Western Ecological Research Center

Stephens' Kangaroo Rat Monitoring on MCB Camp Pendleton

2005 to 2010 Multi-year Trend Analysis
And
5-year Program Review and Optimization

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Stephens' Kangaroo Rat Monitoring on MCB Camp Pendleton: 2005 to 2010 Multi-year Trend Analysis and 5-year Program Review and Optimization.

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Executive Summary

In 2005, we implemented a new 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. 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 the Stephens' kangaroo rat and/or the Dulzura kangaroo rat (*D. simulans,* DKR). In order to provide continuity with previous monitoring efforts, we also live-trapped 10 SKR grids that were historically monitored biennially from 1996 to 2002.

After five years of the current program, we present a multi-faceted report on SKR monitoring with: 1) Multiyear trend analysis for the past five years (2005 to fall/winter 2009/2010). This includes assessment of factors associated with SKR occupancy, probability of detection, colonization and extinction; and 2) A monitoring program evaluation, optimization, and recommendations for future monitoring. This includes re-evaluation of the sampling area and power analyses of current and proposed alternate sampling scenarios to detect changes in the occupancy of SKR on Base.

Multi-year Trend Analysis:

Overall, the estimated area occupied by SKR in 2009-10 on MCB Camp Pendleton has been relatively stable since 2007-8 (within a single standard error) and is greater than the initial years of monitoring at MCBCP in 2005-6 and 2006-7. Within the high suitability stratum (which defines almost all know SKR habitat), we estimated SKR occupied 118.4 ha (SE=39.1) in 2009-10, in comparison to a high estimate of 147.3 ha (SE=39.1) in 2008 and low estimate of 60.0 ha (SE=24.2) in 2005. We detected no SKR in the medium suitability stratum. In areas occupied by SKR in 2009-10, animal

densities were higher than all previous years at 30.2 and 47.1 SKR/ha, which is considered "high" for this species (Tetratech and SJM Biological Consultants 1999). The positive trend suggests a continued pattern of high survivorship and colonization of SKR in the high suitability stratum

This was the first year we were able to analyze all of the data in a multi-state framework and established that SKR are positively associated with the proportion of open ground and forbs, military disturbance, years since last fire, and greater fire frequency.

The proportion of open ground and forbs was a positive predictor of SKR. The odds of SKR occupying a plot averaged 2.3 times greater (95% CI: 1.6-3.2) for every 20% increase in open ground and forbs (0% vs. 20%, 20% vs. 40%, etc.), so a plot with 100% open ground and forbs was 62 times (95% CI: 12.0-144) more likely to be occupied by SKR than a plot with none.

The index of military disturbance was a positive predictor in two of the four top models. This index ranges from 0 to 5 and is the sum of disturbance observed from military vehicle tracks (0-2), artillery (0-2), and foot traffic (0-1). Both the raw index and square root transformed index performed well, indicating that the relationship may be linear or nonlinear. In the linear model, a plot with the highest disturbance level (5) was 8.5 times (95% CI: 1.7-43) more likely to be occupied by SKR than a plot with no military disturbance. In the nonlinear model, a plot with the highest disturbance level (5) was 3.6 times (95% CI: 0.7-18.4) more likely to be occupied by SKR than a plot with no military disturbance.

The number of years since the last fire was a negative predictor in one of the four top models. The odds of SKR occupying a plot averaged 3.4 times lower (95% CI: 1.0-11.3) for every ten years without a fire, so that a plot that had not burned since 1974 had 107 times (95% CI: 1.1 -10,070) lower odds of being occupied by SKR than a plot that had recently burned. There was moderate support for the model containing the square root of fire frequency. The odds of SKR occupying a plot averaged 2.6 times lower (95% CI: 0.7-9.9) in habitat that burned an average of every ten years versus habitat that burned more frequently every year. The highest level of SKR occupancy was in sample plots that burned an average of every 2 to 4 years.

All of the covariates in the top models were significantly correlated to one another, so that increased military disturbance was associated with more fires and greater proportion of open ground and forbs.

SKR have long been associated with open forb-dominated areas. The results since 2005 for SKR on MCBCP support this and further show the direct positive effects of disturbance from military training and fires. In fact, since 2005, SKR have increased in all disturbed military training areas while decreasing in the conservation area of Juliett, where disturbance was minimal in that period. Current habitat management actions in Juliett, such as implementation of regular prescribed burning of annual grasses and shrubs, should create habitat more suitable for the species.

Monitoring Program Evaluation:

In originally designing the monitoring protocol, we estimated that SKR occupancy in the high suitability stratum (740 ha) would be ~50% or 370 ha (Brehme et al. 2006). This assumption was based upon numbers reported in 1996 and 1997, where SKR occupied an estimated ~324 ha (800 acres, Montgomery et al. 1997) and 293 ha (724 acres, Tetratech and SJM Biological Consultants 1999) based upon extensive burrow surveys and some supplemental trapping. Note that the loose boundaries around the SKR habitat that were identified during these previous efforts were used to define our 740 ha "high suitability" stratum for SKR sampling. We discuss possible and probable reasons for this disparity in our 2005 SKR report (Brehme and Fisher 2008). However, the implications of these results are that SKR are likely much rarer on MCB Camp Pendleton than previously thought, greatly increasing the importance of active management for this species along with these monitoring efforts.

In the high suitability stratum, our estimate of proportion of area occupied over the past three years has been less than 0.20 (or 20%). Recommended occupancy is between 0.2 to 0.8 (with 0.5 ideal) to have good precision for parameter estimates (i.e., occupancy, detection probability, colonization, and extinction) and sufficient power to model habitat and environmental covariates (MacKenzie et al. 2006).

After five years of monitoring, we have revised this stratum to encompass all known SKR populations on Base. We propose this to become the focal "Monitoring Area" totaling 628 ha. For the revision, we added nearby suitable habitat and all known recent occurrences of SKR. We excluded unsuitable habitat and areas that are thought to be extirpated (i.e. HOLF in Bravo, Range 210 Area).

In addition, we performed a power analysis comparing several sampling designs with different allocations of effort. We found all of our alternate designs had reasonable power to detect a 25% decrease in occupancy over a 5-year period (62 to 100%, depending upon background colonization and extinction equilibrium dynamics). From our results, we recommend a sampling design that is a reasonable balance between monitoring and discovery efforts. The design will significantly increase our ability to detect trends in SKR over time, as the number of permanent plots will double from 50 to 100 (33-66% of total effort). An additional 17% of effort will be used to sample random plots within the monitoring area to get a more complete understanding of the patchy nature of SKR occupancy over time. Finally, rather than allocating half of our effort to discovery each year (i.e. sampling where SKR are very unlikely to occur), we propose to continue with a more reasonable 17% of effort to this task.

Along with a continued effort to discover SKR populations outside of the monitoring area, the result of our recommendations should be higher and more precise SKR occupancy estimates, more complete coverage of SKR habitat, greater power to detect trends over time, and greater power to model SKR habitat occupancy dynamics. This will allow for a better understanding of the importance of habitat characteristics, environmental factors, fire and military disturbance in the occupation and persistence of SKR. This will also better lay the framework for an information feedback loop between monitoring and management for SKR on the Base.

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" (MCB Camp Pendleton 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 implement this monitoring program in 2005 (Brehme et al. 2006).

After five years of the current program, we present a multi-faceted report on SKR monitoring with: 1) Multiyear trend analysis for the past five years (2005 to fall/winter 2009/2010), and recommendations for management. This includes assessment of factors associated with SKR occupancy, probability of detection, colonization and extinction and 2) A monitoring program evaluation, optimization, and recommendations for future monitoring. This includes re-evaluation of the sampling area and power analyses of current and proposed alternate sampling scenarios to detect changes in the occupancy of SKR on Base.

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 in 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, 1994a, 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. 1994b, 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 from off road vehicle use.
4. Lack of open habitat and/or corridors for dispersal.

The average life span of a Stephens' kangaroo rat 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 125,000 acres 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 units" of SKR, one of 11 populations units targeted for conservation by the U.S. Fish and Wildlife Service (1997). SKR habitat within MCBCP, along with the neighboring Fallbrook Naval Weapons Station, was designated as one of five "High Priority" reserves for 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 a large number of dirt roads, paths, and firebreaks that support 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 may result in direct mortality and/or destruction of habitat.

Population Monitoring

In order 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) 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). There were large variations in the number of captures and number of burrows among grids and years.

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, we designed 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.

This program was largely designed during a two-day scientific workshop 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.

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 Dulzura kangaroo rat (*Dipodomys simulans*, 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 involves a complete search for any potential kangaroo sign to include burrows, tracks, and scat on all sample plots. If any potential sign is observed, at least two nights of live-trapping was conducted for the second phase. The live-trapping results are used to calculate a density index.

We designed this program to be compatible with the SKR monitoring program on the adjacent Naval Weapons Station, which, together with MCBCP, encompass one of the five proposed "High Priority" Reserves for SKR by the US Fish and Wildlife Service. Because the species is rare, it was most efficient to stratify sampling effort based on the probability of occupancy or habitat suitability. Thus, 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 (Figure 1). In 2005, fifty 50m x 50m 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). Since 2006, we chose to focus our efforts solely in the medium and high suitability strata to get better estimates of occupancy. We re-sampled the same 50 plots in each strata and added another 25 + randomly chosen plots. We also continued to sample 10 plots that were monitored biennially from 1996 to 2002 in order to provide continuity with previous monitoring efforts.

Major Elements of the monitoring protocol are presented in Table 1.The program was designed to be adaptive, so that habitat quality boundaries, sample allocation, and other aspects of the protocol can be updated as new information is gained. This report contains a 5-year review and protocol optimization.

FIGURE 1. HABITAT SUITABILITY MAP FOR SKR MONITORING ON MCBCP

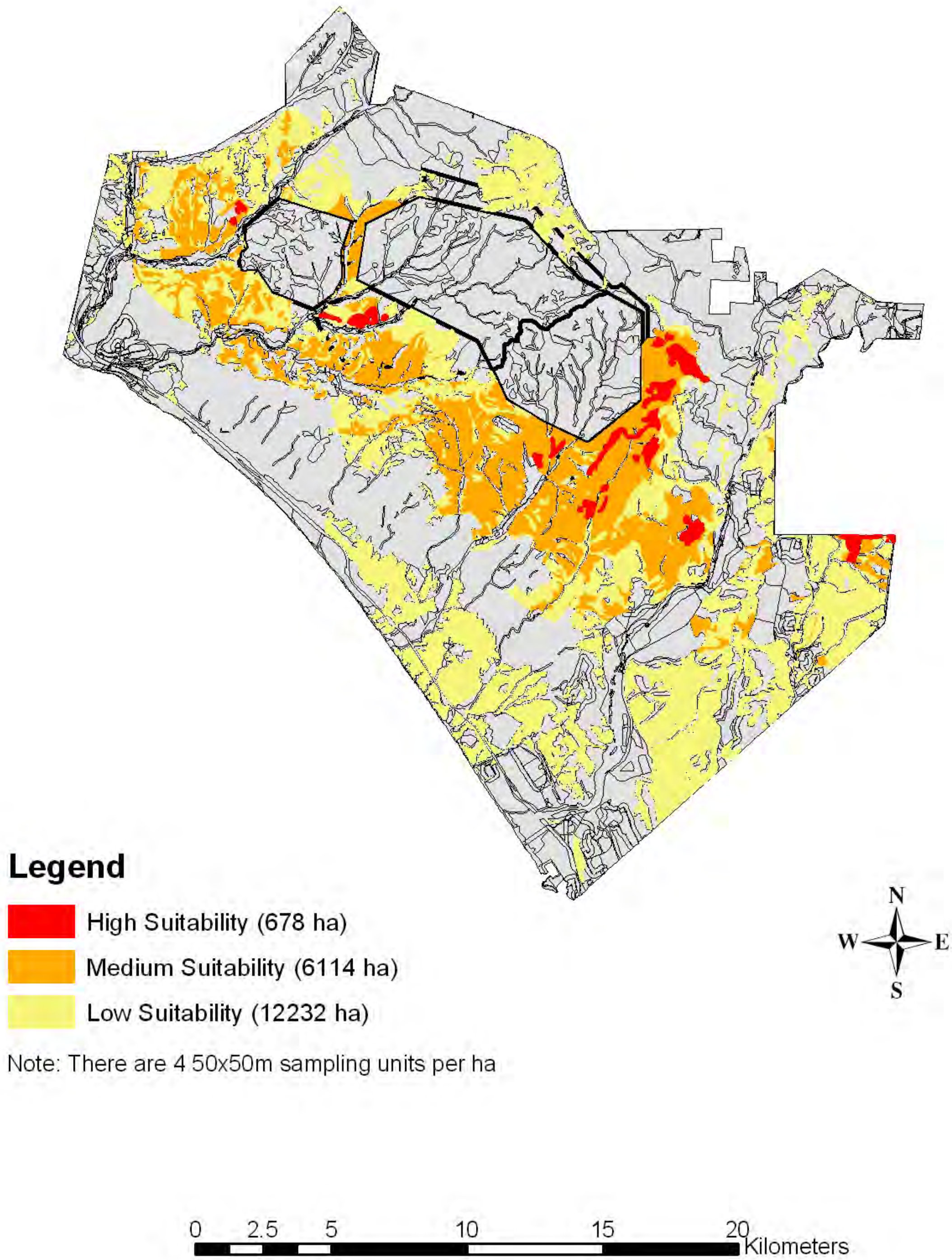


TABLE 1. MCB CAMP PENDLETON SKR MONITORING PROTOCOL ELEMENTS

Protocol Element	Purpose(s)	Procedure(s)	Timing
Habitat Suitability Model	To determine spatial extent of current and potential habitat.	Current knowledge of SKR habitat associations & distribution on MCBCP.	At onset of protocol.
	To rate habitat and stratify sampling effort based upon likelihood of occupancy	Use of GIS layers (soils, slope, vegetation, pre-existing mapped SKR habitat and capture locations, impact area boundaries).	Quality ratings to be re-evaluated every 2 to 5 years to coincide with new information
	4 strata: 1) high, 2) medium & 3) low SKR suitability & 4) 1996-2002 monitoring plots.	Groundtruthing based on aerial photographs and site visits.	
Sample Allocation	First year(s): Determine proportion area occupied within each stratum & SKR detection probabilities.	First year: 40-50 sample plots per stratum + 10 previous monitoring plots = 130-160 total sample plots	At onset of protocol.
	Second/Third year: Optimize sample allocation based on first year data.	Second year: TBS, see "Sampling Scheme: Sample Allocation"	
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 (50 m^2)	Late summer and Fall, Yearly
Burrow/ Sign Search and Habitat Characterization	To determine presence or absence of kangaroo rats	Complete survey of sample plots for any potential kangaroo rat burrows or sign	Late summer/ early Fall (Sept-Oct)
	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 (Oct-Nov)
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). Up to two active burrows with confirmed kangaroo rat scat were marked and flagged at each plot. 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, a number of 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 sent to the Soil and Plant Analysis Lab at Brigham Young University for 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. We also revisited marked and flagged individual burrows in order to gather information on use of individual burrows.

