Coachella Valley Conservation Commission

March 8, 2012

Coachella Valley Multiple Species Habitat Conservation Plan and
Natural Community Conservation Plan

Aeolian Sand Communities and Species Monitoring Protocols

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

Coachella Valley Multiple Species Habitat Conservation & Natural Community Conservation Plan

Aeolian Sand Communities and Species Monitoring Protocols

Natural Communities
Active Sand Dunes
Ephemeral Sand Fields
Stabilized Sand Fields
Stabilized Sand Dunes (Mesquite Hummocks)

Listed Species
Coachella Valley Fringe-Toed Lizard (*Uma inornata*)
Flat-Tailed Horned Lizard (*Phrynosoma mcallii*)
Giant Sand-Trader Cricket (*Macrobaenetes valgum*)
Coachella Valley Milkvetch (*Astragalus lentiginosus* var *coachellae*)
Round-Tailed Ground Squirrel (*Spermophilus tereticaudus*)
Coachella Valley Jerusalem Cricket (*Stenopelmatus cahuilaensis*)

These Protocols are subject to future revision as deemed necessary by the CVMSHCP's adaptive management process – this version was last updated on March 8, 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).

AEOLIAN SAND COMMUNITIES DESCRIPTIONS

The naturally occurring aeolian sand communities of the Coachella Valley floor include active dunes, stabilized dunes (also referred to as mesquite hummocks), ephemeral sand fields, and stabilized sand fields. These communities were initially defined based on distinct geomorphologies (Table 1), but also have distinct species associations and abundances (Barrows and Allen 2007a, Barrows and Allen 2010). Those communities that have undergone the greatest amount of loss due to human development include the active sand dunes and stabilized sand fields which would have occupied much of the central portion of the valley floor. As much as 83%-95% of these communities have been lost (Barrows et al. 2008). Another community which has lost much of its original extent is the stabilized dune, or mesquite hummock community type. Most of that loss occurred in the eastern portions of the valley in what are now the cities of La Quinta, Indio and Coachella. Ephemeral sand fields have been least impacted by human development, likely due to the high intensity wind and sand movement characterizing this community, making it less hospitable to human uses. The general locations where these communities still occur are shown in Figure 1.

Conceptual models can provide valuable tools in clarifying hypotheses as to how natural systems are formed, function, and how stressors may impact those systems (Barrows et al. 2005). A conceptual model for the development of the Coachella Valley aeolian sand communities is depicted in Figure 2. This model is unique to this valley due to the unidirectional (northwest) nature of winds strong enough to catalyze aeolian sand transport and the strong west to east gradient in precipitation. Identified stressors include barriers limiting fluvial inputs of sand (upstream damming and/or channelization), barriers to aeolian sand transport (wind breaks), and stabilization due to the spread of invasive vegetation.

Geomorphic and Habitat Characteristics	Active Dunes	Stabilized Sand Fields	Ephemeral Sand Fields	Stabilized Dunes
Aeolian sand depth	> 3 m	0-2 m	0-2 m	> 3 m
Base substrate	aeolian sand	silt, cemented sands	gravel, rocks	aeolian sand
Shrub Density	Mean < 0.005/ m^2	Mean > 0.01/ m^2	Mean > 0.049/ m^2	Mean > 0.048/ m^2
Wind velocity	moderate	moderate	high	moderate
Sand movement	high	moderate	very high	low
Precipitation gradient	extreme (low)	extreme (low)	moderate	moderate
Covered species primarily associated with this community	**Fringe-toed lizard** **Sand-trader cricket** Milkvetch Round-tailed ground squirrel Flat-tailed horned lizard	Fringe-toed lizard Round-tailed ground squirrel **Flat-tailed horned lizard**	**Fringe-toed lizard** **Sand-treader cricket** **Milkvetch** **Jerusalem cricket**	Fringe-toed lizard **Round-tailed ground squirrel**

Table 1. Geomorphic characteristics and species associations of the four community divisions of the Coachella Valley Aeolian Sand landscape. Species in bold type are populations that can reach the highest abundance when habitat conditions are appropriate.

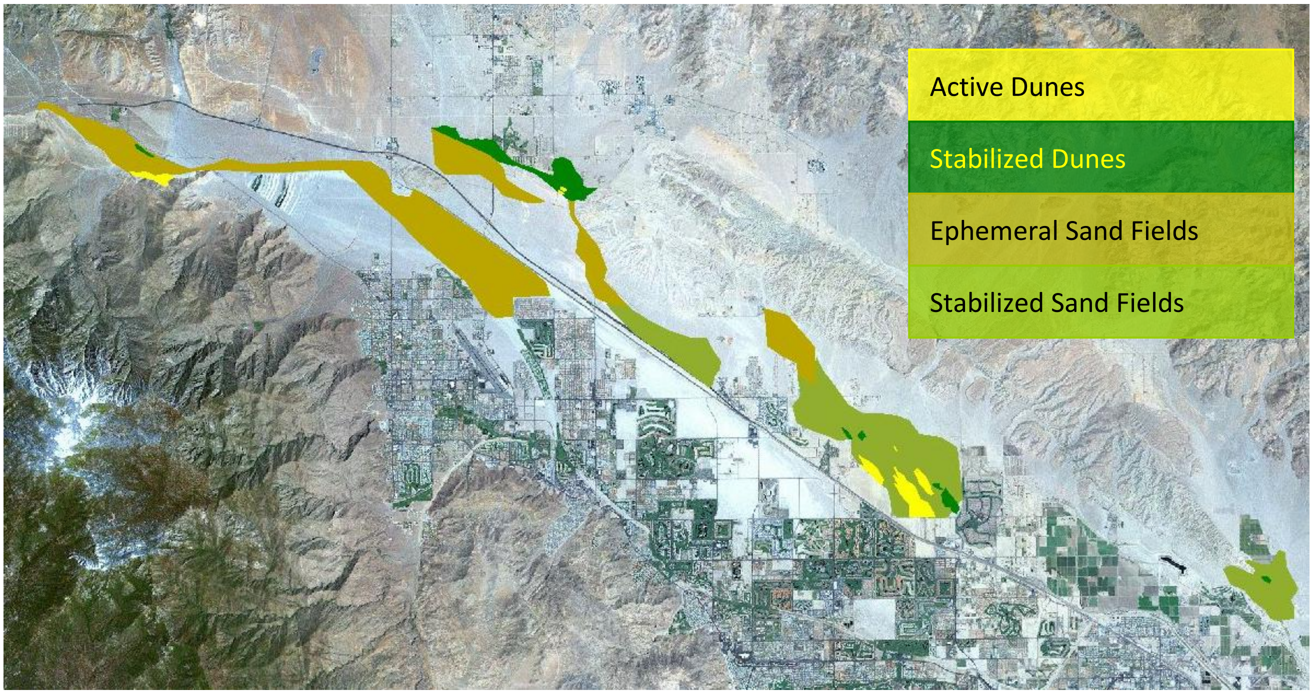

Figure 1. General location of the four naturally occurring Aeolian Sand communities of the Coachella Valley. Small sand deposits in the Indio Hills are not shown at this scale.

The model indicates the likely loss of both ephemeral sand fields and active dunes if either sand inputs or wind velocity are blocked. The more stabilized habitats will likely persist longer, but they too will degrade over time. The models also indicate that the honey mesquite, *Prosopis glandulosa*, which is usually associated with stabilized dunes, could be negatively impacted with changes in the availability of permanent water at their root zone. Finally, active dunes may be the most sensitive to the effects of invasive plant species. On ephemeral sand fields the intense wind and sand movement appears to limit the establishment of invasive species. Active dunes are also somewhat resilient to invasive species, though less so than ephemeral sand fields, however the potential for stabilization of active dunes appears to be much greater, with negative impacts to active dune associated endemic species (Barrows et al. in press).

