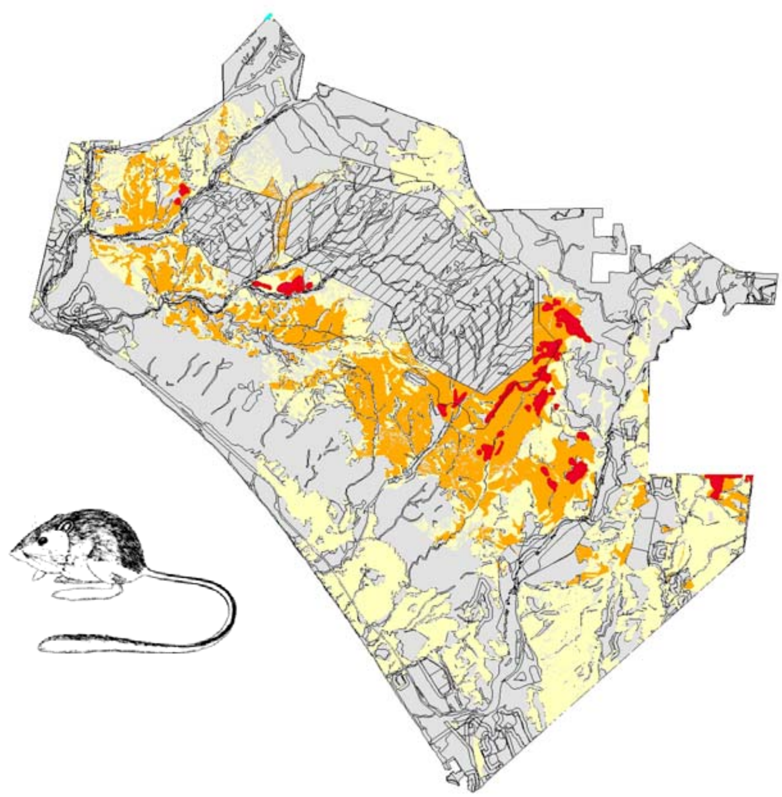
Western Ecological Research Center

Stephens' Kangaroo Rat (*Dipodomys stephensi*) Monitoring Protocol for MCB Camp Pendleton

Final Report

By Cheryl S. Brehme[1], Kenneth P. Burnham[2], Douglas A. Kelt[3], Anthony R. Olsen[4], Stephen J. Montgomery[5], Stacie A Hathaway[1], and Robert N. Fisher[1]



Prepared for:

Wildlife Management Branch
AC/S Environmental Security
Marine Corps Base Camp Pendleton

U.S. Department of the Interior
U.S. Geological Survey

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Image of Stephens' kangaroo rat (California Department of Fish and Game)
Habitat Suitability Map of Stephens' kangaroo rat on MCB Camp Pendleton (Randy Nagel, USFWS and Cheryl Brehme, USGS)

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Abstract

This document presents a monitoring protocol for the Stephens' kangaroo rat (*Dipodomys stephensi*, SKR) on Marine Corps Base Camp Pendleton (MCBCP). A two-day scientific workshop was held in 2004 for the purpose of designing this program. 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 panel and other members reviewed and discussed SKR life history, conceptual models, monitoring schemes, and detection methods before reaching consensus on the basics of a monitoring program. Protocol specifics were determined by consultation among the USGS, the scientific panel, and MCBCP after the workshop.

There is a large body of evidence to show that SKR populations are both spatially and temporally dynamic. SKR abundance and capture probabilities are highly variable making 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 will track yearly trends in the total area occupied by SKR on base over a large number of fixed 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.

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 proportion 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 multi-phased approach for sampling using a combination of active kangaroo rat sign searches and live-trapping. The first phase involves a complete search for any potential kangaroo sign to include burrows, tracks, and scat on sample plots. If any potential sign is observed, two nights of live-trapping will be conducted for the second phase. The live-trapping results will be used to calculate a density index.

Because the species is rare, it is most efficient to stratify sampling effort based on the probability of occupancy or habitat suitability. Thus, we have defined 17,795 ha of high, medium, and low suitability habitat on MCBCP using previously mapped SKR habitat and established soil and vegetation associations. During the first year(s), forty to fifty 50 m x 50 m plots within each stratum will be randomly sampled to estimate expected occupancy rates. We will then optimize sampling for the highest precision over the monitoring area. If there are no or very few SKR found in the lower suitability habitat, we may focus all sampling to the high and medium suitability habitats. In the first year(s), lower quality habitat will be sampled primarily to test our current assumptions about SKR, determine whether low levels of SKR persist in these habitats, and to provide needed data for our habitat model. Once sample allocation is optimized, we propose to keep all sample plots permanent in order to have the greatest ability to detect trends over time. At the onset of the program, we will also be sampling 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 will be adaptive, so that habitat quality boundaries, sample allocation, and other aspects of the protocol can be updated as new information is gained.

This program provides the model framework for powerful statistical analyses of trends in metapopulation dynamics, as well as the effects of habitat and environmental variables and management actions on SKR populations. We hope this may serve as a model for monitoring trends in SKR populations over a broader geographic scale, so that range-wide trends in spatial distribution and relative density of this kangaroo rat can be assessed.

Introduction

On July 19th and 20th, 2004, a workshop was held in order to develop a scientifically valid and cost-effective monitoring program for the Stephens' kangaroo rat (*Dipodomys stephensi*, SKR) on Marine Corps Base Camp Pendleton (MCBCP). The main objectives of this monitoring program are to document short term variation and long-term trends in the distribution and status of Stephens' kangaroo rat population(s) on base. The workshop attendees included a four member Scientific Peer Review Panel from the U.S. Geological Survey, U.S. Environmental Protection Agency, UC Davis, and SJM Biological Consultants. The panel members were chosen for their considerable expertise in spatial and statistical monitoring design as well as local and regional SKR biology. In addition, wildlife professionals from the U.S. Geological Survey, MCBCP Camp Pendleton, U.S. Fish and Wildlife Service, California Departments of Fish and Game (Riverside and San Diego), the San Diego County Park Department, and Fallbrook Naval Weapons Station also participated in the discussions (Appendix 1). The workshop process was as follows:

1. Reviewed and revised a conceptual model of current knowledge and understanding of SKR population structure, demographics, and stressors (Appendices 2, 3, & 4).
2. Reviewed what is known about the historic and current status of SKR on MCBCP (Appendix 4).
3. Reviewed several current and/or proposed monitoring programs and sampling methods for SKR and other similar kangaroo rat species (Appendix 5).
4. Reached consensus on best overall strategy to monitor the status of SKR population(s).
5. Discussed some specifics of protocol such as habitat mapping, sampling strategies, co-occurrence issues with the Dulzura kangaroo rat (DKR), density indices, and utility for management.
6. Visited Camp Pendleton for firsthand look at current monitoring grids, SKR and DKR burrows, and low versus high quality habitat (Scientific Panel).

This report is a summary and compilation of the background materials, results and consensus reached during this workshop. Protocol specifics were determined by consensus of the USGS, the scientific panel, and MCBCP after the workshop. The theoretical and practical reasons for protocol decisions and components are detailed below. We hope this may serve as a program model for monitoring trends in SKR populations over a broader geographic scale, so that range-wide trends in spatial distribution and relative density can be assessed. The basics of this program may also be helpful for consideration of monitoring programs for other species with similar life history characteristics.

Background

Stephens' kangaroo rat

Stephens' kangaroo rat (*Dipodomys stephensi*, SKR) 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). The SKR historically had a relatively small geographic distribution in western Riverside, southwestern San Bernardino and northern San Diego Counties. The species has lost approximately 50% of its historic habitat due to agriculture and residential development and 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)

Life History

A detailed conceptual model of the Stephens' kangaroo rat is presented in Appendix 4. In summary, the Stephens' kangaroo rat is a medium-sized nocturnal rodent of the family Heteromyidae. Many rodents of this family are physiologically adapted to hot and arid environments (French 1993). To minimize water loss while foraging, they collect seeds and other materials in external cheek pouches. Heteromyid rodents also keep seed caches in and around their burrows for times when food resources are low.

All kangaroo rats travel using bipedal locomotion (hopping on hind feet) and, therefore, require open habitat on gentle slopes for efficient movement and foraging. Within its range, Stephens' kangaroo rat prefers 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). They 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 2004c). 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 2004b). 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.
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. May reduce mating due to Allee effects, where widely dispersed, low-density populations are less likely to find mates. Increases 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 not uncommon. 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, Spencer 2002, Price and Gilpin 1996, Mary Price personal communication) suspect that SKR primarily follow a form of meta-population dynamics[1], where availability of suitable habitat patches is spatially and temporally dynamic (i.e. Fahrig 1992). This is contrary to traditional fixed populations that vary in density over time, but exhibit no spatial heterogeneity.

Monitoring Methodologies and Evaluation

Currently and historically, two main approaches for monitoring SKR populations have been used; live-trapping and active burrow counts. Live-trapping methods for small mammals are well documented in the literature (e.g., Jones et al. 1996). Most efforts minimally include a standard transect or grid of box traps, which are set out in a pattern and run for a number of consecutive nights. Most efforts include the use of permanent or temporary marks on the animals in order to estimate density, capture probabilities and/or other demographic parameters (abundance, birth rate, survivorship). To date, trapping efforts for SKR have varied widely in grid size, session length and frequency. Capture probability appears to be highest during the late summer and early fall periods when food resources are low (O'Farrell and Uptain 1987, Montgomery 2002).

The second method for monitoring SKR populations is burrow counting (O'Farrell 1992, Montgomery et al. 2005). This is less costly in terms of effort and is often used for initial habitat assessment, as a replacement for live-trapping, or in conjunction with live-trapping. This method was described by O'Farrell (1992) and involves searching for active SKR burrows in predefined areas (belt transects or circular searches). Burrows must show some type of recent activity, such as loose soil, footprints, and/or scat, in order to be counted. In areas where only SKR occur, burrow counts have a consistent significant positive correlation to SKR density as determined by live-trapping (O’Farrell 1992, Diffendorfer and Deutschman 2002). In areas where the sympatric Dulzura kangaroo rats occur,

[1]A metapopulation is a set of local populations within some larger area, where typically migration from one local population to at least some other patches is possible (Hanski and Simberloff 1997). The degree of isolation between local populations can be high or low depending upon dispersal distance. Metapopulation dynamics are typically based on the equilibrium between colonization and extinction of local populations rather than demographics of individual local populations.

this method must be followed by live-trapping in order to confirm SKR presence. Burrow counts are slightly complicated by the fact that SKR may share burrows with conspecifics. Brock and Kelt (2004c) reported that the proportion of SKR that share burrows varied by location and, thus, influences the relationship between burrow counts and number of animals present. Burrow counts are typically conducted in the late summer and fall, after annual herbaceous vegetation has died and disarticulated, to increase the probability of detecting burrow openings (O'Farrell 1992, Montgomery et al. 1997).

