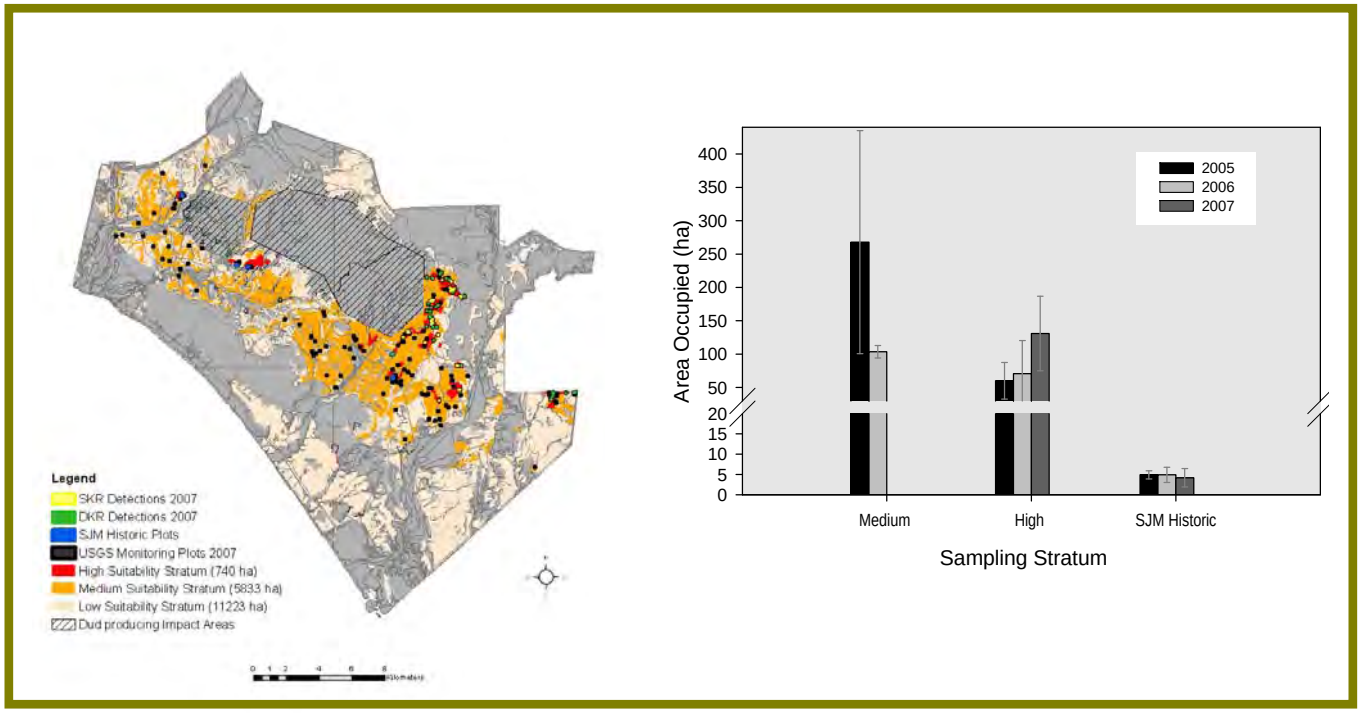
Western Ecological Research Center

Stephens' Kangaroo Rat Monitoring Results on MCB Camp Pendleton, Fall/Winter 2007/2008.

By Cheryl S. Brehme, Stacie A. Hathaway, and Robert N. Fisher



Data Summary

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Stephens' Kangaroo Rat *(Dipodomys stephensi)* Monitoring Results on MCB Camp Pendleton, Fall/Winter 2007/8.

By Cheryl S. Brehme, Stacie A. Hathaway, and Robert N. Fisher

Abstract

In 2005, we implemented a new monitoring program for the endangered Stephens' kangaroo rat (*Dipodomys stephensi*) 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*). 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.

Overall, the estimate area occupied by SKR in 2007 on MCB Camp Pendleton was greater than the past two years of monitoring at MCBCP. Within the high suitability stratum in 2007, we estimate SKR occupied 130.7 ha (SE=33.3) in comparison to 70.8 ha (SE=) in 2006 and 60.0 ha (SE=24.2) in 2005. 2007 was a dry year in San Diego County with about one-third of the normal rainfall (98mm 2007; 274mm historical average). The increase in area occupied by SKR in 2007could be due to high survivorship and successful expansion and colonization of SKR from the previous year, where we had estimated particularly high densities. Occupancy was again positively associated with open ground, herb and forb cover, which may be largely attributable to disturbance and frequent fire intervals.

In areas occupied by SKR in 2007, densities were estimated between 5.4 and 6.0 SKR/ha, which is considered "low" (Tetratech and SJM Biological Consultants 1999) for this species. Density was comparable to 2005, but substantially less than in 2006, where particularly high densities of 20 SKR/ha were estimated (Note: The 2006 density estimates were recalculated and corrected for this report). At this time, we are not finding support for SKR existing at multiple densities across habitats, but in similar (but low to medium) densities within a patchy framework, often co-occurring with DKR.

In the high suitability stratum, our estimates of proportion of area occupied (PAO) over the past two years have been less than 0.10 (or 10%). At this low level, we have very little power to model habitat suitability and have low precision for our occupancy estimates. These are of utmost importance to MCBCP for assessing the status and trends of SKR as well as understanding the importance of habitat, environmental, and disturbance variables to inform management decisions. Similarly, in the medium suitability stratum, we only captured a single SKR on a single plot in 2005 and no SKR in 2006 or 2007, leading to highly imprecise and likely biased (high) estimates within this stratum. We would like to continue to survey the 2005 plots and new random plots in these areas for several years. By 2011, these and other SKR data can be used to designate new smaller boundaries for the high suitability stratum. This will serve to increase the value and precision of PAO estimates, allow for better annual coverage of this area, and allow inclusion of all data since 2005. We propose the new high suitability stratum to be used for the long-term monitoring metric and the medium stratum to be used for discovery" of new SKR locations.

Despite the low power to model environmental covariates due to low occupancy, we did find that the amount of open ground and forbs (OGF) was a significant positive linear predictor of SKR. For every increase of 20% in OGF cover (0% vs. 20%, 20% vs. 40%, etc.), the odds of SKR occupying a plot increased 7.6 times (95% CI: 2.7-21.8). This again conforms to habitat associations known for this species and supports thinning of shrubs and grasses as a management technique for SKR. Recommendations continue to focus on managing SKR habitat in the SKR Mitigation Area within the Juliett training area. Because this area is currently dominated by dense scrub and non-native annual grassland habitats unsuitable for SKR, we recommend the timely implementation of regular prescribed burning of annual grasses and thinning of shrubs.

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).

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 non-native 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.

Because the species is rare, it was most efficient to stratify sampling effort based on the probability of occupancy or habitat suitability. Thus, we originally defined 17,795 ha of high, medium, and low suitability habitat on MCBCP using previously mapped SKR habitat and established soil and vegetation associations. 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). This year, we chose to focus our efforts 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 plan to continue to re-sample the original 50 plots and select 25+ new random plots each year to gain more information on status, trends, and spatial distribution within these strata.

At this time, we also continue to sample 10 plots that were monitored biennially from 1996 to 2002 in order to provide continuity with previous monitoring efforts.

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. 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. A review and protocol optimization will occur within 5 years of the onset of this program. Major Elements of the monitoring protocol are presented in Table 1.

