Final Stephens' Kangaroo Rat Monitoring on MCB Camp Pendleton: Results and Trend Analyses for Fall-Winter 2017-18

2017 Annual Data Summary

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Final Stephens' Kangaroo Rat Monitoring on MCB Camp Pendleton: Results and Trend Analyses for Fall-Winter 2017-18

2017 Annual Data Summary

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Cover photograph: Adult Stephens' kangaroo rat, and Kangaroo rat burrow (Denise R. Clark photographer).

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Stephens' Kangaroo Rat Monitoring on MCB Camp Pendleton: Results and Trend Analyses for Fall-Winter 2017-18.

Abstract

In 2005, we implemented a monitoring program for the endangered Stephens' Kangaroo Rat (*Dipodomys stephensi,* SKR) on Marine Corps Base Camp Pendleton (MCBCP). It is a relatively simple, multi-tiered, habitat-based, adaptive monitoring program designed to track yearly trends in the total area occupied by SKR on base. We revised the program in 2011 after a five-year review and program evaluation to increase our power to document population changes over time and gain a better understanding of the importance of habitat characteristics, environmental factors, fire and military disturbance in the occupation and persistence of SKR. We focused our sampling and monitoring efforts within the recently revised SKR habitat boundaries totaling 628 hectares. Seventeen percent of our sample effort is for discovery of SKR within potentially suitable habitat outside of these boundaries. There is a two-phased approach for sampling. The first phase involves a complete search for any potential kangaroo rat sign and measurement of habitat and environmental variables. If any potential sign is observed, two to four days of live-trapping are conducted for the second phase. Live-trapping is necessary to determine if plots are occupied by SKR and/or the Dulzura Kangaroo Rat (*D. simulans,* DKR).

Within the SKR Monitoring Area in Fall/Winter 2017/18, SKR occupied an estimated 231 ha which was an insignificant 6.6% decrease in comparison to 2016/17. Long term results indicate the amount of habitat occupied by SKR steadily increased from a low estimate of only 60 ha in 2005 to 248 ha in 2016/17, a four-fold increase, and has remained relatively stable for the past 7 years. SKR density estimates in occupied areas (11 SKR/0.25 ha) were also high in relation to historic values (1-10 SKR/0.25 ha) and have been stable and/or increasing for the past 6 years.

SKR have often been associated with open forb- dominated areas and have historically been shown to respond positively to habitat disturbance. Occupancy models showed that open ground was a significant predictor of all parameters of SKR dynamics (occupancy, colonization, extinction). The greatest probability of SKR occupancy was with between 40 to 80% open ground. Additionally, forb

cover > 40%, more compact soils and flat slopes were also top predictors of SKR occupancy. Forbs are the primary seed resource for SKR, while firmer soils may increase seed foraging efficiency for SKR and better support their burrow structures from disturbance. Low to moderate foot traffic, vehicle traffic, artillery training, and frequent fires on MCBCP serve to compact loose soils, decrease cover of shrubs and non-native grasses and maintain the open ground and forb dominated habitat that is suitable for SKR. It is important to note that extreme disturbance resulting in open ground with little to no forb cover is not suitable for SKR occupancy. Also, SKR are likely to be less tolerant of ground disturbance creating deep ruts that may destroy burrows and disrupt movement.

Although total area occupied has remained very stable over the past 5+ years, it is not a static system. We have documented annual colonization and extinction dynamics within the SKR Monitoring Area. As evidenced by high levels of localized extinction and colonization among years, SKR appear to move frequently among the habitat patches within their population boundaries based upon changes in habitat suitability. SKR were more likely to colonize habitat with >40% open ground and <20% shrub cover while extinction was more likely in habitat with < 20% open ground and > 40% non-native grass cover.

Regular disturbance (military, fire, vegetation thinning) up to a level that supports open forb dominated habitat over that of non-native grasses and shrubs should continue to benefit SKR on Base. In the Juliett Management Area, continued habitat management and regulated military disturbance should increase habitat suitability to support the persistence of the translocated population, particularly in coordination with Fallbrook NWS to increase connectivity to its larger SKR population.

We also suggest several studies to better inform SKR management on Base. This includes use of radiotelemetry to better understand SKR movement dynamics. By documenting movement in relation to training activities, this would directly inform the Base on effect of military training on SKR. Secondly, we would like to better model the relationship between SKR and the sympatric Dulzura kangaroo rat on Base using interactive two-species occupancy models to determine if they are directly competing for resources. Finally, we suggest a diet analysis of SKR and co-occurring species (such as DKR) in relation to available resources using genetic analysis of scat. Results could inform habitat restoration efforts with specific plant species that may be linked with reproductive success and greater resilience of local SKR populations.

Introduction

The primary mission for Marine Corps Base Camp Pendleton (MCBCP) is "to operate an amphibious training Base that promotes the combat readiness of operating forces by providing facilities, services, and support responsive to the needs of Marines, Sailors, and their families" (MCBCP Strategic Plan 2002). In addition, the base has committed to fulfill stewardship and regulatory requirements for the natural resources on base. This includes monitoring and management for the endangered Stephens' Kangaroo Rat (*Dipodomys stephensi*, SKR) as described in the MCBCP Integrated Natural Resources Management Plan (October 2001).

The U.S. Geological Survey was contracted to develop a science-based monitoring program for the Stephens' kangaroo rat on MCBCP in 2004 and implemented this monitoring program in 2005 (Brehme et al. 2006). In 2010, we conducted a five-year program review and optimization of the SKR monitoring protocol. We revised sampling boundaries and re-allocated sampling effort to increase the power to document population changes over time and gain a better understanding of the importance of habitat characteristics, environmental factors, fire and military disturbance in the occupation and persistence of SKR (Brehme et al. 2011a). Here, we report on the seventh year of sampling under the revised program and present trends since 2005 for SKR occupied habitat and SKR population densities.

Stephens' Kangaroo Rat

Stephens' Kangaroo Rat (SKR) is a medium-sized nocturnal rodent of the family Heteromyidae. SKR are primarily known to eat seeds and are physiologically adapted to hot and arid environments (French 1993). They travel using bipedal locomotion (hopping on hind feet) and, therefore, require open habitat on gentle slopes for efficient movement and foraging. Within the range of the species, SKR prefer open herb and grassland habitat with minimal shrub cover, greater than 50% to 70% bare ground, and friable soils for digging and dust bathing (Bleich 1973, 1977, Thomas 1975, O'Farrell and Uptain 1989, Goldingay and Price 1997, USFWS 1997).

The Stephens' kangaroo rat was listed as a Threatened Species by the California Department of Fish and Game in 1971 and as an Endangered Species by the U.S. Fish and Wildlife Service on September 30, 1988 due to extensive habitat loss, degradation, and fragmentation (USFWS 1997). Historically, this species had a relatively small geographic distribution in western Riverside, southwestern San Bernardino and northern San Diego Counties. Approximately 50% of this historic habitat has been lost due to agriculture and residential development and SKR is currently estimated to occupy 25,000 acres (10,117 ha) in Riverside and San Diego counties. Most of these areas support low-density populations (<1 animal/ ha) of SKR (O'Farrell and Uptain 1989, USFWS 1997).

To minimize water loss while foraging, heteromyid rodents collect seeds and other materials in external cheek pouches. They also keep seed caches in and around their burrows for times when food resources are low. SKR eat primarily native and non-native seeds, but also eat plant material and insects (Thomas 1975, Lowe 1997). By removing and redistributing seed, they, like other kangaroo rats, help to maintain the open conditions they require and may act as a keystone species for their habitat (Brown and Heske 1990, Goldingay et al. 1997, Brock and Kelt 2004b). Creation and maintenance of SKR habitat is also largely attributed to natural and unnatural disturbances such as fire, scouring, grazing, and shallow disking. In fact, most of these methods have been successfully used for management (Price et al. 1993, 1994b, Kelt et al. 2005). Because their burrows are sufficiently deep (23 to 46 cm; O'Farrell and Uptain 1987), they can easily survive most fires and other surface disturbances and colonize the newly disturbed habitat. Vegetative succession of thick grasses and/or shrubs create habitat that is not suitable for SKR and, as a result, leads to rapid decline in population size (O'Farrell and Uptain 1987, 1989).

It is thought that adult SKR typically disperse only short distances (<50 m), but they are known to make at least occasional long range (>1 km) movements, often using dirt roads or other open ground as travel corridors (Thomas 1975, O'Farrell and Uptain 1989, Price et al. 1994a, Brock and Kelt 2004a). SKR regularly co-occur with a sympatric species, the Dulzura Kangaroo Rat (*Dipodomys simulans*, DKR), although DKR tend to prefer shrubland habitats (Goldingay and Price 1997).

Primary stressors to SKR habitat needs include:

1. Habitat fragmentation.
2. Succession to native scrub habitats or thick invasive grasslands.
3. Excessive soil compaction that inhibits seed establishment, vegetation growth (forbs, grasses, and shrubs), and burrow excavation.
4. Lack of open habitat and/or corridors for dispersal.

The average life span of SKR is reported to be 4 to 8 months, with approximately 14 to 18% surviving beyond their first year (McClenaghan and Taylor 1993, Price and Kelly 1994). These estimates do not distinguish between death and emigration, so actual survivorship may be longer, and a proportion of juveniles probably disperse to surrounding habitats. Females typically begin estrous with the start of winter rains and conclude estrous after seed dispersal (McClenaghan and Taylor 1993). After gestating for about 30 days, they give birth to an average of two to three young, twice yearly (Lackey 1967b). The young are then weaned from the nest between 18 and 22 days after birth. In prosperous years, females born in the spring may reproduce their first year.

Primary stressors to survivorship and reproduction may include:

1. Low seed production due to drought (decreased food supply).
2. Excessive predation pressure from owls, snakes, coyotes, fox, feral cats and/or invasive ants.
3. Excessive competitive pressure from other rodents and/or ants who share the same resource base.
4. Small and/or low-density populations. This may result in reduced mating and reproduction due to Allee effects, where widely dispersed, low-density populations are less likely to find mates. Small populations have increased susceptibility to environmental and demographic stochastic events (Jones and Diamond 1976, Lande 1988, Berger 1990).
5. Direct mortality from consumption of pesticides, trampling, and road kill.

Large fluctuations in both distribution and density over time have been documented for this species (O'Farrell and Uptain 1987, 1989, Price and Endo 1989, McClenaghan and Taylor 1993, Diffendorfer and Deutschman 2002, Montgomery 2004, Kelt et al. 2005). Ten-fold changes in abundance within and among years are common. Densities also vary vastly over space due to changes in habitat conditions and natural successional dynamics. Therefore, declines in population sizes at some locations may be concurrent with increases at other locations (O'Farrell and Uptain 1989, Diffendorfer and Deutschman 2002). Because of this evidence, we and others (Burke et al. 1991, Price and Gilpin 1996, Spencer 2002, Mary Price personal communication) suspect that SKR primarily follow a form of meta-population dynamics, where availability of suitable habitat patches is spatially and temporally dynamic (i.e. Fahrig 1992).

Study Site

Marine Corps Base Camp Pendleton (MCBCP) is located on approximately 50,585 ha (125,000 ac) within the Peninsular Ranges physiographic province of California. This province is characterized by a narrow, sandy shoreline, seaside cliffs, coastal plains, low hills, canyons, and mountains that rise to elevations of approximately 2,200 feet (823 m, NEESA 1984). MCBCP is bordered by the cities of San Clemente and Oceanside to the northwest and south, while the Cleveland National Forest and the Pacific Ocean border the northern and western portions, respectively. To date, the base is largely undeveloped and encompasses the largest remaining expanse of undeveloped coastline and coastal habitat in southern California. Because of this, many species that were once common throughout the Peninsular Range now find refuge within the borders of MCBCP. MCBCP harbors the southwestern-most population of SKR and is targeted for conservation by the U.S. Fish and Wildlife Service (1997). As a result, SKR habitat within MCBCP, along with the neighboring Fallbrook Naval Weapons Station, was designated as one of four "Conservation planning areas" developed to help with conservation and recovery of SKR (USFWS 1997).

Habitats within the MCBCP include oak woodlands, coastal sage scrub, native and non-native grasslands, coastal dunes, riparian forest/woodland/scrub, as well as wetlands. Because of the use of the land for military training, unique factors are present which affect habitats within MCBCP. First, most land within MCBCP is at some time disturbed by military training activities. These disturbances include troop movements on foot or in military vehicles, artillery fire, and bombing. Secondly, there is a high frequency of fire within MCBCP, especially within and near, but not limited to, firing and bombing ranges. Frequent fires may result in substantial changes in the vegetative composition of habitats, including the transformation of chaparral and coastal sage scrub communities into grasslands (Zedler et al. 1983, Callaway and Davis 1993, Keeley 2002). SKR are most often associated with grasslands. The perennial and annual grasslands at MCBCP mainly occur on fine-textured soils of coastal terraces and rolling hills with deeper soils at higher elevations. It is unknown how much of the grasslands may be stable over time without regular disturbance. Many areas would be expected to revert to shrubland or woodland habitats if disturbance were significantly reduced (MCBCP 2001). Finally, there are many dirt roads, paths, and firebreaks that support the above activities. Dirt roads have been shown to facilitate movement for SKR (O'Farrell and Uptain 1989, Brock and Kelt 2004a). Additionally, road edges created by uplifting of the soil during road excavation and maintenance can create suitable soil conditions for burrowing. For the most part, disturbances such as those described above are thought to have positive effects on SKR habitat and populations, however, heavy disturbances (e.g. vehicle maneuvers, foot traffic) may result in direct mortality and/or destruction of habitat.

Population Monitoring

To census populations of SKR, a monitoring program was first implemented on MCBCP from 1996 to 2002 (Montgomery et al. 1997, Montgomery 2002, 2004). In summary, 13 survey grids (0.9 to 1.0 ha [2.22 to 2.47]) were originally placed to represent all historical and currently known SKR populations (Figure 1) occurring on sparse to dense exotic annual grassland and/or native perennial grasslands, and sparse sage scrub (Montgomery et al. 1997). The grids were surveyed during autumn every other year (1996, 1998, 2000, and 2002) using both burrow counting and live-trapping methods (Montgomery 2004).

This and other studies have shown that SKR abundance and capture probabilities are highly variable, which makes detection of demographic trends problematic and time intensive. Suitable habitat for SKR may also vary through time and space in relation to disturbance and vegetation succession. This is particularly true on MCBCP, where there is a relatively high level of disturbance from frequent fires and military training activities.

In consideration of these and other factors, a two-day scientific workshop was held to design the basics of the SKR monitoring program in 2004. The workshop attendees included a four-member Scientific Peer Review Panel with expertise in spatial and statistical monitoring design and SKR biology, and additional biologists from several federal, state, and local wildlife agencies. The discussion points, consensus, and complete theoretical protocol are detailed in Brehme et al. (2006). Protocol specifics were determined by consultation among the USGS, the scientific panel, and MCBCP after the workshop. The result was a relatively simple, multi-tiered, habitat-based, adaptive monitoring program for SKR. This monitoring program was designed to track yearly trends in the total area occupied by SKR on base over a large number of sample plots. It includes measurement of habitat and environmental variables that are hypothesized to affect the probability of occupancy, rate of colonization, and/or rate of extinction over time. Predictors that are found to be significant will be used for habitat-based recommendations for management. We designed this program to be compatible with the SKR monitoring program on the adjacent Naval Weapons Station Fallbrook.

It is unknown whether trends in SKR distribution are directly related to trends in SKR abundance; therefore, the program includes a density index. We considered active burrow counts for use as an index, as they have been shown to correlate and trend with SKR density estimates from live-trapping. However, previous monitoring efforts on MCBCP have shown that even in optimum habitat, SKR frequently co-exist with the sympatric DKR, and that the ratio of SKR/DKR is both spatially and temporally variable. As a result, we cannot expect a consistent relationship between kangaroo rat burrow counts and SKR abundance. Therefore, we chose a two-phased approach for sampling. The first phase involved a complete search for any potential kangaroo rat sign to include burrows, tracks, and scat on all sample plots. If any potential sign was observed, at least two nights of live-trapping were conducted for the second phase. The live-trapping results were used to calculate a density index.

