Western Ecological Research Center

Stephens' Kangaroo Rat Monitoring Results on MCB Camp Pendleton, Fall/Winter 2006.

By Cheryl S. Brehme and Robert N. Fisher

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Stephens' Kangaroo Rat *(Dipodomys stephensi)* Monitoring Results on MCB Camp Pendleton, Fall/Winter 2006.

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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 estimates of SKR occupancy in 2006 on MCB Camp Pendleton were similar to the previous year. Within the high suitability stratum, we estimated SKR occupied 70.8 ha (SE=29.7) in 2006 compared to 60.0 ha (SE=24.2) in 2005. At the spatial scale of 50x50m grids, occupied habitat is approximately 20% of that expected and reported before the onset of this program. In areas occupied by SKR, density was estimated at 5.5 SKR/ha (SE=2.3), which is considered "medium" for this species (O'Farrell and Uptain 1987) or "low" (Tetratech and SJM Biological Consultants 1999) and were comparable to 2005 estimates of 4 to 7 SKR/ha in occupied habitat. At this time, we are not finding support for SKR existing at multiple densities across habitats, but in similar densities in a patchy framework, often co-occurring with DKR. We are also finding that DKR are much more prevalent in the pre-identified SKR habitat (or high suitability stratum) than are SKR. These results continue to indicate that SKR are likely much rarer on MCB Camp Pendleton than previously thought, greatly increasing the importance of active management for this species.

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, 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.

In 2006, we found evidence of low probabilities of SKR capture and detection in the months of September and October in comparison to November and December. It is possible that the decreased detectability during this time was due to altered seed availability or to lower SKR activity in response to recent fires. We will continue to investigate this in future years to determine if this is an annual phenomenon. As with 2005, we found support that SKR were 1) less likely to be captured within the first 24 hours of placing live-traps in comparison to subsequent days and 2) were more likely to be captured after their initial capture (i.e. "trap happy"). There was also support that moon illumination had a negative effect on both detection and capture of SKR.

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 2.3 times (95% CI: 1.0-5.2). This 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 2006

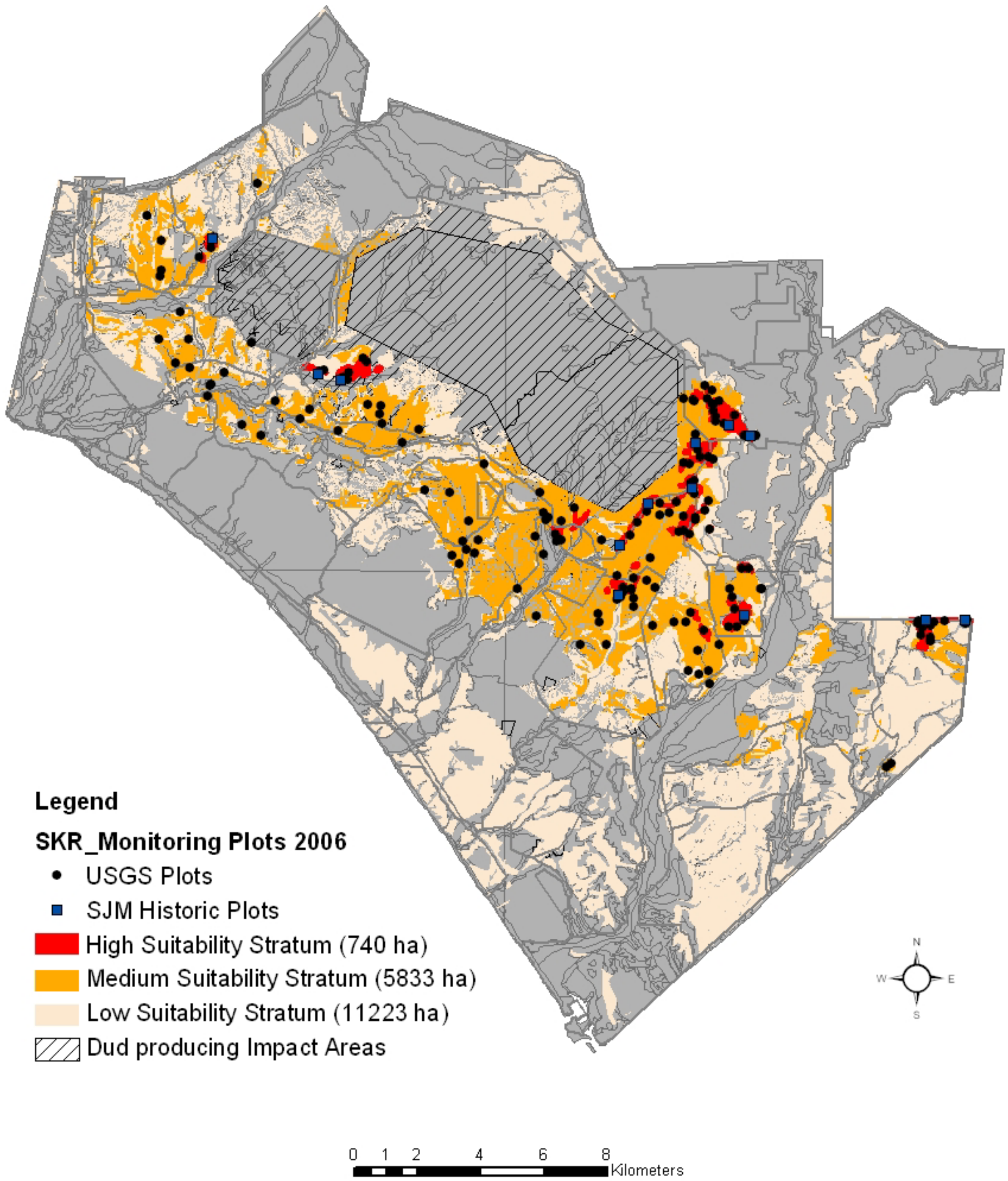


TABLE 1. MCB CAMP PENDLETON SKR MONITORING PROTOCOL ELEMENTS

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

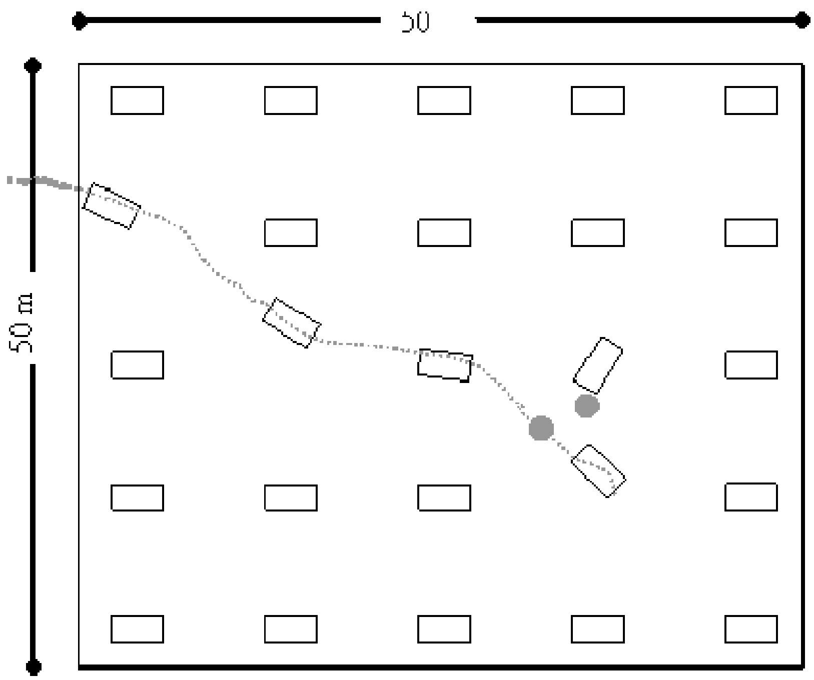
SKR occurs sympatrically, and often syntopically, with DKR on MCBCP. Both kangaroo rats are similar in size and there are no physical characteristics that distinguish SKR burrows from DKR burrows; therefore, all sample plots containing potential kangaroo rat burrows were live-trapped for a minimum of two consecutive nights (4 trap events). In 2005, the probability of detecting SKR on a plot after two nights was estimated to be 0.97 (95% CL: 0.88-1.00) and the probability of capturing an individual SKR was 0.83 (95% CL: 0.67-0.94). 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 late summer and fall months (September- December). 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. 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 may decrease during full moon periods (O'Farrell 1974, Kaufman and Kaufman 1982, Price et al. 1984), we attempted to conduct all trapping during new and part moon phases only.

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.

This year, we attempted to use the new multi-state PRESENCE program to accommodate these data. However, there were several analysis and computer software glitches that were unable to be corrected in a timely manner for this report (pers. comms. Darryl MacKenzie, Jim Hines). 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).