FIGURE 1. HABITAT SUITABILITY MAP WITH SAMPLE PLOTS FOR SKR MONITORING PROGRAM 2007

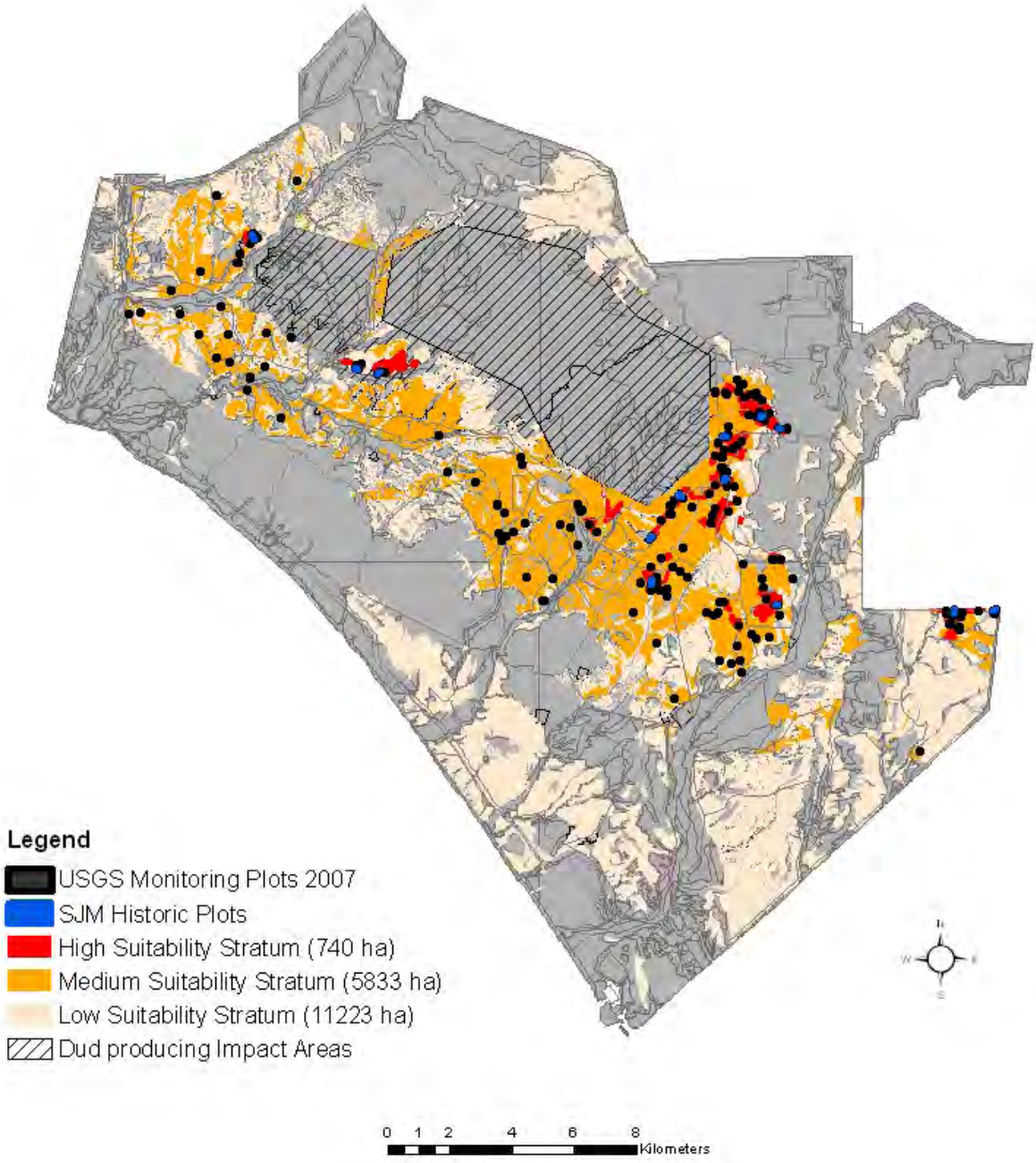


TABLE 1. MCB CAMP PENDLETON SKR MONITORING PROTOCOL ELEMENTS

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). Program MARK (density index)	Yearly (all)
	Density within and among strata		
	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.

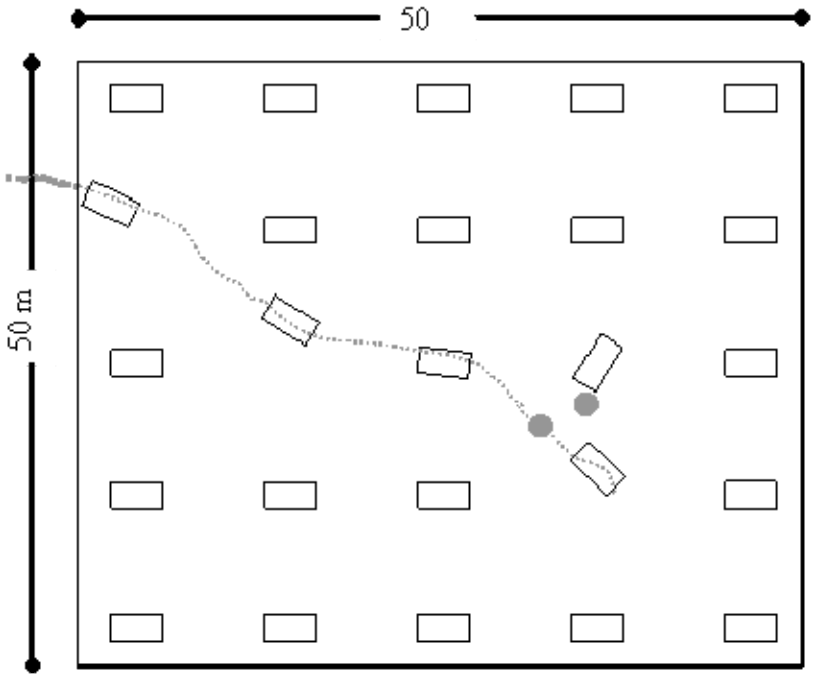
Twenty-five live-traps (Fifteen measuring 3×3.5×12 inches and ten measuring 4×4.5×15 inches) were placed in a 5 × 5 array, spaced approximately 10 m apart, on each plot (Figure 2). When obvious kangaroo rat sign was within a few meters of a trapping point, the trap was placed next to burrow entrances,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

Proportion area occupied (PAO) by the Stephens' kangaroo rat (SKR) on Base was estimated using the single-year single season logistic model in program PRESENCE. This program computes detection probabilities from the survey data to produce an unbiased estimate of PAO. Because of the limitations of the single-state program PRESENCE for analyzing these two-phased survey data, we continued to only Phase 2 live-trapping data for initial estimation of PAO and detection probability parameters in program PRESENCE. We then adjusted PAO values for proportion of plots trapped using Equation 1 (below). Plots absent of any potential kangaroo rat sign during the Phase 1 habitat surveys were considered "unoccupied" (see Brehme et al. 2006 for discussion). Therefore, we assumed that we had perfect probability of detecting 'unoccupied' plots on the Phase 1 habitat survey[1]. We expect that this is close to the truth as we systematically searched the entire sample plot and were liberal in designating plots as having potential SKR sign.

For future years, particularly after optimization of the monitoring program, we anticipate using the new multi-state version of PRESENCE that will have the ability to analyze all of our data to estimate PAO and detection probabilities for each method (Phase 1 kangaroo rat sign search, Phase 2 trapping).

Equation 1. Calculations for combining Percent Area Occupied (PAO) means and variances within strata (Phase 1 kangaroo rat sign search and Phase 2 live-trap results) and among strata (high and medium suitability strata or "focal monitoring area"; Cochran 1977, Krebs 1989).

$$\bar{x}_{ST} = \frac{\sum_{h=1}^{L} N_h \bar{x}_h}{N}$$

$\bar{x}_{ST}$ = Stratified proportion mean

N_h = Size of stratum h (ha)

h = Stratum number (1,2,3,…L)

$\bar{x}_h$ = Observed proportion mean for

N = $\sum_h N_h$

$$\text{Variance of } (\bar{x}_{ST}) = \sum_{h=1}^{L} \left[\frac{w_h^2 s_h^2}{n_h} (1 - f_h) \right]$$

W_h = Stratum weight = N_h/N

s_h^2 = Observed variance of stratum h

n_h = Sample size in stratum h

f_h = Sampling fraction in stratum $h = n_h/N_h$

[1] Authors note: recent statistical exploration of these data by Larissa Bailey, USGS, using the multi-state version of PRESENCE currently being developed, resulted in a Phase 1 detection probability estimate of 1.0 for potential sign..

Environmental and landscape covariates were also evaluated for the plots that were trapped in single-state PRESENCE (same reasons as above). In 2005, we presented the averages and standard errors of each covariate for 1) all plots, 2) plots with kangaroo rats (both species), and 3) plots with Dulzura kangaroo rat only, and 4) plots with Stephens' kangaroo rat only (Brehme and Fisher 2008). After five years of sampling, we will analyze the full covariate dataset using logistic regression.

For PAO modeling (Phase 2 trapping data only), 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 night and morning (night_morning), each individual trapping session (t), or if DKR were present 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). In 2006, we had poor trap success in the earlier months (late September and October) versus the later months (November and December). Therefore, we also analyzed month as a covariate for ρ, as well as moon illumination (moon) and mean temperature (temp). We tested models with 2-group heterogeneity (2 groups), meaning that that some animals were more detectable than others, but the corollary factor is unknown. 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).

For modeling Proportion Area Occupied by SKR (Ψ), we compared models in which Ψ was constant, varied with stratum (strata= all strata; stratumSJM = SJM historic sites vs. high and medium strata), disturbance (level of military disturbance, fire), proximity to road (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 over the sample period and with rainfall. For model selection and inference, we followed the information-theoretic approach (Burnham and Anderson 2002) and methods recommended by MacKenzie and Bailey (2004) for analyzing the fit of site-occupancy models.

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 ten 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 also collected data on individual active burrows on the initial habitat survey and again upon resurvey (Brehme et al. 2006). Individual burrow data will be presented & analyzed in a future report. 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 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).

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

We surveyed 167 plots in the historic (Montgomery 2002, 2003, 2004, Montgomery et al. 1997, 2005), high and medium suitability strata. Of these, 78 plots contained potential kangaroo rat sign (potential burrows, tracks, and/or scat) on the initial survey. 75 of these plots, along with nine plots that did not contain any observable sign, were live trapped for 2 to 4 days (4 to 8 trap events). We could not re-access three of the plots. Overall, we captured SKR in 20 plots and DKR in 43 plots (Table 3). All habitat and trapping surveys were completed between September 2007 and January 2008.

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 through 5.

