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Compilation of Island Fox Literature

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Abstract.—The Island Fox (*Urocyon littoralis*) provides a solid lesson in biogeography as well as conservation as all six subspecies are listed as Threatened by the State of California: San Miguel Island Fox (*U. l. littoralis*; Baird 1858), Santa Rosa Island Fox (*U. l. santarosae*; Grinnell and Linsdale 1930), Santa Cruz Island Fox (*U. l. santacruzae*; Merriam 1903), Santa Catalina Island Fox (*U. l. catalinae*; Merriam 1903), San Clemente Island Fox (*U. l. clementae*; Merriam 1903), and San Nicolas Island Fox (*U. l. dickeyi*; Grinnell and Linsdale 1930). The first four subspecies also are listed federally as Endangered. Herein is a compilation of peer-reviewed information on the Island Fox. Gray literature reports, theses, dissertations, and inter-agency articles are not included because, ideally, anything noteworthy in these publications has been published in scientific journals. Also included in this collection are significant conference proceedings, book chapters, and books written on these foxes. Caution should be exercised when reading older works. Recent works either confirm or invalidate older hypotheses, and cross-referencing by the reader is recommended.

Key Words.—Biogeography; Channel Islands; California; Island Fox; North America; *Urocyon littoralis*

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Notes

Predation by the Long-nosed Snake (*Rhinocheilus lecontei*) on the Endangered Blunt-nosed Leopard Lizard (*Gambelia sila*)

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Abstract.—The Blunt-nosed Leopard lizard (*Gambelia sila*) is an endangered lizard of the San Joaquin Desert of California and knowing the species that are predators can be useful to the conservation and recovery of the species. Besides the three snakes and six birds that are known to eat Blunt-nosed Leopard Lizards, we add an additional snake. On 15 May 2015, we dug a Long-nosed Snake (*Rhinocheilus lecontei*) out of a kangaroo rat (*Dipodomys* spp.) burrow system at the same location of the radio transmitter of a Blunt-nosed Leopard Lizard that had obviously been through a digestive system of an animal. The radio transmitter belonged to an adult male Blunt-nosed Leopard Lizard that had not moved from this location for 10 d. This is the first record of a Long-nosed Snake eating a Blunt-nosed Leopard Lizard.

Key Words.—California; lizards; predators; San Joaquin Desert; snakes

The Blunt-nosed Leopard lizard (*Gambelia sila*) is state and federally listed as endangered and has lost about 85% of its historic range (Germano and Williams 1992; U.S. Fish and Wildlife Service 1998). It occurs throughout the San Joaquin Desert (Germano et al. 2011) and is a fairly large lizard reaching up to 120 mm snout-vent length (SVL: Montanucci 1965; Germano 2009). Recovery efforts would be aided by knowing likely predators of this reptile. Several predators are known to eat Blunt-nosed Leopard Lizards including the San Joaquin Coachwhip (*Masticophis flagellum ruddocki*), Gopher Snake (*Pituophis catenifer*), Northern Western Rattlesnake (*Crotalus oreganus*), Red-tailed Hawk (*Buteo jaimacensis*), Prairie Falcon (*Falco mexicanus*), American Kestrel (*Falco sparverius*), Loggerhead Shrike (*Lanius ludovicianus*), Burrowing Owl (*Athene cunicularia*), and Greater Roadrunner (*Geococcyx californianus*: Montanucci 1965; Tollestrup 1979; Germano and Carter 1995; Germano and Brown 2003). Here we report on an additional snake that ate a Blunt-nosed Leopard Lizard.

As part of a radio-telemetry study of Blunt-nosed Leopard Lizards in the Lokern area of the San Joaquin Desert, we noted that the signal from one male (115 mm SVL and 42.5 g when we collared him 28 April 2015) was coming from a kangaroo rat (*Dipodomys* spp.) burrow system (35°21’04”N, 119°32”58”W) and had not changed locations in 7 d. This prompted us to dig into the burrow system to determine if the lizard was still alive and to recover the transmitter. While digging into the system, we saw the upper 10 cm of a Long-nosed Snake (*Rhinocheilus lecontei*) come out of a tunnel. After it noticed us, the snake retreated back into the tunnel. We returned 3 d later on 15 May 2015 and the transmitter signal was still at the same location, so we dug into the burrow system again. After about 20 min, we recovered both the Long-nosed Snake and the radio transmitter at the same spot where we found the snake. The radio transmitter of the lizard had obviously been through a digestive system of an animal (Fig. 1) based on the discolored beaded chain and the adherence of the chain to the transmitter. The Long-nosed Snake was an adult 68 cm total length and died the next day from wounds suffered when we dug into the burrow system. The Long-nosed Snake has been found in parts of the San Joaquin Desert (Robert Hansen, unpubl. data), but we have rarely seen it in the 25+ y that we have worked in the valley. This is the first record of a Long-nosed Snake eating a Blunt-nosed Leopard Lizard, but because of the relative rarity of this snake and its small size relative to an adult leopard lizard, we suspect that these predation events are uncommon.

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Figure 1. Long-nosed Snake (*Rhinocheilus lecontei*) with a Holohil BD2 radio transmitter originally attached to a male Blunt-nosed Leopard Lizard (*Gambelia sila*) that was being radio-tracked on the Lokern in Kern County, California. (Photographed by David J. Germano).

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Current Status of the Mohave Ground Squirrel (*Xerospermophilus mohavensis*): A Five-Year Update (2008–2012)

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Abstract.—The Mohave Ground Squirrel (*Xerospermophilus mohavensis*) is endemic to the western Mojave Desert of California and is listed as Threatened by the State of California. Its current conservation status is of great interest because of the large-scale development of renewable energy resources in the California desert. To document its current distribution and status, I assembled a comprehensive database covering unpublished field studies and surveys conducted during the five-year period from 2008–2012, updating a publication covering the preceding 10 y (Leitner 2008). These data confirm that Mohave Ground Squirrels are still present in all areas known to be occupied during the period 1998-2007. Recent surveys have documented new occurrences in additional areas, especially in the central part of the range. Although the southern portion of the range was most intensively sampled during 2008–2012, the only positive records were from Edwards Air Force Base, with an additional detection in Victor Valley. This suggests that local extirpations may have occurred in recent decades throughout much of the southern part of the historic range. Systematic surveys are recommended for large areas in the central and northern portions of the range where occurrence data are lacking. In particular, the status of the species on the China Lake Naval Air Weapons Station and Fort Irwin should be better documented. The possible expansion of the closely-related Round-tailed Ground Squirrel (*Xerospermophilus tereticaudus*) along the eastern edge of the Mohave Ground Squirrel range may have serious impacts and should be carefully monitored.

Key Words.—conservation; distribution; geographic range; Mojave Desert; renewable energy; *Xerospermophilus tereticaudus*

The Mohave Ground Squirrel (*Xerospermophilus mohavensis*) is listed as a Threatened species under the California Endangered Species Act. It is restricted to a small geographic area in the western Mojave Desert of California. Although the species was originally listed because of low numbers throughout its range with the cause unknown, it is currently of intense conservation interest because of recent proposals for renewable energy development within its range. Several state and federal agencies are currently in the process of planning for the conservation of desert species and ecosystems while facilitating the appropriate development of utility-scale renewable energy in the California deserts. To support these planning efforts, it is important to document the current geographic distribution of the Mohave Ground Squirrel, as well as existing data on its status throughout the historic range. I have previously presented all available information on the status of the Mohave Ground Squirrel for the period 1998–2007 (Leitner 2008).

In this study, I have updated that analysis, bringing together information from unpublished field surveys conducted during the five-year period from 2008 through 2012. I obtained reports for all sponsored research efforts and received the results of protocol trapping surveys from consulting biologists. The data I present here include both positive records documenting Mohave Ground Squirrel occurrence and negative records from field surveys in which the species was not detected. The overall purpose of this review is to document current known geographic occurrences of the Mohave Ground Squirrel, to identify areas in which the species no longer appears to be present, and to recommend additional field studies and other management actions where needed. I have also included some recent occurrence records for the closely-related Round-tailed Ground Squirrel (*Xerospermophilus tereticaudus*) to better define its current contact zone with the Mohave Ground Squirrel. The Round-tailed Ground Squirrel is widely distributed throughout the eastern Mojave Desert of California and there is increasing evidence that it is expanding westward, replacing the Mohave Ground Squirrel in certain areas.

Methods

I used several sources of information regarding the distribution and occurrence of the Mohave Ground Squirrel from 2008–2012: the California Natural Diversity Database (CNDDB), regional field studies, protocol trapping at proposed development sites, and incidental observations reported by field biologists. The CNDDB is a statewide program managed by the California Department of Fish and Wildlife (CDFW) that maintains an inventory of the status and locations of rare species and natural communities. This program only lists positive occurrences and is not designed to provide a systematic survey. The CNDDB contained 399 occurrence records for the Mohave Ground Squirrel as of June 2013. There were 28 occurrences at new locations submitted from 2008–2012 plus eight new records at previously known locations for the species. A number of regional field studies using live-trapping were conducted from 2008–2012, many of them funded by state and federal agencies. I have reviewed unpublished reports that describe the results of such trapping surveys and have also obtained data from several biologists whose surveys have not been documented in formal reports. These studies provide positive records of

Mohave Ground Squirrel occurrence, as well as negative results where trapping efforts failed to detect the species.

David Delaney and I conducted a large-scale field investigation using trail cameras in 2011 and 2012 at 123 sites widely distributed within and adjacent to the historic range (Leitner and Delaney 2014). These camera sites were randomly located on public lands within 12 large study areas that stretched from Lucerne Valley in the south to Searles Valley in Inyo County. Additional data on Mohave Ground Squirrel distribution was derived from the protocol trapping surveys carried out at proposed development sites as required under CDFW guidelines (California Department of Fish and Game 2010). To collect records of protocol trapping surveys for the period 2008–2012, I contacted all biologists who possessed a CDFW Memorandum of Understanding authorizing take of Mohave Ground Squirrels. All biologists who were actively conducting surveys during that period provided their records, including dates of trapping sessions, locations of trapping grids, number of trap-days of sampling effort, and whether or not Mohave Ground Squirrels were detected.

I have classified as incidental observations all records reported by biologists who observed or captured Mohave Ground Squirrels incidental to other field studies. This category includes visual and auditory detections, captures made while trapping for other species, and highway mortalities. I list the number of records obtained for this review from regional trapping and camera surveys, protocol trapping, and incidental observations (Table 1). For regional and protocol surveys, a record is defined as a single trapping session (usually five days) at a specific grid location. If no Mohave Ground Squirrels were detected, such records were considered negative, while a positive record was a trapping session in which > one Mohave Ground Squirrels were captured. For regional camera surveys, a positive record indicates that there was > one Mohave Ground Squirrel detection at a particular study site. For incidental observations, all records were positive. The sampling effort for regional and protocol surveys is calculated as the number of traps operated per day times the number of days per trapping session, summed over all trapping sessions.

I entered data from all sources into Excel spreadsheets. I developed a series of base maps covering the geographic range of the Mohave Ground Squirrel using GIS techniques. I plotted all records, both positive and negative, on these digital maps for visual analysis. In this way, the distribution of Mohave Ground Squirrel occurrences over the five year period from 2008–2012 could be visualized in relation to the distribution of sampling effort (with blank areas denoting no sampling).

Results

General distribution.—Sampling efforts during 2008–2012 covered approximately 70% of the geographic range of the Mohave Ground Squirrel (Fig. 1). Overall, the regional and protocol trapping surveys plus the camera surveys resulted in 868 negative records, as compared to only 141 sessions in which at least one Mohave Ground Squirrel was detected. Although the regional trapping studies involved only 22.2% of the total trapping effort, they accounted for 89.7% of the positive trapping records. On the other hand, the protocol surveys made up 77.8% of trapping effort, but contributed only 10.3% of Mohave Ground Squirrel trapping detections. I recorded Mohave Ground Squirrels at 73 of the 123 camera trapping sites.

There was very little survey activity in Inyo County, the northern part of the range. However, I regularly detected the species by live-trapping at two long-term study sites in the Coso Range on China Lake Naval Air Weapons Station (NAWS; Leitner 2010, 2011, 2012). There were also several positive records in northern Searles Valley based upon camera trapping, live-trapping, and visual observations. The only other occurrences reported for Inyo County were four incidental observations in the Indian Wells Valley area of China Lake NAWS.

In the central part of the range, from Ridgecrest south to State Route 58, there was extensive survey activity during 2008–2012 with a large number of Mohave Ground Squirrel detections noted. As in the period 1998–2007, positive records confirmed the continued presence of Mohave Ground Squirrels in Little Dixie Wash southwest of Inyokern, around the Desert Tortoise Research Natural Area (DTRNA), and in Superior Valley on Fort Irwin (Leitner 2008). The camera study carried out in 2011–2012 sampled the central part of the range from Ridgecrest south to Kramer Junction and east to Hinkley. I detected Mohave Ground Squirrels at 71% of camera sites in this region.

The southern part of the Mohave Ground Squirrel range, south of State Route 58, was sampled extensively

Table 1. A summary of the data sources used for this review of the Mohave Ground Squirrel (*Xerospermophilus mohavensis*), indicating the total number of records of each type, the number of positive records, and the sampling effort for trapping surveys as measured by the number of trap-days.

Type of Data	Total Records	Positive Records	Trap-days
Regional Trapping Surveys	172	61	98,155
Regional Camera Surveys	123	73	15,200
Protocol Surveys	714	7	344,665
Incidental Observations	99	99	---
Totals	1,108	240	458,020

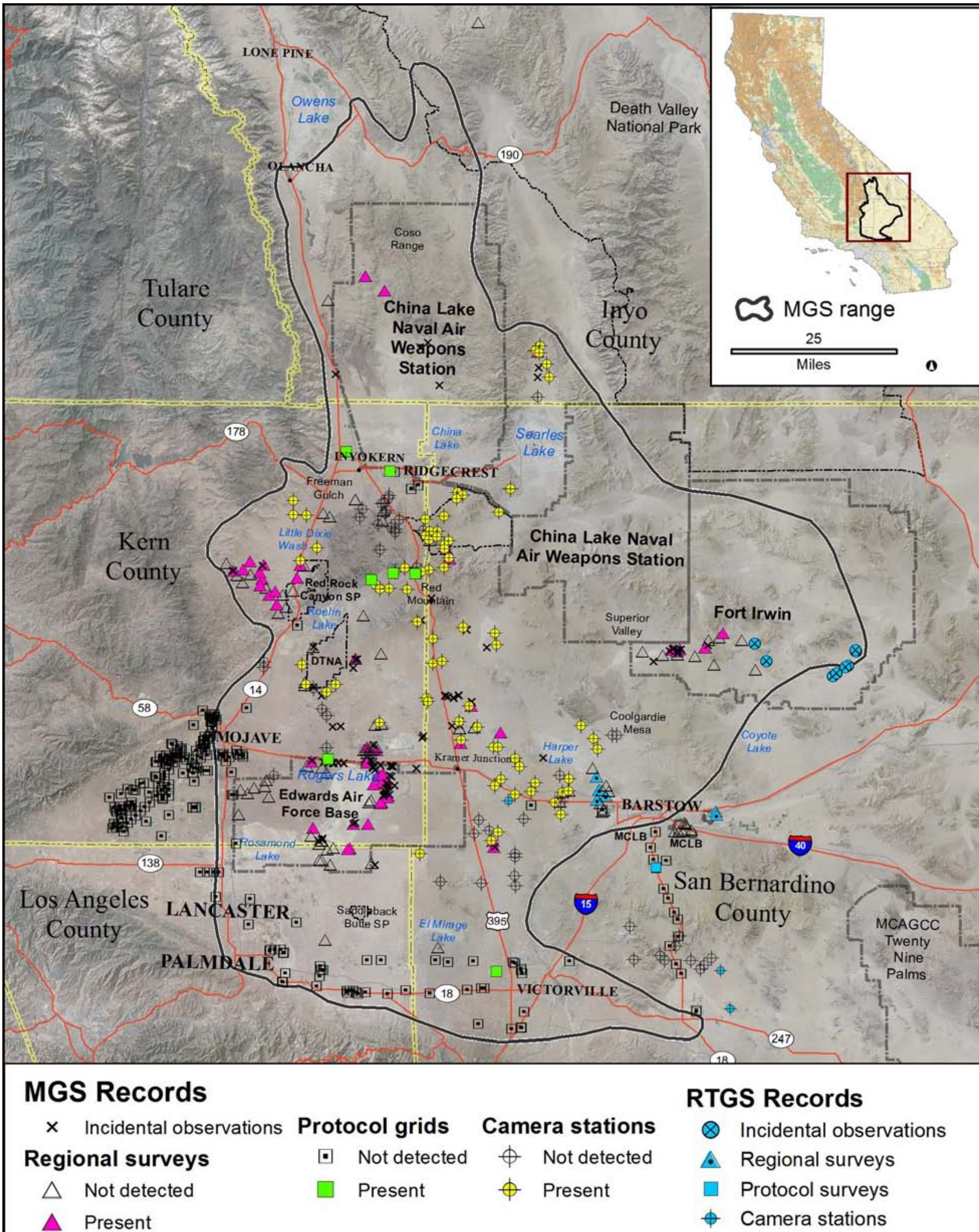

FIGURE 1. The geographic distribution of all Mohave Ground Squirrel (*Xerospermophilus mohavensis*) records for the period 2008–2012. Occurrences of the Round-tailed Ground Squirrel (*Xerospermophilus tereticaudus*) in the contact zone between the two species are also shown.