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)

Trapping Surveys

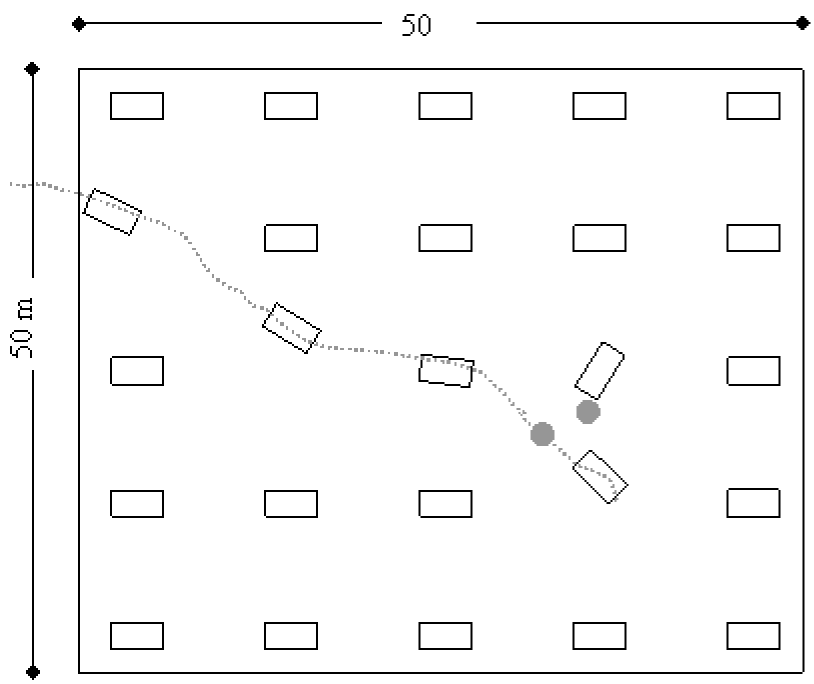
SKR occurs sympatrically, and often syntopically, with DKR on MCBCP. Both kangaroo rats are similar in size and there are no physical characteristics that distinguish SKR burrows from DKR burrows; therefore, all sample plots containing potential kangaroo rat burrows were live-trapped for a minimum of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

Twenty-five live-traps (Fifteen measuring 3×3.5×12 inches and ten measuring 4×4.5×15 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).

Trapping was conducted during the fall and winter months (October- January). 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. In 2006, we found that detection probabilities were much lower in September and October than in November and December (Brehme and Fisher 2009). Thus, we tried to conduct most of the trapping during these latter months. 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 in the afternoon 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 pulled a small number of dorsal hairs and photographed all animals identified as SKR and at least one individual identified as DKR on all occupied plots for voucher purposes. Starting in 2008, all SKR marked with a unique ear tag that will allow us to follow individuals over multiple years. All other animals were temporarily batch marked by clipping a small amount of fur from the hip area to document recaptures.

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



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

Data Analysis

Proportion Area Occupied

Because of new advances in modeling multi-year and multi-state data, this was the first time we were able to analyze data across all plots and years. Previously, we used single year two-state models with data from live-trapped plots only to estimate annual occupancy. This was due to the inability of these two-state models to incorporate the two-phase sampling data (see Brehme et al. 2006, 2007, 2009). This year, proportion area occupied (PAO) by the Stephens' kangaroo rat (SKR) on Base was estimated using the multi-year integrated habitat occupancy logistic model in program PRESENCE (MacKenzie et al. 2011.). For our purposes, it allows us to analyze the data from the two survey methods simultaneously (sign search and live-trapping) as we define the habitat states, (A) no potential sign and (B) presence of potential sign. We do not focus on the transition probabilities between the states of having potential sign or not, as this is not useful information. As with the 2-state multi-year program, we continue to focus on the parameters of proportion area occupied (Ψ), colonization (γ), extinction (ε) and detection probabilities (ρ). Thus, we set pA=pB, psiA=psiB, ε A= ε B, γ A= γ B.

For PAO modeling, we treated night and morning live-trapping sessions as individual surveys 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 2008), we tested models where ρ differed between the first two sessions and all subsequent sessions (Day 1_other). Finally, because the SJM historic plots are larger than the standard 50x50m plots, we expect the probability of detecting SKR to be higher. Thus, all models included this covariate for ρ (StratumSJM).

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 (high suitability, medium suitability, SJM historic), disturbance (index of military disturbance, years since last fire, fire frequency 1974-present), proximity to roads (Road_prox), presence of DKR (DISI), and different types of vegetative cover (shrubs, perennial grass, annual grass, 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. This has become increasingly challenging due to priorities of military readiness, and rain or fire delays. Because of this, much of our sampling took place on weekends and holidays.

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), 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.

In order 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 2009 and 2010, we surveyed 174 plots in the high and medium suitability strata and SJM historic plots (Montgomery 2002, 2003, 2004, Montgomery et al. 1997, 2005). Of these, 76 plots contained potential kangaroo rat sign (potential burrows, tracks, and/or scat) on the initial survey. Seventy-six of these plots, along with 11 plots that did not contain any observable sign, were live trapped for 2 to 4 days (4 to 8 trap events). Overall, we captured 115 SKR in 21 plots and 295 DKR in 46 plots (Table 3). All habitat and trapping surveys were completed between September 2009 and January 2010.

SKR detections were limited to the training areas immediately south of the Zulu Impact Area in the 409 Impact Area, Range 408A, Kilo 1, Kilo 2, AFA 31 in India. We did not capture SKR within the Juliette mitigation area along the border to the Fallbrook Naval Weapons Station. Maps of plot locations and SKR detections, as well as DKR detections are presented in Figures 3 and 4.

TABLE 3: SUMMARY OF 2009-10 SURVEY EFFORT AND PRESENCE OF KANGAROO RATS

			PLOTS						CAPTURES	
			Plots with potential k-rat sign			Plots with NO potential k-rat sign			Total Individuals Captured	
Stratum	No. Plots Surveyed	No. with potential k-rat sign	No. Trapped	No. with SKR	No. with DKR	No. Trapped	No. with SKR	No. with DKR	SKR	DKR
Low Suitability	0	-	-	-	-	-	-	-	-	-
Medium Suitability	81	18	16	0	6	5	0	0	0	28
High Suitability	80	48	48	15	34	6	0	1	41	240
SJM Historic	13	12	12	6	6	0	0	0	74	27
Total	174	78	76	21	46	11	0	1	115	295

FIGURE 3A. SKR DETECTIONS ON MONITORING PLOTS 2009/10

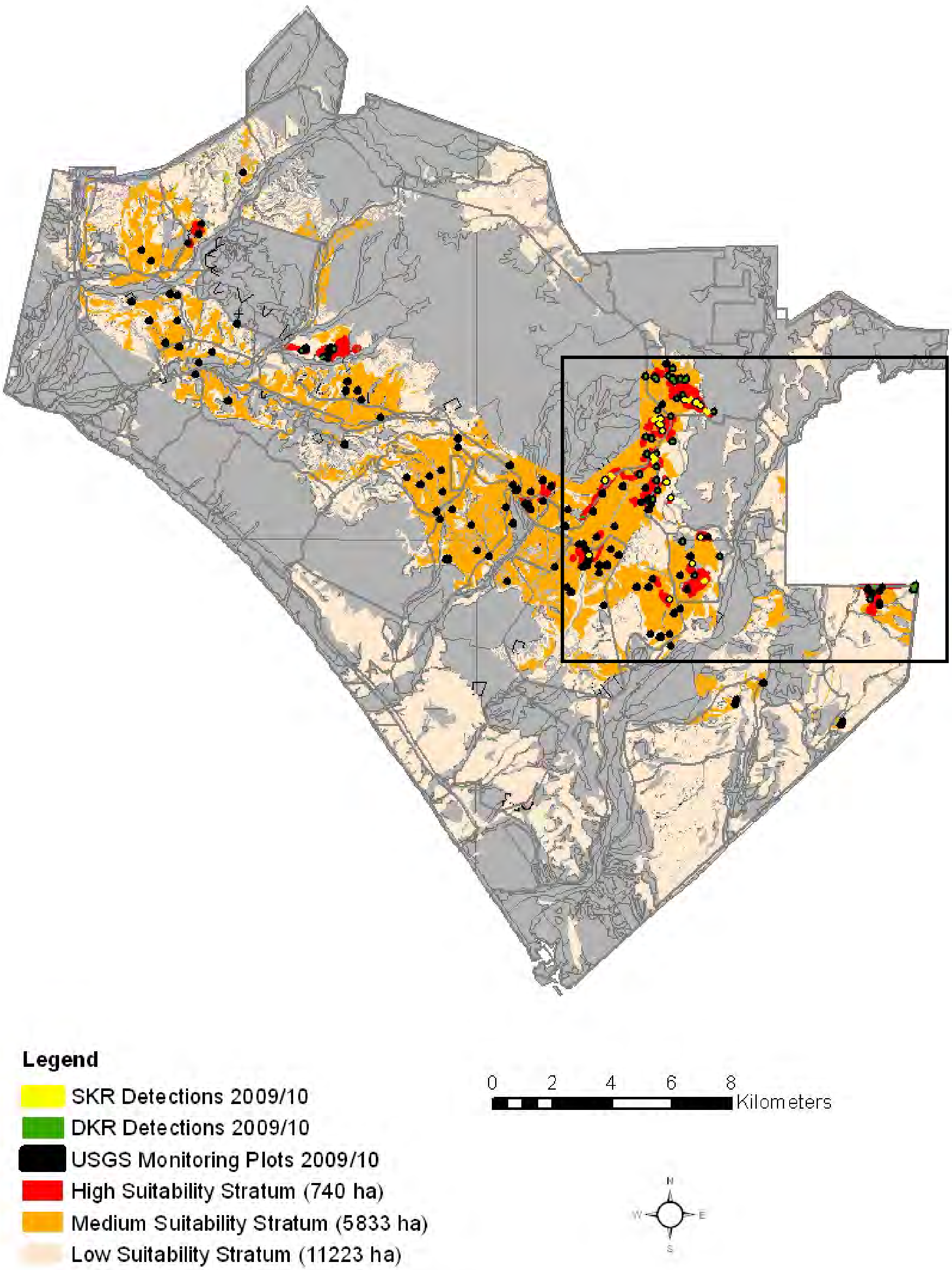


FIGURE 3B. SKR DETECTIONS ON MONITORING PLOTS 2009/10 (MAGNIFIED VIEW FROM INSET)

