Coachella Valley Conservation Commission

January 1, 2012

Coachella Valley Multiple Species Habitat Conservation and Natural Community Conservation Plan

Alluvial Fan Communities and Species Monitoring Protocols

Prepared by the University of Riverside Center for Conservation Biology
for the Coachella Valley Conservation Commission

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<u>Natural Communities</u>
Sonoran Creosote Scrub
Sonoran Mixed Woody and Succulent Scrub

<u>Listed Species</u>
Burrowing Owl (*Athene cunnicularia*)
Casey's June Beetle (*Dinacoma caseyi*)
Desert Tortoise (*Gopherus agassizii*)
Le Conte's Thrasher (*Toxostoma lecontei*)
Mecca Aster (*Xylorhiza cognate*)
Little San Bernardino Mountains Linanthus (*Linanthus maculatus*)
Orocopia Sage (*Salvia greatae*)
Palm Springs Pocket Mouse (*Perognathus longimembris bangsii*)

These Protocols are subject to future revision as deemed necessary by the CVMSHCP's adaptive management process – this version was last updated on January 1, 2012.

U.C. Riverside Center for Conservation Biology

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INTRODUCTION

There are two aspects of the monitoring framework presented here that are unique among conservation plans elsewhere. First, this framework is explicitly science-based. In addition to providing abundance and occurrence data, our approach focuses on hypothesis driven questions that assess the risk stressors pose to meeting conservation objectives (Barrows et al. 2005). The effectiveness of this framework requires an experimental design that examines the performance of populations with or without a particular stressor, and long-term data sets that establish the temporal influence of stressors along with the resilience of populations when a stressor's impact is reduced. This approach leads to the identification of cause and effect relationships for population dynamics, allowing the separation of typical changes in populations from those beginning a trajectory toward local extinction (Barrows and Allen 2007b).
Second, this framework embraces the multiple species – community basis for the conservation design and goals of the Coachella Valley MSHCP-NCCP. This approach creates efficiency, but more importantly develops a view of the impacts of environmental stressors and management options across the breadth of biodiversity and multiple scales at which stressors can have impacts within designated conservation areas (Barrows et al. 2005).

Compliance with specific monitoring criteria and tasks of the Coachella Valley MSHCP-NCCP are detailed in a separate document (Monitoring Framework).

COMMUNITY DESCRIPTIONS

Alluvial fans are composed of the soil eroded from mountain bedrock and transported by fluvial processes onto valley margins. Over time, floods take different courses, resulting in a fan-shaped depositional area. Occasionally secondary uplift of alluvial fans results in low hills, (e.g., the Indio Hills) or foothills (e.g., the lower elevations of the Little San Bernardino, San Bernardino, San Jacinto, and Santa Rosa mountains). Alluvial fan soils are typically well drained, poorly sorted mixtures of fluvially transported rock, gravel and sand. The fluvial processes on alluvial fans can vary from relatively gentle sheet flows to violent channel-entrenching and depositional flows that reshape the fans' topography. Both fluvial process types are important to the species composition of the fan. Gentler sheet flows typify habitats where Little San Bernardino Mountains linanthus (*Linanthus maculatus*), Casey's June beetle, *Dinacoma caseyi*, and Palm Springs pocket mice (*Perognathus longimembris bangsii*) find their greatest abundances. More violent flows create steep banks, which allow burrow excavation and provide thermal refuge for Burrowing Owls (*Athene cunnicularia*).

Plant communities associated with alluvial soils within the Coachella Valley include Sonoran creosote bush scrub and Sonoran mixed woody and succulent scrub. These two communities represent opposite ends of a gradient in community structure within the alluvial fan ecosystem. The mixed woody and succulent scrub community is more succulent-rich and species-diverse, whereas the Sonoran creosote bush scrub has few if any succulents and is overall more species-depauperate. Within the Coachella Valley, the Sonoran creosote bush scrub is the more widely distributed of these two communities (Figure 1). Mixed woody scrub occurs in more westerly areas and at higher elevations characterized by greater levels of overall precipitation, especially summer rain. Primary threats to these communities include loss of fluvial processes due to upstream dams and channelization, suburban habitat conversion, invasive species such as *Schismus barbatus, Bromus* sp., and Sahara mustard (*Brassica tournefortii)*, and the increased fire frequency facilitated by exotic weeds.

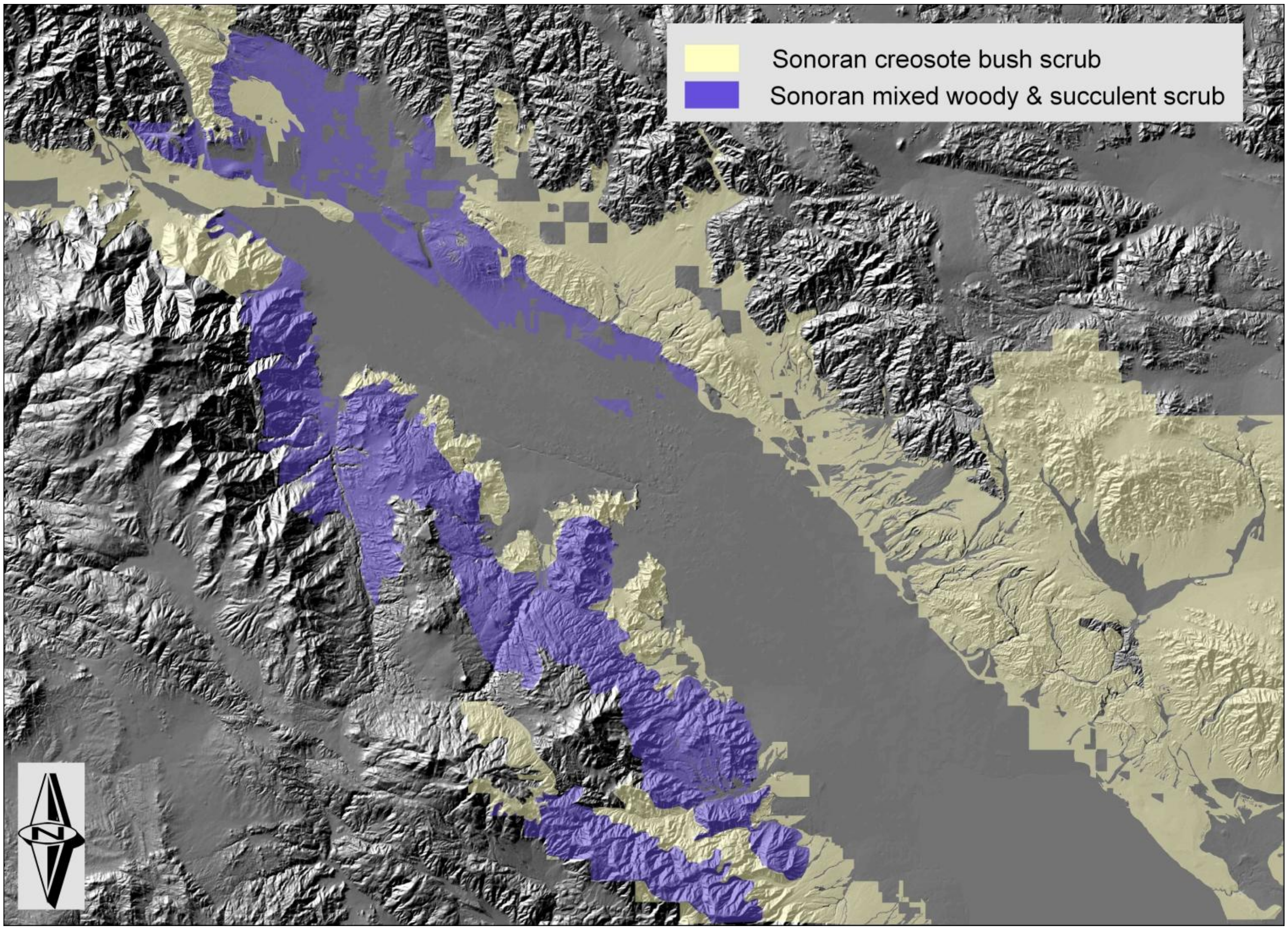

Figure 1. Distribution of the two alluvial fan plant communities within the Coachella Valley, CA.