The interaction of potential stressors with covered species' populations is shown conceptually in Figure 3. This and Figure 2 capture hypotheses as to interactions of stressors, as well as identify research questions that test the utility of those hypotheses and the level of risk stressors pose to the sustainability of the community composition and the populations of covered species therein.

INITIAL RESEARCH QUESTIONS (TO BE ADDERSSED WITH MONITORING DATA)

Numbers in bold correspond to color-coded portions of the conceptual models.

- **(1)** What are the rates of sand transport for each of the aeolian communities? Are within community sand transport rates changing in a consistent trajectory, or are the rates oscillating around a mean?

- **(1)** Are sand depths and extent (volume) changing in a consistent trajectory, or are the rates oscillating around a mean?

- **(1)** Is the aerial extent of the aeolian sand communities changing in a consistent trajectory?

- **(1)** How does landscape pattern (patchiness, juxtaposition of community types) influence population abundance and species richness?

- **(2)** Is the apparent senescence of mesquite on stabilized dunes the result of reduced upwelling along earthquake fault zones, over-drafting of aquifers, climate patterns, disease, or old age?

- **(2)** How does the loss of honey mesquite on stabilized dunes impact species composition and abundance there?

- **(3)** Are species negatively impacted by "edge effects" – altered boundary processes – as a result of habitat fragmentation? (vehicle mortality – predation pressure from suburban-augmented predators – exotic/invasive species interactions)

- **(3)** Are species loosing genetic fitness due to fragmentation? (population isolation – increase genetic homogeneity – reduced reproductive responses and/or survivorship to positive resource inputs)

- **(4)** Are species responding negatively to invasive species occurrences? (reduced native annual plant species)

- **(4)** Are native arthropods responding negatively to invasive species? (reduced abundance and/or species richness)

- **(4)** Are food webs becoming less complex and potentially less robust and resilient to changing conditions?

- **(4)** Are invasive species resulting in increased sand compaction and stabilization?

- **(4)** Are invasive species impacts creating trajectories in habitat conditions with likely long-term population declines, or are the impacts ephemeral, with no long-term consequences?

- **(5)** How do populations respond (relative numbers, reproductive response, survivorship, mortality) to changes in resources (rain, annual plants, detritus, arthropods) across a gradient of conditions?

- **(5)** Which species are most sensitive to the effects of climate change?

- Are management actions resulting in desired outcomes?

Surveys will be designed so that data collected can contribute to these research questions. The questions also are not designed to provide threshold values, beyond which management actions are indicated. Rather they are designed to assess the risks that given stressors pose to the goal of the MSHCP/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 OBJECTIVES

1. Sand Transport/Ecosystem Processes (metrics to be collected)

- Areal extent of each community type
- Mean and plot-specific sand transport rates within each community type
- Mean and plot specific change in aeolian sand depth within each community type
- Percent cover of aeolian sand versus gravel/rocks or silt/cemented sand in the ephemeral and stabilized sand field communities
- Mean and plot specific sand compaction within each community type

2. Mesquite on Stabilized Dunes (metrics to be collected)

- Quantify health of mesquite on stabilized dunes (e.g. proportion of dead branches).
- Groundwater depths compared with mesquite health.
- Water isotope signatures for water within the plants, at deep groundwater levels and at perched, shallow groundwater sources.
- Well depth records for locations near degraded versus healthy mesquite.
- Species associations with healthy versus degraded/senescent mesquite on stable dunes

Shallow groundwater depths will be measured with ground penetrating radar employed along the gradient of mesquite health conditions. Water samples for isotope analyses will be collected by 1) distilling water directly from the plant tissue, 2) digging down to shallow water sources, and 3) collecting water from nearby well sources. Well depth records will be requested from the Coachella Valley Water District.

3. Urbanization and Fragmentation (metrics to be collected)

- Species distributions with respect to conservation area edges
- Occurrence of predators (feral and natural)
- Occurrence of off-road vehicle trespass
- Reproductive recruitment rates for selected species
- Periodic analyses of genetic heterogeneity for selected covered species

4. Invasive Species (metrics to be collected)

- Measure the occurrence (density and percentage cover) of invasive exotic annual plants as well as the same metrics for native annual plants.
- Measure the patterns of occurrence of invasive and native species at the landscape level.
- Measure the relative abundance of native versus exotic species
- Determine variables (e.g. sand quality and quantity; rainfall) that favor invasive species and natives.
- Determine the influence of atmospheric pollutants (nitrogen, phosphorous) on the invasive behavior and success of exotic and native plant species.
- Measure the degree to which invasive species affect sand stability and aeolian transport as compared to the effect of native species.
- Determine the effectiveness of control efforts.

The ultimate objective for these data will be for constructing a management model for if, when and how to implement control measures for invasive annual species. Methods for measuring annual species densities, percentage cover, and sand compaction and aeolian sand transport are described below. Aerial/satellite Imagery will be employed to measure landscape-level patterns of occurrence. Sensors will be deployed to measure carbon, nitrogen and phosphorus levels in the near ground atmosphere.

5. Community Trajectories/Biotic Sustainability/Effect of Climate (metrics to be collected)

- Occurrence and changes in relative abundance of species with respect to resources including annual rainfall patterns, annual plants, perennial plants, arthropods, exotic species and sand characteristics
- Occurrence and changes in relative abundance of species with respect to the East-West temperature and precipitation gradient across the Coachella Valley