Diffendorfer and Deutschman (2002) recently conducted a statistical review of 14 SKR studies using live-trapping and/or burrow counts. In summary, they verified positive correlations between live-trapping and burrow counts, but found the slope of the relationship to be spatially and temporally variable. They also reported very large spatial and temporal variability in SKR densities (live-trapping and burrow counts) and capture probabilities. They concluded that it is difficult to detect large-scale trends in SKR abundance because of their tremendous variability in numbers across time and space.

MCB Camp Pendleton

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 2,700 feet (NEESA 1984). MCBCP is bordered by the cities of San Clemente and Oceanside to the northwest and southeast, 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.

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). Stephens' kangaroo rat is 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, whereas gravel and paved roads may be an impediment to movement (O'Farrell and Uptain 1989, Brock and Kelt 2004b). 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.

Historical and current occurrence of SKR on MCB Camp Pendleton

The total amount of historically and currently occupied habitat for SKR on MCBCP was estimated to be 800 acres in 1996 (324 ha, Montgomery et al. 1997). Several additional locations within artillery firing areas were confirmed in surveys conducted during 2001 and 2003 (AMEC 2004). We will use the term "population groups" to describe animals residing in relatively distinct areas, although it is unknown whether these groups represent multiple separate populations or one large metapopulation.

Historically, four general areas supported known population groups of SKR (Figure 1). First, two small groups historically occupied habitat along the upland portion of lower San Mateo Canyon (1) and San Onofre Canyon (2). No animals have been documented in San Onofre since 1992 and in San Mateo since 1994, presumably as a result of concurrent base projects, so these population groups are thought to be extirpated (Montgomery 2002). Third, there is a very large discontinuous population group south and east of the Zulu impact area in the central portion of the base (3). Many of the existing SKR population groups occurring in this area are primarily found on habitat that is frequently disturbed by training, such as artillery firing areas, live fire ranges, and impact areas. Occupancy of SKR within adjacent dud producing impact areas is unknown, however, a wide strip along the south and west perimeters of the Zulu and Whiskey impact areas, as well as portions of the Quebec impact area, may be suitable for SKR. These areas potentially harbor SKR or at least provide suitable dispersal habitat. Finally, there is a small group in the Juliett training area (4) abutting a much larger population on the Fallbrook Naval Weapons Station. A portion of the Juliett area is now being managed as a mitigation bank for SKR on MCBCP (USFWS 1992), but has not been subjected to regular disturbance. On many areas of MCBCP, SKR co-occur with or are adjacent to populations of the Dulzura kangaroo rat (*Dipodomys simulans*, DKR)

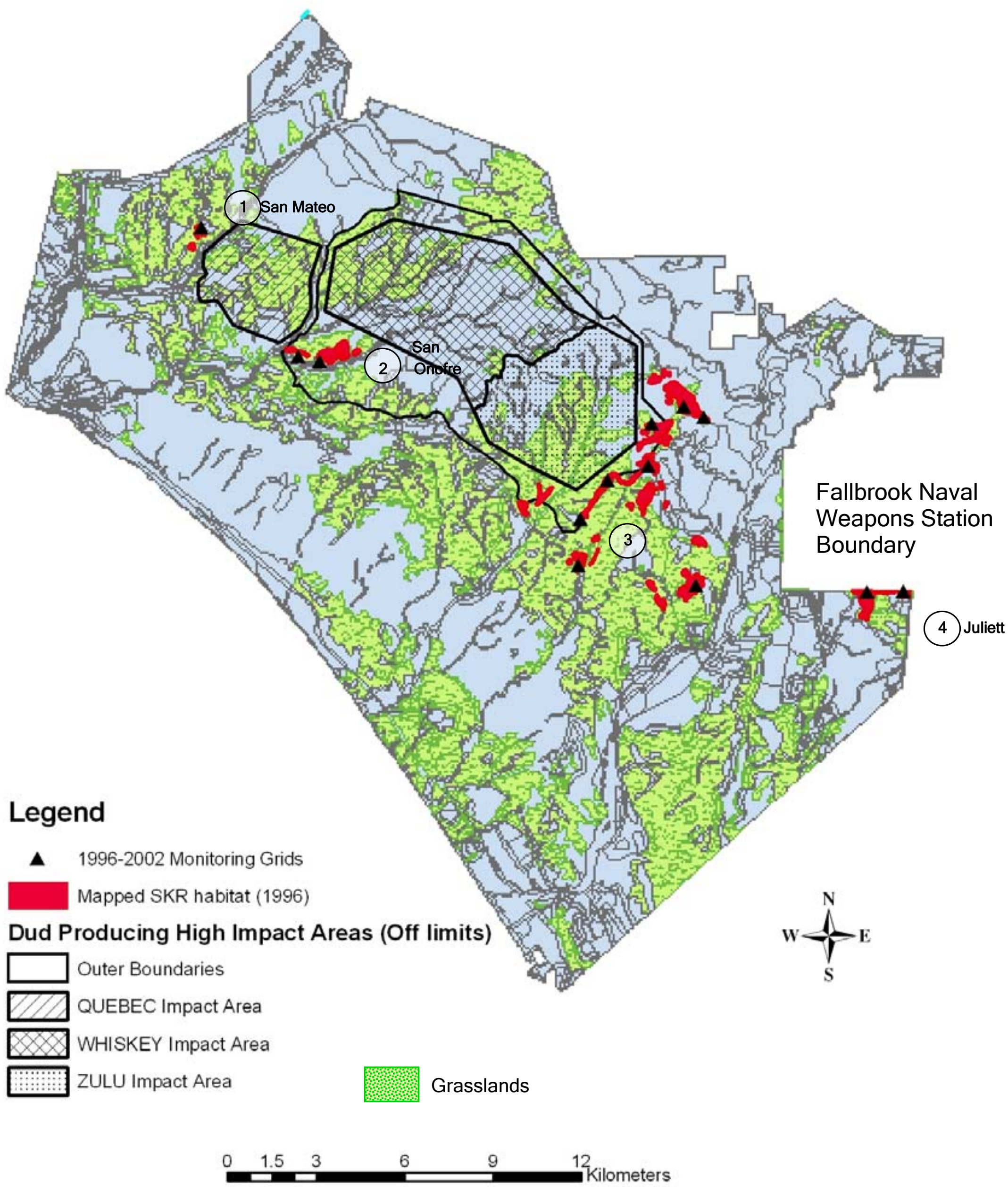


Figure 1. Current and historical Stephens' kangaroo rat habitat within MCB Camp Pendleton mapped during 1996 (S. Montgomery, Tetratech) and 2003 (AMEC). Population groups 1 to 4 are circled. Groups 1 and 2 are presumed extirpated. Group 3 encompasses all known SKR localities south of the dud producing Zulu impact area and north of the Santa Margarita River. Group 4 is contiguous with a larger SKR population located in the Fallbrook Naval Weapons Station. Black triangles denote locations of 13 old and new trapping grids used for monitoring SKR from 1996 to 2002.

A monitoring program for SKR on MCBCP was implemented 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).

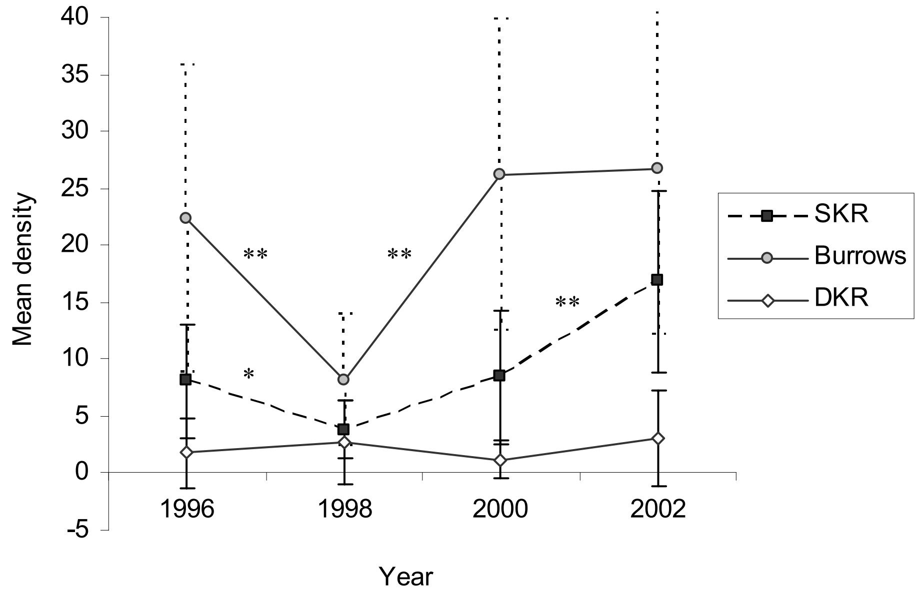
There were large variations in the number of captures and number of burrows among grids and years (Figure 2a). Since three of the grids were not trapped each survey year (Population 1 & 2 grids discontinued in 1998, 2000 and two new grids in Population 3 added), we analyzed the data for the 10 grids that were surveyed each year using mixed-model repeated measures ANOVA and follow-up paired t-tests. SKR density, as measured by both trapping and burrow counts, varied by year ($F_{27,3}$=9.449, p<0.0005 and $F_{27,3}$=4.895, p=0.008, respectively). Densities decreased from 1996 to 1998 and increased from 1998 to 2002 (Figure 2a). There were no significant differences in the sympatric DKR densities among years ($F_{27,3}$=0.957, p=0.427).

SKR occupancy among years followed a similar pattern to density, with an apparent pattern of colonization, extinction, and recolonization in two of the grids. This pattern was exhibited in both live-trapping and burrow counting. The sympatric DKR occupied six of the ten SKR grids among years (Figure 2b).

Over all surveys, there was a very significant positive correlation between burrow counts and trapping of SKR (r^2= 0.770, p<0.0005, n=50), however, this correlation declined as the ratio of SKR/DKR declined and was not significant when the ratio of SKR to DKR was less than or equal to two (i.e. 66% SKR to 33% DKR) (Table 1). This situation occurred in 24% of the total surveys. Since the current monitoring grids were chosen in the best known SKR habitats, we expect that these grids represent some of the greatest ratios of SKR/DKR on MCBCP. Therefore, we do not believe burrow counts will be a reliable method to use for an expanded monitoring program on MCBCP, where results from randomly selected sites will be extrapolated to SKR status on MCBCP lands.

Overall, these results support our conceptual model of SKR dynamics and earlier conclusions on SKR monitoring efforts. The scientific panel expected SKR occupancy to be a more stable monitoring metric than SKR density. Between survey periods from 1996 to 2002, occupancy among grids varied by 25%, while density varied by 158% (trapping) and 226% (burrow counts).

A.



B.