TABLE 3: SUMMARY OF 2007 SURVEY EFFORT AND PRESENCE OF KANGAROO RATS

			PLOTS						CAPTURES	
			Plots with potential k-rat sign			Plots with NO potential k-rat sign			Total No. 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	75	15	14	0	3	5	0	0	0	4
High Suitability	79	53	51	14	33	4	0	0	14	43
SJM Historic	13	10	10	6	7	-	-	-	18	12
Total	167	78	75	20	43	9	0	0	32	59

FIGURE 3A. SKR DETECTIONS ON MONITORING PLOTS 2007

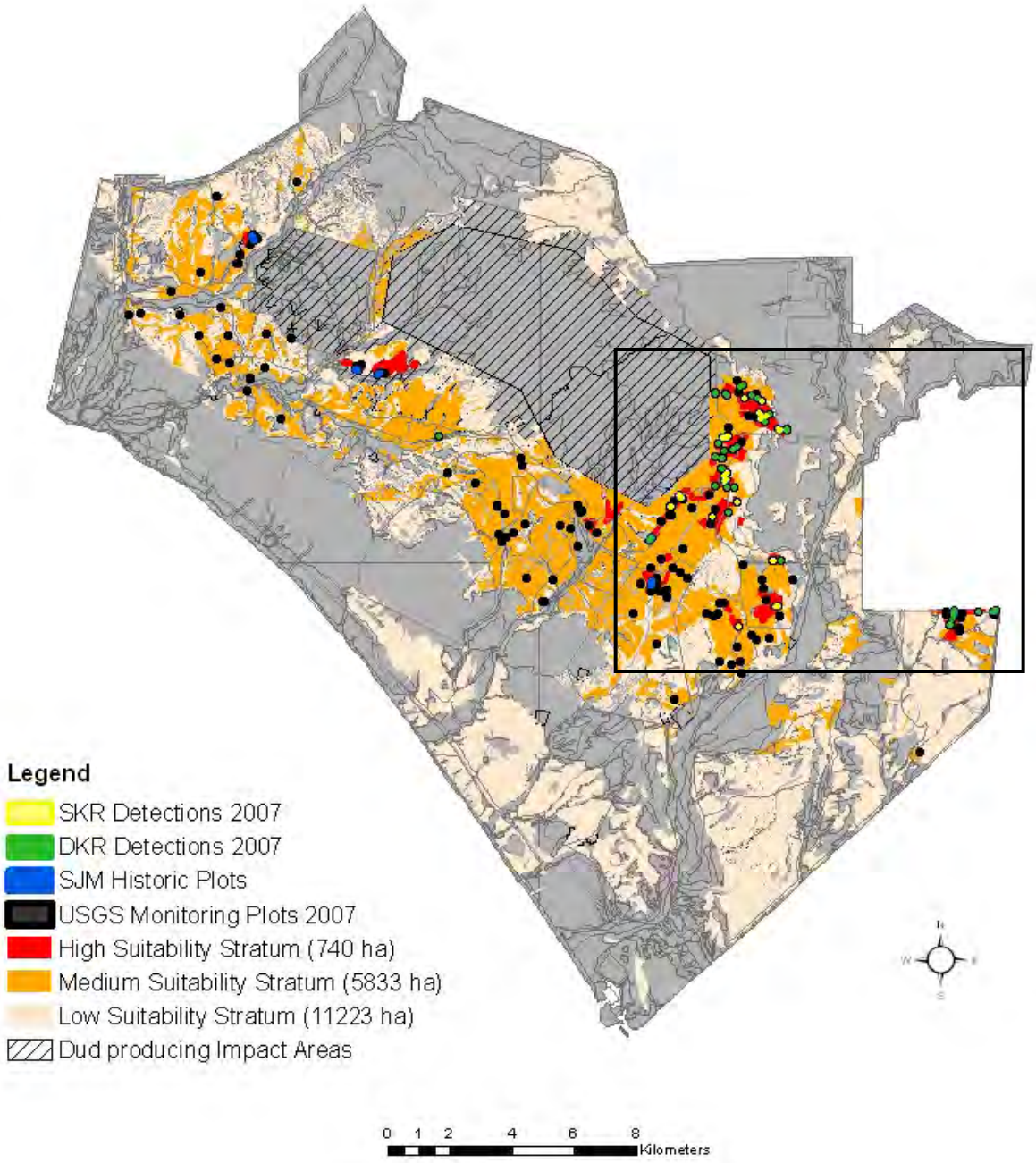


FIGURE 3B. SKR DETECTIONS ON MONITORING PLOTS 2007 (MAGNIFIED VIEW FROM INSET)