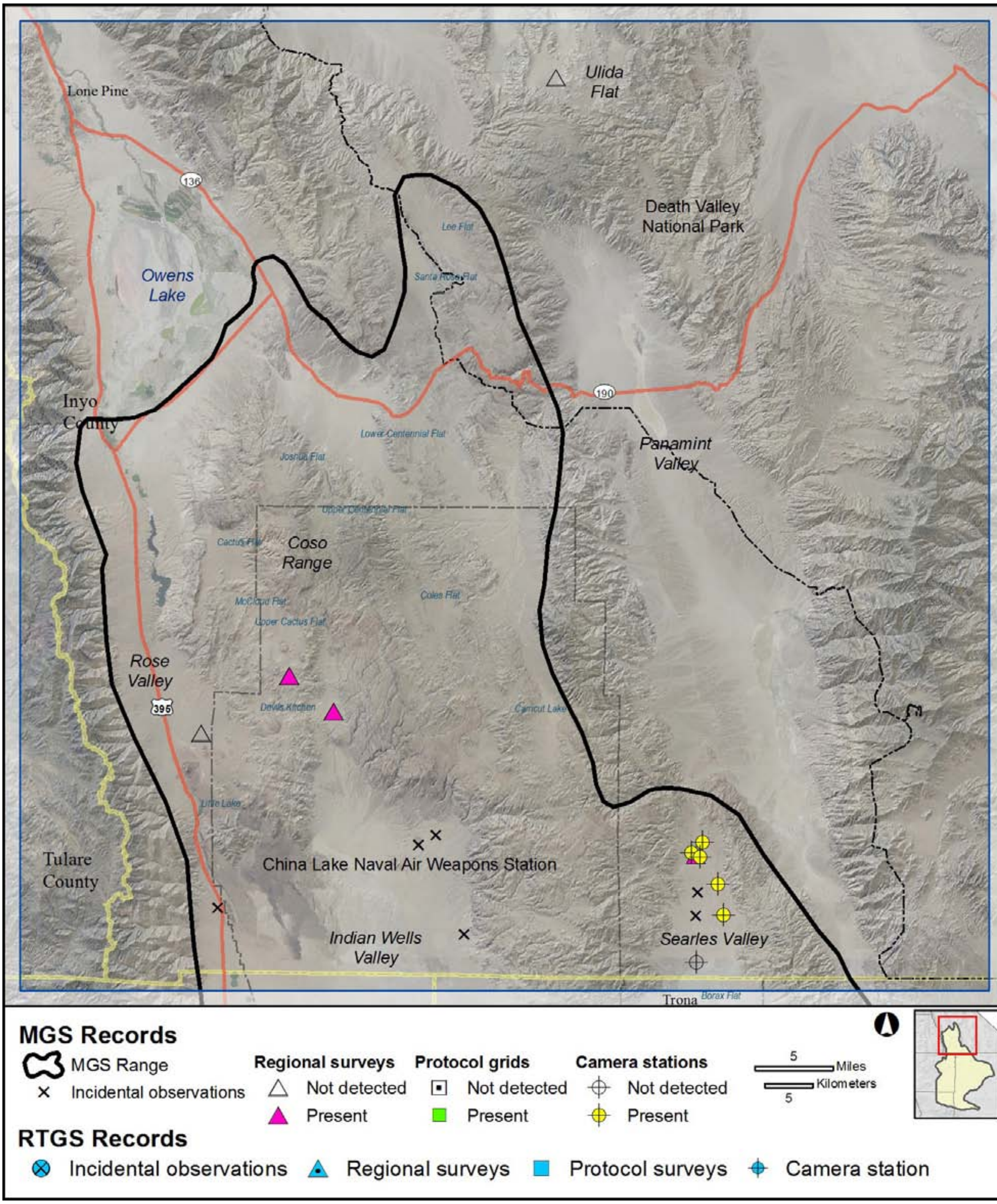

Figure 2. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range within Inyo County, California. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

during 2008–2012. Regional studies on Edwards Air Force Base (EAFB) confirmed the continued presence of the species throughout the central portion of the installation. I also detected Mohave Ground Squirrels at three of 12 camera sites south of State Route 58 and east of EAFB. From 2008–2012, there were only 48 protocol surveys in the southern portion of the range as compared to 247 during the previous 10 y (Leitner 2008). Although these protocol sites were well-distributed from Lancaster and Palmdale east to Victorville, the sole detection was a juvenile Mohave Ground Squirrel captured at a site in Adelanto in 2011.

From 2008–2012, 186 survey sites were sampled in two areas outside the generally accepted boundaries of the Mohave Ground Squirrel geographic range. During this five-year period, 66% of all protocol trapping sites were located southwest of the town of Mojave, an area of large-scale wind energy development. No Mohave Ground Squirrels were detected here despite this intensive sampling effort. In the region from Barstow south to Lucerne Valley, protocol trapping and camera surveys were conducted at 27 locations. There were no Mohave Ground Squirrel occurrences, but Round-tailed Ground Squirrels were found at three of these sites.

Regional analysis.*—Inyo County.*—The Mohave Ground Squirrel range in Inyo County is almost entirely made up of federal lands (Fig. 2.). These include China Lake NAWS as well as public lands administered by US Bureau of Land Management (BLM). No protocol trapping was carried out in Inyo County from 2008–2012. Regional surveys conducted annually at two long-term monitoring sites in the Coso Range yielded 241 captures over this 5-y period. However, trapping at a nearby site in Rose Valley in 2010 produced negative results. Four incidental observations in Indian Wells Valley between the Coso Range and Ridgecrest are significant as they suggest that this area is occupied by Mohave Ground Squirrels. Finally, eight occurrences were documented in northern Searles Valley, including camera detections, live-trap captures, and incidental sightings.

Ridgecrest area and Little Dixie Wash, Kern County.—During 2008–2012, consulting biologists conducted trapping at five protocol grids in the vicinity of Ridgecrest and Inyokern (Fig. 3). Mohave Ground Squirrels were captured at two of these sites, confirming the continued presence of the species in this partially urbanized area. A number of Mohave Ground Squirrel records were reported in the Little Dixie Wash region, which stretches southwest from Inyokern to Red Rock Canyon State Park. These included 12 regional survey sites in and near Red Rock Canyon at which the species was captured (Biosearch Associates 2012). In addition, I detected Mohave Ground Squirrels at all five of the camera study sites in this region. The El Paso Wash area to the southwest of Ridgecrest was intensively sampled with 14 camera sites in 2011 and 2012 (Leitner and Delaney 2014). The results were entirely negative, with no Mohave Ground Squirrel detections recorded in either year. This was consistent with negative results in 2011 from two regional trapping grids in this same area. Camera trapping yielded entirely different results in 2012 at 26 sites to the south and southeast of Ridgecrest (Leitner and Delaney 2014). I detected Mohave Ground Squirrels

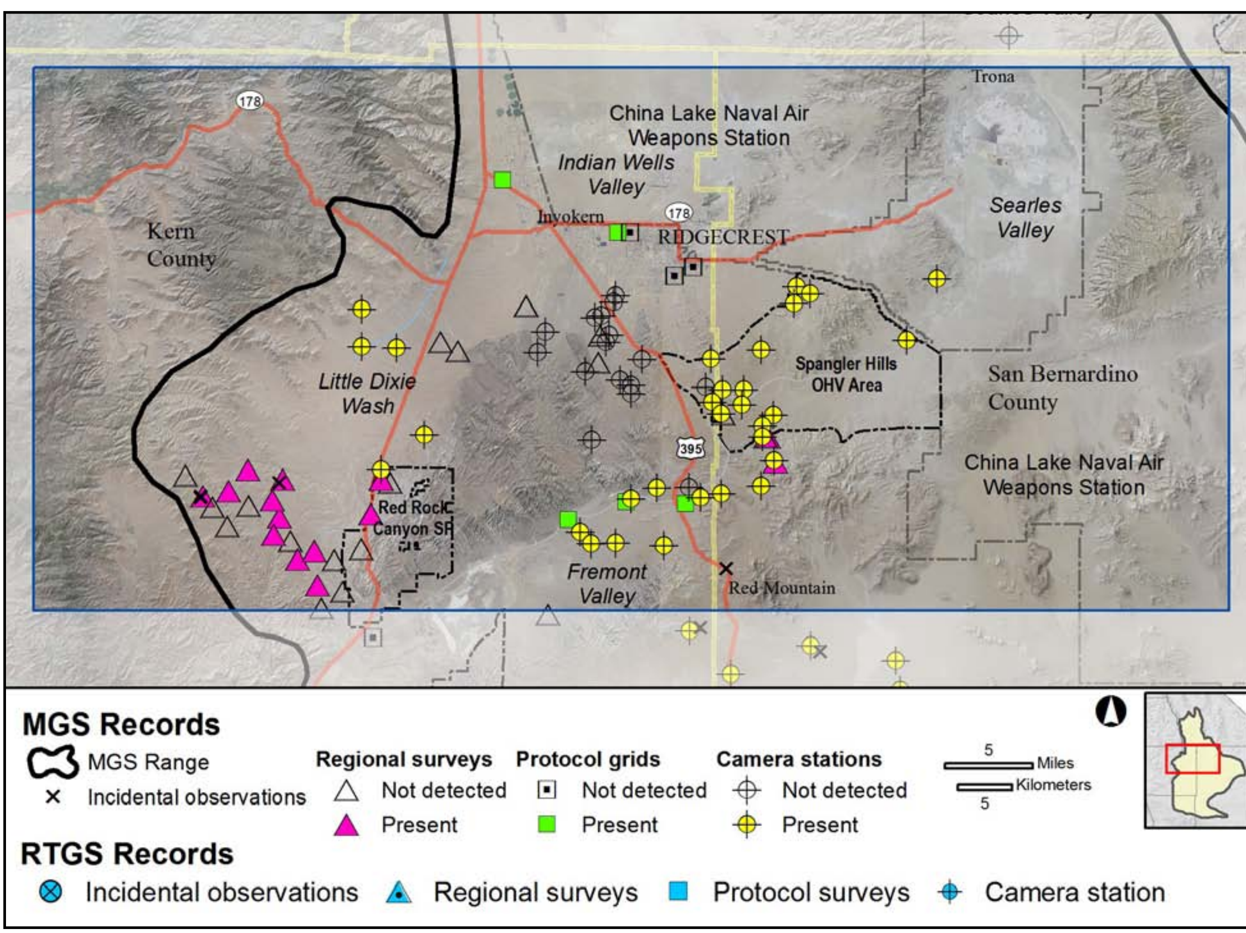

Figure 3. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range in the vicinity of Ridgecrest and in the Little Dixie Wash region. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

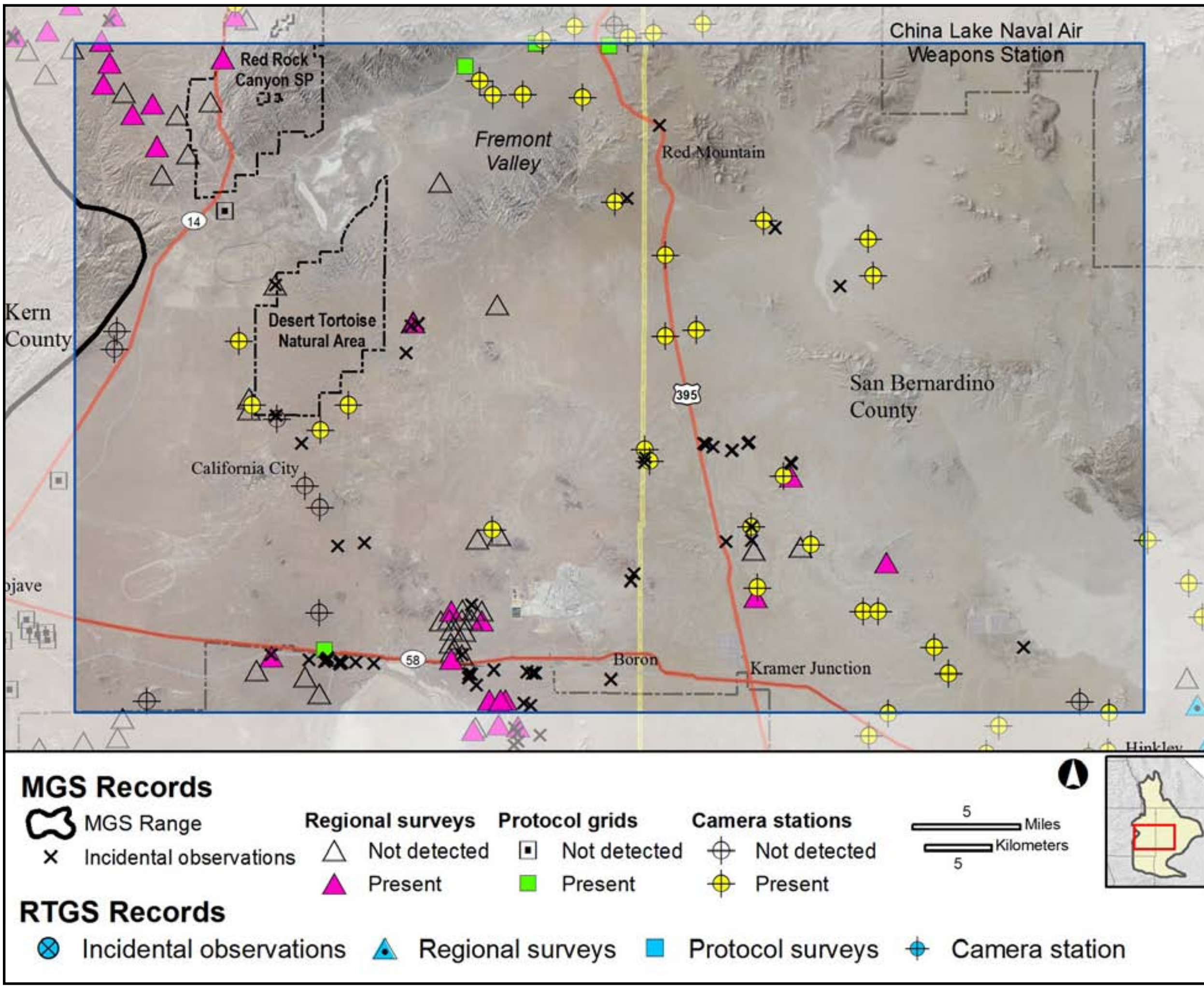

FIGURE 4. Mohave Ground Squirrel range (*Xerospermophilus mohavensis*) extending from Fremont Valley to Edwards Air Force Base. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

at 24 of these 26 locations, which extended over a span of about 50 km (30 mi). Because the Spangler Hills OHV Open Area is heavily impacted by off-road vehicles, it is particularly noteworthy that 14 of 15 camera sites there were occupied by Mohave Ground Squirrels. I also confirmed that the species was present in the upper portion of Fremont Valley, where it was found at six camera sites and three protocol trapping grids. From 1998–2007 there were almost no data available for the Spangler Hills Open Area or Fremont Valley with the exception of several unsuccessful trapping attempts in 2002 and 2003 (Leitner 2008).

Fremont Valley to Edwards Air Force Base, Kern County.—A number of Mohave Ground Squirrel detections were documented in the region from Fremont Valley south to EAFB (Fig. 4). There was intensive sampling in several locations along State Route 58 from Boron west for about 25 km (16 mi). Regional surveys, incidental observations, and a single protocol grid yielded Mohave Ground Squirrel records at more than 25 sites adjacent to State Route 58. The species was also documented at four camera sites and a regional survey trapping grid around the western, southern, and eastern boundaries of the DTRNA. Staff of the Desert Tortoise Preserve Committee, Inc., which manages the DTRNA in collaboration with the BLM, made visual and trail camera detections of Mohave Ground Squirrels in and adjacent to the preserve both in 2011 and 2012 (Mary Logan, pers. comm.). The occurrence of Mohave Ground Squirrels at the DTRNA was reported in Leitner (2008) and these records confirm the persistence of the species in this area. There were also three Mohave Ground Squirrel occurrence records between the DTRNA and EAFB, providing evidence that this area is occupied by the species. Leitner (2008) suggested that Mohave Ground Squirrels might be present in the region extending northward from Kramer Junction to Red Mountain roughly parallel to US 395. Field studies from 2008–2012 have shown that this region is in fact occupied and can provide genetic and demographic continuity across a distance of more than 40 km (25 mi). The evidence includes detections at 15 camera stations and several regional survey sites plus numerous visual observations across this region. Taken together with the recent documentation of Mohave Ground Squirrel occurrences

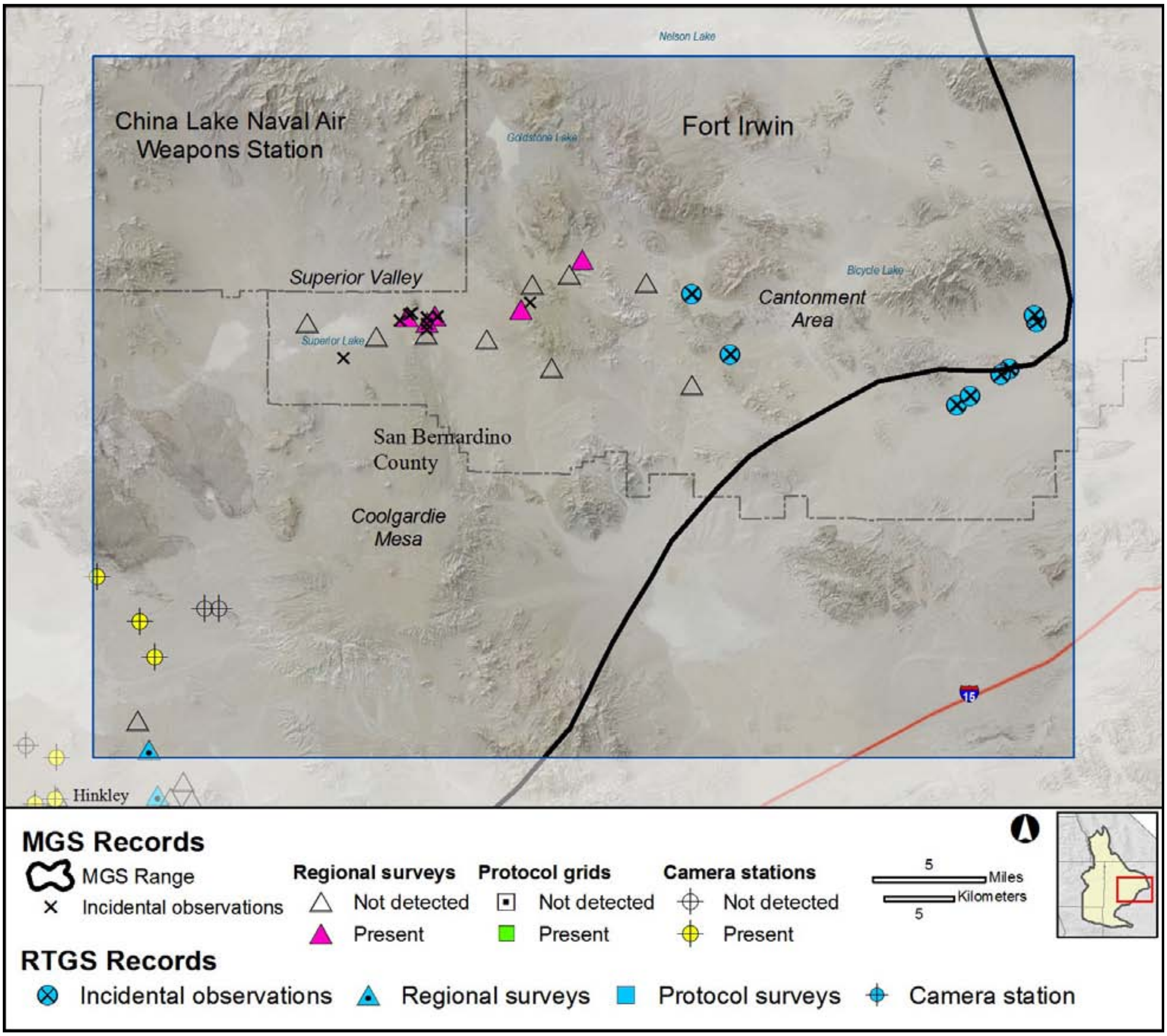

Figure 5. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range on Coolgardie Mesa and Superior Valley and east onto Fort Irwin. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative. Round-tailed Ground Squirrel (*Xerospermophilus tereticaudus*) records are also shown.

south from Ridgecrest toward Red Mountain, it appears that a continuous belt of occupied habitat connects EAFB with the Ridgecrest area.