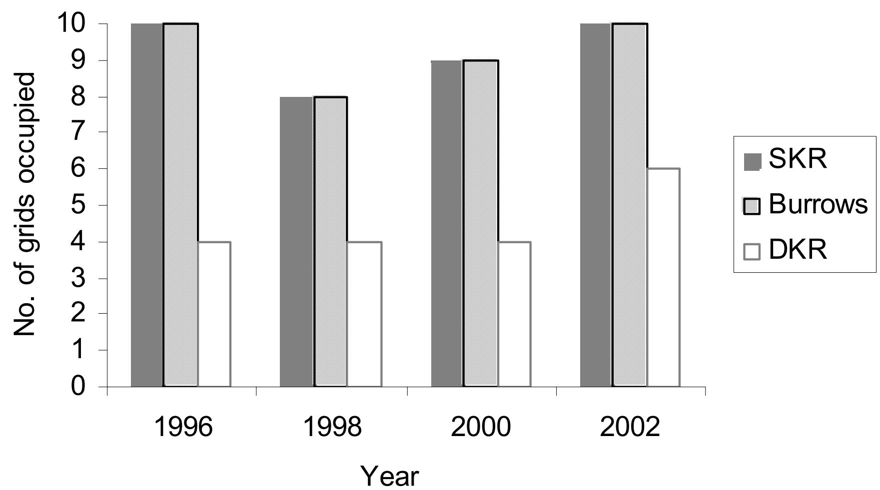


Figure 2. MCBCP Monitoring results for SKR density (a) and SKR occupancy (b) on 10 grids sampled from 1996 to 2002 (excluded those that were not sampled all 4 years). Significant changes between years are denoted by asterisks (* p<0.05, ** p<0.01)

Table 1. The loss of significant correlations between burrow counts and live-trapping as the proportion of SKR to DKR decreases (i.e. the ratio 1:1 would equal 50% SKR and 50% DKR).

Proportion of SKR/ DKR[1]	n	Pearsons correlation coefficient	p-value
≤ 1:1	8	0.087	0.838
≤ 2:1	12	0.346	0.271
≤ 10:1	17	0.815	<.0005
≤ 30:1	21	0.853	<.0005
all data[2]	50	0.866	<.0005

[1] calculated from 1996 to 2002 MCBCP SKR monitoring data (Montgomery 2004)
[2] includes grids with no captures and SKR only

Protocol Design: Overview and Theory

The primary objective of this protocol is to monitor trends in status of SKR on MCBCP. Here we present key considerations taken in designing the protocol, highlights of the protocol design, and proposed outputs:

Key Considerations

1) The current state of SKR knowledge indicates that SKR likely act more like a spatially structured metapopulation within occupied landscapes rather than isolated fixed single populations. This is apparent by well documented extinction and recolonization dynamics in relation to disturbance and vegetation succession. Because of this, the availability and location of suitable habitat patches also varies through time and space. This is particularly true on MCBCP, where there is a relatively high level of disturbance from frequent fires and military training activities.

2) SKR abundance and capture probabilities are highly variable through time and space, making detection of demographic trends in populations very difficult and time intensive. The traditional method of trapping animals on a relatively few number of fixed grids assumes fixed populations with no spatial heterogeneity. These assumptions are clearly violated for this species. Additionally, intensive trapping efforts on a relatively small number of fixed grids will leave little statistical power to analyze critical habitat based changes in SKR occupancy and/or densities.

3) SKR are rare on base. Because of low probabilities of occupancy in any habitat type, precision around occupancy and/or abundance estimates is expected to be low.

4) Many of the known subpopulations occur within non-dud producing impact areas and firing ranges. SKR population status outside of these areas is largely unknown.

5) SKR populations often co-occur with DKR populations on base. Therefore, burrow counts are not a good correlate to SKR densities in most occupied areas.

6) From 1996 to 2002, SKR were monitored biennially on 10 survey plots using live-trapping for five consecutive nights each fall. Continuity with these historical monitoring data is preferable.

In consideration of these and other factors, we designed a relatively simple, multi-tiered, habitat-based, adaptive monitoring program for SKR. This monitoring program tracks trends in overall occupancy of SKR on base and includes a relative density index. The basics of the program are listed below and are presented in Table 2.

Monitoring Program Highlights

1) Habitat-based monitoring program for SKR occupancy.

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

2) SKR Density Index.

   It is preferable to include some measure of SKR density since it is still unknown whether trends in SKR occupancy and density are correlated. In addition, density may positively influence the probability of detection and, therefore, should be included in any occupancy model. An index of SKR density within strata will be generated from live-trapping data. Thus, we will also track trends in SKR density over time.

3) Spatially stratified sampling of potential SKR habitat.

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

4) Continuity with 1996 to 2002 SKR monitoring efforts.

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

5) Two-tiered sample strategy.

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

   a) Habitat Characterization and Burrow Search.

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

   b) Live-trapping.

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

6) Permanent sample plots.

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

7) Adaptive Protocol.

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

We propose a number of analyses and products to be generated for SKR monitoring.

Design outputs

1) Yearly estimates of occupancy with a density index.

   A yearly map of SKR occupancy and density estimates for MCBCP. This map will contain probabilities of occupancy and density indices with 90 & 95% confidence limits for the low, medium, and high quality habitats, and historic monitoring plots. A separate map will be generated showing the spatial distribution of SKR occupancy among individual plots.

2) Trend analysis.

   Starting in second year of monitoring, calculated rates of occupancy , colonization, and extinction within and among strata over time (i.e. rate of change in occupancy with 90 & 95% confidence intervals.

3) Continued trend analysis of 13-predefined study sites (1996-2000).

4) Habitat and management analyses.

   Analysis of habitat and other covariates for predicting occurrence, density and detectability of SKR. Analysis of changes in occupancy and density in relation to habitat changes and management actions on MCBCP. Significant predictors will be used to make habitat-based recommendations for management.

5) Evaluation of monitoring program.

   Every 2 to 5 years. Ability to update habitat model for SKR on MCBCP & adjust definitions of high, medium, and low quality in concert with updated GIS habitat information for MCBCP as well as SKR habitat modeling results. Evaluate sample sizes, survey procedures, and analyses for utility for MCBCP objectives and power to detect SKR population trends.

Table 2. 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 acreage 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

Protocol Specifics

In the following section, we describe each part of the protocol in detail. These are habitat mapping, sampling scheme (sample allocation, burrow searches, live-trapping), data analysis, and design assumptions.

SKR Habitat Mapping

The study area for future SKR monitoring on MCBCP includes all habitats that are currently suitable for SKR or have reasonable potential to become suitable for SKR in the future. The study area includes native and non-native grasslands, open woodlands with grassland understory, and coastal sage scrub habitats on appropriate soils and slopes within four kilometers of all current and historically known SKR habitat. Grasslands on loamy soils are included throughout the base. All developed land, off-limit training areas, inappropriate soils, steep slopes, and other vegetation were not included in the study area. The entire study area encompasses 17,795 ha (43,970 acres).

The study area is divided into three main strata: low, medium, and high suitability SKR habitat. We also include the 1996-2000 sampling grids as a fourth stratum (Table 3, Figure 3). We hypothesize that SKR occupancy will be more variable between than within strata. We can therefore optimize sampling to improve efficiency of estimation, as well as provide individual estimations within each stratum (i.e. Krebs 1989, Schreuder et al. 2004, Geissler and McDonald 2005).

Our designations of habitat quality for SKR were based upon established SKR habitat associations and knowledge of the current and historical distribution of SKR on MCBCP (O'Farrell and Uptain 1989, Montgomery et al.1997, Goldingay and Price 1997, Spencer 2002, AMEC 2004). Soil quality definitions for SKR were provided by W. Spencer (unpublished ratings prepared for the San Diego County Mammal Atlas). Specific criteria for each stratum are presented in Table 3. All initial habitat designations were performed using ArcGIS software and available GIS layers. Groundtruthing and aerial photographs obtained from Environmental Security AC/S (2003 Color Ortho (AC/S ES) and 2000 Color IR Ortho (SANDAG)) were used to verify and/or adjust MCBCP GIS vegetation layers during the spring of 2005. During our groundtruthing efforts, we found low mapping accuracy for the different grassland types (native, non-native, valley and foothill), so they were not separated in any suitability definitions.

Table 3. Criteria used for the Proposed SKR Habitat Quality Map.

SKR Habitat Quality Definitions for Strata[1]			
High		All SKR habitat mapped in 1996 (Ref) All SKR captures through 2003 with 50m buffer	
Medium		Slope:	< 50%
		Soil Classes[2]:	2, 3
		Vegetation:	Grasslands (native, non-native, valley and foothill), disturbed habitat, open engelmann oak woodland
		Other	Within 4 km of high quality stratum
Low	a)	Slope:	< 50%
		Soil Classes[2]:	0,1,2,3
		Vegetation:	Grasslands (native, non-native, valley and foothill), disturbed habitat, open engelmann oak woodland
		Other	None
	b)	Slope:	< 50%
		Soil Classes[2]:	2, 3
		Vegetation:	Coastal sage scrub, Coastal scrub-chaparral scrub, coast live oak open oak woodland
		Other	Within 4 km of high quality stratum

[1]Impact areas and PPM habitat were excluded from all strata.