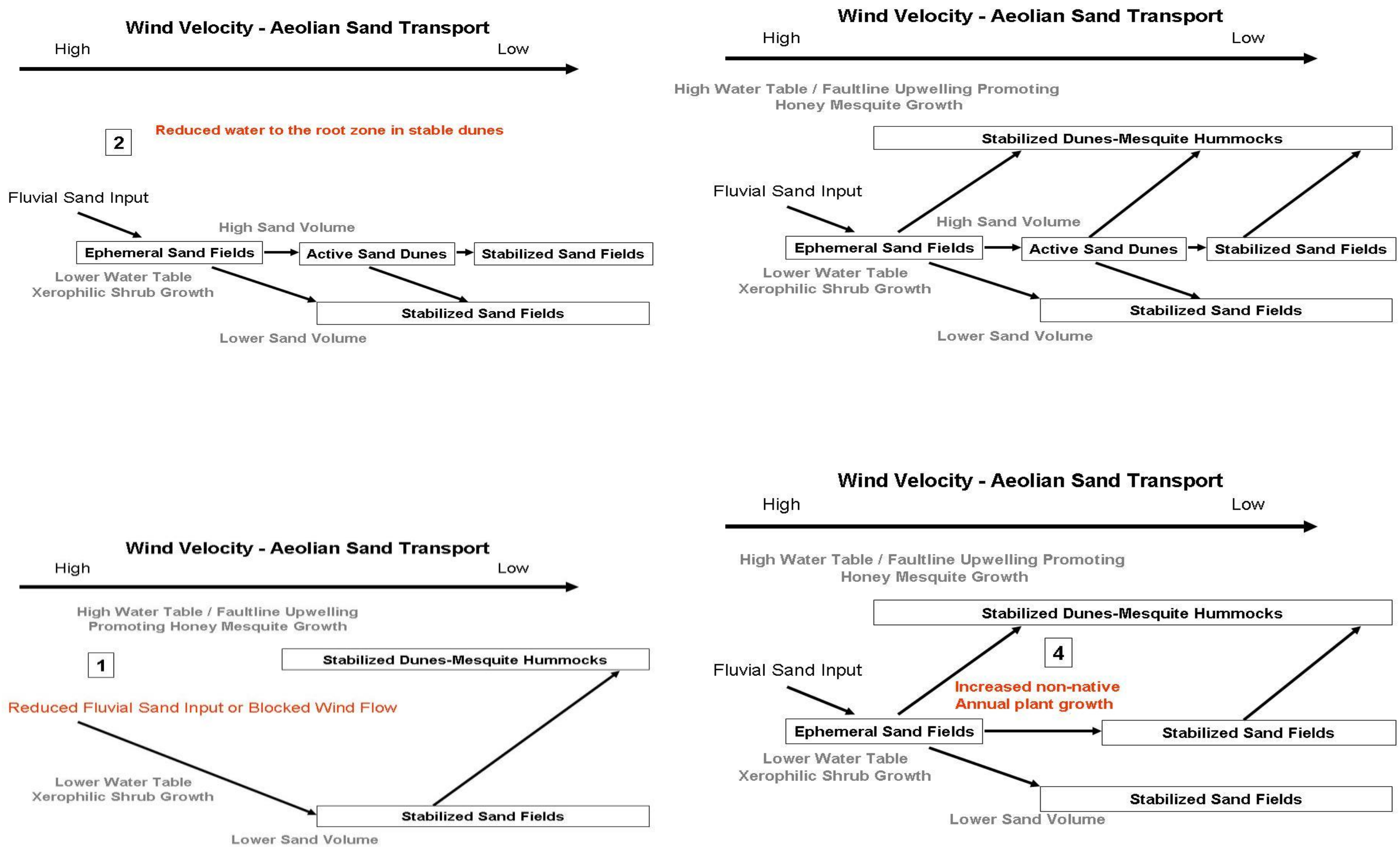

Figure 2. Conceptual models of the processes and patterns of the occurrence of the four aeolian sand communities of the Coachella Valley. Potential stressors and impacts on those communities are shown as well. Numbers correspond to research questions and monitoring objectives, which are described below.

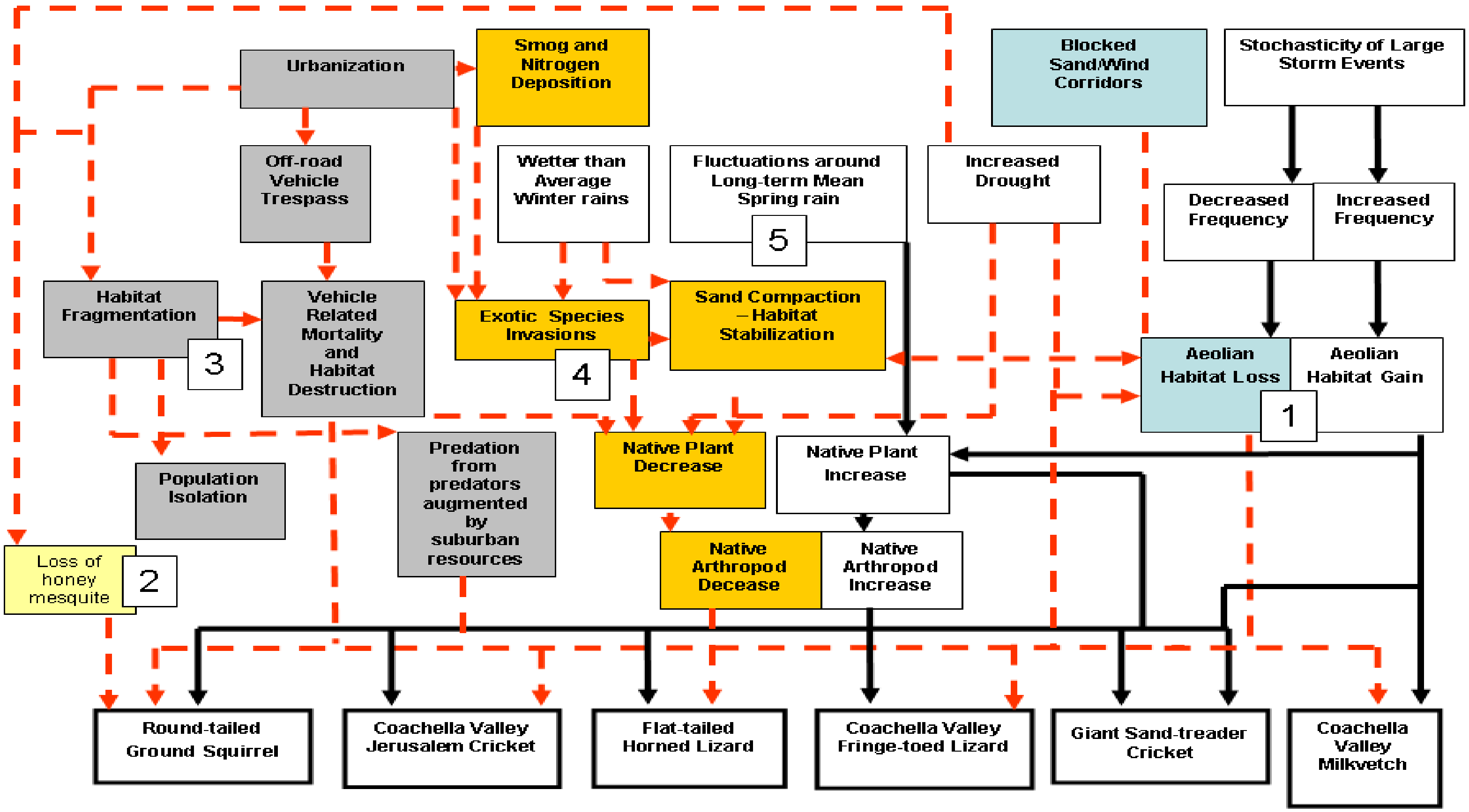

Figure 3. Covered species focused conceptual model indicating likely influences to population dynamics. Red dashed pathways indicate stressors, black solid lines indicate drivers. Colored boxes indicate anthropogenic sources. Numbers correspond to research questions and monitoring objectives described below.

MONITORING METHODOLOGIES

Sand Transport Monitoring Methodology

Using high-resolution aerial/satellite imagery and ground-truthing, the aerial extent of each of the aeolian community types will be mapped into GIS layers at least every three years.

Sand traps (Lancaster and Baas 1998) will be distributed across each of the aeolian community types to measure sand transport rates. At least one sand trap will be placed at each monitoring plot (described below). On each plot a metal rod will be permanently placed; sand depth will be measured from the top of the rod (constant height) to the sand surface. In conjunction with annual plant monitoring (see below) the relative percent cover of aeolian sand, cemented sand/silt, and gravel/rocks will be visually estimated in 12, 1m squares within each monitoring plot annually.