Coolgardie Mesa and Superior Valley, San Bernardino County.—This extensive plateau area north of Barstow has yielded many Mohave Ground Squirrel records dating back to 1977 (Wessman 1977). From 2008–2012 regional surveys were carried out at 14 sites in this region, all within the boundaries of Fort Irwin (Fig. 5). Mohave Ground Squirrels were trapped at five of these locations and there were a number of visual detections as well. However, trapping at the two easternmost sites failed to capture Mohave Ground Squirrels and there were two incidental observations of Round-tailed Ground Squirrels nearby. In addition, I observed Round-tailed Ground Squirrels at six sites to the east of the Fort Irwin cantonment area, where earlier records had reported Mohave Ground Squirrels. These findings raise questions concerning the present location of the contact zone between these two closely related species on Fort Irwin.

Wind resource area southwest of Mojave, Kern County.—The major wind resource area to the southwest of the town of Mojave has been the site of extensive energy development in recent years. Although most of this area is outside the generally accepted boundaries of the Mohave Ground Squirrel range, there is much apparently suitable desert scrub habitat (pers. obs.). From 2008–2012 protocol trapping surveys were carried out at 159 sites here (Fig. 6). In spite of this extensive sampling effort, there have been no visual detections or captures of Mohave Ground Squirrels. This is entirely consistent with the lack of detections at 26 protocol sites trapped here prior to 2008 (Leitner 2008).

Edwards Air Force Base, Kern County.—Edwards Air Force Base (EAFB) has continued a Mohave Ground Squirrel monitoring program, with regional surveys car-

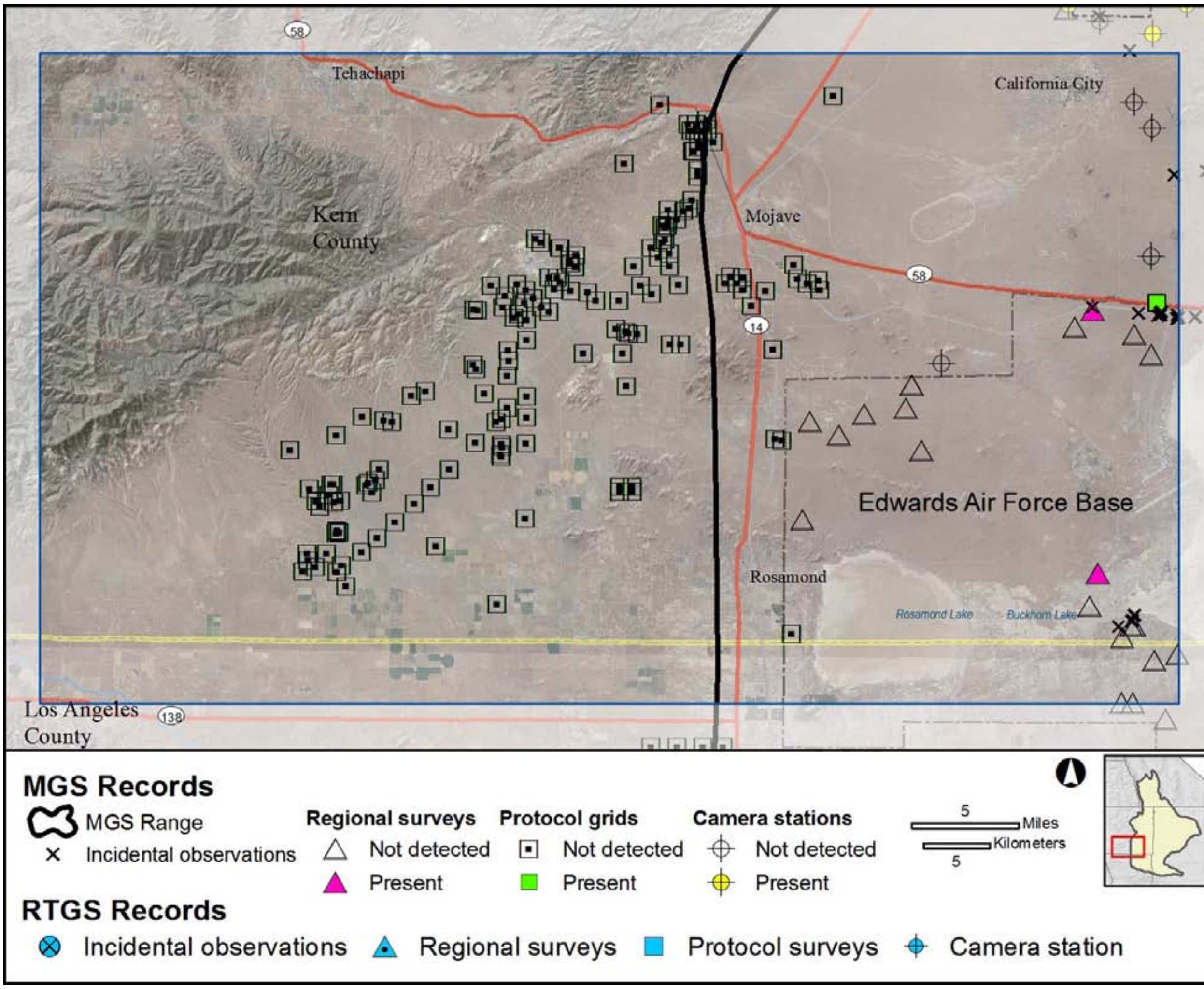

Figure 6. Mohave Ground Squirrel range (*Xerospermophilus mohavensis*) in the vicinity of the town of Mojave. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

ried out during several recent years (United States Air Force 2010a, 2010b, 2011). The distribution of Mohave Ground Squirrel occurrences was generally similar to that reported in Leitner (2008) for 1998–2007 (Fig. 7). Regional trapping surveys at seven sites in the far western section of EAFB yielded no detections, which is consistent with the lack of occurrences there from 2003–2007. More than 30 captures and incidental observations were reported in areas to the south and east of Rogers Dry Lake, a pattern noted in earlier studies (Leitner 2008). However, recent surveys have documented nine new Mohave Ground Squirrel records to the northwest and northeast of Rogers Dry Lake in areas not surveyed intensively for many years. Two detections were reported just beyond the southern boundary of EAFB, one an incidental sighting in northeastern Los Angeles County and the other at a camera site west of US 395 in San Bernardino County.

Kramer Junction to Barstow, San Bernardino County.—I sampled the region to the east of Kramer Junction extensively by camera trapping in 2012 (Fig. 8). I found Mohave Ground Squirrels at 23 out of 33 randomly located camera sites in this region. The geographic pattern of detections indicates that Mohave Ground Squirrels are widely distributed over the broad expanse of low hills and plains east of Kramer Junction. From 1998–2007 there was almost no sampling in this region (Leitner 2008), but there are a number of CNDDB records of the species here from 1988 and earlier. Several Mohave Ground Squirrel occurrences were also documented in a small area south of the Kramer Hills and east of US 395, the first record of Mohave Ground Squirrels here since 1994 (Scarry et al. 1996). Regional surveys in the agricultural area around Hinkley have confirmed the presence of Round-tailed Ground Squirrels (Vanherweg 2012). Based upon data presented in Leitner (2008), the contact zone between these two closely related species was thought to be just west of Hinkley. However, I detected both species in 2012 at a camera site 11 km (7 mi) west of the previous western-most Round-tailed Ground Squirrel record.

Los Angeles County.—Protocol trapping efforts in northeastern Los Angeles County from 2008–2012 (Fig. 9) have failed to find the species. Just as in the previous 10-y period, the only positive records were at several sites within or very close to EAFB. Regional trapping surveys in Los Angeles County at several locations on EAFB and at two county parks were unsuccessful.

Victor Valley, San Bernardino County.—Because of the depressed local economy, there has been little housing or commercial development in the Victor Valley and consequently a much reduced level of protocol trapping from 2008–2012 (Fig. 10). However, a juvenile female Mohave Ground Squirrel was captured by a consultant in 2011 at a solar project site near Adelanto, suggesting that a relict population is still extant in this region.

Mojave River to Lucerne Valley, San Bernardino County.—The area east of the Mojave River was sampled by extensive protocol trapping along State Route 247 from Barstow south to Lucerne Valley (Fig. 10). This trapping survey yielded no Mohave Ground Squirrel detections, but a Round-tailed Ground Squirrel was captured about 8 km (5 mi) south of Barstow. In 2011, I recorded Round-tailed Ground Squirrels at two camera survey sites in Lucerne Valley. There has been no evidence of Mohave Ground Squirrels east of the Mojave River between Victorville and Lucerne Valley since a capture reported by Wessman (1977).

Discussion

Geographic range. — The generally-recognized boundary of the Mohave Ground Squirrel geographic range has been basically unchanged since the publication of a map in Gustafson (1993). The range map featured in Leitner (2008) was based on that 1993 map, but showed a minor extension to the north in Inyo County to include two confirmed records at Lee Flat in 1993 and 2007 (CNDDB Occurrence No. 327). Leitner (2008) also discussed two incidental observations outside of the generally accepted boundary. These records were approximately 8 km (5 mi) beyond the mapped range limits, but within the dispersal range of juvenile Mohave Ground Squirrels (Harris and Leitner 2005). There have been no subsequent detections in either area and no evidence of resident populations there. Two other incidental observations were reported to the southwest of the town of Mojave in 2006, but these supposed records were apparently based on mistaken identification and have been withdrawn from the CNDDB. The US Fish and Wildlife Service (2011) recently suggested that the western por-

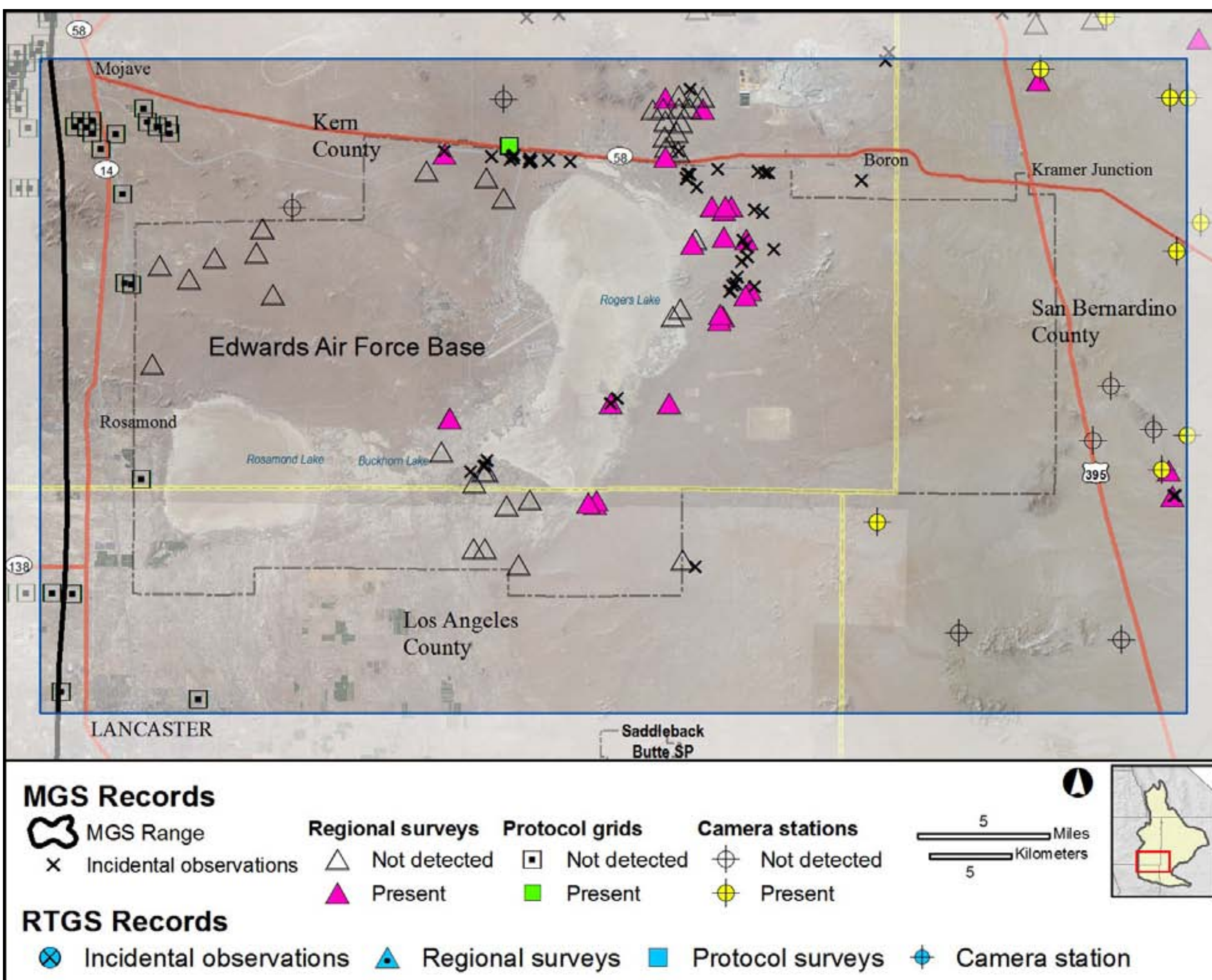

Figure 7. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range on Edwards Air Force Base and vicinity. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

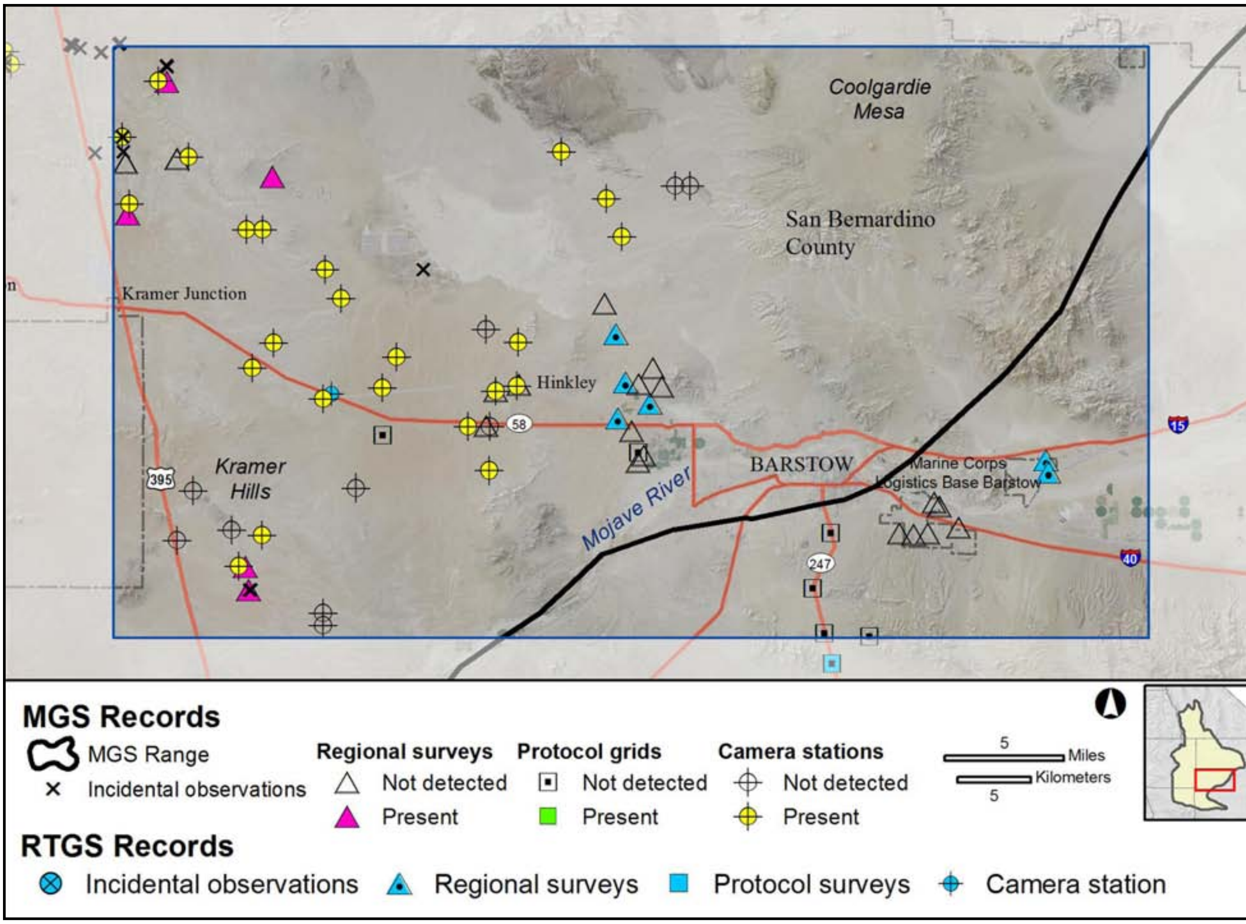

FIGURE 8. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range from Kramer Junction east to Barstow. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative. Round-tailed Ground Squirrel (*Xerospermophilus tereticaudus*) records are also shown.

tion of the Antelope Valley be included within the range of the Mohave Ground Squirrel. This does not seem justified as there has never been any record of the species to the west of State Route 14 between Mojave and Palmdale, in spite of extensive protocol trapping over much of this area.