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

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

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

N_h = Size of stratum h (ha)

h = Stratum number (1,2,3,…L)

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

N = $\sum n_h$

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 could not be tested with the entire dataset 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). Since we documented only one new plot with SKR in 2006, we did not redo these analyses. Likewise, logistic regression with the use of habitat covariates was not attempted due to the extremely low number of occupied plots and associated problems with generating meaningful models.

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 detection probability, we compared models where ρ was constant (.), varied by night and morning (night_morning), or each individual trapping session (t). 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).

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 Ψ, we also tested models with 2-group heterogeneity (2 groups) and presence of DKR. 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 nine 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, 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 takes 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), between the first session and all subsequent sessions (Day 1_other), by month (month; Sept/Oct vs. Nov/Dec), by moon illumination, or mean temperature. 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).

For closed capture modeling in Program MARK, we first analyzed models using the complete trapping dataset with both night and morning live-trapping events. These data were not initially pooled since many animals were captured on both night and morning events. However, these models showed evidence of very poor fit to the data (dispersion: c-hat >7). Therefore, we used a condensed dataset for the analysis with night and morning data pooled into a single “session-day”.

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.

Historic Monitoring Plots

We continued to analyze trends for the ten historic grids that were monitored in 1996, 1998, 2000, and 2002 (Montgomery 1996, 2002) and 2005 (Brehme and Fisher 2008). These plots were historically trapped for five consecutive days, as five days are hypothesized to achieve a near perfect probability of capture (O'Farrell 1992). We adjusted our numbers of SKR captured over 2 to 4 night/days to a 5-day estimate using the following equation #3:

$$N_{5day} = \frac{Count_{x\ days}}{p_{x\ days}}$$

where: Count is the number of unique individuals captured

p is probability of capturing SKR over X number of days

p over 5 days from 1996 to 2002 is assumed to be near 1.0.

x is number of days the plot was trapped

For SKR we used the capture probability (p) of our best model from Mark recapture analyses. As this analysis is very time intensive, for DKR we used the cumulative capture rate (for p) from all plots that were trapped for 4 nights, assuming we captured all DKR over the 4 nights.

Species Discrimination

It is very important to this program that SKR be accurately identified in the field (i.e. properly discriminated from the sympatric DKR). At this time, SKR are identified by their larger postorbital width, eye position, and baculum angle on males. Other characteristics that are mostly consistent in SKR are a lighter pelage color, lack of a large white spot at the base of the ear, and typically a lack of white hairs at the very tip of the tail. Still, especially with juveniles and subadults, proper identification is largely based upon the skill of the observer. We analyzed measurement data of all kangaroo rats captured in 2005 using discriminant function analysis (DFA, Brehme and Fisher 2008). We included hind foot length, ear length, head length, preorbital width, and postorbital width measurements as independent variables and species (SKR vs. DKR) as the dependant variable. Models were evaluated by their strength in discriminating species in a classification matrix. Year 2006 and 2007 data will be used to cross validate the model and compare to the canonical discrimination function reported by Price et al. (1992). We seek to verify expert identifications by DNA in the near future.

Results

We surveyed 169 plots in September and October of 2006 in the historic (Montgomery 2002, 2003, 2004, Montgomery et al. 1997, 2005), high and medium suitability strata. Of these, 60 plots contained potential kangaroo rat sign (potential burrows, tracks, and/or scat) on the initial survey. 58 of these plots, along with 9 plots that did not contain any observable sign, were live trapped between September and December for 2 to 4 days (4 to 8 trap events). We could not re-access two of the plots. Overall, we captured SKR in 12 plots and DKR in 38 plots (Table 3).

As with 2005, 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, and the border to the Fallbrook Naval Weapons Station (Juliett). Maps of plot locations and SKR detections, as well as DKR detections are presented in Figures 3 through 5.

TABLE 3: SUMMARY OF 2006 SURVEY EFFORT AND PRESENCE OF KANGAROO RATS

			Plots with potential k-rat sign			Plots with NO potential k-rat sign		
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
Low Suitability	0	-	-	-	-	-	-	-
Medium Suitability	80	11	8	0	4	1	0	0
High Suitability	76	39	39*	5	28	7	0	0
SJM Historic	13	10	10	7	6	1	0	0
Total	169	60	57	12	38	9	0	0

*one plot had krat sign upon 2nd survey only and DKR was captured.

FIGURE 3A. SKR DETECTIONS ON MONITORING PLOTS 2006

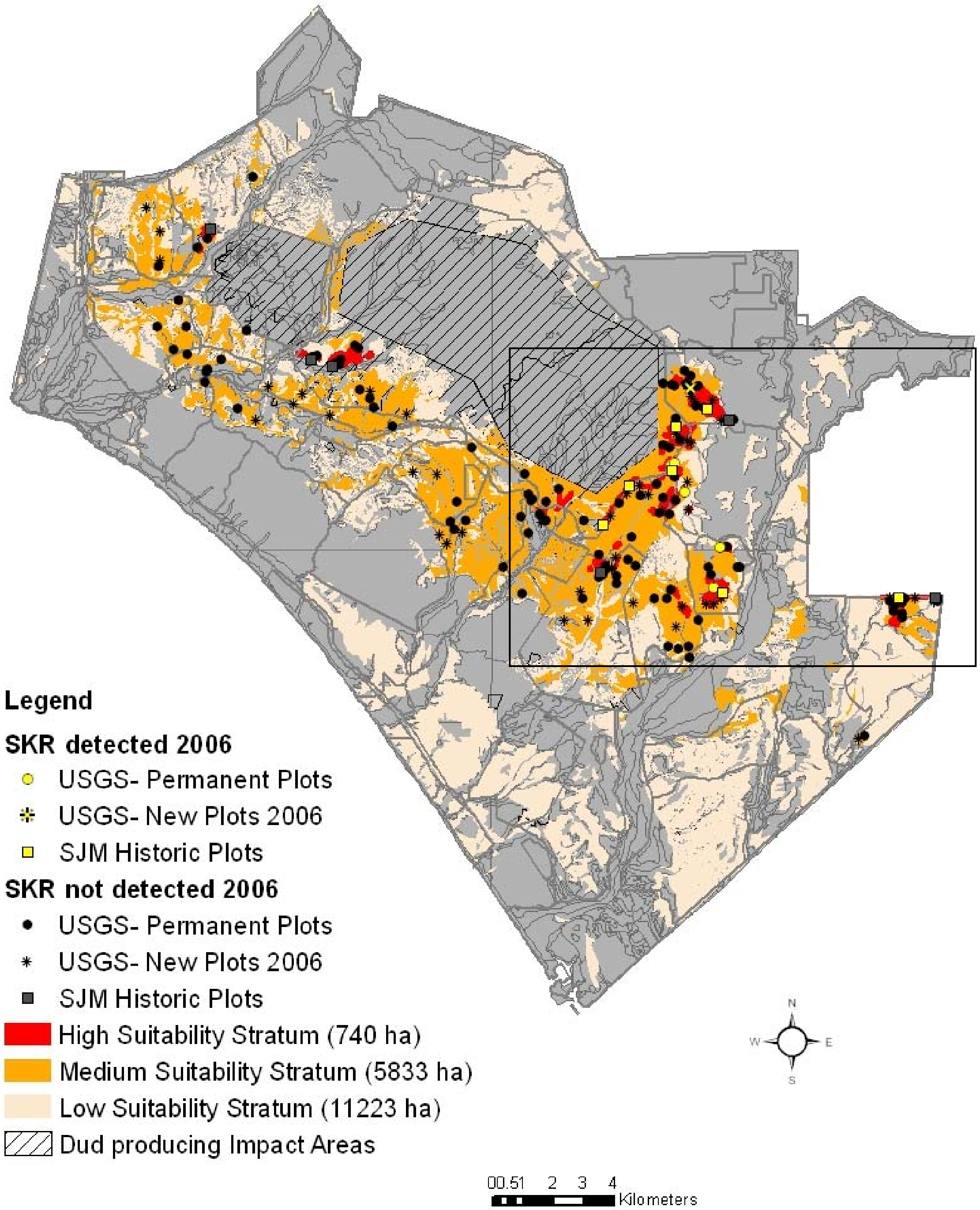


FIGURE 3B. SKR DETECTIONS ON MONITORING PLOTS 2006 (MAGNIFIED VIEW FROM INSET)