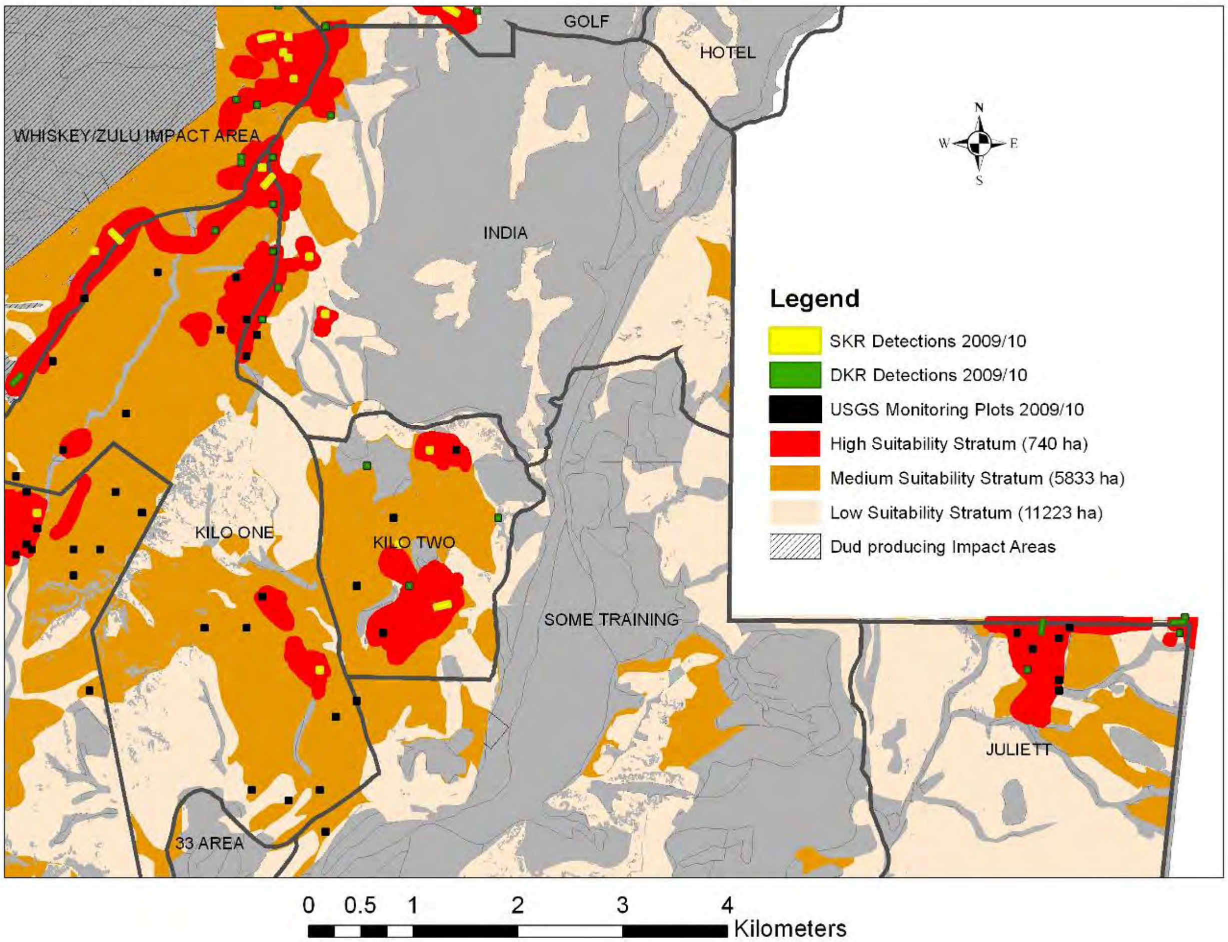


FIGURE 4A. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2010

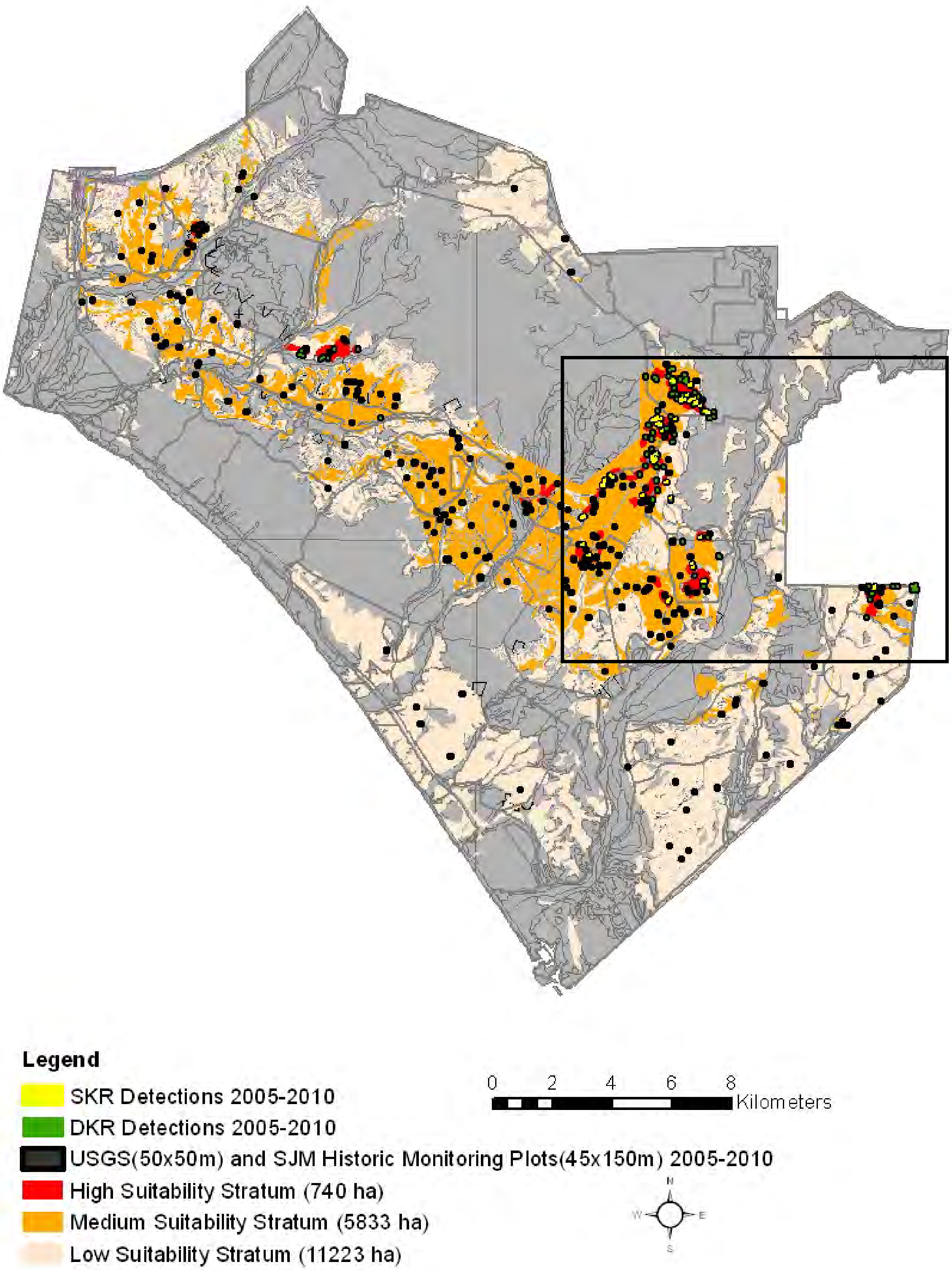
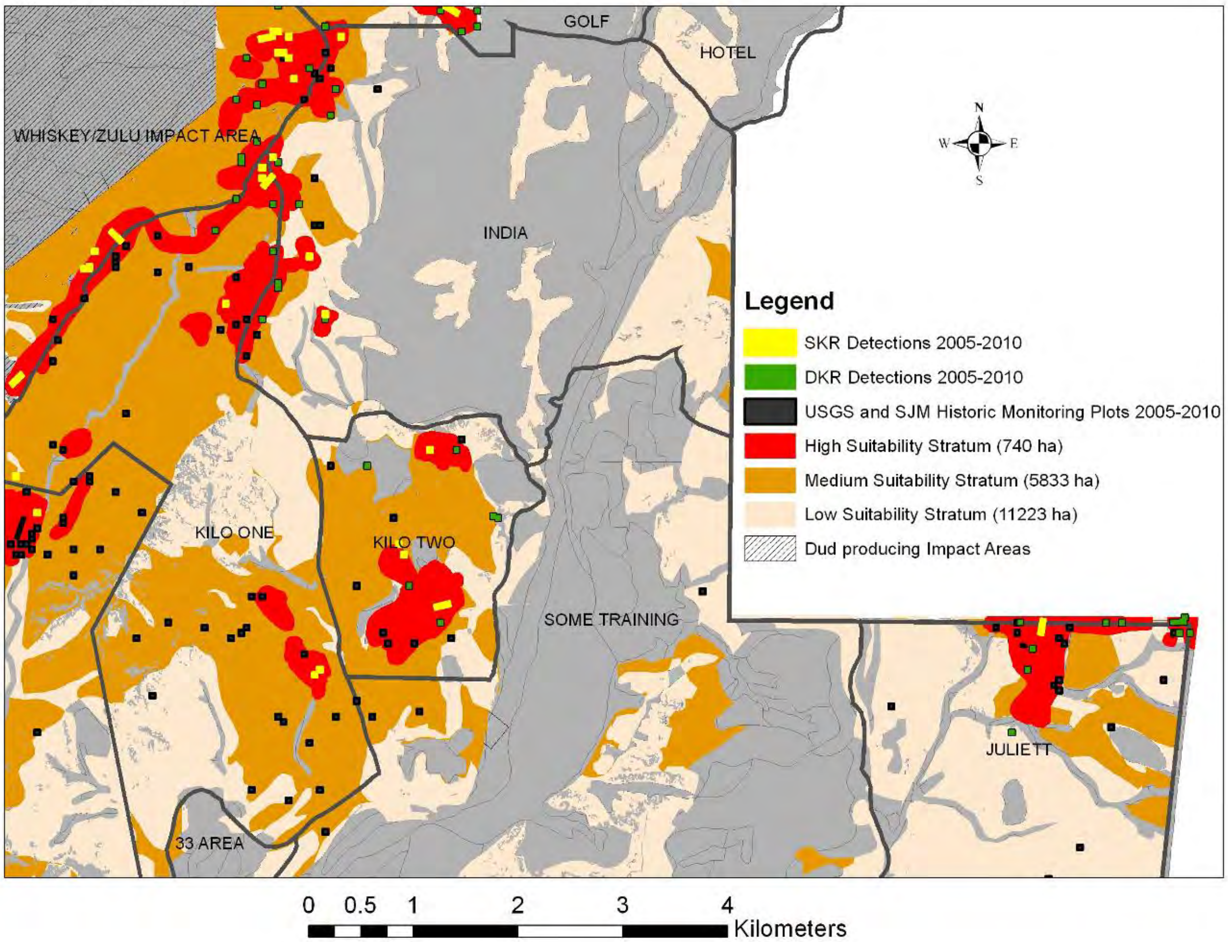


FIGURE 4B. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2010 (MAGNIFIED VIEW FROM INSET)



Results and Trends from 2005 to 2010

For the fall/winter 2009/10 season, estimates of the percentage of total area occupied by SKR were 0% and 16.0% in the medium and high suitability strata and 55.8% in the SJM historic monitoring plots. Estimates of density were 30 SKR per hectare (ha) within occupied areas of the high suitability stratum and 47 SKR/ha within occupied areas of the SJM monitoring plots.

Trends in SKR are most meaningful for the high suitability stratum, which contains almost all of the known SKR populations on the Base. Results from the high suitability stratum show SKR occupancy steadily increased for three years (60 ha in 2005-6 to 131 ha in 2007-8) and has since been relatively stable, with an estimated 118 ha occupied by SKR in the 2009-10 season (Table 4, Figure 5). Thus far, trends in density have not mirrored trends in occupancy. Annual density estimates have ranged from five to 30 SKR/ ha with a peak in 2006-7 (20 SKR/ ha) and again in 2009-10 (30 SKR/ ha) (Figure 5).

The few captures in plots within the Medium suitability stratum across the years have been in very close proximity to the high suitability stratum. This has resulted in no or very low estimates of occupancy within this stratum. Because captures are skewed to plots near the high suitability stratum, the occupancy estimates for this stratum are highly biased (Figure 5).

Trends in the SJM historic plots represent subjectively chosen areas with historically high densities of SKR, so trends may only be inferred to the area within the plots themselves. This stratum represents 13 plots totaling approximately 12 ha. Occupancy has been relatively stable for the last 5-years but with widely varying density estimates (6- 47 SKR/ ha).

The probability of detecting any SKR within the 0.25 ha sampling plots has remained very high, averaging close to perfect after two days and night of live-trapping (Figure 6). The probability of capturing an individual SKR has varied among years, but has been estimated to be greater than 0.80 after 2 days and nights of trapping (Brehme et. al. 2008, 2009, 2010). In 2009-10, however, individual capture probabilities were only ~0.20 after 2 days and nights of trapping (Figure 7). We were unable to attribute the low rate to any environmental variables. We captured many animals for the first time only on the third night of trapping. Once captured, the probability of recapture was very high at 0.88 per night (95% CI: 82-100%) Because densities of SKR were high in 2009-10, overall detection of SKR within the plots remained high.

TABLE 4. ESTIMATES FOR AREA OCCUPIED BY SKR AMONG SAMPLING STRATA IN 2009-10

	Year				
	2005-6	**2006-7**	**2007-8**	**2008-9**	**2009-10**
High Suitability Stratum					
Proportion Area Occupied	0.081 (.037)	0.096 (.041)	0.177 (.045)	0.199 (.048)	0.160 (.035)
Total Hectares Occupied	60.1 (27.5)	70.8 (29.7)	131.0 (33.3)	147.3 (39.1)	118.4 (39.1)
Density in Occupied Habitat (SKR/ha)	6.1 (0.5)	20.4 (8.7)	5.4 (0.2)	12.9 (2.9)	30.2 (13.4)
Medium Suitability Stratum*					
Proportion Area Occupied	0.046 (.029)	0.018 (.007)	0	0.034 (.023)	0
Total Hectares Occupied	267.8 (167.1)	103.7 (5.5)	0	198.3 (124.9)	0
Density in Occupied Habitat (SKR/ha)	4.3 (0.3)	0.0 (.0)	0	13.2 (0.5)	0
SJM Historic Plots					
Proportion Area Occupied	0.545 (.113)	0.543 (.123)	0.462 (.150)	0.437 (.052)	0.558 (.136)
Total Hectares Occupied	4.9 (1.0)	4.9 (1.1)	4.2 (1.4)	3.9 (0.6)	5.0 (0.6)
Density in Occupied Habitat (SKR/ha)	6.9 (0.5)	21.6 (9.2)	6.0 (0.2)	15.2 (5.0)	47.1 (20.9)

**very low confidence- zero to one plot occupied each year*

FIGURE 5. TRENDS IN OCCUPIED AREA AND DENSITY OF SKR AMONG SAMPLING STRATA FROM 2005 TO 2010 WITH 90% CONFIDENCE LIMITS

Proportion Area Occupied

Total Area Occupied (hectares)

Density in Occupied Areas (No. SKR/ hectare)