ALLUVIAL FAN SPECIES DESCRIPTIONS

The following are brief species accounts aimed at providing a basic understanding of each species' natural history and a context for the proposed monitoring and research questions and approach to monitoring. The current records for the distribution of these species within the CVMSHCP are shown in Figure 2.

Burrowing Owl

Burrowing owls are widely distributed in western North America, occurring in deserts, grasslands, shrub-steppe and agricultural and suburban-edge modified landscapes. They hunt for a wide variety of prey, including insects, small mammals and lizards, and are capable of hunting in various habitats, including those moderately developed by humans, such as agricultural lands. Unlike other generalist species (e.g., crows, Red-tailed Hawks and raccoons which are common across broad landscapes), however, Burrowing Owls occur sporadically and often patchily across their range. The lack of full occupancy across otherwise seemingly suitable habitats indicates the finer scale processes underlying their distributional and population dynamics are not well understood. Burrowing Owls nest in burrows often initially excavated by burrowing mammals so the presence of burrowing mammals or naturally occurring earthen cavities likely contribute to the owls' distribution. Washes characterized by intense flooding and channelization provide a viable substrate attractive to burrowing mammals and, therefore, Burrowing Owls. Anthropogenic stressors may include off-highway vehicle (OHV) traffic and consequent destruction of burrows, intense urban development resulting in a loss of prey base and introduction of novel predators (i.e., cats and dogs), and invasive species (e.g., Sahara mustard) that disrupt the open habitat structure necessary for the owls to detect potential predators, defend nest sites, and forage efficiently. Although intense development can be detrimental, moderate levels of agricultural or urban development can also cause soil disturbance attractive to burrowing mammals and therefore beneficial for Burrowing Owls. The sparse woody vegetation of the Sonoran creosote bush scrub and Sonoran mixed woody and succulent scrub, along with their well drained soils, apparently provide adequate Burrowing Owl foraging and nesting habitat since owls are known to live and breed in these habitats.

Palm Springs Pocket Mouse

A subspecies of the little pocket mouse (*Perognathus longimembris*), the Palm Springs pocket mouse, (P. l. bangsii) is solitary, nocturnal, and spends the day in underground burrows. They are thought to breed from January–August and hibernate in the winter (Dodd 1996). The Palm Springs subspecies generally occupies gently sloping habitat with sparse-to-moderate vegetative cover and loosely packed, sandy soils. It is broadly distributed throughout CVMSHCP conserved lands with those characteristics, but is more abundant in the mesic, western portions of the plan area (Barrows et al. in press). Suspected population threats include habitat destruction, degradation, and fragmentation caused by development (urban and agricultural), roads, and railroads. OHV use, illegal trash dumping, and feral/domestic predators may also affect populations. Given the pocket mouse's limited dispersal ability, the potential for habitat fragmentation to cause genetic isolation and a concomitant loss of genetic diversity is of some concern. In addition as granivores, invasive plant species that reduce the availability of preferred seed types and/or sizes may also threaten the Palm Springs pocket mouse.

Le Conte's Thrasher

The Le Conte's Thrasher occurs in a variety of desert habitats with sparser cover than is preferred by other thrashers (i.e., T. crissale and T. redivivum). Most commonly, the Le Conte's Thrasher occurs in sparsely vegetated desert flats, dunes, alluvial fans, or gently rolling hills with a high proportion of saltbush (Atriplex spp.) and/or cylindrical cholla cactus (Opuntia spp.). In suitable habitat, shrubs are scattered and the ground is generally bare or with sparse patches of grasses or annual forbs. This species is rarely found in habitats consisting entirely of creosote bush (Larrea tridentata). Leaf litter provides diurnal cover for most arthropods that form the prey base for this species. Territories are typically relatively flat, although the species can occupy broad canyon floors with large flood plains; poorly vegetated sites are acceptable. For nesting, Le Conte's Thrasher prefers thick, dense, and thorny shrubs or cholla cactus. Principal threats to the species may include habitat loss or degradation due to development (agricultural or urban), OHV traffic, fire, and pesticides. Shooting, collisions with cars, predation by feral predators (e.g., cats), and alteration of the preferred open habitat characterized by invasive plants such as Saharan mustard, may also impact populations.

Desert Tortoise

Desert tortoises range widely throughout the Sonoran and Mojave deserts, as well as deciduous forest, in northern Mexico and southwestern United States. Throughout their range, desert tortoises commonly concentrate in certain localities with large intervening areas of apparently suitable habitat containing relatively few, if any, individuals. Within alluvial fan communities in the Coachella Valley, desert tortoise burrows have been found in various microhabitats, including desert wash and upland areas. The Coachella Valley tortoise population in the Whitewater Hills/Mesa region at the west end of the valley is believed to be densest (J. Lovich, pers. com.); tortoises are otherwise rarely encountered and so presumed to be uncommon, but known to occur from upper alluvial fans up-slope to several thousand feet above the valley floor throughout the rest of the conserved lands. Primary threats to desert tortoise population viability may include predation, especially by ravens, habitat degradation due to OHV use, urbanization, overgrazing, road and utility corridor construction and invasive plants, such as Saharan mustard, that competitively exclude preferred native annual plant forage (Barrows et al. 2009). In addition, invasive species can facilitate fire, which can destroy native vegetation and disrupt natural processes that maintain optimal soil integrity (i.e., either soil compaction or erosion can be deleterious). Disease carried by feral pet tortoises may also threaten desert tortoise, although significant levels of disease have not been described locally.

Casey's June Beetle

There is very little known about this species and there are no published reports of their ecological needs or behavior. The following account is based entirely on unpublished observations by multiple observers. This species is currently known from a small distribution center on the Smoke Tree Ranch resort in south Palm Springs. All known records are within one mile of this location. The reasons for this restricted distribution are unknown as there are no suspected host plants or soil types similarly restricted. This beetle's life history in part explains their distribution; females emerge from underground burrows for only a few short weeks in spring (late March – early May) but never move more than a few centimeters from their burrow. Attracted by pheromones, males locate the females as soon as they emerge and immediately copulate with them. Once inseminated the females retreat underground once again to lay their eggs not to emerge again that year or perhaps not ever again; the females have not been seen flying and only rarely occur in collections. Emergence appears to be correlated with accumulated precipitation and the onset of warmer spring evening temperatures. This species is at risk from habitat loss and by habitat traps – the males are attracted to the polarized light reflected off swimming pools and once in the water usually die.

Native Plants

Little San Bernardino mountain linanthus (hereafter LSBM linanthus), Mecca aster (*Xylorhiza cognate*), and Orocopia sage (*Salvia greatae*) are the three native floral species associated with alluvial fans and protected under the CVMSHCP. The LSBM linanthus is a small annual plant that specializes on loose sandy soils characteristic of desert wash habitats. To germinate, the species requires sheet floods that inundate the soil with moisture but do not incise wash channels and erode the sandy topsoil. Since sandy desert washes also attract OHV traffic, LSBM linanthus may be especially vulnerable to OHV disturbance.

Mecca aster is restricted to the Mecca and eastern Indio hills and is mainly associated with specific soil types (Palm Springs and Canebrake formations; Stewart 1991). Mecca aster has been observed primarily along disturbed washes, trails and roads, although rigorous surveys have not been completed. If the species is associated with washes, trails and roads, population abundance may be lower than is indicated by available data. Orocopia sage occurs in rocky soils on alluvial fan terraces typically elevated above flood plain washes. Because of their affinity for relatively inaccessible habitats, this species may be the least threatened by OHV activity. Orocopia sage is highly drought tolerant. It is very patchily distributed but can be the dominant plant within patches it occupies. The species' limited geographic distribution (Orocopia and Chocolate mountains) provides reason for some conservation concern.

