (WHSA) ecosystem has received little study to date
- No information exists regarding the distribution or population dynamics of kit foxes, one of the monument's most iconic and important species
- Our research will enable wise resource management, ensuring the persistence of kit foxes and other mammalian species at WHSA

Research Background, cont.

Mammalian carnivores can greatly affect ecosystem structure and function (Berger et al. 2001, Crooks and Soule 1999)

Investigating the ecological role of carnivores at WHSA is therefore key to understanding the monument's broader ecology

Research Objectives

Primary Objective:

Investigate carnivore distributional patterns across WHSA using remote cameras

Research Objectives – Focal Species

Kit fox (*Vulpes macrotis*)

Research Objectives – Focal Species

Coyote (*Canis latrans*)

Research Objectives – Focal Species

American badger (*Taxidea taxus*)

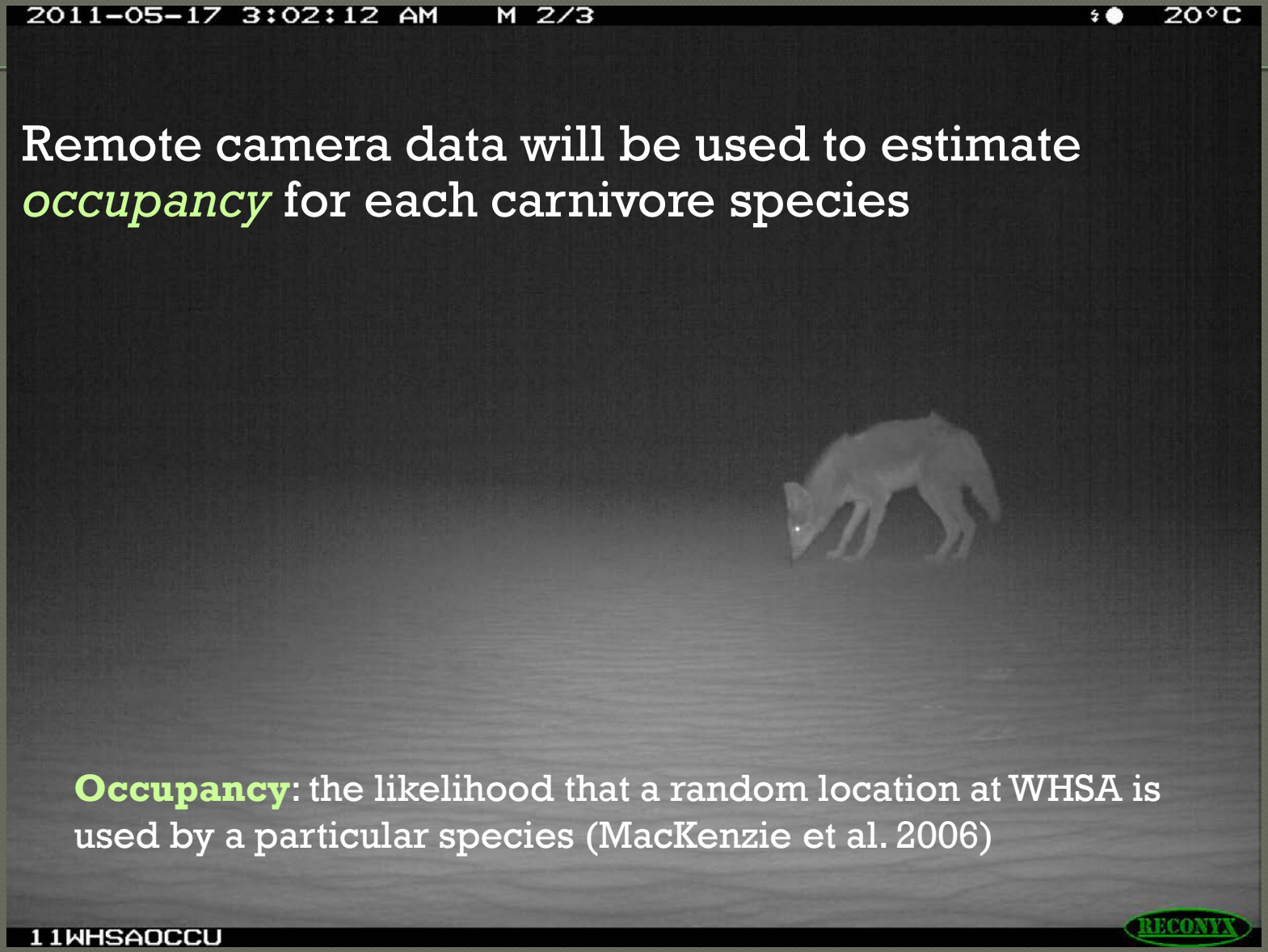
Research Objectives – Focal Species

Bobcat (*Lynx rufus*)

Research Objectives – Focal Species

Striped skunk (*Mephitis mephitis*)

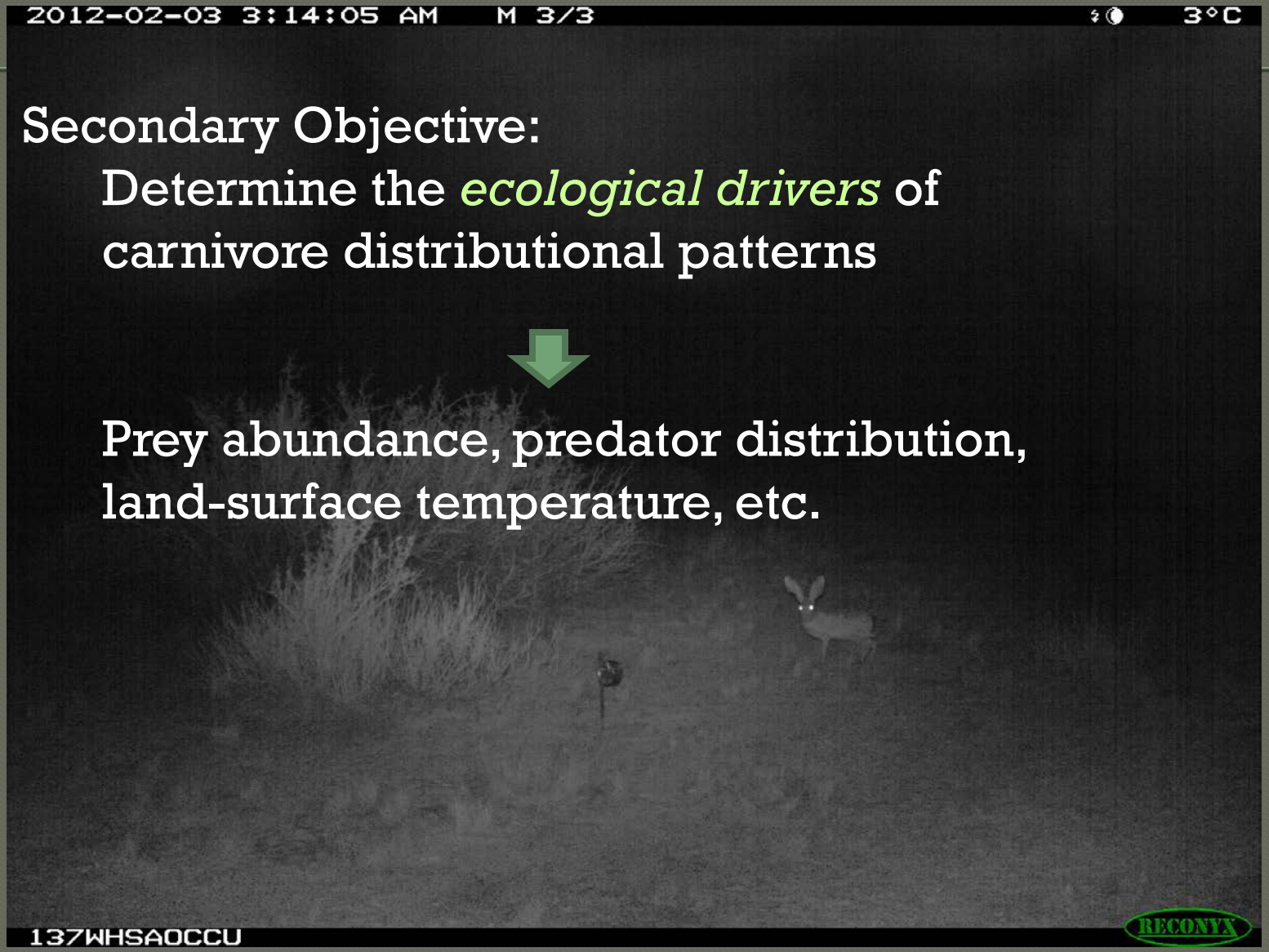
Research Objectives



Remote camera data will be used to estimate *occupancy* for each carnivore species

Occupancy: the likelihood that a random location at WHSA is used by a particular species (MacKenzie et al. 2006)

Research Objectives



Secondary Objective:

Determine the *ecological drivers* of carnivore distributional patterns

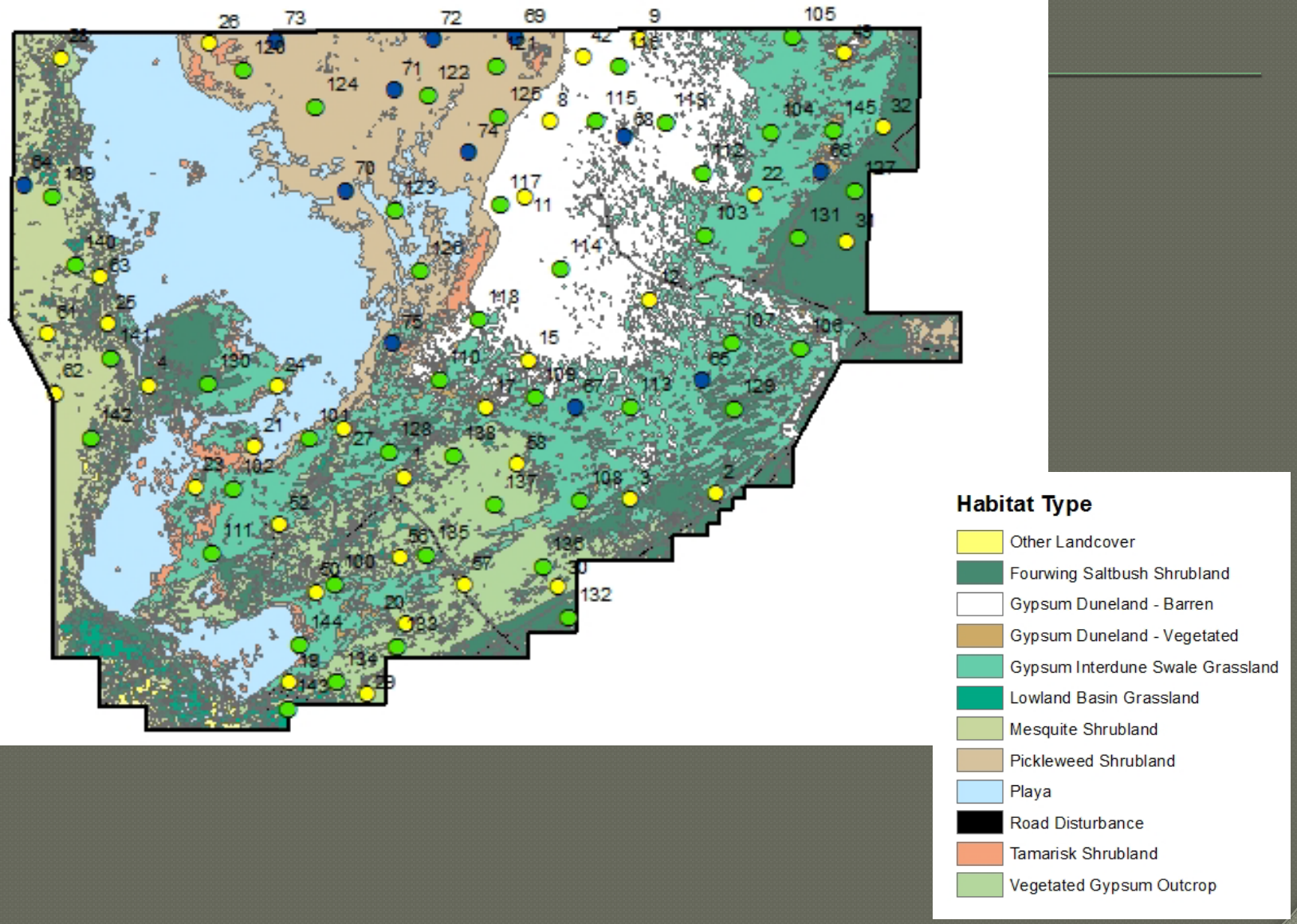
Prey abundance, predator distribution, land-surface temperature, etc.

Research Methods – Carnivore Occupancy

46 remote camera sites were randomly chosen in both 2011 and 2012

Habitat Type	Proportion of Study Area	# Cameras (N = 46)
Interdunal Grassland	0.27	12
Barren Gypsum Duneland	0.18	8
Pickleweed Shrubland	0.15	7
Fourwing Saltbush Shrublands	0.14	6
Vegetated Gypsum Outcrop	0.12	6
Mesquite Shrubland	0.08	4
Lowland Basin Grassland	0.03	1
Tamarisk Shrubland	0.02	1
Vegetated Gypsum Duneland	0.02	1