At the onset of the monitoring program, we stratified the sampling effort based on the probability of occupancy or habitat suitability. We defined 17,795 ha of high, medium, and low suitability habitat on MCBCP using previously mapped SKR habitat and established soil and vegetation associations (Brehme et al. 2006). In 2005, fifty 50 m x 50 m plots within each stratum were randomly sampled to estimate expected occupancy rates. There were no SKR found in the low suitability stratum, and very low proportions in the other strata (Brehme and Fisher 2008). From 2006 to 2010, we chose to focus our efforts solely in the medium and high suitability strata to get better estimates of occupancy; however, estimates of occupancy were consistently less than 20% in the high suitability stratum and less than 1% in the medium suitability stratum (Brehme et al. 2011a). This resulted in lower than optimal power to detect population declines.

Therefore, in 2010, we conducted a five-year program review and optimization and defined a focal “Monitoring Area” and “Discovery Area” for SKR (Figure 1; Brehme et al. 2011a). The long-term Monitoring Area is a single stratum of 628 ha [1,552 ac] that represents all historically known SKR occupied habitat as of 2011 and adjacent suitable habitat. The Monitoring Area includes most of the previous high suitability stratum with SKR occupied and nearby suitable habitat added, and unsuitable and inaccessible habitat removed (i.e. DUD producing areas and riparian habitat). We also removed the historical Bravo One habitat presumed to be extirpated (due to Helicopter Outlying Landing Field or HOLF installation). Any areas removed from the high suitability stratum were added to the medium suitability stratum to create the potentially suitable Discovery Area. This discovery sampling area encompasses 5,520 ha [13,640 ac] and represents grasslands (native, non-native, valley and foothill), disturbed habitat, and open Engelmann oak woodland with slopes under 50% within 4 km of known occupied habitat.

Along with the revised Monitoring Area, we modified the sampling scheme to increase our ability to detect trends in SKR over time by doubling the number of permanent plots to 100 (66% of total effort). We continue to sample random plots within the Monitoring Area to get a more complete understanding of the patchy nature of SKR occupancy over time (17% of effort). Finally, we allocated another 17% of effort to potential discovery of unknown SKR populations each year (i.e. sampling in the Discovery Area). The revision of the Monitoring Area along with the modification of sampling allocation increases the power to document population changes over time as well as to identify associated factors (Brehme et al. 2011a). The winter of 2017 was the seventh year of SKR sampling under the revised program. Major elements of the protocol are presented in Table 1.

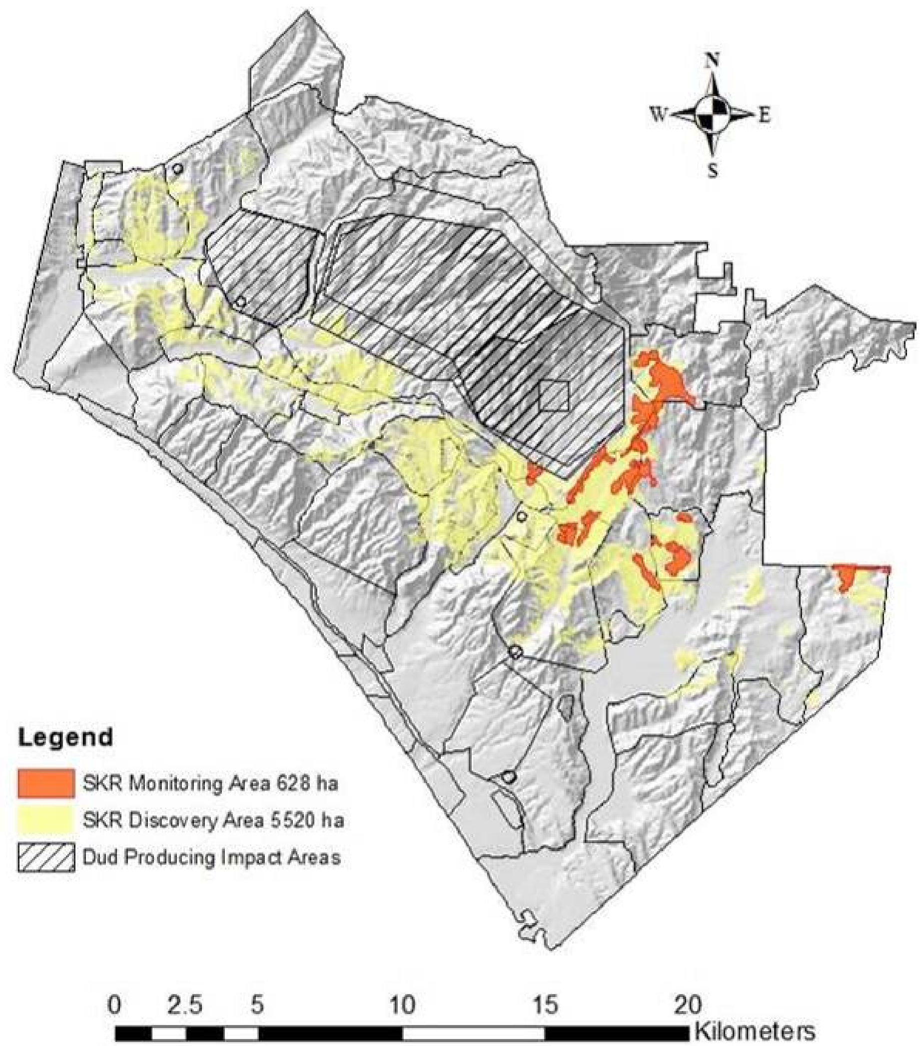


FIGURE 1. SKR MONITORING AND DISCOVERY AREAS ON MCBCP

TABLE 1. MCB CAMP PENDLETON SKR MONITORING PROTOCOL ELEMENTS

Protocol Element	Purpose(s)	Procedure(s)	Timing
Habitat Suitability Model	To determine spatial extent of occupied habitat to define annual SKR Monitoring Area	Current knowledge of SKR habitat associations & distribution on MCBCP	Program optimization 2011
	To define Discovery Area	Use of GIS layers to map potentially suitable SKR habitat (soils, slope, vegetation, impact area boundaries)	Program optimization 2011
Sample Allocation	Optimize sample allocation for highest power to detect changes over time and greatest coverage of known SKR habitat over time	125 plots in Monitoring Area (100 permanent and 25 new every year)	Yearly
	Discovery of new populations	25 plots in the Discovery Area (new each year)	Yearly
Sampling Protocol	To monitor trends in potential habitat areas occupied by SKR, estimated density within and among strata	Burrow/sign searches + live-trapping in randomly chosen permanent sample plots ($50m^2$)	Yearly
Burrow/sign Search and Habitat Characterization	To determine presence or obsence of kangaroo rats	Complete survey of sample plots for any potential kangaroo rat burrows or sign	Late summer and Fall (Sept-Dec), Yearly
	To collect habitat covariate data to model, better understand & predict SKR habitat relationships	Survey habitat characteristics thought to be associated with SKR presence	
Live-trapping Surveys	To confirm presence or absence of SKR. Produce metric of density. Calculate detection and capture probabilities for models	Live-trap for 2+ nights with standard 25 trap grid	Late summer and Fall (Sept-Dec)
Analyses	Total area (ha) of habitat on MCBCP occupied by SKR. Probabilities of SKR occupancy within and among strata	Program PRESENCE or equivalent: Occupancy [1,2,3] and Point Count Model [4] (all).	Yearly (all)
	Density within and among strata	Program MARK (density index)	
	Multi-year: patch occupancy and extinction (i.e. metapop growth rate)		
	Model habitat and other covariates for value in predicting SKR occupancy, detection, density, colonization, & extinction		

[1] Mackenzie et al. 2002, [2]Mackenzie et al. 2003, [3]Royle 2004, [4]Royle and Nichols 2004

Methods

Habitat Surveys

A complete search for active kangaroo rat sign (burrows, tracks, dust bathing sites, scat, and runways) was conducted on each 50 m × 50 m sample plot. We define active kangaroo rat burrows as those that are the proper size (approximately 1.5 inches in diameter), have loose soil, footprints, and/or fresh scat with an obvious trail or clearing leading up to the entrance. Each sample plot was defined as potentially occupied by kangaroo rat(s) if it contained any kangaroo rat sign or one or more possible active burrow(s). Kangaroo rat burrows may be confused with burrows of other rodents (mice, gophers, squirrels). This is particularly true with gopher burrows, as they are the same diameter as SKR burrows (Montgomery 2003). In addition, like many other rodents, SKR are thought to use burrows that were previously dug by gophers or other species (Thomas 1975). Therefore, designation decisions were generous. All burrows that were presumed to be inhabited by gopher or squirrel were examined carefully for secondary sign such as appropriate [i.e. mounding and lack of runways (gopher burrows), scat, tracks]. If there was any question to the surveyor, the plot was designated as potentially occupied for follow-up trapping. If a sample plot did not contain any kangaroo rat sign or potentially active kangaroo rat burrows, it was defined as "not occupied". All habitat surveys were conducted in the late summer and fall time periods (September through December) when detectability of burrows is highest due to the drying and disarticulation of annual herbs and grasses (O'Farrell and Uptain 1987, Montgomery 2002).

In addition to surveying for potential kangaroo rat sign and burrows, habitat variables were recorded to use as covariates for habitat modeling (Table 2). All habitat characteristics measured have been hypothesized to be important for SKR habitat suitability (O'Farrell and Uptain 1987, Montgomery et al. 1997, USFWS 1997) and were based on the current SKR habitat characterization protocol for Fallbrook Naval Weapons Station (Montgomery et al. 2005). Soil samples were collected for future texture and salinity analyses.

To gather information on whether we met assumptions of temporal closure within a season (i.e. the occupancy state of plot did not change), we searched again for kangaroo rat sign when revisiting a plot to conduct live-trapping.

TABLE 2. FIELD SURVEY FORM

Field Measure/ Covariate	Method	Data Fields	Purpose
Landscape			
Slope	clinometer	Percent slope	Habitat suitability
Aspect	compass	Degrees	Habitat suitability
Soil compaction	Lang penetrometer	PSI	Habitat suitability- burrow suitability, vegetation growth
Soil Texture	Laboratory Analysis- Brigham Young University	Sand (%) Silt (%) Clay (%)	Habitat suitability
Soil Conductivity	same as above	EC (dS/M)	Habitat suitability
Digital Photograph	Digital camera	Photo Number	Voucher
Vegetation			
Vegetation Type	From Zedler et al. 1997	Veg list + Other (write-in)	Habitat suitability
Percent Cover- Open ground Percent Cover- Annual Grasses Percent Cover- Perennial Grasses Percent Cover- Forbs Percent Cover- Shrubs/ Trees	Visual estimate	Enter %	Habitat suitability
Dominant Species- Annual Grasses Dominant Species- Perennial Grasses Dominant Species- Forbs Dominant Species- Shrubs/Trees	Visual Assessment	Species comprising >25% total cover in each vegetation layer (list)	Habitat suitability
Kangaroo Rat Sign			
Presence of Active Kangaroo Rat Sign	Search	Y/N	
IF YES to above:			
Type	Search	burrows (1.5" diam.) with apron, burrows (1.5" diam.) without apron, tracks, scat, dust bathing / cache sites, runways, none	Kangaroo Rat occupation
Individual Rodent Sign Form			
Date		Automatic	
Type marked		burrows (1.5" diam.) with apron, burrows (1.5" diam.) without apron, tracks, scat, dust bathing / cache sites, runways, none	Testing of temporal closure Assumption (see section "Supplements to ore Protocol" Brehme et al. 2006)
Location	GPS	Lat/Long	
Photo	Voucher	Y/ N (check off)	Voucher
Previously Marked?	Y/N	Pin flag, flag tape, other (choose one)	
Burrow Probe Used?	Y/N	Burrow empty, blocked, not able to negotiate turn, too narrow, too extensive	Check potential burrow for presence/ absence. Test utility of burrow probe.
Animal Found?	Y/N	Genus (species if possible)	
Disturbance/ Other			
Presence of gopher burrows	Search, Visual estimate	None/ Low/ High	Habitat suitability
Presence of squirrel burrows	Search, Visual estimate	None/ Low/ High	Habitat suitability
Presence of road/ firebreak	Search	Y/N (Type: dirt road, gravel road, paved road, firebreak)(Fill in distance for each: 0, 1-50, 51-200, >200 meters)	Habitat suitability/ dispersal
Recent Disturbance	Visual search & estimate	Vehicle tracks, footprints, hoofprints, fire, artillary (none, low or high- designation for each)	Management

Adapted from Montgomery et al. (2005)

Modified Military Training and SKR Habitat Disturbance Data Collection

As part of the base-wide SKR monitoring program in Fall/Winter 2014, three types of habitat disturbance from military training were scored in the field; 1) Flat compaction disturbance from personnel foot traffic, bivouacking, and vehicle use, 2) Rutted disturbances from vehicle usage in wet or moist conditions or digging, and 3) presence of berms and targets. Scores for both the spatial extent of habitat disturbance (from 0 to >75% of habitat affected) and severity of disturbance were multiplied together to determine each disturbance index. The spatial score was the median value of the index range divided by 10. For instance, if the direct footprint of disturbance covers 11 to 25% of the plot, the spatial score is 1.8 (median of 18% /10). The severity scores ranged from 0-5 for rutted disturbance and 0-6 for compaction related disturbance. The presence of foot and tire tracks, depth of tracks (for rutted index), soil compaction, and presence or absence of plant growth at location of disturbance were used to score severity (see definitions in Table 3). The disturbance index for berms and targets was calculated based only on spatial extent. For overall military disturbance, we summed all indices and normalized to a 0 to 100 scale. Photographs from 2012 and 2013 were also analyzed and evaluated using the same scoring system. Each military disturbance index was run as a site covariate in the occupancy modeling described in the Analysis section.

As a note, in 2014/15 we attempted to incorporate range use data provided from RFMSS Range scheduling to directly relate military activities to habitat disturbance. However, the use data for various ranges was highly variable in its completeness, which hindered our ability to do these analyses. In addition, range-wide activity data was at a much broader spatial scale than useful for prediction of localized impacts at the scale of SKR sampling and patchy distribution within the ranges.