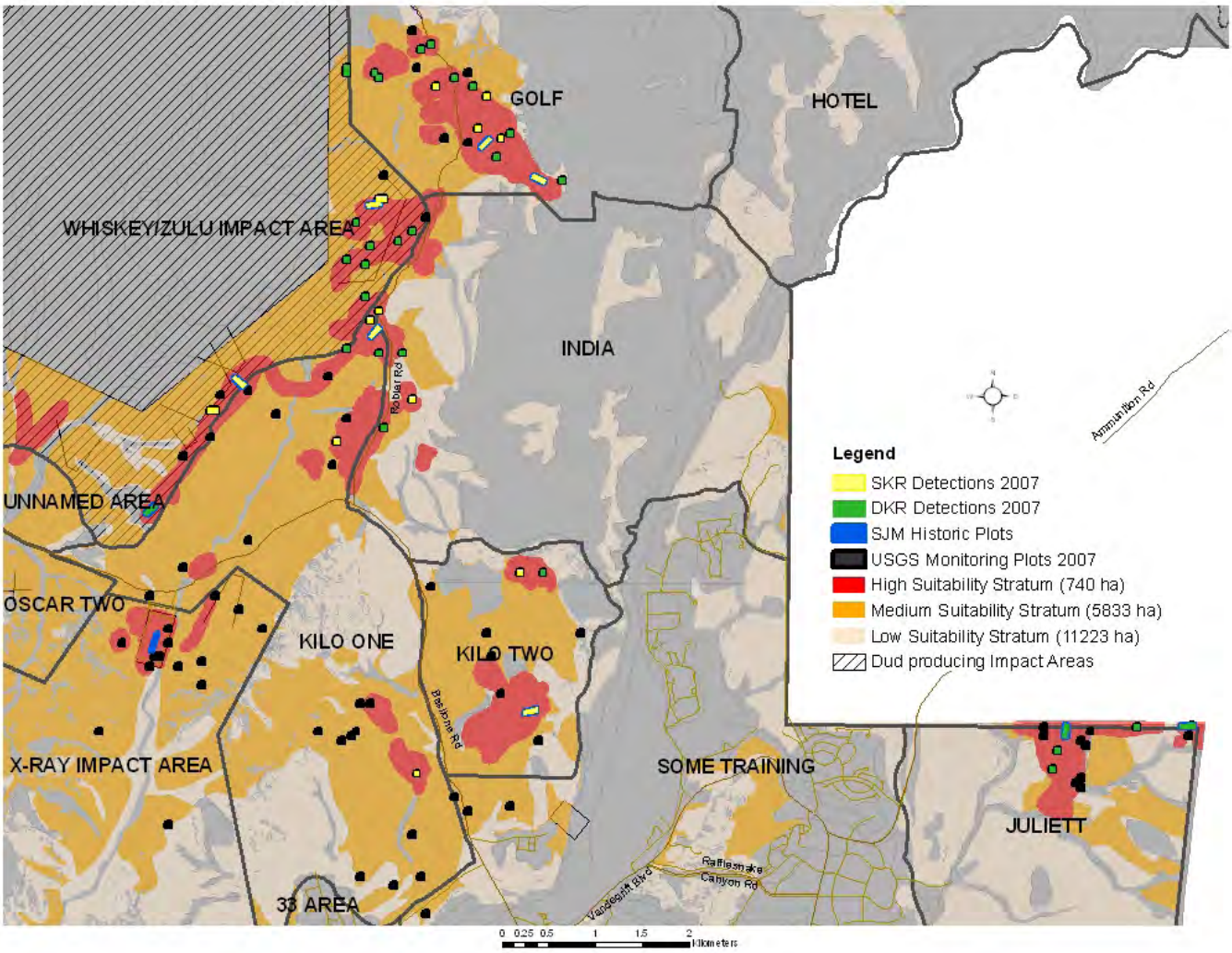


FIGURE 4. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2007

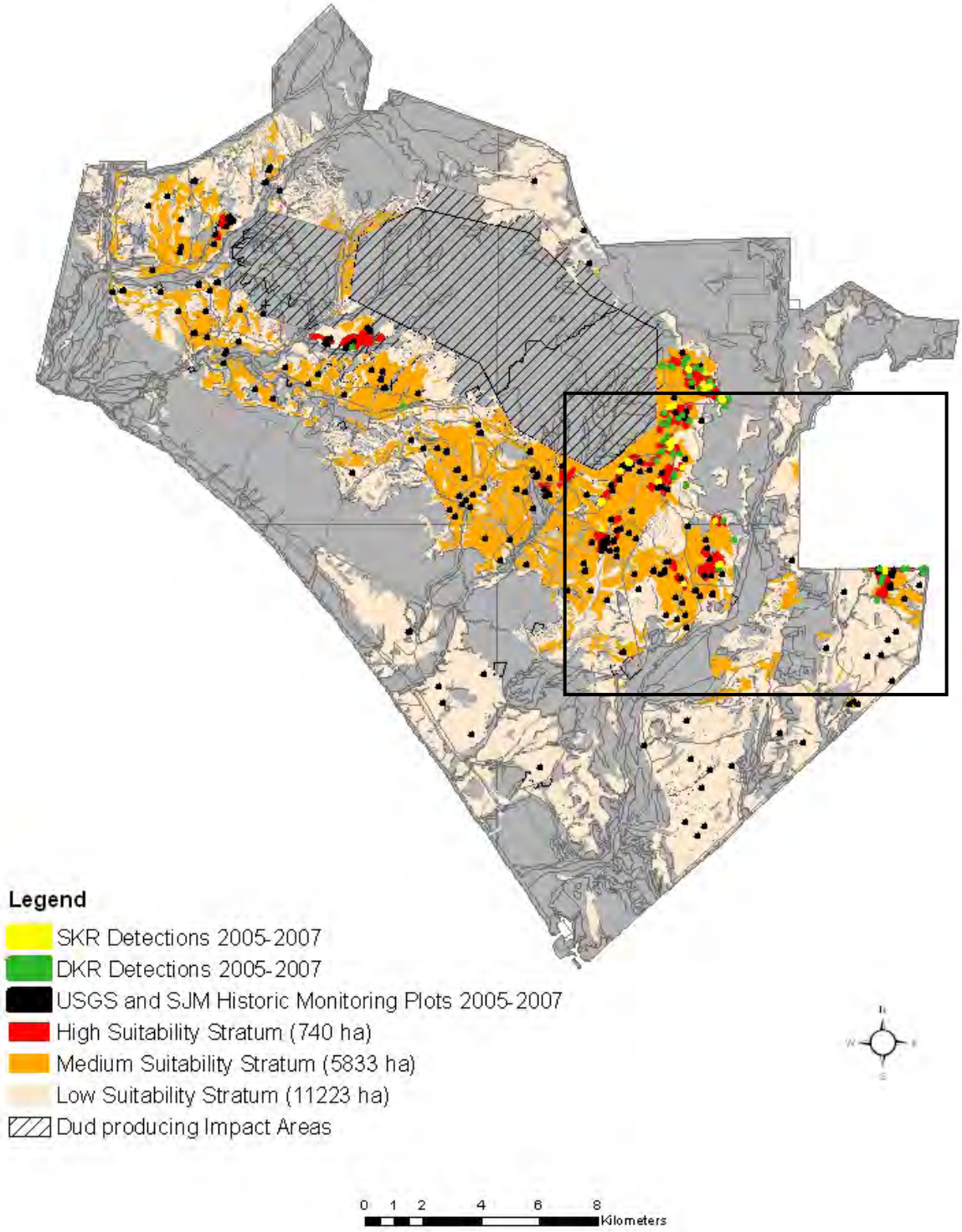
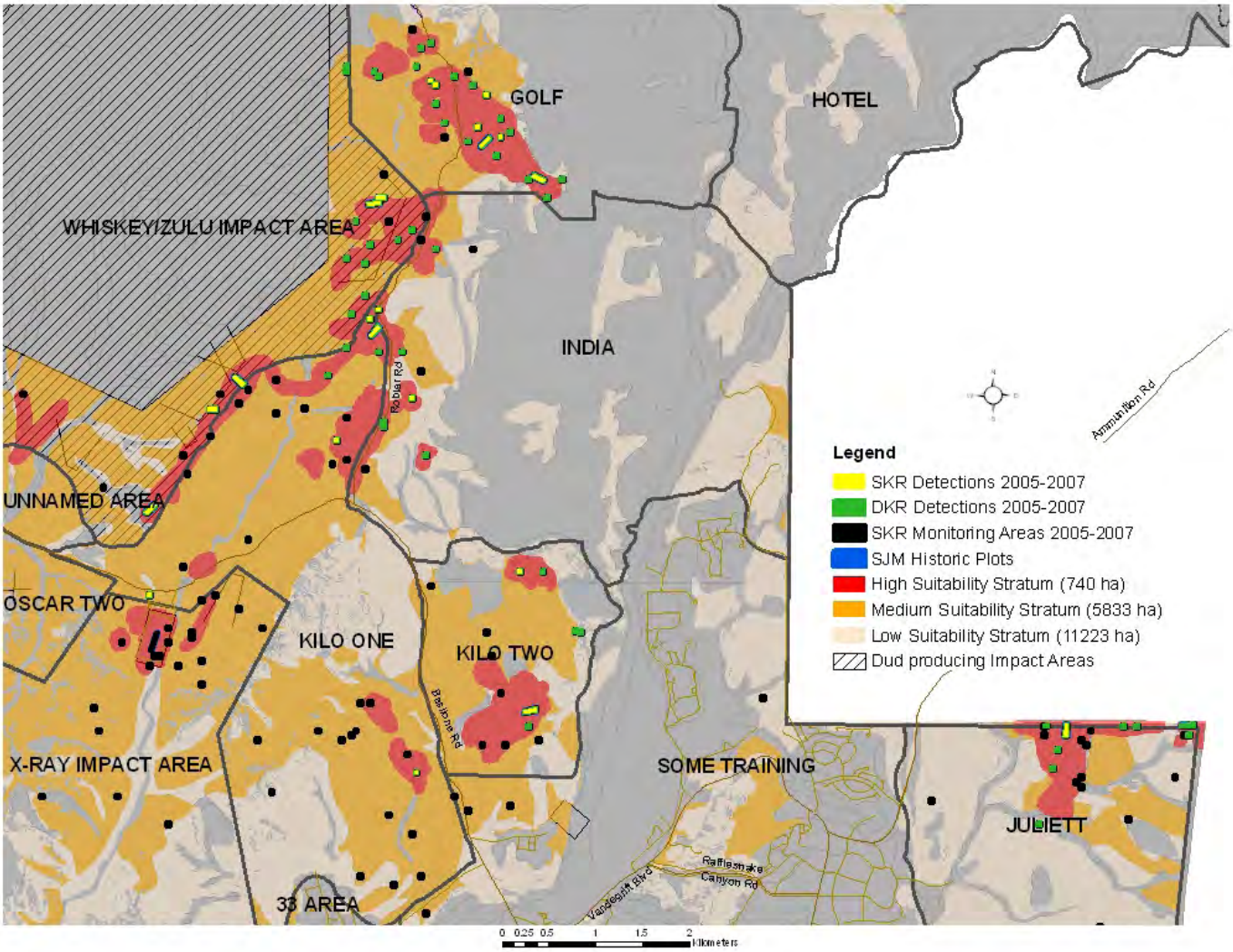


FIGURE 4B. CUMULATIVE SKR DETECTIONS ON MONITORING PLOTS 2005 THROUGH 2007 (MAGNIFIED VIEW)



Proportion Area Occupied

Estimates of the percentage of total area occupied by SKR within each of the strata were 0% and 17.7% in the medium and high suitability strata, respectively. Occupancy among the historic monitoring plots was much higher at 46.2% (inference for plots only). Estimates, standard errors, and 90% confidence intervals for proportion and total area occupied by SKR from 2005 to 2007 are presented in Table 4 and Figure 6.

We found that in 2007, as in 2006, stratum and the proportion of open ground and forbs were most predictive of SKR occupancy. The historic SJM stratum had a much higher proportion area occupied than medium or high suitability plots. This was expected, as they were chosen in known occupied habitat. Of the plots that were live-trapped, the odds of SKR occupying a plot were 7.6 times greater (95% CI: 2.7-21.8) for every 20% increase in open ground and forbs (0% vs. 20%, 20% vs. 40%, etc.).

Three covariates were significant in modeling detection probability, stratum (stratumSJM), day one versus subsequent days (Day1_other) and the presence of DKR (DKR). The probability of detecting SKR was greater on the larger SJM historic plots, on trapping days 2 through 4, and when no DKR were present (Tables 5 and 6, Figure 7). There was no support for models that included “night vs. morning” trap checks in estimating detection probability (ρ).

TABLE 4. ESTIMATES FOR AREA OCCUPIED BY SKR AMONG SAMPLING STRATA IN 2007

	Proportion Area Occupied		Area Occupied (hectares)		90% Confidence Limits (hectares)	
Stratum	estimate	se	estimate	se	low	high
"Low Suitability"	n/a					
"Medium Suitability"	0.000	0.000	0.0	0.0	0.0	0.0
"High Suitability"	0.177	0.045	130.7	33.3	74.9	186.5
"SJM Historic"	0.462	0.150	4.1	1.4	1.9	6.4
"Focal Monitoring Area" (Med+High Suitability)	0.020	0.005	130.8	32.9	75.7	185.9

FIGURE 6. TRENDS IN PROPORTION AND TOTAL AREA OCCUPIED BY SKR AMONG SAMPLING STRATA IN 2005 THROUGH 2007 WITH 90% CONFIDENCE LIMITS