Biotic Monitoring Methodology

Since 2002 monitoring protocols have been under development for species occurring within the aeolian sand communities of the Coachella Valley. These methodologies and resulting data have generated a series of peer-reviewed, published papers (Barrows and Allen 2007a, 2009, 2010; Barrows et al, 2006; Barrows et al. 2009). The criteria described briefly above are evaluated here with respect to the monitoring protocols for two of the aeolian sand community reptiles, the Coachella Valley fringe-toed lizard, *Uma inornata*, the flat-tailed horned lizard, *Phrynosoma mcallii*, along with sand treader crickets, *Macrobaenetes valgum*, round-tailed ground squirrel, *Spermophilus tereticaudus*, and Coachella Valley milkvetch, *Astragalus lentiginosus* var *coachellae*. The approach adopted here includes measures of food resources, cover, sand conditions, species associations (including small mammals and terrestrial birds) and food web linkages (potential predator and prey species) layered onto each plot, and so is community based by design. A separate survey methodology has been developed for the Coachella Valley Jerusalem cricket, *Stenopelmatus cahuilaensis*, which is described following that for the other five covered aeolian sand obligate species. This protocol was developed in 2003-2004, and then used again in 2009.

Plot Distribution

The basic design of the recommended surveys includes a set of randomly placed study plots, each 10 m x 100 m (0.1 ha) (Fig 4). The random component of plot establishment is essential for statistical inference and to extrapolate observed patterns to a community patch, community type (multiple patches of the same community) or landscape (multiple community types and patches).The distribution of current plots is shown in Figures 5 and 6. The plot distribution is stratified with respect to the four aeolian sand communities and with respect to specific research questions (page 6 & 7) which reflect the hypotheses identified in Figures 2 & 3. The stratification by community is such that within a polygon or patch of a community type the plots were randomly located and that a sufficient number of plots within each community type and placement along the precipitation gradient were sampled. That location was identified by first randomly selecting a starting point along a line within the community so that each plot was wholly contained within the community patch; plots were located at random locations along that line. Random points that occurred closer than 50 m from the previous plots were rejected to maintain independence between plots.

Plots that were stratified due to specific data needs reflect the research questions listed above (page 6-7). For instance, to identify the influence of anthropogenic edges on within-reserve biotic integrity, plots needed to be distributed with respect to the reserve edge (Barrows et al. 2006). Using roadways as clearly defined edges, clusters of plots were established from 0-250 m from that roadway as well as within the core of the reserve. The random component was the position of the "0" plot along the roadway; the plots extending into the reserve were then at regular intervals to facilitate statistical analyses of edge effects. Similarly to evaluate the effectiveness of restoration efforts, plots need to be distributed randomly with respect to management treatment. Paired control plots need to be established that are close enough to the management treatment to avoid introducing additional confounding site specific characteristics that obscure the effect of the management treatment. Control plots may then be established at an *a priori* position/distance with respect to the treatment plot (e.g. Barrows et al. 2009).

Each plot was marked with a short wooden stake at the beginning, middle, and end so that a biologist conducting surveys can easily determine their position within each plot. The stakes are shorter than the surrounding vegetation so that they will not become perches for predatory birds and have a biased impact on the species being surveyed. Between January and July data are collected each year for sand-treader crickets (January-February) annual and perennial vegetation, including Coachella Valley milkvetch (February to March), arthropods (April), sand compaction (May), and vertebrates (May through July, and for a sub-set of those plots again in September and October).

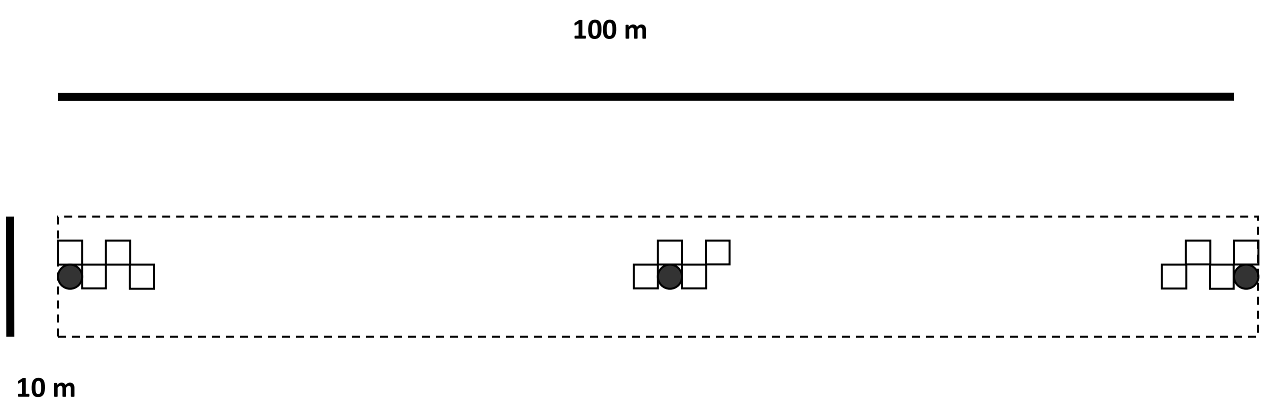

Figure 4. Schematic of basic plot design (not to scale). The twelve small squares represent locations for 1 m2 frame placement for annual vegetation density and cover estimates. The solid circles represent the approximate location of three arthropod pitfall traps (always removed after sampling occurs).

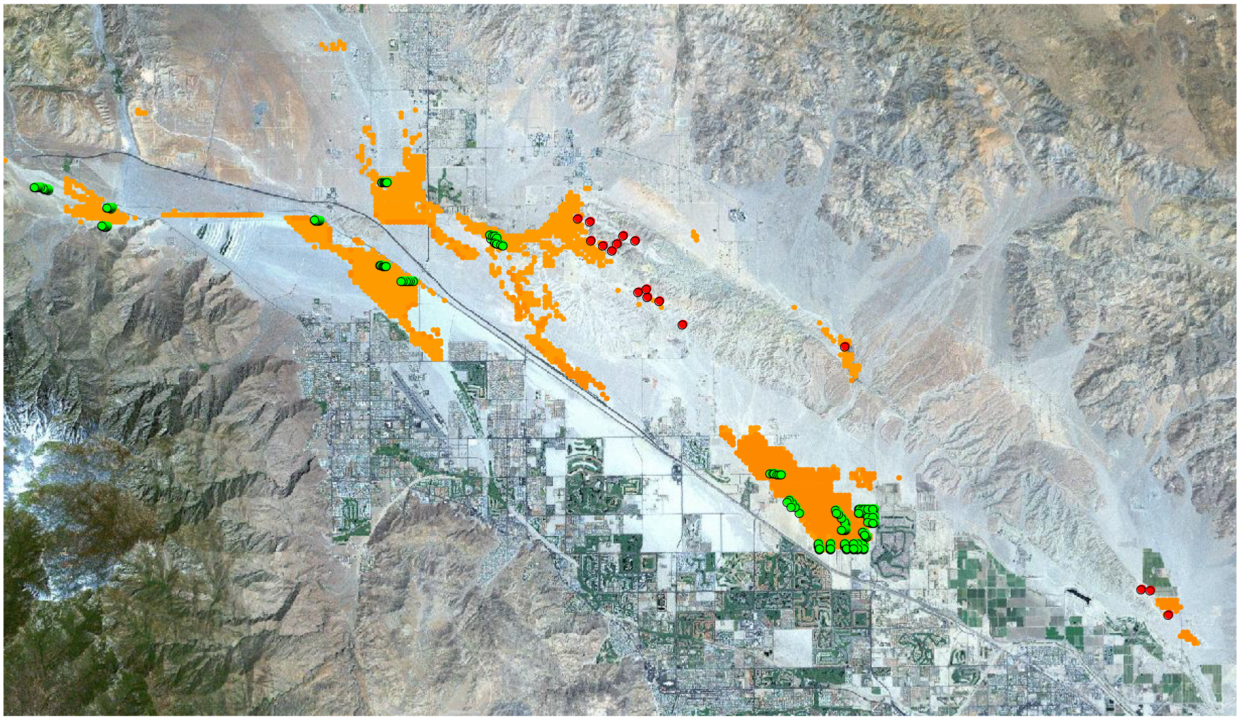

Figure 5. Distribution of the 150 monitoring plots (green dots) superimposed on the modeled distribution of current potential habitat for the Coachella Valley fringe-toed lizard. Potential habitat (HSI ≥ 0.333) was modeled using a Mahalanobis D^2 analysis (Barrows et al. 2008). Red dots are located on small isolated sand patches where annual presence-absence surveys occur.