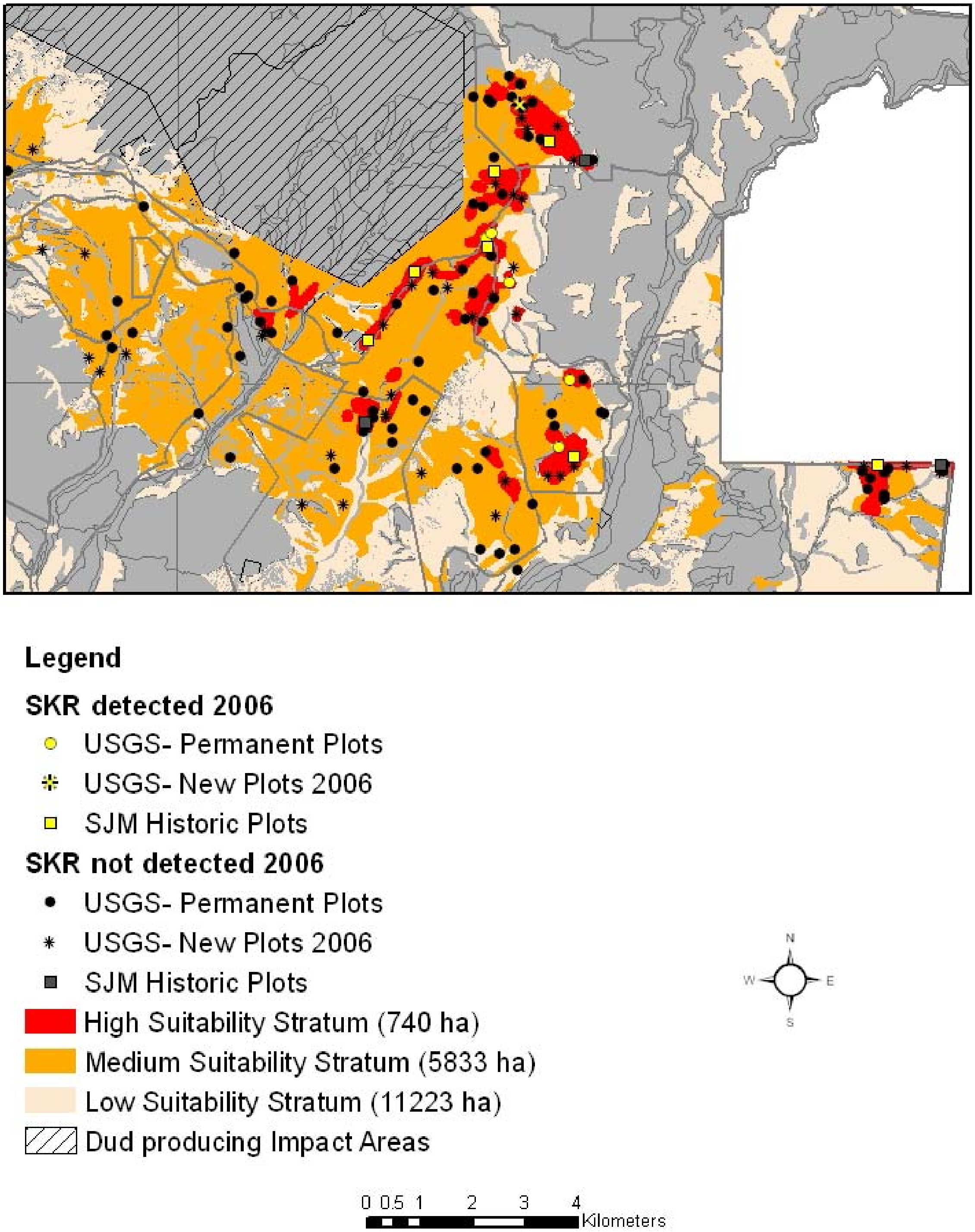


FIGURE 4. KANGAROO RAT DETECTIONS (SKR AND DKR) ON MONITORING PLOTS 2006 (MAGNIFIED VIEW)

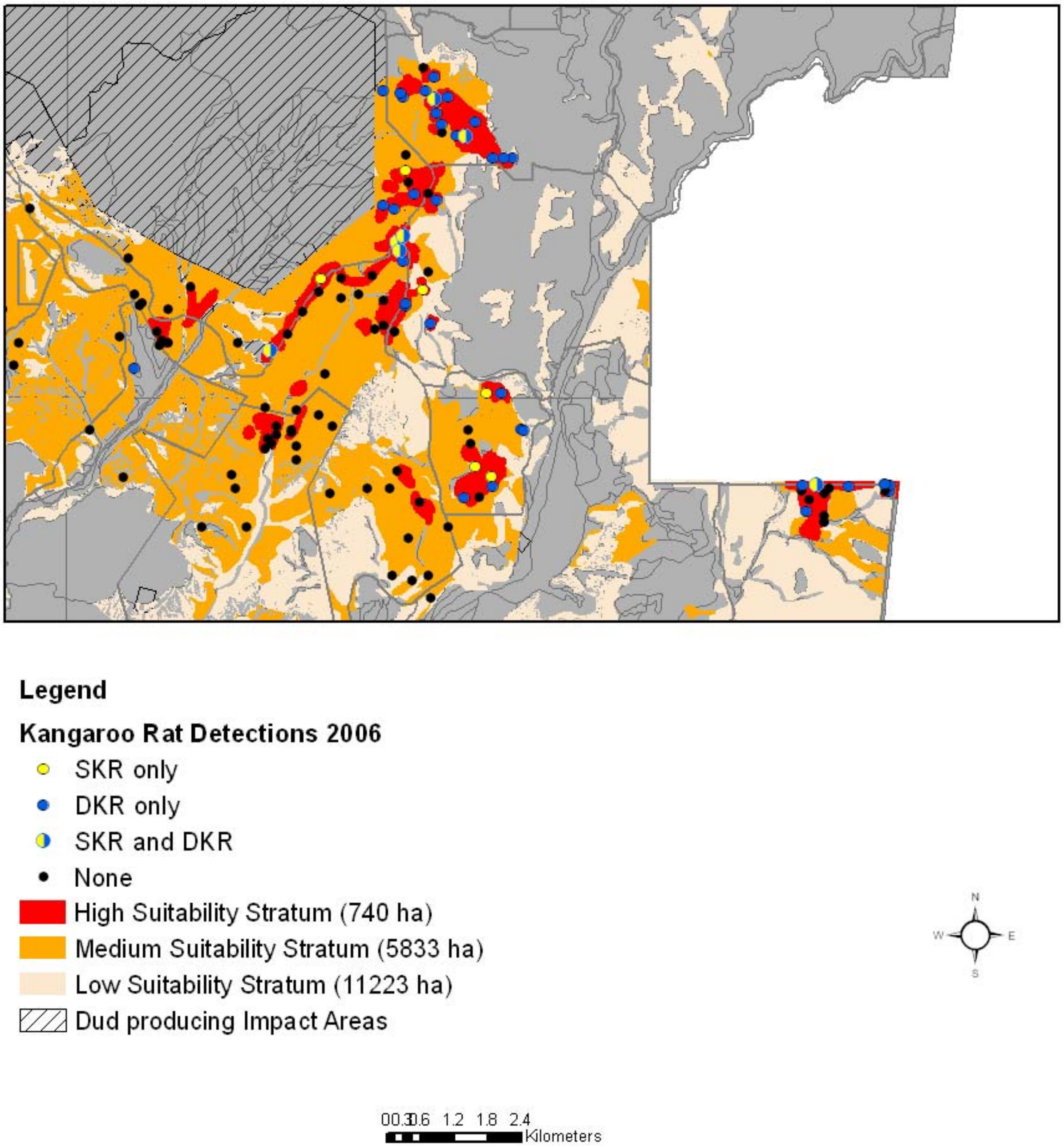
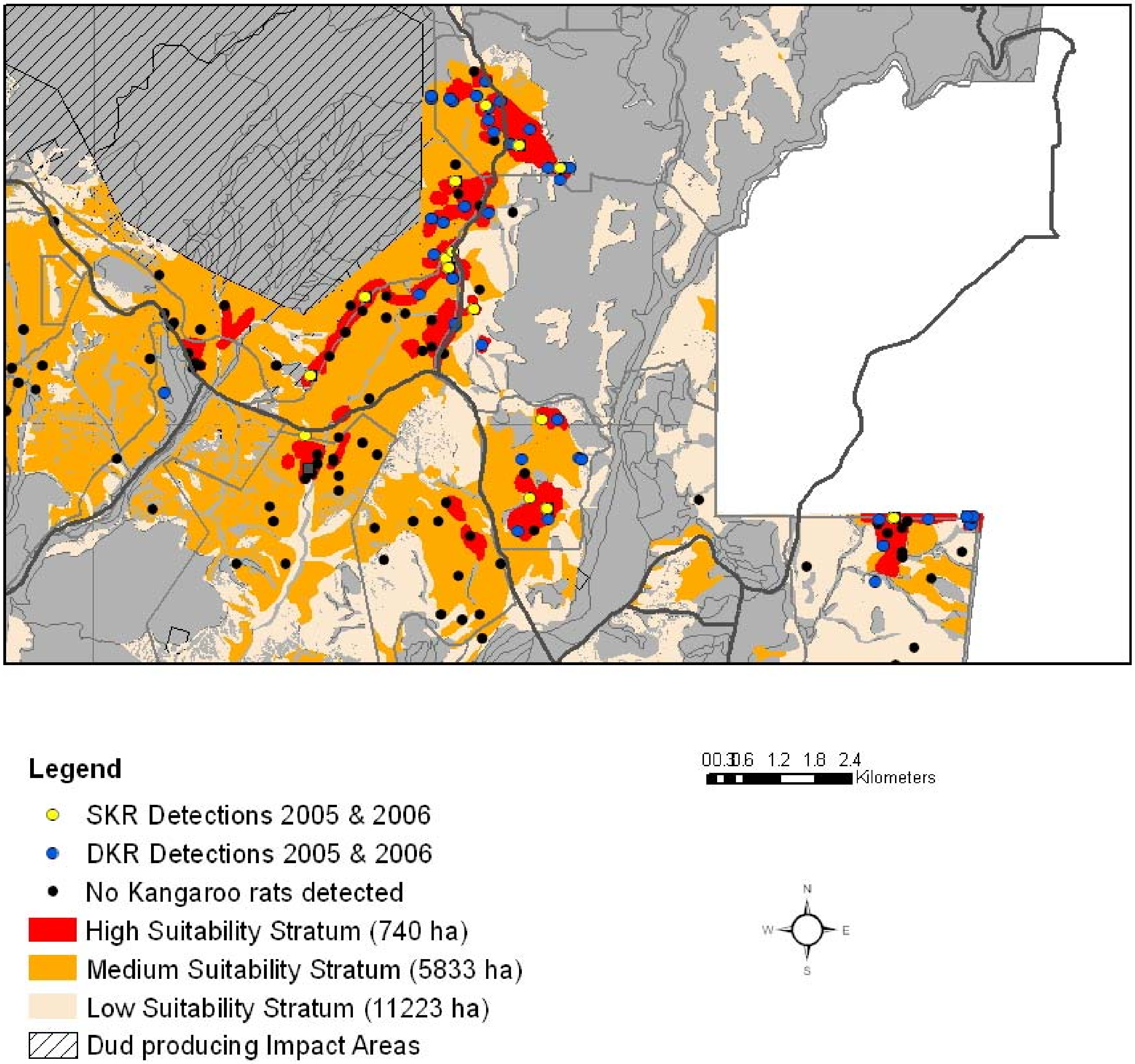