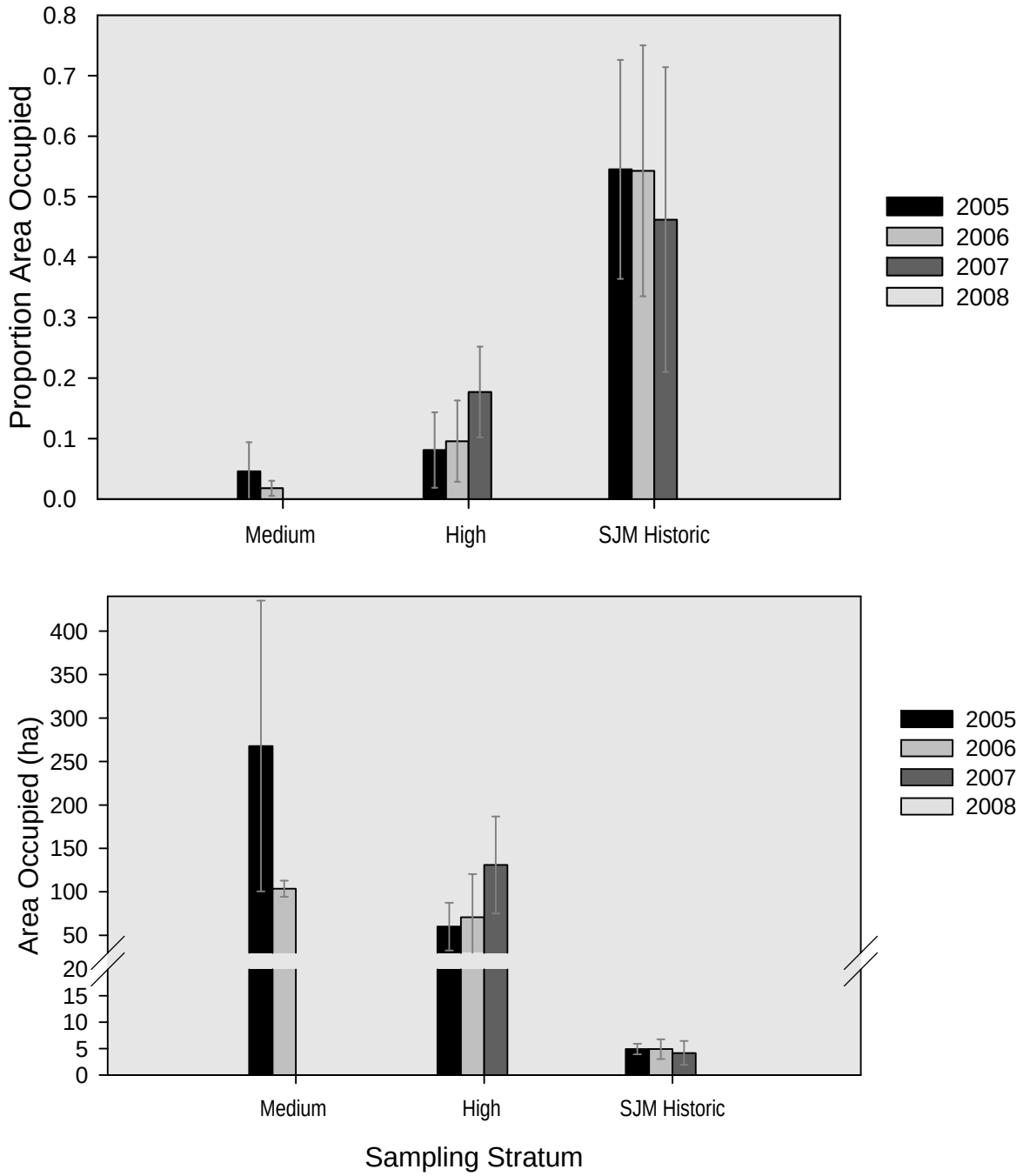


TABLE 5. PAO MODEL COMPARISON

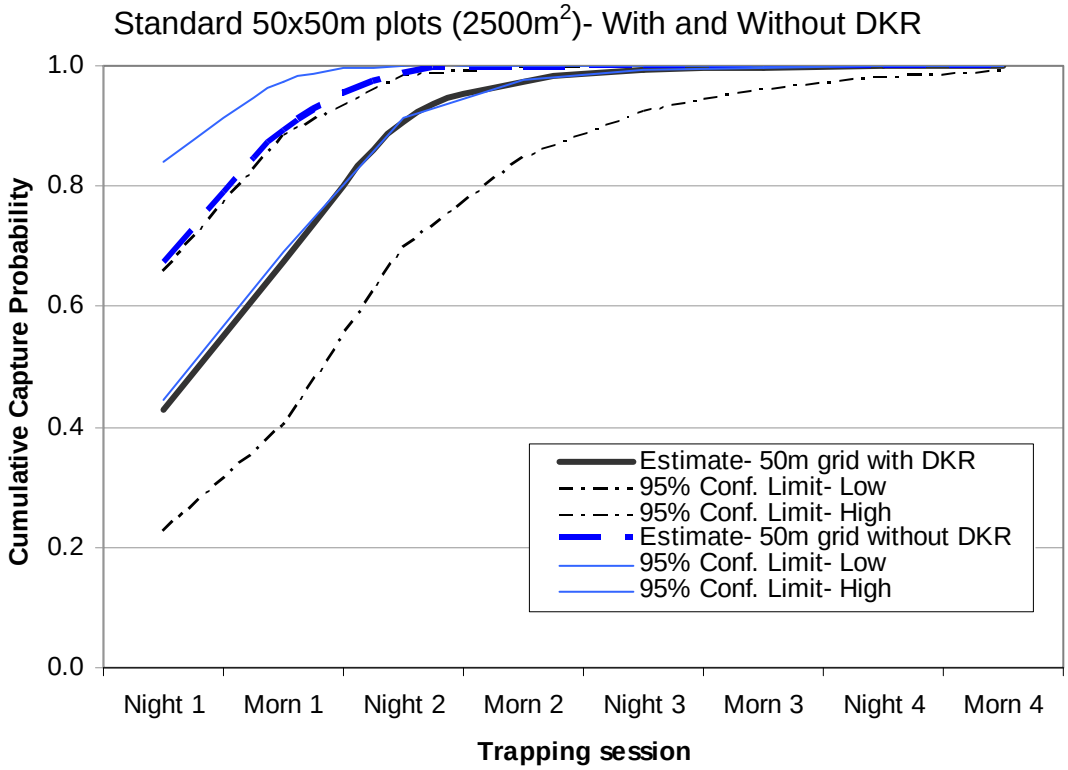
Model	Model Comparison Criteria					
	AIC	delta AIC	AIC weight	Model Likelihood	No. Par.	(-2*LogLike)
psi(OpenGrdForbs,StratumAll),p(Day1_other,DKR,StratumSJM).	153.24	0.00	0.72	1.00	8	137.24
psi(OpenGrdForbs,StratumAll),p(Day1_other, StratumSJM).	155.18	1.94	0.27	0.38	7	141.18
psi(OpenGrdForbs),p(Day1_other)	164.03	10.79	0.00	0.00	4	156.03
psi(OpenGrdForbs,Disturbance),p(Day1_other)	164.15	10.91	0.00	0.00	5	154.15
psi(OpenGrdForbs,AnnualGrass),p(Day1_other)	166.02	12.78	0.00	0.00	5	156.02
psi(StratumAll),p(Day1_other,DKR,StratumSJM).	178.30	25.06	0.00	0.00	7	164.30
psi(AnnualGrass),p(Day1_other)	180.27	27.03	0.00	0.00	4	172.27
psi(AnnualGrass/Forbs),p(Day1_other)	181.91	28.67	0.00	0.00	4	173.91
psi(Disturbance),p(Day1_other)	184.38	31.14	0.00	0.00	4	176.38
psi(.),p(Day1_other, DKR)	190.99	37.75	0.00	0.00	4	182.99
psi(PerGrass),p(Day1_other)	191.66	38.42	0.00	0.00	4	183.66
psi(RoadProximity),p(Day1_other)	191.71	38.47	0.00	0.00	4	183.71
psi(.),p(Day1_other)	191.90	38.66	0.00	0.00	3	185.90
psi(.),p(night_morn, DKR)	192.19	38.95	0.00	0.00	4	184.19
psi(shrub),p(Day1_other)	192.35	39.11	0.00	0.00	4	184.35
psi(.),p(night_morn, Day1_other)	192.53	39.29	0.00	0.00	5	182.53
psi(DKR),p(Day1_other)	193.05	39.81	0.00	0.00	4	185.05
psi(.),p(night_morn)	194.11	40.87	0.00	0.00	3	188.11
psi(.),p(DKR)	194.16	40.92	0.00	0.00	3	188.16
psi(.),p(t)	195.29	42.05	0.00	0.00	9	177.29
psi(.),p(.) = *Null Model* (i.e. occupancy and detection probability constant across sites)	195.65	42.41	0.00	0.00	2	191.65
psi(.),p(stratumSJM)	195.89	42.65	0.00	0.00	3	189.89
psi(.), p(2groups)	196.72	43.48	0.00	0.00	4	188.72
psi(.),p(moon)	197.32	44.08	0.00	0.00	3	191.32
psi(.),p(month)	197.63	44.39	0.00	0.00	3	191.63
psi(.),p(temp)	197.65	44.41	0.00	0.00	3	191.65
psi(DISI),p(.)	185.63	76.11	0.00	0.00	3	179.63

TABLE 6. DETECTION PROBABILITY BY PLOT TYPE, PRESENCE OF DKR, AND DAY

Plot Type	DKR Detected	Day	Model estimate*	se	95% CI low	95% CI high
50m	DKR	Day 1	0.430	0.118	0.227	0.659
		Day 2-4	0.718	0.099	0.495	0.868
50m	no DKR	Day 1	0.673	0.106	0.445	0.841
		Day 2-4	0.874	0.056	0.718	0.950
SJM	DKR	Day 1	0.675	0.137	0.380	0.876
		Day 2-4	0.875	0.075	0.645	0.964
SJM	no DKR	Day 1	0.851	0.091	0.585	0.958
		Day 2-4	0.951	0.037	0.805	0.989

*Top model

FIGURE 7. CUMULATIVE DETECTION PROBABILITY OF SKR WITH AND WIOTHOUT THE PRESENCE OF DKR



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 (similar size burrows with no aprons, marks that may be tracks/tail drag). 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). Presence and species were confirmed by live-trapping. 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 5 medium suitability, and 4 high suitability plots where no kangaroo rat sign was detected upon the initial habitat survey. No kangaroo rats were detected during these surveys.