Thus, there is no solid evidence that the generally accepted boundaries of the Mohave Ground Squirrel geographic range should be expanded. However, a review of the 1998–2012 distributional data suggests that the species may no longer be present in six distinct regions within its currently mapped range. First, there have been no Mohave Ground Squirrel records in the Fremont Valley west of California City since 2002. Second, no Mohave Ground Squirrels have been trapped or observed in the western portion of EAFB since a single record in 1994, in spite of regional trapping surveys at 22 randomly selected sites. Third, there have been very few recent Mohave Ground Squirrel detections in the northeastern portion of Los Angeles County where it was commonly reported from 1920 until 1989. The only sites in Los Angeles County where the species has been trapped or observed since 1991 are on or very close to EAFB where the species is known to be widespread. The fourth area of concern is east of the Mojave River in the area from Victorville to Lucerne Valley where there have been no Mohave Ground Squirrel records since 1977. The fifth region where Mohave Ground Squirrels seem to be absent is around Barstow and west to Hinkley Valley. The Round-tailed Ground Squirrel appears to be widely distributed here and may well be extending its range to the west along the State Route 58 corridor. The only Mohave Ground Squirrel report east of the Mojave River since 1998 was a single visual detection south of Barstow in 2006 (Leitner 2008). Finally, the current range boundary as mapped includes much of Fort Irwin, but the only recent records here are in the extreme western part of the installation. There are recent Round-tailed Ground Squirrel occurrences in areas of Fort Irwin where Mohave Ground Squirrels were reported in earlier decades (Wessman 1977; Krzysik 1994).

Distribution of survey efforts.—Protocol trapping surveys are almost always undertaken to determine the potential of proposed projects to impact the Mohave Ground Squirrel (California Department of Fish and Game 2010) and may be sponsored by private developers or by public agencies such as California Department of Transportation. These surveys are usually located on private property, although in the case of linear projects such as highways, pipelines, or communication infrastructure there may be trapping sites on public land as well. During the 10-y period from 1998–2007, the great majority of protocol surveys were located in the southern portion of the Mohave Ground Squirrel range (Leitner 2008). This pattern was even more pronounced from 2008–2012, with only 10 of 240 protocol sites located in the central portion of the range and none in the northern area.

Regional trapping studies tend to be focused on military and public lands and are often funded by state and federal agencies. From 2008–2012, the majority of regional trapping surveys were conducted on military installations, including EAFB, Fort Irwin, China Lake NAWS, and Marine Corps Logistics Base Barstow. Surveys took place at 24 sites in and adjoining Red Rock Canyon State Park, as well as on conservation lands managed by CDFW and by Rio Tinto Borax. In comparison to 1998–2007, there were fewer regional trapping sites on BLM land (Leitner 2008).

For the first time, David Delaney and I used trail cameras for large-scale surveys in 2011 and 2012 on public lands managed by BLM, CDFW, and California State Parks (Leitner and Delaney 2014). We sampled 123 randomly selected sites during this survey effort, covering a significant portion of the Mohave Ground Squirrel geographic range plus a large region outside the range to the east of the Mojave River near Lucerne Valley. This has provided positive occurrence data for a number of areas that had not been surveyed adequately, from Searles Valley in the north, from Ridgecrest south to Kramer Junction, and then east toward Barstow.

Significant portions of the Mohave Ground Squirrel range were not adequately sampled from 2008–2012.

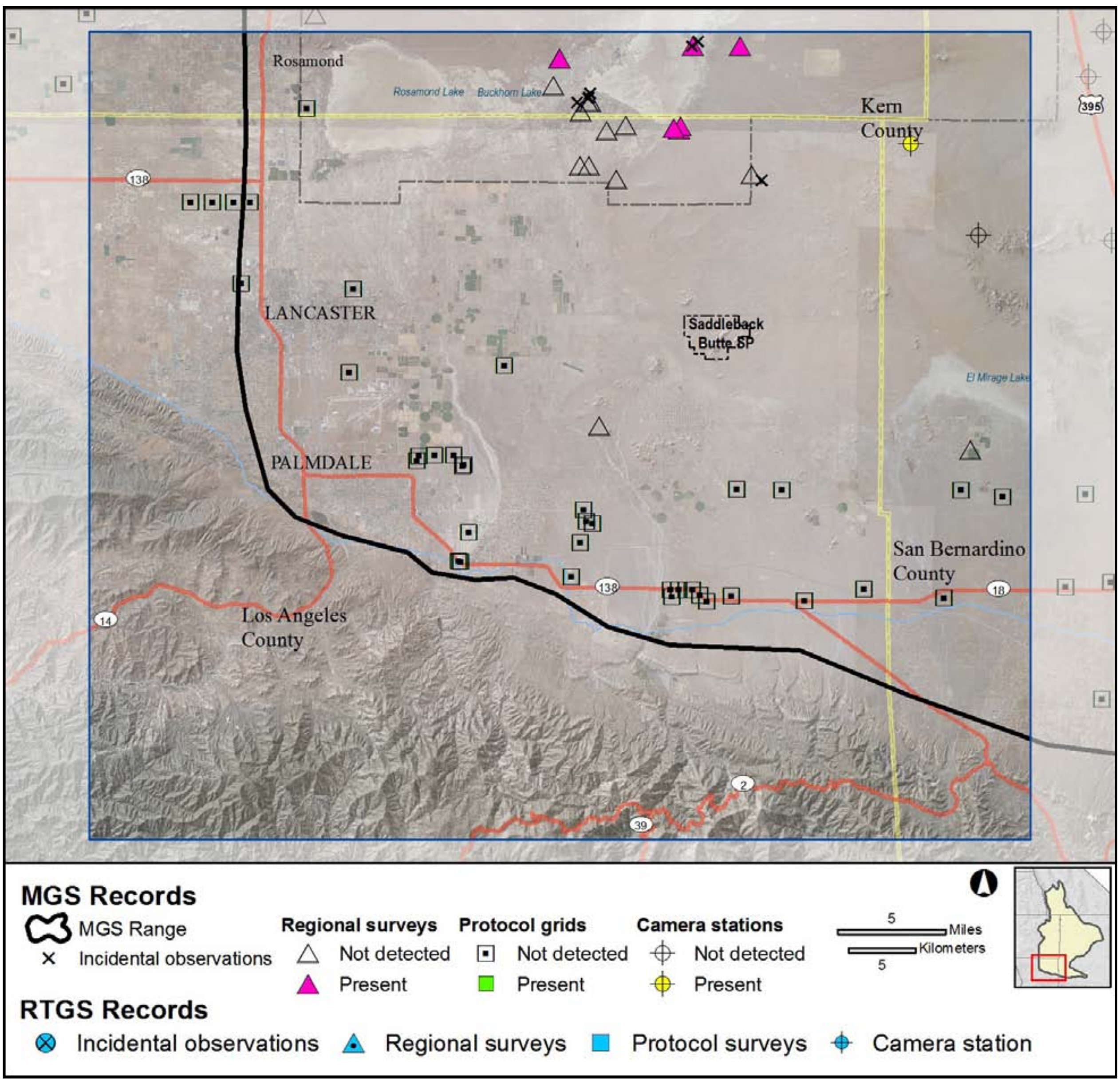

Figure 9. Mohave Ground Squirrel (*Xerospermophilus mohavensis*) range in Los Angeles County, California. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative.

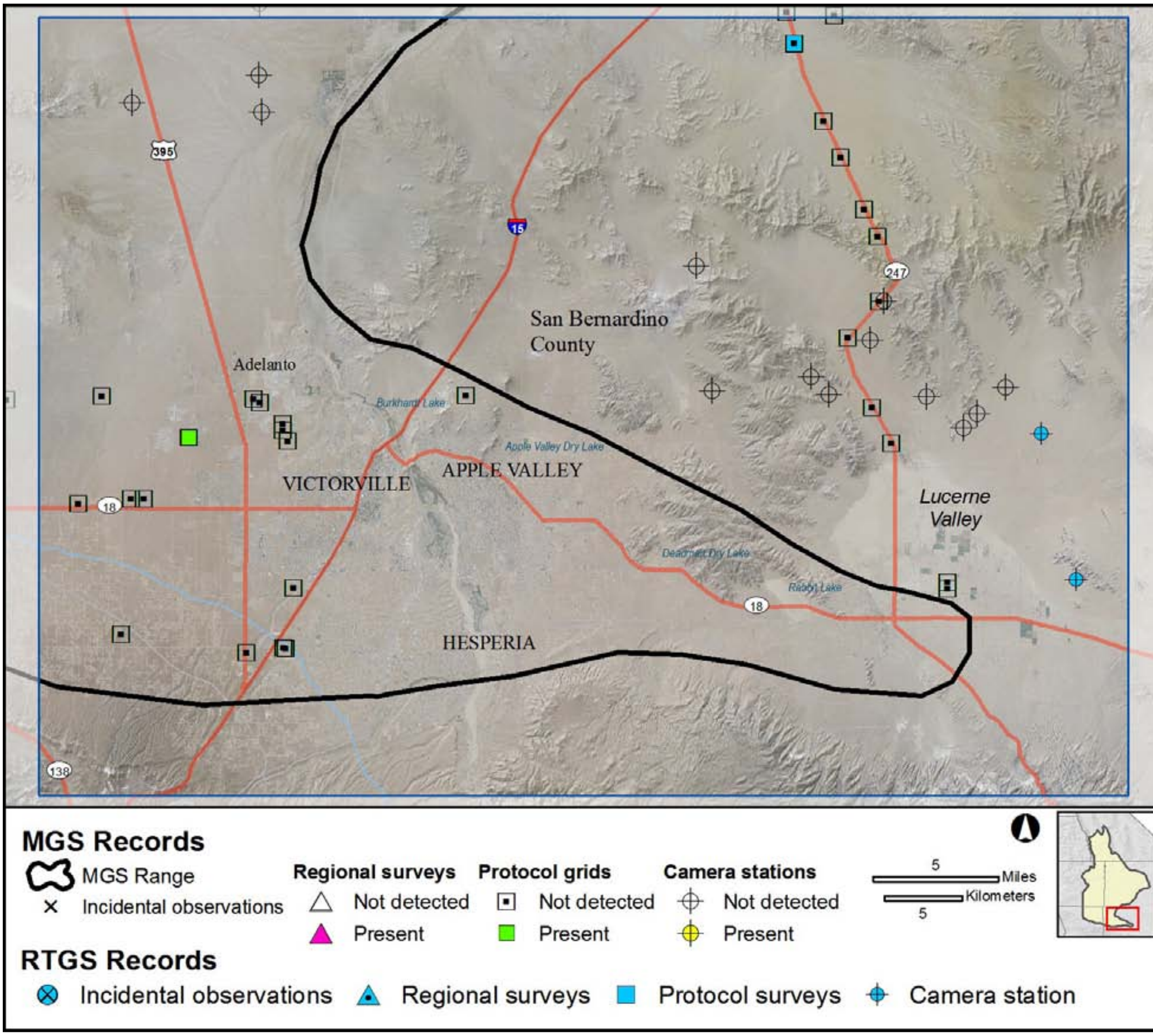

Figure 10. Mohave Ground Squirrel range (*Xerospermophilus mohavensis*) from the vicinity of Victorville east to Lucerne Valley. Symbols indicate locations of 2008–2012 Mohave Ground Squirrel records, both positive and negative. Round-tailed Ground Squirrel (Xerospermophilus tereticaudus) records are also shown.

With the exception of the Coso area and northern Searles Valley, there were no surveys in Inyo County. As was the case from 1998–2007 as well (Leitner 2008), there was very little sampling effort from 2008–2012 on China Lake NAWS and on much of Fort Irwin. These military lands represent the largest remaining areas for which we have inadequate data on Mohave Ground Squirrel distribution and abundance.

Management Recommendations

Mohave Ground Squirrel database.—Leitner (2008) recommended that the 1998–2007 database of Mohave Ground Squirrel records be maintained by a public agency and made available to interested parties. In response, the CDFW has incorporated several Mohave Ground Squirrel datasets into the Biogeographic Information & Observation System (BIOS), which allows users to visualize these data online using a GIS platform. The datasets available include maps from Leitner (2008) that show the boundaries of the historic range and the locations of Mohave Ground Squirrel occurrences. All data for 1998–2007 covering protocol trapping, regional surveys, and incidental observations are now entered into BIOS. It is recommended that CDFW put in place a permanent system to collect annually all Mohave Ground Squirrel data, including unsuccessful survey efforts, from biologists, consultants, and agency staff.

Needed regional surveys.—Leitner (2008) pointed out the lack of current data on the status of the Mohave Ground Squirrel in certain areas in the northern and central parts of its range. Extensive camera surveys in 2011–2012 from EAFB north to Ridgecrest have demonstrated that the species is present throughout this region (Leitner and Delaney 2014). Additional field data have also clarified the distribution of Mohave and Round-tailed Ground Squirrels on the southern part of Fort Irwin. Nevertheless, there have been no systematic surveys on China Lake NAWS or on much of Fort Irwin. Well-designed comprehensive field surveys on these installations are strongly recommended, as they make up much of the total range of the species.

The status of the Mohave Ground Squirrel in the southern portion of its range between Lancaster and Victorville is poorly understood. Since 2008, there have been a number of protocol surveys in this area, but only one Mohave Ground Squirrel occurrence has been documented. This occurrence was recorded near Adelanto, in an area that is known to support a relict population. Additional surveys are urgently needed in the southern part of the range, especially in northeastern Los Angeles County where state and county parks may have the potential to support Mohave Ground Squirrel populations.

Wind energy special survey area.—The West Mojave Plan (US Bureau of Land Management 2003) recommended that the region southwest of the town of Mojave be surveyed to determine if it might support a previously undocumented Mohave Ground Squirrel population. Because of extensive wind energy development here, protocol trapping was required at 159 sites from 2008–2012. There have been no Mohave Ground Squirrel detections here and it seems clear that no further surveys are needed.

Interactions with Round-tailed Ground Squirrel.—Recent surveys have confirmed that Round-tailed Ground Squirrels are widely distributed in Hinkley Valley west of Barstow (Leitner 2008; Vanherweg 2012). In 2012, I detected Round-tailed Ground Squirrels at a camera site approximately 20 km (12 mi) to the west of Hinkley. The same study documented Mohave Ground Squirrels at a number of sites just to the west and north of Hinkley. These observations suggest that this region is an active contact zone between the two species and that Round-tailed Ground Squirrels may be extending their range westward here. Survey data since 2008 indicates that there may be an extensive contact zone on Fort Irwin as well, with Round-tailed Ground Squirrels shifting westward there as well. Recent habitat modeling studies using climate change scenarios project that by 2030 there could be significant loss of suitable habitat for the Mohave Ground Squirrel in the region west of Hinkley and on Fort Irwin (Esque et al. 2013). If the Round-tailed Ground Squirrel is better adapted to projected hotter and drier conditions, this species may already be expanding its range in response to climate change. Comprehensive field studies are urgently needed to monitor changes in the distribution of these two ground squirrel species. Comparative data on competitive interactions between Mohave and Round-tailed Ground Squirrels are also needed including information on diet, dispersal capabilities, annual cycle, and reproductive performance in relation to rainfall.

Use of trail cameras for ground squirrel studies.—Delaney (2009) and Leitner (2009) explored the use of trail cameras to detect Mohave Ground Squirrels in the Western Expansion Area of Fort Irwin. Trail cameras used with bait readily attracted Mohave Ground Squirrels and were found to be at least as effective as live traps in confirming their presence. Based upon this finding, David Delaney and I successfully carried out a large-scale survey using trail cameras in 2011 and 2012. It is recommended that the results of this survey be used as a baseline for future monitoring efforts. Although camera surveys cannot be used to estimate population density or abundance, the results of the 2011–2012 camera study can serve to identify future changes in the distribution and status of the species through the use of occupancy analysis (MacKenzie et al. 2006).