FIGURE 5. CUMULATIVE KANGAROO RAT DETECTIONS (SKR AND DKR) ON MONITORING PLOTS 2005 AND 2006 (MAGNIFIED VIEW)



Proportion Area Occupied

Estimates of the percentage of total area occupied by SKR within each of the strata were 4.6% and 8.1% in the medium and high suitability strata, respectively. Occupancy among the historic monitoring plots was much higher at 70.8% (inference for plots only). Estimates, standard errors, and 90% confidence intervals for proportion and total area occupied by SKR in 2005 and 2006 are presented in Table 4 and Figure 6.

We found that in 2006, stratum (StratumSJM) 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. There was no support for models with separate estimates for the high and medium suitability plots. Of the plots that were live-trapped, the odds of SKR occupying a plot were 2.3 times greater (95% CI: 1.0-5.2) 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 month (Sept/Oct versus Nov/Dec). The probability of detecting SKR was greater on the larger SJM historic plots, on trapping days 2 through 4, and in November and December (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 2006

	Proportion Area Occupied		Area Occupied (hectares)		90% Confidence Limits (hectares)	
Stratum	estimate	se	estimate	se	low	high
"Low Suitability"	n/a					
"Medium Suitability"	0.018	0.007	103.7	43.4	30.9	176.5
"High Suitability"	0.096	0.040	70.8	29.7	21.1	120.5
"SJM Historic"	0.543	0.124	4.9	1.1	3.0	6.7
"Focal Monitoring Area" (Med+High Suitability)	0.027	0.008	174.4	52.6	86.3	262.6

FIGURE 6. ESTIMATES FOR PROPORTION AND TOTAL AREA OCCUPIED BY SKR AMONG SAMPLING STRATA IN 2005 AND 2006 WITH 90% CONFIDENCE LIMITS