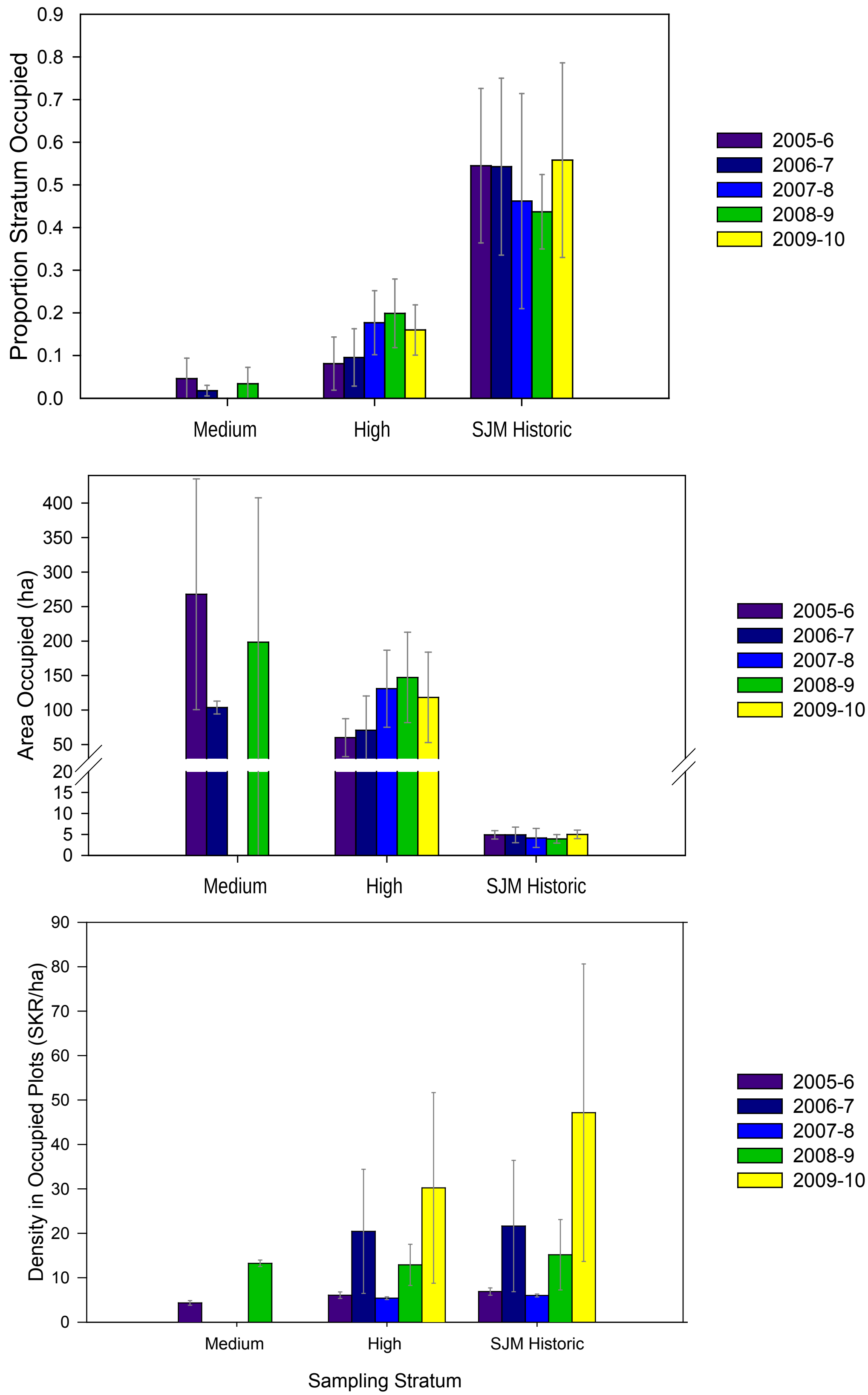


FIGURE 6. CUMULATIVE DETECTION PROBABILITY OF SKR

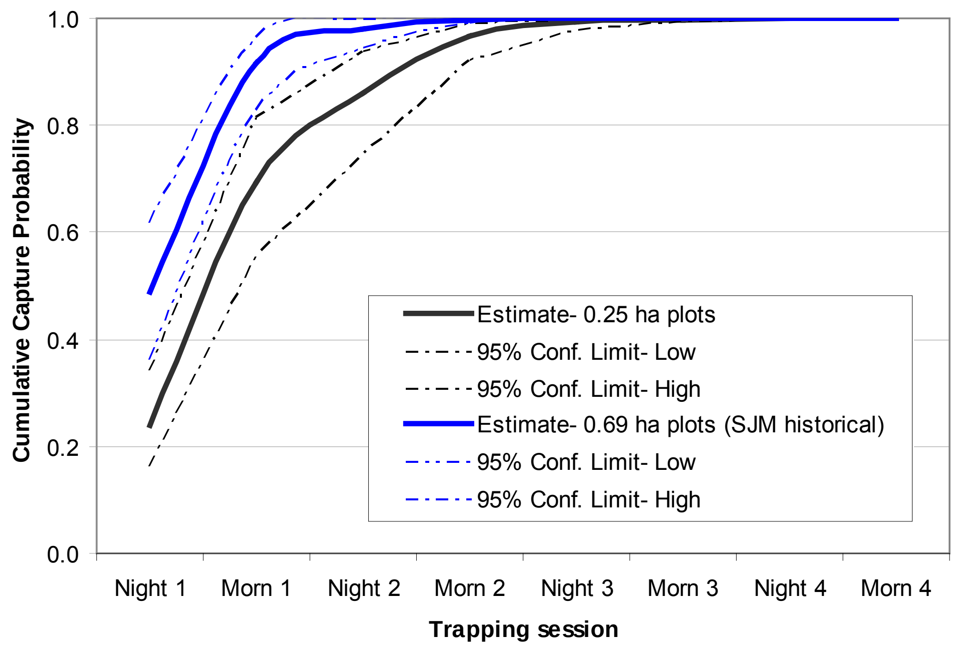
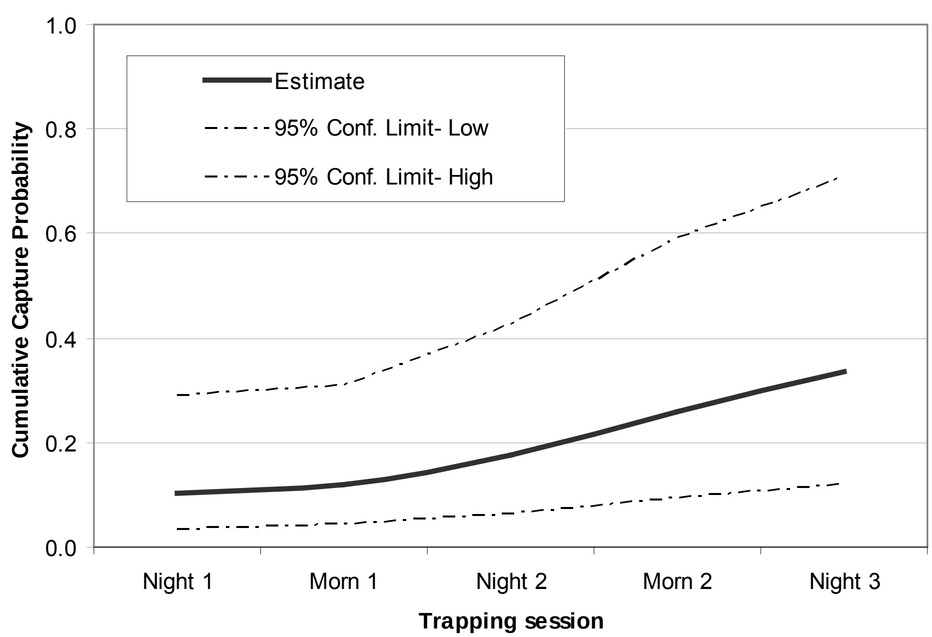


FIGURE 7. CUMULATIVE CAPTURE PROBABILITY OF INDIVIDUAL SKR



Integrated Habitat Occupancy Models

Because of new advances in modeling multi-year and multi-state data, this was the first time we were able to analyze data across all plots and years. Thus, we were able to test a wide variety of landscape and disturbance related covariates (see Methods) to explain variability in SKR occupancy across space and time.

From 2005 to 2010, four models best explained the variation in the proportion of habitat area occupied by SKR. These models all included sampling stratum and one or more of the following covariates, proportion of open ground and forbs, military disturbance, and number of years since last fire (Table 5). We present distributions of these covariates where SKR are present vs. not detected as well as the relationship between the covariate and odds of SKR occupying a plot as predicted by our models (Figures 8 to 15).

Sampling stratum (Stratum) was a primary predictor of SKR occupancy, with highest occupancy in the SJM plots and high suitability stratum. (Ex. Table 4, Figure 5).

All top models also contained the variable "proportion of open ground and forbs" (OpenGrd+Forbs) as a positive predictor of SKR occupancy. The odds of SKR occupying a plot averaged 2.3 times greater (95% CI: 1.6-3.2) for every 20% increase in open ground and forbs (0% vs. 20%, 20% vs. 40%, etc.), so a plot with 100% open ground and forbs was 62 times (95% CI: 12.0-144) more likely to be occupied by SKR than a plot with none (Figure 8 and 9).

The index of military disturbance (MilitaryDist, MilitaryDistSQRT) was a positive predictor in two of the four top models. This index ranges from 0 to 5 and is the sum of disturbance observed from military vehicle tracks (0-2), artillery (0-2), and foot traffic (0-1). Both the raw index and square root transformed index performed well, indicating that the relationship may be linear or nonlinear (i.e. the slope of the positive relationship may decrease after an intermediate level of disturbance. In the linear model, the odds of SKR occupying a plot averaged 1.5 times greater (95% CI: 1.1-2.1) for every step increase in the index, so a plot with the highest disturbance level (5) was 8.5 times (95% CI: 1.7-43) more likely to be occupied by SKR than a plot with no military disturbance. In the nonlinear model, the odds of SKR occupying a plot averaged 1.7 times greater (95% CI: 0.8-3.7) for every step increase of the square root of the index, so a plot with the highest disturbance level (5) was 3.6 times (95% CI: 0.7-18.4) more likely to be occupied by SKR than a plot with no military disturbance (Figures 10 and 11).

The number of years since the last fire (YearSinceLastFire) was a negative predictor in one of the four top models. This covariate ranges from 0 to 38 years from fire data across the Base since 1974

(Information Systems Branch, ES). The odds of SKR occupying a plot averaged 3.4 times lower (95% CI: 1.0-11.3) for every ten years without a fire, so that a plot that had not burned since 1974 had 107 times (95% CI: 1.1 -10,070) lower odds of being occupied by SKR than a plot that had recently burned (Figures 12 and 13). To better understand the role of fire disturbance on SKR habitat suitability, we also present the relationship between SKR occupancy and fire frequency (i.e. average number of years between fires. There was moderate support for the model containing the square root of fire frequency (FireFrequencySQRT). The odds of SKR occupying a plot averaged 2.6 times lower (95% CI: 0.7-9.9) in habitat that burned an average of every ten years versus habitat that burned more frequently every year. The highest level of SKR occupancy was in sample plots that burned an average of every 2 to 4 years (Figures 14 and 15).

All of the covariates in the top models were significantly correlated to one another, so that increased military disturbance was associated with more fires and greater proportion of open ground and forbs (Figure 16).

TABLE 5. PAO MODEL COMPARISON

Model	Model Comparison Criteria AIC	delta AIC	AIC weight	Model Likelihood	No. Par.	(-2*LogLike)	
pi, psi(Stratum, OpenGrd+Forb,MilitaryDist), gam(.), eps(.), p(Session, plotSize)	2560.28	0.000	0.500	1.000	17	2526.28	*highest weighted models*
pi, psi(Stratum, OpenGrd+Forb,YearSinceLastFire), gam(.), eps(.), p(Session, plotSize)	2560.41	0.130	0.439	0.937	17	2526.41	
pi, psi(Stratum, OpenGrd+Forb), gam(.), eps(.), p(Session, PlotSize)	2560.62	0.340	0.356	0.844	16	2528.62	
pi, psi(Stratum, OpenGrd+Forb,MilitaryDistSQRT), gam(.), eps(.), p(Session, plotSize)	2560.87	0.590	0.277	0.800	17	2526.87	
pi, psi(Stratum, YearSinceLastFire), gam(YearSinceLastFire), eps(.), p(Session, plotSize)	2565.93	5.650	0.002	0.059	20	2525.93	
pi, psi(Stratum, YearSinceLastFire), gam(.), eps(.), p(Session, PlotSize)	2567.66	7.380	0.000	0.025	16	2535.66	
pi, psi(Stratum, MilitaryDisturb), gam(.), eps(.), p(Session, PlotSize)	2569.46	9.180	0.000	0.010	16	2537.46	
pi, psi(Stratum, PerGrass), gam(.), eps(.), p(Session, PlotSize)	2570.73	10.450	0.000	0.005	16	2538.73	
pi, psi(Stratum, FireFreqSQRT), gam(.), eps(.), p(Session, PlotSize)	2572.05	11.770	0.000	0.003	16	2540.05	
pi, psi(Stratum, YearSinceLastFireSQRT), gam(.), eps(.), p(Session, plotSize)	2572.78	12.500	0.000	0.002	16	2540.78	
pi, psi(Stratum, AnnGrass), gam(.), eps(.), p(Session, PlotSize)	2573.43	13.150	0.000	0.001	16	2541.43	
pi, psi(Stratum, FireFreq), gam(.), eps(.), p(Session, PlotSize)	2573.72	13.440	0.000	0.001	16	2541.72	
pi, psi(Stratum, Shrub), gam(.), eps(.), p(Session, PlotSize)	2574.48	14.200	0.000	0.001	16	2542.48	
pi, psi(Stratum), gam(.), eps(.), p(Session, PlotSize)	2574.49	14.210	0.000	0.001	15	2544.49	
pi, psi(Stratum, DirtRoadProx), gam(.), eps(.), p(Session, PlotSize)	2575.07	14.790	0.000	0.001	16	2543.07	
pi, psi(Stratum, DISI), gam(.), eps(.), p(Session, PlotSize)	2575.14	14.860	0.000	0.001	16	2543.14	
pi, psi(Stratum, FGR), gam(.), eps(.), p(Session, plotSize)	2575.73	15.450	0.000	0.000	16	2543.73	
pi, psi(Stratum, RoadProx), gam(.), eps(.), p(Session, PlotSize)	2576.36	16.080	0.000	0.000	16	2544.36	
pi, psi(Stratum, MilitaryDisturb), gam(MilitaryDisturb), eps(.), p(Session, plotSize)	2576.38	16.100	0.000	0.000	20	2536.38	
pi, psi(Stratum, Clay), gam(.), eps(.), p(Session, PlotSize)	2576.45	16.170	0.000	0.000	16	2544.45	
pi, psi(Stratum, Sand), gam(.), eps(.), p(Session, PlotSize)	2576.48	16.200	0.000	0.000	16	2544.48	
pi, psiA, psiB(Stratum), gam(.), eps(.), p(Session, PlotSize)	2577.63	17.350	0.000	0.000	16	2545.63	
pi, psi(Stratum, MilitaryDisturbSQRT), gam(.), eps(.), p(Session, plotSize)	2570.05	9.770	0.000	0.010	16	2538.05	
pi, psi(OpenGrd+Forb,MilitaryDisturb), gam(.), eps(.), p(Session, plotSize)	2584.32	24.040	0.000	0.000	15	2554.32	
pi, psiA, psiB, gam(.), eps(.), p(Session, PlotSize)	2587.48	27.200	0.000	0.000	14	2559.48	
pi, psiA, psiB, gam(.), eps(.), p(Session)	2608.81	48.530	0.000	0.000	13	2582.81	
pi, psiA, psiB, gam(.), eps(.), p(survey)	2610.02	49.740	0.000	0.000	16	2578.02	
pi, psi, gam(.), eps(.), p(Session, PlotSize)	2616.13	55.850	0.000	0.000	15	2586.13	
pi, psiA, psiB,eta(Full identity), gam(.), eps(.), p(Session)	2624.78	64.500	0.000	0.000	25	2574.78	
pi, psiA, psiB, gam(.), eps(.), p(Day1_other)	2624.79	64.510	0.000	0.000	11	2602.79	
pi, psiA, psiB, gam, eps, pA(.), pB(.)	2670.85	110.570	0.000	0.000	17	2636.85	
pi, psiA, psiB, gam(.), eps(.), p(.)	2676.68	116.400	0.000	0.000	10	2656.68	
pi, psiA, psiB, gam(Year), eps(Year), p(.)	2686.74	126.460	0.000	0.000	16	2654.74	

Note: Covariates tested for occupancy (psi), colonization (gam), and extinction (eps) included Military Distubance Index (MilitaryDisturb), Years since last fire (YearSinceLastFire), Fire frequency (FireFreq), % Open ground and forbs (OpenGrd+Forb), % Annual grasses (AnnGrass), % Perennial grasses (PerGrass), % Shrubs (Shrub), % Clay in soil (Clay), % Sand in soil (Sand), Road proximity index (RoadProx), Dirt road proximity index (DirtRoadProx), Presence of DKR (DISI), and Sampling stratum (Stratum). Covariates tested for detection probability (p) included Sampling stratum (Stratum), Trapping session (Session), and Plot size- 0.25 ha vs. 0.69 ha historic (PlotSize). Models are not shown when there is evidence of poor fit such as parameter estimate coefficients >20, no covariance matrix, standard errors>parameter estimates.