WHSA Remote Camera Locations, 2011-2012



Research Methods – Drivers of Carnivore Occupancy

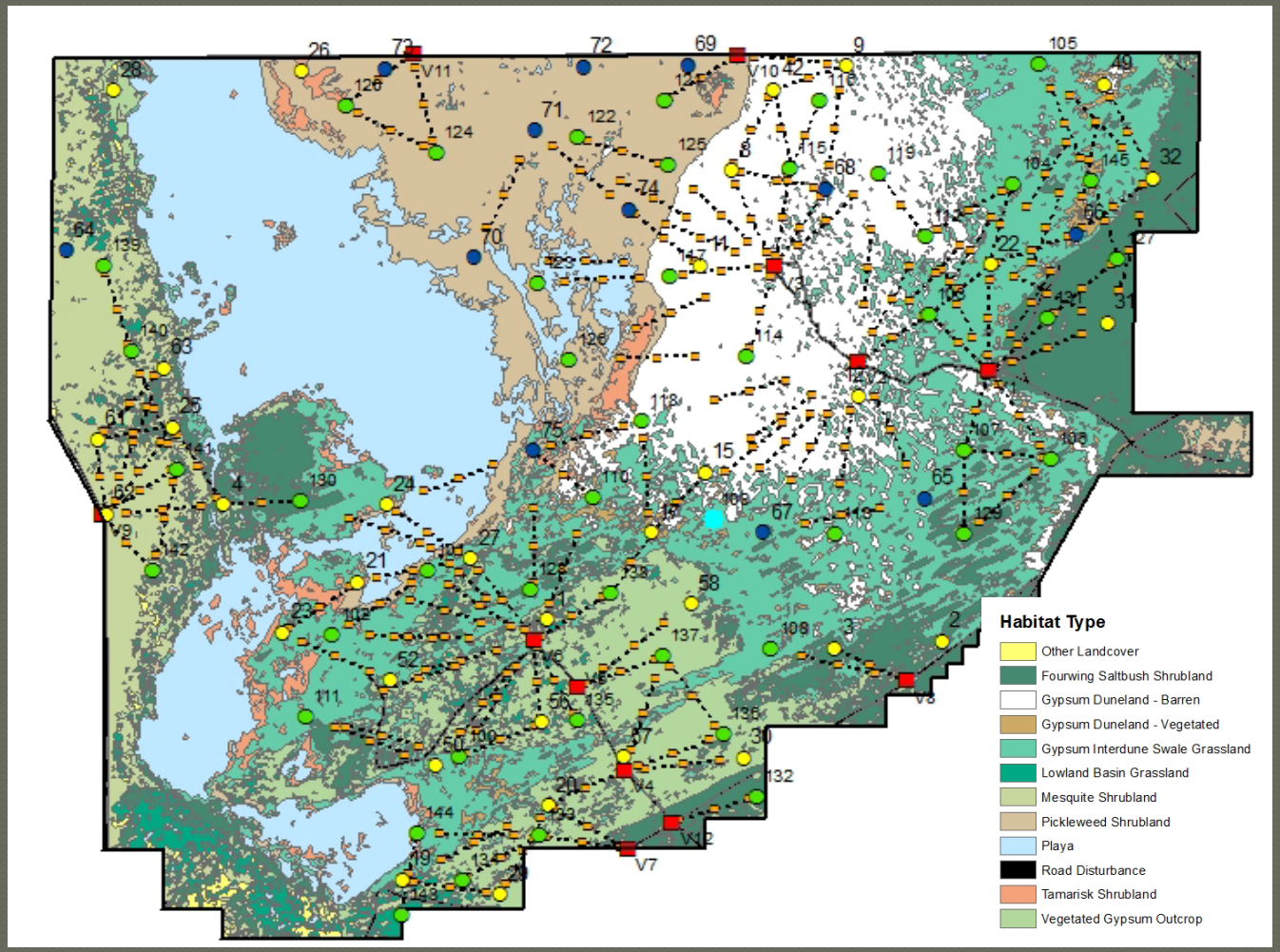
Possible determinants of carnivore distributional patterns:

-- Rabbit density
-- Rodent abundance
-- Invertebrate abundance
-- Predator distribution
-- Land-surface temperature
-- Habitat type

These factors will have different estimates in each habitat type at WHSA

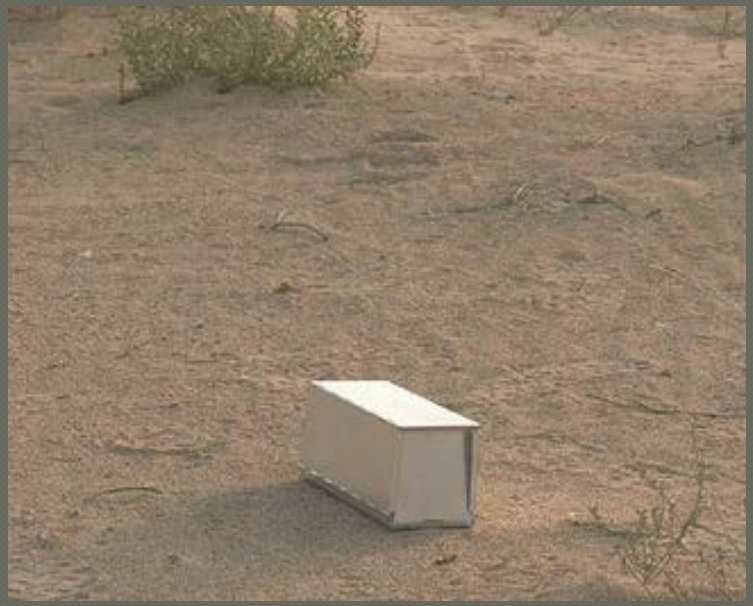
Research Methods – Drivers of Carnivore Occupancy

Rabbit density will be estimated by distance sampling (Buckland et al. 2001)

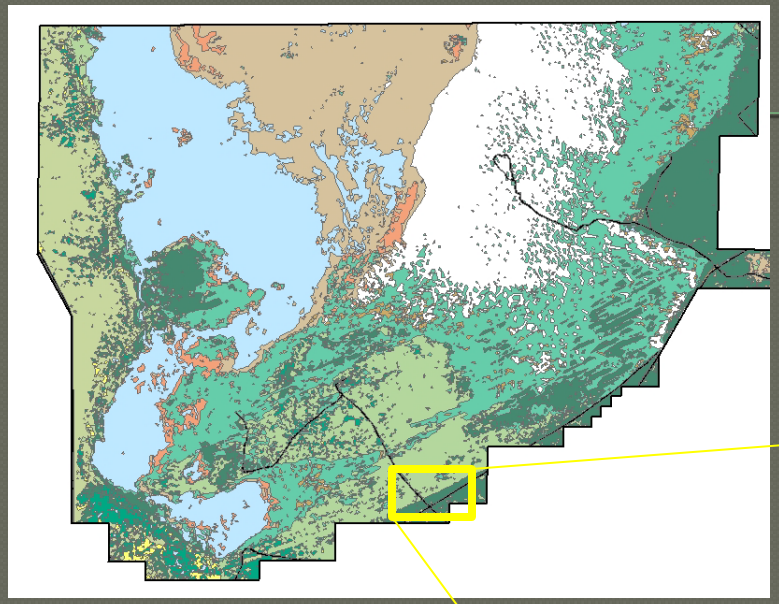


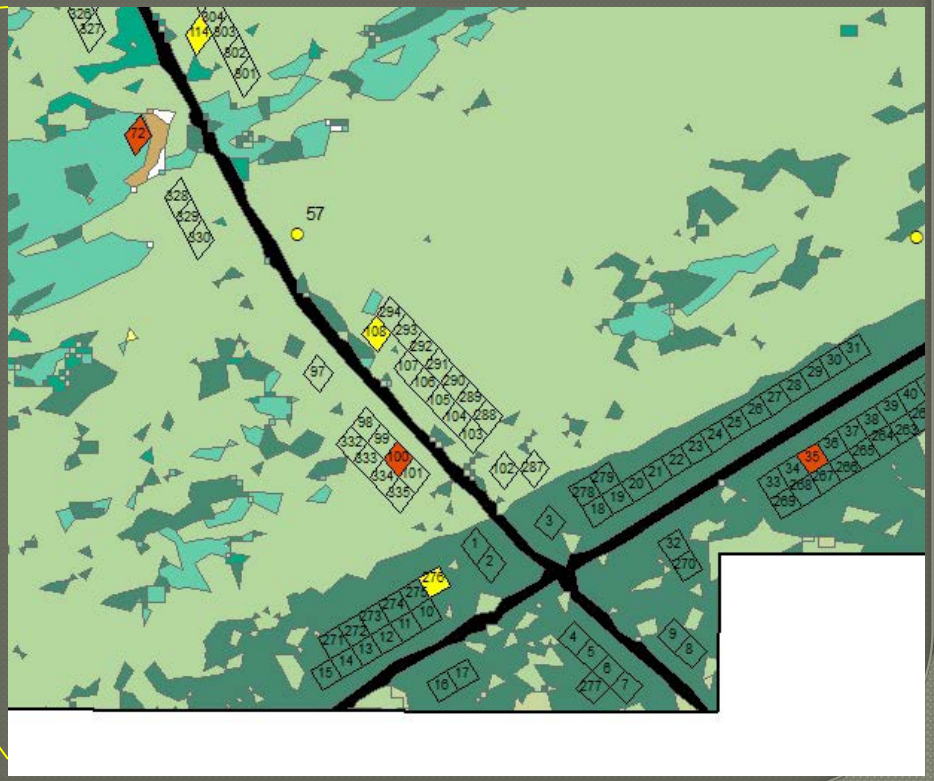
Research Methods – Drivers of Carnivore Occupancy

Rodent abundance will be estimated by capture-recapture live trapping



Rodent Trapping Sites





Research Methods – Drivers of Carnivore Occupancy

Invertebrate abundance will be estimated by pitfall trapping

Research Methods – Drivers of Carnivore Occupancy

Kit fox distribution may be influenced by coyote distribution, due to intra-guild predation / interference competition

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Research Methods – Drivers of Carnivore Occupancy

Kit foxes may selectively occupy areas that are unsuitable habitat for coyotes.

Kit foxes are well adapted to persist in such areas:

-- Obtain all water from food
-- Year-round use of dens
-- Nocturnal
-- Small size
-- High thermal neutral zone (31-33 °C, Golightly and Ohmart 1983).

69WHSAOCCU
RECONYX

Results – 2011 Camera Detection Data

Habitat Type	*Probability of Image / Day*				
	Coyote	*Kit fox*	*Badger*	*Bobcat*	*Skunk*
1. Interdunal Grassland	0.017	0.005	0.001	0.000	0.001
2. Barren Gypsum Duneland	0.004	0.023	0.000	0.000	0.002
3. Pickleweed Shrubland	0.000	0.011	0.000	0.000	0.000
4. Fourwing Saltbush Shrubland	0.047	0.009	0.001	0.000	0.000
5. Vegetated Gypsum Outcrop	0.021	0.006	0.000	0.001	0.000
6. Mesquite Shrubland	0.031	0.007	0.004	0.002	0.000

Results – 2011 Camera Detection Data

	Coyote	*Kit fox*	*Badger*	*Bobcat*	*Skunk*
χ^2 value ($\alpha = 0.05$, $\chi^2 = 11.07$, df = 5)	**151.2**	**36.65**	**26.84**	9.93	10.04
Apparent Habitat Preference	Fourwing Saltbush Shrubland	Barren Gypsum Duneland	Mesquite Shrubland	NA	NA

2011 camera data suggests that carnivore distribution across WHSA is not random.

Results – 2011 Prey Data

Habitat Type	*Rabbit Detections per km Sampled*	*Individual Rodents Captured per Trapping Grid*
1. Interdunal Grassland	0.35	1.8 (SD = 1.5)
2. Barren Gypsum Duneland	0.00	0.3 (SD = 0.5)
3. Pickleweed Shrubland	0.00	0.0 (SD = 0.0)
4. Fourwing Saltbush Shrubland	0.44	5.0 (SD = 2.9)
5. Vegetated Gypsum Outcrop	0.72	4.4 (SD = 1.9)
6. Mesquite Shrubland	0.85	5.0 (SD = 3.9)
	Total km sampled: 260.5	**Total grids sampled: 54**

Preliminary Conclusions

- Carnivore distribution across WHSA does not appear to be random.
- Kit foxes appear to *avoid* habitat types where rodents and rabbits – potentially key food sources – are relatively abundant. Kit fox distribution may be driven by predator avoidance or other factors.
- Coyotes and badgers appear to preferentially occupy habitat types where rodents and rabbits are relatively abundant.

Literature Cited

Berger J., Stacey P.B., Bellis L., and M.P. Johnson. 2001. A mammalian predator-prey imbalance: Grizzly bear and wolf extinction affect avian neotropical migrants. Ecological Applications 11: 947-960.

Buckland S.T., Anderson D.R., Burnham, K.P. Laake, J.L., Borchers, D.L and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford University Press, New York.

Crooks K.R. and M.E. Soule. 1999. Mesopredator release and avifaunal extinction in a fragmented system. Nature 400: 563-566.

Golightly, R.T. and R.D. Ohmart. 1983. Metabolism and body temperature of two desert canids: coyotes and kit foxes. Journal of Mammalogy 64: 624-635.

MacKenzie D.I., Nichols J.D., Royle J.A., Pollock K.H., Bailey L.L., and J.E. Hines. 2006. Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. New York, Academic Press, Elsevier Inc.

Remote Camera Pictures

Camera Site 09, Barren Gypsum Duneland

Remote Camera Pictures

Camera Site 58, Vegetated Gypsum Outcrop

Remote Camera Pictures

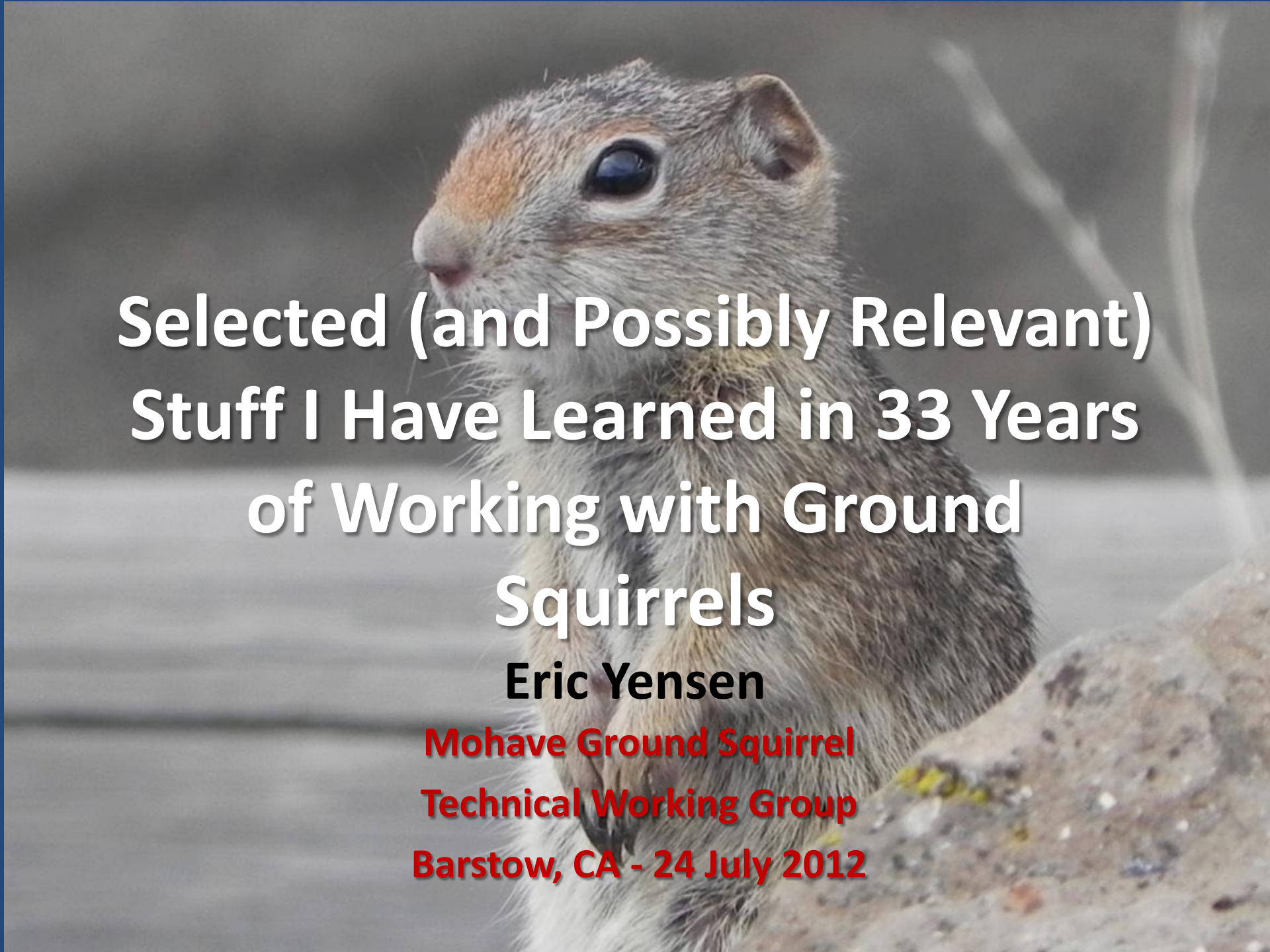
Camera Site 127, Fourwing Saltbush Shrubland

Remote Camera Pictures

Camera Site 25, Lowland Basin Grassland

Remote Camera Pictures

Camera Site 49, Barren Gypsum Duneland



Selected (and Possibly Relevant) Stuff I Have Learned in 33 Years of Working with Ground Squirrels

Eric Yensen

Mohave Ground Squirrel Technical Working Group

Barstow, CA - 24 July 2012

Statistics

- 60 publications in peer-reviewed journals, 13 book chapters, 2 books co-authored, 6 manuscripts in review or in press
- ~80 unpublished agency, grant, and consulting reports
- 42 Contributed Papers at Professional Meetings 1974-2012
- 45 manuscript reviews for peer-reviewed journals
- 8 graduate student committees
- Full teaching load at a liberal arts college

Types of Studies

- Taxonomy
  - description of *Urocitellus endemicus*
  - Genetics
  - phylogeny of *Spermophilus*
- Ecology
  - Distribution
  - Diet
  - Burrow structure
  - Habitat Selection
  - Demography, Fitness, and Habitat Quality
  - Interspecific competition
- Conservation
  - Translocation
  - Population Viability Analysis
  - Monitoring
  - Diseases
  - Habitat Modeling
  - Northern Idaho Technical (Recovery) Team
  - Southern Idaho Ground Squirrel Technical Working Group
- Review articles
- Education
  - Field Guide

Species

- Southern Idaho ground squirrel
- Northern Idaho ground squirrel
- Piute (Great Basin) ground squirrel
- Washington ground squirrel
- Columbian ground squirrel

Rock squirrel, Baja California rock squirrel, ground-dwelling squirrels of Pacific Northwest, *Spermophilus* and *Ammospermophilus* of North America, squirrels of NW Mexico, phylogeny of *Spermophilus* (*sensu latu*), etc.