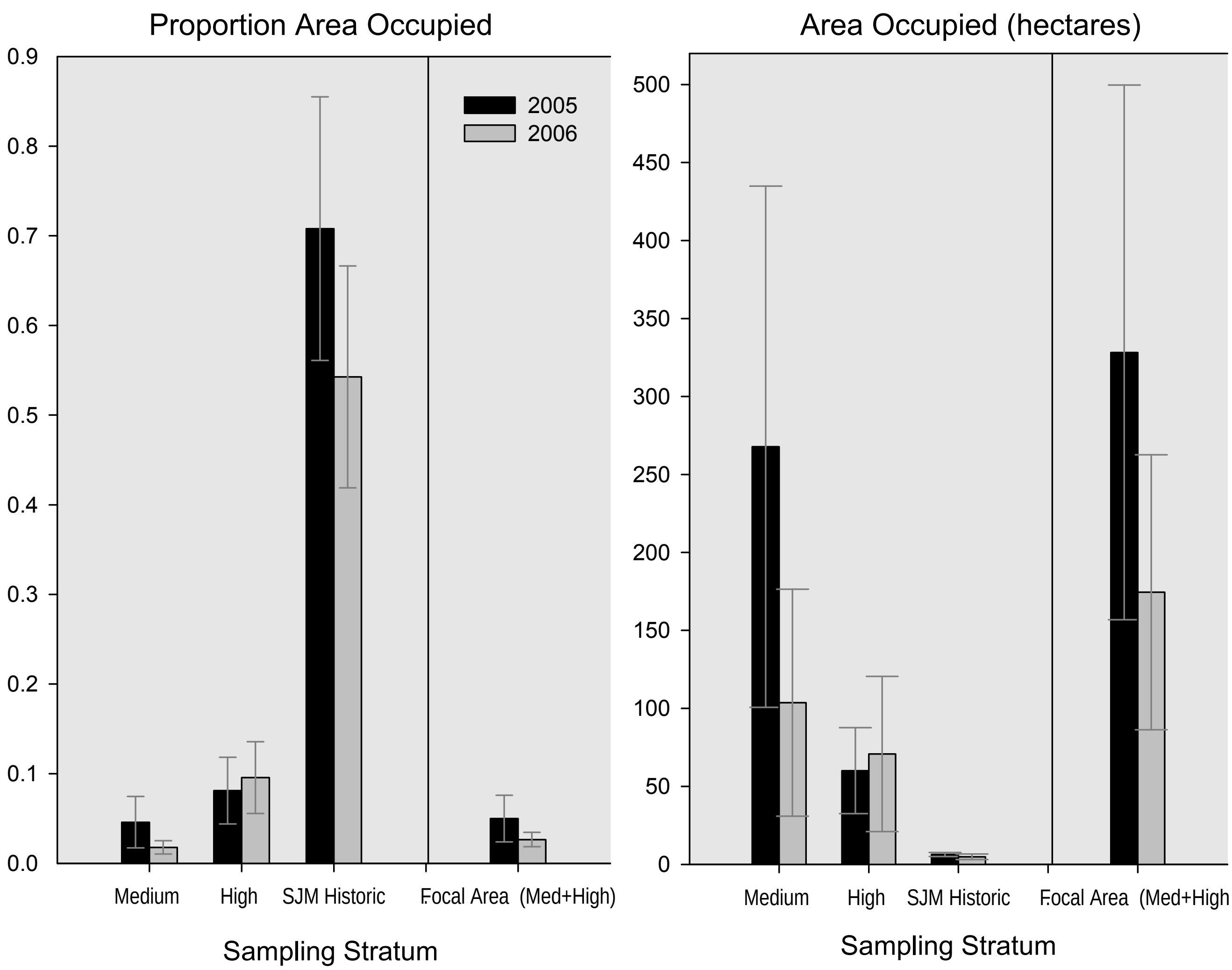


TABLE 5. PAO MODEL COMPARISON

Model	AIC	delta AIC	AIC weight	Model Likelihood	No. Par.	(-2*LogLike)
	Model Comparison Criteria					
psi(OpenGrdForbs,stratumSJM),p(stratumSJM,Day1_other,month)	109.52	0.00	0.685	1.000	7	95.521
psi(stratumSJM),p(stratumSJM,Day1_other,month)	111.90	2.38	0.208	0.304	6	99.896
psi(stratumSJM),p(stratumSJM,month)	114.56	5.04	0.055	0.081	5	104.561
psi(OpenGrdForbs),p(stratumSJM,month)	115.12	5.60	0.042	0.061	5	105.122
psi(.),p(stratumSJM,Day1_other,month)	118.40	8.88	0.008	0.012	5	108.396
psi(.),p(stratumSJM,month)	121.57	12.05	0.002	0.002	4	113.573
psi(sjmstratum_other),p(month)	140.04	30.52	0.000	0.000	4	132.043
psi(.),p(stratumSJM,moon)	143.15	33.63	0.000	0.000	4	135.148
psi(.),p(month)	144.26	34.74	0.000	0.000	3	138.261
psi(stratumSJM),p(.)	149.88	40.36	0.000	0.000	3	143.876
psi(strata),p(.)	150.02	40.50	0.000	0.000	4	142.022
psi(.),p(Day1_other, month)	150.62	41.10	0.000	0.000	4	142.622
psi(.),p(t)	151.44	41.92	0.000	0.000	9	133.444
psi(.),p(moon)	152.86	43.34	0.000	0.000	3	146.860
psi(.),p(stratumSJM)	154.82	45.30	0.000	0.000	3	148.815
psi(openGrdandForbs),p(.)	155.97	46.45	0.000	0.000	3	149.968
psi(.),p(Day1_other)	157.02	47.50	0.000	0.000	3	151.024
psi(PerrGrass),p(.)	159.27	49.75	0.000	0.000	3	153.272
psi(shrub),p(.)	161.66	52.14	0.000	0.000	3	155.662
psi(.),p(nightday)	161.79	52.27	0.000	0.000	3	155.793
psi(.),p(Temp)	162.23	52.71	0.000	0.000	3	156.233
psi(.),p(shrub)	162.39	52.87	0.000	0.000	3	156.391
psi(.),p(DISI)	162.52	53.00	0.000	0.000	3	156.524
psi(.),p(.) =*null model (i.e. occupancy & detection probability constant across sites)*	162.60	53.08	0.000	0.000	2	158.601
psi(disturbance),p(.)	163.50	53.98	0.000	0.000	3	157.503
psi(AnnualGrass),p(.)	164.16	54.64	0.000	0.000	3	158.160
psi(Road_prox),p(.)	164.60	55.08	0.000	0.000	3	158.601
psi(DISI),p(.)	185.63	76.11	0.000	0.000	3	179.627

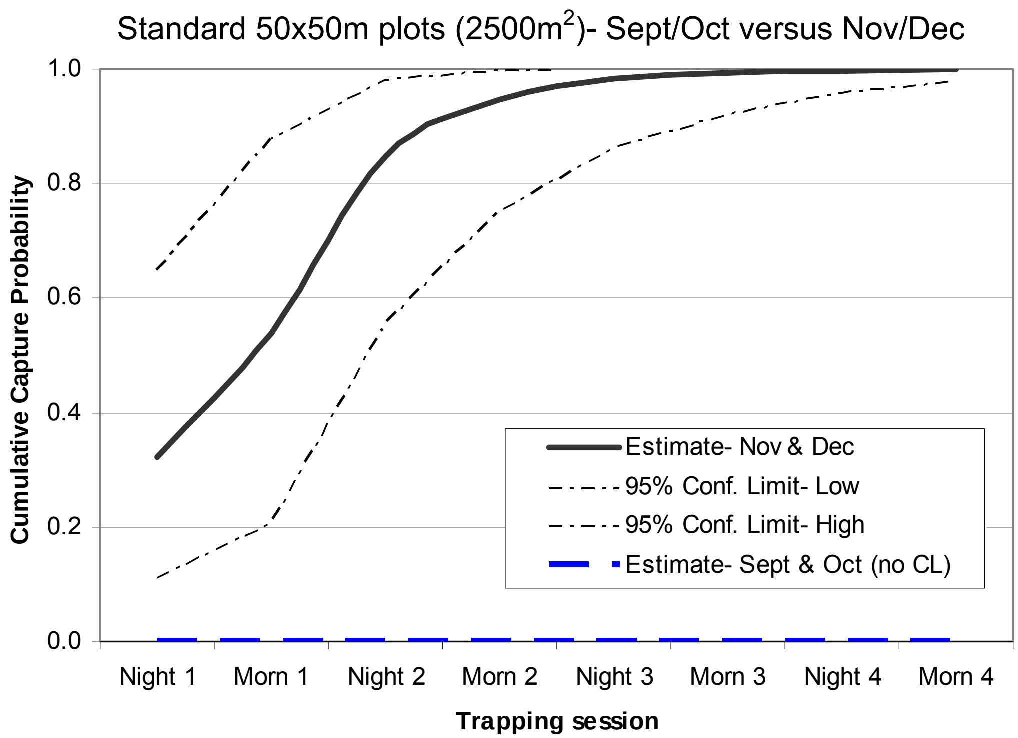
Estimate of c-hat for most parameterized (global) model=1.0062, therefore AIC is used for model ranking (Burnham and Anderson 2002)

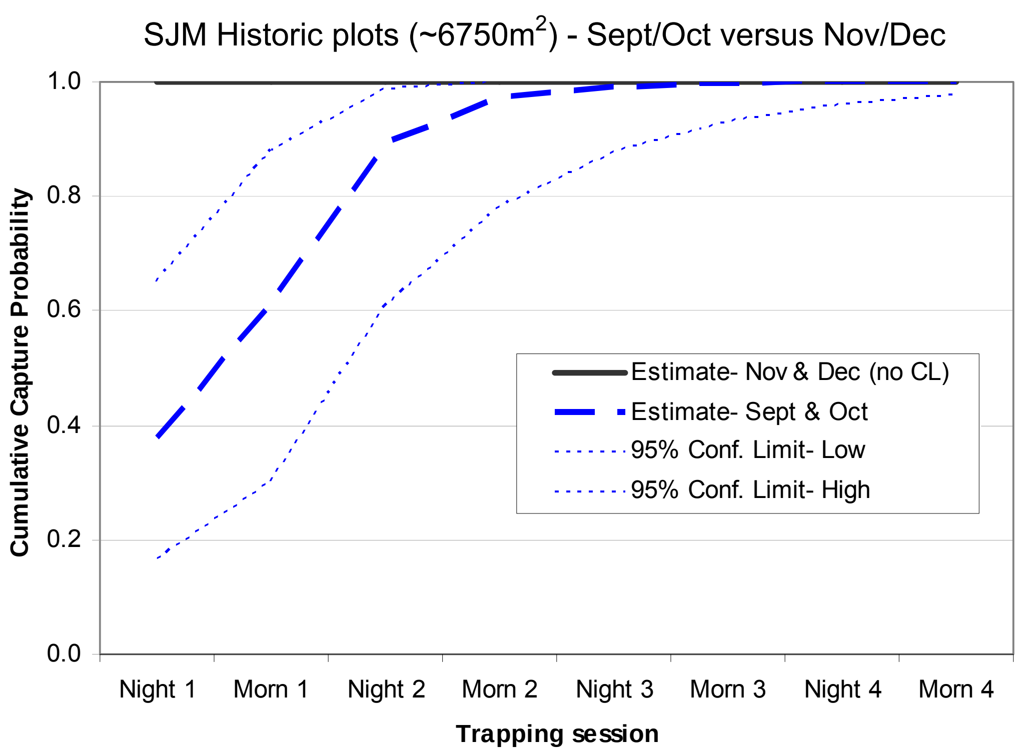
TABLE 6. DETECTION PROBABILITY BY MONTH, PLOT TYPE, AND DAY

Month	Plot Type	Day	Model estimate*	se	95% CI low	95% CI high
Sept./Oct.	50m	Day 1	0.000	0.000	0.000	0.000
		Day 2-4	0.000	0.000	0.000	0.000
Nov./Dec.	50m	Day 1	0.322	0.151	0.109	0.648
		Day 2-4	0.665	0.106	0.439	0.834
Sept./Oct.	SJM	Day 1	0.379	0.135	0.165	0.652
		Day 2-4	0.719	0.122	0.439	0.893
Nov./Dec.	SJM	Day 1	1.000	0.000	1.000	1.000
		Day 2-4	1.000	0.000	1.000	1.000

*Top model

FIGURE 7. CUMULATIVE DETECTION PROBABILITY OF SKR BY PLOT TYPE AND MONTH SURVEYED





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 1 medium suitability, 7 high suitability, and 1 SJM historic plots where no kangaroo rat sign was detected upon the initial habitat survey for 2 -4 days (4 -8 trap events). No kangaroo rats were detected during these surveys.

Temporal Closure

The period from the beginning of habitat surveys to the end of live-trapping encompassed approximately 15 weeks. 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 57 plots where potential sign was recorded, all 57 still contained at least potential sign upon the pre-trapping resurvey. Of the nine plots that were resurveyed after no potential sign was initially detected, a single plot (High 60) showed evidence of change in occupancy between the first survey (9/12/06) and trapping (11/11/06). This plot was located in Range 409a with a dirt road running through the middle. On the second survey, a new kangaroo rat burrow was found along the side of the road and kangaroo rat tracks were observed on the road. Two DKR were subsequently captured on the road (male and female). The female, upon release, went into the burrow. No SKR were detected.

Density Estimation

SKR density within occupied areas of MCBCP in 2006 was estimated to be 5.5 (SE = 2.3) SKR/ha. These were calculated using the abundance estimates from the best fitting closed capture model divided by total area sampled.