FIGURE 8. PROPORTION OF PLOTS OCCUPIED BY SKR IN RELATION TO THE PROPORTION OF OPEN GROUND AND FORBS

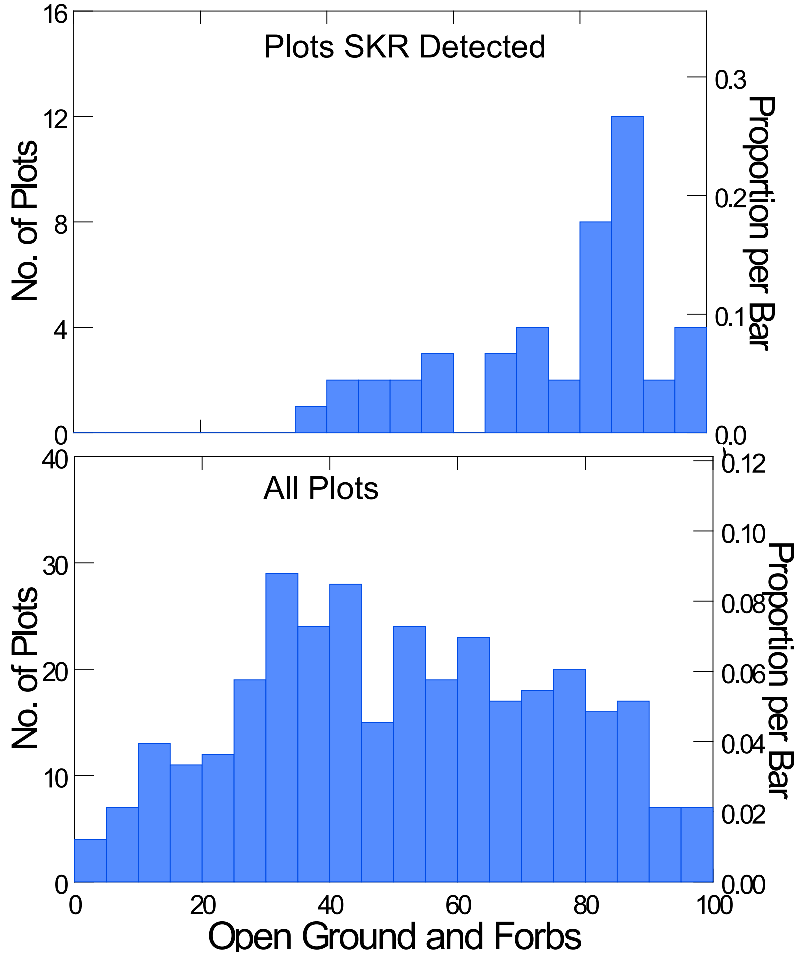


FIGURE 9. ODDS OF SKR OCCUPANCY IN RELATION TO THE PROPORTION OF OPEN GROUND AND FORBS

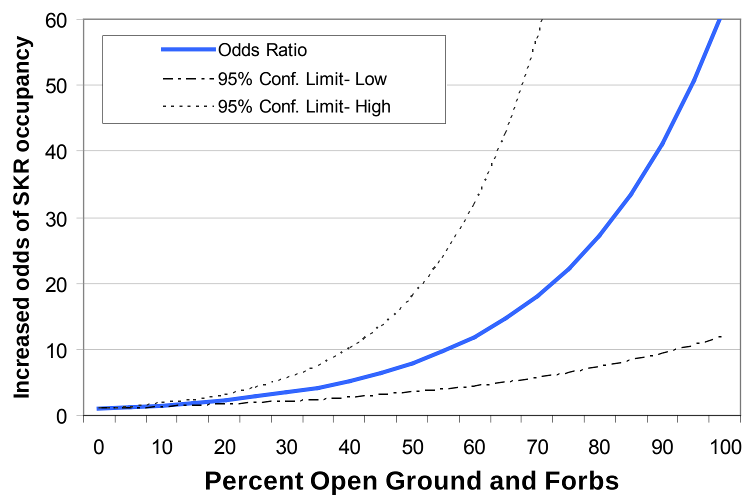


FIGURE 10. PROPORTION OF PLOTS OCCUPIED BY SKR IN RELATION TO AN INDEX OF MILITARY DISTURBANCE

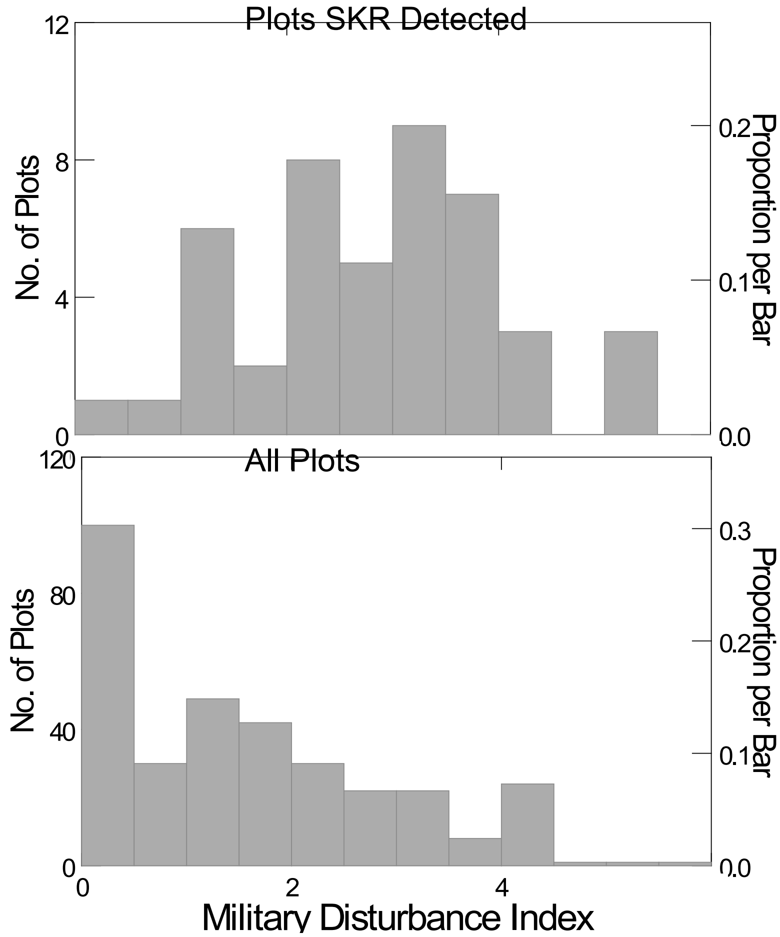


FIGURE 11. ODDS OF SKR OCCUPANCY IN RELATION TO AN INDEX OF MILITARY DISTURBANC

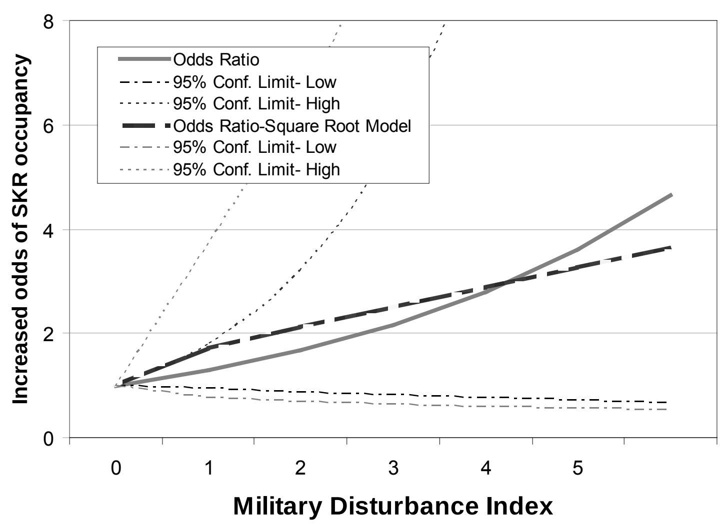


FIGURE 12. PROPORTION OF PLOTS OCCUPIED BY SKR IN RELATION TO YEARS SINCE LAST FIRE

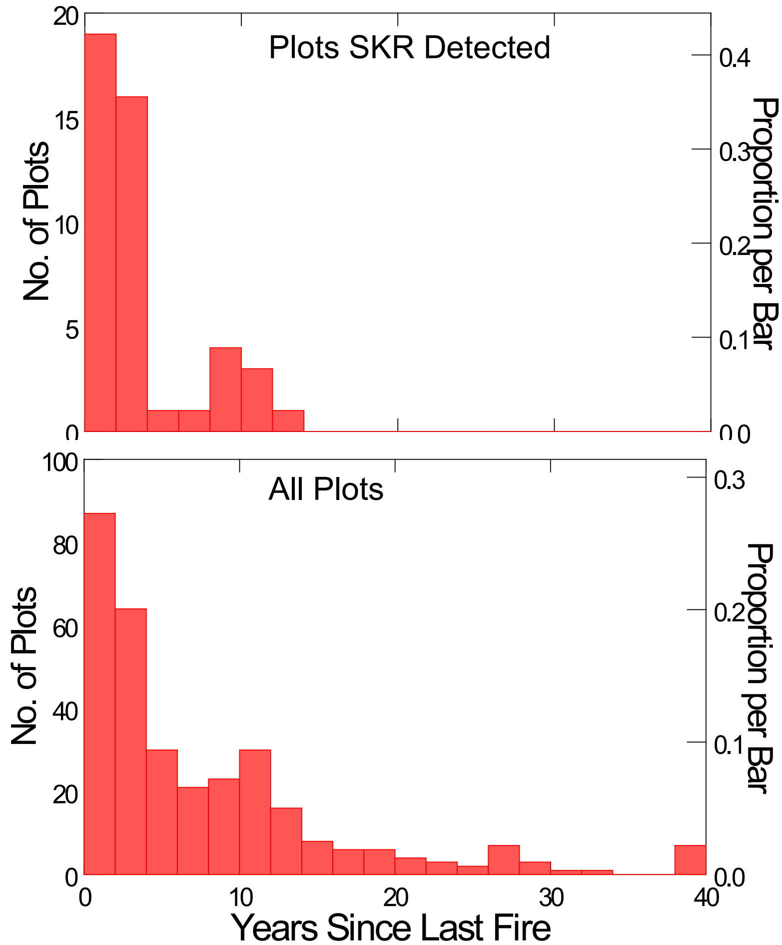


FIGURE 13. ODDS OF SKR OCCUPANCY IN RELATION TO YEARS SINCE LAST FIRE

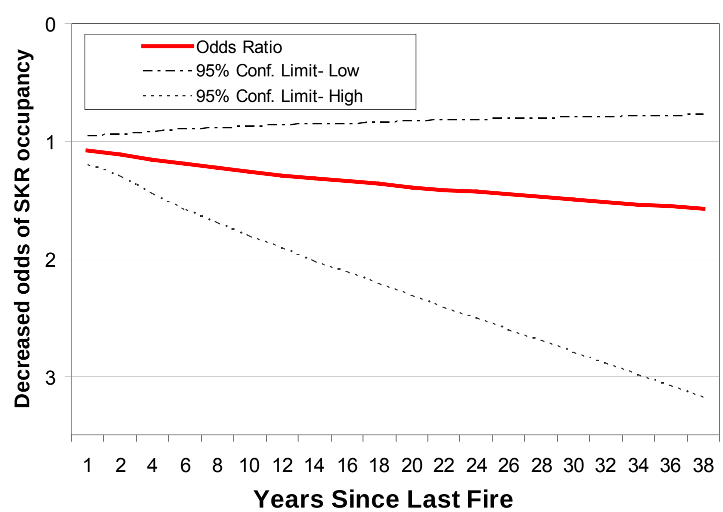


FIGURE 14. PROPORTION OF PLOTS OCCUPIED BY SKR IN RELATION TO FIRE FREQUENCY

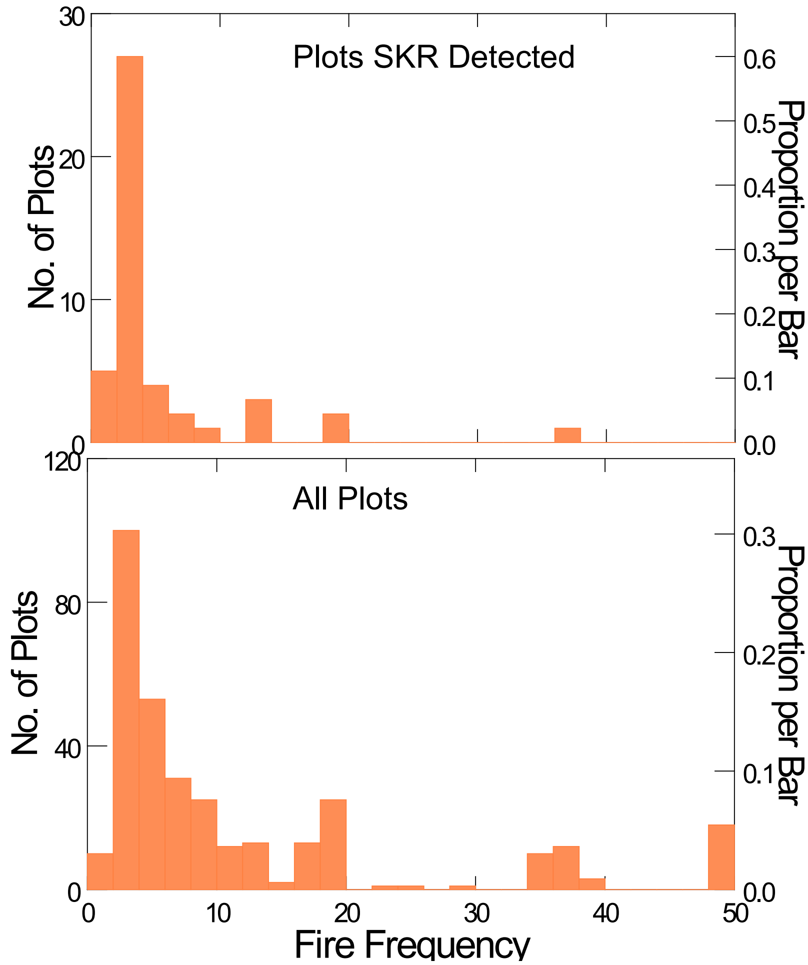


FIGURE 15. ODDS OF SKR OCCUPANCY IN RELATION TO FIRE FREQUENCY

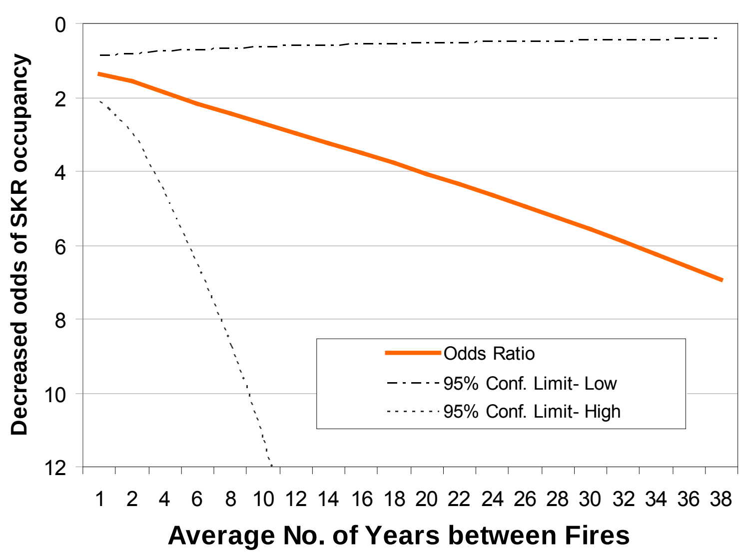
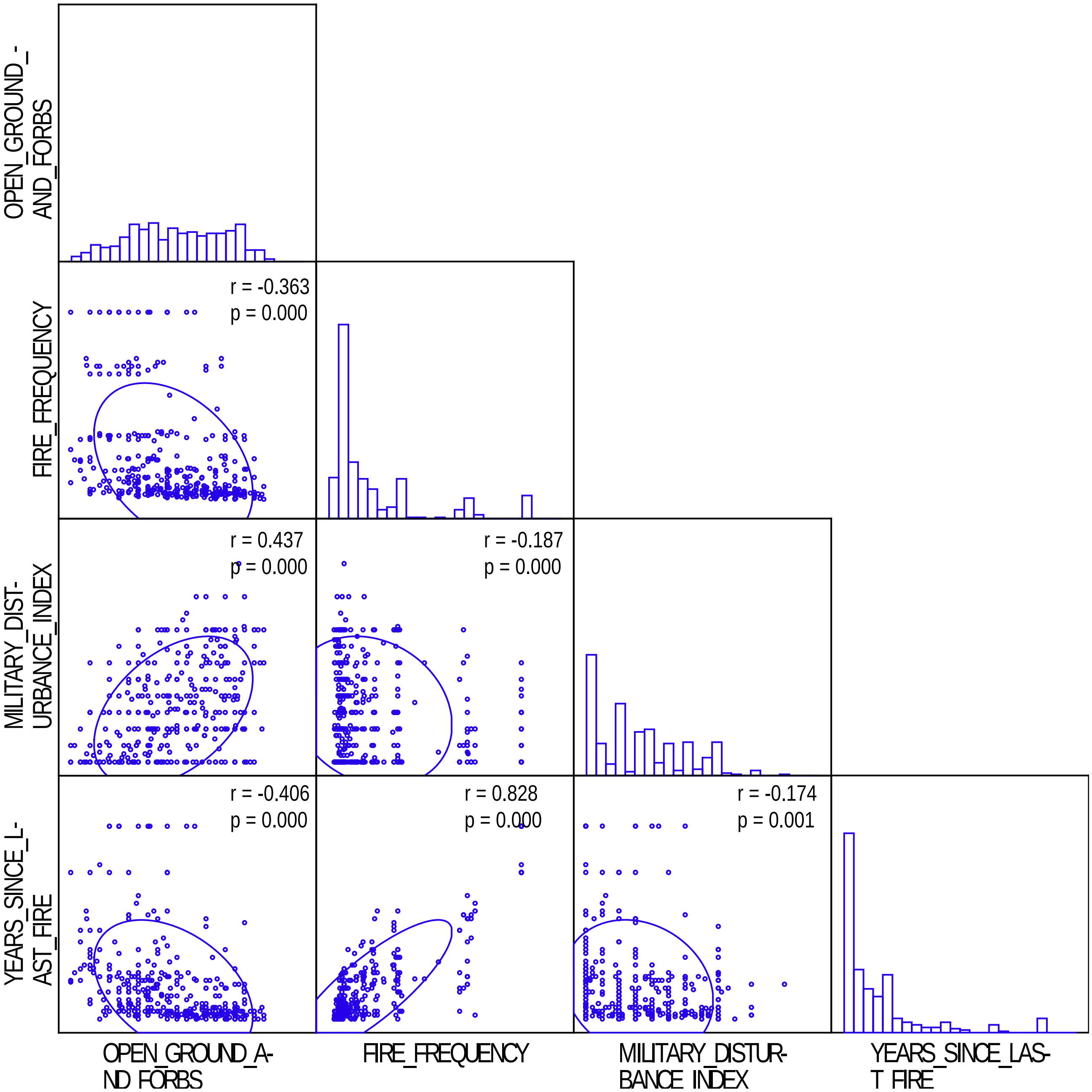


FIGURE 16. CORRELATIONS AMONG COVARIATES ASSOCIATED WITH SKR OCCUPANCY.



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. By being liberal in the designation of plots as potentially occupied, we assumed that we had a perfect probability (1.0) of detecting plots that are absent of sign (for further explanation, see Brehme et al. 2006). We annually test this Phase 1 assumption by live-trapping at least 9 plots that are designated as "Unoccupied" after the sign survey.

We live-trapped five medium suitability and six high suitability plots where no kangaroo rat sign was detected upon the initial habitat survey. No Stephens' kangaroo rats were detected during these surveys. We did detect a Dulzura kangaroo rat at one of the negative plots; it was captured on a dirt road transecting the plot.

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. Of the 76 plots where potential sign was recorded, all 76 still contained at least potential sign upon the pre-trapping resurvey. Two plots that were negative upon first survey were positive for sign on second survey (High 52, High 167). Both of these plots were resurveyed and live- trapped approximately 2-3 months after the first survey (High 52: 10/15-12/16; High 167: 10/3-12/23).

SKR Long-term Monitoring Program Evaluation

The initial protocol for SKR was designed to be adaptive, so that results of sampling would not only inform SKR management, but would also be used to evaluate the effectiveness of the monitoring program. Therefore, at the onset of creating this monitoring protocol, we committed to a 5-year programmatic evaluation that would analyze our ability to detect increases or decreases in SKR populations on Base and make any recommended revisions to the protocol.

The following are the seven main program elements from the original Stephens' Kangaroo Rat (*Dipodomys stephensi*) Monitoring Protocol for MCB Camp Pendleton (Brehme et al. 2006, p.13-14). We evaluated these elements based upon monitoring results from 2005-2010.

Evaluation of Original Program Elements

1) Habitat-based monitoring program for SKR occupancy.

"Rather than focus on traditional time intensive capture-recapture methods for modeling animal demographics on a small number of fixed plots, we chose a habitat based occupancy monitoring scheme where a large number of plots are surveyed on a yearly basis. A loglinear modeling program, such as PRESENCE (MacKenzie et al. 2002), will be used to estimate the proportion of area occupied by SKR and correct for imperfect probabilities of detection. Covariate data, to include habitat variables, environmental variables, presence of other species, and SKR density indices will be collected at each sample plot. These data will be included in models to determine what factors are significant in predicting occupancy and/or influence probabilities of detection. Multi-year analysis will allow us to monitor extinction and colonization rates among sample plots. Finally, this program can directly incorporate ongoing resource management and be used to make informed management recommendations in the future."

Evaluation: Five year analysis shows that landscape and habitat use covariates are useful in modeling SKR spatial distribution through time. These results directly inform habitat management.

2) SKR Density Index.

"It is preferable to include some measure of SKR density since it is still unknown whether trends in SKR occupancy and density are correlated. An index of SKR density within strata will be generated from live-trapping data. Thus, we will also track trends in SKR density over time."

Evaluation: Density estimates have been variable from year to year. Variance around estimates would be smaller if 1) we had more plots occupied by SKR, and 2) higher capture probabilities of individual animals.

3) Spatially stratified sampling of potential SKR habitat.

"Because the species is rare, it is most efficient to stratify sampling effort based on probability of occupancy. Thus, we have defined high-, medium-, and low-suitability habitat on MCBCP using historic and currently known occupied habitat and established SKR soil and vegetation associations. The first year, each strata will be randomly sampled with equal effort (40 to 50 random sample plots per strata) to determine expected occupancy rates. Then sampling effort will be optimized for the best precision in the "focal monitoring area", defined as the high and medium-suitability habitats, so as not to focus the bulk of sampling effort to habitats unlikely to support SKR. Lower quality habitat will be sampled in order to test our current assumptions about SKR, determine whether low levels of SKR persist in these habitats, and to provide needed data for our habitat model. After the first several years, the need for continued monitoring or revision of this stratum will be evaluated."