[2]Soil quality rated for SKR (3= highest, 0= lowest), W. Spencer

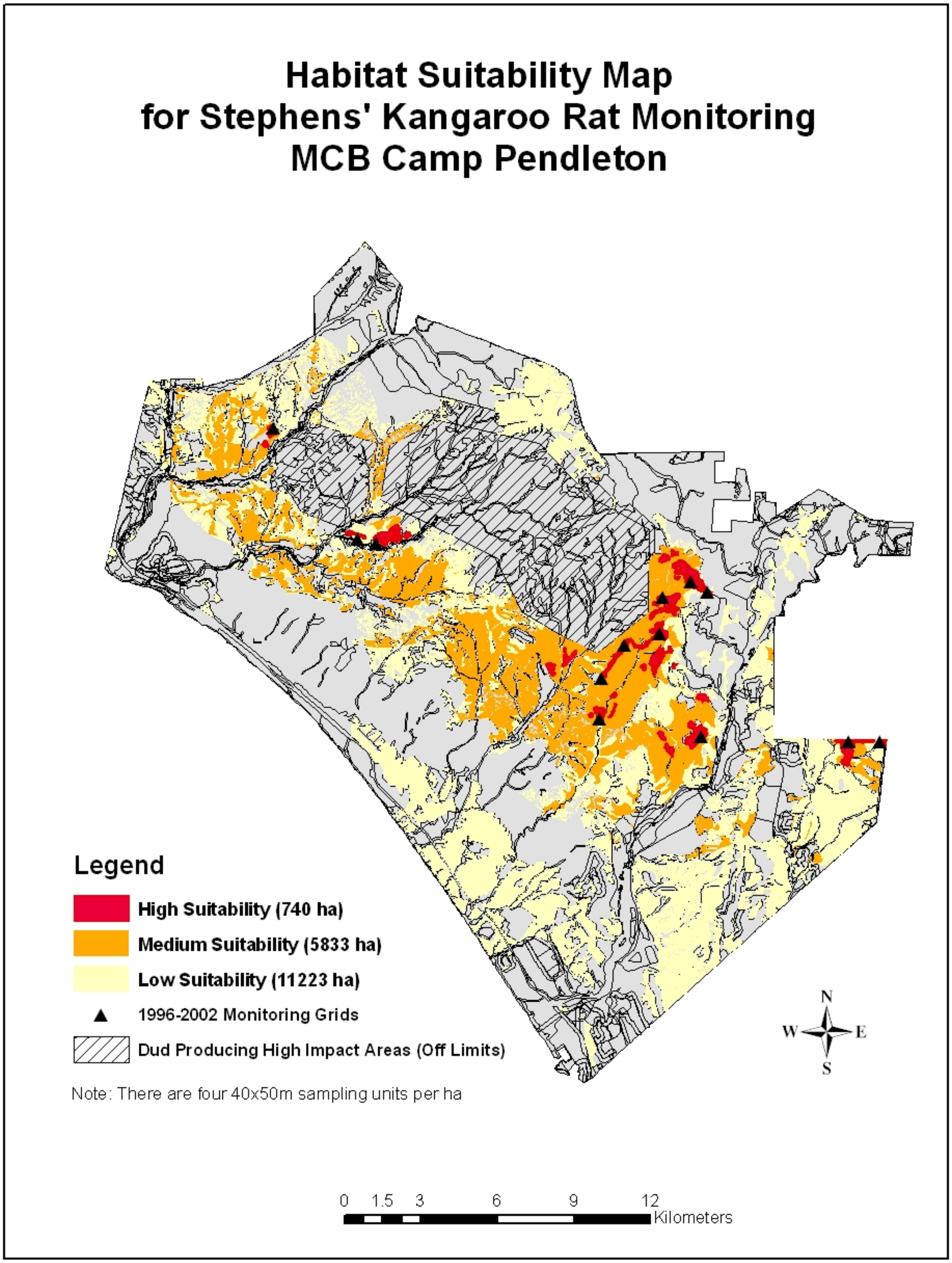


Figure 3. Proposed habitat suitability map for SKR Monitoring Program

We chose an area of 50m × 50m for our sample unit. The sample unit size (2500 m^2) encompasses an area greater than the largest reported home range for SKR (1600 m^2,Thomas 1975), is small enough to be relatively homogeneous for habitat characterization, and is the established plot size for SKR monitoring in the nearby Fallbrook Naval Weapons Station (Montgomery et al. 2005).

ArcGIS software was used to divide the entire study area into the 50m × 50m sample plots. Plots that lie on habitat quality boundaries were assigned according to the majority of habitat within the plot. Therefore, if the plot contained 60% “medium suitability” habitat and 40% “low suitability” habitat, the plot fell into the “medium suitability” habitat boundaries.

Habitat suitability boundaries may be redrawn periodically to coincide with more precise vegetation and soil mapping efforts on MCBCP. Our current model designations are based upon the state of our current knowledge. Habitat suitability definitions may be revised based upon species-habitat relationships that come out of analyses of the first several years of monitoring data. In addition, significant associations may be shared with SKR researchers working on regional SKR habitat models for greater understanding of the species.

Sampling Scheme

A total of 130 to 160 sample plots will be surveyed in the first year(s) among the strata. These data will then be used to determine optimum sample allocation for the following years. All sample plots will be characterized for habitat and landscape variables and surveyed for potential kangaroo rat burrows. If there are no potential burrows, the plot will be deemed unoccupied. If any potential burrow is identified in a sample plot, the plot will be live-trapped for two consecutive nights.

Sample allocation

In the first year, 40 to 50 sample plots will be randomly selected from each stratum; additionally, the ten historical monitoring plots will be sampled. We will use the results (proportion occupied, detection probabilities) from the first year to optimize sample size and allocation among the strata for the following years (i.e. Cochran 1977, Krebs 1989). At that time, we will allocate the sampling effort in order to obtain the best precision within the high and medium quality strata, which we will refer to as the "focal monitoring area". Because there is a very large amount of low quality habitat, we do not foresee expending substantial effort sampling habitat unlikely to support SKR. We will initially sample the low quality habitat to determine whether low densities of SKR persist in these areas and to aid in future habitat models. If, after the first one or two years, SKR occupancy in the low quality habitat is determined to be too low to warrant continued effort (i.e. <4%), this stratum may be revised or removed from the study. In that case, we may increase sampling effort in the focal monitoring area and recommend the addition of random sampling units, if preferred by MCBCP, to obtain greater coverage of the focal monitoring area over time. Otherwise, all sample plots will be permanent plots to be sampled every year. This approach will yield the greatest power to detect positive or negative trends in SKR occupancy and distribution on MCBCP (Elzinga et al. 1998, Schreuder 2004), which is the primary goal of this monitoring program.

Phase 1: Burrow/ Sign Searches and Habitat Characterization

A complete search for active kangaroo rat sign (burrows, tracks, dust bathing sites, scat, runways) will be 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 (Figure 4). Each sample plot will be defined as potentially occupied by kangaroo rat(s) if it contains any kangaroo rat sign or one or more possible active burrow(s). Kangaroo rat burrows may be confused with burrows of other rodents (mice, gophers, squirrels). This is particularly true with gopher burrows, as they are the same diameter as SKR burrows (Montgomery 2003). In addition, like many other rodents, SKR are thought to use burrows that were previously dug by gophers or other species (Thomas 1975). Therefore, designation decisions will be generous. All burrows that are presumed to be inhabited by gopher or squirrel will be examined carefully for secondary sign such as appropriate scat, mounding (gopher burrows), and/or tracks for confirmation. If there is any question to the surveyor, the plot will be designated as potentially occupied for follow-up trapping. If a sample plot does not contain any kangaroo rat sign or potentially active kangaroo rat burrows, it will be defined as "not occupied". In order to promote quality and consistency, all participants will be trained in burrow identification and the number of surveyors will be kept to a minimum. If a sample plot contains only one or two questionable burrows, a burrow probe (Peep-a-roo, Sandpiper Technologies, Inc. Manteca, California) may be used to help confirm presence or absence. Absence can only be confirmed using this method if the burrow(s) can be fully explored and contain only a single entrance/exit hole. All surveys will be conducted in the late summer/early fall time period 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 will be recorded to use as covariates for habitat modeling (Table 4). 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).

Figure 4. Small mammal burrows. Kangaroo rat burrows with tracks and tail drags (a) and scat at entrance with apron of excavated soil (b), similar sized gopher burrows in clumped configuration with plugged openings (c), and much larger squirrel-sized burrow entrance (d). Note that kangaroo rats may use burrows dug by other small mammals, so observation of secondary sign is important. Lens cap is approximately 1.5 inches (40 cm) in diameter. Photos were taken in early (b-d) and late (a) spring.

Table 4. Habitat characterization form for all SKR sample plots.

Field Measure/ Covariate	Method	Data Fields	Purpose
Landscape			
Slope	clinometer	Percent slope	Habitat suitability
Aspect	compass	Degrees	Habitat suitability
Soil compaction	penetrometer	PSI	Habitat suitability- burrow suitability, vegetation growth
Soil Texture	TBD	Sand (enter %) Silt (enter %) Clay (enter %)	Habitat suitability
Digital Photograph	Digital Camera	Photo Number	Voucher
Vegetation			
Vegetation Type	From Zedler et al. 1997	Veg list + Other (write-in)	
Percent Cover- Open ground	Visual estimate	Enter %	Habitat suitability
Percent Cover- Annual Grasses	Visual estimate	Enter %	Habitat suitability
Percent Cover- Perennial Grasses	Visual estimate	Enter %	Habitat suitability
Percent Cover- Forbs	Visual estimate	Enter %	Habitat suitability
Percent Cover- Shrubs/Trees	Visual estimate	Enter %	Habitat suitability
Dominant Species- Annual Grasses	Visual assessment	Species comprising >25% total cover in annual grass layer (list)	Habitat suitability
Dominant Species- Forbs	Visual assessment	Species comprising >25% total cover in forb layer	Habitat suitability
Dominant Species- Shrubs/Trees	Visual assessment	Species comprising >25% total cover in shrub/tree layer (list)	Habitat suitability
Kangaroo Rat Sign			
Presence of Active Kangaroo Rat Sign	Search	Y/N	
IF YES to above:			
Type	Systematic Visual Search	burrows (1.5" diam.) with apron, burrows (1.5" diam.) without apron, tracks, scat, dust bathing / cache sites, runways	Kangaroo Rat occupation
Individual Rodent Sign Form			
Date			
Type	same as above	same as above	Testing of temporal closure Assumption (see section "Supplements to Core Protocol")
Location	GPS	Lat/Long	
Previously Marked?	Y/N	Pin flag, flag tape, other (choose one)	
Newly Marked?	Y/N	Pin flag, flag tape, other (choose one)	
Burrow Probe used?	Y/N		
Animal found	N	Burrow empty, blocked, not able to negotiate turn, too narrow	Check potential burrow for krat presence/absence. Test utility of burrow probe.
	Y	Animal record- Would most likely be to genus only	
Photo Taken?	Y	Digital Camera	Voucher
Disturbance/ Other			
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, fire, artillary (none, low or high- designation for each)	Management
Presence of gopher burrows	Search, Visual estimate	None/ Low/ High	Habitat suitability
Presence of squirrel burrows	Search, Visual estimate	None/ Low/ High	Habitat suitability

Adapted from Montgomery et al. (2005)

Phase 2: Live-Trapping

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 will be live-trapped for two consecutive nights. Trapping for two nights is needed to calculate and correct for imperfect capture and detection probabilities (see analysis section). Capture probabilities for this species have been reported to range from 22 to 100% (O'Farrell 1992, Montgomery 2002, 2003, Diffendorfer and Deutschman 2002) and average 60% (14 studies, Diffendorfer and Deutschman 2002). Therefore, we expect two nights should yield between 39 to 100 % (average 84%) of the total SKR occupying sample plots. In order to increase the precision for estimates of PAO, detection and capture probabilities, at least three sample plots will be trapped for three to four nights. These sample plots will be chosen opportunistically as access to the training areas and survey scheduling will allow.

Twenty-five live-traps (Fifteen measuring 3×3.5×12 inches and ten measuring 4×4.5×15 inches) will be placed in a 5 × 5 array, spaced approximately 10 m apart, on each plot (Figure 5). When obvious kangaroo rat sign is within a few meters of a trapping point, the trap will be placed next to burrow entrances, dust-bathing sites, or within runways to maximize capture success (O'Farrell 1992, Jones 1996). Diffendorfer and Deutschman (2002) report correlation coefficients of 57 to 66% when comparing simulated results of a 5 × 5 grid trapped for two days to a 9 × 9 grid trapped for three days. Thus, we expect this design will produce a reasonable index of SKR density.