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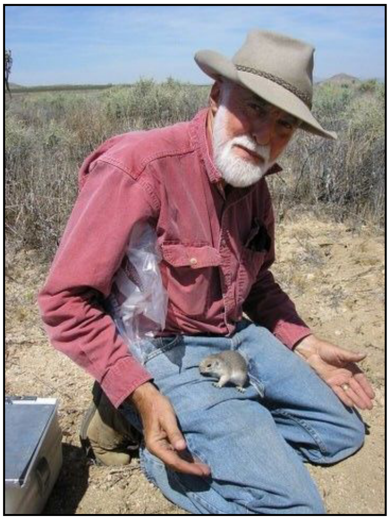

Philip Leitner has been associated with the Endangered Species Recovery Program of California State University, Stanislaus since 2001. However, his research interest in the state-listed Mohave Ground Squirrel goes all the way back to 1988. He has spent many months in the Mojave Desert using live-trapping, camera trapping, and radiotelemetry to investigate the current distribution, habitat requirements, and annual cycle of this elusive little rodent. (Photographed by Kelly Lesher).

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Probability of Occupancy of Blunt-nosed Leopard Lizards on Habitat Patches of Various Sizes in the San Joaquin Desert of California

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Abstract.—The Blunt-nosed Leopard Lizard (*Gambelia sila*) is a California and federally listed endangered lizard species native to the San Joaquin Desert. The species has lost approximately 85% of its original native habitat. Numerous conservation efforts have been pursued to recover the species, but most of these efforts have a multispecies focus that may have limited benefits for Blunt-nosed Leopard Lizards. We surveyed 13 isolated, potential habitat patches of Blunt-nosed Leopard Lizards and we used survey data collected by others at seven sites to determine the effect of habitat patch size on the probability of occurrence of Blunt-nosed Leopard Lizards. There was a significant positive relationship between habitat patch size and presence of Blunt-nosed Leopard Lizards ($G = 13.289$, df = 1, $P < 0.001$; Pearson's $\chi^2 = 10.097$, $P = 0.929$). Only one habitat patch smaller than 250 ha had a Blunt-nosed Leopard Lizard observation. Given these results and the relative lack of information about patch dynamics for this species, we recommend that conservation efforts pursue large habitat patches that support extant Blunt-nosed Leopard Lizard populations (e.g., Carrizo Plain, Lokern Natural Area) and expand smaller habitat patches that support the species on the San Joaquin Valley floor (e.g, Buttonwillow Ecological Reserve, Pixley National Wildlife Refuge).

Key Words.—conservation; endangered species; *Gambelia sila*; logistic regression; surveys

Introduction

Conservation for some rare species depends on preserving remaining habitat that supports the species. Because resources are chronically limited for this task, resource agencies must choose which remaining habitats are best to be protected in the near term. For a variety of vertebrate species, the size of reserves affects abundance and ultimately occupancy with lower numbers as reserve size decreases (Pickett and Thompson 1978; McCoy and Mushinsky 1999; Bradford et al. 2003; Hokit and Branch 2003). For some species, abundance shows steep declines when reserve size is lower than 600 ha (Humphreys and Kitchener 1982). Based on the size and ecology of the species, some parcels of native habitat may simply be too small to support a population. Determining the lower limit of parcel size at which a species can occupy habitat is important to making the right choices of habitat to purchase and protect.

The Blunt-nosed Leopard Lizard (*Gambelia sila*; Fig. 1) is the largest lizard species in the San Joaquin Valley (Stebbins and McGinnis 2012). Due in large measure to habitat loss on the floor of the San Joaquin Valley, the Blunt-nosed Leopard Lizard was listed as endangered in 1967 pursuant to the Endangered Species Preservation Act of 1966, and subsequently listed as endangered pursuant to the California Endangered Species Act in 1971 (U.S. Fish and Wildlife Service [USFWS] 1998, 2010). Numerous conservation efforts have been planned within the range of the Blunt-nosed Leopard Lizard that protect or restore habitat features, including: 14 Habitat Conservation Plans (HCPs); the Central Valley Project Conservation Program (CVPCP); Central Valley Project Improvement Act Habitat Restoration Program (HRP); California Department of Fish and Wildlife ecological reserves; national wildlife refuges; conservation banks; and habitat compensation for incidental take of state or federal endangered species (USFWS 2010). Most of these efforts have a multispecies focus. Specific management criteria for blunt-nosed leopards are listed for some of the above referenced conservation efforts, but the continued survival of Blunt-nosed Leopard Lizards is not a stated objective for several of them, and some conservation efforts are only coarsely evaluated (USFWS 2010).

Blunt-nosed Leopard Lizards inhabit relatively flat, sparsely-vegetated areas of the San Joaquin Desert (Germano et al. 2011) including the valley floor, Carrizo Plain, Elkhorn Plain, Cuyama Valley, and surrounding foothills (Germano and Williams 1992; USFWS 1998). Vegetation communities associated with the Blunt-nosed Leopard Lizard include alkali sink scrub, saltbush (*Atriplex* spp.) scrub, Ephedra scrub, and native and non-native grasslands (Germano and Williams 2005; USFWS 2010). Habitat loss from agricultural, energy, and urban development pose the greatest threat to Blunt-nosed Leopard Lizards (USFWS 2010). Germano and Williams (1992) estimated that the Blunt-nosed Leopard Lizard had lost 80–85% of its native range at the time of their publication, and the most recent five-year status report for the species (USFWS 2010) reports that an additional 35,000 acres of permanent impacts and 10,000 acres of temporary disturbance have been authorized. Remaining habitat for the species, especially on the valley floor, is highly

Figure 1. Female Blunt-nosed Leopard Lizards (*Gambelia sila*) from the Lokern Natural Area of the San Joaquin Desert, California. (Photographed by David J. Germano).

fragmented and limited to southern Merced County south to Kern, San Luis Obispo, and northern-most Santa Barbara and Ventura counties (USFWS 1998, 2010).

Few large, continuous patches of habitat now occur on the floor of the San Joaquin Valley. Many parcels of natural habitat are relatively small and isolated. Criteria for recovery of the Blunt-nosed Leopard Lizard include identification of conservation areas, minimum population size and densities, and best management practices (USFWS 1998). There have been no estimates of the minimum habitat patch size that would be required to support a minimum viable population (MVP) for Blunt-nosed Leopard Lizards. Shaffer (1981) defined a MVP as the "the smallest isolated population having a 99% chance of remaining extant for 1,000 years despite the foreseeable effects of demographic, environmental, and genetic stochasticity, and natural catastrophes." A population model from 1989 tried to estimate the viability of Blunt-nosed Leopard Lizard populations through 50 years (Marybeth Buechner, unpubl. report), but it was deemed to have poor accuracy (Germano and Williams 1992). No other MVP estimates have been attempted for Blunt-nosed Leopard Lizards. An understanding of minimum habitat patch size for Blunt-nosed Leopard Lizards is necessary to model the population dynamics of this species.

We surveyed patches of potential Blunt-nosed Leopard Lizard habitat in the southern San Joaquin Valley to begin to estimate the minimum patch size required by this species. We also used recent survey data on Blunt-nosed Leopard Lizards by environmental companies and we reviewed information from the California Natural Diversity Database (CNDDB). Because habitats have been fragmented for many years, we assumed that even one individual on site would indicate that the patch of habitat was large enough to support a long-term population of leopard lizards. We used these data in a logistic regression analysis to determine the probability of occurrence of Blunt-nosed Leopard Lizards at various habitat patch sizes.

Methods

We surveyed 13 isolated, potential habitat patches for Blunt-nosed Leopard Lizards. We also incorporated survey results provided by personnel of two environmental companies that were conducted in the past few years in isolated, potential habitat patches of Blunt-nosed Leopard Lizards. We reviewed CNDDB records for Blunt-nosed Leopard Lizard occurrences in isolated habitat patches. The survey data and CNDDB record review identified seven additional habitat patches for analysis that met our criteria for isolation. In total, we evaluated 20 isolated habitat patches for presence of Blunt-nosed Leopard Lizards.

We considered habitat patches isolated if the habitat was surrounded by one or more of the following features: a marked two-lane road, active agriculture or other ground disturbance (e.g., recent disking), water or canal, high density oil or other mineral extraction, or urban or residential development. All sites surveyed were considered moderate to good habitat based on soil and vegetation structure. We did not group or eliminate habitat patches based on specific vegetation or other habitat characteristics (e.g., soil type) because the number of parcels available to be surveyed was limited and Blunt-nosed Leopard Lizards occur on all habitats in the Valley except riparian and marsh (Montanucci 1965; Germano and Williams 1992, 2005). Habitat patches with evidence of historic disturbance (e.g., disking, former oil well pads) were not excluded if saltbush or other shrubs had been reestablished on the site and a source population was within 500 m because Blunt-nosed Leopard Lizards have been observed on previously disturbed habitat patches with suitable habitat features such as the Buttonwillow Ecological Reserve (pers. obs.). We estimated the size of habitat patches (in ha) using imagery from Google Earth (2013).

Table 1. Presence / absence of Blunt-nosed Leopard Lizards (*Gambelia sila*) on 20 habitat patches of various sizes in the San Joaquin Valley, California.

Habitat Patch Size (ha)	Blunt-nosed Leopard Lizards Observed
19	No
42	No
43	No
63	No
69	No
80	No
96	No
102	No
130	No
173	No
181	No
238	Yes
246	No
259	Yes
315	No
374	No
397	Yes
667	Yes
1706	Yes
4415	Yes

We surveyed for lizards on isolated, potential habitat patches in 2010 using meandering transects across a site for five non-consecutive days. We conducted surveys from late April through early July at optimal temperatures for adult leopard lizard activity (Germano and Williams 2005). Surveys of Blunt-nosed Leopard Lizards for only five days have been found to detect 90% of first observations of Blunt-nosed Leopard Lizards and there is a 95% chance of detecting Blunt-nosed Leopard Lizards if they occur at a site (Germano 2009). We believed that the low possibility of missing a lizard on a site if we surveyed for more days was compensated for by being able to survey more sites in a year.

We compared survey data for Blunt-nosed Leopard Lizards and CNDDB records to historical aerial photos on Google Earth. If historical aerials indicated a parcel was isolated before and after the date of a survey or CNDDB occurrence, we considered the habitat patch was isolated at the time of survey or CNDDB occurrence. Blunt-nosed Leopard Lizard surveys conducted by personnel of the environmental companies followed the California Department of Fish and Wildlife approved survey methodology. The CNDDB only documents positive results and negative results are not recorded. Protocols are not reported in the occurrence records. We used logistic regression ($\alpha = 0.05$) to determine the probability of occurrence of Blunt-nosed Leopard Lizards based on varying patch size of natural habitat.

Results

Blunt-nosed Leopard Lizards were observed on six of the 20 evaluated habitat patches (Table 1). Habitat patches with Blunt-nosed Leopard Lizard observations ranged from 238 to 4,415 ha. Only one habitat patch smaller than 250 ha had a Blunt-nosed Leopard Lizard observation (Table 1). Four of the remaining six habitat patches with Blunt-nosed Leopard Lizard observations were greater than 400 ha. Habitat patch size was predictive of the occurrence of Blunt-nosed Leopard Lizards ($G = 13.29$, df = 1, $P < 0.001$; Pearson's $\chi^2 = 10.10$, $P = 0.929$). The model had a y intercept of -4.497 and a slope of 0.01354. The relationship has a steep prediction curve between 200 and 400 ha (Fig. 2). Based on this model, there is only a 4.14% chance of Blunt-nosed Leopard Lizards occurring on a habitat patch ≤ 100 ha, a 14.3% chance of occurrence at 200 ha, a 56.0% chance at 350 ha, and a 90.7% chance of occurrence at 500 ha.

Discussion

The size of habitat patches has been found to be important in several species where this parameter has been studied. For the Florida Scrub Lizard (*Sceloporus woodi*), abundance, survivorship, and recruitment were positively associated with the size of eight scrub patches in Florida that varied in size from eight to 256 ha (Hokit

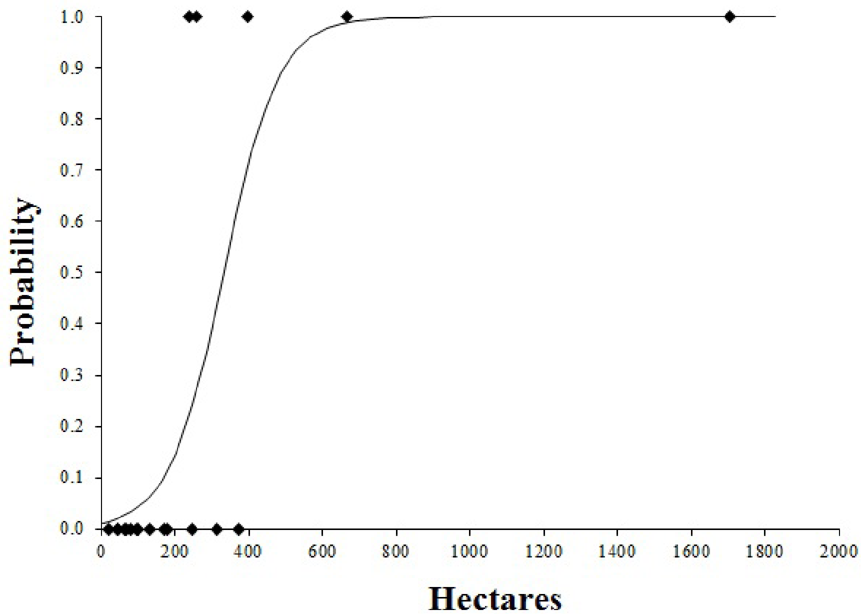

Figure 2. Probability of occurrence of Blunt-nosed Leopard Lizards (*Gambelia sila*) based on presence/absence surveys of habitat patches of varying sizes in the San Joaquin Valley, California.

and Branch 2003). Also in Florida scrub habitat, 11 of 18 species of vertebrates were positively correlated with area of habitat, although several rare species maintained relatively large numbers in small habitat patches (McCoy and Mushinsky 1999). The occupancy of Red-spotted Toads (*Bufo punctatus*) in southern Nevada increased with increased patch size (Bradford et al. 2003). Humphreys and Kitchener (1982) found that mammals, birds, and lizards that were restricted to native habitat in Australia declined in abundance as area of habitat decreased, and these declines were steep when reserve area was smaller than 600 ha.

Pickett and Thompson (1978) described nature reserves and patches of habitat as habitat islands in which, similar to true islands, the area affects the rate of extinction and that small populations, or populations necessarily confined to small areas, will be more subject to extinction. As habitat patch size is reduced, the risk of extinction increases primarily due to reduced population size (Picket and Thompson 1978). It may be true that for some species, small reserves (< 40 ha) can be valuable (Shafer 1995). In the San Joaquin Valley, some rare annual plants and the endangered Tipton kangaroo rat (*Dipodomys n. nitratoides*) can persist on habitat patches < 40 ha (pers. obs.). However, for most animal species, small patch size likely will reduce population size below the minimum viable population, making it unlikely the population can survive the catastrophic and stochastic events expected to occur over time (Shaffer 1981). For these species, small patch size greatly increases the deleterious effects of habitat edge. In five studies of amphibian and reptile species, the effect of edge on species inhabiting forest habitats was either negative (16 instances) or neutral (three instances), never positive (Ries et al. 2004). The average home range size of Blunt-nosed Leopard Lizards in the Lokern area of the southern end of the valley ranges from 2.85 to 9.36 ha, depending on methodology, year, and sex, with some individuals having home ranges up to 31.5 ha (unpubl. data). Average daily distances moved by these lizards ranged 65.5 to 108.4 m with the greatest daily movement as high as 316 m (unpubl. data). Therefore, it is not surprising that the wide-ranging Blunt-nosed Leopard Lizard is more likely to be absent as habitat patch size decreases.

Three of the seven habitat patches with Blunt-nosed Leopard Lizards in our study were larger than 405 ha, and a fourth patch was 397 ha. However, at least two habitat patches smaller than 405 ha, including the 397 ha habitat patch, may actually be part of habitat patches > 405 ha. The Kerman Ecological Reserve and Buttonwillow Ecological Reserve are bisected by Seventh Standard Road and Highway 180, respectively. Both roads are paved, two-lane roads that receive moderate to heavy traffic. Based on our criteria for isolation, a two-lane road was considered a barrier. This criteria resulted in two habitat patches for the Kerman Ecological Reserve of 397 ha and 315 ha, and two habitat patches for the Buttonwillow Ecological Reserve of 667 ha and 259 ha. However, Blunt-nosed Leopard Lizards have been observed crossing roads similar to Seventh Standard Road (Kacey O'Malley, pers. comm.). Traffic volume on Seventh Standard Road, though, has increased greatly in the past decade (pers. obs.) because trucks use it to connect I-5 and Highway 99, and likely lizards have trouble crossing this road now. Although Highway 180 and similar roads may pose ongoing threats to Blunt-nosed Leopard

Lizards occupying adjacent habitat, they may not be significant movement barriers if traffic volume is relatively low. If the habitat patches of Kerman Ecological Reserve are combined, the habitat patch size increases to 712 ha.

According to Soulé (1987, cited in Shafer 1995), the estimated population size of vertebrate species to achieve a 95% survival expectation varies between 200–20,000 individuals, with a median of 2,000 individuals. If Soulé's median estimate for a population to persist 200 years is assumed for Blunt-nosed Leopard Lizards, then it would require a population of at least 2,000 individuals. An early estimate of density (Tollestrup 1979) was 3.2 Blunt-nosed Leopard Lizards per ha (1.3/ac). At this density, at least 623 ha of habitat would be needed to support Soulé's median estimate using the simplest of calculations (number of individuals/individuals per ha). However, densities of adult Blunt-nosed Leopard Lizard can be as high as 4.35/ha to 16.0/ha in exceptional years, which does not even include hatchling densities that can range from 23.9 to 35.6 lizards/ha (Germano and Williams 2005). Based only on these adult densities, and if only the sheer number of lizards determined long-term occupancy, then habitat patch size could be as small as 125 ha.