Evaluation: After the first year, we found most of the low suitability stratum was unsuitable for SKR and discontinued sampling effort for the stratum. We also initially estimated that the occupancy would be ~50% in the high stratum and ~20% in the medium stratum. These two together would make up the "Focal Monitoring Area". However, SKR occupy <20% of the high stratum and <2% of the medium stratum. Therefore, we propose to refine the "Focal Monitoring Area" to reflect all known SKR habitat (Revision of Sampling Strata, p.41). We recommend sampling potentially suitable habitat outside the monitoring area be done for discovery purposes only. For ongoing monitoring, we propose that 83% of effort be used for sampling the revised "Monitoring Area" and that 17% of effort be used for discovery efforts in potentially suitable habitat outside the monitoring area (Power Analysis and Allocation of Sampling Effort, p.46)

4) Continuity with 1996 to 2002 SKR monitoring efforts.

The thirteen original 1996-2002 monitoring plots will be defined as an additional stratum to be sampled in their entirety (i.e. 100% probability of being sampled). This will allow continued trend analyses for these sites while implementing a new protocol.

Evaluation: Now that the current program has been in place for 5-years, we recommend discontinuation of the annual sampling the historical monitoring plots. Because the plots were chosen subjectively, inference of results is restricted to the area within each plot rather than across the Base.

5) Two-tiered sample strategy.

"A two-tiered approach will be used to survey all sample plots (see Sampling Scheme, below, for details). This strategy will provide both proportion occupancy and density indices and account for imperfect detection probabilities."

First Tier: Habitat Characterization and Burrow Search. "Habitat is characterized based on variables expected to be related to SKR occupancy. Sample units (50 m x 50 m) are methodically searched for any possible kangaroo rat burrows. If any potential burrows are identified, follow-up live-trapping will take place."

Evaluation: The two –tiered approach is cost-effective by increasing our ability to survey a large number of plots and reserve trapping to those with any potential sign. The assumption of perfect detection has been well met in the last 5-years, with few violations. We will continue to live-trap a proportion of plots where we do not find any potential sign and estimate the probability of detection in negative plots in our modeling efforts.

Second Tier: Live-trapping. "Grids with potential SKR burrows will be trapped for two consecutive nights using a standard 25-trap grid design with 10 m spacing between traps."

Evaluation: Two consecutive nights has largely given high detection probabilities of SKR on a plot. However, to improve our density estimates, we propose to live-trap for three consecutive nights if we are able to get access permissions. Additionally, we will repeat trapping if sign is positive and no kangaroo rats have been captured.

6) Permanent sample plots.

"Once the sample effort is optimized among strata and random plots are chosen within each stratum (after the first five years), we propose all sample plots to be permanent. This design will enable maximum power to detect trends over time and enhance ability to incorporate and analyze effects of management actions on SKR. The large number of sample plots will allow for accurate assessments of both status and trend for SKR on MCBCP."

Evaluation: Thorough sampling of potential SKR habitat and knowledge of SKR occupied habitat is very useful to the Base Environmental Security. Therefore, we will continue to randomly sample plots both inside and outside the focal monitoring area to get a more detailed map of their spatial distribution over the Base. Randomized plots make up 33% of the total effort in our recommended revised sampling scenario.

7) Adaptive Protocol.

"All elements of the protocol will be re-evaluated after the first 2 to 5 years of monitoring."

Evaluation: We continue to recommend an evaluation of this program every 5 years or as deemed necessary.

Revision of Sampling Strata

Five years of sampling across the medium suitability stratum indicate that SKR populations on Base are largely represented by the current high suitability stratum. There have been some new SKR detections by us and others (AECOM, S. Montgomery) right outside of this stratum. In addition, our surveys have found that some areas within the high suitability stratum are of low suitability and should be removed.

We propose a revised Focal "Monitoring Area" for SKR. This is a single stratum of 628 ha that includes most of the previous high suitability stratum and any occupied areas that have been identified since 2005 (Figure 17). Specifically, we added areas encompassing SKR detections in the medium suitability stratum from our monitoring efforts and from other live-trapping efforts (provided by Base GIS and Steve Montgomery, pers comm). Boundaries were also expanded to include adjacent suitable habitat as determined by carefully examining aerial photographic layers and topography in ArcGIS. We removed any area that fell within unsuitable habitat (i.e. inaccessible DUD producing areas and riparian habitat). We removed the historical Bravo One habitat from the FMA as it was presumed to be extirpated when we designed the program in 2005 (due to HOLF installation) and we have not detected SKR after an additional 5 years of monitoring. We also removed small areas around Ranges 210 and west of AFA 17 near Basilone Road (Figure 18). SKR were never verified in these locations since initial surveys in the 1970's and we have not detected any SKR from 2005-2010. The reduction in overall monitoring area should increase the average proportion area occupied (Ψ) by SKR to 0.20 or higher (i.e. 2009-10: 118 ha occupied/ 628 ha total area).

Any areas removed from the high suitability stratum were added to the medium suitability stratum to create the potentially suitable "Discovery Sampling Area". This discovery sampling area encompasses 5520 ha 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. Some areas were removed within the Whiskey/X-Ray Impact Area that have been inaccessible since 2005 (Figure 19).

FIGURE 17. PROPOSED MONITORING AREA: REVISION OF PREVIOUS HIGH SUITABILITY SAMPLING STRATUM BASED UPON SKR DETECTIONS SINCE 2005, ACCESSIBLITY, AND SUITABLE HABITAT.