For modeling, we tested hypotheses about variables that may affect the probability of SKR capture (p) and/or recapture (c). We conducted these analyses both with the full dataset (night and morning trap events) and with a condensed dataset (pooled night and morning events). Model results and estimates were very close between the two datasets, but full dataset models had very high dispersion parameter estimates (c-hat >7) in comparison to condensed dataset models (c-hat = 3-3.5). Dispersion is a measure of sample variance in comparison to model assumptions and is ideally around 1.0. To correct for overdispersion, we used Quasi-AICc for model ranking and multiplied standard errors by a variance inflation factor from the most parameterized model (√c-hat or √3, Burnham and Anderson 2002). Models are ranked in Table 7. Many models resulted in erroneous results with unestimable parameters. This was apparent when estimates were close to zero and had exceedingly large standard errors. Models that included heterogeneity (pi, i.e. multiple groups), constant p, Day 1_other, stratum, and temperature covariates for p, were removed from model weighting for these reasons.

There was most support for models that included 'month' as a covariate for p. The odds of capturing an SKR were 12 times greater in November/December than in September/October (95% CI= 3.6 to 40.5). This did not appear to be attributable to temperature, as models that contained temperature as a covariate did not perform well. We also had support for models containing 'moonphase'(% illumination. The odds of capturing an SKR were 4 times greater during a new moon versus a full moon (95% CI= 1.4 to 12.2).

For November/December, our probability of capturing an individual SKR present on the plot was 0.61 (95% CI= 0.09-0.99) after 2 days and nights (4 trap events. After four trap events in November/December, the estimated capture probability increased to 0.85 (95% CI=0.16-1.0). The probability of capturing an individual SKR in September/October was estimated to be less than 0.2 after four events.

This is notably lower than last year, when the probability of capturing an individual SKR present on the plot was 0.83 (95% CI= 0.67-0.94) after two trap events. Capture probabilities as related to month and moon phase are presented in Figures 8 and 9.

TABLE 7. CLOSED CAPTURE MODEL COMPARISON

	Model Comparison Criteria					
Model	QAICc	delta QAICc	QAICc weight	Model Likelihood	No. Par.	QDeviance
p(month) c(.)	60.23	0.00	0.432	1.000	3	54.115
p(month, moon) c(.)	61.74	1.51	0.203	0.470	4	53.547
p(month) c(month)	62.08	1.85	0.171	0.396	4	53.889
p(t,month) c(.)	64.22	3.99	0.059	0.136	5	53.931
p(moonphase) c(.)	64.44	4.21	0.053	0.122	3	58.322
p(t,moonphase) c(.)	64.61	4.38	0.048	0.112	5	54.316
p(t, moonphase) c(moonphase)	66.68	6.45	0.017	0.040	6	54.266
p(t) c(t)	67.25	7.02	0.013	0.030	6	54.845
pi(t) p(t) c(t)	69.39	9.16	0.004	0.010	7	54.845

pi=mixture/2 groups, p=capture probability, c=recapture probability

FIGURE 8. CUMULATIVE INDIVIDUAL CAPTURE PROBABILITY OF SKR IN SEPTEMBER/OCTOBER VS. NOVEMBER/DECEMBER 2006

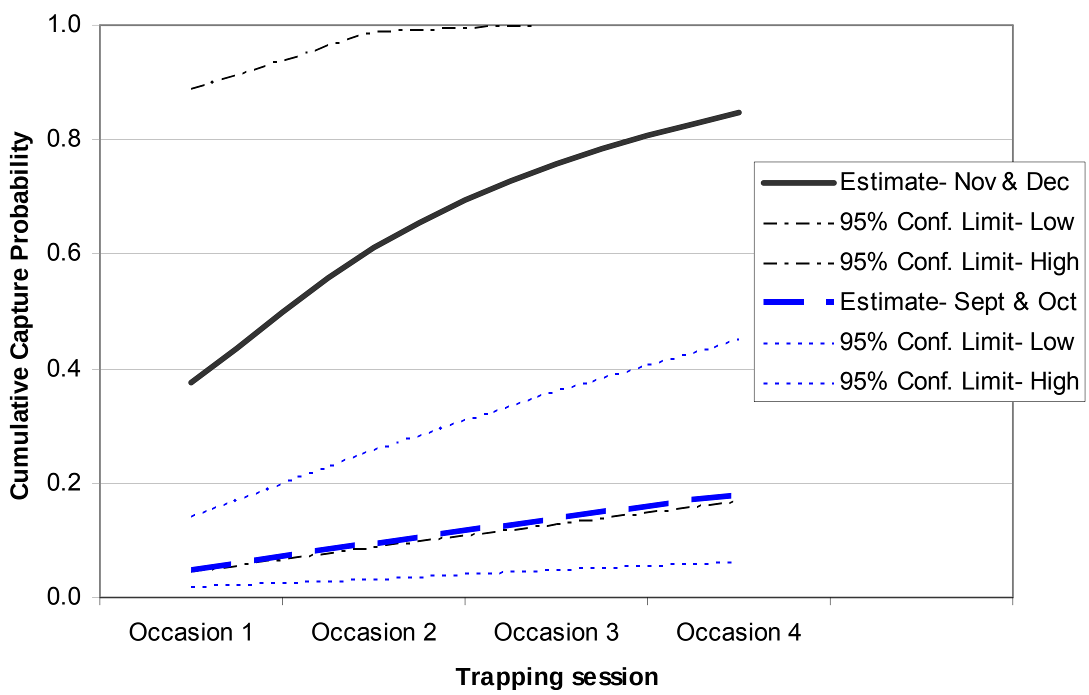
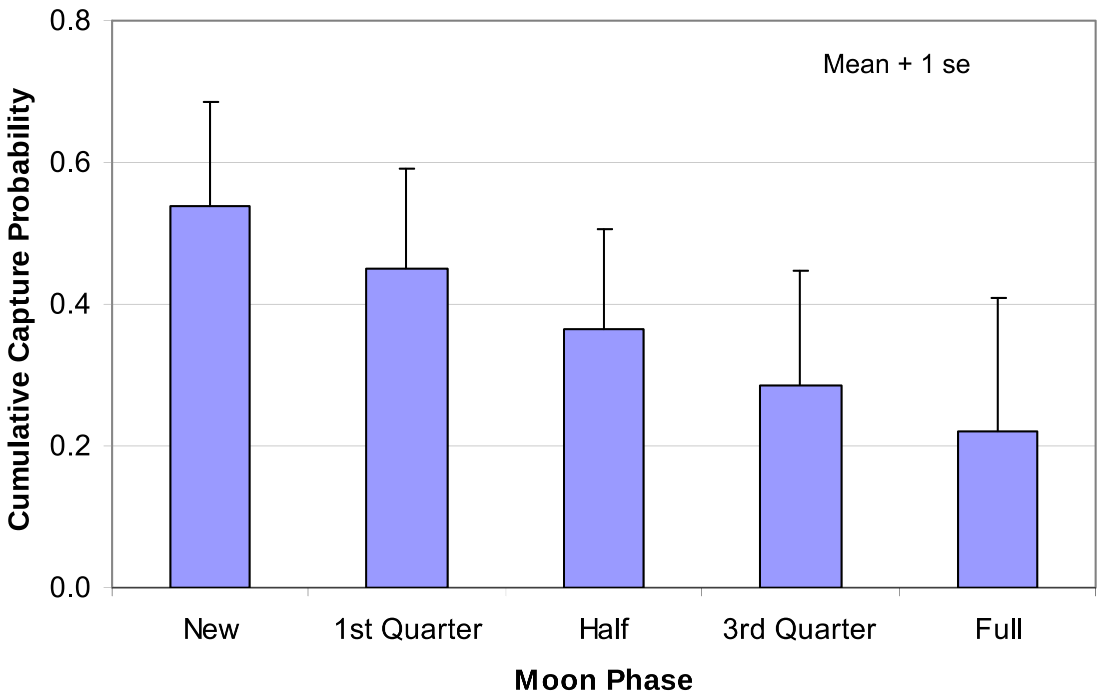


FIGURE 9. CUMULATIVE INDIVIDUAL CAPTURE PROBABILITY OF SKR BY MOON PHASE



SJM Historic Plots

The estimated total number of SKR on all historic plots increased two-fold over 2005 levels. This was in part due to lower capture probabilities in 2006 (Table 8 and 9). The proportion of plots occupied by SKR remained the same as the previous year, which are below those recorded from 1996 to 2002. In contrast to SKR, the proportion of plots occupied by DKR increased in comparison to 1996 to 2002 (Figure 10). Density of SKR over time has been markedly more variable than density of DKR among these plots since 1996 (Figure 11).