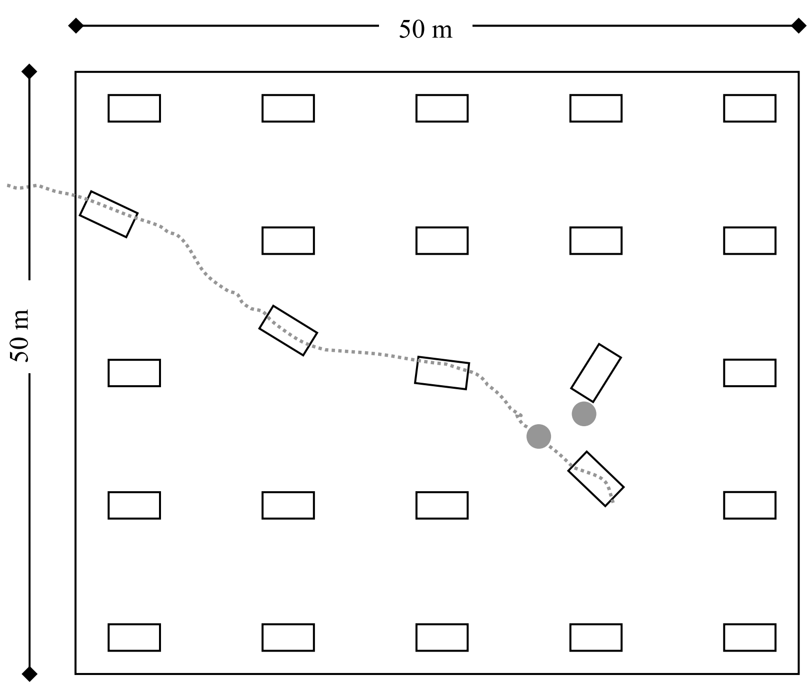


Figure 5. Diagram of live-trapping grid on 50m x 50m sample plot. Nearby traps are placed near kangaroo rat burrows (●) and trails (---) to increase probability of capture.

Trapping will be conducted during the late summer and fall months (September- November). 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 will attempt to conduct all trapping during new and part moon phases only.

Following approved protocols, trapping will be conducted by experienced small mammal researcher(s) with a current U.S. Fish and Wildlife permit for trapping SKR. All traps will be set in the afternoon using heat inactivated rolled oats as bait. If approved by USFWS, we will check traps in the early morning only. If temperatures reach 55°F or below, in the case of heavy fog, if reproductive females are found, or if not approved by USFWS, a midnight trap check will also be employed. Individuals will be 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) will be taken of all kangaroo rats, and angle of bacula will be examined on all males (Lackey 1967a, Best and Schnell 1974). We will pull a small number of dorsal hairs and photograph at least one individual identified as SKR and one individual identified as DKR on all occupied plots for voucher purposes. All animals will be temporarily marked by clipping a small amount of fur from the hip area to document recaptures.

Analysis/ Output

Proportion area occupied (PAO) will be calculated using a version of the logistic modeling program PRESENCE. This program computes detection probabilities from the survey data that are then used to produce an unbiased estimate of PAO. Calculations and equations are similar to those used for capture-recapture analyses (MacKenzie et al. 2002, 2003). PRESENCE also enables these parameters (PAO, detection probability) to be computed as a function of covariates. Thus, potential correlates to SKR occupancy (habitat and landscape variables) and probability of detection (habitat & landscape variables, environmental variables, animal density) can be evaluated. We will also explore presence-absence models which incorporate repeated species count data (Royle and Nichols 2003, Royle 2004) and species interactions (MacKenzie et al. 2004), although they are not currently designed for multi-year data.

For preliminary analysis, we will assume the probability of detection for sign and burrow searches is one. Therefore, variation in probability of detecting SKR will be from trapping data only. There are several reasons for doing this. First, we expect that the probability of detecting an active kangaroo rat burrow will be almost perfect, as we are systematically searching the entire sample plot and being liberal in the designation of potential burrows. Second, because this portion of the dataset necessarily contains 0's only (i.e. detection of possible kangaroo rat sign does not denote SKR occupancy), PRESENCE cannot compute an accurate probability for this survey method (will incorrectly estimate at near zero value). Finally, setting this parameter to one in the analysis will ensure that SKR occupancy corrected for imperfect detection probabilities is not overestimated. We will test this assumption in a supplemental study, detailed in the next section. For live-trapping, we will allow PRESENCE to calculate SKR detection and capture probabilities directly from the data.

There is some question as to whether the current version of PRESENCE will be capable of modeling this multi-phase design (i.e. model fitting difficulties with perfect or near perfect probability of detecting burrow absence), however, a new version of PRESENCE is being developed that will easily accommodate this data (D. MacKenzie, J. Nichols, J. Hines, personal communication). Therefore, first year analyses may require the use of manual calculations along with PRESENCE to figure PAO estimates corrected for imperfect detection probabilities within and among strata (Equation 1) and the use of WinBUGS (MRC and Imperial College of Science, Technology and Medicine at St Mary's, London) or other program to perform the covariate analyses.

Equation 1. Calculations for combining percent area occupied (PAO) means and variances within strata (burrow search and 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 stratum h

N = Total area size (ha) $= \sum N_h$

W_h = Stratum weight

s_h^2 = Observed variance of stratum n

n_h = Sample size in stratum h

f_h = Sampling fraction in stratum h = n_h / N_h

We present examples of proposed data input, covariates, and initial estimations of confidence intervals for PAO both within and among the strata for the first year (Tables 5, 6, and 7). As explained earlier, the PAO values produced from the first few years of monitoring will be used to optimize sample allocation over the focal monitoring area (high and medium suitability strata) for future years (Cochran 1977, Krebs 1989). Precision around our parameter estimates will improve if covariates are found to account for some heterogeneity in probabilities of detection and occupancy. Along with the habitat and landscape data collected during the burrow search surveys, we will also test the effects of other potential covariates. These include those that may influence the likelihood of occupancy and colonization in spatially structured populations, such as spatial relationships of sample plots (Stevens and Olsen 2002), distance from nearest occupied patch (i.e. Stauffer 1985, Keitt et al. 1997) and distance from roads (reviews Merriam 1993, Trombulak and Frissel 2000). Examples of covariates for analysis are presented in Table 6.

Table 5. Proposed data input structure (without covariates) for a single year using hypothetical data.

Data Input				Sampling Scheme Explanation		
Plot	Detection History			Burrow Search	Trap Night 1	Trap Night 2
1	-	0	0	Potential burrows identified	No captures	No captures
2	-	1	1	Potential burrows identified	SKR captured	SKR captured
3	0	-	-	No Potential burrows identified	N/A	N/A
4	0	-	-	No Potential burrows identified	N/A	N/A
5	-	0	1	Potential burrows identified	No captures	SKR captured

where 0= not detected, 1= detected, and "-" = not surveyed. Data input for potential kangaroo rat sign in Phase 1 of protocol is entered as "-", as potential kangaroo rat sign and/or burrows is not a positive detection of SKR.

Table 6. Examples of covariates that may be evaluated in SKR models.

Covariate		Hypothesized Effect	
Type	Variable	PAO	Probability of Detection
Habitat	% Shrub cover	X	X
	% Annual herbs/ grasses	X	X
	Soil Type	X	
	Slope	X	
Management	Disturbance type (compaction/artillery)	X	
	Disturbance level	X	
	Years since last fire	X	
Other	SKR Density		X
	Distance to nearest occupied patch	X (Colonization)	
	Distance to nearest dirt road/ firebreak	X (Colonization)	

Table 7. Estimated precision in PAO and area estimates illustrated using simulated datasets. Simple models were generated under a number of possible scenarios. Sample allocation will be optimized for high and medium strata "focal monitoring area (high and medium strata)" after first year. Low suitability habitat estimates were highly variable for all runs except where p_{BS} = 0.2. Precision will increase if any covariates account for a significant amount of heterogeneity in SKR occupancy.

		Parameter Estimates				Output (n=50)			
	Stratum	Proportion of plots with potential K-Rat Burrows/Sign (p_{BS})*	SKR Burrow/Sign detection probability (p_{BD})*	SKR live-trap detection probability (p_{LT})*	Percent Area Occupied (PAO)**	PAO (se)	90% CL	Area Occupied (ha) + 90% CL	Result
Control	High	0.6	1.0	0.6	50%	0.504 (.060)	.402- .606	298- 448	
	Medium				6.0 -7.5%	0.075 (.040)	.007- .144	43- 837	
	Low				2.0 -2.5%	0.024 (.023)	0- .063	0- 703	
	High + Medium				12.5%	0.124 (.036)	.063- .184	414- 1207	
low p_{LT}	High	0.6	1.0	0.4	50%	0.504 (.089)	.352- .657	261- 486	↓ Precision
	Medium				6.0 -7.5%	0.075 (.044)	.001-.149	9- 871	
	Low				2.0 -2.5%	0.047 (.046)	0- .125	0- 1400	
	High + Medium				12.5%	0.124 (.040)	.056- .191	368- 1253	
high p_{LT}	High	0.6	1.0	0.8	50%	0.504 (.046)	.426- .582	315- 431	↑ Precision
	Medium				6.0 -7.5%	0.066 (.035)	.006- .126	38- 738	
	Low				2.0 -2.5%	0.042 (.053)	0- .132	0-1478	
	High + Medium				12.5%	0.115 (.031)	.063- .168	413- 1103	
Variable p_{BS}	High	0.6	1.0	0.6	50%	0.504 (.060)	.402- .606	298- 448	↑ Precision
	Medium	0.4			6.0 -7.5%	0.077 (.039)	.010- .145	56- 848	
	Low	0.2			2.0 -2.5%	0.021 (.018)	0- .052	0- 300	
	High + Medium				12.5%	0.125 (.035)	.066-.184	436- 1209	
p_{BD} not fixed	High	0.6	not fixed	0.6	50%	0.873 (.096)	.713- 1.0	527-740	↑ PAO ↑ Bias*** ↓ Precision
	Medium				6.0 -7.5%	0.133 (.088)	0- .28	0- 1633	
	Low				2.0 -2.5%	0.079 (.054)	0- .169	0- 1899	
	High + Medium				12.5%	0.217 (.079)	.085- .348	2230- 9159	
no strata	High + Medium	0.6	1	0.6	12.5	0.13 (.049)	.048- .212	317- 1392	↓ Precision

*p_{BS}= proportion of grids with potential kangaroo rat burrows, p_{BD}= probability of detecting an SKR burrow, if one or more is in plot, p_{LT}= probability of capturing an SKR, if one or more is in plot

**Calculated using Equation 1. Combined results of live-trapping (using PRESENCE) and burrow counts for each stratum.

*** Bias due to inability of program to estimate parameter with negative (0) data only.

The precision of PAO estimates (status) for any given year are important. However, we are fundamentally interested in monitoring change over time. Therefore, the precision of our main index of population growth or decline (rate of colonization/ extinction) is equally, if not more important. We can maximize the precision to detect positive and negative trends by making all of our sample plots permanent (re-sampled every year; i.e. Elzinga et al. 1998, Schreuder et al. 2004). This basically removes nearly all variability between sample plots from the error term, thereby increasing the statistical power to detect differences between years. Providing that we 1) have a large number of samples and 2) our survey methods do not affect SKR occupancy among years, the use of all permanent sample plots should not compromise the accuracy of our yearly PAO estimates (D. MacKenzie personal communication). There are currently no readily available programs to estimate the power of detecting trends in these types of patch occupancy models. However, simple comparisons for precision in detecting population declines with permanent vs. random sample plots are presented in Table 8. After two years of data are collected, we can estimate the actual precision around this parameter. As with other parameters, confidence intervals around the rate of population growth or decline will improve if covariates are found to account for heterogeneity in the rates of colonization and extinction.