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 75 plots where potential sign was recorded, all 75 still contained at least potential sign upon the pre-trapping resurvey. Of the 9 negative plots, none had potential sign upon resurvey.

Density Estimation

SKR density was estimated to be 5.4 (SE = 0.2) SKR/ha in occupied areas of the high suitability stratum and 6.0 SKR/ha (SE=0.21) in the SJM historic plots. This was close to the density estimated in 2005, but less than in 2006(Figure 8, Note: 2006 density estimates are corrected from Brehme et al. 2009).

There was most support for models that included 'night versus morning' as a covariate for p. The odds of capturing an SKR were 2.8 times greater at the morning trap check than at midnight (95% CI= 1.3 to 6.2, Table 7). Our probability of capturing an individual SKR present on the plot was high at 0.88 (95% CI= 0.71-0.97) after 2 nights. After four nights, the estimated capture probability increased to 0.98 (95% CI=0.90-1.0, Figure 9). Once an individual was captured, the probability of recapture was 0.86 (SE=0.03).

FIGURE 8. TRENDS IN DENSITY OF SKR AMONG MONITORING PLOTS IN 2005 THROUGH 2007 WITH 90% CONFIDENCE LIMITS

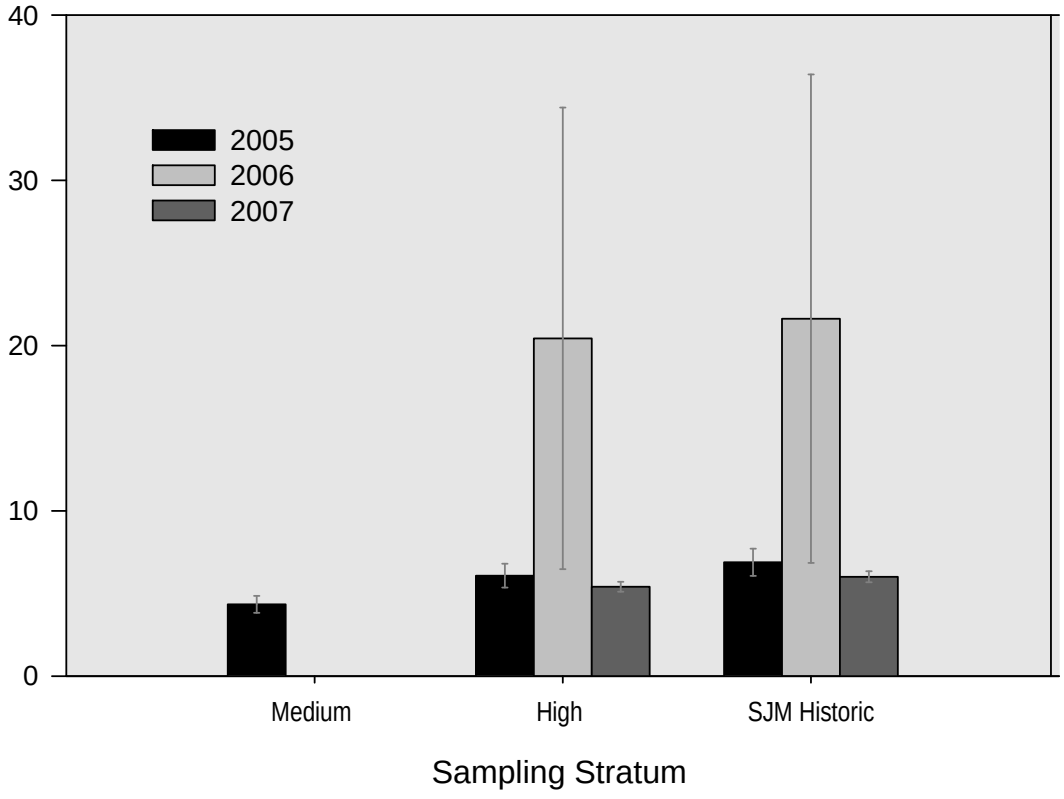
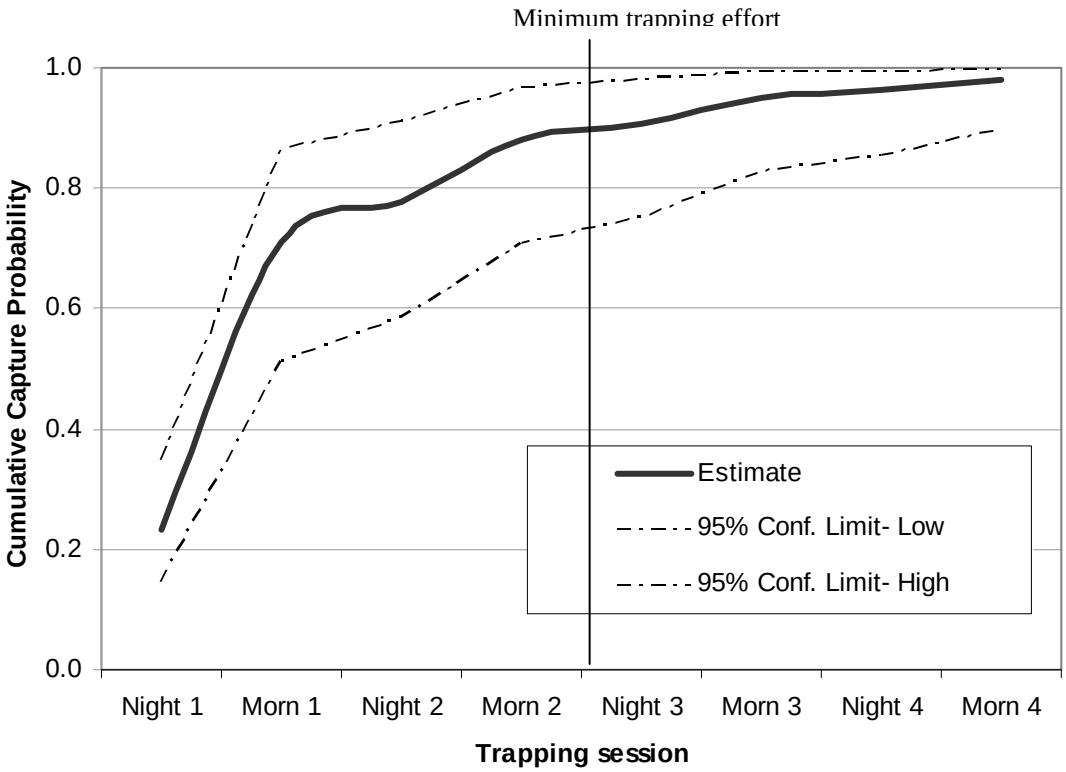


TABLE 7. CLOSED CAPTURE MODEL COMPARISON

Model	Model Comparison Criteria					
	AIC	delta AIC	AIC weight	Model Likelihood	No. Par.	(-2*LogLike)
{p(NightMorning), c(.)}	252.28	0.00	0.70	1.00	3	240.24
{p(.),c(.)}	257.12	4.84	0.06	0.09	2	247.11
[pi(.), p(.), c(.)}	257.12	4.84	0.06	0.09	2	247.11
{p(sex), c(.)}	257.12	4.84	0.06	0.09	2	247.11
{p(t), c(.)}	257.54	5.26	0.05	0.07	8	235.14
{p(Day1_other), c(.)}	258.83	6.55	0.03	0.04	3	246.79
{pi(.), p(sex), c(.)}	259.15	6.87	0.02	0.03	3	247.11
{p(.), c(t)}	261.51	9.24	0.01	0.01	7	241.21
{p=c (.)}	271.77	19.49	0.00	0.00	1	263.79

FIGURE 9. CUMULATIVE INDIVIDUAL CAPTURE PROBABILITY FOR SKR



Discussion

Overall, the estimate area occupied by SKR in 2007 on MCB Camp Pendleton was greater than the past two years of monitoring at MCBCP. Within the high suitability stratum in 2007, we estimate SKR occupied 130.7 ha (SE=33.3) in comparison to 70.8 ha (SE=) in 2006 and 60.0 ha (SE=24.2) in 2005. 2007 was a dry year in San Diego County with about one-third of the normal rainfall (98mm 2007; 274mm historical average). The increase in area occupied by SKR in 2007could be due to high survivorship and successful expansion and colonization of SKR from the previous year, where we had estimated particularly high densities. Occupancy was again positively associated with open ground, herb and forb cover, which may be largely attributable to disturbance and frequent fire intervals. In areas occupied by SKR in 2007, densities were estimated between 5.4 and 6.0 SKR/ha, which is considered "low" (Tetratech and SJM Biological Consultants 1999) for this species. Density was comparable to 2005, but substantially less than in 2006, where particularly high densities of 20 SKR/ha were estimated (Note: The 2006 density estimates were recalculated and corrected for this report). At this time, we are not finding support for SKR existing at multiple densities across habitats, but in similar (but low to medium) densities within a patchy framework, often co-occurring with DKR.