TABLE 8. LIVE-TRAPPING RESULTS AND ABUNDANCE ESTIMATES FOR SJM 'HISTORIC' MONITORING PLOTS 2006

Study Grid	No. SKR captured	# Days/Nights (Sept/Oct)	# Days/Nights (Nov/Dec)	Capture Prob (p)	No. SKR (adjusted)	No.DKR captured	Cap Rate correction	No.DKR (adjusted)
Kilo 1	8	2	2	0.67	11.9	3	1.00	3.0
Kilo 2	14	2	2	0.67	20.8	0	1.00	0.0
Range-116	0		2	0.61	0.0	0	0.50	0.0
407-1	2		2	0.61	3.3	9	0.50	18.0
407-2	6		2	0.61	9.8	0	0.50	0.0
408-1	4	2		0.09	42.9	0	0.50	0.0
409-1	0	2	2	0.67	0.0	18	1.00	18.0
409-2	9	2	2	0.67	13.4	7	1.00	7.0
Juliett-1	1		3	0.76	1.3	2	0.85	2.4
Juliett-2 (NE)	0		3	0.76	0.0	6	0.85	7.1
TOTALS	44				103.3	45		55.4

TABLE 9. LIVE-TRAPPING RESULTS FOR SJM 'HISTORIC' MONITORING PLOTS FROM 1996 TO 2006

	1996		1998		2000		2002		2005		2006	
Study Grid	SKR	DKR	SKR	DKR	SKR	DKR	SKR	DKR	SKR*	DKR*	SKR*	DKR*
Kilo 1	17	0	3	0	10	0	28	0	4.8	0.0	11.9	3.0
Kilo 2	8	0	4	0	24	0	23	1	9.4	1.2	20.8	0.0
Range-116	1	0	0	0	0	0	2	0	0.0	0.0	0.0	0.0
407-1	3	13	2	7	6	3	21	4	3.6	7.6	3.3	18.0
407-2	6	0	7	0	5	0	28	1	0.0	1.9	9.8	0.0
408-1	20	1	11	2	7	1	21	6	19.2	11.3	42.9	0.0
409-1	14	0	4	3	20	1	27	0	1.2	0.0	0.0	18.0
409-2	2	1	0	0	2	0	6	1	1.2	1.9	13.4	7.0
Juliett-1	4	0	2	0	8	0	6	0	2.0	0.0	1.3	2.4
Juliett-2 (NE)	6	3	5	15	2	7	6	18	0.0	18.0	0.0	7.1
TOTALS	81	18	38	27	84	12	168	31	41.5	41.9	103.3	55.4

*estimates adjusted for capture probability <1 over 2 to 4 days of live-trapping

FIGURE 10. PROPORTION OF SJM 'HISTORIC' MONITORING PLOTS OCCUPIED BY SKR AND DKR FROM 1996 TO 2005

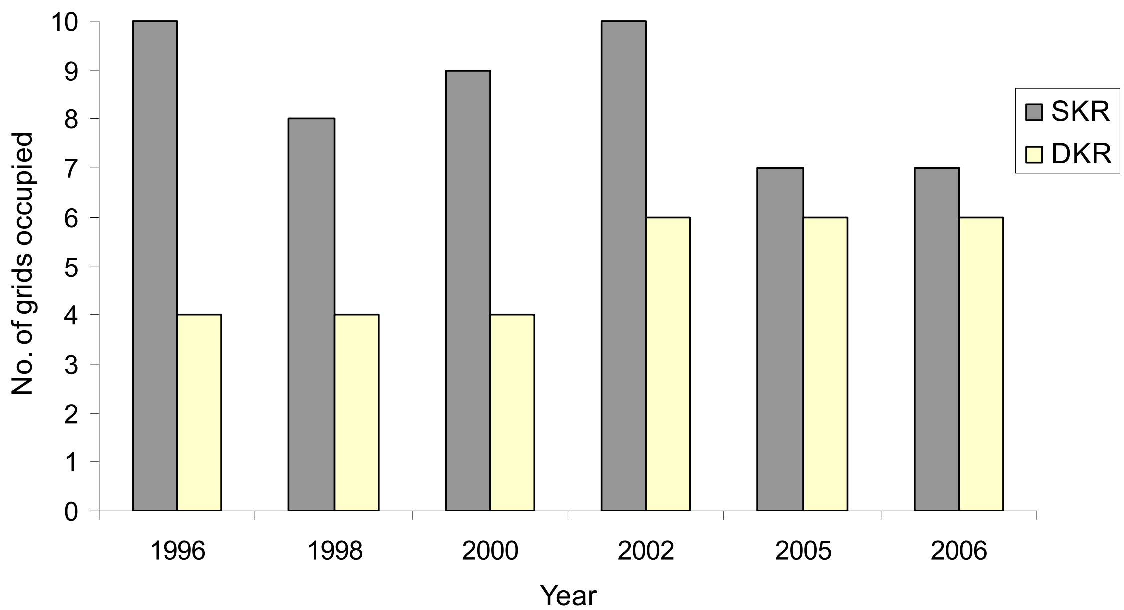
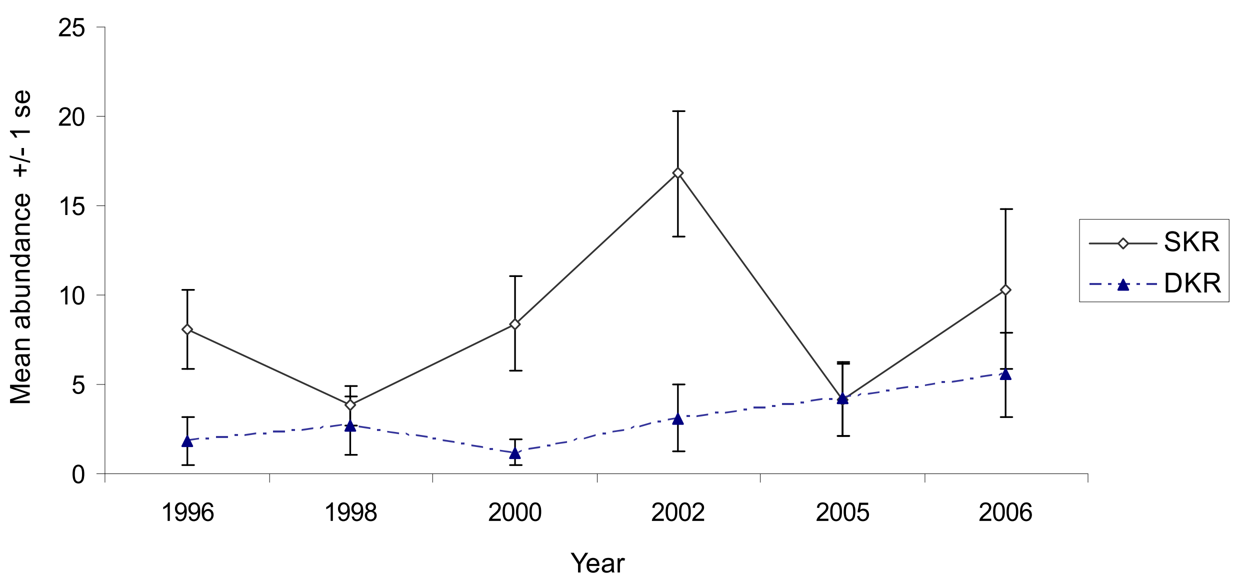