The number of Blunt-nosed Leopard Lizards at a site varies markedly over relatively short time spans (Germano and Williams 2005; Germano et al. 2012). Therefore, in years when abundances are low, a small patch size may not support enough adults to overcome stochastic events such as an unusually cold, wet winter or an increase in predators over a short time span. A large habitat patch will contain more lizards in low density years and will be more resilient to stochastic events.

Although we did not use Occupancy Modeling to determine presence of lizards at a site, we believe that our data are a good start to determining sizes of habitat that will support leopard lizards. We are assuming that the 0.907 probability of lizards occurring on a patch of 500 ha means that Blunt-nosed Leopard Lizards will persist at a site this size long into the future if the site is not altered. Conversely, smaller patch sizes have a rapidly decreasing likelihood of lizard occurrence and may not support a population of Blunt-nosed Leopard Lizards long-term. Although our sample size is not large, we did not find leopard lizards on any patch smaller than 238 ha. Remaining small habitat patches in the southern San Joaquin Valley will likely not be useful to recovering the Blunt-nosed Leopard Lizard unless they are linked to much larger areas of contiguous habitat. Given these results and the relative lack of information about patch dynamics for this species, we recommend that conservation efforts pursue large habitat patches that support extant Blunt-nosed Leopard Lizard populations (e.g., Carrizo Plain, Lokern Natural Area) and expand smaller habitat patches that support the species on the San Joaquin Valley floor (e.g., Buttonwillow Ecological Reserve, Pixley National Wildlife Refuge). Additional efforts using Occupancy Modeling to refine habitat patch size would be helpful also.

Size of patches will not matter, however, if appropriate habitat management is not followed to maintain suitable habitat conditions. Blunt-nosed leopard lizards, and many other small vertebrates in the San Joaquin Valley, do not tolerate persistent high cover of herbaceous plants (Germano et al. 2001, 2012). Grazing by livestock, or some other mechanism to remove herbaceous ground cover in high cover years, must be used on sites to provide proper conditions for lizard persistence.

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Influence of Invasive European Beachgrass on Mesopredator Activity in the Coastal Dunes of Northern California

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Abstract.—Invasive species impact local flora and fauna directly and indirectly. The coastal dunes of Northern California have been altered by the introduction of the European Beachgrass *Ammophila arenaria*. Previous studies have shown that rodent abundance is higher in areas where the beachgrass dominates. This direct impact could prompt an indirect response in mesopredators that prey upon the rodents, but this hypothesis has not yet been examined in coastal dunes. We used camera traps to examine the activity of mesopredators in invaded dunes with very high density of beachgrass and in restored dunes with very low density of beachgrass, from March to September 2013. Our results indicate that the activity of the mesopredators was significantly higher in the restored habitat. Mesopredators may be more active in this area because of other available food and because the high cover of the beachgrass in the invaded habitat may render prey less accessible than in the more diverse and open restored area.

Influencia de la Hierba Invasora Barrón en la Actividad de los Meso-depredadores en las Dunas Costeras del Norte de California

Resumen.–Especies invasoras impactan la flora y fauna local en forma directa e indirecta. Las dunas costeras del Norte de California han sido alteradas por la introducción de la hierba barrón *Ammophila arenaria*. Estudios anteriores han demostrado que la abundancia de roedores es más alta en areas donde predomina el barrón. Esta interacción podría afectar indirectamente a los meso-depredadores que se alimentan de roedores locales; sin embargo, esta hipótesis aún no ha sido examinada en la dunas costeras. Usamos cámaras de visión nocturna para examinar la actividad de los meso-depredadores en dunas invadidas con alta densidad de barrón y en dunas restauradas con baja densidad de barrón de Marzo a Setiembre del 2013. Nuestros resultados indican que la actividad de los meso-depredadores fue significativamente mayor en el habitat restaurada. Los meso-depredadores podrían mantenerse más activos en el area restaurada ya que podría haber otro tipo de alimento disponible, y porque la alta densidad del barrón en las dunas invadidas les dificultaría el acceso a su presa.

Key Words.—Ammophila arenaria; competition; dunes; Gray Fox; mesocarnivore; predation; rodents; Striped Skunk

Introduction

Ecosystem functions have been shown to be directly associated with biodiversity (Chapin et al. 2000; Cardinale et al. 2006; Duffy et al. 2007). In the last decades, habitat loss and invasive species have been considered among the main causes for the loss of species (Wilcove et al. 1998). Invasive species can alter entire habitats, modify the abundance of species, and affect food webs which can lead to a cascade of indirect effects (Vitousek et al. 1996; Mooney and Cleland 2001). In the coastal dunes of Northern California, the ecosystem has been altered by the presence of the invasive European Beachgrass (*Ammophila arenaria*). European Beachgrass, hereafter beachgrass, is a rhizomatous grass that was introduced in California in the mid-1800s to stabilize the coastal dunes, and it competes with native dune plants (Pickert 2013). This invasion has not only impacted native plants (Buell et al. 1995) but also other creatures such as the threatened Western Snowy Plover (*Charadrius alexandrinus nivosus*: U.S. Fish and Wildlife Service 1993, Muir and Colwell 2010). However, relatively little research has examined its effects on other vertebrates.

The most common rodents in the coastal dunes of Northern California are the North American Deermouse (*Peromyscus maniculatus*), Western Harvest Mouse (*Reithrodontomys megalotis*), and California Vole (*Microtus californicus*). The presence of the beachgrass has provided a new habitat for these rodents, and mark-recapture analysis of data suggest they are more abundant in habitat invaded by beachgrass than in native dune habitat (Daniel Barton and Justin Brice, unpubl. data). Moreover, artificial food tray analyses suggest rodents perceive less predation risk due to the extra cover of beachgrass, which can grow to over one meter in height (Johnson and De León 2015).

Mesopredators are small to mid-sized generalist carnivores. Their diets include a broad variety of prey, and they far outnumber specialist carnivores in abundance (Prugh et al. 2009; Roemer et al. 2009). Mesopredators play a critical role in many ecosystems and previous studies suggest that they are capable of suppressing small mammal populations in fragmented landscapes (Eagan et al. 2011). In the coastal dunes of Humboldt Bay, Gray Foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), feral cats (*Felis catus*), and Striped Skunks (*Mephitis mephitis*) are nocturnal mesopredators that prey on rodents, so the impacts of beachgrass on rodent abundance and perceived risk of predation could trigger effects in the activity of mesocarnivores as well.

The coastal dunes of Manila, Humboldt County, California are owned by private and public bodies with different land management practices and histories, resulting in marked differences in habitat on adjacent properties. This allows wildlife communities to be compared on habitats that have been invaded by *Ammophila* versus those that have been restored to a native plant community (e.g., Johnson and De León 2015). Here, we examine the effect of European Beachgrass on mesopredator activity in these coastal dunes. Previous work has shown that relative abundance of rodent prey was on average over four times higher on trapping grids in the invaded than in the restored habitat (Daniel Barton and Justin Brice, unpubl. data). A strong difference in prey density could affect foraging mesopredators (Abrams and Ginzburg 2000), therefore, we hypothesized that mesopredators would be more frequently detected in invaded habitat. Using remote cameras, we tested the prediction that the detection frequency of mesopredators is higher in invaded habitat than in restored habitat in our study area.

Methods

Study area.—The coastal dunes of Northern California are one of the most diverse dune systems in the West coast and support endemic plant species such as Pink Sand Verbena (*Abronia umbellata brevifolia*), Humboldt Bay Owl's Clover (*Castilleja ambigua humboldtiensis*), Dark-eyed Gilia (*Gilia millefoliata*), American Glehnia (Glehnia littoralis leiocarpa), Humboldt Bay Wallflower (*Erysimum menziesii eurekensii*), and Beach Layia (*Layia carnosa*; U.S. Fish and Wildlife Service 2015. Humboldt Bay homepage. Avaialble at http://www.fws.gov/refuge/humboldt_bay/. [Accessed 22 August 2015]). The study was conducted from March to September 2013 in coastal habitat in Humboldt County in northwestern California on two adjacent properties managed by the Friends of the Dunes (FOD) and the Bureau of Land Management's (BLM) Ma-le'l Dunes cooperative management area. The beachgrass-invaded area was located on FOD property, which is a non-profit organization created in 1982 focused on the ecology of coastal dunes. The FOD area was dominated by a very dense population of beachgrass during our study (Fig. 1). The area with low beachgrass density (restored) was located on adjacent BLM property. The BLM partnered with the California Conservation Corps for 14 y (1997–2010) to successfully remove the invasive beachgrass. The BLM site is dominated by native plant species and the density of the beachgrass is very low (Johnson and De León 2015). We conducted our study on a single 2.1 km transect that spanned the border separated these two habitats.

Figure 1. Habitat invaded and dominated by European Beachgrass, *Ammophila arenaria* (top), and restored habitat with higher plant diversity and lower vegetative cover (bottom). (Photographed by Matthew D. Johnson).

Data collection.—With one exception, we collected data for six consecutive days the last week of each month (every 28 d) from March through September of 2013, for a total of 41 sampling nights. September was sampled for only five nights and at an interval of 35 d due to the federal government shutdown on 2 October during our last night of data collection. We used this interval to largely control for moonphase in this study (mean lunar illumination ± 1 SE = 70.7 ± 8.1%), and preliminary analyses indicated it was not a significant predictor of mesopredator activity. We used camera trapping due to its low invasiveness, and because it is a viable method for detecting mammals at different scales (Rowcliffe et al. 2008; Thorn et al. 2009). We deployed 20 night vision cameras (Trophy Cam®, Bushnell Outdoor Products, Overland Park, Kansas) at 1900 (± 30 min) and retrieved them at 0700 (± 30 min) the following morning. We placed 20 cameras along a line transect laid parallel to the foredune (60–80 m from the ocean's waveslope), 10 in the area with beachgrass (FOD property) and 10 in the restored habitat (BLM). We distributed cameras at 100 m intervals, with a 100 m buffer zone between the two adjacent habitats, making a total transect length of 2.1 km (including the buffer zone). We mounted each camera on 2-m wooden pole (0.5 m buried in the sand and 1.5

m above sand level). Cameras were set on photograph mode (three shots per perceived detection) with a 1 min recovery period before the next detection. People setting up the cameras always left the station walking across the camera to make sure it was, in fact, working properly.

We baited each camera station with a 260 g can of Valley Fresh® 100% natural chicken breast in water (Hormel Foods, Austin, Minnesota) placed roughly 3 m away from the base of the wooden pole. We placed baits in patches with low vegetation and with field of view of 5 × 6 m. Cans remained unopened and we made five holes (approximately 0.5 cm diameter) on the top to release the scent of the chicken, and we staked each can firmly into the sand with a 20 cm tent spike driven through the container. Cans remained in place for each 6-d sampling period per month, and we used new cans each month. We trained cameras directly at the bait cans with a field of view approximately 8-10 m wide. Bait cans were not obscured by grass or other vegetation. Cameras never failed to detect field workers setting up or checking the stations, and all detections of mesopredators included multiple photographs during a given visit to a bait station. Animals as small as rodents were successfully detected by the cameras, and the most frequently detected mesopredator species were not the largest (see Results), so we assume there was no size bias to detection. Therefore, we assume that our detection rate (probability of obtaining a detection if the animal actually visited the bait station) was nearly 100% and did not vary between habitats.

Data analysis.–We used the number of detections of each species per month as index of activity. We considered each photograph of a mesopredator at a camera station as one detection as long as it was at least 60 min from the previous photograph of that species at that station. Multiple detections of the same individual animals were possible even on the same night, and almost certainly occurred within the week and among the seven months of the study. Therefore, our detection rate provided an index of mesopredator activity, rather than a measure of local abundance. For the analysis, we checked for temporal autocorrelation in the number of mesopredator detections among months. Finding none (see Results), we analyzed the data in Program R with the numbers of detections as our response variable in linear mixed effects Poisson models to test for the effects of habitat, month, and their interaction on mesocarnivore activity. We performed analyses on all mesopredator species pooled, and species-specific analyses for skunk and raccoon (the two most commonly detected species, see Results). For each response variable, we created five a priori candidate models with various combinations of predictor variables, with habitat and month as fixed terms, and station as a random effect. We compared models using Akaike's Information Criterion corrected for small sample size (AICc) and selected the best model based on the lowest AICc value; models within two AICc were considered competitive with the best models.

Results

We recorded 188 mesopredator detections of five species (Table 1). Western striped skunk was the most commonly detected species with 93 detections (49.5%), followed by 62 detections of gray fox (33%), 21 of feral cat (11.2%), eight of opossum (4.3%), and four of raccoon (2.1%), with numbers varying between habitats (Table 1). There was little evidence of temporal autocorrelation from one month to the next, with autocorrelation values ranging from -0.08 to 0.52 (all $P > 0.25$) depending on species and habitat. Therefore, we subsequently treated month as a fixed effect. There were strong effects of habitat, month, and their interaction on the number of total mesopredator detections. Model selection indicated the full model was better supported than simpler models ($\Delta AIC > 4$), though a model with habitat and month as additive rather than interactive terms was also competitive ($\Delta AIC = 0.81$; Table 2). Mesopredator activity was significantly higher in the restored habitat, with 132 detections in the restored habitat and 56 detections in the invaded habitat (Table 1, Fig. 2). Activity peaked in mid to late summer in the restored habitat, while in the invaded habitat it peaked in the early summer (Fig. 2).

The activity of skunks and foxes each showed effects of habitat and month. For skunks, there were strong effects of habitat, month, and their interaction, though once again an additive model with month and habitat was competitive (Table 2). Skunks were detected more in the restored than the invaded habitat, and this difference was especially pronounced in mid to late summer months (Fig. 3a). For gray foxes, the top model included habitat and month as additive effects (Table 2). Foxes were

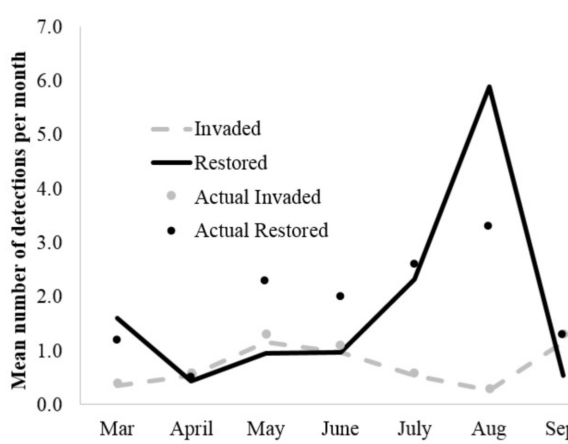

Figure 2. Detections per month of all mesocarnivores in coastal dune habitats of Northern California that were dominated by the invasive grass *Ammophila arenaria* (gray) or restored to native vegetation (black), March-September 2013. Observed data are indicated by points, model predicted patterns (see Table 2) are indicated by lines.

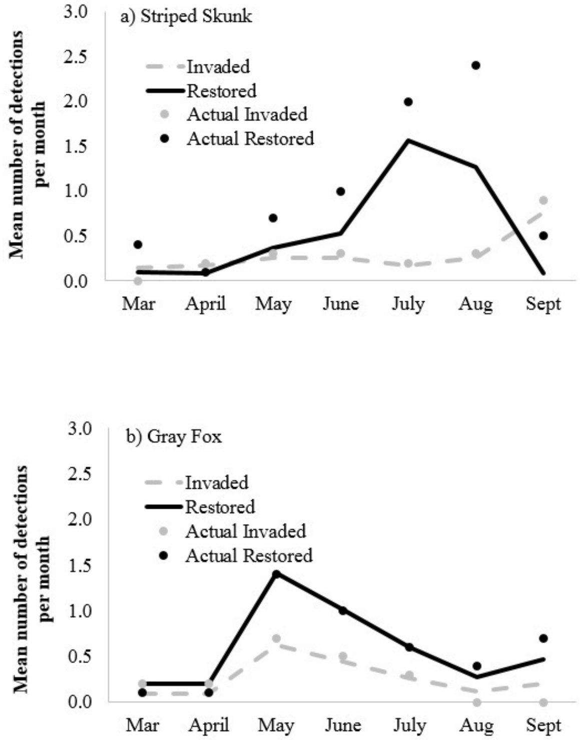

Figure 3. Detections per month of all Striped Skunks (a; *Mephitis mephitis*) and Gray Foxes (b; *Urocyon cinereoargenteus*) in coastal dune habitats of Northern California that were dominated by the invasive grass *Ammophila arenaria* (gray) or restored to native vegetation (black), March-September 2013. Observed data are indicated by points, model predicted patterns (see Table 2) are indicated by lines.

detected more frequently in the restored than the invaded habitat, and detections peaked in early summer, but there was little evidence for an interaction between habitat and month (Fig. 3b).

Discussion

We hypothesized that higher prey abundance in the invaded habitat than in the restored habitat would correspond with higher mesopredator activity. Our findings were contrary to this hypothesis. Although local studies have shown that prey is more abundant in the invaded areas (Daniel Barton and Justin Brice, unpubl. data), mesopredators may spend more time in the restored habitat because prey there are more exposed and vulnerable to attack, which has been found for other canids (Thibault and Ouellet 2005; van der Meer et al. 2014). Results from a study of rodent foraging in our study system also suggests that rodents perceive greater predation risk in the more open restored habitat (Johnson and De León 2015).