For model selection and inference, we will follow the information-theoretic approach (Burnham and Anderson 2002) and recommended methods for analyzing the fit of site-occupancy models (MacKenzie and Bailey 2004)

A density index for SKR within each stratum will be calculated using a simple closed capture model available in Program MARK (White and Burnham 1999). Estimates will be generated for the following parameters: probability of initial capture, probability of recapture, and population size. The population size estimate and 90% confidence interval will be used as our density index.

We will continue to concurrently analyze trends for the ten historic grids as presented in Figure 2.

Assumptions

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 PAO model.

1. There is a perfect probability of detecting active kangaroo rat sign/burrows. This will be tested with supplemental study 1, described below.

Table 8. Simple sensitivity estimates for detecting SKR population decline between years. Two sampling schemes are compared; one in which all sites are permanent and resurveyed every year and another in which sites are randomly chosen each year. Precision for sampling schemes that use both types of sites would fall between these estimates. Note that the precision of detecting declines with permanent sites is reduced with increasing background levels of colonization and extinction, as this reduces the positive correlation of values between surveys.

Sample Scheme	**Hypothetical patch occupancy dynamics**[1]	**Estimates of initial sensitivity to detect SKR population decline with 90% confidence**[2]			
		Stratum	Initial PAO estimate	Minimum detectable decrease in PAO (Proportion)	Minimum detectable decrease in PAO (Percentage)
Permanent sites only					
	(a) Extinction only, no colonization	High	0.500	0.060	12%
		Medium	0.075	0.060	80%
		High + Medium	0.125	0.030	24%
	(b) Net extinction over background rates of 10% in both colonization & extinction	High	0.500	0.110	22%
		Medium	0.075	0.080	-
		High + Medium	0.125	0.050	40%
All Random					
	n/a	High	0.500	0.180	36%
		Medium	0.075	0.134	-
		High + Medium	0.125	0.103	77%

[1] (a) assumes that no new patches become occupied. Therefore, if SKR occupancy is 0.50 for the high quality stratum in year 1, we can detect a decrease in SKR occupancy in year 2 of 0.06 (to 0.46) or 12% with 90% confidence. (b) assumes that there are both extinction and colonization events between time 1 and time 2 (rates of 10% each) with an added net rate of extinction. Therefore, if initial SKR occupancy is 0.50 for the high quality stratum in year 1, we can detect a net decrease in SKR occupancy in year 2 of 0.11 (to 0.39) or 22% with 90% confidence over an above background colonization and extinction rates of 10% (i.e. 10% of the patches become unoccupied and the same number become newly occupied for no net change in occupancy). If all sites are randomly chosen each year, only the net change in occupancy is statistically testable.

[2] McNemar's test for correlated proportions (permanent) and chi-square test of independent proportions with continuity correction (random) using NCSS/PASS software (Kayesville, Utah). n = 50 per stratum

2. The population is closed in both time and space. Therefore, no kangaroo rats are moving to or from sample plots within the time of sampling. The model should be robust to all but large systematic violations of this assumption (Kendall 1999) which we will test in supplemental study 2, described below. We will also attempt 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 possible.

Management

In the Draft Biological Assessment and Management Plan for SKR on MCBCP (1999), a goal to keep a total of 1000 acres (405 ha) occupied by SKR was suggested. The final goal is currently unknown, as it will be determined after future consultation with the Fish and Wildlife Service. Until a final goal is reached, however, we will recommend specific management actions for SKR if the total area occupied estimate with 90% confidence limits falls below 1000 acres (405 ha) within the high suitability stratum. If, due to low occupancy or detection probability, these confidence limits are too wide to be a useful threshold for management action, we may recommend use of lesser confidence limits or estimated mean area occupied to trigger action. Even if corrected estimates of SKR occupancy within MCBCP remain within the specified limits, we encourage ongoing management of SKR habitat. We will also recommend management actions if SKR occupancy declines markedly for any of the known population groups (p.8 and Figure 1). Management typically involves removal of shrub cover (i.e. burning, scraping, grazing, mowing), but can also take the form of soil decompaction, digging artificial burrows (S. Montgomery, personal communication), and/or reduced training impacts (i.e. heavy vehicles and artillary). A detailed review of potential management actions for MCBCP is presented by Tetratech Inc. (1999).

Management actions should be linked to this monitoring effort in order to evaluate their effectiveness in increasing SKR habitat boundaries and/or densities. Management treatments can be conducted, but not limited to the permanent study grids, so that the results on SKR populations can be monitored through time. Disturbances created by fire or troop activities that are not the result of purposeful management actions may also incorporated or evaluated separately for effects on SKR occupancy and density in the model. A simple study design is presented below under Future Study Recommendations.

Further Study Recommendations

First, we present a recommended list of supplemental studies to support or answer questions related to the "core" protocol. Some of these studies are necessary for at least the first year of monitoring, others are optional. Second, we recommend optional primary studies to fill in information gaps in our basic knowledge of SKR biology. Although these studies may not be feasible at this time, they would greatly increase our understanding of SKR if the opportunity presents itself in the future.

Specific: Supplements to core protocol

Burrow Searches: Detection probability

For our Phase 1 sampling, we assume that we have a perfect probability of detecting SKR absence by the observed absence of any potentially active kangaroo rat burrows. We will continually scrutinize this assumption by yearly live-trapping three randomly selected sample plots per strata that were judged to be absent after conducting a thorough burrow search.

In addition, we will test the difference in detectability between observers by conducting double-observer surveys for kangaroo rat burrows and other kangaroo rat sign on a predefined selection of 5 to 10 sample plots.

Sign and Burrow Search: Testing Closed Population Model Assumptions:

This aspect of the protocol will be implemented in the first year of surveys to test whether the state of SKR occupancy (present/ absent) may change between the time of conducting sign/ burrow searches and live-trapping. During the initial phase, in all sample plots with potentially active burrows, we will mark at least one potentially active burrow with a pin flag and document the burrow with a photograph. Upon returning to the sample plot for live-trapping, the flagged burrow will be reassessed for potential occupancy and another photograph will be taken. We will also reassess all grids that are live-trapped, including the nine initially absent sites (see Burrow Searches: Detection Probability) for potential kangaroo rat burrows upon returning for live-trapping.

Effects of SKR Habitat Management

In order to study the effects of management on SKR populations, we recommend a simple repeated measures ANOVA design that can be directly incorporated into the monitoring protocol. This design could determine whether SKR return to historic habitat or move into adjacent habitat after management and if so, the timeliness and duration of this response (Table 9). The management areas would be chosen randomly from the set of permanent grids and/or chosen opportunistically in response to MCBCP availability and land use constraints. Disturbance that is not related to active management but that result in habitat clearance, such as fire or trampling, can also be evaluated in this manner.

Table 9. Simple ANOVA design to study effects of management.

Factors	**Levels**
Between-subject	
Management	Y/N (≥3 replicates each)
Within-subject	
Time	Years (0,1,2,3,..)
Response Variables	
Occupation by SKR	Y/N
Density of SKR	quantitative or low/high
Normalize for following factors before study:	
Occupation status before treatment	
Distance to nearest known current population	

Alternate methods of species confirmation:

Scat

Often, scat can be found near the opening of active kangaroo rat burrows. We would like to explore the development of an assay to differentiate SKR from DKR using mitochondrial DNA obtained from shed epithelial cells found in scat (Foran et al. 1997). This may provide a cost effective alternative to live-trapping for discriminating these two species.

Hair snares

Hair snares are commonly used as a cost-effective indirect detection method for medium and large elusive mammals, such as fishers, martens, wolverines, lynx, and bears (Zielinski and.Kucera. 1995, Mills et al. 2000, Boulanger et al 2002). They have also been used with some success for smaller mammals (Suckling 1978, Dickman 1986, Sanecki and Green 2005). We would like to explore the development of a passive hair snare devise for kangaroo rats. Species could be identified based upon hair characteristics or genetic analysis (Mills et al. 2000). Information gained from genetic analyses of DNA extracted from hair follicles could not only be used to model SKR distribution and abundance but could potentially be used to elicit information on population demography, heredity, and dispersal (Girman et al. 2001, Boulanger et al 2002, Ernest et al. 2003, Valero 2004, Stanley and Royle 2005).

General: Information Gaps

Although the Stephens' kangaroo rat has been relatively well studied in comparison to other rodents, there are still large gaps in our basic knowledge of life history traits and population dynamics.

Dispersal

There have been few studies on SKR dispersal (Price et al. 1994b, Kelt 2005). Of these, most are primarily based on live-trapping (i.e. "dispersal rings", movements between grids) that can result in underestimation of dispersal rates and distances, because movements in and out of the study grid often cannot be differentiated from mortality and recruitment. The current evidence has shown that SKR are fairly sedentary, although adults and juveniles do make long range movements greater than one kilometer (Price et al. 1994b). There are many questions of SKR dispersal that need further study; Is dispersal related to density? Are there patterns in the timing of dispersal? Is dispersal distance related to sex or age class? Is the likelihood of dispersal between populations related to distance between suitable habitat patches and/or availability of dispersal corridors? Because our monitoring protocol is conducted only one time per year, we do not expect that permanent marking would reveal information on dispersal, although documentation of some individual movements are possible. However, we can collect hair or other tissue from captured individuals. We believe that genetic analyses of SKR populations in Camp Pendleton using microsatellite DNA and other markers would be a cost-effective way to uncover information on recent and historical dispersal dynamics (e.g. Boulanger et al. 2002, Ernest et al. 2003, Valero 2004). Also, seasonal or year-long radiotelemetry studies conducted on at least two independent trapping sites may generate added information on SKR dispersal dynamics, such as dispersal as it relates sex, age, and population density (e.g. Gillis and Krebs 1999, Loew 1999). Non-traumatic methods for transmitter attachment may need to first be explored on a similar species.

Demography

Demographic models for SKR have been problematic due to high spatial and temporal variability in abundance and capture probability. We support participation in a long-term demographic study over the extent of SKR habitat in San Diego and Riverside Counties (Diffendorfer and Deutschman 2002). Because SKR densities are typically low, this effort requires the use of large trapping grids. In addition, because of the spatial and temporal variability, this effort also will require a large number of grids to be trapped at frequent intervals for an estimated ten to twenty years. The relationship between dispersal and demographic parameters is also largely unknown (Price et al. 1994b). Therefore, co-implementation of a dispersal study (above) is recommended.