TABLE 3. MILITARY DISTURBANCE INDEX CALCULATION

Rutted Disturbance Spatial Extent	score
0	0
1-10	.5
11-25	1.8
26-50	3.8
50-74	6.3
≥75	8.8

multiplied by (X)

Rutted Surface > 1 inches deep	score
None	0
Historic ruts <3" with grown over plants	1
Deep Ruts > 3" deep old	3
New ruts <2", with plant growth	3
New ruts <3", no plant growth	4
Deep Ruts > 3" deep new, no plants	5
max score-all deep ruts	44

Flat Disturbance Spatial Extent	
0	0
1-10	.5
11-25	1.8
26-50	3.8
50-74	6.3
≥75	8.8

multiplied by (X)

Flat Surface- Disturbance Level	score
None	0
Light disturbance high plants	1
Med disturbance low plants	2
Heavy dirt road/bivuoc/compacted. No plants	4
Paved road/cement	6
max score-all pavement	52.8

Berm/ Target Spatial Extent	score
0	0
1-10	8
11-25	16
26-50	24
50-74	32
≥75	40
max score-all berms and/or targets	40

Rutted Surface Disturbance	SE*RS score
Compact/Flat Surface Disturbance	SE*FLAT score
Berm/Target Disturbance	SE score
Overall Military Disturbance	SUM of above

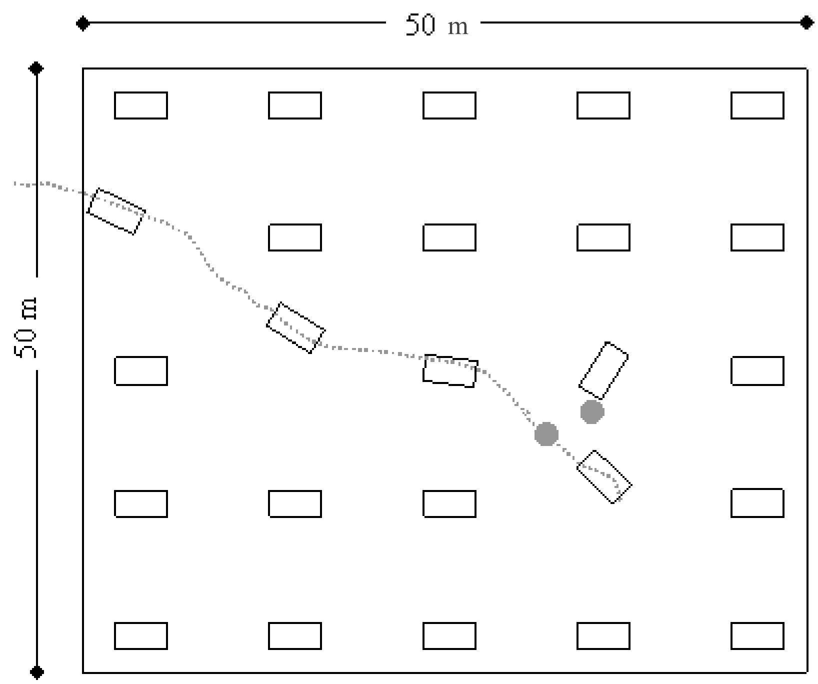
Trapping Surveys

SKR occurs sympatrically, and often syntopically, with DKR on MCBCP. Both kangaroo rats are similar in size and there are no physical characteristics that distinguish SKR burrows from DKR burrows; therefore, all sample plots containing potential kangaroo rat burrows were live-trapped for a minimum of two consecutive nights (4 trap events). To increase the precision for estimates for proportion area occupied (PAO), overall detection and individual capture probabilities, we trapped most plots for three trap nights as access to the training areas and survey scheduling would allow.

Twenty-five live-traps (Fifteen measuring 4×4.5×15 inches and ten measuring 3×3.5×12 inches) were placed in a 5 × 5 array, spaced approximately 10 m apart, on each plot (Figure 2). When obvious kangaroo rat sign was within a few meters of a trapping point, the trap was placed next to burrow entrances, dust-bathing sites, or within runways to maximize capture success (O'Farrell 1992).

Most of the trapping was conducted during the fall and winter months (September- December). Two training areas were trapped in April 2018 due to site access and weather conditions. Fall months are reported to have the highest capture probabilities for SKR due to low availability of food resources (O'Farrell and Uptain 1987) and temperatures are often mild during this period, which should result in less stress to trapped animals. During this time period, we also expect to be sampling the more stable adult populations, as SKR young have likely dispersed or died (McClenaghan and Taylor 1993). Because capture probabilities decrease during full moon periods (O'Farrell 1974, Kaufman and Kaufman 1982, Price et al. 1984, Brehme and Fisher 2009), we attempted to conduct all trapping during new and part moon phases only. However, because of access restrictions, this was not always possible.

Following approved protocols, trapping was conducted by experienced small mammal researcher(s) with a current U.S. Fish and Wildlife permit for trapping SKR. All traps were set a few hours before sunset using heat inactivated rolled oats and birdseed as bait. Traps were then checked midnight and early morning hours each trap night. Individuals were assessed for age, sex, and reproductive condition. For further species verification, hind foot length, ear length, head length, preorbital width, and postorbital width measurements (Price et al. 1992) were taken of all kangaroo rats, and angle of bacula was examined on all males (Lackey 1967a, Best and Schnell 1974). We photographed a minimum of three animals identified as SKR and at least one individual identified as DKR on all occupied plots for voucher purposes. Starting in 2008, all SKR were marked with a unique ear tag that will allow us to follow individuals over multiple years. In addition to SKR in 2011, we began marking all DKR with a unique ear tag to allow us to follow both species. All other animals were temporarily batch marked by clipping a small amount of fur from the hip area or marking with a marker to document recaptures.



Note: Nearby traps are placed near kangaroo rat burrows (●) and trails (---) to increase probability of capture.

FIGURE 2. DIAGRAM OF LIVE-TRAPPING GRID ON 50M X 50M SAMPLE PLOT

Additional Survey plots within the Juliett SKR Management Area

SKR has been intermittently surveyed in Juliett and RSOP 90 from 1980 to present. Surveys conducted by Beauchamp (1981) and Friesen (1993) documented low numbers of captures of SKR in Juliett. Montgomery captured 10 SKR in 1996 (Tetra Tech 1999). Since 2005, Juliett has been part of a Basewide monitoring program that monitors trends in distribution and density using live trapping, habitat, and disturbance methods (Brehme et al. 2006). USGS captured 2 SKR in Juliett in 2005, 1 SKR in 2006, and no SKR from 2007 through 2013 as part of the monitoring program. Along with the presumed local extirpation of SKR within Juliett after 2006, the habitat was documented to be largely unsuitable for SKR due to the presence of thick non-native grasses or shrublands (Brehme et al. Annual Reports 2006-2014). Habitat management by prescribed burning was implemented in RSOP 90 in 1992 to reduce the non-native grassland and to maintain the area as a native grassland/forbland (USFWS 1992). The SKR population has since returned with the addition of 21 SKR from Area 25 Combat town in 2011 (USFWS 2011) and the restoration of habitat in the Juliett SKR Management Area. The translocated SKR were protected and monitored in an outside enclosure until summer 2014, when holes were placed in the enclosure to allow the SKR to move in and out of the enclosure.

To better track occupancy and spatial trends of the new translocated SKR population within the Juliett SKR Management Area, 4 additional survey plots were established in 2014 in and around the fenced enclosure. In 2017, the fence was removed around the enclosure and an additional 4 plots were added to the nearby area. The new Juliett specific plots are shown in the Results section.

Data Analysis

Proportion Area Occupied

Proportion area occupied (PAO) by SKR on Base was estimated using the hierarchical logistic modeling program package Unmarked (v. 0.9-9) in R. A single season model was used to estimate the annual trend metric of area occupied by SKR (Ψ). Multiyear models were used to model habitat covariates predictive of occupancy (Ψ), detection probabilities (ρ), as well as localized colonization (γ) and extinction (ε) between years.

For PAO modeling, we combined night and morning live-trapping sessions in estimating SKR detection probability (ρ) and proportion area occupied (Ψ). These data were not pooled since many animals were captured on both night and morning events, which increased our ability to model the data and to produce more precise parameter estimates. In modeling ρ, we compared models where ρ was constant (.), varied by each individual trapping session (t), or varied depending upon DKR presence on the plot (DKR). Because small mammals may be more likely to enter a trap after a period of acclimation (see Brehme and Fisher 2008), we also included a model where ρ differed between the first session and all subsequent sessions (Night 1_other).

Environmental and landscape covariates that have been hypothesized to affect SKR population dynamics were evaluated for their ability to explain variation in PAO (Ψ) and year to year colonization (γ) and extinction (ε) probabilities. We compared models in which Ψ was constant, varied with stratum (monitoring vs. discovery areas), disturbance (indices of military disturbance, years since last fire, fire frequency 1974-present), proximity to roads (road_prox; dirt, gravel and paved), presence of DKR (DISI), and different types of vegetative cover (shrubs, perennial grass, annual grass, forbs, open ground and open ground/forbs). The proportion of forbs and open ground were combined due to differing levels of live, dead, and disarticulated forbs. For model selection and inference, we followed the information-theoretic approach (Burnham and Anderson 2002).

Detection probabilities (ρ) are conservatively presented with 95% confidence intervals. All other annual trend parameters are presented with 90% confidence intervals (Brehme et al. 2006). Cumulative probabilities of detection were calculated by subtracting the product of probabilities an SKR was not detected (1- ρ) during each successive trap event from 1 through n (Equation 2).

Equation 2:

$$\text{Cumulative } \rho = 1-(1-\rho_1)*(1-\rho_2)*\ldots*(1-\rho_n)$$

where ρ = detection probability

n= trap event

Model Assumptions & Tests

Any attempt to quantify changes in species occupancy may be biased if actual conditions do not follow the basic assumptions of the statistical model. The following two assumptions are important to our program.

1. There is a near-perfect probability of detecting the absence of active kangaroo rat sign. So the plot is "unoccupied" if no potential sign is detected. This was tested by live-trapping 13 plots in which no potential sign was detected.

2. The population is closed in both time and space. Therefore, the state of occupancy (occupied vs. unoccupied) does not change during sampling. We tested this by resurveying plots for potential sign when setting traps. We attempted to minimize any violations of this assumption by 1) surveying in the fall and winter, after we expect most juveniles have dispersed and reproductive activity has ceased, and 2) conducting Phase 1 burrow searches and Phase 2 trapping as close in time as logistically possible. The main reasons for any violations are related to gaining access to live fire training and impact areas containing SKR survey plots.

Density Estimation

A density index for SKR within each stratum was calculated using the Huggins closed capture and full closed capture with heterogeneity models available in Program MARK (Huggins 1989, 1991). These models allowed for missing data and inclusion of individual covariates to model probability of initial capture (p) and probability of recapture (c). Estimates of population size (N) are then conditioned out of the likelihood.

The probability of initial capture (p) is different from the detection probability parameter (ρ) estimated for occupancy analysis. In occupancy analyses, we estimated the probability of detecting *one or more SKR on a sample plot* (ρ). In contrast, in closed capture abundance analysis we estimate the probability of capturing *an individual SKR* (p). Thus, the sample unit is the plot for occupancy analysis and the individual animal is the sample unit for abundance analysis.

For this analysis, we tested models where capture probability (p) was constant (.), varied by sex (sex), by time (t), by Night vs. morning trapping sessions (Night_Morn), and between the first session and all subsequent sessions (Day 1_other). Heterogeneous mixture models included a mixture proportion estimate (π) representing a proportion of SKR (group 1) that have a different capture rate from the other 1- π (group 2). These groups are not predefined, but formed from any natural grouping in the data, so could be related to sex, age, or any other unknown factor that may affect trap behavior.

To test for a positive or negative behavioral response to being trapped (i.e. "trap happy" or "trap shy"), we compared models where probability of recapture (c) was equal to the probability of initial capture (p) versus models where p and c were unequal. We followed the information-theoretic approach for model selection (Burnham and Andersen 2002). To correct for overdispersion, we used Quasi-AICc for model ranking (Burnham and Anderson 2002).

Cumulative probabilities of capture were calculated in the same manner as cumulative detection probabilities (Equation 2). Capture probabilities (p) are conservatively presented with 95% confidence intervals. All other annual trend parameters are presented with 90% confidence intervals (Brehme et al. 2006). Density estimates of SKR within occupied habitat were calculated using the abundance estimates from the best fitting closed capture model divided by total area sampled.

Results

In the fall and winter of 2017-18, we surveyed 117 plots in SKR Monitoring Area and 17 plots within the Discovery Area. Sixteen plots were not surveyed due to denial of access. Of the 134 plots surveyed, 133 plots contained potential kangaroo rat sign (potential burrows, tracks, and/or scat) on the initial survey. All these plots, along with 1 plot that did not contain any observable sign, were live trapped for 2 to 4 days (4 to 8 trap events). Overall, we captured 304 SKR in 49 plots and 271 DKR in 52 plots (Table 4). All habitat and trapping surveys were completed between September and May of 2017-18.

SKR detections were limited to the training areas immediately south of the Zulu Impact Area in the 409 Impact Area, Range 408, Range 408A, Range 407, Kilo 1, Kilo 2, AFA 31, and AFA 26, 31, and 32 in India of the SKR Monitoring Area. SKR were captured in 8 out of 18 plots within the Juliett Management Area (Figure 4). All occupied plots were just north, south and west of the fenced area where an SKR population was translocated in 2011 by SJM Biological Consultants. Single year and cumulative year maps of survey plot locations and SKR detections are presented in Figures 3 to 5.

DKR detections were in areas south of the Zulu Impact area and in the Juliett Management Area. Training areas south of the Zulu Impact area include 409 Impact Area, R408, Range 407, R117, Kilo 1, Kilo 2 and AFA's 26, 31 and 32 in India. There were 14 plots in the Monitoring Area that had both SKR and DKR detections.

In 2017-18, we detected 8 species of non-target rodents. Of those species, we most commonly detected deer mice (*Peromyscus maniculatus* -105 plots). Results of all non-target species are presented in Table 5.

TABLE 4: SUMMARY OF 2017-18 SURVEY EFFORT AND PRESENCE OF KANGAROO RATS

			PLOTS						CAPTURES	
			Plots with potential k-rat			Plots with NO potential k-rat			Total Individuals	
Stratum	# Plots Surveyed	# Plots with potential k-rat sign	# Plots Trapped	# Plots with SKR	# Plots with DKR	# Plots Trapped	# Plots with SKR	# Plots with DKR	SKR	DKR
Monitoring Area	117	117	117	49	52	0	0	0	304	271
Discovery Area	17	16	16	0	0	1	0	0	0	0
Total	134	133	133	49	52	1	0	0	304	271

TABLE 5: SUMMARY OF NON-TARGET SPECIES CAPTURES WITHIN SKR MONITORING AREA

		Monitoring Area		Discovery Area		Total	
Common Name	Scientific Name	# Individuals	# Plots Detected	# Individuals	# Plots Detected	# Individua ls	# Plots Detected
Deer Mouse	*Peromyscus maniculatus*	463	92	98	13	561	105
Harvest Mouse	*Reithrodontomys megalotis*	38	18	20	9	58	27
California Pocket Mouse	*Chaetodipus californicus*	224	12	48	12	272	24
House Mouse	*Mus musculus*	0	0	0	0	0	0
California Ground Squirrel	*Otospermophilis beecheyi*	19	9	0	0	19	9
Cactus Mouse	*Peromyscus eremicus*	106	30	25	8	131	38
California Mouse	*Peromyscus californicus*	11	6	5	1	16	7
Woodrat	*Neotoma species*	43	18	10	6	53	24
California Meadow Vole	*Microtus californicus*	0	0	0	0	0	0
Brush Mouse	*Peromyscus boylii*	3	1	0	0	3	1