Another point to consider is the proximity of the habitat to a nearby forest. Nocturnal mesopredators may seek refuge in more forested habitats during the day, and move into the dunes for nocturnal foraging. In our study, there is a mixed coastal forest closer to the restored area than to the invaded area, so it is possible this proximity is partly responsible for the higher mesopredator activity we observed. Because we had no site replication, we cannot distinguish the effect of this confounding variable from apparent effects of invasive grass in our study. Nevertheless, the rate of mesopredator detections in the restored area did not increase with proximity to forest. Future research should focus on replicating our study in two or more locations and should examine the influence of adjacent forested habitats on mesopredators.

Our study did not examine the influence of abiotic factors such as temperature and precipitation. The spatial extent of our study was small enough (2.1 km) that these factors likely affected the restored and invaded habitats similarly, though we cannot exclude the possibility of an interaction between habitat and temperature or precipitation (e.g., temperature affects mesopredator activity in the invaded but not the restored habitat). We collected our data approximately every 28 d to largely control for possible confounding effects of moonlight (see Methods). However, rodents and their predators are known to respond to moonphase (Perea et al. 2011; Prugh and Golden 2014; Johnson and De León 2015), so future researchers may wish to examine variation in predator activity and moonphase in this system.

Previous studies have documented the negative effects of invasive beachgrass on native plants in our study area (Pickert 2013). Although the dense beachgrass may provide habitat for native rodents, our results suggest that at these sites the beachgrass negatively influences

Table 1. The number of mesopredator detections from March to September 2013 in the coastal dunes of Northern California that were dominated by the invasive grass *Ammophila arenaria* or restored to native vegetation.

Species		Number of detections	
		Invaded	Restored
Striped Skunk	*Mephitis mephitis*	22	71
Gray Fox	*Urocyon cinereoargenteus*	19	43
Feral Cat	*Felis catus*	11	10
Virginia Opossum	*Didelphis virginiana*	2	6
North American Raccoon	*Procyon lotor*	2	2
Total		56	132

Table 2. Generalized linear mixed-effect models and AICc values for the number of detections of Striped Skunks (*Mephitis mephitis*), Gray Foxes (*Urocyon cinereoargenteus*), and all mesocarnivores pooled in coastal dunes of Northern California. Station (20 camera stations) was a random effect, while habitat (invaded by *Ammophila arenaria* or restored) and month (March to September 2013) were fixed effects.

Model		Mesocarnivores		Skunks		Foxes	
	df	AICc	ΔAICc	AICc	ΔAICc	AICc	ΔAICc
detections ~ 1 + (1|Station)	2	468.89	11.66	331.32	24.00	261.90	15.81
detections ~ Habitat + (1|Station)	3	464.46	7.23	327.66	20.34	257.82	11.73
detections ~ Month + (1|Station)	8	462.16	4.93	311.81	4.49	249.86	3.77
detections ~ Habitat + Month + (1|Station)	9	458.04	0.81	308.46	1.14	246.09	0.00
detections ~ Habitat * Month + (1|Station)	15	457.23	0.00	307.32	0.00	254.64	8.55

the use of dunes by skunks, and foxes. Even though our detection rate of feral cats was low (11% of all detections), the number of detections was similar between the two habitats, suggesting this non-native predator may be more resilient to the effect of the invasive beachgrass, at least at our study site. We conclude that the restoration of coastal dunes in this system likely benefits mesocarnivores, which can stabilize ecosystem processes.

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Dr. Matt Johnson is a Professor of Habitat Ecology in the Department of Wildlife at Humboldt State University in California. He obtained a B.S. in Wildlife from U.C. Davis, and a Ph.D. in Ecology from Tulane University. His research focuses on habitat ecology and conservation of terrestrial wildlife, with a particular emphasis on animals in ecosystems heavily modified by human activity. (Photographed by Matthew D. Johnson).

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Notes

Subcutaneous Neoplasm on the Chin of an Endangered Blunt-nosed Leopard Lizard (*Gambelia sila*)

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Abstract.—The Blunt-nosed Leopard lizard (*Gambelia sila*) is an endangered lizard of the San Joaquin Desert of California. During a radio telemetry study of the effect of oil development on home range parameters of these lizards, we recaptured an adult female because a mass on its chin had increased greatly in size and she appeared significantly thinner than when first captured. The female had lost > 10 g when we recaptured her. In the laboratory, we removed a 0.9 g mass. We closed the skin and sealed it with cyanoacrylic glue. The lizard showed no distress during the operation, ate crickets the day after surgery, but died on the third day. Neoplasms of various kinds are known for many species of lizards, but in our experience, this is the first occurrence of a subcutaneous neoplasm on a Blunt-nosed Leopard Lizard.

Key Words.—California; lizards; neoplasms; San Joaquin Desert

Neoplasms are any new and abnormal growth of tissue in the body (Jacobson 1981). Almost all neoplasms of reptiles are known from zoo animals (Jacobson 1981; Sykes and Trupkiewicz 2006) and, in lizards, have been recorded in various species in nine families (Machotka 1984). Neoplasms can be relatively benign masses or cancerous tumors in any part of the body (Jacobson 1981; Machotka 1984; Barten 2006). A number of benign and cancerous neoplasms occur in the integument of lizards (Jacobson 1981; Machotka 1984; Barten 2006; Sykes and Trupkiewicz 2006). Even if not cancerous, a large mass could interfere with the functioning of an individual, and could lead to its death.

During the course of a radio-telemetry study of the effect of oil field development on Blunt-nosed Leopard Lizards (*Gambelia sila*), a state and federally listed endangered species (Germano and Williams 1992; U.S. Fish and Wildlife Service 1998), we noticed a mass under the chin of an adult female that appeared to be interfering with feeding. The mass under the chin was a small bump when we first collared her 28 April 2015. This female had a snout-vent length of 114 mm and she weighed 39.5 g. During the course of the next month, the subcutaneous mass increased greatly in size (Fig. 1) and the female became noticeably thinner.

By 25 May 2015, we decided that she likely would die if the mass remained under her chin. We captured her and returned her to our laboratory to remove the mass. One of us (DJG) had seen a similar mass under the skin on the right shoulder of a captive Common Chuckwalla (*Sauromalus ater*) in the 1980s. Surgery on this chuckwalla removed a fatty mass and the chuckwalla lived on after the operation. The female leopard lizard had lost 10.2 g of mass when we recaptured her. We carefully sliced open the skin under the chin and removed an intact mass of tissue (Fig. 2). The mass weighed 0.9 g (with slight loss of fluid) and was approximately 10 × 12 mm in size (Fig. 3). We did not conduct a histological examination of the excised tissue.

The female exhibited no signs of stress during the operation. We pressed the skin together after removing the mass and sealed it with cyanoacrylic glue (Fig. 2). We placed the female in a 18.9 L bucket and placed in crickets for her to eat. Although she ate several crickets, we found her dead in the bucket on the third day after surgery. Although the operation was not successful ultimately, we think she did not have long to live in the wild because of her significant weight loss. This is the first recorded instance of a subcutaneous neoplasm in a Blunt-nosed Leopard Lizard, and based on the thousands of leopard lizards we have caught over 26 y, does not seem to be a significant source of mortality for the species.

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Figure 1. Female Blunt-nosed Leopard Lizard (*Gambelia sila*) with a subcutaneous neoplasm. She was being radio-tracked on the Lokern Natural Area in Kern County, California as part of a study of oil-field development effects. (Photographed by David J. Germano).

Figure 2. Female Blunt-nosed Leopard Lizard (*Gambelia sila*) showing incision where the neoplastic mass (lower left) was extracted. (Photographed by David J. Germano).

Figure 3. The subdermal mass that was removed from a female Blunt-nosed Leopard Lizard (*Gambelia sila*) that was being radio-tracked on the Lokern Natural Area in Kern County, California. (Photographed by David J. Germano).

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Western Snowy Plover (*Charadrius alexandrinus nivosus*) Nest Site Selection and Oyster Shell Enhancement

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Abstract.—The Pacific Coast population of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) is federally listed as Threatened and is as a California Species of Special Concern. To manage, increase in number, and expand the distribution of these imperiled birds in the San Francisco Bay requires detailed knowledge about their nest site selection requirements. We measured the percentage of crushed oyster shells, shell dimensions, number of shells, and total shell surface area for 19 nests of Western Snowy Plover that occurred at the Least Tern Colony at Hayward, California, from 2008 to 2015. Using pairwise *t*-tests, we compared these measurements to those obtained from 19 randomly chosen non-nest sites. Results indicate that Western Snowy Plovers at this location select nest sites with a greater percentage of crushed oyster shell substrate, more oyster shells, and a greater surface area of shells than paired random sites.

Key Words.—birds; conservation; experiment; habitat enhancement; nesting

The Western Snowy Plover (*Charadrius alexandrinus nivosus*; Fig. 1) generally nests on bare ground or sparsely vegetated beaches and salt pans adjacent to tidal waters (Robinson-Nilsen et al. 2011). The Pacific Coast population of the Western Snowy Plover was federally listed as a threatened species in 1993 (U.S. Fish and Wildlife Service 2012) and is currently listed as a California Species of Special Concern (California Department of Fish and Wildlife 2015). Western Snowy Plover numbers have decreased due to habitat loss, increased predation, and human disturbance (U.S. Fish and Wildlife Service 2007). To support shorebird conservation goals, Helmers (1992) recommended the implementation of vegetation and predator management programs. For example, by removing sandbar vegetation at restored sites for Piping Plovers (*Charadrius melodus*) and Interior Least Terns (*Sterna antillarum athalassos*), nesting success improved due to the lack of vegetation, which also minimized the effects of predators (Thompson et al. 1997; Kruse et al. 2001). Other researchers have focused on the removal of non-native plants such as the invasive iceplant (*Carpobrotus* spp.) as an essential tool to encourage Western Snowy Plover nesting (Kelly Melissa, unpubl. report). Previous studies have suggested that Western Snowy Plovers may select nest sites based on the amount of oyster shell substrate (Zarnetske et al. 2010), which provides camouflage for eggs and chicks and potentially protects them from blowing wind and sand (Pearson et al. 2009). At the Hayward Regional Shoreline, on the eastern shore of San Francisco Bay in California, where oyster shell substrate has been added, observers reported the negative effects that Killdeer (*Charadrius vociferus*) have on Western Snowy Plovers when nesting in close proximity (Riensche et al. 2010).

Since 2001, the East Bay Regional Park District has managed nesting habitat for the California Least Tern (*Sterna antillarum browni*) at the Hayward Regional Shoreline by augmenting the amount of oyster shells at the site annually (Riensche 2007). As has happened elsewhere in coastal California (Powell and Collier 2000), these management efforts have resulted in the attraction of breeding Western Snowy Plovers to the site (Riensche et al. 2010). We used data from 19 nest sites of Western Snowy Plovers that occurred at the Hayward California Least Tern Colony from 2008–2015 to investigate the effectiveness of adding crushed oyster shell addition as habitat enhancement for plovers.

Figure 1. Western Snowy Plover (*Charadrius alexandrinus nivosus*) on the eastern shore of the San Francisco Bay, California. (Photographed by Daniel I. Riensche).

Figure 2. Western Snowy Plover (*Charadrius alexandrinus nivosus*) nest with three eggs on crushed oyster shell at Hayward Regional Shoreline on the eastern shore of the San Francisco Bay, California. (Photographed by Daniel I. Riensche).

Methods

Study site.—The study site was at Island Five (37.629739°N, 122.146039°W) within a brackish water marsh of the Hayward Regional Shoreline, located on the eastern shore of the San Francisco Bay, California. Island Five is 0.24 ha (0.6 ac) in size and is one of 15 islands created within a man-made marsh system. We found nests of Western Snowy Plovers (Fig. 2) by systematically walking through the colony during the breeding season while performing Type One In-colony Surveys of California Least Tern nests (Marschalek 2005). In this method, biologists permitted to work on California Least Terns and their assistants enter the colony to mark nests and record the number of eggs and chicks. This type of intensive monitoring is conducted twice a week, yielding data on clutch size, hatching success, and any evidence of predation. We included all 19 nests we found from 2008 to 2015 in the data analysis (Fig. 3). In a 1-m^2 area surrounding each nest site, we recorded the substrate composition (percentage crushed oyster shell vs. percentage sand), number of oyster shells (with a surface area greater than 8 cm^2), and total surface area of oyster shells measured. We also took the same measurements at 19 randomly chosen non-nest sites that were within a 5-m radius of the active nests. To determine whether nest sites differed from paired random sites across these parameters, we used pairwise t-tests ($\alpha = 0.05$).

Results

We found that Western Snowy Plover nest sites differed from paired random sites for composition of the substrate, number of oyster shells, and total shell surface area. Nest sites exhibited significantly more oyster shell and less sand than paired random sites ($t = 0.0087$, df = 18, $P < 0.001$), showing 73% crushed oyster shell and 27% sand on nest sites and 42% oyster shell and 58% sand on the random sites. Nest sites showed a significantly higher number of shells surrounding the nest within 1-m^2 than did random sites ($t = 0.00026$, df = 18, $P < 0.001$). On average, occupied nests had 11 more oyster shells than random sites (Fig. 4), with oyster shells averaging 42.7 cm^2 in size regardless of site. Nest sites averaged 28.1 oyster shells and paired random non-nest sites averaged 16.8. Total shell surface area was also higher by approximately 562.5 cm^2 when compared to the random sites ($t = 0.00096$, df = 18, $P < 0.001$).

Discussion

Essential habitat requirements for breeding water birds include nest sites that provide cover in arrangements that minimize predation while also supplying adequate nutritional resources (Kadlec and Smith 1992). Shorebird species such as the American Avocet (*Recurvirostra americana*) and Black-necked Stilt (*Himantopus mexicanus*), which nest among Western Snowy Plovers at the Hayward Regional Shoreline site, require open flats or the sparsely vegetated edges of shallow marshes to breed (Cogswell 1977; Paulson 1993). It has also been suggested that Western Snowy Plovers may choose to nest among California Least Terns due to the increased predator protection provided by the tern colony to the plover chicks through the use of alarm calls and other group defense behaviors (Powell 2001). Understanding the ecological mechanisms that control population dynamics is crucial to successfully managing listed species (Schuetz 2011).

Western Snowy Plovers, a federally listed threatened species and a California Species of Special Concern, select nest sites with unobstructed views of their surroundings to provide more time to leave the nest as soon as a predator is spotted (Colwell 2010). Thus, upon leaving

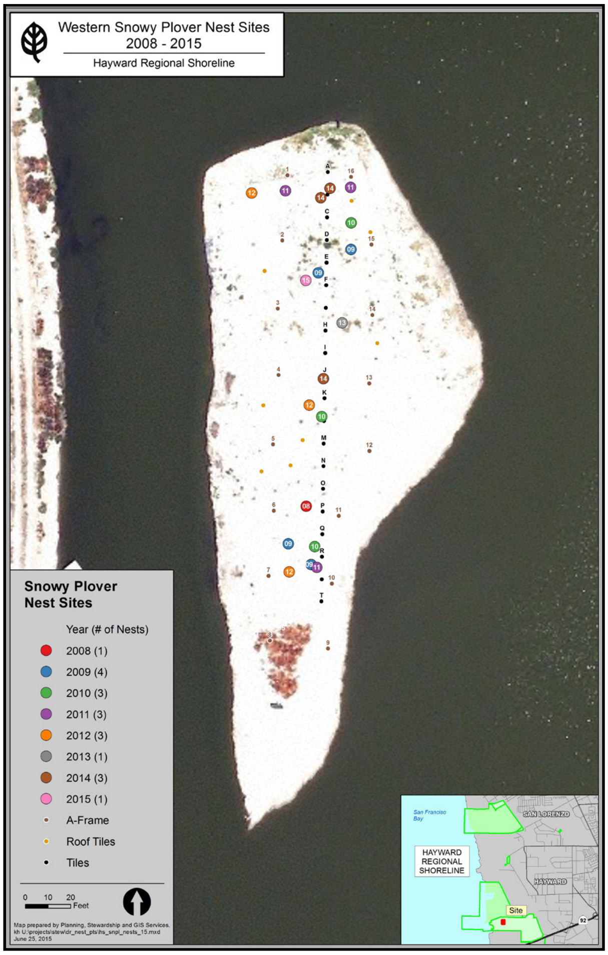

Figure 3. Map of Island Five at Hayward Regional Shoreline on the eastern shore of the San Francisco Bay, California, showing 19 nests of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) found from 2008 to 2015.

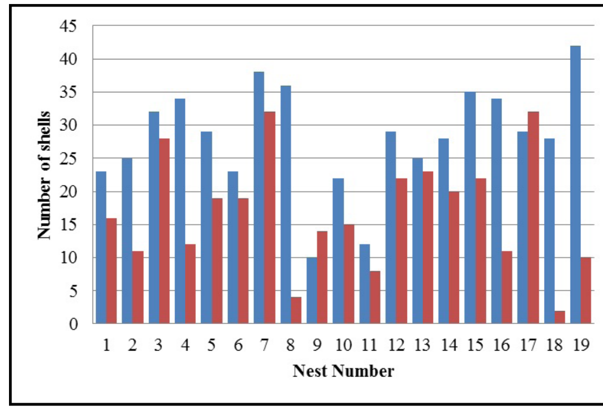

Figure 4. Number of oyster shells at each nest site (blue bars) of the Western Snowy Plover (*Charadrius alexandrinus nivosus*) and randomly chosen comparison sites (red bars).

the nest, they depend on their cryptic eggs to blend into the surrounding environment and to hopefully go undetected by predators. Western Snowy Plovers select for heterogeneous substrates that include rocks the size of their eggs to help better camouflage their nests (Colwell 2010).

The area around the San Francisco Bay contains the largest breeding Pacific Coast population of Western Snowy Plovers (Small 1994). The Western Snowy Plover Recovery Plan calls for the creation, management and enhancement of breeding habitat and the maintenance of an average of 500 breeding adults in the San Francisco Bay, California for a 10-y period (U.S. Fish and Wildlife Service 2007, 2012). The mechanisms by which these threatened shorebirds select nesting sites in this local area have received little attention in the literature. We focused on the importance of nesting habitat; specifically, how oyster shell enhancement effects Western Snowy Plover nest site selection.