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Appendix 1. Scientific Panel and SKR Workshop members

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Kenneth Burnham. Statistician, USGS/ Colorado State University – Peer Review Panel
Douglas Kelt, Associate Professor of Wildlife Ecology, UC Davis – Peer Review Panel
Anthony Olsen, Environmental Statistician. US Environmental Protection Agency. Peer Review Panel
Stephen Montgomery, Biologist, SJM Biological Consultants- Subject Matter Expert

Additional Participants:

Andrea Atkinson, US Geological Survey
Lianne Ball, US Fish and Wildlife Service
Maeve Hanley, County of San Diego
Robbie Knight, Fallbrook NWS
Dave Lawhead, CA Dept. of Fish and Game
Robert Lovich, Anteon Associates
Samantha Marcum, US Fish and Wildlife Service
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Mark Pavelka, US Fish and Wildlife Service
Christy Wolf, Anteon Associates/ MCBCP
Julie Yee, US Geological Survey

Roles of Workshop Members

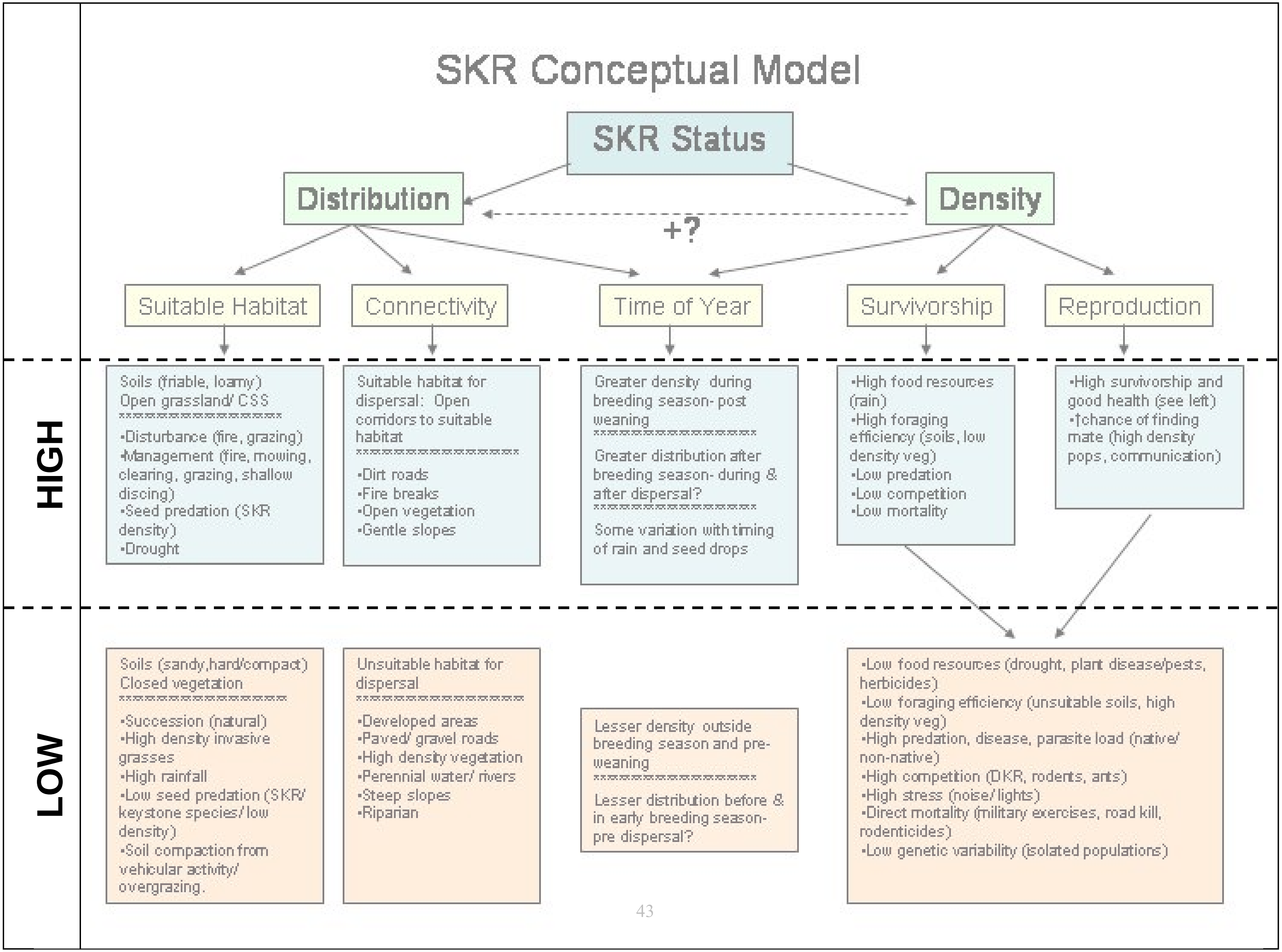
The Scientific Peer Review Panel (SPRP) consists of scientists with a strong background in wildlife monitoring methodologies and statistics, small mammal ecology and/or SKR natural history. Prior to the workshop, the SPRP will review the relevant background literature provided to them by USGS. At the workshop, the SPRP will evaluate existing monitoring design(s) and decide upon a design to meet the program objectives. After the workshop, USGS will submit a draft of the monitoring protocol to the SPRP. The SPRP will then provide USGS with their review and comments of the draft.

USGS is responsible for organizing the panel and workshop, developing a protocol review system, managing of the process, and the completion of the draft and final monitoring protocol.

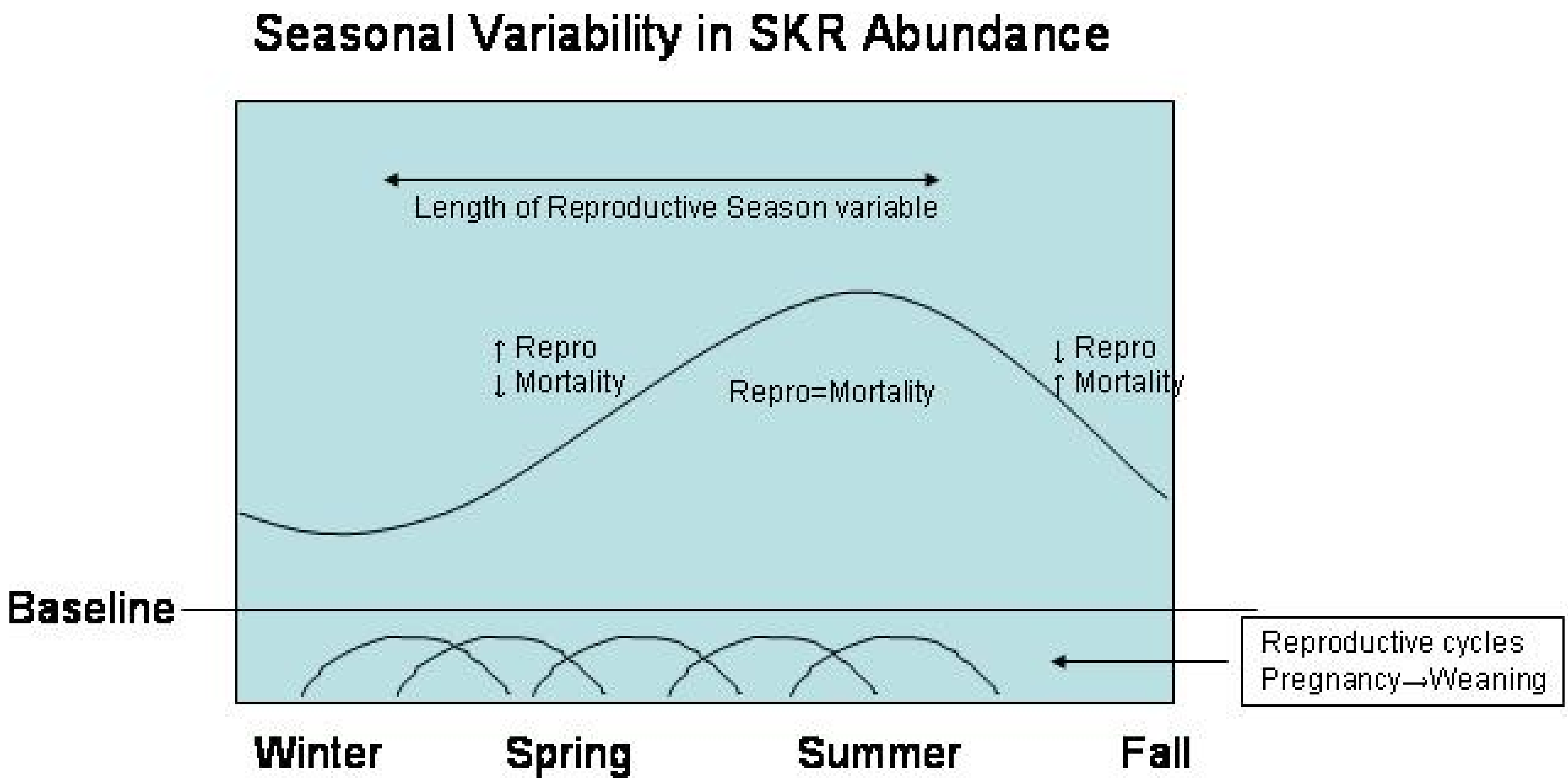
The MCBCP representative and his designee will provide an oversight role to USGS and will be engaged in all meetings and correspondence.

Invited representatives from USGS, USFWS, CDFG, SDSU and other agencies and scientists will act in a support capacity to the Scientific Peer Review Panel during the workshop, and are encouraged to join in the discussion. Representatives will be provided a draft of the monitoring protocol but are not required to submit their comments to USGS staff. The SPRP will have the final decision on the monitoring protocol recommendations for implementation on MCB Camp Pendleton

Appendix 2. SKR Conceptual Model



Appendix 3. SKR Model of Seasonal Variability and Abundance



Appendix 4. SKR Life History & Stressors

General:

Bipedal locomotion, requires open habitat for movement, collects seeds in external cheek pouches, physiologically adapted to warm and dry climates, nocturnal.

Average life span 4-8 months (estimate does not distinguish mortality from emigration). Live up to 18 months (McClenaghan and Taylor 1993). 14-18% live beyond first year. Population densities reported between 7.5-57.5/ha. Population structure is not known, but theorized to act as metapopulation(s) due to dependence upon early successional, disturbed habitat.