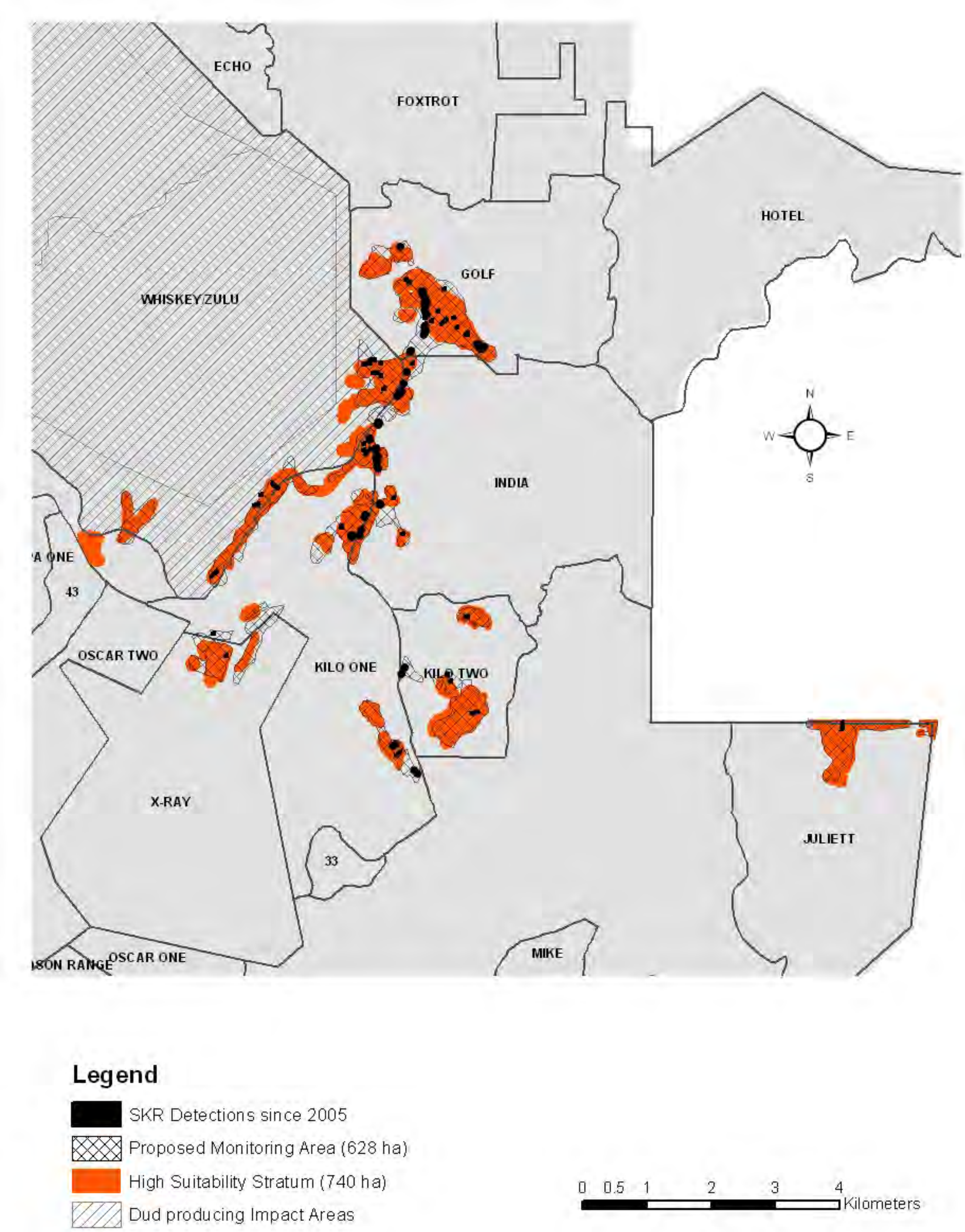


FIGURE 18. REVISED MONITORING AREA SHOWING AREAS ADDED AND REMOVED FROM PREVIOUS HIGH SUITABILITY STRATUM.

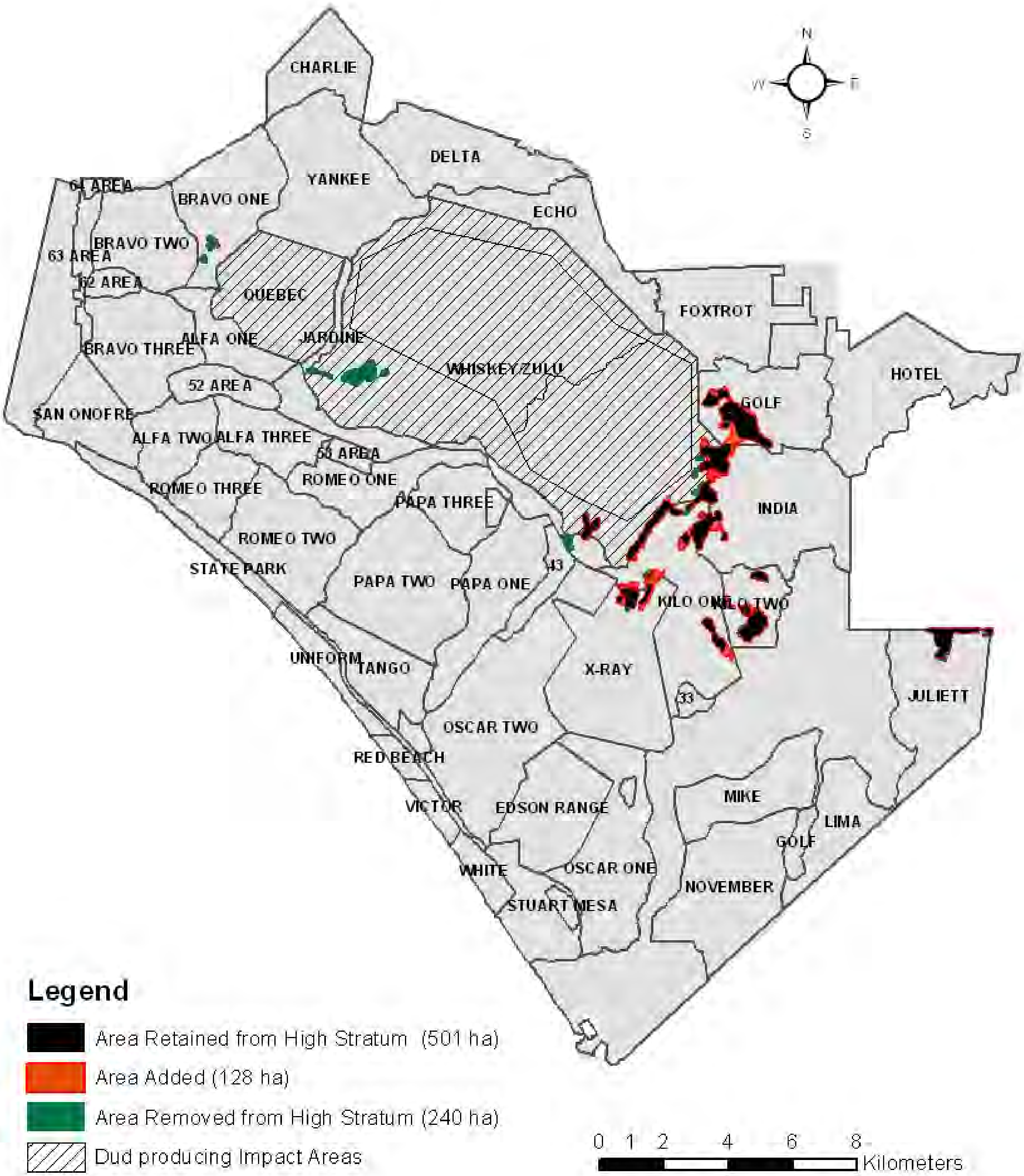
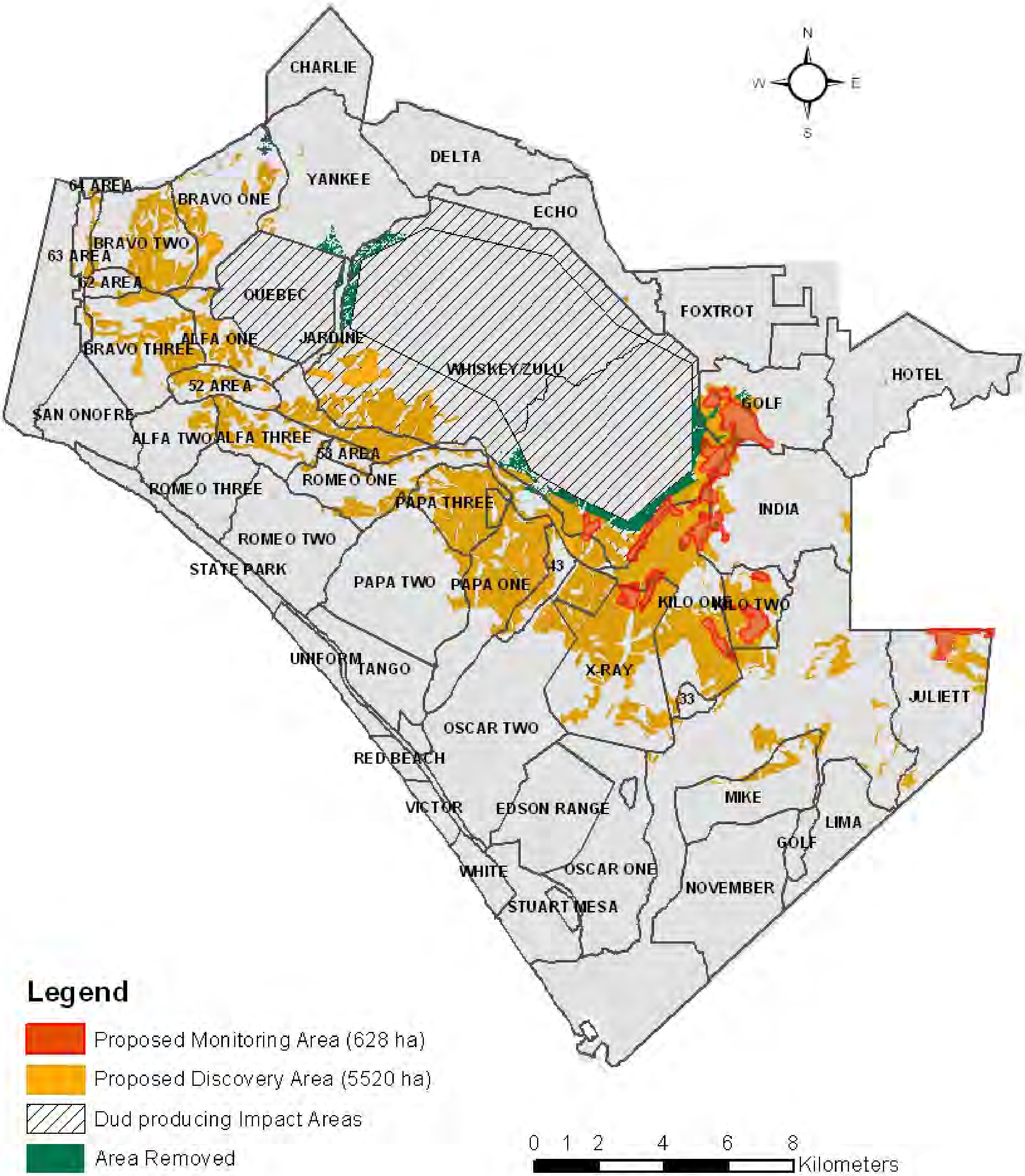


FIGURE 19. PROPOSED AREAS FOR MONITORING AND DISCOVERY OF SKR ON MCBCP.



Power Analysis and Allocation of Sampling Effort

We evaluated four sampling designs for future SKR monitoring on Base. Keeping the overall number of plots constant at 150, the sampling designs differ in the allocation of effort toward discovery and monitoring (Table 6). Within the SKR Monitoring Area, maximizing the number of permanent plots will increase our ability to monitor trends over time, which is the primary goal of this program. Maximizing the number of random plots to be surveyed each year within the SKR Monitoring Area is important for complete sampling of SKR habitat over time, so that eventually we will have surveyed all 628 ha for SKR. This information is of great value to the Base for SKR management and conservation decisions. Finally, sampling of random plots within potential habitat outside of the monitoring area will maximize the chance of discovering new SKR occupied habitat (Discovery Area).

Power is the probability that a study will find a significant effect if it exists. For example, a power of 80% means that the correct model for a sampling design will produce a statistically significant effect 8 times out of 10.

We compared the power of these designs to detect a gradual 25% decrease in SKR occupied habitat (starting proportion area occupied (Ψ) at 0.20 declining to 0.15 after 5 years, Table 7). To reflect the range of observed colonization and extinction dynamics, we simulated data for scenarios with and without background equilibrium colonization and extinction (i.e. some plots become occupied each year while other plots go extinct each year). The simulated data were modeled using the multi-year design in Program PRESENCE. In each case, the gradual decline model was considered the "true" generating model, or the alternative hypothesis (H_a), and the null hypothesis (H_0) was represented by equilibrium models representing no change in occupancy. To compare the ability of each sampling design to detect the gradual decline, we used a likelihood ratio test (LRT) between competing models (H_0 & H_a) to approximate power (Burnham et al., 1987:214-217). The chi-square statistic from the LRT was the noncentrality parameter, λ, used to calculate power from a non-central chi-squared distribution (Burnham et al., 1987; Bailey et al., 2007, Mattfeldt et al. 2009).

It is important to understand how sampling designs or models may affect the bias and precision of estimates. Systematic bias, particularly in estimates of proportion area occupied (Ψ) and detection probability (ρ) can result in incorrect conclusions and thus negate our ability to understand true system dynamics. Low precision can cause failure to detect even large declines or increases. To compare the accuracy and precision of the sampling designs, we calculated bias (the difference between the parameter estimate and the ‘true’ parameter value- divided by the ‘true’ parameter value) and precision (ratio of standard error over estimate) for all parameters (Table 8).