- *I have trapped or collected 23 of 27 North American true ground squirrels (excluding antelope squirrels, but including Mexican endemics), and seen all but one…*

Case Study:
Northern Idaho Ground Squirrel

Fig. 1. Range of *Spermophilus brunneus* as depicted by Howell (1938).

Fig. 2. Range of *Spermophilus brunneus* as depicted by Davis (1939b)

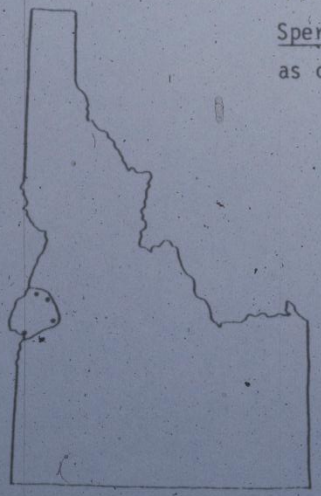
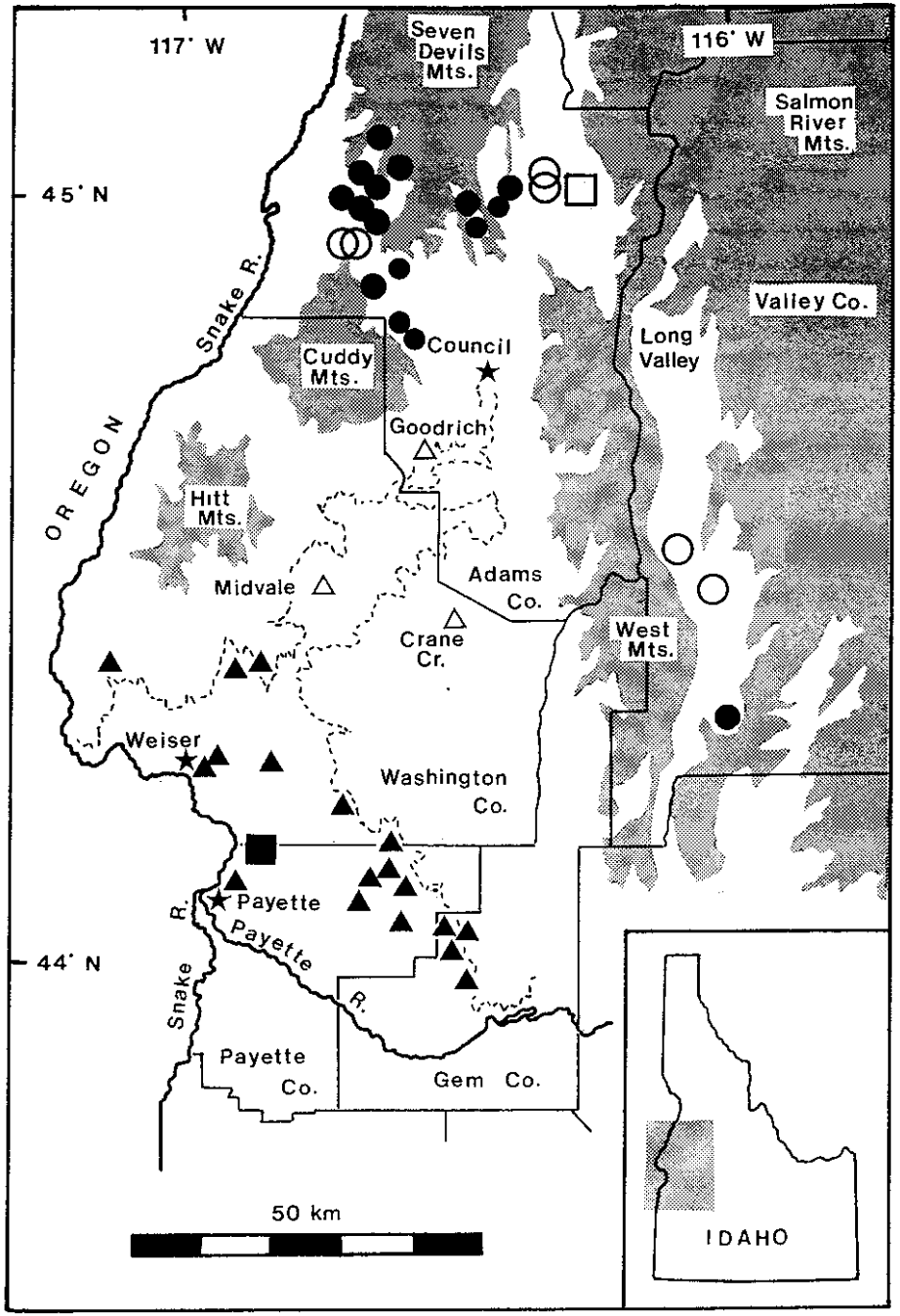
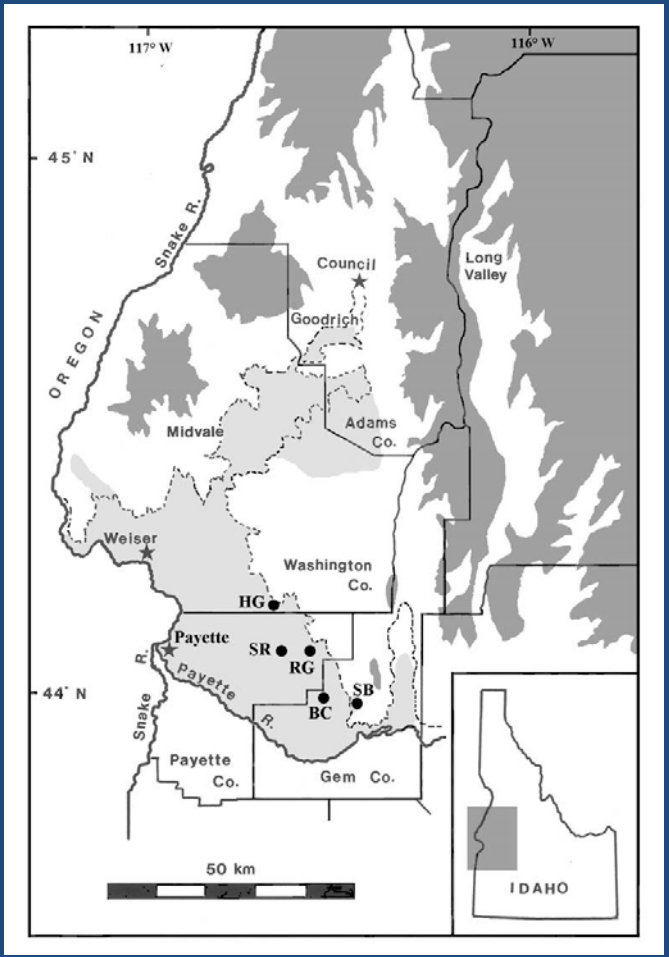


Fig. 3. Range of *Spermophilus brunneus* as presented in Hall and Kelson (1959).



Revision of *Urocitellus brunneus*



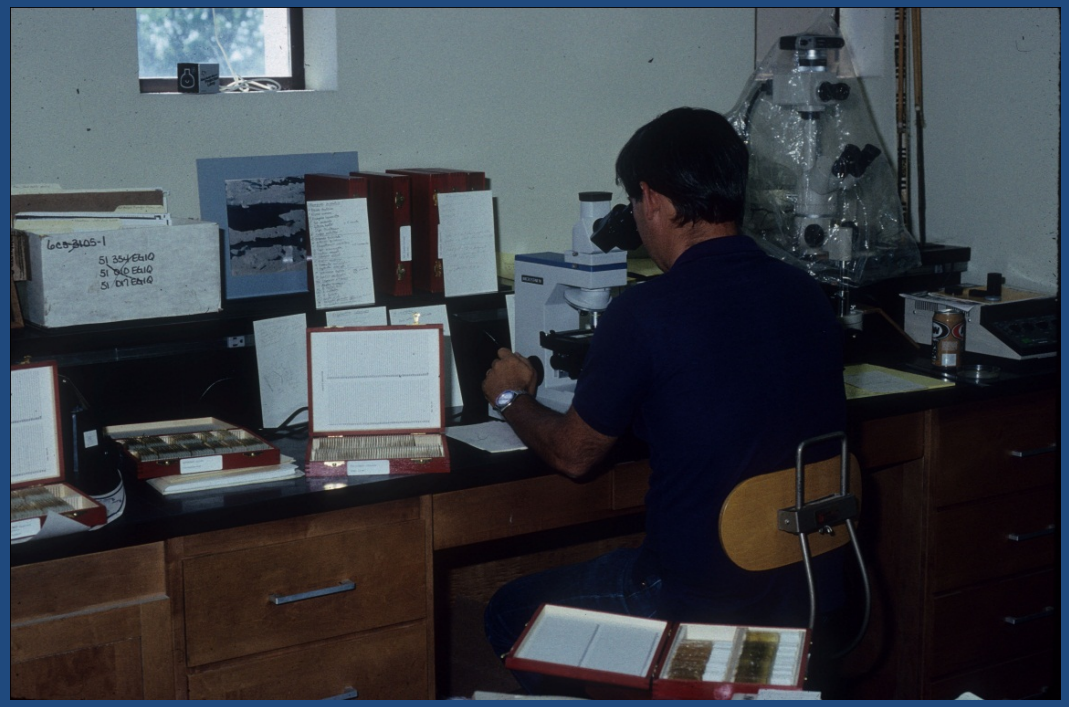
Why is the Idaho Ground Squirrel Rare?

Microhabitat Differences

Vegetation Analysis

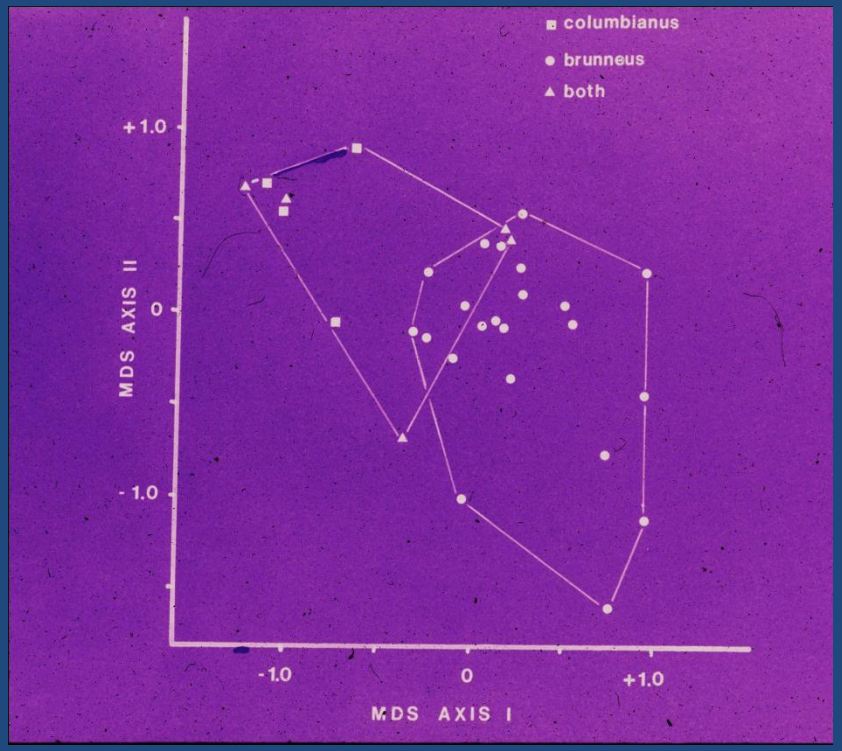
Vegetation Height

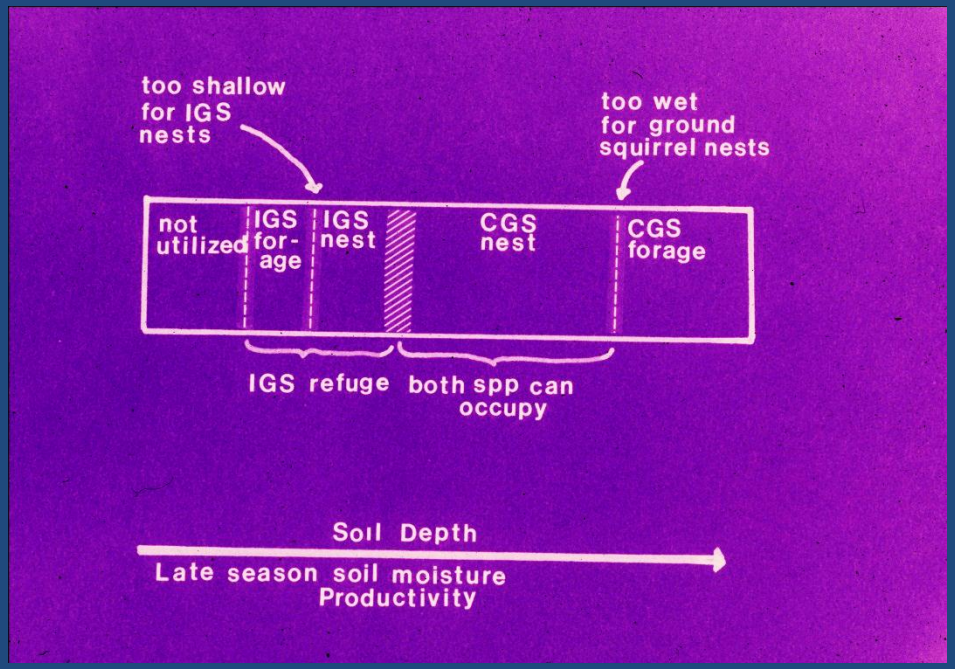
Diet Analyses



Northern Idaho Ground Squirrel
Southern Idaho Ground Squirrel
Piute Ground Squirrel
Washington Ground Squirrel
Columbian Ground Squirrel