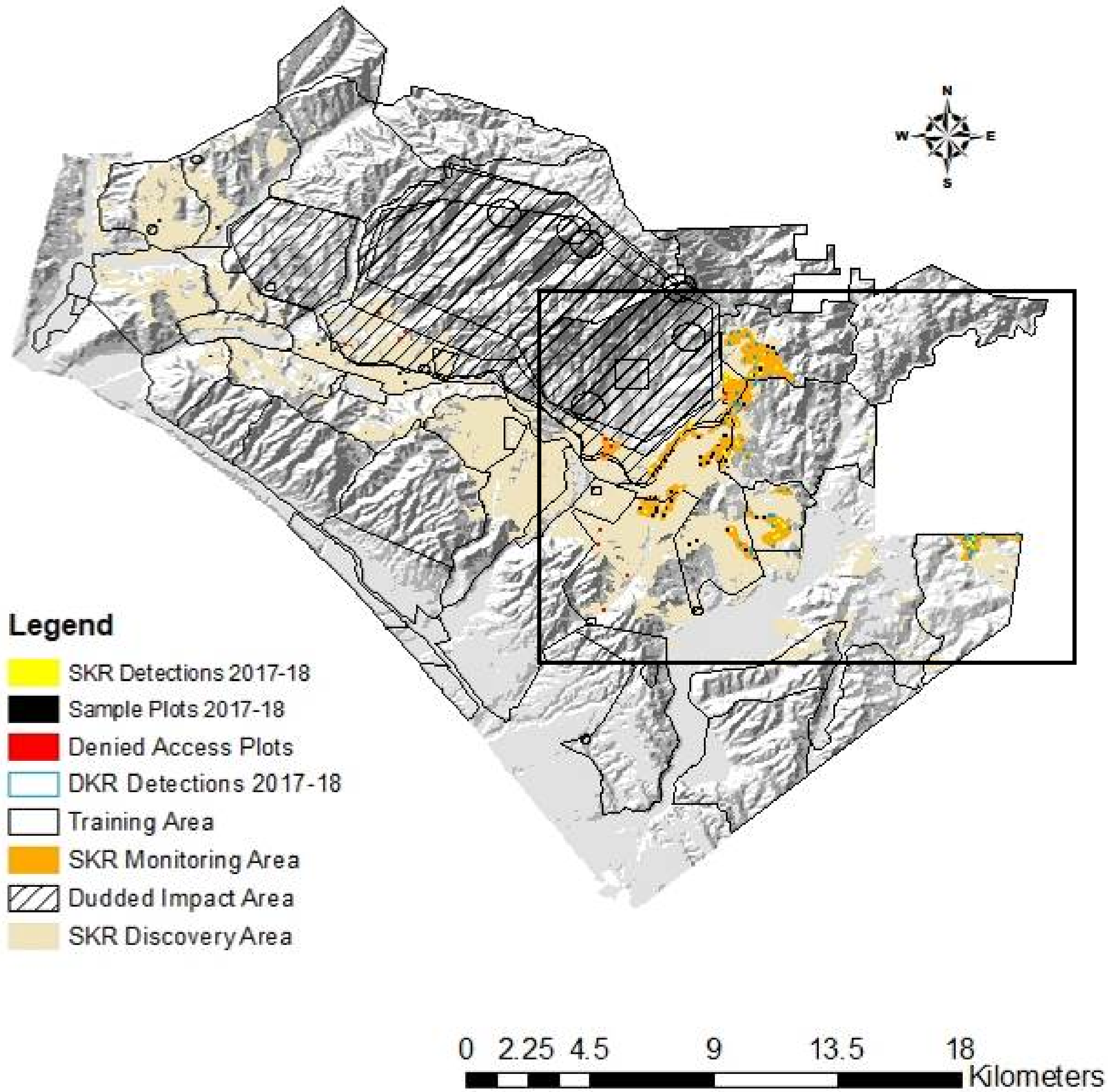


FIGURE 3A. SKR DETECTIONS ON MONITORING PLOTS 2017-18

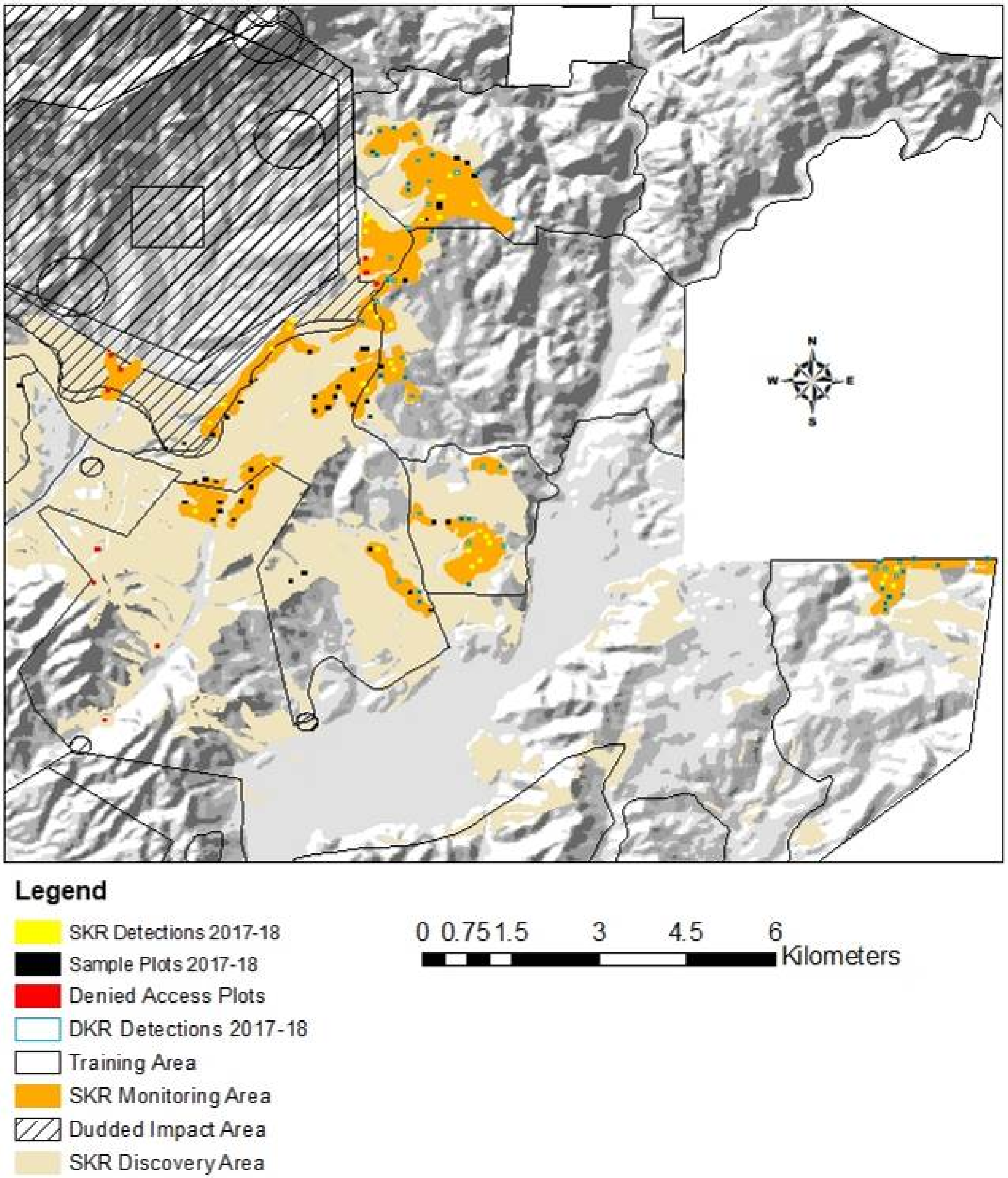


FIGURE 3B. SKR DETECTIONS ON MONITORING PLOTS 2017-18 (MAGNIFIED VIEW FROM INSET)

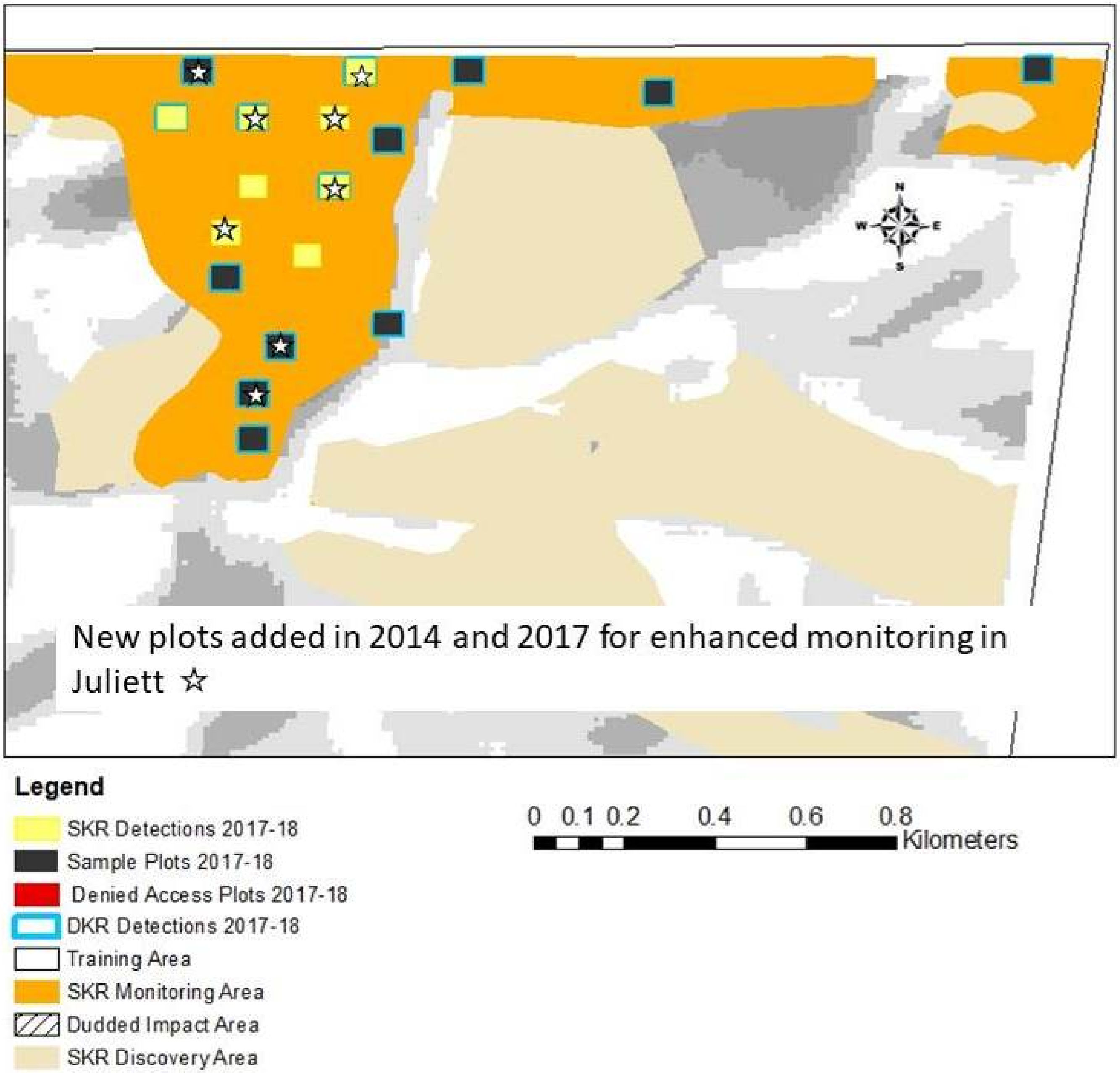


FIGURE 4. SKR DETECTIONS IN JULIETT 2017-18

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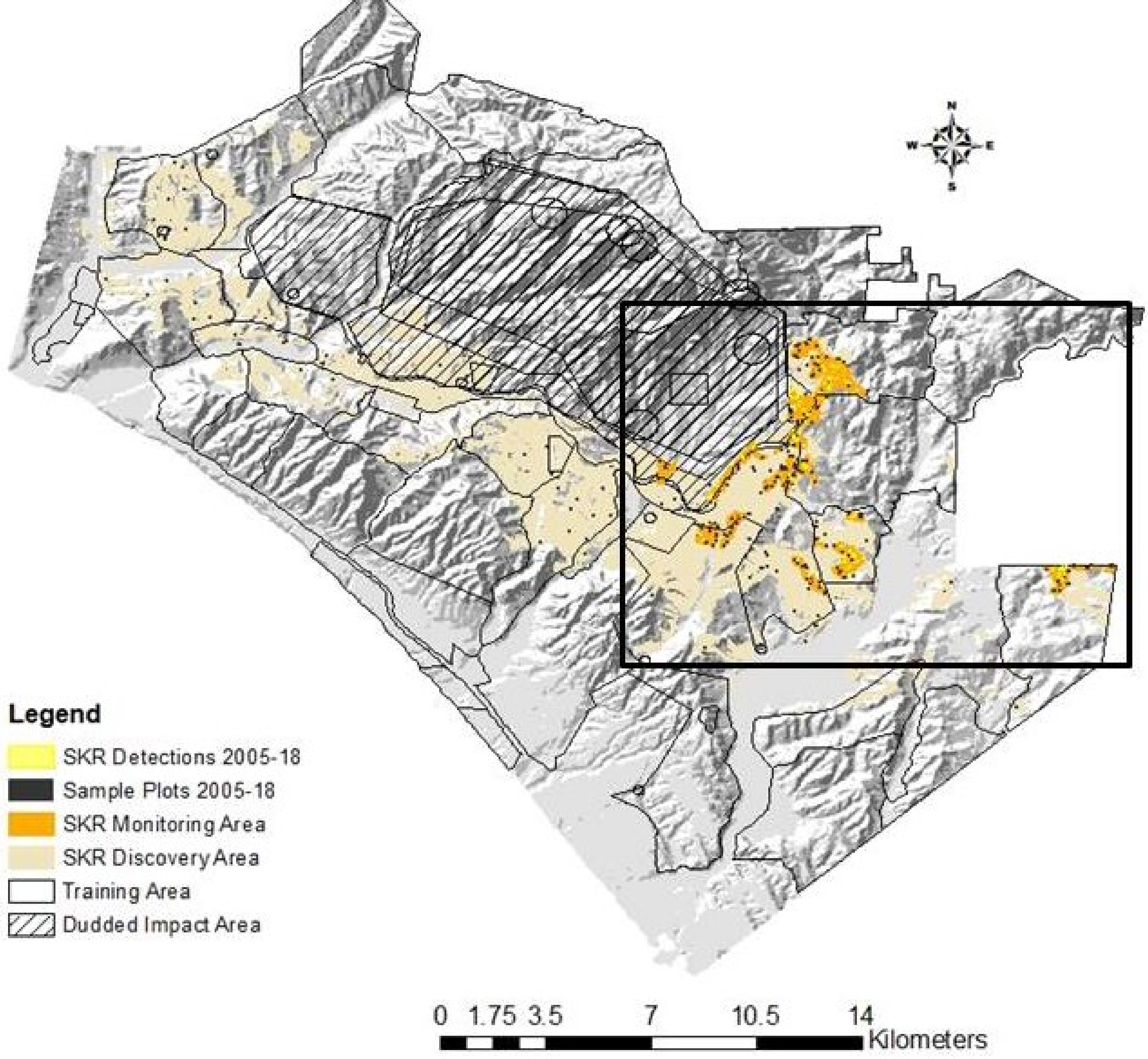


FIGURE 5A. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2017-18.

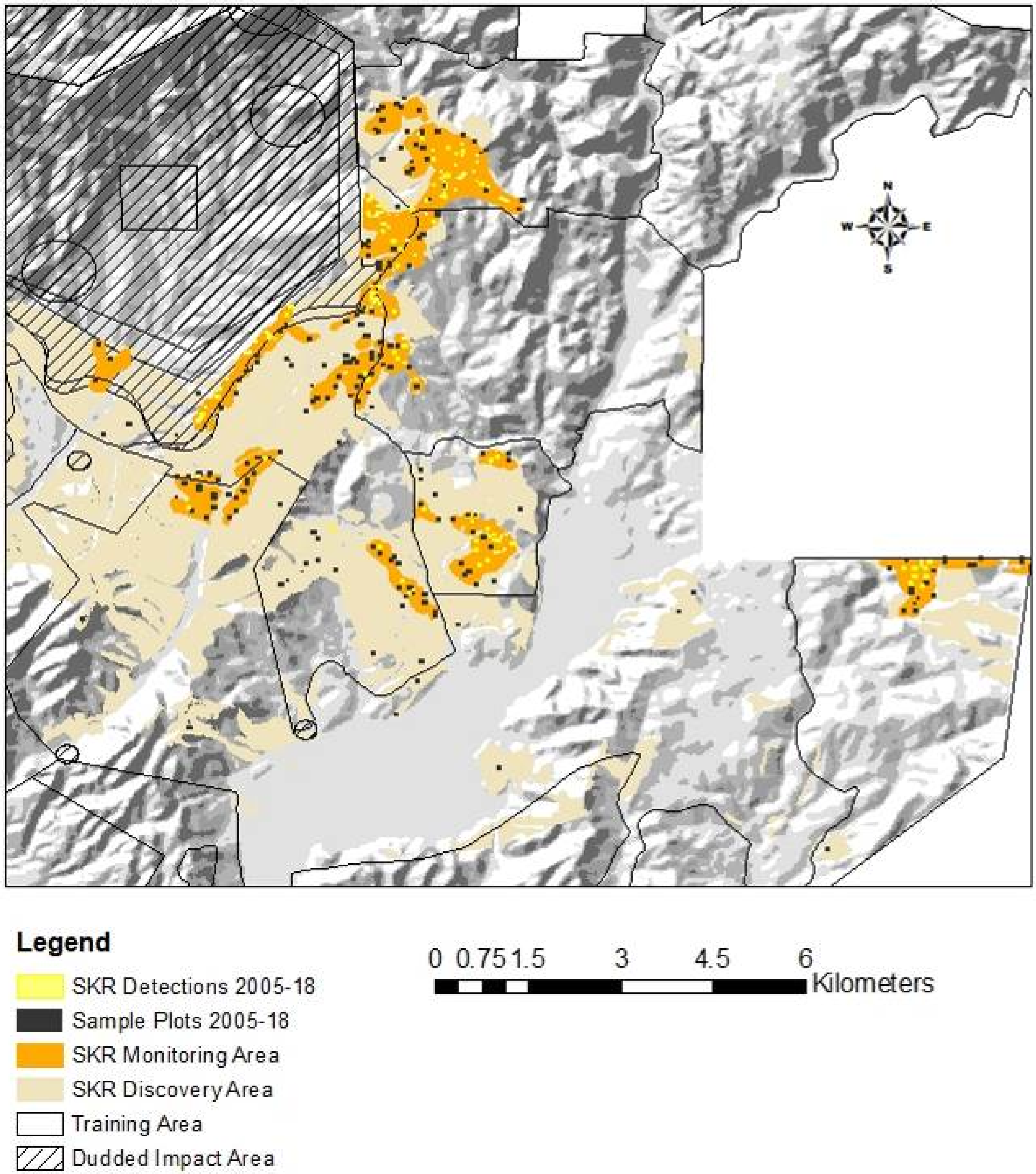


FIGURE 5B. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2017-18 (MAGNIFIED VIEW FROM INSET)

Basewide Results and Trends from 2005-6 to 2017-18

For the Fall/Winter 2017/18 season, the estimate of total monitoring area occupied by SKR was 231.1 ha (SE 31.4) which is a 6.6% decrease in comparison to the previous year although estimates have not significantly differed in the past 7 years. Long term results indicate the amount of habitat occupied by SKR steadily increased from a low estimate of 60 ha in 2005 to 248 ha in 2016/17 and has remained relatively stable (Table 6; Figure 7a).