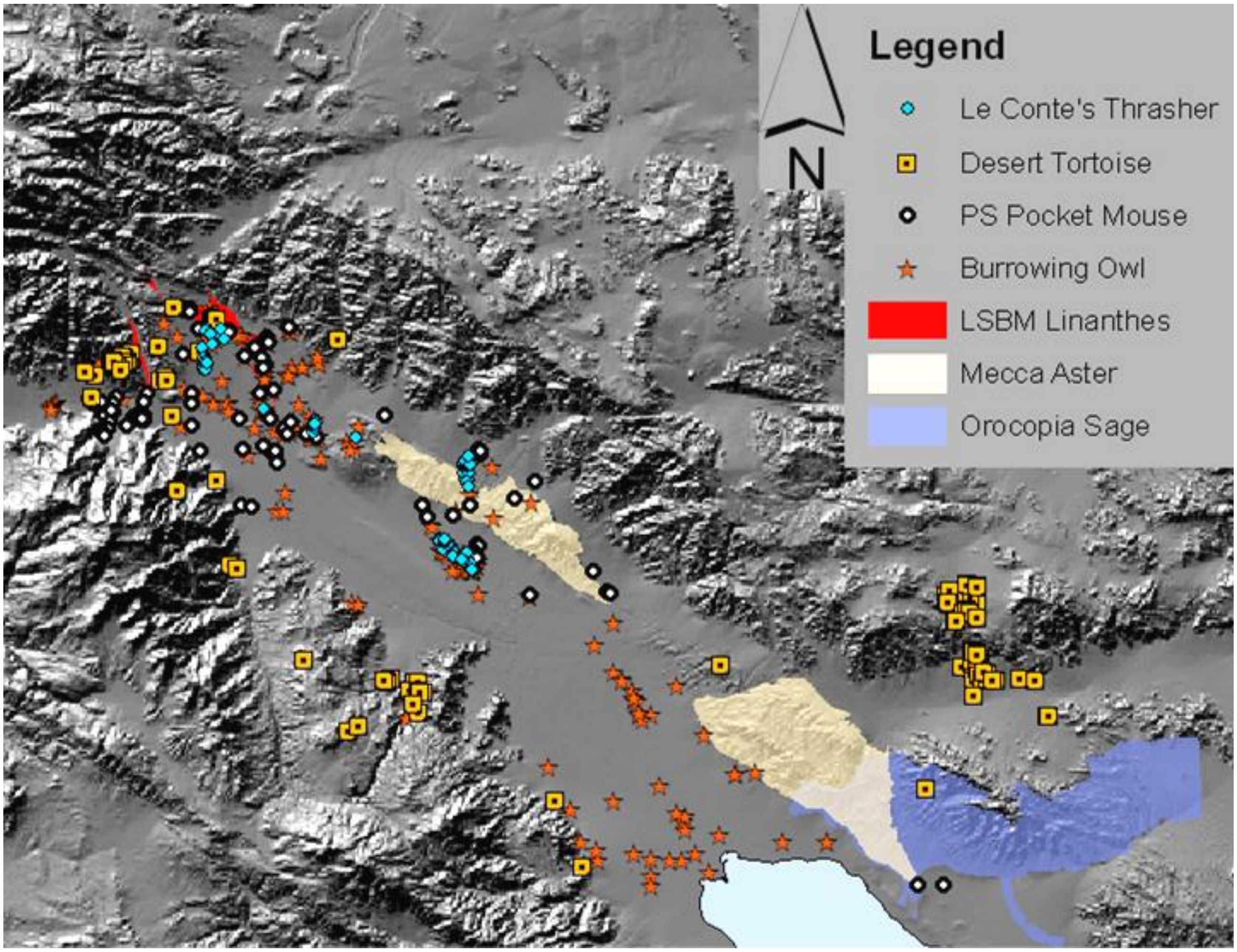

Figure 2. Current and historic records for the alluvial fan species covered under the CVMSHCP. The plant species are depicted as polygons encompassing all know locations whereas the vertebrates are shown as individual sight records. Casey's June beetle is not depicted as it occurs in only a very restricted area of south Palm Springs.

Little is known about the pollination and dispersal mechanisms for any of these native species. To the extent that arthropods pollinate these plants, threats to arthropod communities could threaten pollination processes and ultimately population viability. In addition, habitat fragmentation and edge effects could inhibit the biophysical processes (e.g., flooding) potentially required for dispersal.

CONCEPTUAL MODELS DESCRIBING POTENTIAL DRIVERS AND STRESSORS

Conceptual models provide valuable tools for clarifying hypotheses regarding how natural systems are formed and how they function. Specifically, conceptual models identify potential *population drivers*, environmental factors that promote or are required for population persistence, and *population stressors*, factors that erode or threaten population persistence. Thus, conceptual models facilitate identification of research questions to guide biological monitoring (Barrows et al. 2005). We created a conceptual model to identify research questions and develop a monitoring protocol for alluvial fan communities in the Coachella Valley (Figure 3).

Alluvial fan habitats are maintained by several natural processes (Figure 3). Periodic and rare violent channel entrenching and depositional flows reshape the fan’s topography and can remove patches of existing vegetation while creating areas for the establishment of new vegetation. This disturbance, while rare, can create zones of different aged vegetation in addition to creating a matrix of disturbance histories, therefore providing suitable habitat both for species with disturbance-tolerant as well as disturbance-avoiding life history strategies. On a broader landscape scale, soil moisture principally drives variation in plant community structure (i.e., Sonoran creosote bush scrub versus the Sonoran mixed woody and succulent scrub communities). Elevation gradients and their associated climatic heterogeneity maintain a large portion of the spatial and temporal variation in soil moisture. Intermittent flooding also contributes to spatial heterogeneity in soil quality via fluvial processes, as well as temporal variation in soil moisture. This process is important to annual plant species, such as the LCBM linanthus. Faunal population and community processes are less understood but may be driven by the aforementioned abiotic processes and the associated heterogeneity in plant community structure.

Human land use (agriculture and urbanization) and human-induced climate change (IPCC 2007, Kerr 2008) are the primary anthropogenic stressors of alluvial fan communities (Figure 3). Agriculture and urbanization result in habitat fragmentation, road development, disturbance from OHV use, flood control, refuse dumping, and the release of feral pets. These factors in turn potentially introduce or facilitate various threats such as reduced population connectivity (fragmentation), increased predation pressure (cats/dogs), disease (pet tortoises), exotic weeds (i.e., Sahara mustard), and wildfire.

Agriculture and urbanization may have a mixed effect on Burrowing Owls, given their unique ecology as ground nesters. Burrows may be destroyed by agricultural disking of fallow fields, OHVs, and other forms of physical disturbance, as well as introduced feral predators. Nevertheless, Burrowing Owls also may benefit from some physical disturbance caused by agricultural and urban development that attracts ground squirrels, which are important for the creation of suitable burrows for owls. In addition, Burrowing Owls are dietary generalists, capable of preying on several taxonomic groups including rodents and arthropods. Consequently, they can forage in a variety of habitats, including both natural and anthropogenically altered ones. Pellet analyses indicate Burrowing Owls in the Coachella Valley prey principally on pocket mice when they are available (Barrows et al. in press). Given the potential importance of pocket mice as prey, threats to pocket mice may also negatively impact Burrowing Owl populations.