Competition with Columbian Ground Squirrels





Excavating Burrows

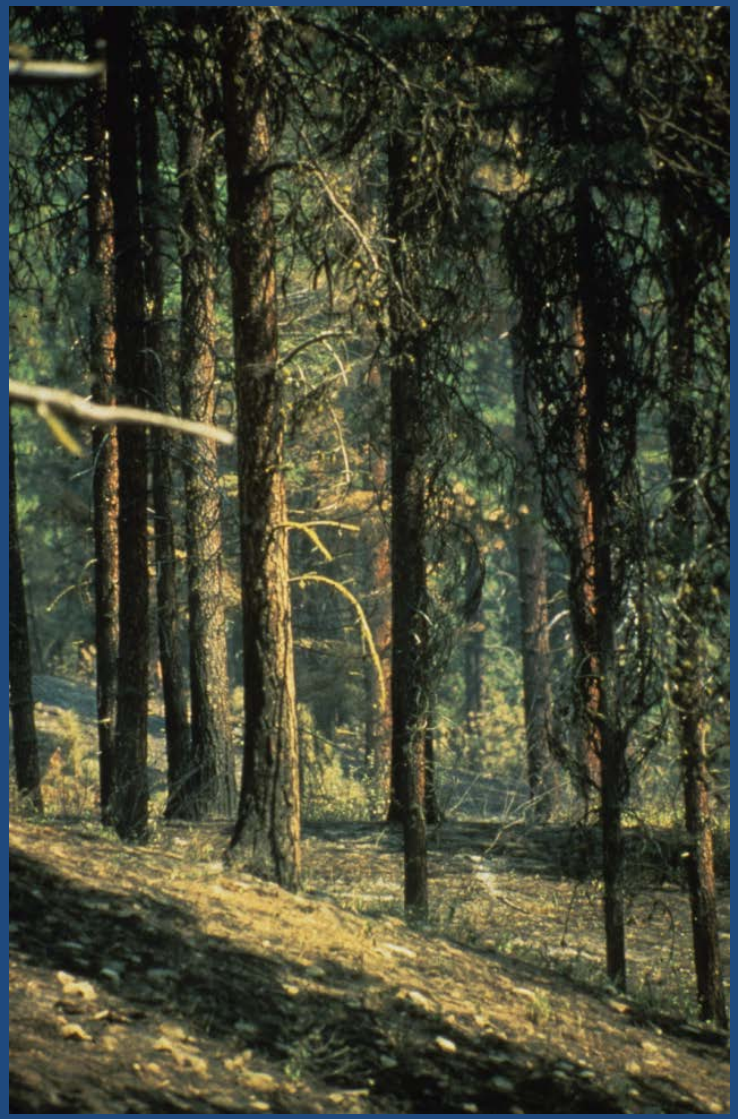
Affect of Thinning and Burning Treatments on Northern Idaho Ground Squirrels

Open Stand of Ponderosa Pine

Near Flagstaff, Arizona, 1914

Ground Fire

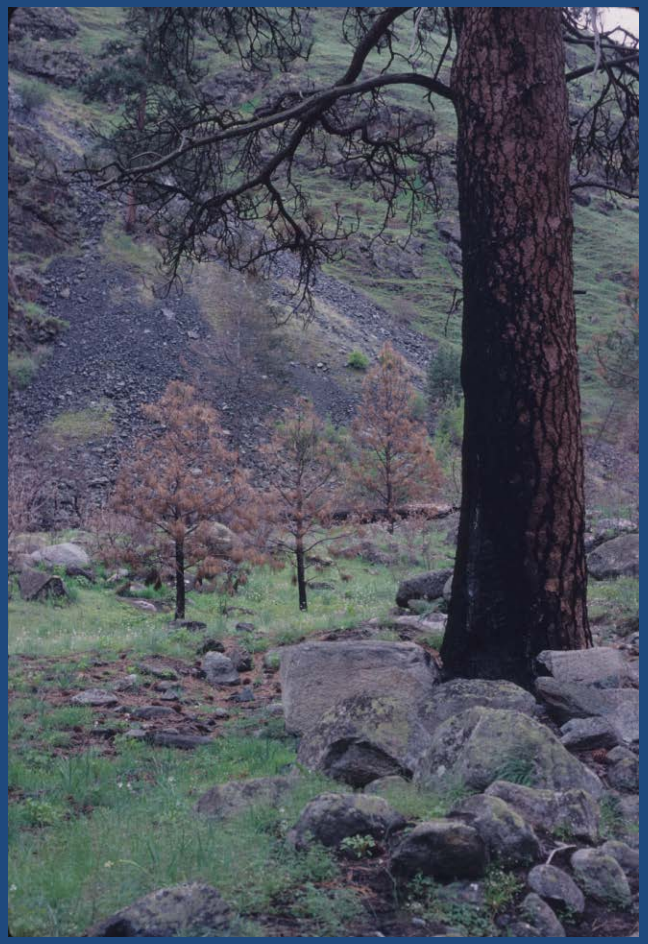
- Boise National Forest
- Notice low height of flames



Ground Fire

- Most of the trees in the photo survived.
- Boise National Forest

Fire-scarred Ponderosa Pine



- Scar is in burned area at base of tree to left.
- Note the dead small ponderosa pines.
- Hell's Canyon, Idaho ca. 1990.

Fire Scars

- Pith of tree at AD 1716
- Tree cut in 1983
- 14 fires to 1891 (175 years)
- Fire return interval = 12.5 years
- No fires from 1891 to 1983
- Boise National Forest

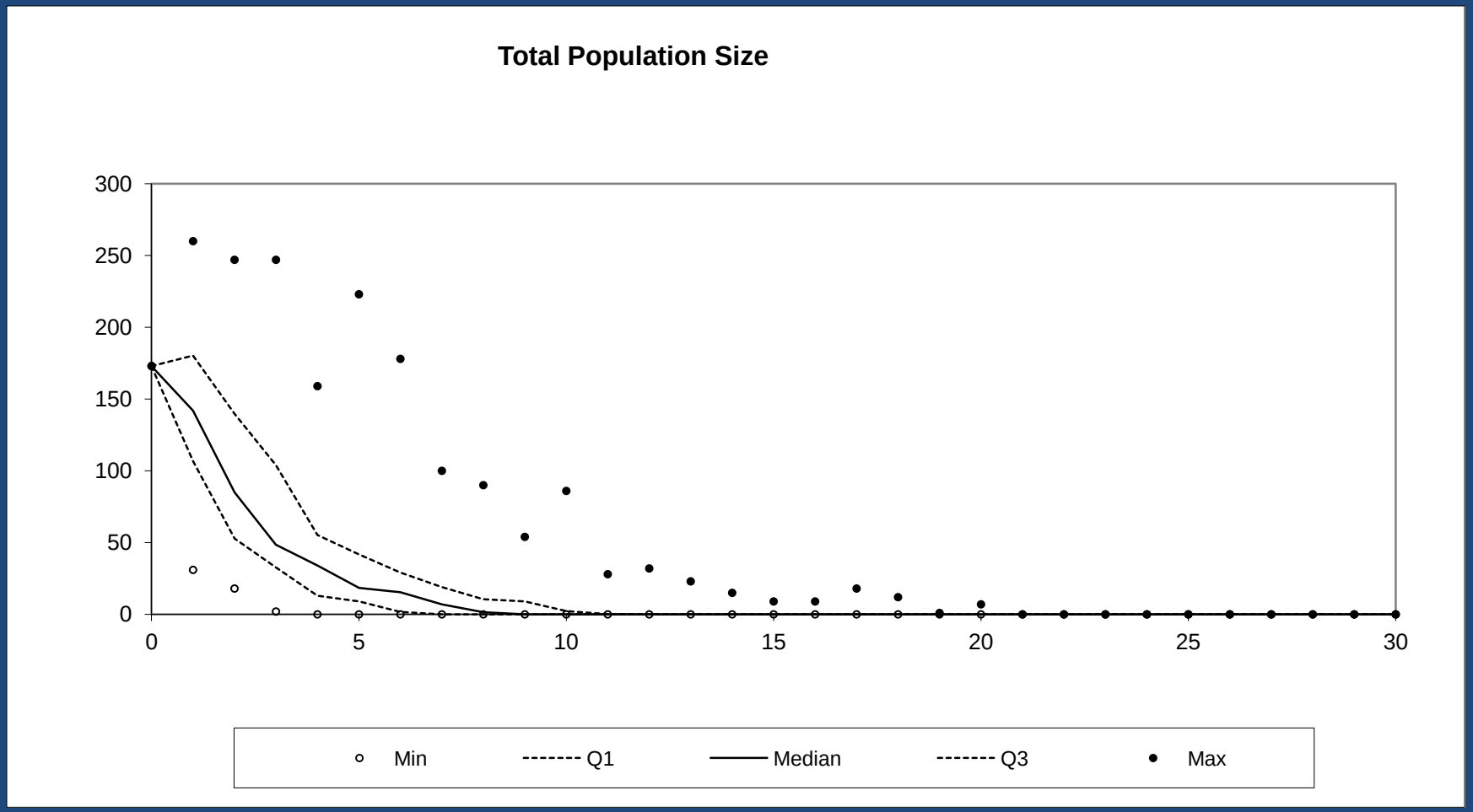
Fire Suppression

- Fire retardant drop, Utah
- Smokejumper, Lolo NF, Montana

Meadow Invasion

Ladder Fuels

Population Viability Analysis


Total Population Size
300
250
200
150
100
50
0
0
5
10
15
20
25
30
Min
Q1
Median
Q3
Max

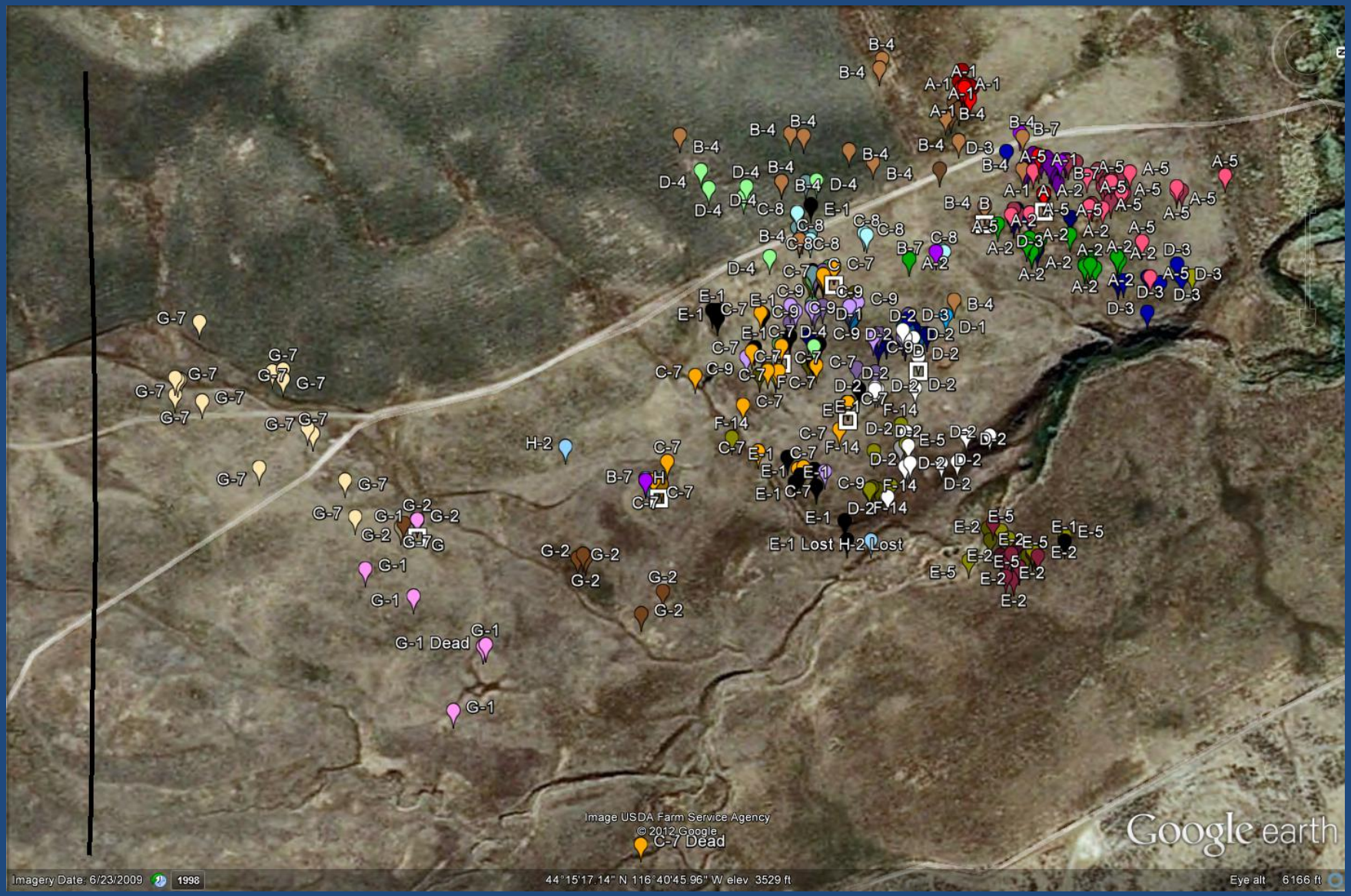
Northern Idaho Ground Squirrel Recovery

- Technical Team
- Recovery Plan
- Coordinator
  - Long-term monitoring (intensive and extensive)
  - Surveying
- Thinning and Burning (Payette National Forest)
- Increase from ~ 500 in 2001 to ~ 2000 individuals today