TABLE 6. SAMPLING DESIGNS

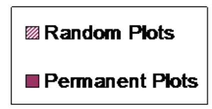
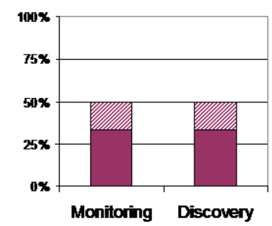
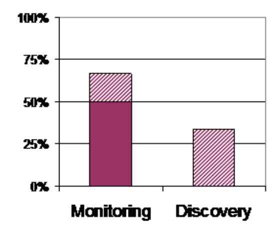
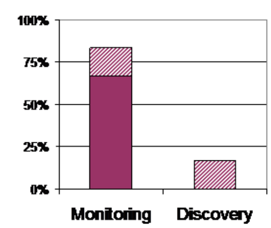
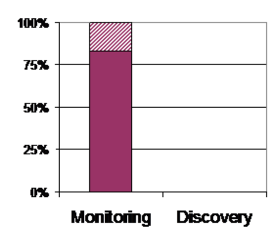
Scenario	High Suitability "SKR Monitoring"		Medium Suitability "Discovery"		
	Permanent Plots	Random Plots	Permanent Plots	Random Plots	
Current (Monitoring and Discovery)	50 33.3%	25 16.7%	50 33.3%	25 16.7%	
Alternate 1 (Monitoring and Discovery)	75 50.0%	25 16.7%	0 0.0%	50 33.3%	
Alternate 2 (Monitoring and Discovery)	100 66.7%	25 16.7%	0 0.0%	25 16.7%	
Alternate 3 (Monitoring)	125 83.3%	25 16.7%	0 0.0%	0 0.0%	

TABLE 7. SAMPLING DESIGNS EVALUATED POWER TO DETECT POPULATION CHANGE (25% GRADUAL DECLINE OVER 5 YEARS)

		Sample Designs			
		Current Design	**Alternate 1**	**Alternate 2**	**Alternate 3**
	Permanent Monitoring Sites	**50**	**75**	**100**	**125**
	Random Monitoring Sites	**25**	**25**	**25**	**25**
	"Discovery" Sites	**75**	**50**	**25**	**0**
Scenario 1: 25% Decline + background metapopulation dynamics (colonization & extinction)					
Equilibrium Model: psi, gamma(fix), eps(fix), p(.)	LLR H_0	141.14	224.93	301.51	382.42
"True" Model: psi, gamma(.), eps(.), p(.)	LLR H_a	136.79	220.00	295.47	375.57
	df H_0	2.00	2.00	2.00	2.00
	df H_a	4.00	4.00	4.00	4.00
Likelihood Ratio Test	Deviance χ^2	4.35	4.93	6.04	6.85
	df	2.00	2.00	2.00	2.00
	Power α=0.10	**57%**	**62%**	**70%**	**75%**
	Power α=0.20	**71%**	**75%**	**82%**	**86%**
Scenario 2: 25% Decline - background metapopulation dynamics (no colonization & extinction)					
Equilibrium Model: psi, gamma(fix), eps(fix), p(.)	LLR H_0	150.12	233.13	308.28	386.00
"True" Model: psi, gamma(.), eps(.), p(.)	LLR H_a	119.06	187.77	247.41	311.39
	df H_0	2.00	2.00	2.00	2.00
	df H_a	4.00	4.00	4.00	4.00
Likelihood Ratio Test	Deviance χ^2	31.06	45.36	60.87	74.61
	df	2.00	2.00	2.00	2.00
	Power α=0.05	**100%**	**100%**	**100%**	**100%**
	Power α=0.10	**100%**	**100%**	**100%**	**100%**

Model abbreviations: psi= occupancy (Ψ), gamma= colonization rate (γ), eps= extinction rate (ε), p= detection probability (ρ)
Likelihood Ratio Tests; LLR= Likelihood ratio, df= degrees of freedom, Deviance (χ^2)= LLR test statistic
Scenario 1: Equilibrium Model fixed values of colonization (γ=.028) and extinction (ε=0.10) result in no net change in occupancy over 5 years
Scenario 2: Equilibrium Model fixed values of colonization (γ=0) and extinction (ε=0) result in no net change in occupancy over 5 years

The results showed that all sampling designs had 100% power to detect a 25% decline in the absence of background equilibrium colonization and extinction dynamics. Power decreased to 57% to 75% (α= 0.10) to detect the same decline with background equilibrium dynamics. However, we expect the actual power will be higher as variation in SKR occupancy dynamics are explained by environmental or landscape covariates.

TABLE 8. SAMPLING DESIGNS EVALUATED FOR BIAS AND PRECISION

	parameter	expected	Current Design	Alternate 1	Alternate 2	Alternate 3
			Sample Designs			
Permanent Monitoring Sites			**50**	**75**	**100**	**125**
Random Monitoring Sites			**25**	**25**	**25**	**25**
"Discovery" Sites			**75**	**50**	**25**	**0**
Bias (observed /expected)	Ψ	0.20	0%	0%	+1%	+1%
	ε	0.10	-21%	0%	+7%	+6%
	γ	0.01	-38%	-18%	-15%	-7%
	ρ	0.80	+14%	+12%	+12%	+12%
Precision (standard error /mean)	Ψ	0.20	28%	23%	20%	18%
	ε	0.10	57%	43%	34%	31%
	γ	0.01	98%	70%	62%	53%
	ρ	0.80	3%	3%	2%	2%

Fortunately, there was very little bias in estimation of proportion area occupied (Ψ) across all designs (0 to 1%, Table 8). All designs resulted in estimates of detection probability (ρ) biased slightly high (12 to 14%). Except for the current sampling scheme, extinction probabilities were all within 7% of the "true" value. There was a negative bias for estimates for colonization probabilities, ranging from 3% to 7% with increasing the number of permanent sampling sites. The "true" value was only 0.01, so it is expected to observe greater bias. Precision estimates were all positively associated with the magnitude of the parameters (i.e. better precision for estimated probabilities that were closer to 1 vs. closer to 0). This resulted in lower than optimal precision for annual estimates of occupancy (+/- 18 to 28%); however, we expect our simulated occupancy probability of 0.20 to be a conservative estimate for the revised monitoring area. Of the annual designs, Alternates 1, 2, and 3 were comparable in showing the least bias and greatest precision in estimating all parameters.

Increasing the number of sample plots above what was considered in the alternate designs would have minimal impact power and precision. It would be of greater value to find habitat or other covariates that are predictive of SKR population dynamics that would inform a feedback loop to management.

From these results, we recommend sampling design "Alternate 2" to be a reasonable balance between monitoring and discovery efforts within the monitoring and discovery sampling areas. Along with the revised monitoring area, this design will significantly increase our ability to detect trends in SKR over time, as the number of permanent plots will double from 50 to 100 (33-66% of total effort). An additional 17% of effort will be used to sample random plots within the monitoring area to get a more complete understanding of the patchy nature of SKR occupancy over time. Finally, rather than allocating half of our effort to discovery each year (i.e. sampling where SKR are very unlikely to occur), we propose to continue with a more reasonable 17% of effort to this task.

Discussion

Overall, the estimated area occupied by SKR in 2009-10 on MCB Camp Pendleton has been relatively stable since 2007-8 (within a single standard error) and is greater than the initial years of monitoring at MCBCP in 2005-6 and 2006-7. Within the high suitability stratum (which defines almost all know SKR habitat), we estimated SKR occupied 118.4 ha (SE=39.1) in 2009-10, in comparison to a high estimate of 147.3 ha (SE=39.1) in 2008 and low estimate of 60.0 ha (SE=24.2) in 2005. We detected no SKR in the medium suitability stratum. In areas occupied by SKR in 2009-10, animal densities were higher than all previous years at 30.2 and 47.1 SKR/ha, which is considered “high” for this species (Tetratech and SJM Biological Consultants 1999). The positive trend suggests a continued pattern of high survivorship and colonization of SKR in the high suitability stratum

This was the first year we were able to analyze all of the data in a multi-state framework and established that SKR are positively associated with the proportion of open ground and forbs, military disturbance, years since last fire, and fire frequency. SKR have often been associated with open forb-dominated areas. The results since 2005 for SKR on MCBCP support this and further show the direct positive effects of disturbance from military training and fires. SKR were most common in areas with greater than 80% forbs and open ground, a moderate level of military disturbance (foot and vehicle traffic, artillary), areas that burned within the past 3 years, and with a fire frequency of 2 to 3 years. Since 2005, SKR have increased in all disturbed military training areas while decreasing in the conservation of area of Juliett, where disturbance was minimal in that period. Current habitat management actions, such as implementation of regular prescribed burning of annual grasses and shrubs, should create habitat more suitable for the species. Overall, it is unclear as to how much disturbance is optimal for SKR and its habitat. Military and fire disturbance models showed linear relationships better fit the data; however, we should not assume that unlimited disturbance is optimal. It is likely that the level required to keep forbs and open ground dominant over grasses and shrubs is optimal.

Once again, in designing the monitoring protocol, we estimated that SKR occupancy in the high suitability stratum (740 ha) would be ~50% or 370 ha (Brehme et al. 2006). This assumption was based upon numbers reported in 1996 and 1997, where SKR occupied an estimated ~324 ha (800 acres, Montgomery et al. 1997) and 293 ha (724 acres, Tetratech and SJM Biological Consultants 1999) based upon extensive burrow surveys and some supplemental trapping. Note that the loose boundaries around the SKR habitat that were identified during these previous efforts were used to define our 740 ha "high suitability" stratum for SKR sampling. We discuss possible and probable reasons for this disparity in our 2005 SKR report (Brehme and Fisher 2008). However, the implications of these results are that SKR are likely much rarer on MCB Camp Pendleton than previously thought, greatly increasing the importance of active management for this species along with these monitoring efforts.

In the high suitability stratum, our estimate of proportion of area occupied over the past three years has been less than 0.20 (or 20%). Recommended occupancy is between 0.2 to 0.8 (with 0.5 ideal) to have good precision for parameter estimates (i.e., occupancy, detection probability, colonization, and extinction) and sufficient power to model habitat and environmental covariates (MacKenzie et al. 2006).

We have revised this stratum to exclude unsuitable habitat and areas that were thought to be extirpated (i.e. HOLF in Bravo, Range 210 Area) and included nearby suitable habitat and all known recent occurrences of SKR. Because this encompasses all known SKR populations, we propose this to become the focal "Monitoring Area". The revision resulted in an overall decrease from 740 ha to 628 ha for this stratum. In addition, we completed a power analysis comparing several sampling schemes and have recommended increasing the allocation from 50% to 83% of total effort to this area. As presented, this includes 100 permanent plots (surveyed every year) and 25 randomly chosen plots each year. The result of our recommendations should give higher and more precise SKR occupancy estimates, more complete coverage of SKR habitat, greater power to detect trends over time, and greater power to model SKR habitat occupancy dynamics. This will allow for a better understanding of the importance of habitat characteristics, environmental factors, fire and military disturbance in the occupation and persistence of SKR. This will also better lay the framework for an information feedback loop between monitoring and management for SKR on the Base.

Conversely, in the medium suitability stratum, we only captured seven individual SKR in two out of the five years of monitoring. All captures were in plots located very close to the high suitability stratum. We suspect that most of the medium suitability stratum is unoccupied. We have proposed this to become the "Discovery Area" where we allocate 17% of our effort to survey 25 randomly chosen plots each year for discovering unknown populations or dispersal corridors.

Recommendations

Management

SKR largely occur within heavily used impact areas and artillery ranges. These areas are also vital areas for training military personnel. Recommendations regarding military training activities are thoroughly treated in the draft Biological Assessment and Management Plan for MCBCP (Tetratech and SJM Biological Consultants 1997). These generally recommend reasonable avoidance of SKR habitat compaction and destruction by military vehicles, military personnel, and maintenance and construction activities. Our results indicate that moderate levels of disturbance are positive for SKR and its habitat. Thus, we do not recommend avoidance. For SKR management, we recommend regular disturbance (military, fire, vegetation thinning) up to a level that supports abundant forb growth over non-native grasses and shrubs (i.e. fire frequency of every 2-3 years).

In 1992, the Fish and Wildlife Service issued a Biological Opinion that identified 9.9 ha (24.4 acres) around a firebreak within the Juliett training area to be managed for SKR in mitigation for take in the 210 range areas (FWS 1992). The Base also designated an additional 11.6 ha (28.7 acres) immediately adjacent to this area as a mitigation bank for SKR (see red area on Figure 13 for general boundaries of mitigation area). Although immediately adjacent to a large population of SKR on the Fallbrook Naval Weapons Station (NWS), these areas were not initially considered suitable for SKR because they were covered by denser sage scrub. Prescribed burning, grazing or mowing was needed to maintain a suitable open grassland community. The Base conducted disking and grading activities to the Juliett fire road area to manage the habitat sometime between 1992 and 1993. Subsequently, in 1996, SJM Biological Consultants found SKR were present at densities ranging from <2/ha to 10-30/ha (Montgomery et al. 1996). However, monitoring efforts from 1998 to 2002 showed a steady decline in SKR and increase in DKR, particularly at the northeastern portion. Since then, we have captured two SKR in 2005, a single SKR in 2006, and no SKR from 2007-2010 in this area.

At this time, most of the Juliett mitigation area appears to be unsuitable for SKR. Habitat characterization in 2005 and 2006 showed that the eastern portion of the management area is dominated by mixed sage scrub with shrub cover at 40-95%. This habitat favors occupation by DKR. The central portion is largely dominated by thick non-native annual grasses that would not be favorable to either species, as it would hinder kangaroo rat movement and foraging success. Therefore, we highly support the fire management started in 2009 across the Juliett mitigation area to restore suitability of this area for SKR. Disturbance should occur annually in order to maintain a suitable forb dominated habitat.

Monitoring Protocol

1. Accept revised strata for monitoring and discovery. This will allow for a single stratum that encompasses all known SKR populations for monitoring purposes. The second stratum will be used for discovery purposes only. Along with a revised allocation effort, this will increase the effectiveness of annual SKR monitoring.

2. In order to increase precision of SKR occupancy estimates and better understand current distribution, recommend accepting revised allocation of effort as described in Alternate Design 2, where we sample 100 permanent plots and 25 random plots annually in the revised "Monitoring Area". Sample 25 plots per year in the "Discovery Area".

3. To minimize any immigration or emigration of SKR from sample plots within the period of sampling, we continue to recommend the live-trapping surveys be conducted within 6 weeks of the habitat surveys, as permitted by training area access and logistical constraints. This will minimize any violations of the closure assumption for the occupancy calculations and models.

4. Continue to randomly choose plots to live-trap as negative controls. This will provide data that may enable us to correct bias in our estimates and test if the assumption of "perfect detection probability of species absence" is violated. This may be somewhat challenging due to difficulties in obtaining access to multiple training areas for several consecutive days and other logistical constraints.

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