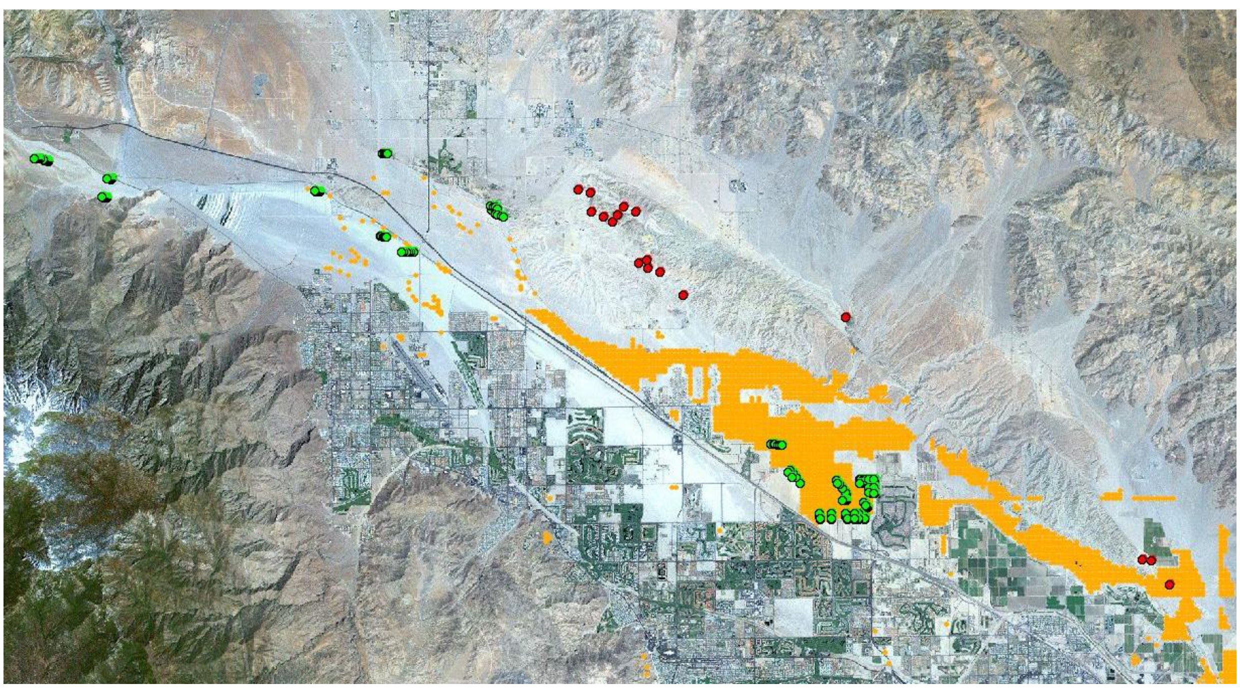

Figure 6. Distribution of the 150 monitoring plots (green dots) superimposed on the modeled distribution of current potential habitat for the flat-tailed horned lizard. Potential habitat (HSI ≥ 0.333) was modeled using a Mahalanobis D^2 analysis (Barrows et al. 2008). Red dots are located on small isolated sand patches where annual presence-absence surveys occur.

Accuracy and Survey Methods

Reptiles - The fine aeolian sand of the Coachella Valley's dune fields provide an opportunity unique to sand dunes (and perhaps snow fields) to quantify the occurrence and abundance of terrestrial species occurring within plots by enumerating numbers of individuals of each species by tracks they left as they moved across or within each plot (i.e. Figs. 7 & 8). An exception to this assumption is an arboreal lizard species, *Urosaurus graciosus.* Long-tailed brush lizards leave distinctive tracks in the sand when moving between shrubs, but the majority of their time is spent in shrubs where they are not detectable using tracking. Their relative abundances using the proposed protocol are likely underestimates of their true occurrences. Another potential exception is the nocturnal banded gecko, *Coleonyx variegatus*. These geckos leave distinctive tracks in fine aeolian sands, but their slow moving gait and light foot-falls may not leave impressions in the coarser sands that characterize the ephemeral sand fields, where they have not been detected. The geckos' delicate skin probably doesn't tolerate the high velocity winds and sand movement occurring almost nightly on the ephemeral sand field community, and so if present at all they likely occur at low densities there. Final exceptions are several snake species known to occur within the aeolian sand communities but whose tracks are not sufficiently distinctive to allow confident species identifications. These include *Arizona elegans, Phyllorhynchus decurtatus, and Salvadora grahamiae*. Excepting those species, each of the reptile species occurring on the aeolian sands can be identified to species and age class by their diagnostic tracks, and so variability in detection plaguing many other survey methods, caused by differences in activity times, cryptic coloration, or stealthy behavior, are largely nullified. We have found this survey method to be robust in the sense that we are able to detect species occurrences even when they are rare in the area being surveyed. Extensive training is required before biologists conducting tracking surveys can be proficient at species identification and enumeration, training levels similar to what would be required for conducting avian surveys where both sightings and vocalizations are used for identification.

As our recommended plot size (0.1 ha) is less than the home range for many of the species we survey, our tracking data were not equivalent to density data, although for at least *Phrynosoma mcallii* when we compared tracking data to mark and recapture derived densities there was a close proportional relationship ($R^2 = 0.9599$ and $P = 0.0006$; Barrows and Allen, 2009). Parallel qualitative results (congruence of peaks and valleys, as well as amplitude of lizard abundance) were produced for fringe-toed lizards by comparing our plot data with an adjacent plot where a 25 yr mark-recapture study has been occurring (Fisher and Muth, pers comm.). We also evaluated the accuracy of tracking for flat-tailed horned lizards by overlaying mark-recapture plots over several groups of 10m x 100m plots. A regression model ($y = 0.1298x + 0.1665$, with y = track-based relative abundance estimates on individual plots and x = asymptotic population estimates from mark-recapture analyses for an area encompassing 4-5 plots and the home ranges of multiple lizards) resulted in an $R^2 = 0.9599$ and $P = 0.0006$ (Barrows and Allen 2009).

In 2002 and each subsequent year we conducted a power analysis to determine the number of repeated samples required to identify statistically significant ($\alpha = 0.05$, $\beta = 0.80$, one sample *t*-test) between year differences for fringe-toed lizards. The number of repeated samples required to meet that standard has consistently varied between 3-6 surveys/plot; we have therefore conservatively stayed with six repetitions per plot. Our tracking data are most accurately characterized as the number individuals of each species that occurred on each plot each survey day, averaged over the six independent surveys per season; for reporting purposes we refer to this statistic as the mean relative abundance of each species / 0.1 ha (the plot area).