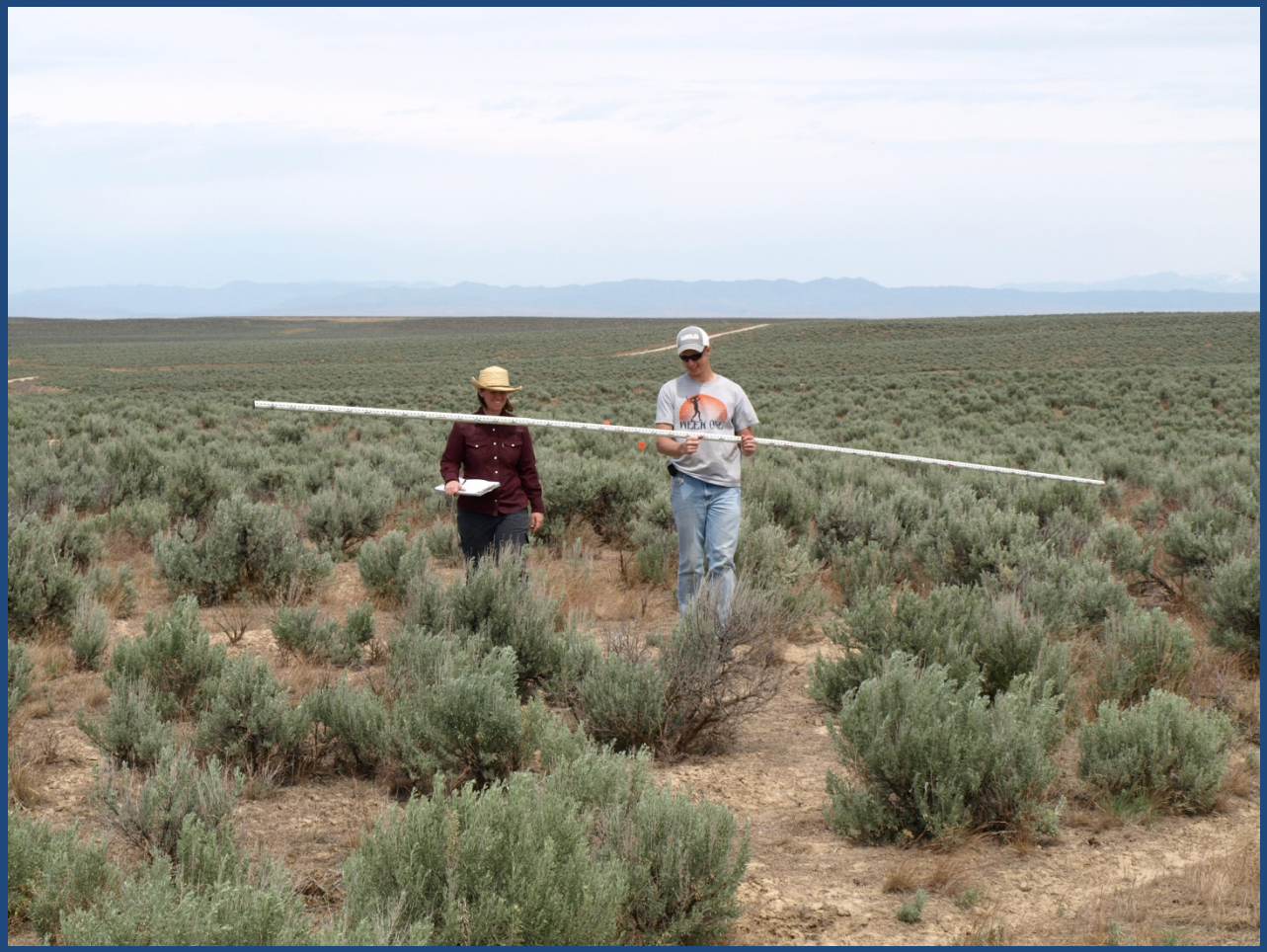
Current Projects

- Development of a successful translocation protocol.
- Evaluating the validity of burrow count transects
- Effects of thinning and burning treatments on northern Idaho ground squirrels.

Radio Locations of Translocated Squirrels



Validity of Burrow Count Transects



Comparison to MGS

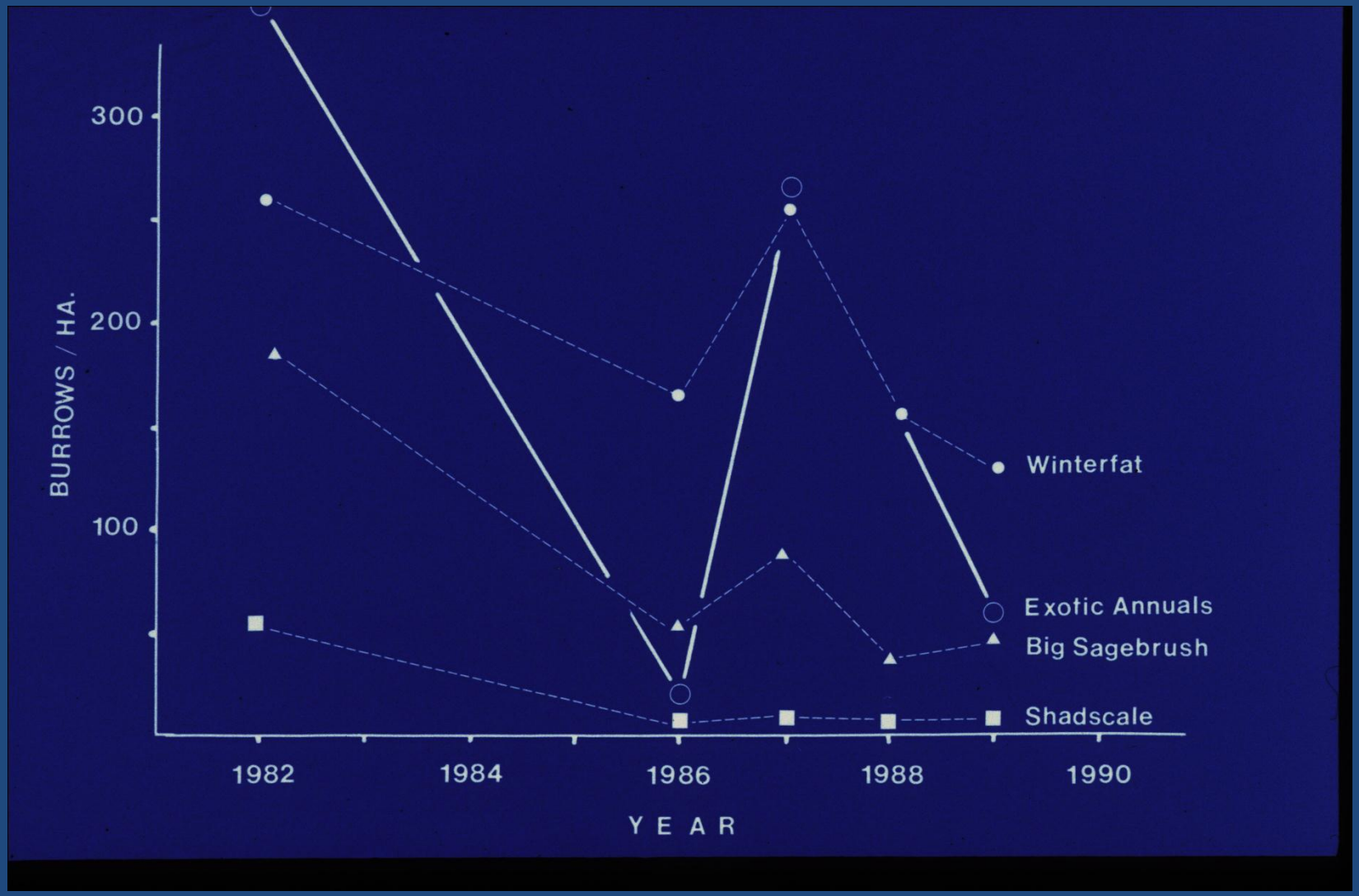
Many Other Ground Squirrels

- Habitats with variable productivity
- Variable population density
- Populations relatively easy to detect
- Higher plant diversity, more dependence on forbs and seeds
- Many no longer live in source populations; hanging on in sink habitats
- Breed every year

Mohave Ground Squirrels

- Very low productivity habitats
- Very low population density
- Populations difficult to detect
- Low plant diversity, more dependence on shrubs
- What are the source/sink populations?
- Breed 2 years out of 3

Population Fluctuations and Habitats



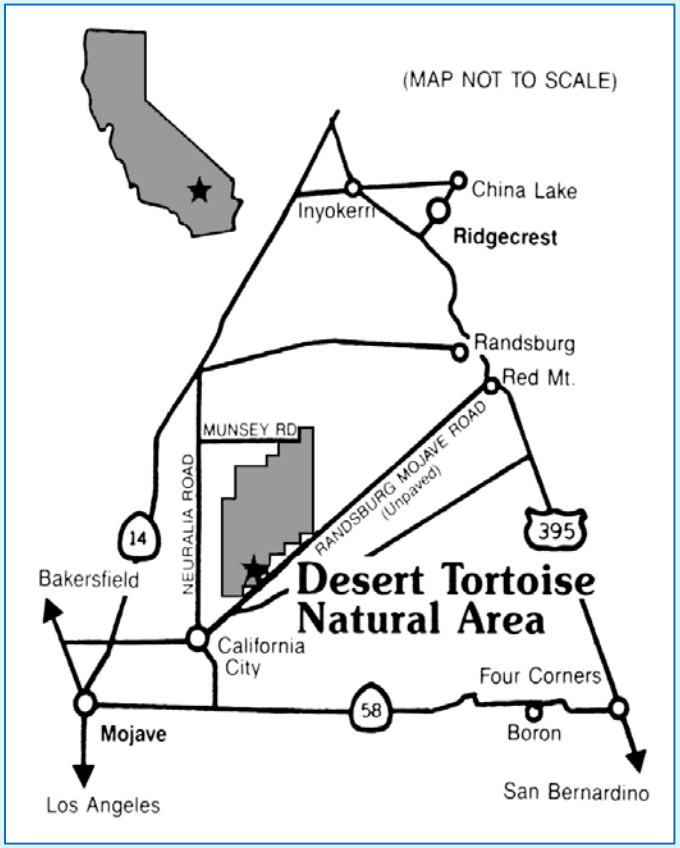
Parasites and Diseases

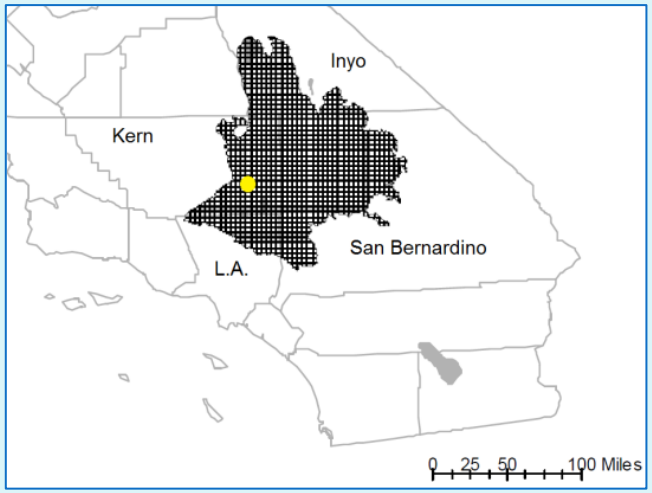
Visual Observations of Mohave Ground Squirrels at the Desert Tortoise Research Natural Area: Preliminary Results

Photo credits: Freya Reder

Mary Logan
Desert Tortoise Preserve Committee, Inc.
July 25, 2012

Desert Tortoise Research Natural Area





- 39.5 sq. miles
- Public, state, and private lands
- Designated Research Natural Area, ACEC, & DWMA
- Site for contemplative recreation & scientific research

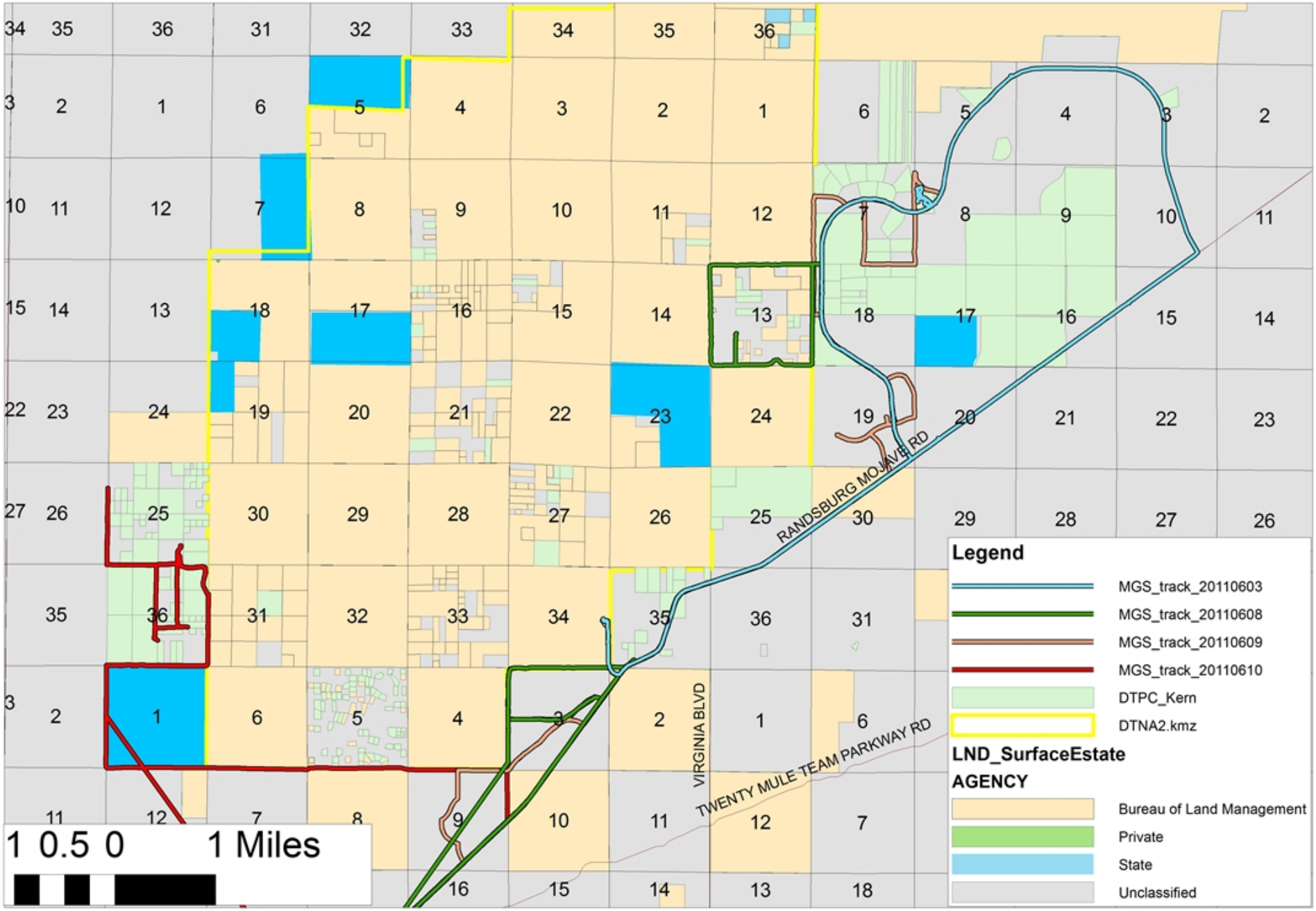
Range map adapted from CDFG 2005

2011 Methods

- 75 hours of surveying from May 19 to June 10, 2011
- 330 miles driven at speeds ≤ 15 mph in the expansion areas east, west, and south of the Desert Tortoise Research Natural Area (DTRNA)
- 900 photographs taken; photographic records for 81% of observations
- Additional observations made by the DTRNA Naturalists on-site from March 12 – June 6, 2011