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 have been less than 0.18 (or 18%). At this low level, we have low power to model habitat suitability and lower precision for our occupancy estimates. 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). This is of utmost importance for assessing the status and trends of SKR, as well as the importance of habitat, environmental, and disturbance factors in the occupation and persistence of SKR on Base. This understanding should lead to scientifically defensible and informed management decisions.

Similarly, we only captured a single SKR in 2005 and zero SKR in 2006 and 2007 in the medium suitability stratum, resulting in low and highly imprecise estimates for this stratum. The single capture in 2006 was very close to the high suitability stratum. We suspect that most of the medium suitability stratum is unoccupied. We can increase PAO by changing the monitoring protocol in two main ways. First, we can increase the size of our monitoring plots. They are now 50x50m. An increase to 75x75m or 100x100m would increase the likelihood of occupancy. However, we initially designed the program to be compatible with that on the adjacent Fallbrook weapons station where 50x50m plots are used. In addition, if we change plot sizes, we will not be able to compare the new data to that obtained with the smaller plots. Second, we can decrease the size of the study area we are using for our long term metric. As we continue to generate new data for SKR locations across the high suitability stratum, we can redraw this stratum and move areas with a low likelihood of occupancy to the medium stratum. The medium suitability stratum would then be sampled primarily for "discovery" of new SKR locations rather than used as a monitoring metric. We believe this second option is preferable, as we can recalculate occupancy estimates from previous years with the new boundaries and not lose value of these historical data. We recommend that we continue to gather new data for SKR in this area for several years. These data from USGS and other SKR surveys on Base can then be used to draw new boundaries for these strata after the fifth year of monitoring in 2009/2010. Occupancy of the high suitability stratum would then be used for the long-term monitoring metric for SKR.

Recommendations

Management

SKR largely occur within heavily used impact areas and artillery ranges. These areas are also vital areas for training military personnel in combat operations. 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, maintenance and construction activities. At this time, we do not have information regarding the dynamics of SKR populations in relation to training impacts. Therefore, we do not recommend any specific actions in these areas. We are again restricting our current management recommendations to the dedicated SKR management area within the Juliett training area.

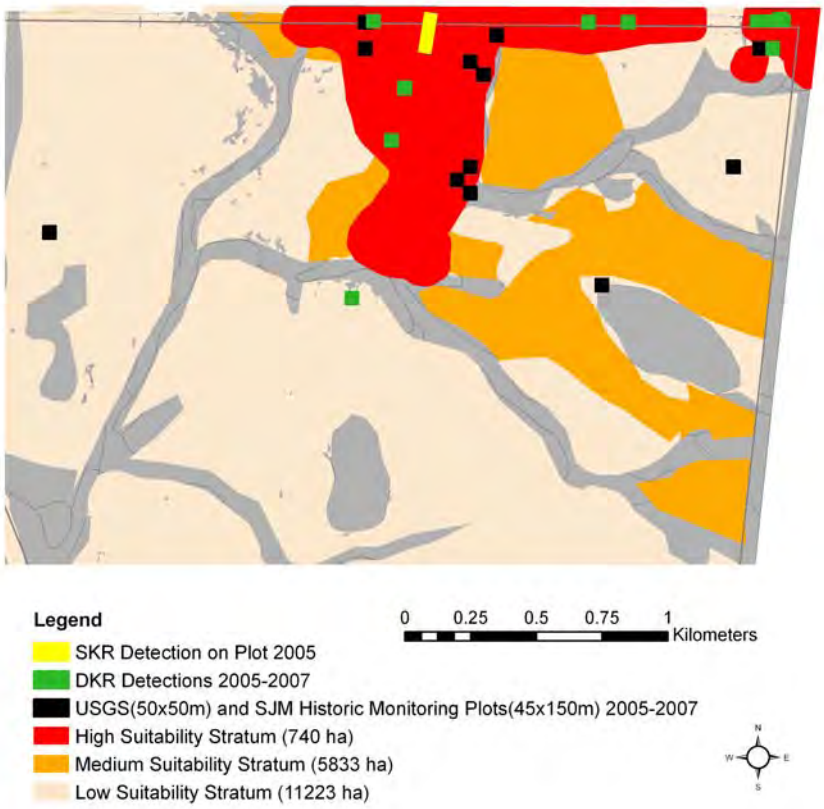
In 1992, the Fish and Wildlife Service issued a Biological Opinion that identified 9.9 ha (24.4 acres) around a firebreak within the Juliett training area to be managed for SKR in mitigation for take in the 210 range areas (FWS 1992). The Base also designated an additional 11.6 ha (28.7 acres) immediately 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.

In early 2002, the Base carried out erosion control activities along the fire road along with a variety of vegetation and soil enhancement efforts. These activities involved loosening of compacted soils by bulldozing to 18 inches with tines (deep ripping & cross-ripping) or bulldozing to 4 inches (track-walking) followed by dragging the soil surface with weighted chain link fence to loosen compacted soil, with or without prior shrub removal (Montgomery 2003). Although a temporary increase in the number of burrows was noted in some treated areas in 2002, it was unknown whether the burrows were occupied by SKR or DKR. From 2005 to 2007, we detected only DKR in this area and only a single SKR at the westernmost historic monitoring grid. The ground in the decompacted areas was composed of very large dense clumps of clay textured soil (i.e. not smooth or flat). Any further soil/habitat enhancement in these areas should consider the addition of sand in conjunction with soil decompaction methods in order to affect soil texture for the longer term.

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 recommend that appropriate and continued management action across the Juliett mitigation area take place as soon as possible to restore suitability of this area for SKR. These areas would benefit from immediate vegetation thinning by prescribed burning or other proven methods.

FIGURE 10. SKR MANAGEMENT AREA WITHIN JULIETT TRAINING AREA (RED) RECOMMENDED FOR IMMEDIATE HABITAT MANAGEMENT



Monitoring Protocol

1. In order to increase precision of SKR occupancy estimates and better understand current distribution, recommend continued allocation of effort to the medium & high suitability strata (vs. low suitability stratum, see Brehme et al. 2006, p.20). Continue to monitor the 50 plots chosen in 2005 and survey an additional 25 to 30 plots in each stratum. These and other data will be used to redraw SKR sampling boundaries by 2011.

2. 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.

3. 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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References Cited

Berger, J. 1990. Persistence of different-sized populations: an empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4:91-98.

Best, T. L., and G. D. Schnell. 1974. Bacular variation in kangaroo rats (genus *Dipodomys*). American Midland Naturalist 91:257-270.

Bleich, V.C. 1973. Ecology of rodents at the United States Naval Weapons Station Seal Beach, Fallbrook Naval Weapons Annex, San Diego County, California. M.A. Thesis, California State University, Long Beach.

Bleich, V.C. 1977. *Dipodomys stephensi*. Mammalian Species 73:1-3.

Brehme, C., Burnham, K., Kelt, D., Olsen, A., Montgomery, S., Hathaway, S., and R. Fisher. 2006. Stephens' Kangaroo Rat (*Dipodomys stephensi*) Monitoring Protocol for MCB Camp Pendleton. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Brehme, C. and R. Fisher. 2009. Stephens' Kangaroo Rat Monitoring Results on MCB Camp Pendleton, 2006. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Brehme, C. and R. Fisher. 2008. Stephens' Kangaroo Rat Monitoring Results on MCB Camp Pendleton, 2005. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Brock, R.E, and D. A. Kelt. 2004a. Influence of roads on the endangered Stephens' kangaroo rat: are dirt and gravel roads different? Biological Conservation 118: 633-640.

Brock, R.E, and D. A. Kelt. 2004b. Keystone effects of the endangered Stephens' kangaroo rat (*Dipodomys stephensi*). Biological Conservation 116: 131-139.

Brown , J.H. and E.J. Heske. 1990. Control of a desert-grassland transition by a keystone rodent guild. Science 250: 1705-7.

Burke, R.L., Tasse, J., Badgley, C., Jones, S.R., Fishbein, N., Phillips, S., and M.E. Soulé. 1991. Conservation of the Stephens' kangaroo rat (*Dipodomys stephensi*): planning for persistence. Bull. Southern California Academy of Science 90(1):10-40.

Burnham, K.P. and D.R. Anderson. 2002. Model Selection and Inference. A Practical Information-Theoretical Approach (2nd Edition). Springer-Verlag, New York.

Callaway, R.M. and F.W. Davis. 1993. Vegetation dynamics, fire, and the physical environment in coastal central California. Ecology 74(5):1567-1578.

Cochran, W.G. 1977. Sampling Techniques (3rd ed.), Wiley, New York.

Diffendorfer, J. and D. Deutschman. 2002. Monitoring the Stephens' kangaroo rat: An analysis of monitoring methods and recommendations for future monitoring. Report for the U.S. Fish and Wildlife Service.