While this study had a relatively small sample size, with mostly unmarked birds (with the exception of two males), within an active California Least Tern colony, these results could have important nesting habitat management applications for the Pacific Coast population of Western Snowy Plovers. Western Snowy Plovers are facultatively polyandrous and polygynous (Warriner et al. 1986). In this mating system, females typically choose, mate, deposit eggs, and then desert the males with their broods within a few days after hatching (Page et al. 1995). While the males rear their broods, females are free to find new mates. So, for example in the years of multiple nesting attempts (2008 to 2012, and 2014) at the Hayward site, we had as many as three separate nests all establishing, maintaining, and hatching within the same time period. Therefore we feel it is reasonable to assume that these are all separate breeding birds (with the exception of a female or two who may have had two male partners) and not the individual preference of one re-nesting bird. Females are cryptic and no more than three were seen at any one time, while as many as four separate males were observed. During the course of this study, only two of these males were banded, but no females were banded. The banded males were not seen again in subsequent nesting seasons. The estimated life span of these birds is only 2.7 y (Patton 1994). While males are more likely than females to retain the same territory in consecutive years (Warriner et al. 1986), it doubtful that the same birds would survive long enough to nest at this site for eight years.

With continued research, our findings may be used to better manage Western Snowy Plover habitat by attracting breeding pairs, thereby supporting the Recovery Plan goals for this threatened species. Our results indicate that the addition of crushed and whole oyster shells could improve nesting habitat for Western Snowy Plovers in the San Francisco Bay. This may be a valuable management tool in creating better nesting habitat. Future research could focus on the optimum amount of oyster shell by looking at plover nesting success in relationship to amount of oyster shell at the nest site (Fig. 5).

Figure 5. Recently hatched Western Snowy Plover (*Charadrius alexandrinus nivosus*) chick next to oyster shells at the Hayward Regional Shoreline, on the eastern shore of the San Francisco Bay, California. (Photographed by Daniel I. Riensche).

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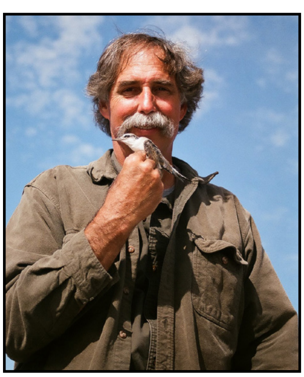

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Sarah C. Gidre is a senior at California State Polytechnic in San Luis Obispo and will graduate receiving her Bachelor of Science in June of 2016. She worked as a wildlife intern for East Bay Regional Park District during the summer of 2014 and 2015 gaining experience working with Western Snowy Plovers, California Least Terns, Forster's Terns (*Sterna forsteri*), Western Pond Turtles (*Emys marmorata*), California Red-legged Frogs (*Rana draytonii*), and Salt Marsh Harvest Mice (*Reithrodontomys raviventris*). (Photographed by David L. Riensche).

Nicole A. Beadle earned her Bachelor of Science from University of California, Davis in 2015. She worked as a summer wildlife intern for East Bay Regional Park District in 2014 where she collected data and worked with Western Snowy Plovers, California Least Terns, Western Pond Turtles (*Emys marmorata*), and Salt Marsh Harvest Mice (*Reithrodontomys raviventris*). (Photographed by David L. Riensche).

Sarah K. Riensche is a fifth-generation Californian who loves exploring and writing about the Golden State's many natural wonders. She has volunteered thousands of hours conducting bird and wildlife research and participating in habitat improvement projects for special status species. For over a dozen years she has helped monitored nesting California Least terns, Western Snowy Plovers, Black Skimmers (*Rynchops niger*), Forster's Terns (*Sterna forsteri*), Western (*Aechmophorus occidentalis*) and Clark's (*Aechmophorus clarkia*) Grebes, and Bald Eagles (*Haliaeetus leucocephalus*). Sarah has participated in survey and monitoring efforts for California Red-legged Frog (*Rana draytonii*), California Tiger Salamander (*Ambystoma californiense*), Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*) and performed radio telemetry tracking of nesting Western Pond Turtles (*Emys marmorata*). Her written contributions have appeared in *Pointing Dog Journal*, *California Waterfowl*, and in local conservationist newsletters. She is interested in pursuing a degree and career in outdoor journalism and science writing. (Photographed by David L. Riensche).

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Notes

Predation Events on the Endangered Blunt-nosed Leopard Lizard (*Gambelia sila*) Including Another by the Long-nosed Snake (*Rhinocheilus lecontei*)

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Abstract.—In our initial report of predation of a Blunt-nosed Leopard lizard (*Gambelia sila*) by a Long-nosed Snake (*Rhinocheilus lecontei*), we speculated that the snake was not an important source of predation on this endangered lizard. Here we report a second instance of predation by the Long-nosed Snake and reassess its impact on Blunt-nosed Leopard Lizards. We also report other suspected predation events on Blunt-nosed Leopard Lizards by other predators that we found during radio-telemetry studies on the Lokern Natural Area, Semitropic Natural Area, and at Pixley National Wildlife Refuge in the San Joaquin Desert of California in 2015.

Key Words.—birds; California; lizards; predators; Red-tailed Hawk; San Joaquin Desert; snakes

Snakes are known predators of Blunt-nosed Leopard lizards (Gambelia sila) and recently we reported on an act of predation by a Long-nosed Snake (Rhinocheilus lecontei) at the Lokern Natural Area in Kern County, California (Germano and Saslaw 2015). Because of the small size of Long-nosed Snakes compared to leopard lizard adults and the relative scarcity of the snake in the San Joaquin Desert, we speculated that this snake likely was not an important source of predation on the endangered leopard lizard (Germano and Saslaw 2015). However, we reassess this view based on a second predation event. We also report other confirmed acts of predation on radio-collared Blunt-nosed Leopard Lizards by other species that we found in 2015 while we were conducting home range studies on the lizards.

In the Semitropic Natural Area of the San Joaquin Desert, we found the signal from a radio transmitter of a male Blunt-nosed Leopard Lizard 14 July 2015 coming from a kangaroo rat (*Dipodomys* sp.) burrow system (35°21’04”N, 119°32”58”W), the location of which had not changed in about 7 d. Because we were close to the end of the active season of adult Blunt-nosed Leopard Lizards in mid-July, we wanted to remove radio collars from all lizards. We suspected that the male had gone down for the year, as can happen in July for adults of this species (Germano and Williams 2005; Germano 2009). The male was an adult that was 101 mm snout-vent length (SVL) and 30.0 g when we collared him 29 May 2015. As with our previous report, we found a live Long-nosed Snake in a tunnel of the burrow system of the kangaroo rat (Fig. 1). We released the snake about

Figure 1. Top) Long-nosed Snake (*Rhinocheilus lecontei*) dug out of a kangaroo rat (*Dipodomys* sp.) burrow and (Bottom) the Holohil BD2 radio transmitter found moist in the same tunnel as the snake. The transmitter was originally attached to a male Blunt-nosed Leopard Lizard (*Gambelia sila*) that was being radio-tracked on the Semitropic Natural Area in Kern County, California. (Top: Photographed by Erin N. Tennant; Bottom; Photographed by David J. Germano).

50 m from the burrow system after we photographed it. At the point where we found the snake in the tunnel, we found a still moist shed skin and the radio transmitter of the lizard. The transmitter was caked in moist dirt and appeared to have passed through the digestive system of an animal (Fig. 1). We suspect that this Long-nosed Snake was the predator of the radio-collared Blunt-nosed Leopard Lizard.

This second find of likely predation of a Blunt-nosed Leopard Lizard by a Long-nosed Snake in the same year at two sites indicates to us that this snake may be a more significant predator of Blunt-nosed Leopard Lizards than we previously considered. This second snake was smaller than the first (although we did not measure it) and the head seemed to us much too small to be able to consume the large head of an adult leopard lizard, especially one carrying a radio transmitter around its neck. Although natural predation is not something we think requires conservation action for this endangered lizard, we do think it would be useful to conduct studies of snake assemblages in the range of Blunt-nosed Leopard Lizards to determine what suite of species are potential predators of the lizard and in what abundance.

During the course our radio telemetry study at four sites in the southern San Joaquin Desert, we found other acts of suspected predation. At the Semitropic Natural Area, we found the radio signal of an adult male (111 mm SVL, 45.2 g) coming from the body of a Northern Pacific Rattlesnake (*Crotalus o. oreganus*) when we were digging up the burrow system of a kangaroo rat 17 July 2015 looking for the lizard. This male had been tracked for almost two months before the signal did not move for several days before we dug up the burrow system. We also found three radio-collared Blunt-nosed Leopard Lizards that seem to have been eaten by Red-tailed Hawks (*Buteo jamaicensis*). The transmitters of two adult males (both 114 mm SVL and 45.5 g) were heard coming from a hawk nest on a transmission line of a double pole H-structure in the Lokern area 2 and 4 June 2015. The transmitters were recovered from between the base of the poles 3 July and 8 June 2015, respectively. At Pixley National Wildlife Refuge, the radio signal of an adult female (110 mm SVL, 33.9 g) was found at the base of a Red-tailed Hawk nest in a Cottonwood (*Populus fremontii*) snag on 29 June 2015. Both the Northern Pacific Rattlesnake and Red-tailed Hawks are known predators of Blunt-nosed Leopard Lizards (Germano and Brown 2003). We also found the remains of an adult male (116 mm SVL, 44.3 g) spread across the ground at the Semitropic Reserve 18 June 2015 (Fig. 2), but we do not know what animal tore it apart. We suspect the predator was a bird. In addition, at the Lokern Natural Area, we found four broken collars on the ground and two transmitters and collars in tunnels of kangaroo rats. The transmitters from the tunnels appeared to have passed through the digestive system of an animal (Fig. 3), but we do not know what species may have predated the lizards that wore these transmitters, although snakes are likely.

Figure 2. The remaining body parts found on the ground of a male Blunt-nosed Leopard Lizard (*Gambelia sila*) that was being radio-tracked on the Semitropic Natural Area in Kern County, California. (Photographed by David J. Germano).

Figure 3. Holohil BD2 radio transmitters originally attached to Blunt-nosed Leopard Lizards (*Gambelia sila*) at study sites in Kern County, California. The transmitter on the left was removed from a living lizard and the transmitter on the right was found in the tunnel of a kangaroo rat (*Dipodomys* sp.). Note the dulled surface of the beaded chain collar and the discoloration of the transmitter on the right. This transmitter likely passed through the digestive system of an animal, probably a snake. (Photographed by David J. Germano).

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Notes

Diet Analysis of a Population of *Phrynosoma blainvillii* From the San Joaquin Desert, California

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Abstract.—The Blainville's Horned Lizard, *Phrynosoma blainvillii*, is in decline throughout much of its range, and is listed in California as a Species of Special Concern. All species of the genus *Phrynosoma* have a dietary specialization for ants, but the degree to which horned lizards consume ants to the exclusion of other available prey varies among species. There have been few studies published on the general ecology of *P. blainvillii*, particularly within their range of the San Joaquin Desert, California, but previous literature indicates that *P. blainvillii* is one of only a few members of the genus that also consumes other insects in abundance. I examined 92 fecal pellets (scats) from a population of *P. blainvillii* in the southern San Joaquin Desert near Alpaugh, California, which showed that 62 scats contained both ant and beetle exoskeletons, 28 scats contained exclusively ants, 13 scats contained ants, beetles, and other arthropods, and two contained exclusively beetles. This is one of few field studies to document the lesser degree of myrmecophagy of *P. blainvillii*.

Key Words.—Blainville's Horned Lizard; Coleoptera; conservation; Formicidae; scat

The Blainville's Horned Lizard (*Phrynosoma blainvillii*) is endemic to California and Baja California and has declined throughout much of its range (Goldberg 1983; Jennings and Hayes 1994; Fisher et al. 2002; Stebbins 2003). *Phrynosoma blainvillii* is listed by the California Department of Fish and Wildlife as a Species of Special Concern (California Department of Fish and Wildlife. 2011. Available from http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPAnimals.pdf [Accessed 02 July 2015]). Dietary considerations are an important component in understanding the relationship of lizards to their habitat (Duffield and Bull 1998; Fisher et. al 2002), yet there have been few studies published on the diet of *P. blainvillii* (Smith 1946; Milne and Milne 1950; Jennings and Hayes 1994; Fisher et. al 2002).

Horned lizards are among the few species that consume primarily ants and the occurrence of horned lizards is closely tied to the presence of ants (Whitford and Bryant 1979; Rissing 1981; Donaldson et al. 1994; McIntyre 2003). Within the genus *Phrynosoma*, however, not all species exhibit an equivalent degree of myrmecophagy. For example, *P. solare* has a diet of approximately 80–90% ants, while *P. asio* has among the lowest degree of myrmecophagy at approximately 20–30% (Pianka and Parker 1975; Montanucci 1989; Sherbrooke 2003). The percentage of ants that comprises the diet of *P. blainvillii* ranges from 45% (Montanucci 1989) to 90% (Pianka and Parker 1975). Other prey items consumed by horned lizards include beetles, flies, grasshoppers, spiders, and other arthropods (Milne and Milne 1950; Pianka and Parker 1975; Montanucci 1989; Sherbrooke 2003). Here I report on the general composition of the diet of a population of *P. blainvillii* in the San Joaquin Desert of California.

While conducting a radio-telemetry study of *P. blainvillii* in the San Joaquin Desert, I opportunistically collected horned lizard scats. Horned lizard scat is easily differentiated from scats of other sympatric lizard species by their large, fat, cigar-shaped pellet (Fair and Henke 1997; Suarez et al. 2000; Sherbrooke 2003). Scats from California Whiptail (*Aspidoscelis tigris munda*) are more slender and less uniform in shape, and Western Side-blotched Lizard (*Uta stansburiana elegans*) scats are much smaller and also less uniform in shape than horned lizard scats (Newbold and MacMahon 2009). Blunt-nosed leopard lizards (*Gambelia sila*), which occurred at one of the sites at which I worked, have scat similar to California Whiptails. Through direct observation of a radio-tagged *P. blainvillii* defecating, I was able to confirm the identifying characteristics of horned lizard scats.

I collected 92 scats beginning 20 April and continued through 15 November 2009. I dried them overnight in a 79.4° C oven to remove water content and prevent fungal growth. Using a dissecting microscope and tweezers, I removed sand, detritus, and the uric acid plug from each scat leaving behind only arthropod exoskeletons. While looking under the microscope I sorted the prey items into either ants (Formicidae), beetles (Coleoptera), or unknown arthropods. I found that nearly all (98%) horned lizard scats contained ants, 67% contained beetles, and 14% contained unknown arthropods. I also found that more scats (67%) contained a combination of ants and beetles rather than exclusively ants (30%). A small percentage (2%) of scats contained only beetles.

These findings are consistent with literature that states *P. blainvillii* has one of the most varied diets of all horned lizards (Milne and Milne 1950; Pianka and Parker 1975; Sherbrooke 2003). Although ants are their primary prey items, beetles may be consumed to a large extent and occasionally dominate their diet, while other arthropods also may be consumed, but to a smaller extent. Considering their dietary composition, *P. blainvillii* in the San Joaquin Desert do not seem to be as highly myrmecophageous as other horned lizards such as *P. solare*. Horned lizards are known to consume soft-bodied arthropods when available (Milne and Milne 1950; Pianka and Parker 1975). Because of the non-invasive nature of this dietary study, I could only identify prey items whose identifiable features survived the digestive tract of lizards, thus introducing a bias toward hard-bodied arthropods. Dietary specialization makes horned lizards particularly vulnerable to environmental changes affecting prey abundance (Suarez and Case 2002; Sherbrooke 2003). Management practices directed toward conservation of *P. blainvillii* should include maintaining the biodiversity of invertebrates on which this species depends.

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2015 Annual Meeting Review

Theme: Conservation Through Collaboration
Program Chair: Don Yasuda
Plenary: Advancing Wildlife Conservation through Integration and Alignment in Planning
Keynote Address: Ellie Cohen, Point Blue Conservation Science
Location: Vineyard Creek Hyatt, Santa Rosa, California
Attendance: 718 registered
Student Weekend: Point Reyes, California

January 26-30, 2015

<u>Awards Bestowed</u>

Chapter of the Year – San Francisco Bay Area
Conservationist of the Year – The Nature Conservancy
Raymond F. Dasmann Professional of the Year – Howard O. Clark, Jr.
TWS Distinguished Service – Bradley Valentine
James D. Yoakum for Outstanding Service – Rhys Evans

<u>Student Presentation Awards</u>

<u>Best Posters:</u>

1st Place—**Julia S. Ersan**, California State University, East Bay / USGS: Neonate prey preferences of Giant Gartersnakes (*Thamnophis gigas*) from the Sacramento Valley of California: Implications of an exotic diet for a threatened native.

2nd Place—**Sarah J. Hegg**, University of Nevada, Reno: Correlates of community structure and diversity of small mammal communities in Great Basin sagebrush habitats.

3rd Place—**Stephanie D. Leja**, Humboldt State University: The effects of habitat restoration and sea level rise on breeding Western Snowy Plovers in coastal Northern California.

<u>Best Presentations:</u>

1st Place—**Matt P. Brinkman**, Institute for Wildlife Studies: Taste aversion, trapping, and translocation: an overview of predator management for two protected beach-nesting birds in southern California.

2nd Place—**Camille D. Boag**, California Polytechnic University, San Luis Obispo: Locomotory performance of a kangaroo rat in a habitat dominated by a non-native grass.

3rd Place—**Stephanie D. Leja**, Humboldt State University: The response of breeding Western Snowy Plovers to habitat restoration evaluated by resource selection function analysis in coastal Northern California.

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