Photo credits: Freya Reder

Example Driving Routes



2011 Detections

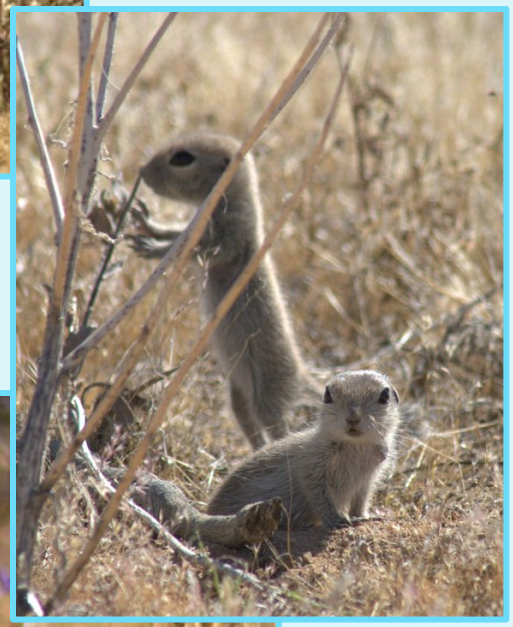
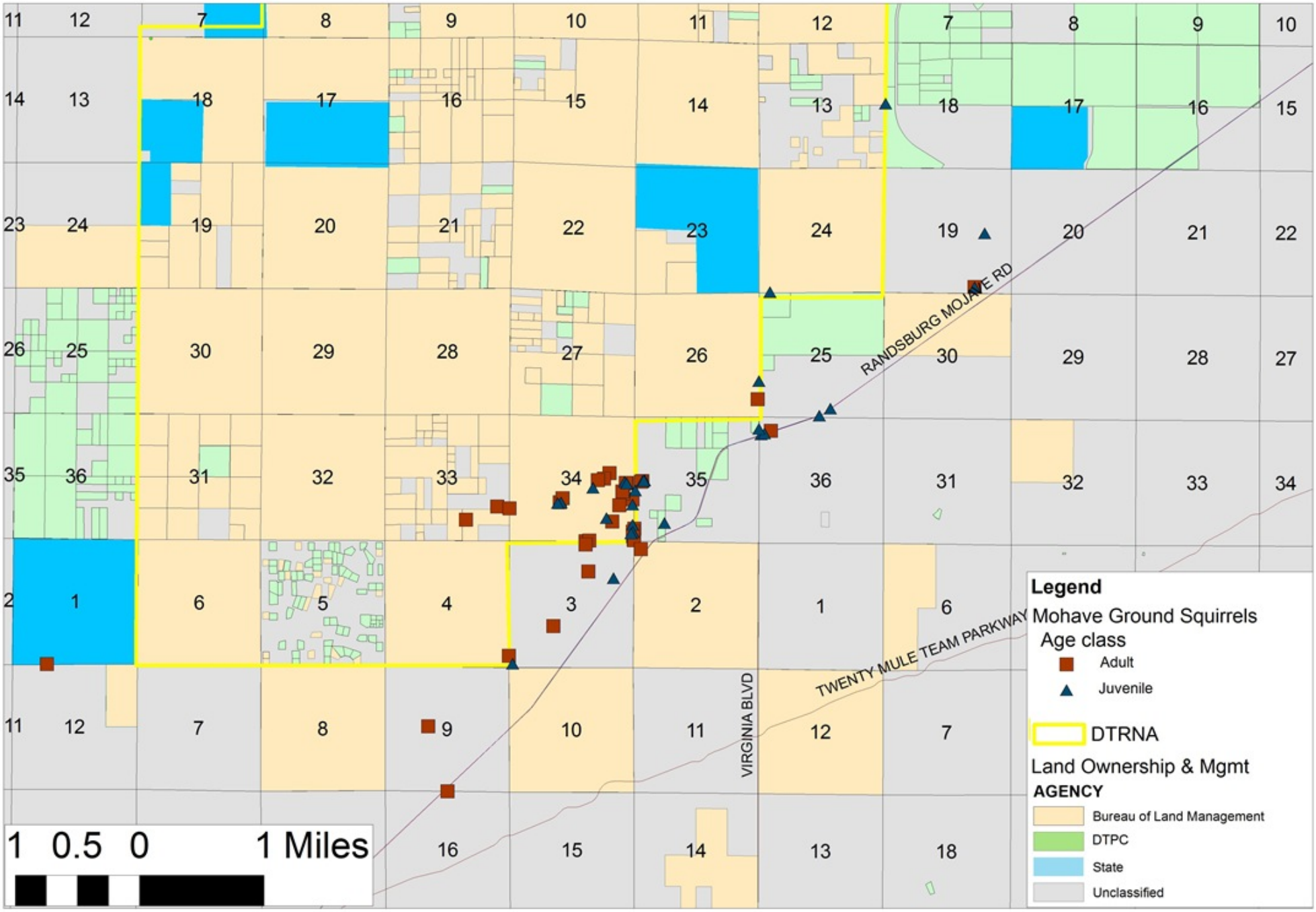


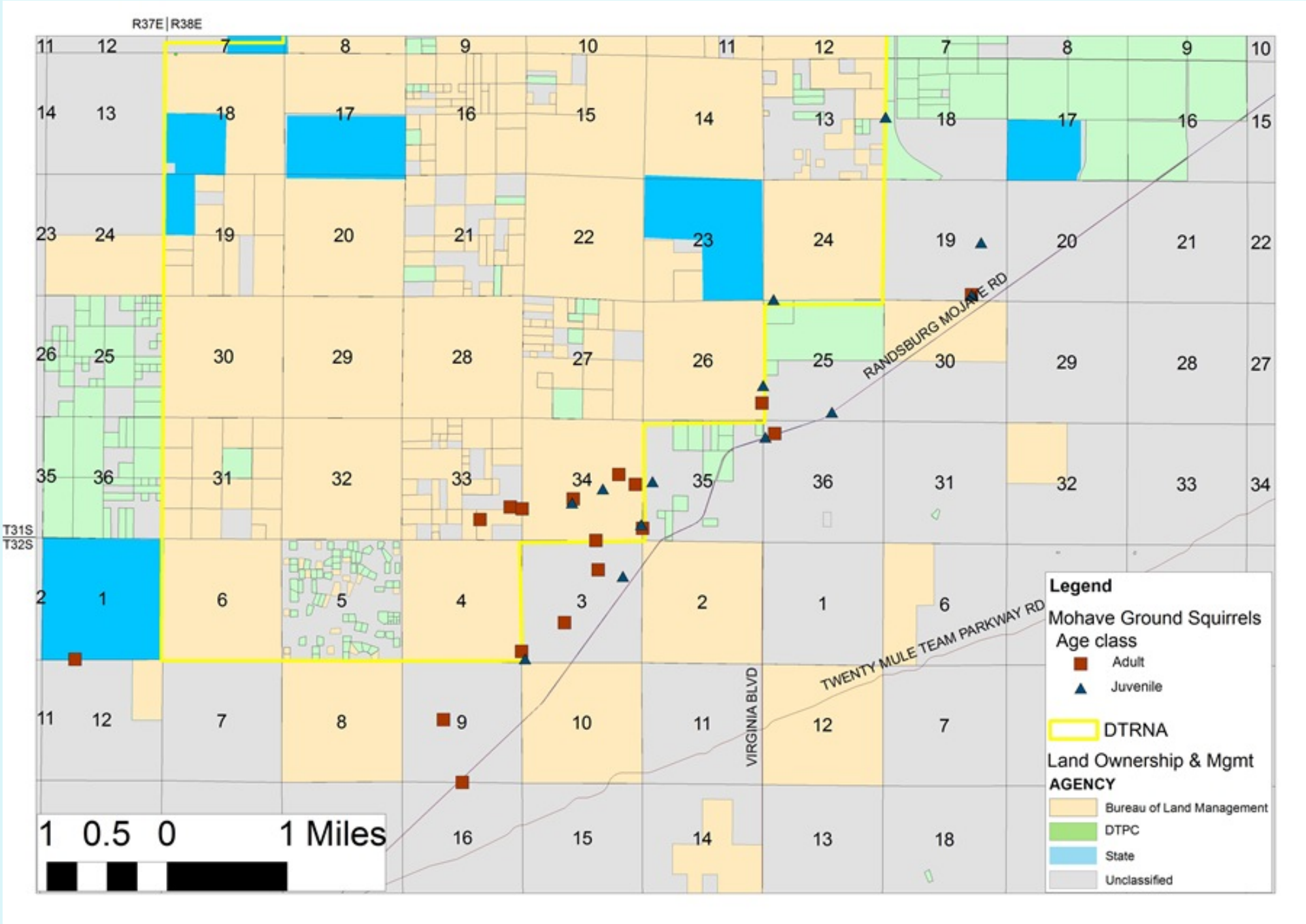
Photo credits: Freya Reder

- 69 MGS observations; estimate of 32 individuals observed
- 19 adults, 13 juveniles
- Of the adults: 3 males, 7 females, 9 unknown sex
- 28 feeding observations; at least 13 different plant species consumed
- 18 individuals (9 adults / 9 juveniles) observed outside of the DTRNA boundaries

MGS observations, Spring 2011

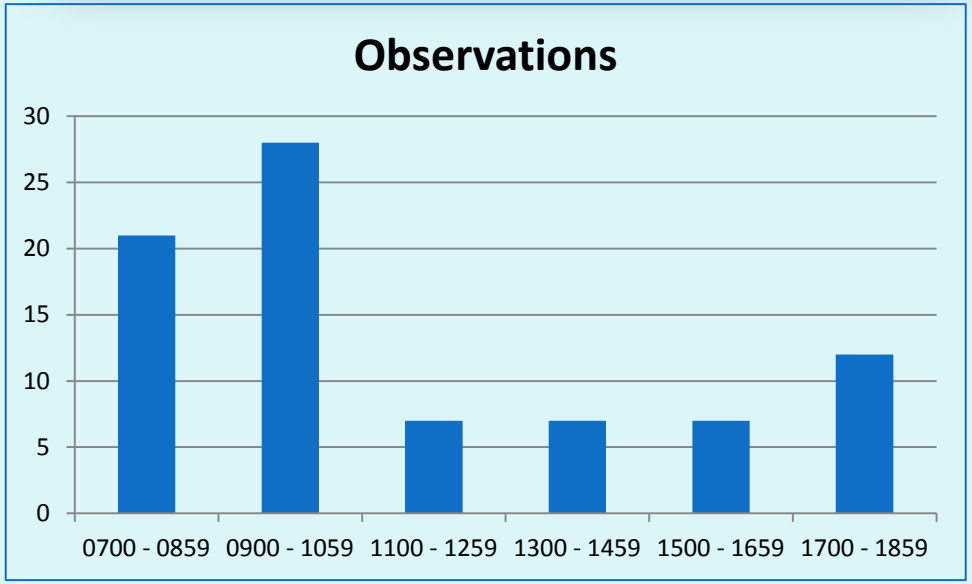


MGS individuals, Spring 2011



Species	# observations
Amsinckia tessellata	16
Erodium cicutarium	7
Larrea tridentata	6
Lasthenia californica	2
Eriogonum gracillimum	2
Salvia carduacea	2
Chaenactis fremontii	1
Lycium andersonii	1
Loeseliastrum sp.	1
Pectocarya sp.	1
Eriastrum diffusum	1
Eschscholizia minutiflora	1
Unknown	2

Additional Data



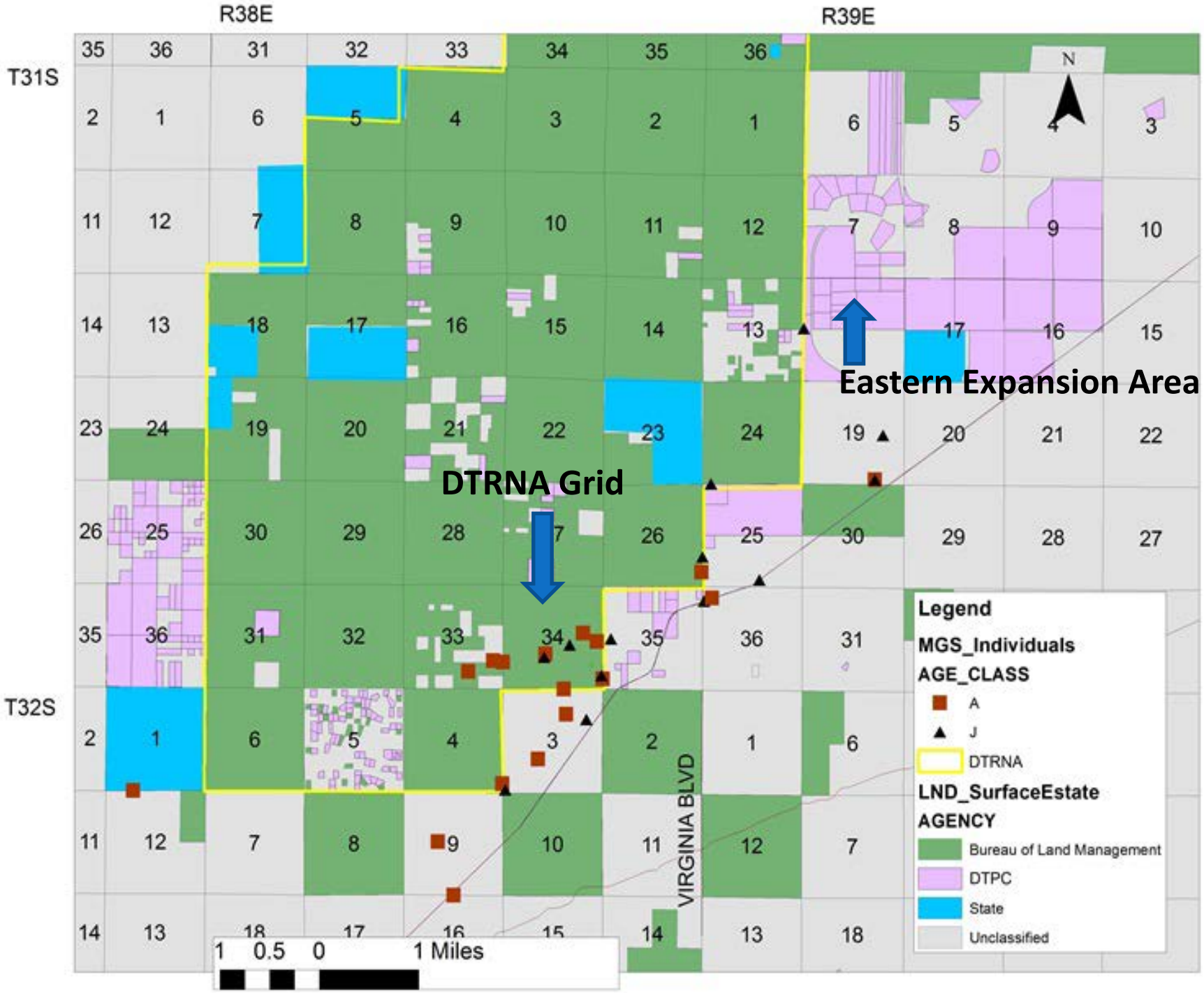
Time of day

- Juvenile emergence and litter size
- Activity patterns
- Feeding behavior throughout the season