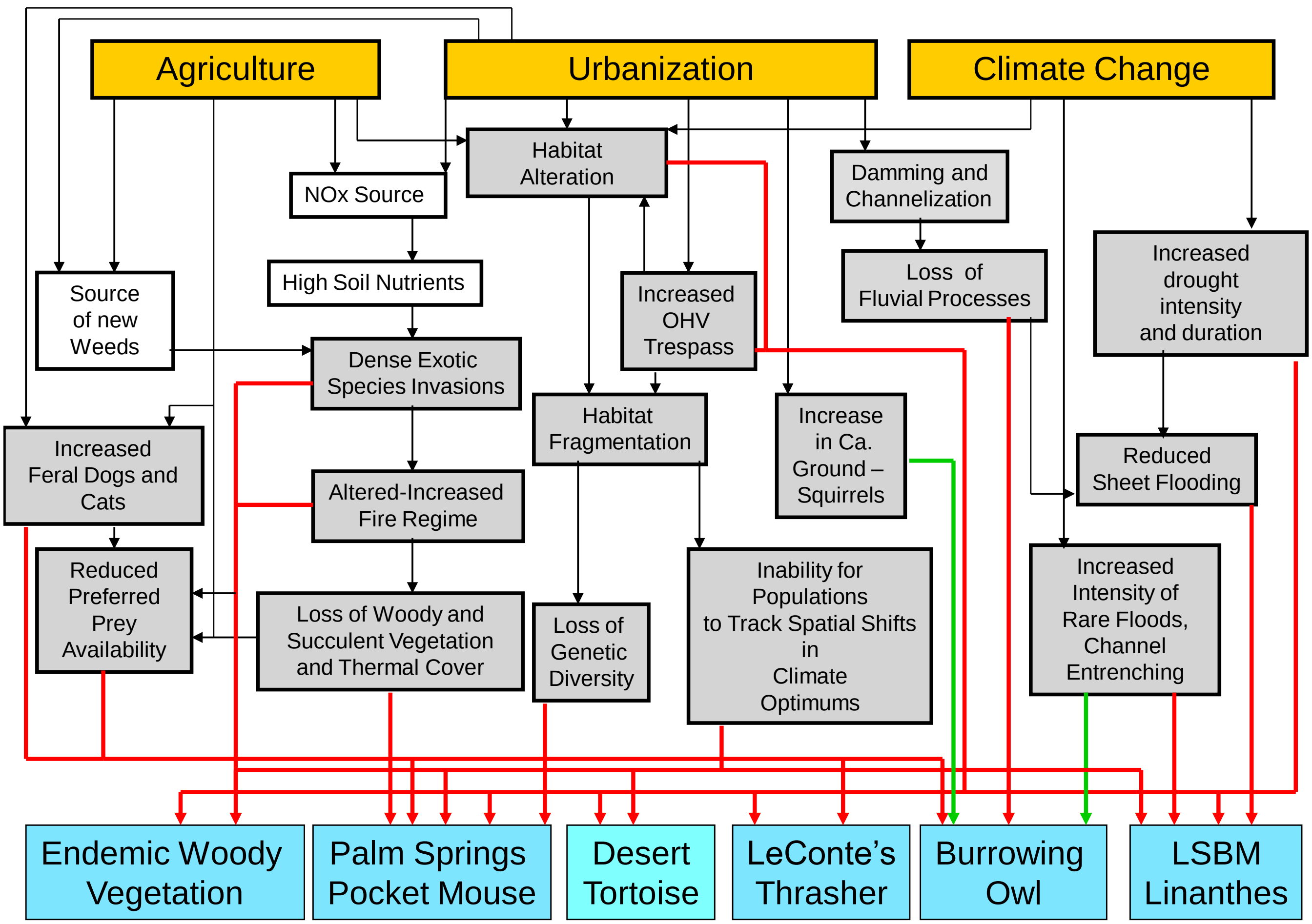

Figure 3. Conceptual framework depicting hypothesized stressors of alluvial fan floral and faunal species (blue-shaded boxes) and community dynamics in the Coachella Valley, CA. Gray-shaded elements are measured directly under this monitoring protocol. Red arrows lead from proximate stressors, those factors the directly impact population persistence; green arrows lead from proximate positive drivers; black arrows indicate suspected environmental relationships of unknown or non-linear directions. Yellow-shaded boxes indicate ultimate sources of stressors.

SHORT-TERM RESEARCH QUESTIONS IN ORDER OF PRIORITY

1. What are the consequences of invasions by exotic plant species? How do various environmental factors contribute to exotic invasiveness, and how do invasions affect native floral and faunal communities? Which exotic species, if any, represent the greatest threat to alluvial fan communities? Given a significant threat, which strategies would be most effective for controlling invasive species populations?
2. Urbanization increases the presence of feral predators or free-roaming pets (i.e., cats, dogs). Is there a "halo" surrounding urbanization zones where feral predators limit native fauna populations? Does urbanization increase the prevalence of released

pet/feral tortoises, and is this prevalence associated with reduced population persistence of desert tortoises (i.e., via increased disease transmission) in their natural range?

3. To what extent do agriculture, urbanization, and soil quality attract Burrowing Owls and facilitate their reproduction either by attracting ground squirrels and/or by creating areas that are locally free of vegetation?
4. What is the relative importance of pocket mice versus arthropods as prey for the breeding success of Burrowing Owls? Do pocket mice and/or arthropod abundances influence owl presence and/or persistence? If so, which anthropogenic and/or natural drivers or stressors (i.e., urbanization, agriculture, precipitation, and exotic species) could potentially affect Burrowing Owls by influencing their prey base?
5. How closely is OHV trespass onto conservation lands associated with urbanization and/roads? How does OHV traffic influence desert tortoise, burrowing owl, and native vegetation? Does the disturbance caused by OHVs facilitate invasion of exotic weeds? Is burrow destruction by OHV a common occurrence, and if so, does it significantly impact burrowing owl reproductive success?
6. Does refuse dumping impact the occurrence of targeted species, condition of natural communities, invasive species occurrence, and/or fire starts?

LONG-TERM RESEARCH QUESTIONS IN ORDER OF PRIORITY

7. How will climate change influence alluvial fan ecological processes? Specifically, how do the abiotic factors that are likely to change with climate (precipitation frequency, precipitation event intensity, fire frequency) and related biotic factors (exotic weeds) influence population dynamics, species' distributions, and community structure? How are distributions of native communities likely to change with a changing climate, and consequently, which species are most vulnerable to the effects of climate change? How is climate change likely to exacerbate or reduce exotic weed invasiveness, the consequent threat of wildfire (D'Antonio 2000), and impacts to the covered alluvial fan species?
8. Does habitat fragmentation associated with agriculture, urbanization, and/or roads restrict population persistence and/or distributions of dispersal-limited species (desert tortoise, Palm Spring's pocket mouse, LSBM linanthus)?
9. How does flood frequency influence floral and faunal community structure? Does flood control associated with agricultural and urban development inhibit the flooding regimes necessary to sustain natural populations and communities?
10. What are the habitat constraints to the Casey's June beetle distribution? Is the current distribution sufficient to provide a persistent population? Could translocation be used to increase its current known distribution?

Surveys will be designed so that data collected can contribute to these larger research questions. The questions are not designed to identify threshold values for demographic parameters, beyond which management action would be indicated. Rather, they are designed to assess the risks that given stressors pose to the goal of the CVMSHCP/NCCP of protecting sustainable populations and communities. If a high risk stressor is having a negative impact and if that impact may have long-term consequences, then remedial management should be considered and if practical employed as soon as possible.

MONITORING METRICS

Anthropogenic Landscape Alteration and Associated Stressors

- Via satellite imagery
  - The extent of urban and agriculture land cover types
  - The degree of habitat fragmentation
  - Road density
- Species distributions with respect to conservation area edges
- Occurrence of predators (feral/pet and natural)
- Occurrence of off-road vehicle (OHV) trespass
- Possible analysis of genetic heterogeneity for Palm Springs pocket mouse

Environmental Factors

- Temperature and precipitation from weather stations
- Flood events/ history from satellite imagery
- Soil moisture from weather stations
- Ground water depth via ground penetrating radar and Coachella Valley Water District records (well depth measurements).

Natural Landscape Features

- Topography (elevation, slope, ruggedness, etc.) from GIS layers
- Soil types
- The extent of plant community types (creosote scrub vs. mixed woody succulent).

Biological Monitoring

- Causes and consequences of invasive species
  - Measure the occurrence (density and percentage cover) of invasive exotic and native annual plants and landscape-scale occurrence and abundance patterns for native and exotic species.
  - Identify factors (e.g. sand quality and quantity; rainfall) that favor invasive species versus natives.
  - Measure whether invasive species versus natives differentially affect soil stability and/or fluvial transport.
  - Test effectiveness of invasive species control efforts.
- Occurrence and changes in relative abundance of covered species.
- Occurrence and/or relative abundance of potential competitors and predators of covered species.

MONITORING METHODOLOGIES

Landscape-Scale, Environmental Features

For GIS-based analyses, data describing landscape-scale environmental features will be derived from existing GIS layers, and calculations from algorithms that convert Digital Elevation Models (DEMs) to topographic metrics, or from PRISM (average annual precipitation; (http://prism.oregonstate.edu/docs/meta/ppt_30s_meta.htm, PRISM Group, Oregon State University). Additional data sources include GAP (http://gapanalysis.nbii.gov) or LANDFIRE (http://www.landfire.gov/) for land cover data, Landsat (e.g., National Land Cover Database) sources for historic data, and SSURGO (http://soils.usda.gov/survey/geography/ssurgo) for soils data. These data should be updated at least once every five years to ensure continual accuracy. For analyses of temporal dynamics, accurate weather data will be derived from an array of deployed weather stations.