The density of SKR within occupied plots in 2017/18 was estimated to be 10.7 SKR per 0.25 hectare (ha) which is higher than in 2016/17 (9.7 SKR/0.25 ha) and all previous years (1.4-7.6 SKR/ha). Although recapture probabilities are high (0.78-0.88), low individual SKR capture probabilities (0.22-0.29) have resulted in high density estimates with large confidence intervals. Trends in SKR density have been variable within occupied habitat patches and have not consistently mirrored trends in total area occupied. However, estimates for density and area occupied by SKR in 2017/18 are among the highest since monitoring began in 2005 and have been stable and increasing for the past 6 years.

The probability of detecting SKR if present (any SKR vs. individual SKR) within the 0.25 ha sampling plots remained very high, at 0.87 (95% CI:0.79-0.93) and averaged close to perfect after three nights of live-trapping (cum ρ=1.00, CI: 0.99-1.00, Figure 6).

As documented in previous years, individual SKR were less likely to be captured on the first night (ρ= 0.22, se=0.06) than on subsequent morning and night sessions (ρ= 0.29, se=0.13). After three nights of trapping, the cumulative probability of capturing any individual on the plot was 0.60 (95% CI: 0.33-0.86; Figure 6).

We have ear-tagged 783 SKR individuals since 2011. In 2017/18, we captured 334 SKR. Only eleven (3.3%) SKR captured in permanent plots were recaptured individuals from the previous year. In previous years, recapture rates have ranged from 6.3 to 15%. One individual was captured three subsequent years in a row. Since the onset of monitoring, we have never captured an individual over a time span greater than 3 years.

This year, we added 4 new plots to better cover the Juliett Management Area and documented SKR presence in 8 out of 18 plots (PAO estimate 0.44, SE= 0.12). At this site, we captured 55 SKR (2 were previously ear-tagged by S. Montgomery- OC37, S472). Average habitat conditions recorded in 2018 were 18.5% open ground, 30% forb cover, 20% annual grasses, 7% native bunch grass, and 24% shrub cover.

TABLE 6. TRENDS IN AREA OCCUPIED AND RELATIVE DENSITY OF SKR WITHIN MONITORING AREA FROM 2005-6 TO 2017-18

SKR Fall/Winter Monitoring Period	Monitoring Area (ha)	Proportion Area Occupied (se)	Total Hectares Occupied (ha, se)	Density in Occupied Habitat (SKR/0.25 ha, se)
2005-6	740	0.081 (.037)	60.1 (27.5)	1.5 (0.1)
2006-7	740	0.096 (.041)	70.8 (29.7)	5.1 (2.2)
2007-8	740	0.177 (.045)	131.0 (33.3)	1.4 (0.1)
2008-9	740	0.199 (.048)	147.3 (39.1)	3.2 (0.7)
2009-10	740	0.160 (.035)	118.4 (39.1)	7.6 (3.4)
2010-11		refinement of monitoring area and program		
2011-12	628	0.297 (.050)	186.5 (31.4)	5.5 (1.9)
2012-13	628	0.309 (.044)	193.7 (27.7)	1.4 (0.2)
2013-14	628	0.304 (.047)	190.9 (29.5)	5.0 (0.7)
2014-15	628	0.268 (.042)	168.1 (26.3)	5.3 (0.4)
2015-16	628	0.334 (.043)	209.7 (27.2)	6.3 (0.4)
2016-17	628	0.394 (.051)	247.4 (32.0)	9.7 (3.3)
2017-18	628	0.368 (.050)	231.1 (31.4)	10.7 (2.8)

se= standard error

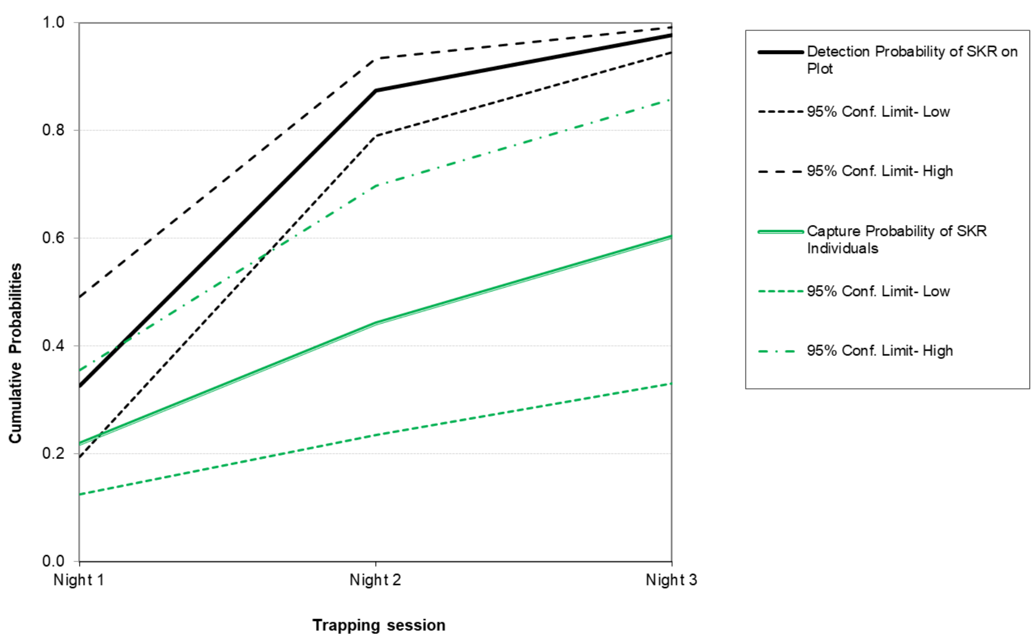


FIGURE 6. CUMULATIVE SKR DETECTION AND INDIVIDUAL CAPTURE PROBABILITIES

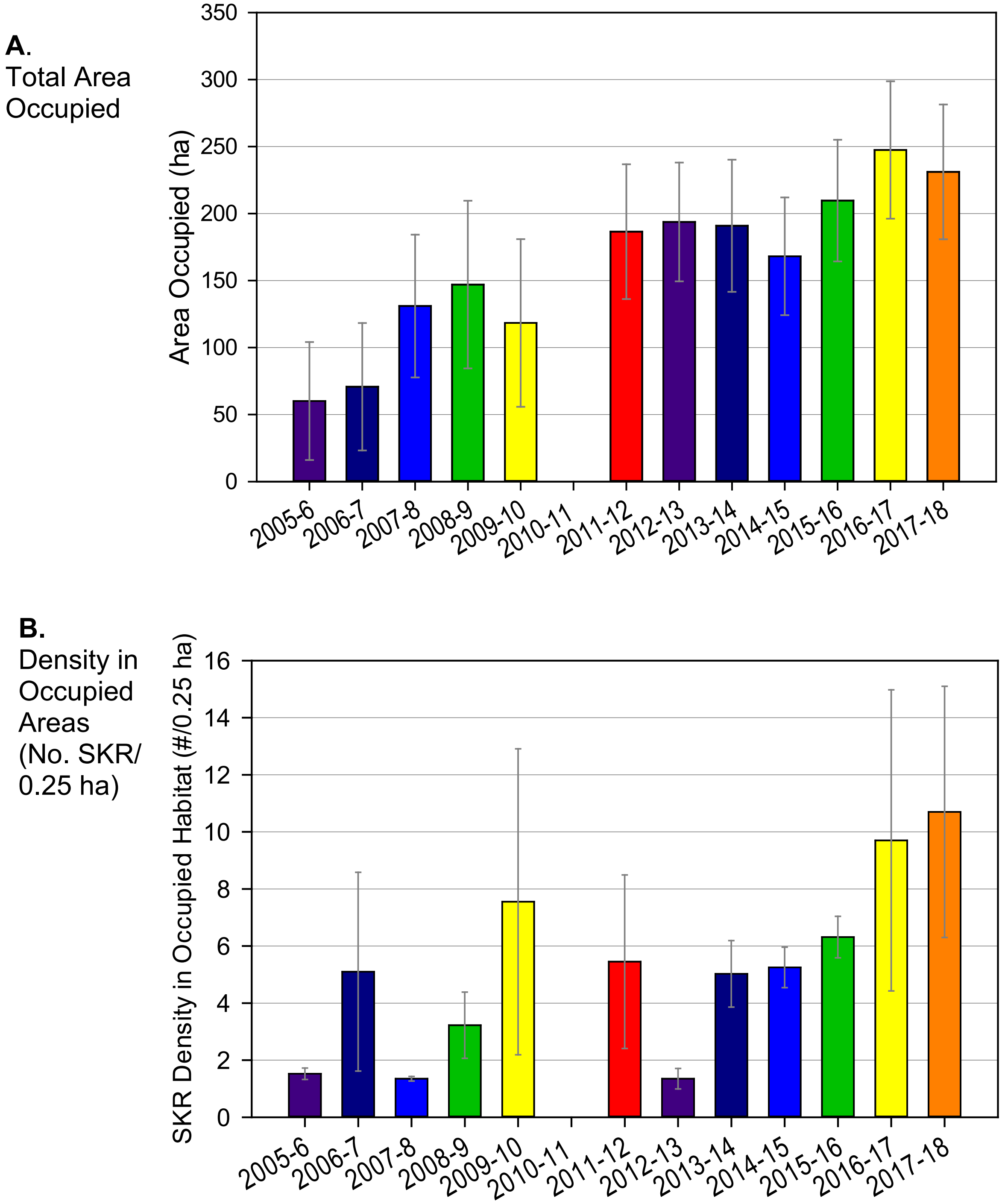


FIGURE 7. TRENDS IN OCCUPIED AREA (A) AND DENSITY (B) OF SKR WITHIN MONITORING AREA FROM 2005-6 TO 2017-18 WITH 90% CONFIDENCE LIMITS

Multi-year Integrated Habitat Occupancy Models

The top models that best explained spatial and temporal dynamics of SKR from 2011/12 to 2017/18 showed that more compact soils (within the range of our measurements), gentle slopes (<10 degrees), moderate proportions of open ground with adequate forb cover were the best predictors for SKR occupancy on MCBCP. Between years, a higher proportion of open ground along with low shrub cover was best at predicting where SKR newly colonized previously unoccupied sites, while areas with high cover of annual grasses and lack of open ground best predicted where SKR were most likely to go locally extinct (Model Comparison Charts: Appendices 1-3). We present relationships between these covariates and parameters of SKR occupancy, colonization and extinction as predicted by our top models in Figures 8 to 15. Correlations among covariates are presented in Figure 16.

The odds of SKR occupying a plot increased 2.7 times (95% CI: 1.5-4.6) for every 20 lbs.-per square-inch (psi) increase in soil compaction and decreased 2.0 times (95% CI: 1.3-3.2) for every 5 degree increase in slope (Figures 8 and 9). High soil compaction is also correlated to low slope (Pearson's r= -0.22, p <.0001; Figure 16). The relationship of SKR occupancy with proportion of open ground was nonlinear with the highest occupancy between 40 to 80% open ground. The odds of SKR occupying a plot also increased 2.4 times (95% CI: 1.6-3.5) for every 20% increase in forb cover (Figures 10 and 11). Surveys are conducted in the fall after many forbs have disarticulated, so open ground is likely over-represented, and forbs under-represented in comparison to spring months.

We continue to document localized extinction and colonization dynamics within the SKR Monitoring Area over time. Among the 100 permanent plots, SKR colonized 4 plots in 2012, 7 plots in 2013, 6 plots in 2014, 6 plots in 2015, 7 plots in 2016, and 6 plots in 2017/18. Concurrently, SKR went locally extinct (or were undetected) at 2 plots in 2012, 3 plots in 2013, 7 in 2014, 7 plots in 2015, 6 plots in 2016, and 8 plots in 2017/18.

SKR were more likely to colonize areas with more open ground and low shrub cover. The odds of SKR colonizing a plot (that was unoccupied the previous year) averaged 2.2 times greater (95% CI: 1.6-3.0) for every 20% increase in open ground and 2.1 times lower (95% CI: 1.1-4.1) with every 20% increase in shrub cover (Figures 12 and 13).

SKR were more likely to become locally extirpated in areas with less than 20% open ground and greater than 40% non-native grass cover. For each 20% increase in open ground, the odds of local extinction decreased 1.5 times (95% CI: 0.9-2.5) and for every 20% increase in annual grass cover (0% vs. 20%, 20% vs. 40%, etc.) the odds of local extinction increased 3.2 times (95% CI: 1.5-6.9; Figures

14 and 15). Annual grasses documented in SKR habitat are primarily non-native grasses such as Brome grasses and Wild oats (Bromus and Avena spp.). High non-native grass cover is correlated to low slopes (Pearson's r= -0.22, p <.0001; Figure 16)

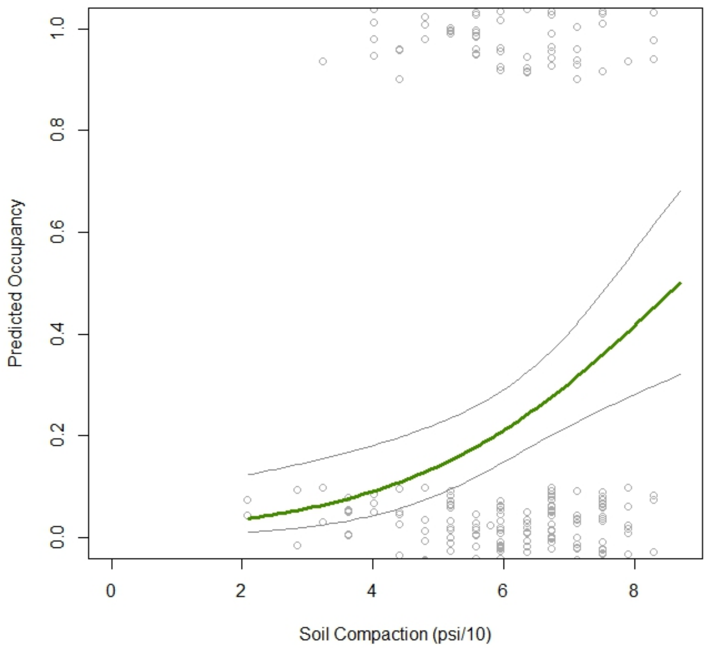


FIGURE 8. PROBABILITY OF SKR OCCUPANCY AMONG YEARS IN RELATION TO SOIL COMPACTION (PSI)

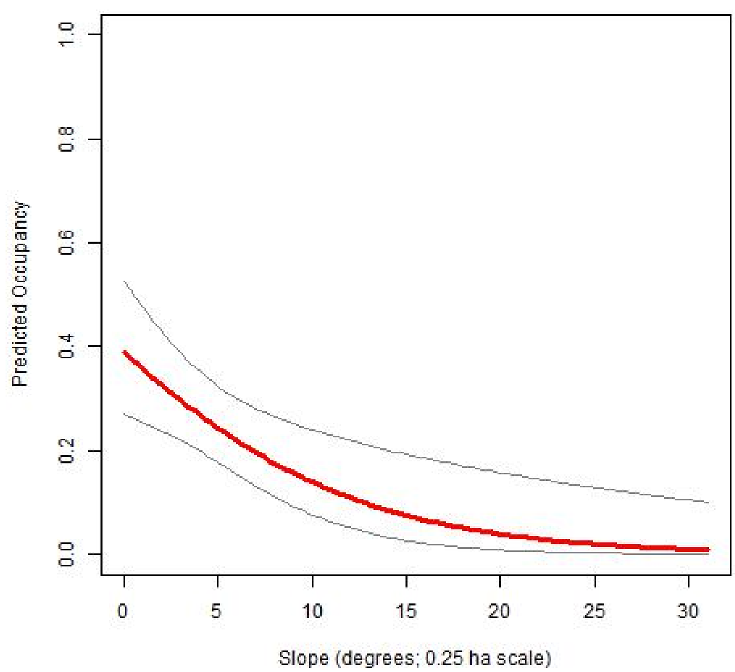


FIGURE 9. PROBABILITY OF SKR OCCUPANCY AMONG YEARS IN RELATION TO SLOPE.