Fahrig, L. 1992. Relative importance of spatial and temporal scales in a patchy environment. Theoretical Population Biology 41:300-314.

French, A.R. 1993. Physiological ecology of the Heteromyidae: economics of energy and water utilization. In H.H. Genoways and J.H. Brown (eds.) Biology of the Heteromyidae, Special Publication No, 10 of the American Society of Mammalogists, pages 509-538.

Goldingay, R.L., Kelly, P.A. and D.F. Williams. 1997. The kangaroo rats of California: endemism and conservation of keystone species. Pacific Conservation Biology 3:47-60.

Goldingay, R.L. and M.V. Price. 1997. Influence of season and a sympatric cogener on habitat use by Stephens' kangaroo rat. Conservation Biology 11:708-717.

Huggins, R. M. 1989. On the statistical analysis of capture-recapture experiments. Biometrika 76:133-140.

Huggins, R. M. 1991. Some practical aspects of a conditional likelihood approach to capture experiments. Biometrics 47:725-732.

Jones, L. and J. Diamond. 1976. Short-term base studies of turnover in breeding bird populations on the California Channel Islands. Condor 78:526-549.

Kaufman, D.W. and G.L. Kaufman. 1982. Effects of moonlight on activity and microhabitat use of Ord's kangaroo rat. Journal of Mammalogy 63:309-312.

Keeley, J.E. 2002. Fire management of California shrubland landscapes. Environmental Management 29(3):395-408.

Kelt, D.A., Konno, E.S., and J.A. Wilson. 2005. Habitat management for the endangered Stephens' kangaroo rat: The effect of mowing and grazing. Journal of Wildlife Management 69(1):424-429.

Kendall, W.L. 1999. Robustness of closed capture-recapture methods to violations of the closure assumption. Ecology 80: 2517-2525.

Krebs, C.J. 1989. Ecological Methodology. Harper Collins Publishers, Inc. New York. 654pp.

Lackey, J.A. 1967a. Biosystematics of the heermani group kangaroo rats in southern California. Transactions of the San Diego Society of Natural History 14:313-344.

Lackey, J.A. 1967b. Growth and development of *Dipodomys stephensi*. Journal of Mammalogy 48:624-632.

Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1455-1460.

Lowe M. 1997. Diet of Stephens' kangaroo rat, *Dipodomys stephensi*. Southwestern Naturalist 42(3): 358-361.

MacKenzie, D. I and L.L. Bailey. 2004. Assessing the fit of site-occupancy models. Journal of Agricultural, Biological, and Environmental Statistics 9(3):300-318.

MacKenzie, D.I., Bailey, L.L. and J.D. Nichols. 2004. Investigating species co-occurrence patterns when species are detected imperfectly. Journal of Animal Ecology 73(3):546.

MacKenzie, D. I., Nichols, J.D., Hines, J.E., Knutson, M.G., and A.B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84(8): 2200-2207.

MacKenzie, D. I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, J.A., and Ca.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83(8): 2248-2255.

Marine Corps Base Camp Pendleton. 2001. Integrated Natural Resources Management Plan. *http://www.cpp.usmc.mil/base/environmental/inrmp.htm*

Marine Corps Base Camp Pendleton. 2002. MCB Camp Pendleton Strategic Plan 2002. http://www.pendleton.usmc.mil/base/environmental/index.asp

McClenaghan, Jr., L.R and E. Taylor. 1993. Temporal and spatial demographic patterns in *Dipodomys stephensi* from Riverside County, California. Journal of Mammalogy 74(3):636-645.

Montgomery, S.J. 2002. Results of a 1998 Field monitoring study of the Stephens' kangaroo rat at Marine Corps Base, Camp Pendleton, CA. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Montgomery, S.J. 2003. Final report of 2002 erosion control activities in the Juliett training area of Marine Corps Base, Camp Pendleton, CA. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Montgomery, S.J. 2004. Results of a 2000 Field monitoring study of the Stephens' kangaroo rat at Marine Corps Base, Camp Pendleton, CA. Draft Report to AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Montgomery, S.J., D.J. Grout, A. Davenport, R.N. Knight, and SJM Biological Consultants. 2005. Stephens' Kangaroo Rat Monitoring Program, and Results of the 2001-2002 Monitoring Session, at Naval Weapons Station Seal Beach, Detachment Fallbrook, Fallbrook, California. Prepared for Conservation Program Manager, Naval Weapons Station Seal Beach, Detachment Fallbrook, Fallbrook, California.

Montgomery, S.J., Sawaski, J, and D. Mitchell. 1997. Survey report and addendum for Stephens' kangaroo rat on Marine Corps Base Camp Pendleton, California. Prepared for AC/S Environmental Security, Marine Corps Base, Camp Pendleton.

Naval Energy and Environmental Support Activity (NEESA). 1984. Initial Assessment Study of Marine Corps Base, Camp Pendleton, California. NEESA 13-057.

O'Farrell, M. 1974. Seasonal activity patterns of rodents in a sagebrush community. Journal of Mammalogy 55:809-823.

O'Farrell, M. 1992. Establishment of a population monitoring program for the endangered Stephens' kangaroo rat. Transactions of the western section of the Wildlife Society 28:112-119.

O'Farrell, M.J. and C.E. Uptain. 1987. Distribution and aspects of the natural history of Stephens' kangaroo rat (*Dipodomys stephensi*) on the Warner Ranch, San Diego County, California. Wassman Journal of Biology 45:34-48.

O'Farrell, M.J. and C.E. Uptain. 1989. Assessment of population and habitat status of the Stephens' kangaroo rat (*Dipodomys stephensi*). California Department of Fish and Game Nongame Bird and Mammal Section, Report 72.

Pollock K. H., Marsh H., Lawler I., Alldredge M. W. 2006. Estimating animal abundance in heterogeneous environments: an application to aerial surveys of dugong. Journal of Wildlife Management. 70: 255–262.

Price, M.V. and 1993 Field ecology class. 1993. The potential value of fire for managing Stephens' kangaroo rat habitat at Lake Perris State Recreation Area. Supplement for California Dept of Parks and Recreation.

Price, M.V. and P.R. Endo. 1989. Estimating the distribution and abundance of a cryptic species, *Dipodomys stephensi* (Rodentia: Heteromyidae), and implications for management. Conservation Biology 3:293-301.

Price, M. V. and M. Gilpin. 1996. Modelers, mammalogists, and metapopulations: designing Stephens' kangaroo rat reserves. In: D. R. McCullough (ed.) Metapopulations and Wildlife Conservation and Management. Island Press, Washington DC, pp. 217-240.

Price, M.V., Goldingay, R. L., Szychowski, S, and N.M. Waser. 1994b. Managing habitat for the endangered Stephens' kangaroo rat (*Dipodomys stephensi*): Effects of shrub removal. Am. Midl. Nat. 131:9-16.

Price, M.V. and P.A. Kelly. 1994. An age-structured demographic model for the endangered Stephens' kangaroo rat. Conservation Biology 8:810-821.

Price, M.V., P.A. Kelly, and R.L. Goldingay. 1992. Distinguishing the endangered Stephens' kangaroo rat (*Dipodomys stephensi*) from the Pacific kangaroo rat (*Dipodomys agilis*). Bull. Southern California Acad. Sci. 91(3):126-136.

Price, M.V., P.A. Kelly, and R.L. Goldingay. 1994a. Distances moved by Stephens' kangaroo rat (*Dipodomys stephensi*) and implications for conservation. Journal of Mammalogy 75:929-939.

Price, M.V., W.S. Longland, and R.L. Goldengay, 1991. Niche relationships of Dipodomys agilis and *Dipodomys stephensi*: two sympatric kangaroo rats of similar size. American Midland Naturalist 126:172-186.

Price, M.V., Waser, N.M. and T.A. Bass. 1984. Effects of moonlight on microhabitat use by desert rodents. Journal of Mammalogy 65:353-356.

Royle, J.A. 2004. Modeling abundance index data from anuran calling surveys. Conservation Biology 18(5):1378-1385.

Royle, J.A. and J.D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84(3):777-790.

Spencer, W. D., Conservation Biology Institute. 2002. Stephens' kangaroo rat survey and management recommendations for the Santa Ysabel Open Space Reserve, San Diego County, California.

Tetratech and SJM Biological Consultants. 1999. Biological Assessment and Management Plan for Stephens' kangaroo rat on Marine Corps Base Camp Pendleton, California. Prepared for AC/SEnvironmental Security, Marine Corps Base, Camp Pendleton.

Thomas , J.R. 1975. Distribution, population densities, and home range requirements of the Stephens' kangaroo rat (*Dipodomys stephensi*). M.A. Thesis, California State Polytechnic University, Pomona, 64p.

U.S. Fish and Wildlife Service. 1992. Biological Opinion on the use of Range 210E, Marine Corps Base, Camp Pendleton, California. (1-6-92-F-48)

U.S. Fish and Wildlife Service. 1997. Draft Recovery Plan for the Stephens' Kangaroo Rat. Region 1, U.S. Fish and Wildlife Service, Portland, OR, 71 pp.

Zedler, P.H., Gautier, C.R., and G.S. McCaster. 1983. Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal scrub. Ecology 64(4):809-818.