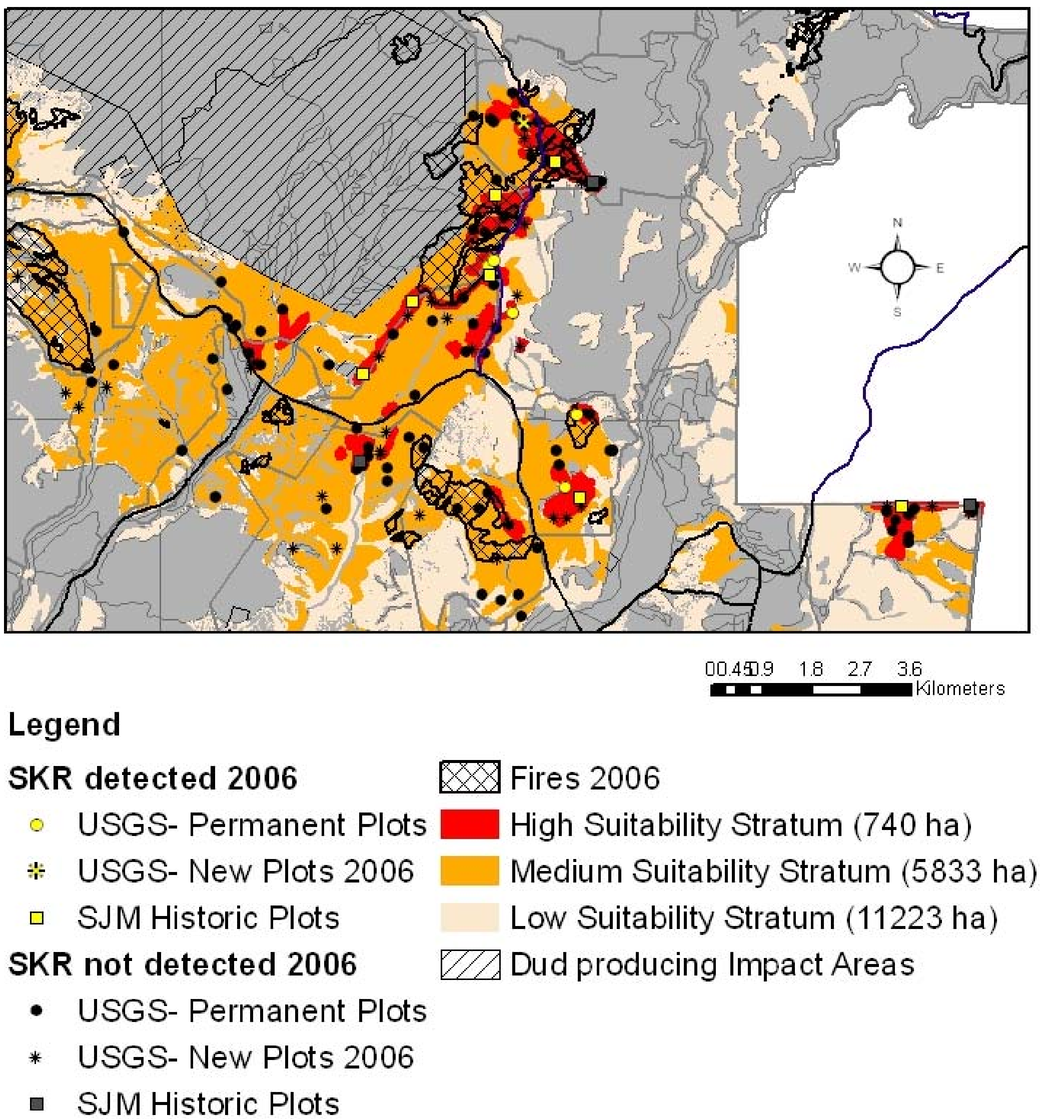
FIGURE 11. SKR AND DKR DENSITY ON SJM 'HISTORIC' MONITORING PLOTS FROM 1996 TO 2005



Landscape and Habitat Characteristics

In 2006, several fires burned SKR study areas within MCBCP (Figure 12). In the medium suitability, high suitability, and SJM historic plots, 3.8%, 43.4%, and 46.2% were noted as 'recently burned' upon the initial habitat survey, respectively. These include plots in the Kilo 1 and Kilo 2 training areas and Ranges 409a and 210B-D. There was little to no vegetation on these plots until the onset of rains in late November.

FIGURE 12. 2006 FIRES IN RELATION TO SKR PLOTS AND DETECTIONS



Discussion

Overall, the estimates of SKR occupancy in 2006 on MCB Camp Pendleton were not significantly different from the previous year. Within the high suitability stratum in 2006, we estimate SKR occupied 70.8 ha (SE=29.7) in comparison to 60.0 ha (SE=24.2) in 2005. At an accuracy level of 50x50m grids, occupied habitat is approximately 20% of what was expected and reported before the onset of this program. In areas occupied by SKR, density was estimated at 5.5 SKR/ha (SE=2.3), which is considered "medium" (O'Farrell and Uptain 1987) or "low" (Tetratech and SJM Biological Consultants 1999) for this species. Density was comparable to the 2005 estimates of 4 to 7 SKR/ha in occupied habitat. 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 estimates of proportion of area occupied 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. 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 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. Occupancy of the high suitability stratum would then be used for the long-term monitoring metric for SKR.

SKR Habitat

Despite the low power to model environmental covariates, we did find that the amount of open ground and forbs (OGF) was a significant positive linear predictor of SKR occupancy; for every 20% increase on OGF, the odds of SKR occupying a plot increased 2.3 times (95% CI: 1.0-5.2).This conforms with habitat associations known for this species and supports thinning of shrubs and grasses as a management technique for SKR.

SKR Trap Behavior

In 2006, the capture and detection probability of SKR in September and October were very low in comparison to November and December. There were several trapping efforts during this time, where we could see abundant kangaroo rat sign on the plots (i.e., numerous burrows, scat, tracks), yet captured few or no kangaroo rats. This did not appear to be attributable to temperature or moon illumination, since these models were not as well supported. It is possible that detection and capture probabilities were lower during this time due to altered seed availability or to decreased SKR activity in response to the recent fires. We re-trapped most of these plots in November and December and captured SKR in much higher numbers. We will continue to investigate this in future years to determine if this is an annual phenomenon.

As with 2005, we found support that SKR were 1) less likely to be captured within the first 24 hours of placing the live-traps versus subsequent days and 2) were more likely to be captured after their initial capture (i.e. “trap happy”). There was also support that moon illumination had a negative effect on both detection and capture of SKR. Trapping for more than two nights with low moonlight is preferable. Because obtaining access to trap in SKR area on Base is very difficult, we will do our best to follow these recommendations, but may need to accept less than perfect conditions in order to trap some areas at all. This will likely continue to be the case, as access for civilian contractors is low priority for range scheduling and much of our trapping efforts are limited to various holidays and weekends.

Model Assumptions

In modeling PAO, we assume that occupancy is closed in both space (sample plot) and time (time between habitat surveys and live-trapping or “season”). We continue to monitor our program for any violations of this assumption. The model should be robust to all but large and systematic violations of this assumption (W.L. Kendall 1999),

In 2006, one out of the 66 plots (1.5%) that were resurveyed for potential kangaroo rat sign showed a change in occupancy status within the time of sampling. This change represented an immigration of an individual DKR (not SKR) onto a previously unoccupied plot. This represents one out of nine (11.1%) negative plots. By minimizing the time between initial survey, resurveys, and trapping, violations of this assumption should be rarer. We will continue to randomly trap negative plots to test this in the future. We did not capture any kangaroo rats on plots where no potential sign was found upon the kangaroo rat sign resurvey (conducted when traps are set).

Recommendations

Management

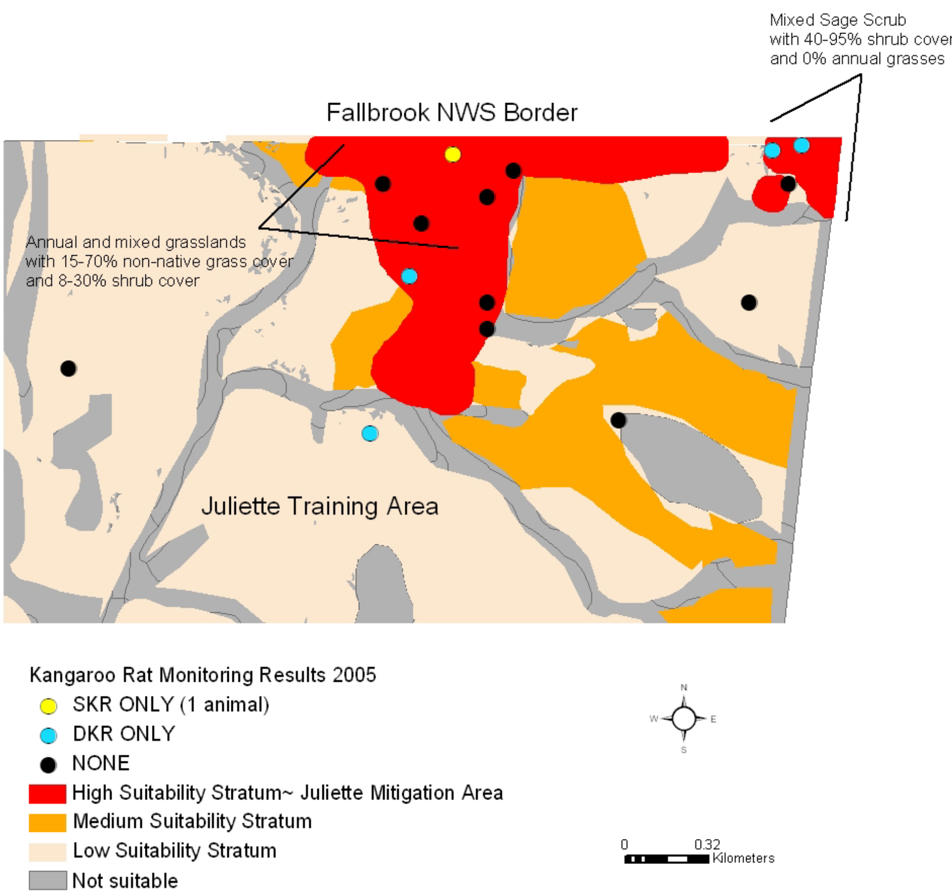
SKR largely occur within heavily used impact areas and artillery ranges. These areas are also vital areas for training military personnel in combat operations. Recommendations regarding military training activities are thoroughly treated in the draft Biological Assessment and Management Plan for MCBCP (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. In 2005 and 2006, 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 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 13. 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.

4. As possible with access constraints, trap a large portion of plots for > 2 nights and avoid nights with high moon illumination (particularly full moon).

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