Selection of Survey Sites

Several sets of sites will be selected for surveying various covered species. Following descriptions of species-specific survey methods we will identify the number of sites where surveys will be conducted. We selected site sampling frequencies capable of providing reasonably robust sample sizes but not overly taxing on monitoring resources given the anticipated logistic demands associated with specific survey methods. We did not employ rigorous quantitative methods (e.g., power analyses) to select site frequencies because such methods require pilot data and/or highly refined *a priori* hypotheses (see Data Analysis section), which we do not currently possess. We anticipate adjusting site frequencies after gathering and analyzing initial datasets following the first five years of monitoring, particularly in so far as initial analyses yield refined research hypotheses that can accommodate quantitative analyses of sample size needs.

In addition to sampling frequencies, we will identify environmental attributes to be used as references when selecting sites. This will put demographic data within the context of the occurrences of potential stressors, providing insight regarding the risks those stressors present with respect to meeting conservation objectives. To allow analyses of population demographic relationships with environmental variables of interest (see Data Analysis section), sites for collecting demographic data will be stratified as much as possible across levels of hypothesized environmental stressors (Figures 3, 4). Generally, sites should be stratified across habitat patches (identified from satellite imagery) varying in (1) size, (2) levels of connectivity with neighboring patches, (3) elevation, (4) climate (i.e., along an east-west gradient), (5) soil structure, (6) geomorphology (e.g., the degree of channelization of nearby desert washes for SBM linanthus), (7) habitat type (e.g., desert wash or upland, and creosote scrub versus mixed-woody scrub), and (8) road density within a one kilometer radius neighborhood. Independent stratification of sites across closely correlated environmental features (e.g., possibly climate and habitat type) may not be possible. Where initial monitoring reveals demographic relationships with correlated features, subsequent research can focus on identifying which features drive demographic variation (e.g., using more intensive sampling or experimental manipulations), if such information is deemed necessary. To minimize the need for ground-truthing during the site selection process, we will mainly use landscape-scale environmental attributes measurable via satellite imagery or remote sensing (i.e., for which data are available as GIS layers) to guide site selection. In addition to these landscape-scale metrics, however, local-scale environmental attributes (i.e., those potentially serving as proximate drivers of demographic heterogeneity) will be measured at survey sites along with species surveys.

Palm Springs Pocket Mice and SBM Linanthus Surveys

A set of sites will be established to survey Palm Springs pocket mice, SBM linanthus, and suspected proximate factors influencing their population ecology. We recommend initial establishment of 40 sites for the first five years of monitoring. This number will be adjusted after initial data enable power analyses for appropriate levels of change detection, and as influences of potential stressors are clarified. These sites will be stratified across environmental features identified in the previous section.

During the first five years of monitoring, three survey methods will be used to study pocket mouse demography: 1) live trapping, 2) track plating, and 3) examination of burrowing owl pellets. During the first year of monitoring, all three methods for surveying pocket mice will be employed at all 40 sites. The initial year of data will be analyzed to evaluate the relative utility of each method. We expect live trapping to be especially reliable for documenting both presence/absence of pocket mice (detection rates approached 100% for Barrows et al., in press) and other demographic parameters (e.g., relative abundance, age and sex distributions). By contrast, track plates would only measure presence/absence, and Burrowing Owl pellet analysis would strictly establish species presence with minimal demands on surveyor time and effort. Track plate and trapping data from the initial year will be used to calculate method-specific detection probabilities (allowing for spatial and temporal heterogeneity in detection; see Data Analyses section) to evaluate their relative efficacy. Track plates will also provide evidence of potential predator occurrences. At the discretion of biologists overseeing monitoring, various types of track plates (e.g., baited versus non-baited, enclosed versus unenclosed; Zielinski and Kucera 1995) may be tested in the first year to identify the specific techniques that produce the best data for the least cost. In addition, pellet data will be compared to data from the other two survey methods to verify the reliability of pellet analysis. If track plates and pellet analysis prove reliable for collecting distributional data, live-trapping may be restricted to a small number of focal sites each year depending upon funding availability and the relative need to inform management for pocket mouse. Allocation of pocket mouse survey efforts should account for the biological questions of most immediate interest, bearing in mind short- and long-term research questions. For instance, the initial five years of monitoring could emphasize the use of track plates and pellet analysis to relate the extent and relative stability of pocket mouse distributions with environmental factors of immediate interest (e.g., invasive species and habitat edges). Subsequently, monitoring efforts may switch to favor live trapping in key sites to elucidate the demographic mechanisms that underlie apparent distributional dynamics (e.g., fragmentation effects on genetic diversity).

Live trapping pocket mice will require that biologists obtain a Scientific Collecting Permit from the California Department of Fish and Game, and if working directly or indirectly with the University of California an Animal Use Permit (AUP) will also be required. Sherman live traps (9 cm x 7.5 cm x 23 cm; aluminum) will be used to capture pocket mice. Following methods described by Barrows et al. (In Press), traps will be deployed in four clusters of 20 traps each with clusters spaced ≥ 250 m apart and centered on each survey site (for a total of 80 traps per site). Within each cluster, the 20 Sherman traps will be laid in a grid composed of 4 lines ~15m apart with 5 traps each spaced 5 m apart (Chew and Butterworth 1964). Trapping will be conducted at each site on three consecutive nights from May–June. If permits allow it, surveyors will record the age, sex, and breeding condition of captured individuals, and they will mark the ears of captured individuals with a Sharpie ink pen to identify them as recaptures when caught on subsequent nights. Surveyors may also collect blood samples from captured individuals to allow analysis of genetic diversity and isolation (i.e., a long-term research goal). Since fitness should decrease with inbreeding depression, however, we only recommend analyzing genetic diversity to help explain unexpectedly negative population growth with no other apparent explanation.

Track plates will consist of aluminum sheets coated with black soot from an acetylene torch (Zielinski and Kucera 1995). Because soot adheres to any object contacting the sheet, animals walking across these sheets will leave their footprints, which can be used to identify them. Track plates will be deployed for three consecutive weeks also from May–June and checked at least once a week for Palm Springs pocket mouse tracks. Track plates will be distributed across the same spatial extent as trap clusters (three plates per track cluster; Fig. 4). Finally, surveyors will collect all Burrowing Owl pellets found in conjunction with efforts to monitor that species. Previous work has established that Burrowing Owls usually prey on pocket mice where they are available (Barrows et al. In Press), so pellet analysis will provide additional data for establishing Palm Springs pocket mouse presence wherever Burrowing Owls occur.

SBM linanthus will be surveyed within six 10×100-m plots centered on each site and spatially coinciding with trap and track plate arrays for pocket mouse surveys. Surveyors will walk the length of each plot twice each monitoring year from March–April (at least two weeks apart) and record the maximum height, length (along longest axis), and width (perpendicular to the length) of each stand of SBM linanthus occurring within the plot.

In addition to surveying the two covered species of interest, surveyors will collect additional data describing local-scale biotic and abiotic environmental attributes.

1. Surveyors will record all mammalian species caught in live-traps, recorded by track plates, and found in burrowing owl pellets.
2. Surveyors will record the heights of all individual shrubs occurring within SBM linanthus plots.
3. Surveyors will count the number of individuals of all herbaceous species (including non-native invasive species) within 16 1-m × 1-m quadrats per site (four quadrats per

trap cluster; Fig. 4). Surveys of the herbaceous layer will be conducted concurrently with SBM linanthus surveys.

4. Surveyors will record any avian species, especially potential predators such as raptors, observed during any of these surveys.
5. During any survey, surveyors will record any sign of OHV activity (e.g., tracks) or other potential conservation hazards (e.g., illegal dumping).
6. Surveyors will record the distance (using a range-finder) and direction (compass bearing) to the nearest wash (if within sight) and the structure of that wash. Structural elements to be measured will include:
    a. wash depth from the deepest visible point to the adjacent upland
    b. the mean slope of the wash's edge for at least 5 measurements taken on each side of the wash
    c. the mean width of the wash for at least five measurements (measured with a range-finder)
7. Finally, a weather station will be installed at the center-point of each site to record daily temperature, precipitation, relative humidity, and other key meteorological attributes.