Because they are essentially ratios and so do not require precise population estimates, a mean relative abundance of the lizards can readily be incorporated to measures of reproductive success (mean relative abundance of hatchlings surveyed in the fall / mean relative abundance of adults surveyed in the late spring, or mean relative abundance of juveniles surveyed in the late spring / mean relative abundance of adults surveyed in the late spring), and population growth (natural log of the product of the mean relative abundance of all lizards surveyed in the late spring in year 2 / mean relative abundance of all lizards surveyed in the late spring in year 1 [e.g. Barrows 2006]). Data for each plot is considered independent, although in rare instances an individual could move from one plot to another and be recorded as occurring on both plots (between plot distance was ≥ 50 m).

Reptile surveys occur between May and July. Due to the timing of our surveys reproductive responses had an apparent one year lag to temporally variable environmental conditions. The reproductive responses (hatchling lizards and snakes) emerged from late summer through early winter, depending on the number and timing of clutches the adult reptiles produced. There is no single period in the fall when the total hatchling cohorts are present and active on the sand surface. The total reproductive effort is thus measured during the following year's survey period. Nevertheless a selected number of plots (62) have been surveyed in the fall [September-October]. These plots provide a snapshot of the lizards' reproductive effort and provide a basis for estimates of reproductive success.

All surveys should begin each morning after the sand surface temperature had risen sufficiently (35^{o} C) so that diurnal reptiles were active. This temperature should be taken at 1 cm above the sand surface, in the sun, to reflect the conditions available to the lizards. Alternatively, with experience, biologists can assess the relative activity of the lizards by identifying fresh tracks while traveling on foot to the plot location. Consistent time of day and temperature reduces those variables' contributions to between survey variability. Surveys continue until late morning when the high angle of the sun reduces the observer's ability to distinguish and identify the tracks across the sand, and coincides with the cessation of activity for the diurnal reptiles due to high surface temperatures. One observer can complete a survey on a given plot in 10-15 minutes, recording all fresh tracks observed within the plot; depending on the travel time between plots that observer could survey 10-15 plots/day.

We used track characteristics to identify individuals as well in order to quantify species' abundance. Track size, unique features, and following tracks off of the plots helped insure that each counted track represented a unique individual for each survey. Because late afternoon and evening breezes usually "wipe the sand clean" the next day's accumulation of tracks should not be confused with those from the previous day. Track identification is a readily learned skill much like identifying bird songs and chip notes for conducting bird surveys. Generally one or two biologists walk the length of the plot moving back and forth across the plot so that all tracks are detected. Differences in track size can often allow biologists to distinguish individual lizards, this along with following tracks off of plots, and noting track evidence distinctive male-male displays allow biologists to conservatively estimate the number and species of each vertebrate that traversed some portion of the plot that morning.

Round-Tailed Ground Squirrels (Fig. 9) – There are two detection methods that work within the proposed monitoring design, tracking and noting the squirrels warning calls. In 2008 when the squirrel population was relatively low, out of 171 total detections, 91% were by tracking and 20% were by vocalizations (at many sites squirrels were both heard and detected by tracks). In 2006 when the squirrels were at a population high, again 91% of over 700 detections were by tracks, and 33% were by their calls. Using just calls alone (locations where no tracks were seen) only 9% of the squirrels were detected in both years. Nevertheless we use both methods in tandem to achieve the maximum detection rate.

Coachella Valley Milkvetch (Fig. 10) – Coachella Valley milkvetch are annual or sometimes biennial plants. The biennial habitat is generally restricted to the western, cooler-wetter portion of the Coachella Valley, and years when high levels of sand moisture stay close to the surface through the summer. These plants usually occur at low densities so we have employed a total count / 10 m x 100 m plot survey protocol. The counts occur coincident to the general vegetation surveys in February-March, but are re-surveyed coincident with the arthropod surveys in April and sand compaction data collection in May to ensure all plants are counted. Data are reported as densities (plants/m^2).

Sand – Treader Crickets (Fig. 11) – Sand treader crickets are nocturnal, moisture sensitive insects. The crickets' first instars emerge coincident with winter rains and appear to be at maximum densities in January-February. After apparently incurring incremental mortality (inferred by their lower densities), the crickets reach adult size by April and by June usually disappear altogether.

Between 2003 and 2008 we compared two methods, pitfall trapping and detections via the cricket's characteristic Δ or delta-shaped burrow excavations. The species-specific burrow excavation shape was confirmed by excavating over 100 burrows. The burrows enter the sand at a shallow angle and generally extend 20-50 cm until the cricket reaches water-saturated sand, usually 5-20 cm below the sand surface during the winter months. Not all are occupied; the crickets appear to dig a new burrow each evening, leaving previous burrows vacant and visible until winds remove the excavations. Excavating the burrows to locate live crickets results in relatively high cricket mortality; once exposed to sunlight, daytime temperatures and low humidity the crickets expire quickly. The same is true for pitfall trapping. For burrow surveys we count all fresh burrows within the entire 10 m x 100 m plot (one survey/plot) in January-February, when their abundance is at its peak. Using this method, for determining fresh versus older burrows, the surveyor requires training and experience. Freshly excavated burrow sand is usually darker (still has residual moisture) than older burrow sand. Pitfall trapping occurs when total arthropod species richness and abundance is assessed in April.

Burrow counts were superior to pitfalls in detecting sand-treader crickets. As an example in 2008, a typical year from the perspective of sand-treader crickets, on all plots 724 crickets were detected using burrow counts, whereas 19 were trapped in pitfalls; burrow counts recorded the crickets on 75% of all plots surveyed whereas pitfalls recorded them on just 8%.

Sampling Habitat Heterogeneity

Originally 150 plots were established in order to assess the level of habitat heterogeneity that occurs across the aeolian sand communities of the Coachella Valley (Figs 4 and 5). Each plot was surveyed for at least three years within the 2002 to 2008; however 77 were surveyed in each year from 2003 to 2008. Many of those were deemed either redundant or were designed to answer a specific research questions regarding the impact of suburban edges of the population trajectories of the species that comprise the sand communities (Barrows et al., 2006). From that set of 150, the core of 96 study plots has been identified to assess the temporal and spatial variability within aeolian sand habitats across the Coachella Valley. Study sites were located in a stratified random manner whenever possible, stratified by four community types as defined Barrows and Allen (2007b) (Table 1). Core plots constituted only those occurring ≥ 100 m from suburban-natural area edges were included here to avoid previously described edge effects (Barrows et al. 2006). The stratification included: 24 plots in "active sand dunes"; 17 plots in "stable dunes"; 31 plots in "stabilized sand fields" (forming the habitat matrix surrounding active dune patches in the east valley); and 24 plots in "ephemeral sand fields". Ephemeral sand fields are located in the western, windiest portion of the valley where wind energy exceeded sand supply (Griffiths et al., 2004) and so the aeolian sands have a much shorter residence interval than the other community types considered here. The dominance of honey mesquite, *Prosopis glandulosa*, on the stable dunes created a logistical problem as dense mesquite copses were impenetrable. Plots there were thus confined to open areas and so were non-randomly placed. Data from these plots characterized those open areas but not the community as a whole. Using GIS software (ArcView 3.2, ESRI) we calculated the extent of the open areas (13%) versus the mesquite copses and other dense vegetation (87%) and then adjusted the relative abundance of those reptiles restricted to the open areas (i.e. *Uma inornata, Dipsosaurus dorsalis, Callisaurus draconoides, Phrynosoma platyrhinos*) downward proportionately. Examples of differential abundances when stratified by community type for the target species are shown in Figs 7-11.