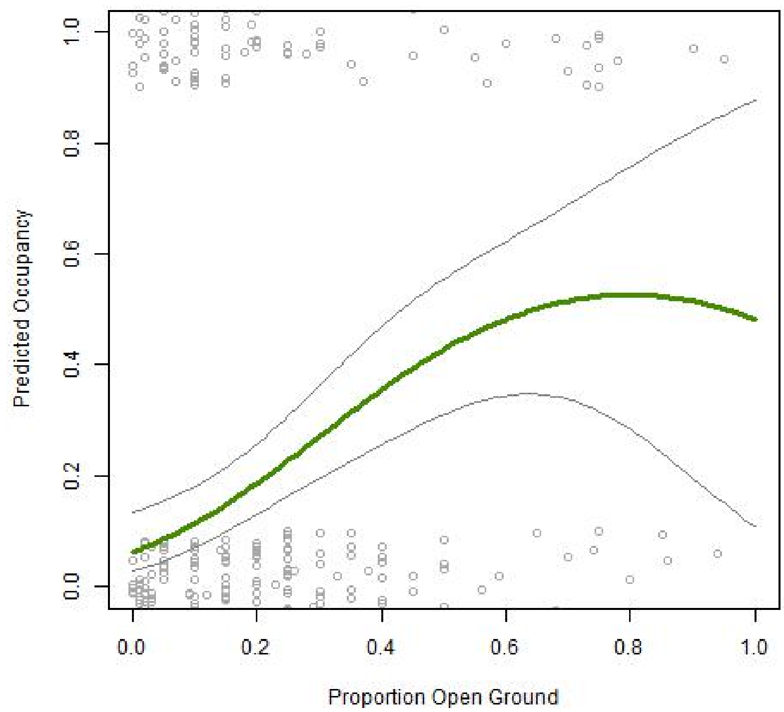


FIGURE 10. PROBABILITY OF SKR OCCUPANCY AMONG YEARS IN RELATION TO OPEN GROUND.

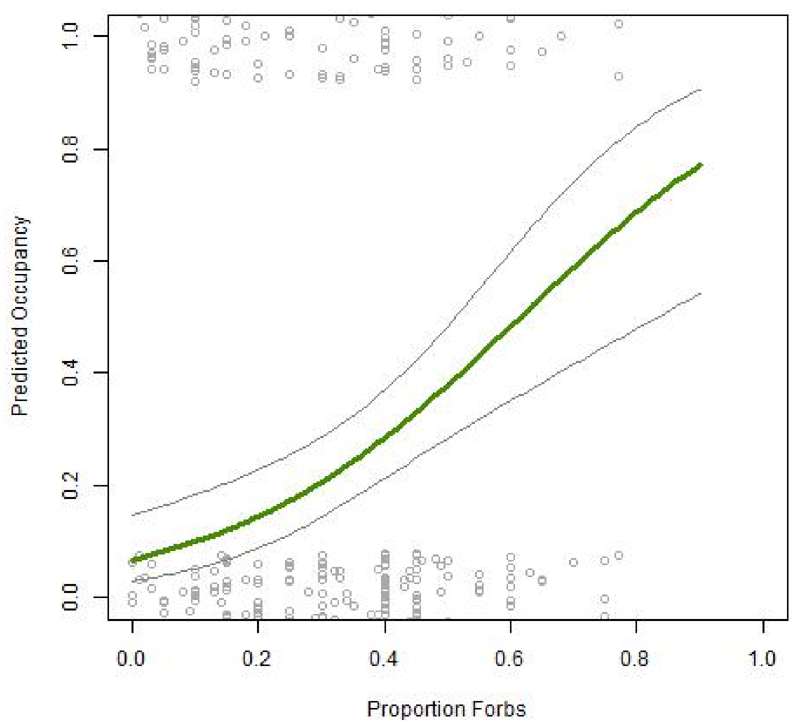


FIGURE 11. PROBABILITY OF SKR OCCUPANCY AMONG YEARS IN RELATION TO FORB COVER.

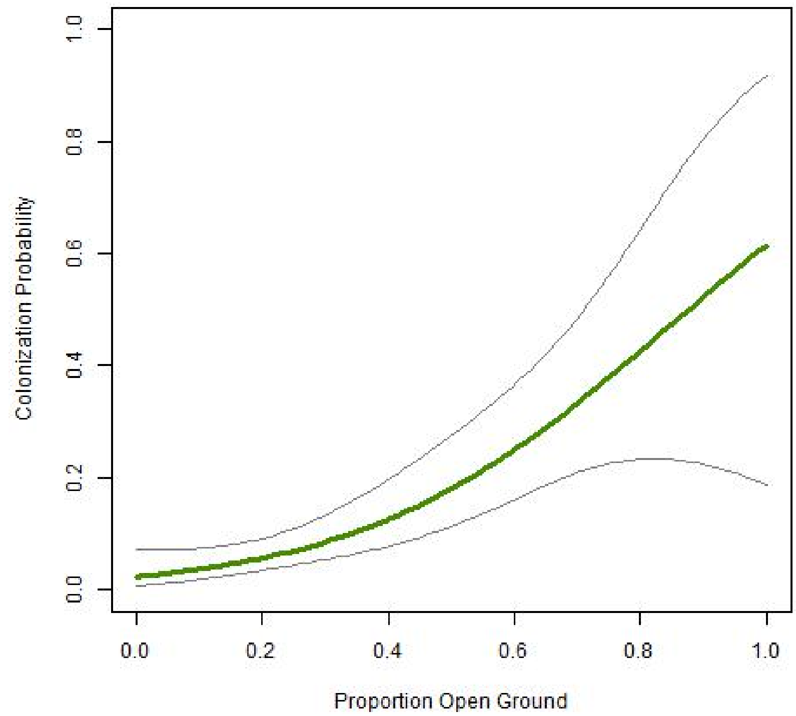


FIGURE 12. SKR COLONIZATION OF PREVIOUSLY UNOCCUPIED HABITAT: PROBABILITY IN RELATION TO OPEN GROUND

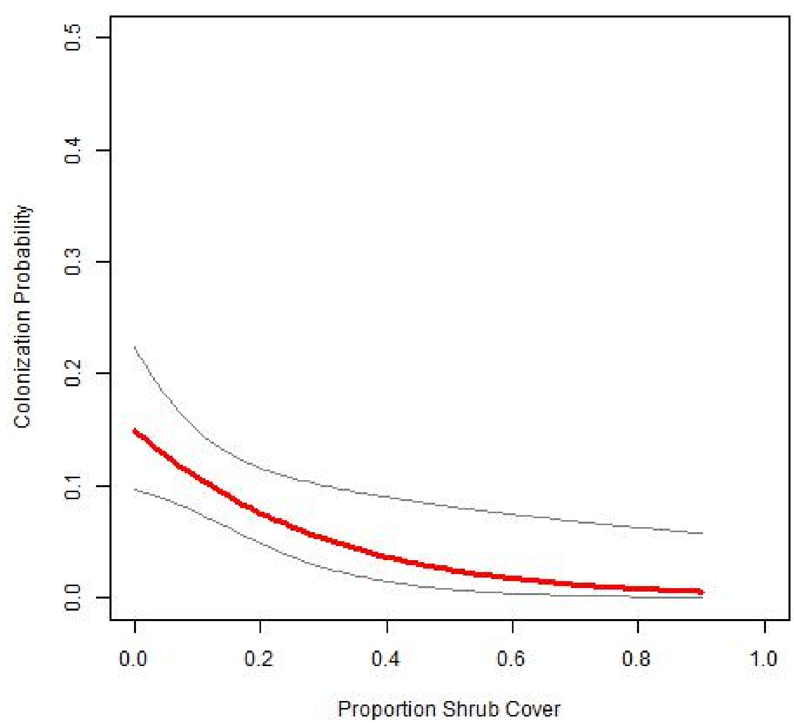


FIGURE 13. SKR COLONIZATION OF PREVIOUSLY UNOCCUPIED HABITAT: PROBABILITY IN RELATION TO SHRUB COVER

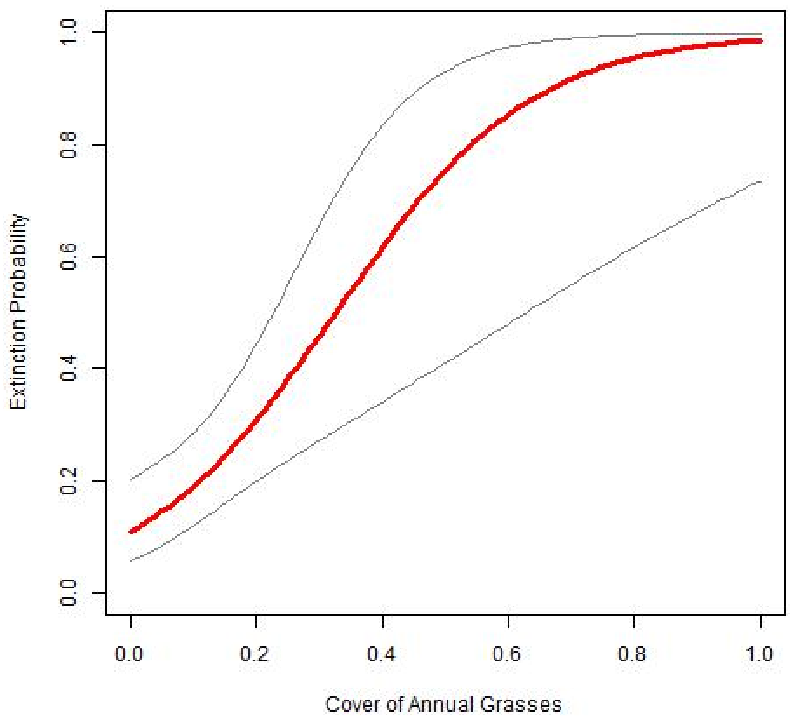


FIGURE 14. PROBABILITY OF LOCAL EXTINCTION IN RELATION TO ANNUAL GRASSES (NON-NATIVE)

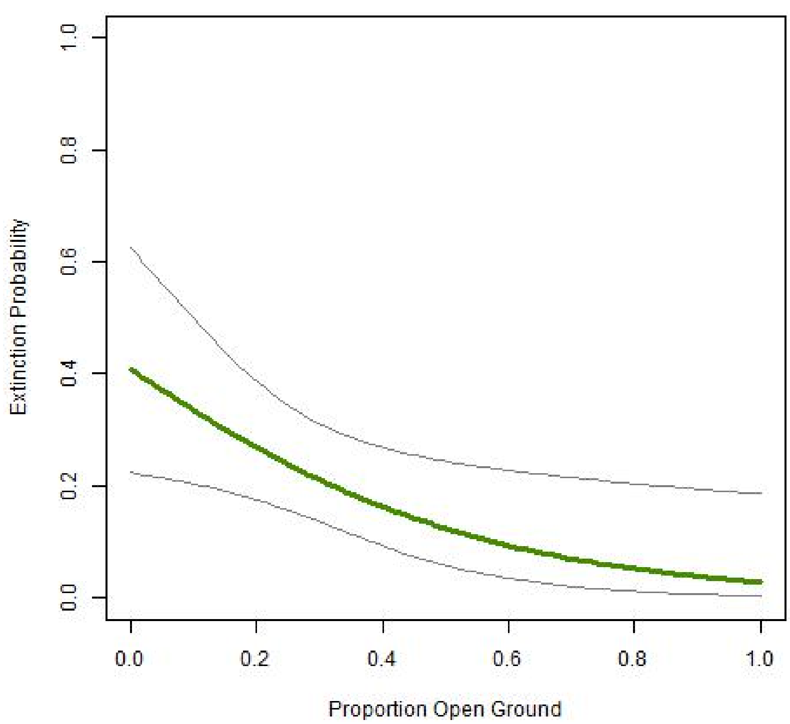


FIGURE 15. PROBABILITY OF LOCAL EXTINCTION IN RELATION TO OPEN GROUND

Correlations among Covariates

Pearson correlations showed that over all covariates across years; higher levels of open ground, soil compaction, and military disturbance measures were positively correlated with one another and all were negatively correlated to slope, vegetation cover, and years since last fire (Figure 16). Within vegetation cover types, SKR were most positively correlated to open ground and forbs while DKR were the most positively associated with high shrub cover low grass cover (native & non-native).