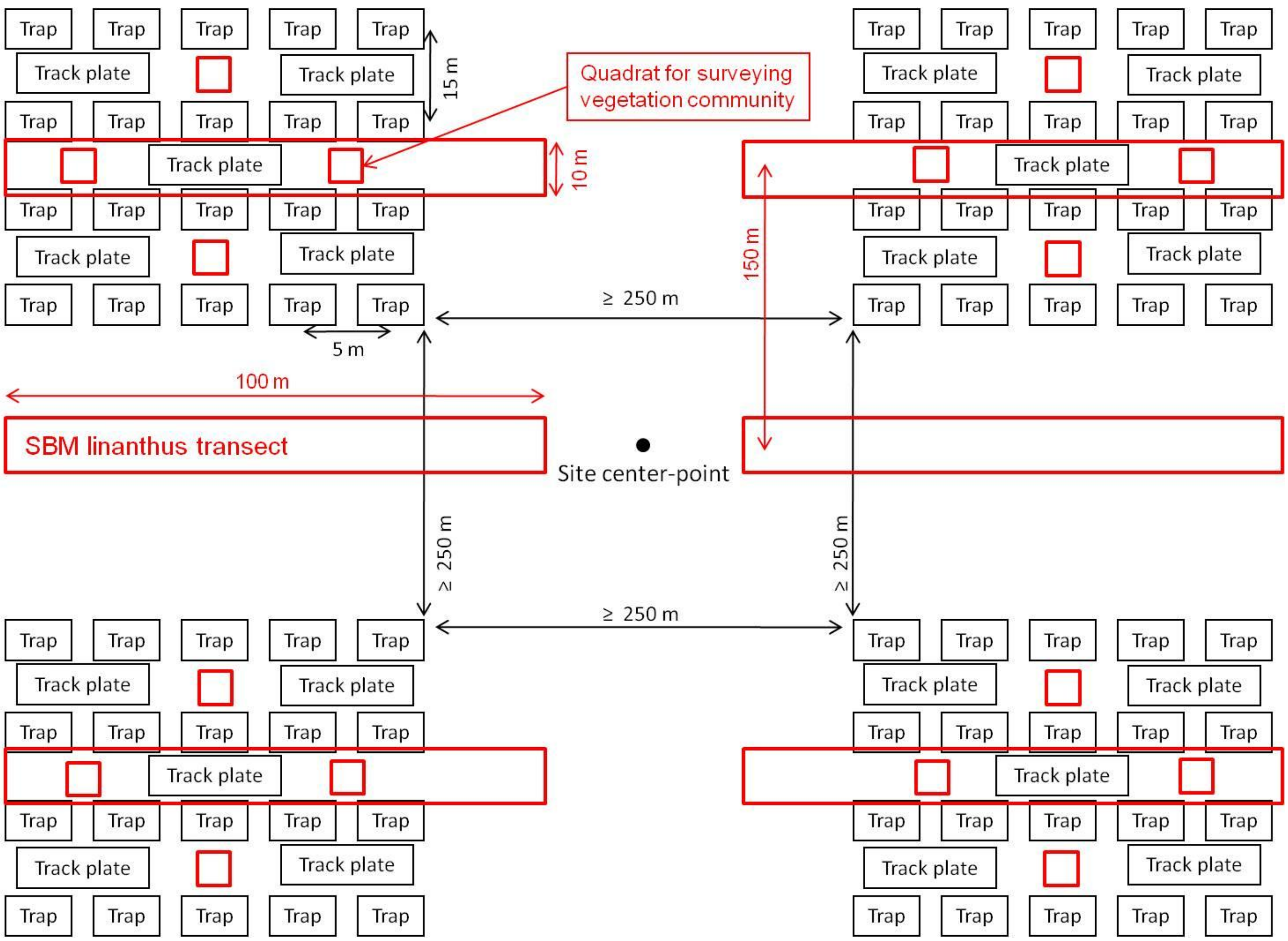

Figure 4. Schematic for deployment of Sherman live-traps and track plates at a hypothetical site for surveying Palm Springs pocket mice (figure not to scale). Transects for surveying SBM linanthus and perennial shrubs and quadrats for surveying the annual plant community are depicted in red.

Perennial Native Plant Species (Orocopia Sage and Mecca Aster)

Forty sites will be established for initial monitoring of both CVMSHCP-covered perennial plant species associated with alluvial fan habitats: Orocopia sage and Mecca aster. Sites will be located within the known range for these species described in the CVMSHCP (CVAG 2007). As much as possible, sites will be stratified across levels of environmental features identified in Selection of Survey Sites. In so far as species' ranges overlap, individual sites can be surveyed for both species to minimize time and financial costs, but the suite of sites surveyed should be representative of the full range of habitat thought to be suitable for each species.

At each site, four 10×100-m plots will be established, spaced ≥ 250 m apart, and centered on the site's center-point. Surveys will consist of walking the length of each plot and recording the height and species of every individual shrub (including Orocopia sage) and Mecca aster occurring within the plot's boundary. Local-scale environmental features also measured at each site will include:

1. Any sign of OHV activity (e.g., tracks) or other potential conservation hazards (e.g., illegal dumping).
2. The distance (using a range-finder) and direction (compass bearing) to the nearest wash (if within sight) and the structure of that wash (attain from satellite imagery if not within sight of site). Structural elements to be measured will include
    a. Wash depth from the deepest visible point to the adjacent upland
    b. The average slope of the wash's edge across at least 5 measurements taken on each side of the wash
    c. The average width of the wash across at least five measurements (with a range-finder)

The forty sites selected initially will be surveyed during the first year. The resulting data will be analyzed to explore hypothesized environmental relationships with perennial plant occurrence and abundance. Based on the results of these initial analyses, hypotheses regarding population stressors and drivers may be revised and the location of sites for subsequent surveys may be adjusted to test new hypotheses as needed. Given their long lifespan, these species need only be surveyed once every five years unless potential conservation threats become acute and/or the need for additional demographic information becomes more immediate.

Le Conte's Thrasher
Surveys for Le Conte's Thrashers will be conducted at sites distributed throughout the species' CVMSHCP range, and during appropriate time periods using appropriate methods identified from surveys and analyses conducted by UCR-CCB staff in 2004 – 2006. Potential Le Conte's Thrasher habitat occurs south of Joshua Tree National Park, north of Palm Springs, and northwest of the Salton Sea. The prior UCR-CCB surveys were conducted at 20+ transects within suitable habitat identified by a GIS-based, species-specific niche model (based on known historic locations [Sheppard 1973] and used in developing the CVMSHCP). To monitor thrashers, surveys will mainly be conducted along these transects, although some alternative transects may be necessary to ensure survey transects adequately stratify environmental factors of interest (i.e., those identified in Selection of Survey Sites). November–January (pre-nesting) and May–July (post-nesting) are the most effective and least intrusive periods for conducting thrasher surveys. To document territory establishment and breeding attempts, audio-playback surveys will be conducted from November – January. Given adequate funding, surveys may be conducted again from May – July to ascertain breeding success, a key demographic parameter that could elucidate how environmental factors affect demography. Given limited funds, however, early-season surveys conducted once a year should provide the minimal baseline data for following population dynamics. If the need for more detailed demographic data and adequate funding arise, more intensive survey protocols may also be considered (Blackman et al. 2009).

Following the UCR-CCB developed survey recommendations, audio playback surveys will be conducted at three points spaced evenly along 1 km transects centered on each survey site. At each point, a 90-second song recording of a male Le Conte's Thrasher recorded from within the Coachella Valley will be broadcast in opposite directions perpendicular to the transect for a total of three minutes. After each three minute broadcast, a four minute detection period will ensue when researchers will scan with binoculars and listen for a vocal response. If no response is detected, then the three minute broadcast and four minute detection period will be repeated up to two more times at increasing playback volumes in order to extend the projection distance without overwhelming nearby birds. If a Le Conte's Thrasher is detected at any time during the broadcast or detection periods, playbacks will cease, data will be recorded, and surveyors will proceed to the next point. If, during data collection, any breeding behaviors, such as courtship feeding, carrying nesting material or carrying food are observed, then the survey will be either terminated or postponed to a date when nesting is expected to be completed. Surveying will not be conducted when winds consistently exceed a 20 km/hr maximum or 15 km/hr average. Data collected for each thrasher survey will include the number of birds detected, as well as potential covariates of detection rates: time of day, volume of playback, distance to each detected individual, type (call or song) and duration of vocalizations.