Limit Observer Impacts

Our method, focused on enumerating individuals by the tracks they left and sightings of active individuals requires no handling of any lizard, cricket or squirrel nor chasing that could constitute harassment (however brief). Therefore this protocol limits observer impacts to the extent possible.

Putting Survey Data in an Ecological Context

All vertebrates are surveyed simultaneously using their tacks as the main metric of abundance and providing a community-level measure of the species occurring on that habitat. In addition resources available to those species were assessed.

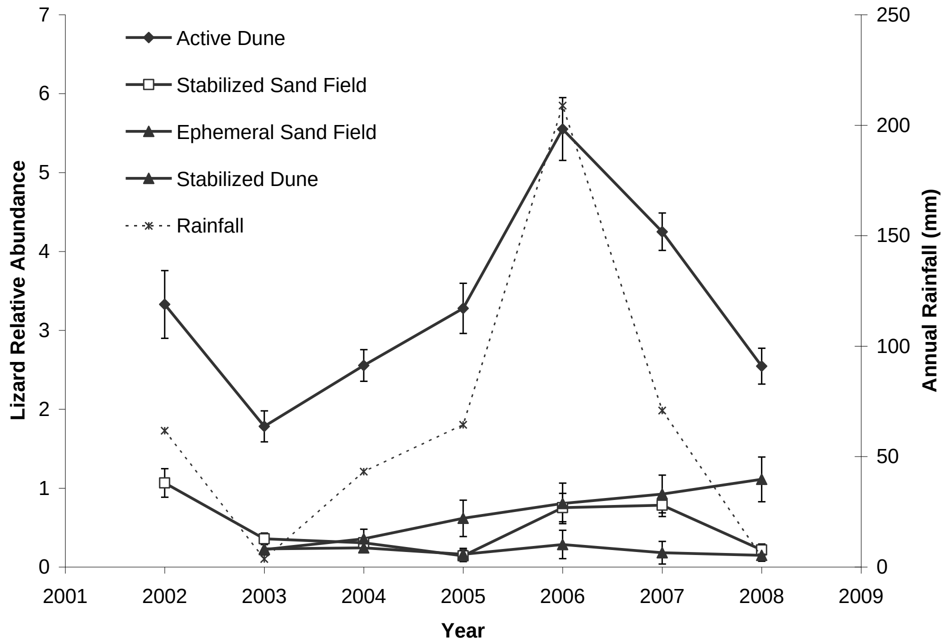

Figure 7. Patterns of abundance for the Coachella Valley fringe-toed lizard across the aeolian sand community types. Rainfall is off-set by one year to match the lizards' demographic responses.

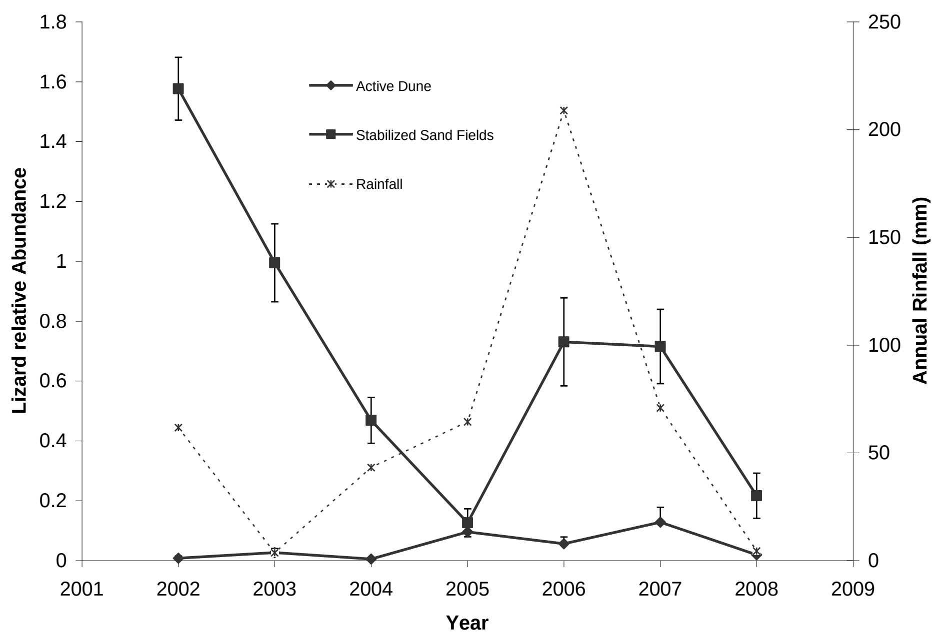

Figure 8. Patterns of abundance for the flat-tailed horned lizard across the aeolian sand community types. Rainfall is off-set by one year to match the lizards' demographic responses.

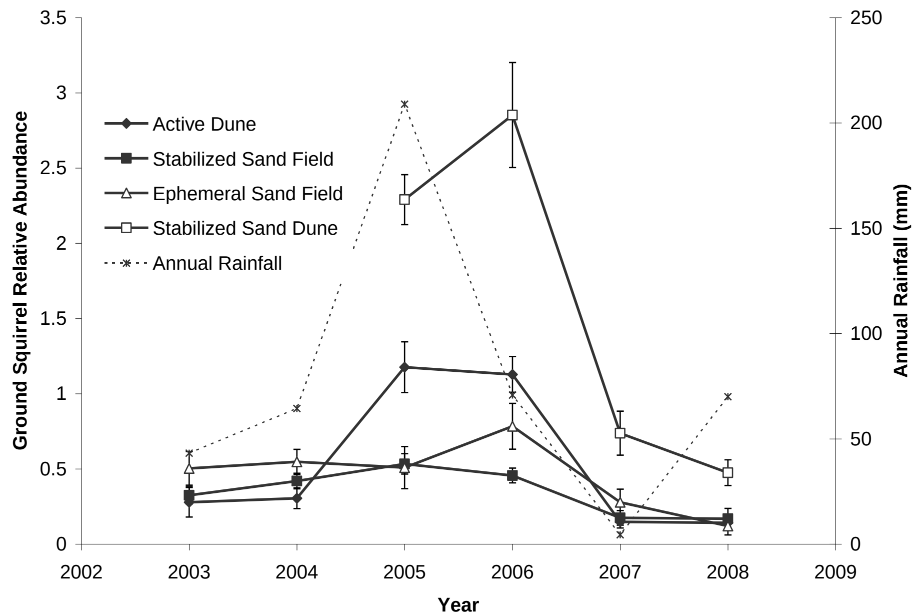

Figure 9. Patterns of abundance for the round-tailed ground squirrel across the aeolian sand community types. Rainfall is not off-set by one year.