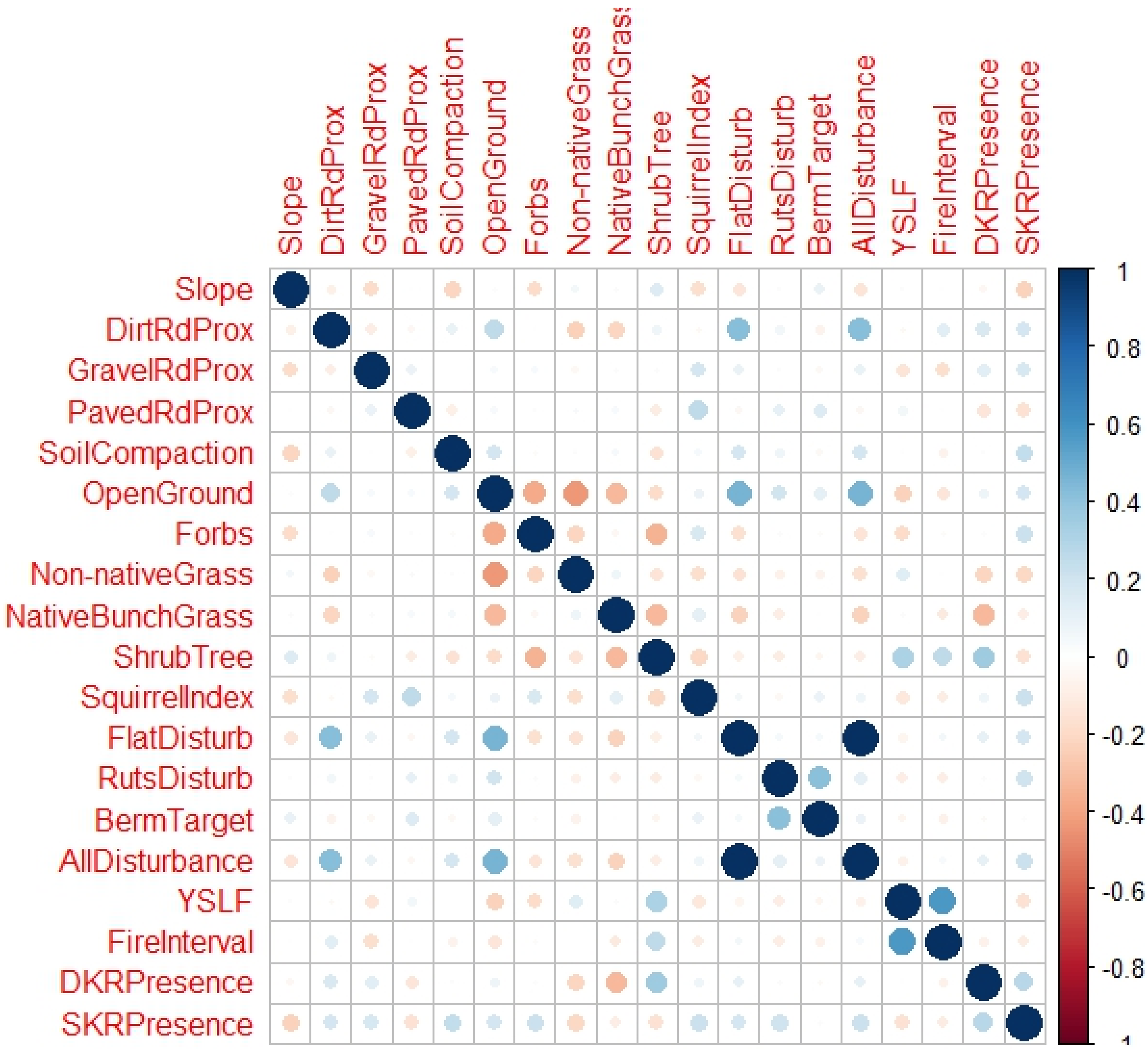


FIGURE 16. CORRELATIONS AMONG COVARIATES

Size of correlation associated with size of circle (i.e. large circle= large correlation or Pearson r-value), Blue indicates positive correlation, Orange indicates negative (see scale on right Y-axis).

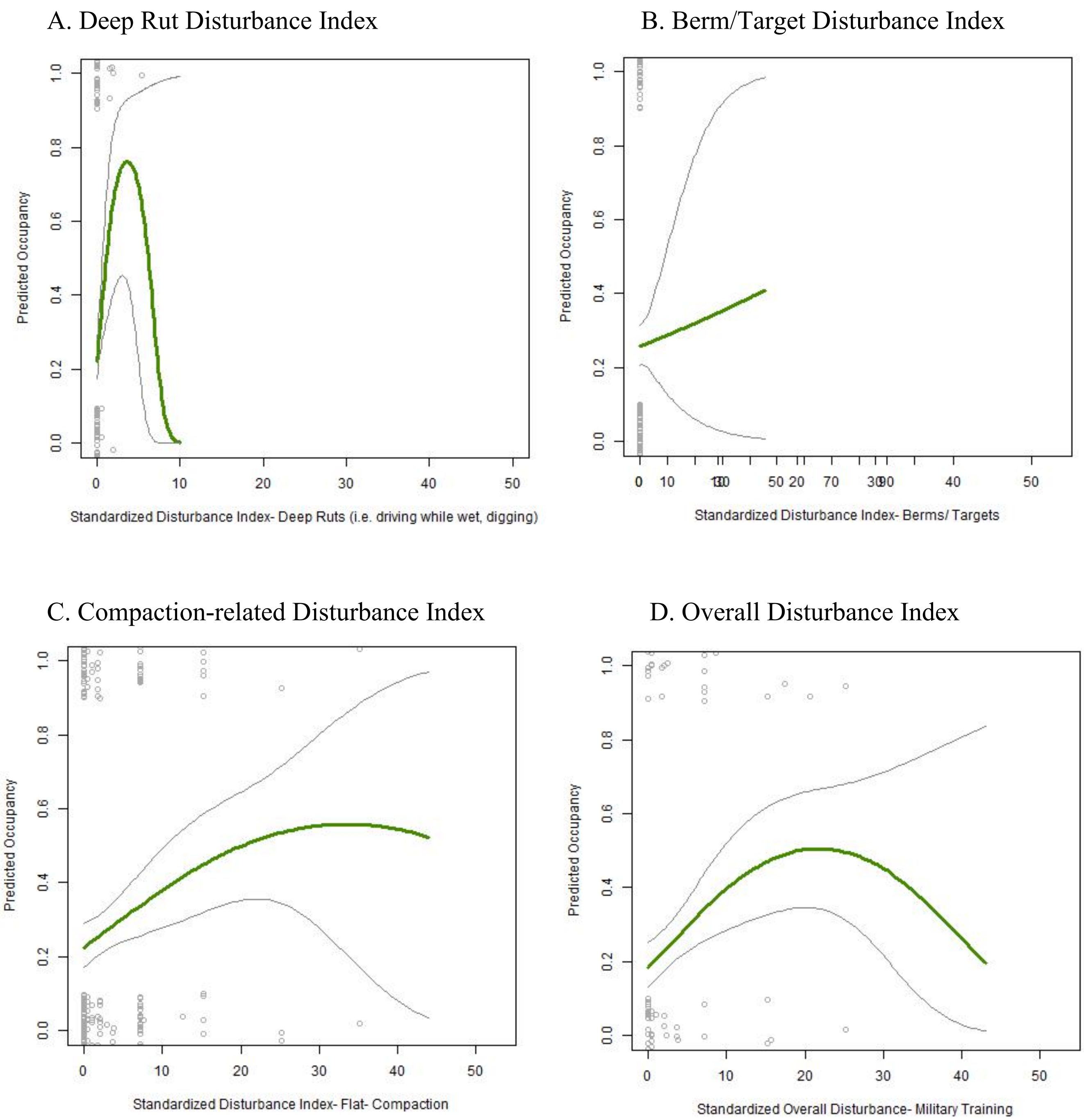
Relationship between SKR and Military Training

In 2014, we revised the military disturbance metric to be more informative with regard to the spatial scale, level, types of disturbance, and their relationship to SKR occupancy. Although no disturbance metric was a primary predictor of SKR population parameters in 2017-18, most covariates of disturbance continue to show a non-linear relationship with disturbance, so that moderate disturbance has a positive effect on SKR, but very high levels of disturbance have a negative effect. We present the relationship between SKR occupancy and the disturbance metrics in Figure 17 A-D that include 2017-18 data. The maximum level of disturbance for each type (flat/compaction, deep ruts, and targets/berms) is the maximum value of the x-axis, which represents the scenario of extreme impact over 100% of the sample plot. Overall disturbance is presented as the cumulative total of each type standardized to a 0-1 scale.

The deep rut and berm target disturbance indices were not good predictors of SKR occupancy. Very large error bars due to low numbers of plots with these types of disturbances result in low confidence in the modeling results (Figures 17A, 17B).

The Overall and Compaction-related Disturbance Index was a stronger predictor of SKR occupancy (Figure 17C). Index values from field surveys ranged from 0 to 44 (out of 53 maximum possible) within the SKR Monitoring Area. The probability SKR occupied habitat was greatest at intermediate levels of disturbance (UOR 5-30). Very low levels of disturbance (<5) and very high levels of disturbance (>30) were less suitable for SKR (Figure 17, Table 7).

Higher probabilities of SKR occupancy were associated with light to high levels of disturbance over SKR habitat. Little disturbance is positively correlated to high cover of shrubs and grasses (Figure 15) that are unsuitable for SKR and very heavy levels of disturbance are associated with habitat that does not support growth of any vegetation (forbs, grasses, and shrubs). Moderate levels of disturbance are associated with the combination of open ground and forb growth that are most suitable for SKR.



Note: lower confidence at higher values

FIGURE 17. PROBABILITY OF SKR OCCUPANCY IN RELATION TO MILITARY DISTURBANCE (2011/12- 2017/18 DATA)

TABLE 7. DISTURBANCE INDEX DESCRIPTIONS FOR COMPACTION RELATED IMPACTS TO SKR HABITAT.

GREEN HIGHLIGHTED VALUES REPRESENT HIGHER PROBABILITIES OF SKR OCCUPANCY.

Spatial Extent (% Area Affected)	Disturbance Level (Description)	Total Score
0-100%	None	0
1-10%	Light disturbance (tire tracks, foot traffic) with abundant plant cover	0.5
11-25%	Light disturbance (tire tracks, foot traffic) with abundant plant cover	2
26-50%	Light disturbance (tire tracks, foot traffic) with abundant plant cover	4
50-74%	Light disturbance (tire tracks, foot traffic) with abundant plant cover	6
≥75%	Light disturbance (tire tracks, foot traffic) with abundant plant cover	9
1-10%	Mid-level disturbance (tire tracks, foot traffic), reduced plant cover	1
11-25%	Mid-level disturbance (tire tracks, foot traffic), reduced plant cover	4
26-50%	Mid-level disturbance (tire tracks, foot traffic), reduced plant cover	8
50-74%	Mid-level disturbance (tire tracks, foot traffic), reduced plant cover	13
≥75%	Mid-level disturbance (tire tracks, foot traffic), reduced plant cover	18
1-10%	Heavy disturbance (tire tracks, dirt road, bivuac site, heavily used/compacted). No plants	2
11-25%	Heavy disturbance (tire tracks, dirt road, bivuac site, heavily used/compacted). No plants	7
26-50%	Heavy disturbance (tire tracks, dirt road, bivuac site, heavily used/compacted). No plants	15
50-74%	Heavy disturbance (tire tracks, dirt road, bivuac site, heavily used/compacted). No plants	25
≥75%	Heavy disturbance (tire tracks, dirt road, bivuac site, heavily used/compacted). No plants	35
≥50%	Paved road/cement- no soil	53
green = UOR: SKR more likely to occupy habitat at 0.25 ha spatial scale		
orange = SKR less likely to occupy habitat at 0.25 ha spatial scale		

Model Assumptions

Phase 1 Sign Survey

In phase 1 of the sampling, we surveyed for any potential kangaroo rat sign (burrows, tracks, and/or scat) and recorded the presence of potential sign if there was any question of kangaroo rat use. We annually test our kangaroo rat sign designation by live-trapping a subset of plots that are designated as “Unoccupied” after the sign survey. In 2017/18, there was only one plot in the discovery area where no possible kangaroo rat sign was observed. No SKR or DKR were detected by live-trapping.

Temporal Closure

The assumption of temporal closure means that if plots are occupied by SKR, they are occupied throughout the survey period and if plots are unoccupied, they are unoccupied throughout the survey period. All plots that had kangaroo rat sign or possible sign (burrows, tracks, scat) after the habitat/sign survey continued to show sign or potential sign at the beginning of the trapping period. No plots changed status in 2017/18 between the habitat/sign survey and trapping.

Discussion

Within the SKR Monitoring Area in Fall/Winter 2017/18, SKR occupied an estimated 231 ha which was an insignificant 6.6% decrease in comparison to 2016/17. Long term results indicate the amount of habitat occupied by SKR steadily increased from a low estimate of only 60 ha in 2005 to 248 ha in 2016/17, a four-fold increase, and has remained relatively stable for the past 7 years. SKR density estimates in occupied areas (11 SKR/0.25 ha) were also high in relation to historic values (1-10 SKR/0.25 ha) and have been stable and/or increasing for the past 6 years.

Occupancy models showed that open ground was a significant predictor of all parameters of SKR dynamics (occupancy, colonization, extinction). The greatest probability of SKR occupancy was with between 40 to 80% open ground. Additionally, with greater proportions of open ground, SKR were more likely to colonize habitat (that was previously unoccupied) and less likely to go locally extinct in habitat that was previously occupied. More compact soils and flat slopes were also top predictors of SKR occupancy. Compact soils may increase seed foraging efficiency for SKR and better support their burrow structures from disturbance. [Note: Our compaction meter (Lang Penetrometer) may not have the range to record subsurface compaction or levels above 20 force-pounds that may occur with extreme levels of disturbance]. Along with this, occupancy models once again showed that SKR are positively associated with forb cover (>40%). SKR have often been associated with open forb-dominated areas and have historically been shown to respond positively to habitat disturbance (e.g. Price et al. 1994, Kelt et al. 2005, Brehme et al. 2011a). Foot traffic, vehicle traffic, artillery training, and frequent fires on MCBCP serve to decrease cover of shrubs and non-native grasses and thus maintain the open ground and forb dominated habitat that is suitable for SKR.

These results along with disturbance models support that SKR more likely to occupy disturbed areas and can tolerate fairly high levels of military disturbance as long as habitat conditions remain to support forb growth. It is important to note that extreme disturbance resulting in open ground with little to no forb cover is not suitable for SKR occupancy. Also, SKR are likely to be less tolerant of ground disturbance creating deep ruts that may destroy burrows and disrupt movement.

Although total area occupied has remained very stable over the past 5+ years, it is not a static system. We have documented annual colonization and extinction dynamics within the SKR Monitoring Area. As evidenced by high levels of localized extinction and colonization among years, SKR appear to move frequently among the habitat patches within their population boundaries based upon changes in habitat suitability. SKR were more likely to colonize habitat with >40% open ground and <20% shrub cover while extinction was more likely in habitat with < 20% open ground and > 40% non-native grass cover.

Since the onset of the monitoring program in 2005, SKR density within occupied habitat has fluctuated greatly among years, ranging from 1-10 animals per 0.25 ha (Brehme et al. 2017). Densities of rodent populations are known to be highly variable within and among years (e.g. Krebs 2013). Although overall SKR occupancy and abundance should be positively associated, we expect SKR densities to be more variable due to annual fluctuations in seed resource availability and related success of breeding and recruitment during the spring, as well as past winter survivorship. Although we cannot manage climatic factors that may cause annual fluctuations in SKR density, we can manage for habitat suitability. Proper habitat management will have positive effects on area occupied by SKR, overall abundance, and persistence.

The Juliett Training Area is largely isolated from the larger central MCBCP SKR population by the Santa Margarita River. However, it borders NWS Fallbrook, which harbors SKR. Prior to the translocation of 21 individuals in 2011, we had not documented SKR within the Juliett Training Area since 2006. We hypothesized the extinction of this SKR population was related to overgrowth of annual grasses (thick grass mats) and shrubs (Brehme et al. 2010, 2011a, 2013a, b). As of November 2016, SJM Biological Consultants (SJMBC) tagged >164 SKR individuals originating from the founder population (Steve Montgomery, pers. Comm) and the fence around the release enclosure was removed in 2017. In April 2018 (delayed trapping from gas line closure), we increased the survey effort in Juliett to 18 plots to better track annual spatial trends for this population. This included one plot that was in the fenced in area. This year, we documented SKR presence in 8 plots (PAO estimate 0.44, SE= 0.12) and captured 55 individual SKR of which 1 was previously tagged by USGS and 2 were previously tagged by SJMBC. The low number of recaptures likely indicates continued recruitment at Juliett. For comparison, we captured 71 individual SKR of which 15 were previously tagged by SJMBC in 2016/17. We will continue to annually monitor proportion area occupied and relative capture numbers on the 18 survey plots at this site.

The Dulzura kangaroo rat (DKR) continues to be slightly more widespread than SKR across the Monitoring Area. In 2017/18, DKR were detected on 3 more plots in comparison to SKR (52 vs. 49). However, SKR were more abundant DKR in 2017/18 (Total captures: 271 DKR vs. 304 SKR). DKR were regularly detected in areas both with and without shrub cover and were captured in 18 plots where we also captured SKR. In areas with shrub cover, DKR are much more common than SKR. This was further supported in 2017/18 by a strong positive correlation between DKR occupancy and shrub cover.