Knowledge of the Le Conte's Thrasher distribution within the Coachella Valley gained from baseline monitoring (first five years) could be used to further refine future monitoring. Sites at which thrashers are never detected during baseline monitoring and which occur outside the model-predicted species' range could be excluded from future surveys or surveyed less frequently (e.g., once in three years). Such adjustments could allow surveys of alternative sites where thrashers are predicted to occur, or surveys of sites useful for testing ecological hypotheses generated from baseline monitoring or that remain untested. In so far as sites for monitoring other species (i.e., Burrowing Owl) occur within suspected Le Conte's Thrasher habitat, those sites can also be used to survey thrashers so as to minimize demands on surveyor effort.

Desert Tortoise

We will rely primarily on an ongoing research program conducted by the USGS (Meyer and Lovich 2004) to monitor the Coachella Valley desert tortoise population. The USGS program employs mark-recapture methods, radio-telemetry, and nest monitoring to measure both survivorship and fecundity for desert tortoises in the Whitewater Hills. USGS biologists have agreed to make their data available to us for analysis of population dynamics. Since desert tortoises are rare everywhere else in the Coachella Valley, we will conduct no additional monitoring activities focused on this species. Nevertheless, we will record desert tortoises located while surveying other species. Any such locations will be combined with USGS data and environmental data (e.g., topography, climate, and habitat values) to analyze tortoise demography. To evaluate potential drivers and stressors for desert tortoise (Fig. 2), we will initially focus on refining niche models based on environmental data (collected mainly via remote sensing or calculated from spatial models; i.e., GIS layers; CVAG 2007) and analyzing longitudinal data describing demographic parameters (i.e., survivorship and fecundity).

Depending upon the information gained from these initial analyses, we will consider more focused studies, perhaps involving local-scale environmental measurements or field experiments, aimed at testing specific hypotheses. Such studies would be conducted in collaboration with USGS biologists.

Casey's June beetle
Initial surveys should focus on presence-absence determination at all known locations. Presence is readily determined using black light traps at dusk and for 2-3 hours following dusk. Black light traps consist of a mobile black light (battery operated) set at the base of a white sheet facing the presumed habitat areas. Male beetles usually fly ≤ 1-m of the ground. Usually one trap/sight is sufficient to detect presence. A biologist needs to monitor the trap continuously to detect incoming beetles. Once a beetle is detected (presence confirmed) the trap can be removed. Each site should be surveyed up to 3 nights or until presence is confirmed each year. Onset of trapping should occur as evening temperatures in spring begin to warm, or if activity is confirmed at Smoke Tree Ranch – usually in mid April.

More intensive trapping and mark-recapture can be employed to answer more detailed questions about population size, distance flown by males, and longevity. Tracking flying males to females is difficult, but the only way to locate females with any reliability. Females will need to be captured if translocation is to be experimentally attempted.

Burrowing Owl
A detailed survey protocol for monitoring Coachella Valley Burrowing Owl populations was developed following a pilot study conducted in 2009 (Rotenberry et al. 2010a). This protocol will form the basis for monitoring Burrowing Owl populations under the CVMSHCP. Burrowing Owl monitoring will rely mainly on roadside surveys. Following results from analysis of method-specific detection probabilities (Rotenberry et al. 2010b), surveys incorporating call-broadcasts (i.e., audio point counts) will be conducted along roadside routes early in the breeding season (April) and visual, driving surveys (i.e., linear surveys) will be conducted late in the breeding season (late July–August). Roadside routes identified prior to and following the 2009 pilot study are distributed widely throughout the Coachella Valley and sample a substantial portion of lands conserved under the CVMSHCP, including those occupied by alluvial fan communities (Fig. 5). Nevertheless, roadside surveys are inherently biased towards roads, so comparable monitoring should incorporate some surveys of roadless areas to supplement roadside survey data. Such data are being collected via track censuses in conjunction with the aeolian sand community monitoring program (Fig. 4; CCB In Review), but track surveys are not appropriate for monitoring communities in alluvial fan habitats since those soils do not reliably record tracks. Instead, we will survey wildland areas (> 400 m roads; i.e., outside the detection range of roadside surveys) within alluvial fan habitats using call-broadcast and visual surveys similar to those employed along roadside routes. Paralleling roadside surveys, stationary, call-broadcast surveys will be conducted from points spaced ~800 m apart (audio point counts) along routes in wildland habitats on foot in April and walking surveys along the same routes in late July–August. To accommodate survey completion within

a day, wildland routes shall be no longer than 5 miles and potentially shorter in particularly rugged and/or inaccessible areas. Finally, active burrows located during early-season surveys will be monitored to allow estimation of reproductive success and identify factors that influence reproduction.

Each year, we will survey two sets of roadside and wildland routes for two distinct purposes: (1) to track population change through time, we will survey a set of routes that remain the same from year to year, and (2) to discover new owls in new locations, we will survey routes not surveyed in the previous year. Both sets will include routes where owls have been observed or that incorporate high quality habitat (based on a previous analysis of habitat relationships; Rotenberry et al. 2010b), as well as routes where owls have not previously been observed or are in low quality habitat (route selection scheme described further in Rotenberry et al. 2010a). Given the low density of owls occurring in wildland habitats (especially east of Desert Hot Springs), the gain in additional burrowing owl sightings with only random sampling of roadless areas is expected to be very small. Therefore, we suggest that all persons conducting property evaluations (e.g., hazardous materials searches), patrolling conservation lands, undertaking management activities such as fence building, sign placement, exotic weed removal, or any natural resource surveys/inventories within the CVMSHCP area be instructed to collect GPS locations for any Burrowing Owls or possible owl activity they encounter. Those locations would then be confirmed by surveyors responsible for monitoring Burrowing Owls. Wildland routes could then target both locations where owl occupancy has been confirmed and, for comparison, a comparable number of routes located randomly in wildland habitats. Routes established for Le Conte's Thrasher surveys could be surveyed for burrowing owls if doing so would improve the efficiency of planning and/or conducting surveys.

Routes should be carefully selected in order to sample those areas that identify important drivers and stressors of Burrowing Owl populations. To maximize power to detect environmental effects on population dynamics, routes should be stratified among levels of environmental attributes thought to influence Burrowing Owl ecology. From our current understanding of Burrowing Owl ecology (Fig. 2) and results from preliminary analyses of habitat relationships (Rotenberry et al. 2010b), potential drivers and/or stressors include land cover (amount of agricultural, urban development, and road density), OHV traffic, presence of Sahara mustard, and presence of disturbed soil and/or burrowing mammals. Given the time and resources available for surveys, stratification of routes across all these factors would be infeasible, so surveys may be stratified across a subset of these factors of most immediate interest (i.e., those appearing in research questions 1 – 6). Once we have documented the effects of factors of primary interest on population dynamics, routes selected in subsequent years can target factors of secondary interest. From a data analysis perspective, comparable numbers of roadside and wildland surveys should be conducted each year. Since wildland surveys will be relatively labor intensive, however, a relatively small portion of routes surveyed in any given year will be located in wildland areas, so careful selection of wildland routes will be critical.