Mohave Ground Squirrel Occupancy Pilot Study: Spring 2012

2012 Study Objectives

- Preliminary estimates of occupancy and detection probability
- Comparison of different survey methods
- Relate occupancy to habitat characteristics


R38E
R39E
T31S
T32S
N
Eastern Expansion Area
DTRNA Grid
VIRGINIA BLVD
Legend
MGS_Individuals
AGE_CLASS
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J
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AGENCY
Bureau of Land Management
DTPC
State
Unclassified
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Methods

- Grids composed of 100, 150 m x 150 m cells in the DTRNA and Eastern Expansion Area
- Camera-trapping and point counts conducted in 48 randomly selected cells in each grid
- 4 walking transects conducted through entire grids
- Habitat data collected at each sampled cell

- Cameras 5 inches above ground
- Bait enclosure 4 – 5 feet from camera
- Cameras checked every 3 – 5 days

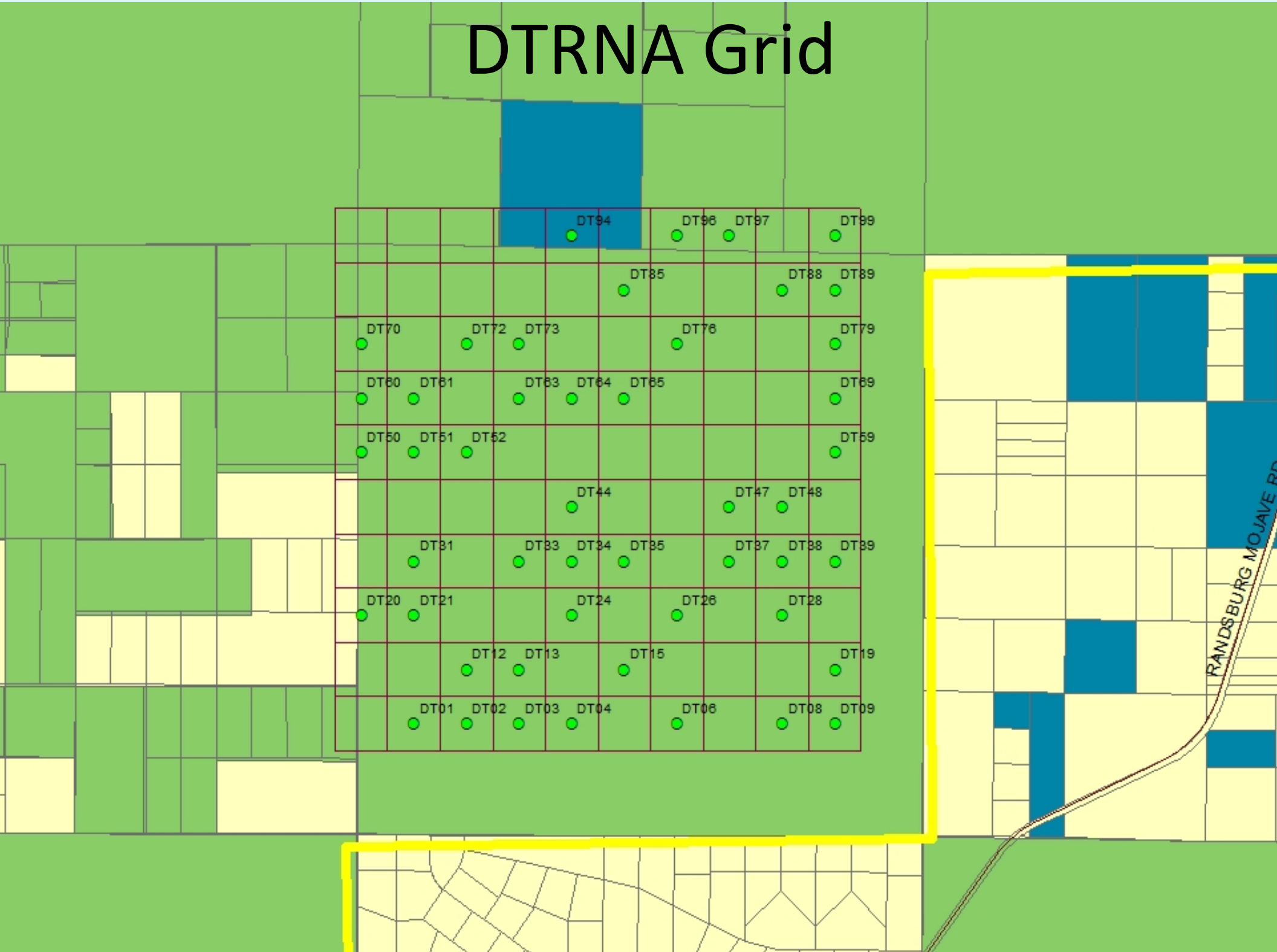
Summary of Effort

- 48 camera stations in DTRNA (3/14 – 5/8)
- 48 camera stations in EE Area (3/15 – 5/9)
- Point counts repeated 2 - 3x at each station
- Walking transects conducted 4x through both grids conducted by Freya Reder

Summary of Results

- 137,336 photos taken over 960 trap-nights
- At least 18 vertebrate species detected:
  - 9 mammals
  - 6 birds
  - 3 reptiles
- MGS detected by all three methods in both study areas

DTRNA Grid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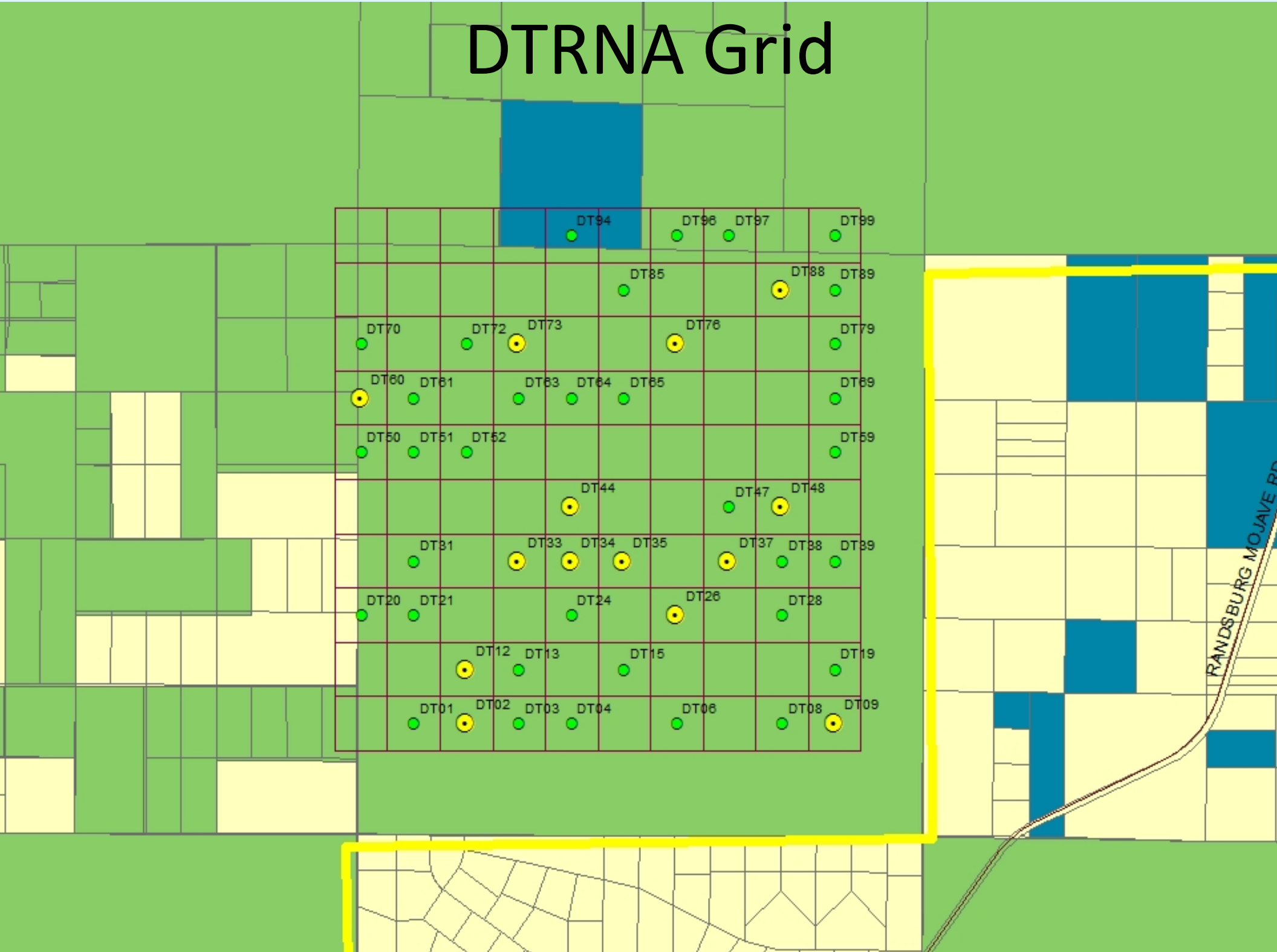
RANDSBURG MOJAVE RD

DTRNA Grid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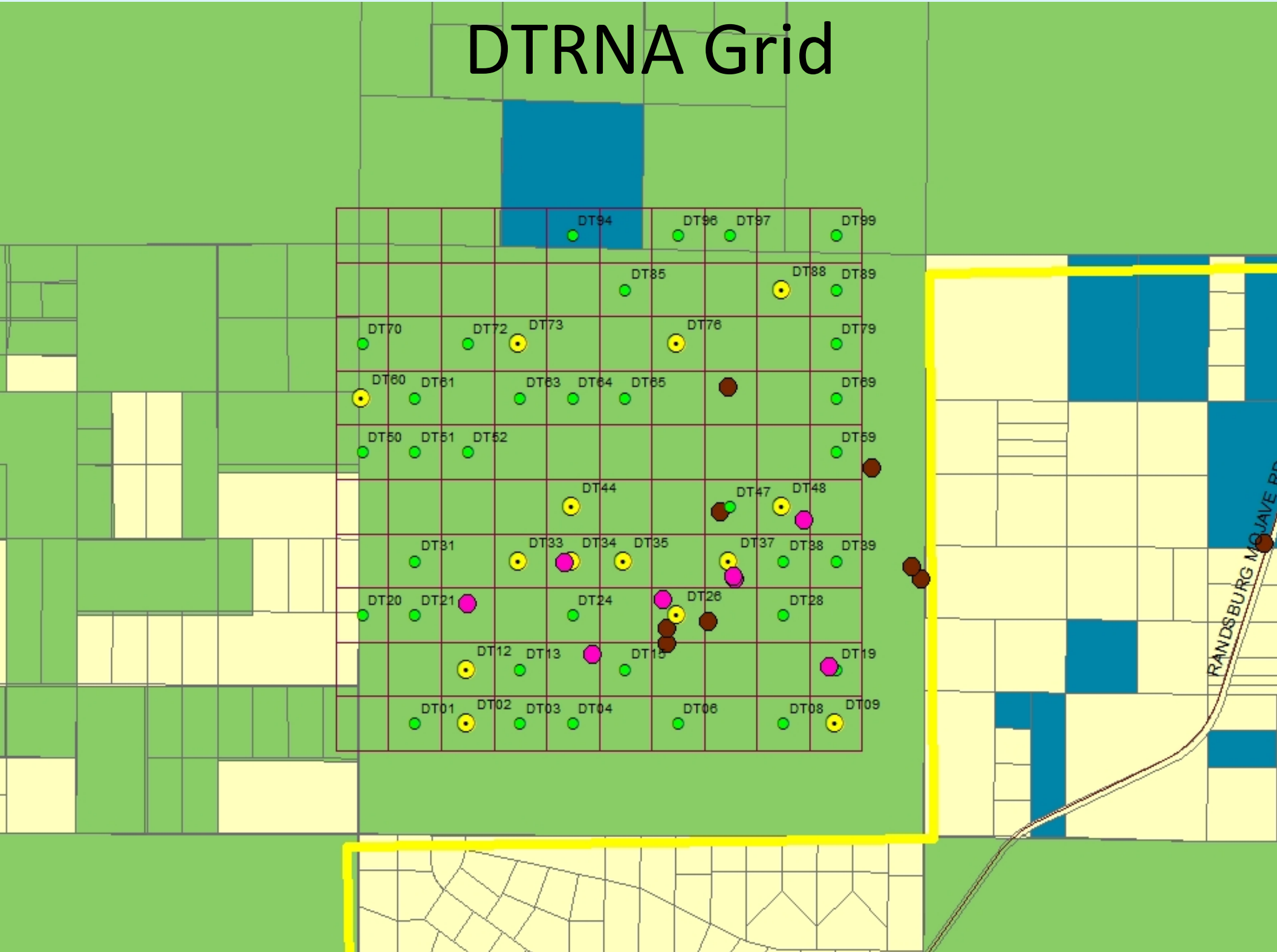
RANDSBURG MOJAVE RD