Stressors:

- Distribution:
  - Lack of suitable habitat
  - Low/no connectivity (dispersal corridors)
- Survivorship/Reproduction:
  - Low food resources
  - High predation pressure (owls, snakes, coyotes, foxes, feral cats, invasive ants)
  - High Competitive pressure (other rodents, ants)

Specific (food habits, home range/dispersal, habitat, behavior):

Food habits: Feeds on relatively large seeds, vegetation, and occasionally insects. In disturbed non-native grasslands, SKR primarily consumed seeds from filaree (*Erodium cicutarium*) and Schismus grass (*Schismus barbatus*). In late winter through early spring when seeds were not available, SKR primarily consumed vegetative parts of grasses, buckwheat (*Eriogonum fasciculatum*), fireweed and California sage (*Artemisia californica*). Thought to get all or most of water from food.

Stressors:

- Low seed production- drought years
- Increased vegetation density. High seed production from high rainfall years may also result in increased plant growth resulting in reduced foraging efficiency.
- Invasive brome grasses create thick mat, reduce foraging efficiency
- Possible competition for seed from sympatric *Dipodomys simulans*
- Consumption of pesticides from rodent control programs.

Reproduction: Females may reach reproductive age same year of birth. Onset of estrous at start of winter rains and conclusion after plants disperse seeds (McClenaghan 1993). Typically late winter through early summer (Gestation ~30 days, average 2 litters/season, 2.5 young/litter). Young weaned between day 18-22.

Stressors:

- Drought. Reproductive output may be reduced or eliminated in drought years.
- Affected by timing of rains (possibly due to resource type availability).
- Low population densities result in decreased chance of finding mate, lower effective population size.

Home range/ Dispersal: Relatively small home ranges reported (0.06- 0.20 ha). Little known about age, timing, mechanisms of dispersal. Dispersal distances of up to 1 km have been documented, largely by females. Dirt roads may be used as dispersal corridors.

Stressors:

- Lack of surrounding open habitat (natural/ unnatural) for dispersal to other habitat patches.

Habitat: Prefers sparsely vegetated, grassy areas within coastal sage scrub.
Previously thought to reside primarily in native grasslands but typically inhabits open scrub/ grassland communities maintained by disturbance (fire, grazing, drought, scouring, discing, fallow agricultural fields). Will rapidly colonize newly disturbed habitat (i.e. post-fire).

Prefers friable, loamy soils (requires soil between clay and large sand for burrowing). Average burrow depth is 46 cm. Can readily survive most fires underground.

Stressors:

- Any dense vegetation (shrubs, brome grasses). Prefers > 70% open/bare ground.
- Invasive non-native grasses (brome) (in high density)
- Succession (grassland transition to shrubland)
- Steep slopes (impedes efficient locomotion?)
- Hardened soils (due to trampling/heavy equipment/drought) affect burrowing ability/ energetics, decrease burrow depth- more susceptible to crushing.
- Competition for marginal habitat from sympatric *Dipodomys simulans*
- Nino cycles (too frequent or infrequent)
- Troop disturbance or bivouacking in excess
- Over grazing or grazing while wet (compacting soils)
- Heavy activity

Behaviors:
Caches food/seed
Possibly avoids foraging in open during full moon.
Dust baths to maintain healthy pelage
Likely uses foot stomping as means of communication.
Some share burrow entrances. Sharing increases with increased pop. densities.
Use auditory senses for predator avoidance, communication

Stressors:

- No loose soil for bathing (result is unhealthy pelage- parasites/ less effective insulation).
- Hardened soil or lack of loose soil may decrease potential cache sites (seed storage).
- Loud noises may interfere with communication and predatory response (artillery fire, bombing, troop movement)
- Artificial lights decrease foraging, foraging efficiency

Population increase & decline (potential causes)

Increase

Natural:

- Habitat gain: Open up previously closed vegetation (natural fires, scouring events, intense drought)
- Increased resource availability: Greater seed output due to normal or high levels of rainfall.
- Decrease of natural predators

Unnatural:

- Habitat gain: Open up previously closed vegetation (unnatural fires-frequent burn intervals, bomb explosions, intense training activities, roads and firebreaks, shallow discing)
- Increased resource availability: Invasive grasses/ herbaceous plants provide greater seed output.

Decline

Natural:

- Habitat loss: Successional changes (mid/late seral communities), overgrowth & invasion of non-native grasses
- Decreased resource availability (Decreased fitness, decreased reproductive success, starvation): drought, plant diseases & pests
- Increased predation/ predator abundance (owls, foxes, coyotes, snakes) (Recovery Plan)
- Increased competition for food/habitat: *Dipodomys simulans*, other rodents.

Unnatural:

- Habitat loss: Development, compaction of soils (troop & heavy equipment movements)
- Fragmentation by infrastructure: Paved roads, buildings
- Decreased resource availability: herbicides, non-native grass removal? (potentially)
- Increased predation/ predator abundance (feral cats, dogs, Argentine ants, fire ants)
- Increased competition: non-native rodents (*Mus musculus?)*
- Direct mortality: Crushed/injured by trampling/ artillery fire/ development of land/rodenticides.
- Damage to eardrum from artillery fire/ bomb impacts.
- Noise/explosions decrease habitat quality by decreasing efficiency of communications, anti-predator strategies, stress levels
- Decreased foraging time and efficiency due to presence of artificial lights.
- Disease transmission from exotic mammals.
- Ingestion of poisons used to control unwanted rodent infestations (i.e. squirrels- plague)

Status and Trend

Overall: (USFWS 1997)

- Habitat: 25688 acres occupied habitat
- Distribution: San Jacinto Valley and adjacent areas of western Riverside, southwestern San Bernardino, & northern San Diego counties.
- Population numbers and sizes: 11 core "populations" targeted for conservation in San Diego and Riverside counties. Occupied habitat for each reported to vary from ~320 to 2000 ha. often with larger potential habitat estimates. Most populations small/ low density (<4/ ha).
- Annual variation: Large variations in abundance (10 fold common). Variation in distribution largely unknown although large fluctuations in distribution of density recorded in Lake Matthew & Shipley reserves from 1991 to 1994.
- Long Term Trends: Thought extirpated from San Bernardino county. Overall trends may be largely unknown.

Camp Pendleton:

(Part of SKR Western Conservation Planning Area of San Diego County with Fallbrook population. Designated as "High Priority" Reserve.)

- Existing monitoring programs: Current program involves trapping and burrow counting at 13 grids across known SKR habitat for every other year since 1996 (November trapping).
- Habitat: In 1997, 684 to 800 acres of SKR habitat were occupied (estimate: Tetratech and SJM Biological Consultants 1999, USFWS 1997). Suitable habitat defined in 1999, but has changed somewhat since survey period.
- Distribution: Four general areas where SKR historically/ presently occur.
    - San Mateo- small population- presumed extirpated. (HOLF, 313B)
    - San Onofre- small population- presumed extirpated. (Range 210)
    - South & East of Whiskey Impact Area-(Includes Kilo 1 & 2, Range 407-409, AFA 24 & 30). Largest Area- Low to High Density "populations".
    - SE corner abutting Fallbrook NWS (Juliett). Small/Med Area- Low Density
    - Note: Presence/abundance within Impact Areas unknown. Off limits.
- Population numbers and sizes: See above and Table 1
- Annual variation: Numbers in grids have varied over time up to 10 fold from 1996 to 2002.
- Trends: Variable among sites. See Table 1.

Potential Management Actions

- Create artificial disturbance to open up vegetation (fire, discing, grazing, mowing, others)
- Create and/or maintain fire breaks/ dirt roads/ open habitat as movement corridors.
- Create artificial burrows for SKR habitation.
- Reduction of artificial lights at night.
- Control of feral pets.
- Prevent any disturbance, degradation of habitat (signage).

Appendix 5. Comparison Tables: Monitoring Methods

Basic Approaches to Metapopulation vs. Single Population Monitoring Schemes

Program	Purpose	Methods	Frequency	Timing	Possible Response Variables	Some strengths	Some limitations (if population assumption incorrect)
PAO/ Patch Occupancy (Metapopulation)	Distribution	Survey for presence throughout potential habitat. Sampling schemes could vary	Could Vary	Could vary	Prop. Area Occupied, Detection probabilities, Colonization/ Extinction, Relationship of covariates to Presence/Absence (i.e., habitat variables, other spp., stressors)	Powerful for tracking meta-population dynamics: Strong relationships established between target species and habitat/stressor variables can directly relate to mgmt actions	No information on abundance/ densities or demographic variables. Large number of sub-populations could "blink out" due to critically low abundance before management action is recommended.
Abundance Monitoring (Single Population)	Population Abundance / Density	Survey for abundance at fixed locations within species habitat. Sampling schemes could vary	Could Vary	Could vary	Estimate total abundance, Capture probabilities, reproductive success, survivorship, relationship of covariates to abundance (i.e. other spp. (competition), stressors)	Powerful for tracking increases and decreases in population size over predefined area. Potential to learn about fluctuations in abundance and demographic variables over time and perhaps in response to environmental/ climatic variables.	No information on distribution. Assume uniform abundance over predefined habitat boundaries. Could conclude species in trouble due to low numbers when location of high density may have only moved. Low power for analysis of habitat variables. Difficult to model when abundance is low.

Features of metapopulations
("population of populations") (Hanski 1996, Weins 1996)

- Many local populations (>2, 10?).
- Each local population has a given extinction probability.
- Each local population has traditional dynamics
- High probability of extinction generates "winking", no probability of extinction generates

- "fixed" populations.
- Dispersal is responsible for re-colonization of vacant sites.

Potential and Current Sampling Methods for SKR

Purpose	Methods	Detection/ capture probability	Some strengths	Some limitations
Presence	Search for sign (active burrows, scat, tracks)	Varies by season & location- Highest in Fall	Low effort, proven method, passive	Could mistake for DKR. May need to trap to confirm SKR presence
Presence	Live-trapping (requires midnight and morning trap checks)	Varies by season & location- Highest in Fall	Proven method, positive species confirmation.	High effort to establish absence (5 night std)
Presence	Infra red cameras*	Unknown	Relatively low effort, passive	Not proven- potential high cost. May need to trap to confirm SKR vs. DKR presence
Presence	Search burrow entrances with visual probe/ camera*	Unknown	Relatively Passive. Potentially also gain information on reproduction and sociality	Burrows may be to deep. Could be time consuming. May still need to trap to confirm SKR vs. DKR.
Presence	Night Vision Goggles	Unknown	passive	Time dependant. May need to trap to confirm SKR vs. DKR presence
Abundance	Count burrows	Varies by season & location- Highest in Fall	Low effort, passive, positive correlation to density	Could mistake for DKR, slope of the relationship to density not stable
Abundance	Live-trapping (requires midnight and morning trap checks)	Varies by season & location- Highest in Fall	Proven. Direct abundance estimates. If frequent, gain information on demography	High effort

*Methods not currently known to be in use for regular monitoring.

Burrow Counts

- Significant Positive correlation to SKR density
- Fluctuate similar to abundance
- Variable slope of relationship in time and space (0.021 to 0.045)
- Numbers may vary temporally and spatially due to sharing of burrows and/or multiple entrances to same burrow