Considerations

Habitat

SKR largely occur within heavily used impact areas and artillery ranges. These areas are also vital areas for training military personnel. For SKR management, regular disturbance via military training, fire management, and vegetation thinning up to a level that still supports abundant forb growth over non-native grasses and shrubs would be expected to benefit SKR. Foot traffic, vehicle traffic, artillery training, and frequent fires on MCBCP serve to decrease cover of shrubs and non-native grasses and thus maintain the open ground and herb/forb dominated habitat that is suitable for SKR. Our new military disturbance measures show that SKR are more likely to occupy disturbed areas and can tolerate moderate levels of military disturbance as long as habitat conditions remain to support healthy forb growth. Avoidance of activities such as vehicle use and bivouacking may be considered immediately after rain to prevent tire ruts in the habitat and to minimize extreme soil compaction.

Management efforts within the Juliett Management Area (e.g. prescribed fire, mowing, chemical treatment) have been successful in increasing the habitat suitability for SKR. A lack of management will very likely result in a reinvasion by annual grasses and increased shrub growth that are not suitable for SKR. In 2017/18, the Juliett monitoring area averaged less than 20% open ground which is associated with an increased risk of local SKR extinction. Continued management and regulated military use of the Juliett SKR Management Area should restore and maintain an open forb dominated habitat. Although large bivouacking operations have opened up some habitat at this site, overuse of the Management Area is a concern due to large areas of soil compaction resulting in lack of forb growth, as well as lights and noise during nocturnal activity periods. That said, all data to date support that some consistent disturbance (military, fire, etc.) is better than no disturbance for the chance of continued SKR persistence at this site. Coordination of SKR habitat management with adjacent Fallbrook NWS may also increase connectivity to the larger Fallbrook SKR population.

Future Studies

Targeted studies may better inform management and resiliency of SKR. We recommend studying the movement dynamics of SKR within MCBCP. Seasonal or year-long radio telemetry studies would generate information on SKR movement patterns in relation to demographic variables (i.e. sex, age, and population density) as well as habitat and disturbance variables (i.e. vegetation structure, roads, military training). By documenting movement in relation to training activities, this would directly inform the Base on effect of military training on SKR.

The relationship between SKR and the sympatric DKR is not fully understood. Negative associations may be due to differences in habitat, seed selection, and/or behavior. We now have and are gathering sufficient data to understand these dynamics better by employing dynamic 2-species occupancy models. These will allow us to understand if local spatial dynamics of these 2 species are purely habitat driven or if there is an interaction between species and if so, to what extent. We recommend funding this type of analysis in the future to better understand the relationship between SKR and DKR and the implications for management of SKR on Base.

Understanding the relationship between seed resources and SKR population dynamics could inform habitat management to help ensure the long-term persistence of the species. We are currently developing a genetic library and protocol to identify the diet of rodents from their scat. We propose to analyze the diet of SKR and co-occurring species (such as DKR) in relation to available resources. A complete study would require extra live-trapping to document seasonal resource availability, resource use, and recruitment. Results could lead to ensuring minimum cover of specific plant species that are directly linked with SKR reproductive success and density.

Monitoring Protocol

The purchase and use of more accurate soil penetrometers with a greater range for future SKR monitoring will allow us to better understand the positive relationship between SKR and high levels of soil compaction.

We recommend the Monitoring Area should be revised if deemed necessary every 5-10 years to incorporate new detections outside of the monitoring area and potentially eliminate areas where we are prohibited access even with an EOD escort. The next potential revision is scheduled to occur after the 2020/21 monitoring season. The Base may want to consider incorporating the two SKR detections and adjacent suitable habitat within Kilo One to the SKR Monitoring Area. This would result in 13.4 ha (2.1%) increase from 628.4 ha to 641.8 ha (Figure 18). To account for the change in area, 2 monitoring plots could be added and an equivalent amount of area inaccessible due to ongoing safety restrictions could be removed. Potential revision considerations will be updated with any new SKR detections as part of this annual report.

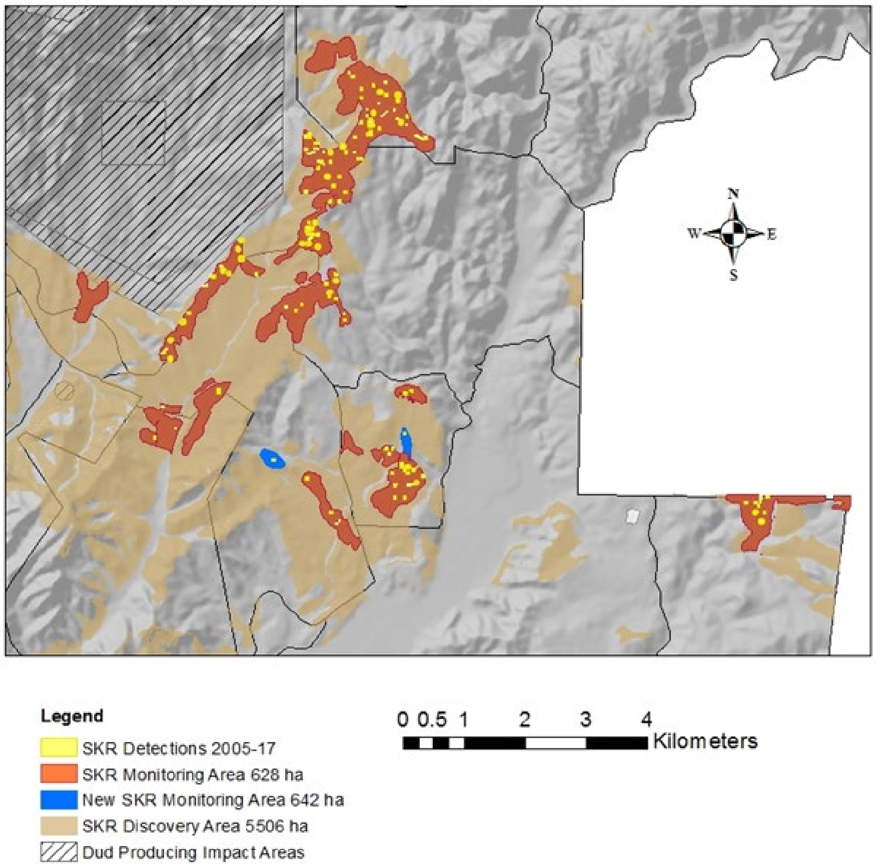


FIGURE 18. POTENTIAL REVISION CONSIDERATIONS TO SKR MONITORING AREA

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Appendix 1: Model Comparison All Years: Occupancy

model	negLogLike	nPars	n	AIC	delta	AICwt	
p(Night1)psi(SoilComp +Slope+ OG^2 +Forbs)	989.33	10	338	1998.66	0.00	0.99	*top model*
p(Night1)psi(SoilComp +OG^2 +Forbs)	994.92	9	338	2007.84	9.18	0.01	
p(Night1)psi(Slope+ OG^2 +Forbs)	996.04	10	338	2012.08	13.42	0.00	
p(Night1)psi(Slope+ DKR)	1004.43	7	338	2022.87	24.21	0.00	
p(Night1)psi(OG^2+ Forbs)	1003.58	8	338	2023.16	24.50	0.00	
p(Night1)psi(SoilComp+ Slope)	1005.98	7	338	2025.95	27.29	0.00	
p(Night1)psi(SoilComp+ DKR)	1006.04	7	338	2026.08	27.42	0.00	
p(Night1)psi(SoilComp+ Forbs)	1006.40	7	338	2026.79	28.13	0.00	
p(Night1)psi(Slope+ OG^2)	1006.35	8	338	2028.71	30.05	0.00	
p(Night1)psi(SoilComp+ NNG)	1007.54	7	338	2029.07	30.41	0.00	
p(Night1)psi(Slope+ NNG)	1008.75	7	338	2031.49	32.83	0.00	
p(Night1)psi(SoilComp+ OG^2)	1008.67	8	338	2033.33	34.67	0.00	
p(Night1)psi(DKR+ Forbs)	1010.77	7	338	2035.54	36.88	0.00	
p(Night1)psi(Slope+ Forbs)	1011.23	7	338	2036.47	37.81	0.00	
p(Night1)psi(DKR+ OG^2)	1011.75	8	338	2039.51	40.85	0.00	
p(Night1)psi(DKR+ NNG)	1012.99	7	338	2039.99	41.33	0.00	
p(Night1)psi(SoilComp10)	1014.18	6	338	2040.35	41.69	0.00	
p(Night1)psi(Slope)	1014.80	6	338	2041.60	42.94	0.00	
p(Night1)psi(NNG+ Forbs)	1014.57	7	338	2043.14	44.48	0.00	
p(Night1)psi(DISI)	1017.34	6	338	2046.68	48.02	0.00	
p(Night1)psi(OG^2+ NNG)	1015.48	8	338	2046.97	48.31	0.00	
p(Night1)psi(OG^2)	1017.70	7	338	2049.40	50.74	0.00	
p(Night1)psi(NNG)	1018.73	6	338	2049.47	50.81	0.00	
p(Night1)psi(Forbs)	1019.02	6	338	2050.04	51.38	0.00	
p(Night1)psi(DIST^2)	1018.19	7	338	2050.38	51.72	0.00	
p(Night1)psi(Squirrel)	1019.51	6	338	2051.03	52.37	0.00	
p(Night1)psi(Paved)	1020.02	6	338	2052.04	53.38	0.00	
p(Night1)psi(Shrub)	1020.59	6	338	2053.19	54.53	0.00	
p(Night1)psi(FLATD)	1020.79	6	338	2053.59	54.93	0.00	
p(Night1)psi(Dirt)	1021.31	6	338	2054.61	55.95	0.00	
p(Night1)psi(Gravel)	1021.52	6	338	2055.04	56.38	0.00	
p(Night1)psi(RdProx)	1022.11	6	338	2056.22	57.56	0.00	
p(Night1)psi(YSLF)	1022.21	6	338	2056.43	57.77	0.00	
p(Night1)psi(PG^2)	1022.79	7	338	2059.58	60.92	0.00	
p(Night1)psi(FireInt)	1024.09	6	338	2060.19	61.53	0.00	
p(Night1)psi(.)	1025.38	5	338	2060.75	62.09	0.00	*null model*
p(Night1)psi(SunIndex)	1024.98	6	338	2061.96	63.30	0.00	
p(Night1)psi(BERMT)	1025.36	6	338	2062.73	64.07	0.00	

n includes 2011 perm plots + random and discovery plots all years with complete covariate data

^2 indicates squared covariate in model (cov + cov^2)

OG= Open Ground, NNG= Non-native grass, YSLF= Years Since Last Fire, RDProx= Road Proximity

BermD=Berm Disturbance, RutD= Rut Disturbance, FlatD=Flat Disturbance (compaction), Disturb= all 3 disturbance types additive

Appendix 2: Model Comparison All Years: Colonization

model	negLogLike	nPars	n	AIC	delta	AICwt	
p(Night1)col(YOpenGrd+ YShrub)	544.65	7	77	1103.29	0.00	0.90	*best model*
p(Night1)col(YOpenGrd)	547.81	6	77	1107.61	4.32	0.10	
p(Night1)col(YSLF + YShrub)	553.22	7	77	1120.44	17.14	0.00	
p(Night1)col(YSLF)	555.72	6	77	1123.43	20.14	0.00	
p(Night1)col(YShrub)	556.43	6	77	1124.86	21.57	0.00	
p(Night1)col(YSoil)	557.14	6	77	1126.28	22.99	0.00	
p(Night1)col(YDIST)	557.28	6	77	1126.56	23.26	0.00	
p(Night1)col(YFlatD)	557.44	6	77	1126.87	23.58	0.00	
p(Night1)col(YSquirrel)	558.44	6	77	1128.89	25.59	0.00	
p(Night1)col(YNNG)	558.79	6	77	1129.58	26.28	0.00	
p(Night1)col(YForbs)	558.97	6	77	1129.94	26.64	0.00	
p(Night1)col(YBermT)	559.75	6	77	1131.51	28.21	0.00	
p(Night1)col(Paved)	559.85	6	77	1131.71	28.41	0.00	
p(Night1)col(.)	560.95	5	77	1131.90	28.61	0.00	*null model*
p(Night1)col(Slope)	560.42	6	77	1132.84	29.55	0.00	
p(Night1)col(YRutD)	560.56	6	77	1133.12	29.83	0.00	
p(Night1)col(YDKR)	560.71	6	77	1133.42	30.13	0.00	
p(Night1)col(YFireInt)	560.78	6	77	1133.55	30.26	0.00	
p(Night1)col(SunIndex)	560.79	6	77	1133.58	30.29	0.00	
p(Night1)col(Dirt)	560.80	6	77	1133.60	30.31	0.00	
p(Night1)col(RdProx)	560.90	6	77	1133.79	30.50	0.00	
p(Night1)col(Gravel)	560.90	6	77	1133.80	30.51	0.00	
p(Night1)col(YPG)	560.94	6	77	1133.88	30.58	0.00	
p(Night1)col(Stratum)	560.95	6	77	1133.90	30.61	0.00	
n includes all perm plots 2010/11-2017/18 with complete data							
Y before covariate indicates it is a yearly covariate (changes every year), ^2 indicates squared covariate in model (cov + cov^2)							
OG= Open Ground, NNG= Non-native grass, YSLF= Years Since Last Fire, RDProx= Road Proximity							
BermD=Berm Disturbance, RutD= Rut Disturbance, FlatD=Flat Disturbance (compaction), Disturb= all 3 disturbance types additive							

Appendix 3: Model Comparison All Years: Extinction

model	negLogLike	nPars	n	AIC	delta	AICwt	
p(Night1)col(YOpenGrd+ YShrub)	544.65	7	77	1103.29	0.00	0.90	*best model*
p(Night1)col(YOpenGrd)	547.81	6	77	1107.61	4.32	0.10	
p(Night1)col(YSLF + YShrub)	553.22	7	77	1120.44	17.14	0.00	
p(Night1)col(YSLF)	555.72	6	77	1123.43	20.14	0.00	
p(Night1)col(YShrub)	556.43	6	77	1124.86	21.57	0.00	
p(Night1)col(YSoil)	557.14	6	77	1126.28	22.99	0.00	
p(Night1)col(YDIST)	557.28	6	77	1126.56	23.26	0.00	
p(Night1)col(YFlatD)	557.44	6	77	1126.87	23.58	0.00	
p(Night1)col(YSquirrel)	558.44	6	77	1128.89	25.59	0.00	
p(Night1)col(YNNG)	558.79	6	77	1129.58	26.28	0.00	
p(Night1)col(YForbs)	558.97	6	77	1129.94	26.64	0.00	
p(Night1)col(YBermT)	559.75	6	77	1131.51	28.21	0.00	
p(Night1)col(Paved)	559.85	6	77	1131.71	28.41	0.00	
p(Night1)col(.)	560.95	5	77	1131.90	28.61	0.00	*null model*
p(Night1)col(Slope)	560.42	6	77	1132.84	29.55	0.00	
p(Night1)col(YRutD)	560.56	6	77	1133.12	29.83	0.00	
p(Night1)col(YDKR)	560.71	6	77	1133.42	30.13	0.00	
p(Night1)col(YFireInt)	560.78	6	77	1133.55	30.26	0.00	
p(Night1)col(SunIndex)	560.79	6	77	1133.58	30.29	0.00	
p(Night1)col(Dirt)	560.80	6	77	1133.60	30.31	0.00	
p(Night1)col(RdProx)	560.90	6	77	1133.79	30.50	0.00	
p(Night1)col(Gravel)	560.90	6	77	1133.80	30.51	0.00	
p(Night1)col(YPG)	560.94	6	77	1133.88	30.58	0.00	
p(Night1)col(Stratum)	560.95	6	77	1133.90	30.61	0.00	

n includes all perm plots 2010/11-2017/18 with complete data

Y before covariate indicates it is a yearly covariate (changes every year), ^2 indicates squared covariate in model (cov + cov^2)

OG= Open Ground, NNG= Non-native grass, YSLF= Years Since Last Fire, RDProx= Road Proximity

BermD=Berm Disturbance, RutD= Rut Disturbance, FlatD=Flat Disturbance (compaction), Disturb= all 3 disturbance types additive