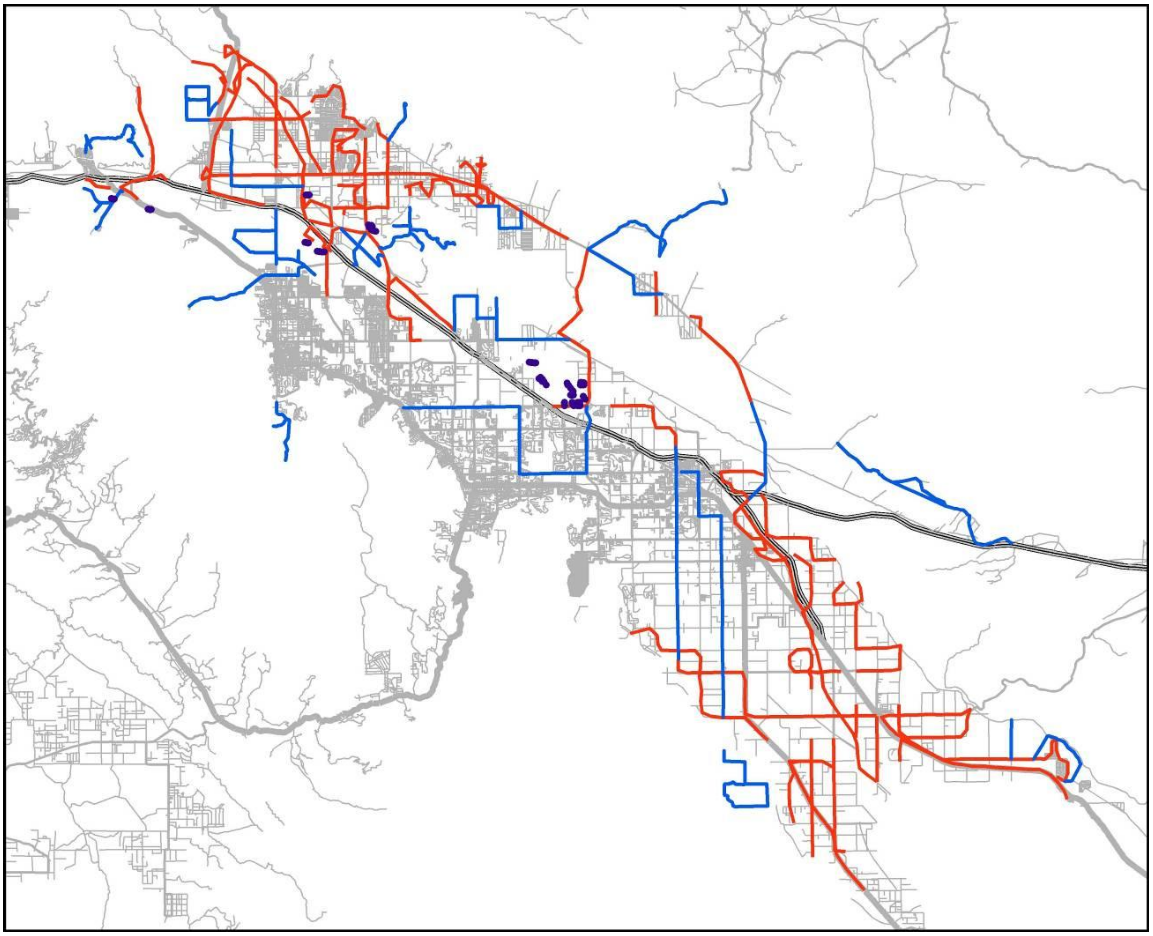

Figure 5. The distribution of linear routes surveyed in 2009 (red lines), alternative routes for future surveys (blue lines), and wildland plots (purple circles).

DATA ANALYSES

In general, analysis objectives of biological monitoring should be to 1) identify whether subject population dynamics are headed towards extinction, and 2) what factors (e.g., environmental change, anthropogenic disturbance) are driving observed dynamics. Typically, analyses of population monitoring data focus on the first of these objectives, i.e., detection of population trends or quantification of extinction risk via population viability analysis. The latter is the more rigorous of the two approaches but requires information that is difficult to acquire and therefore often unavailable (i.e., precise estimates of survivorship and fecundity). Furthermore, such analyses do not test hypotheses regarding suspected population drivers and stressors (objective 2), the likely foci of management action (Barrows et al. 2005, Barrows and Allen 2007). We instead focus our analyses, on testing how suspected population drivers and stressors (Fig. 2) actually relate with demographic parameters.

We will explore environmental relationships with population heterogeneity and dynamics within a comprehensive modeling framework. Newly developed analytic techniques allow explicit and simultaneous analysis of species presence/absence (MacKenzie et al. 2006) and/or relative abundance (Royle and Dorazio 2008) as a function of environmental covariates. These techniques allow explicit analysis of how specific environmental factors relate with spatial demographic heterogeneity, temporal heterogeneity, or both. These techniques are based on generalized linear models (GLMs), such that demographic parameters (Y) are modeled as a linear function of environmental variables (X; i.e., $f(\mathrm{Y}) = f(\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots)$, where α and β_i are parameters describing the shape of environmental relationships with demography). GLMs may be constrained by various assumptions that ecological data do not always meet (e.g., regarding the shape of the distribution of residuals, or independence of observations). Nevertheless, various extensions of GLMs are available that relax many of these assumptions (e.g., mixed models and models that account for spatial or temporal autocorrelation; Bolker 2008, Zuur et al. 2009). Niche models also allow exploration of environmental constraints on species distributions with less restrictive data requirements than GLMs (i.e., presence-only data may be analyzed; Elith et al. 2006, Rotenberry et al. 2006). Although we have some idea of the types of questions to which statistical models are suited, we would ideally select a model following initial exploratory analysis of the focal data (Zuur et al. 2010). Regardless of the specific model structure ultimately selected, however, models will be designed to identify environmental relationships with covered species demography or with previously confirmed population drivers and stressors.

During and immediately following the first five years of monitoring, data analyses should focus on the research questions of most immediate interest (i.e., research questions 1 – 6). Thus, once substantive data are available, researchers should develop models that explore demographic relationships with invasive species demography, proximity to urban and agricultural development, OHV activity, suspected prey species (e.g., pocket mouse for burrowing owl), and other suspected habitat requisites (e.g., proximity to flood zones for SBM linanthus). Following these initial analyses, subsequent monitoring activities and data analytic efforts should focus on questions that remain unanswered. These questions may include primary questions (1 – 6) that initially collected datasets were too sparse to address, in which case quantitative assessments of sample size needs may be necessary (see below) to guide further monitoring. Having confirmed statistically robust environmental relationships with demography, further monitoring efforts should follow up with research necessary to effectively inform management. Relevant topics may include identification of the mechanisms underlying observed environmental relationships (e.g., do feral predators underlie observed edge effects) and/or testing the relative efficacy of potential management activities (e.g., does spraying herbicides effectively control invasive plants). Finally, once questions of immediate interest have been addressed so as to effectively guide management, monitoring can focus on longer-term research questions (7 – 9), for which additional analytic techniques will likely be required. Specifically, predictive distributional models developed from initial analyses may be used to project likely population responses to climate change or changes in flood regimes. Analyses of genetic heterogeneity could be used measure the effects of habitat fragmentation on populations. Finally, an experimental approach could be employed to clarify mechanisms underlying observed environmental relationships with demography and to test possible management options through an adaptive management process.

When designing a study, researchers should consider whether planned sampling procedures will generate enough data to address the research questions at hand. Ideally, a power analyses would be applied to calculate the necessary sample sizes to test hypotheses of interest (Hayek and Buzas 1997). Such an analysis would require the researcher to have in mind a particular effect size that he/she is interested in documenting. As is often the case in ecological studies, however, precise hypotheses and predictions are not currently developed with the population monitoring proposed here. We therefore bear in mind a general rule-of-thumb for multivariate analyses of keeping the ratio between the number of independent variables and the number of observations ≤ 1:10 for selection of initial site frequencies. This rule-of-thumb mainly addresses the potential risk of over-fitting a model to the data (i.e., yielding a non-general model; Osborne and Costello 2004), rather than issues of statistical power. Nevertheless, this rule does provide a useful lower bound for sample size. Thus, survey sites should not be stratified across environmental factors ≥ 1/10 the total number of sites being surveyed. Furthermore, since we have not conducted *a priori* power analyses, we will consider lack of statistical power a potential explanation for any non-significant results arising from initial data analyses. If statistically marginal but potentially biologically meaningful relationships are apparent, subsequent investigation can incorporate additional plots or alternative sampling protocols to address questions of interest as needed. Power analyses based on preliminary data may be used to inform the design of subsequent monitoring or focused studies designed to supplement monitoring data. Simulation techniques provide a flexible approach for analyzing statistical power associated with various statistical analyses (Bolker 2008).

Finally, we note that estimation of detection rates can be incorporated into demographic models given repeated sampling of survey sites (MacKenzie et al. 2006, Royle and Dorazio 2008). Detectability estimates can facilitate both evaluation of survey methods and calculation of accurate and biologically meaningful estimates of demographic parameters. In many cases, we have incorporated repeat sampling (e.g., multiple methods for surveying pocket mice or repeat, within-season surveys of thrashers) to accommodate detectability estimation. We recommend implementing repeated sampling as long as necessary to derive robust estimates of detectability that account for potential sources of heterogeneity (e.g., different observers or timing within the season). Once detectability estimates have been attained for specific survey methods, sampling may be scaled back to minimize the financial cost of monitoring. Subsequent analysis of demographic trends should incorporate detectability estimates as long as data are collected using methods associated with imperfect detection of the target species.

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