DTRNA Grid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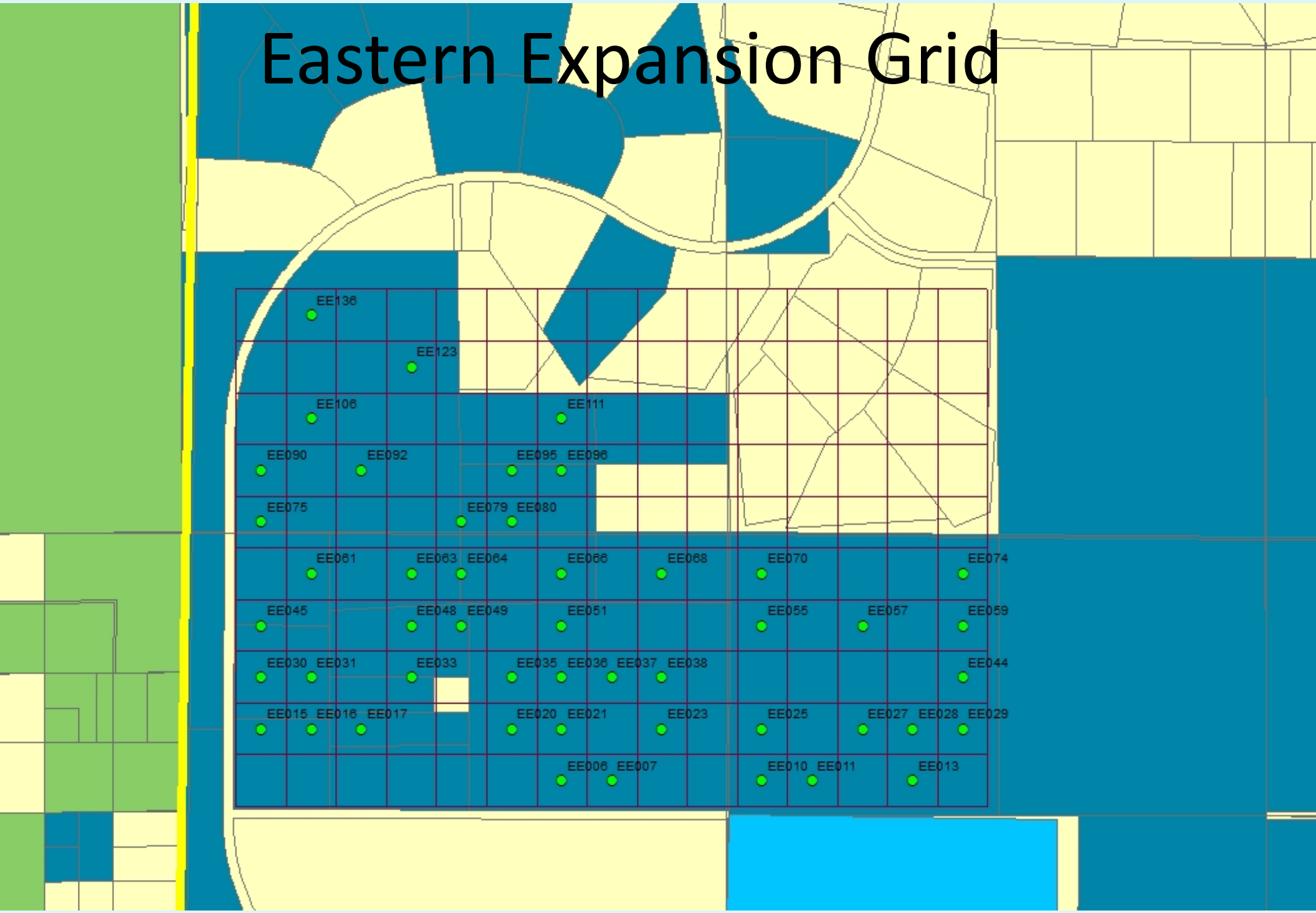
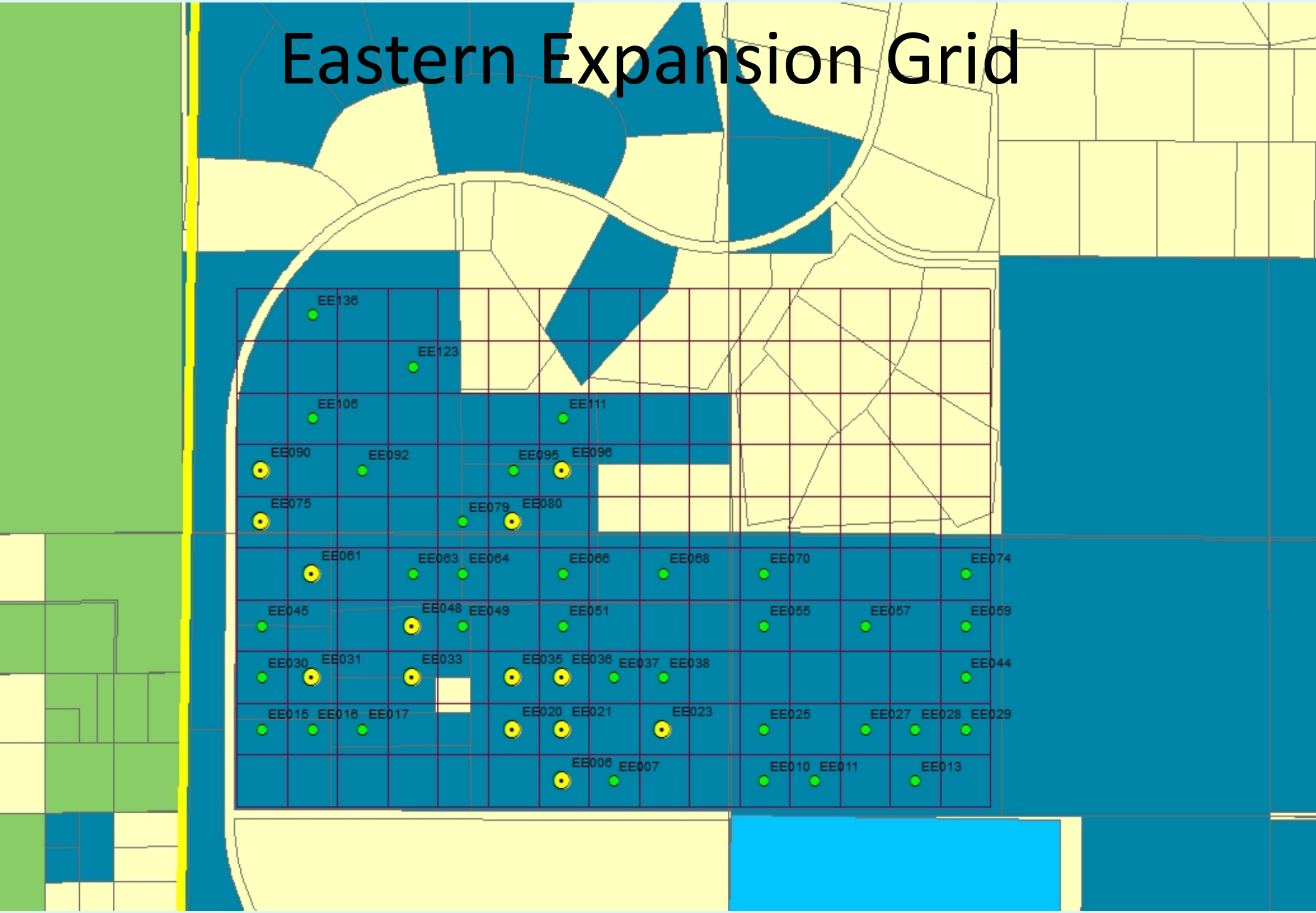
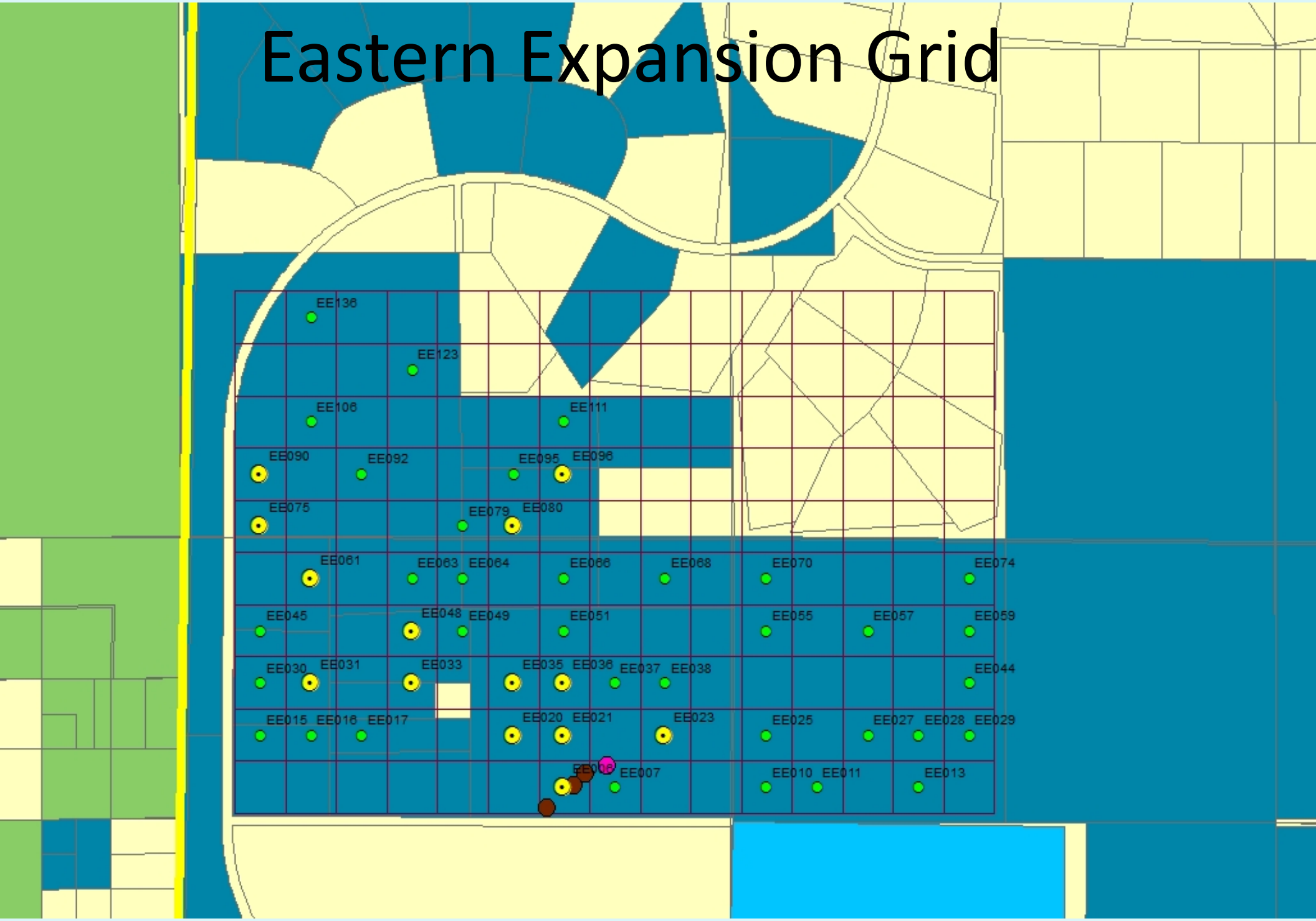
Eastern Expansion Grid



Eastern Expansion Grid



Eastern Expansion Grid



- 14 out of 48 camera stations with MGS detections at both sites
- Naïve occupancy of 0.29
- Probability of detecting MGS at a site < 1.0

	SESSION 1												
SITE	14-Mar-12	15-Mar-12	16-Mar-12	17-Mar-12	18-Mar-12	19-Mar-12	20-Mar-12	21-Mar-12	22-Mar-12	23-Mar-12	24-Mar-12	25-Mar-12	26-Mar-12
DT001	0	0	0	0	0	0	0	0	0	0	0	1	0
DT004	0	0	0	0	0	0	0	0	0	0	0	0	0
DT012	0	0	0	0	0	0	0	0	0	0	1	1	1
DT026	0	0	0	0	0	1	1	0	0	0	0	0	0
DT048	0	0	0	0	0	0	0	1	0	1	1	0	1
DT050	0	0	0	0	0	0	0	0	0	0	0	0	0
DT072	0	0	0	0	0	0	0	0	0	0	0	0	0
DT073	0	0	0	0	0	1	0	0	0	0	0	0	0
DT079	0	0	0	0	0	0	0	0	0	0	0	0	0
DT088	0	0	0	0	0	0	0	0	0	0	1	0	0
DT085	0	0	0	0	0	0	0	0	0	0	0	0	0
DT096	0	0	0	0	0	0	0	0	0	0	0	0	0

Walking Surveys & Incidental Observations

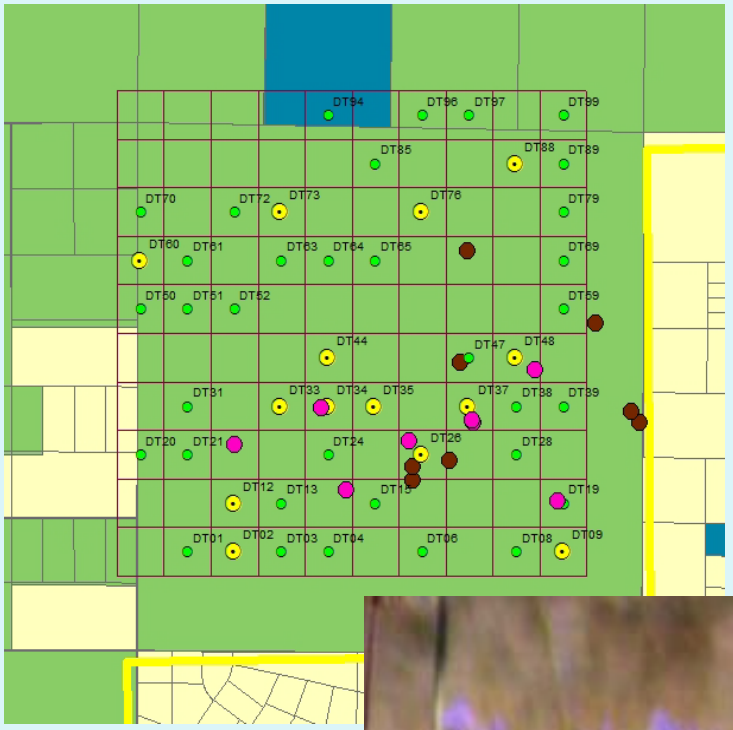
- 7 visual detections during walking transects in DTRNA
- 3 visual detections in Eastern Expansion Area during walking transects in DTRNA
- 2 MGS detected during camera station point counts
- 8 incidental detections of MGS in survey area
- Incidental observations of desert tortoises, burrowing owls, golden eagle, and many other species

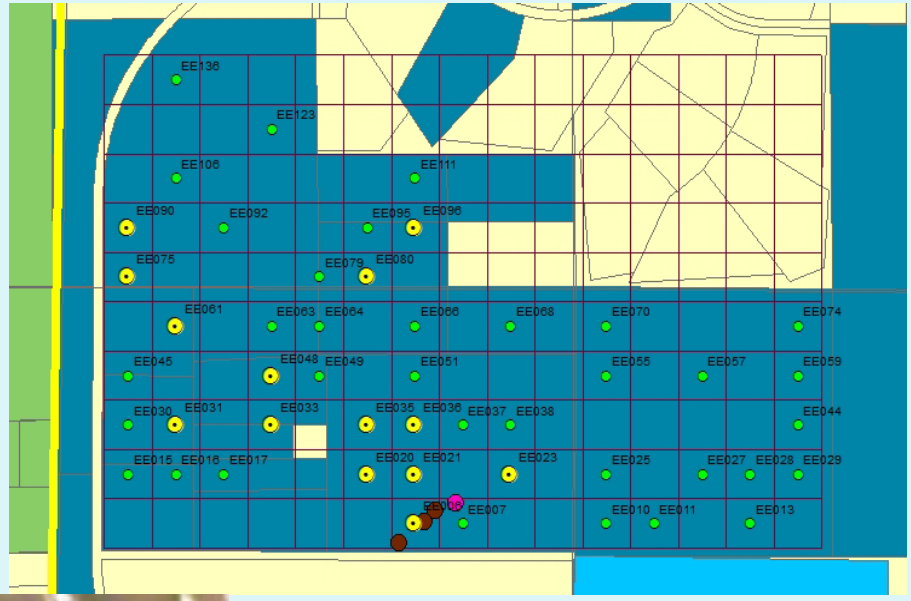
Auditory Detections

- 2011:
  - 3 observations included MGS alarm call
  - 1 detection of MGS alarm call without visual
  - More MGS alarm calls noted when juveniles present

- 2012:
  - 0 / 24 MGS detections by research crew included vocalizations
  - 9 / 94 detections of AGS with vocalizations

Summary





- Camera trapping resulted in detections of MGS at more sites
- Direct observation can provide complementary data and address different research questions

2012-03-21 10:10:46 AM M 1/3
69°F
Please direct any questions to the Desert Tortoise Preserve Committee, Inc. (951.683.3872 / Mary Logan at: dtpc@pacbell.net)
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RECONYX