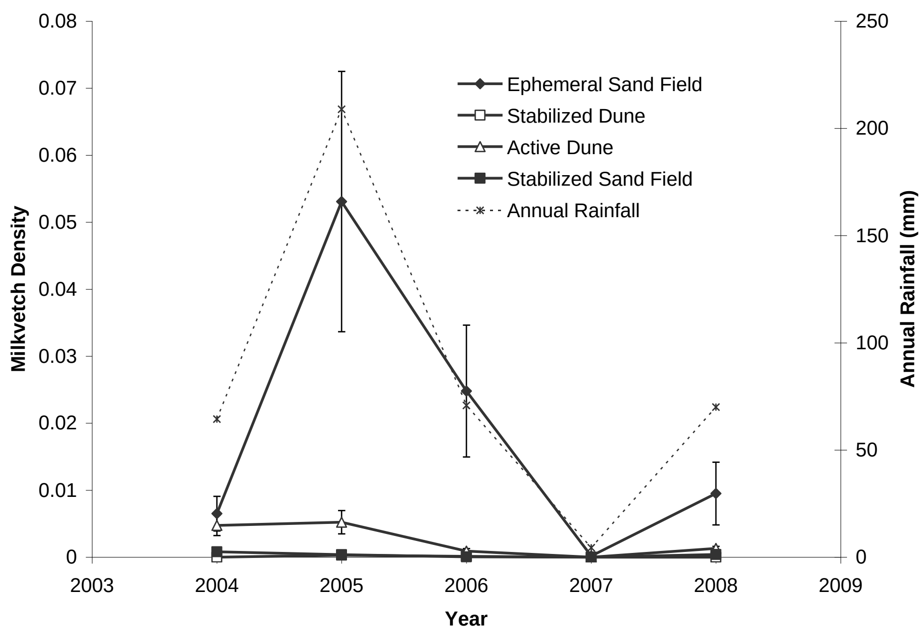

Figure 10. Patterns of abundance for the Coachella Valley milkvetch across the aeolian sand community types. Rainfall is not off-set by one year.

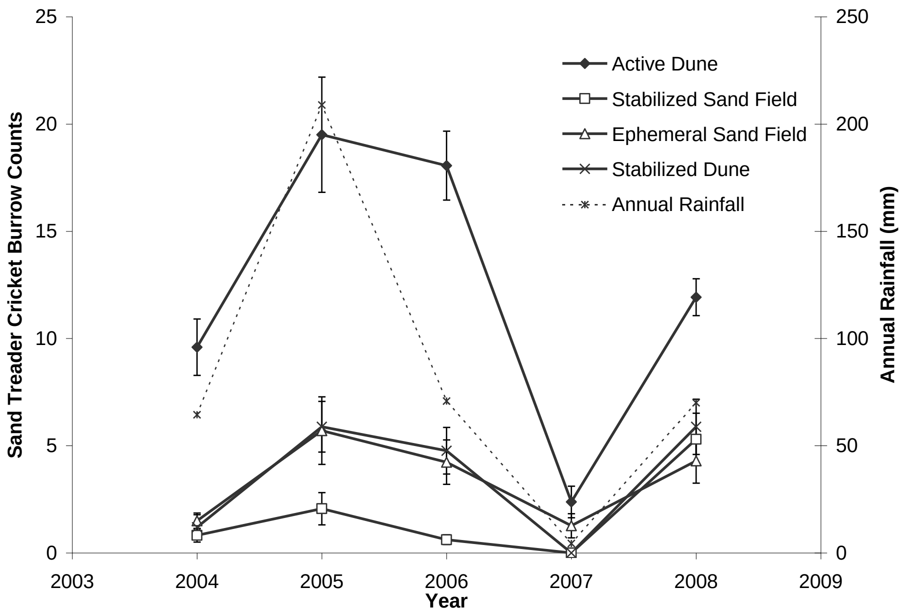

Figure 11. Patterns of abundance for the Coachella Valley giant sand treader cricket across the aeolian sand community types. Rainfall is <u>not</u> off-set by one year.

Habitat Measures

All perennial shrubs are counted by species within the 0.1 ha plots. Annual plants were counted and cover estimated in a 1 m^2 frame placed at 12 locations along the midline of each plot. Four samples were taken on alternating sides of the center line at each end point, and two samples were taken on each side of the center point. In each frame all individual plants were counted by species to determine species densities, and for each species we made a visual estimate of its percent cover within each frame. These values were then averaged for each species for the 12 frames of each plot. Annual plant data presented in our analyses were all measures of percent cover.

Sand compaction has been described as a key habitat variable for *Uma inornata* (Barrows, 1997, 2006). Sand compaction is measured at 25 points, approximately 4 m apart, along the plot midline, each year, using a hand-held pocket penetrometer with an adapter foot for loose soils (Ben Meadows Company, Janesville, WI, USA). Data are recorded as the force (kg / cm^2) required for the penetrometer "foot" to go beneath the sand surface.

Arthropod Sampling

We sample arthropods using dry, un-baited pitfall traps. Previous sampling had shown April to be a peak activity period for the harvester ants and arthropod abundance and species richness, thus pitfall surveys are confined to this month alone (Barrows, 2000). The pitfall traps measure 11 cm wide at the mouth, 14 cm deep, 1.0 L in volume (Fabri-Kal Corp., model no. PK32T 21), and include a tight fitting funnel that inhibited the ability of the ants to escape once they had fallen into the trap. A board measuring 20 cm x 20 cm x 0.5 cm is placed over the pitfall trap and elevated 1-2 cm with three wooden blocks, providing shade and cover for the arthropods captured by the trap. We place three pitfall traps within each plot, one at each end and the third at the plot middle. We collect the contents within 24 hrs of opening the traps. Arthropod data are summarized as the mean number counted per species per pitfall per plot.

Providing Information Resource Managers Can Use
To date, focused hypothesis driven surveys have yielded insights as to the impacts of suburban edges to the natural habitats and possible management responses (Barrows et al. 2006). Additional data collected from these plots have provided key information as to the impacts of invasive plant species such as Russian thistle, *Salsola tragus*, (Barrows 1997) and Sahara mustard, *Brassica tournefortii*, (Barrows et al. 2009), enabling managers to use informed triage in setting priorities toward controlling these species.

Alternative Methodologies
Mark-recapture techniques have been used for both the fringe-toed lizard and flat-tailed horned lizard studies in the Coachella Valley and have provided important insights into the biology of these species. This approach can yield a close approximation of population size on study plots, as well as territory size, reproductive activity at the scale of individuals, longevity (at least residence times on plots), and changes in body size and condition with respect to age and season. For research and/or management questions in which these fine-scale metrics provide critical insights, a mark-recapture approach is superior to the tracking method described above. Fisher and Muth (1989) have developed a permanent marking technique and have found it to have no measurable impact on the lizards when employed by experienced biologists. For shorter term studies ink can suffice to mark the lizards.

When questions are focused at larger scales (population, community, landscape) the labor intensive nature of a mark and recapture approach can limit the number of plots that can be surveyed simultaneously across environmental gradients, limiting temporal comparisons between plots, statistical robustness, and the ability to capture the heterogeneity of a dune landscape. The proposed "tracking" protocol is superior for defining relationships between the lizards (their patterns of occupancy, population trajectories and dynamics, reproductive success, population growth) and environmental gradients (such as habitat characteristics, edge effects, effects of invasive species at different densities, patch size, sand characteristics, rainfall patterns) across larger scales.

Coachella Valley Jerusalem Crickets - The Coachella Valley Jerusalem Cricket (CVJC), Stenopelmatus cahuilaensis, has a narrow distribution and is restricted to southern California's western Coachella Valley. According to Weissman (pers. comm.), CVJC require high humidity and cooler temperatures than occur in the central Coachella Valley. He suggested that other than soil texture, the distribution of the species is most likely based on both temperature and moisture gradients. This apparent sensitivity to both heat and desiccation indicates CVJC may be either relicts from a wetter-cooler climatic regime or may only opportunistically enter the desert during wetter periods. From the eastern Coachella Valley up the San Gorgonio grade there are distinct east to west gradients with a steady drop in temperature and increase in precipitation as the elevation increases from Sea Level to 790 m. This temperature-precipitation gradient may be a key to understanding the current and future CVJC distribution in the face of projected climate change scenarios. The known historic and current distribution of his species is shown in Figure 12.

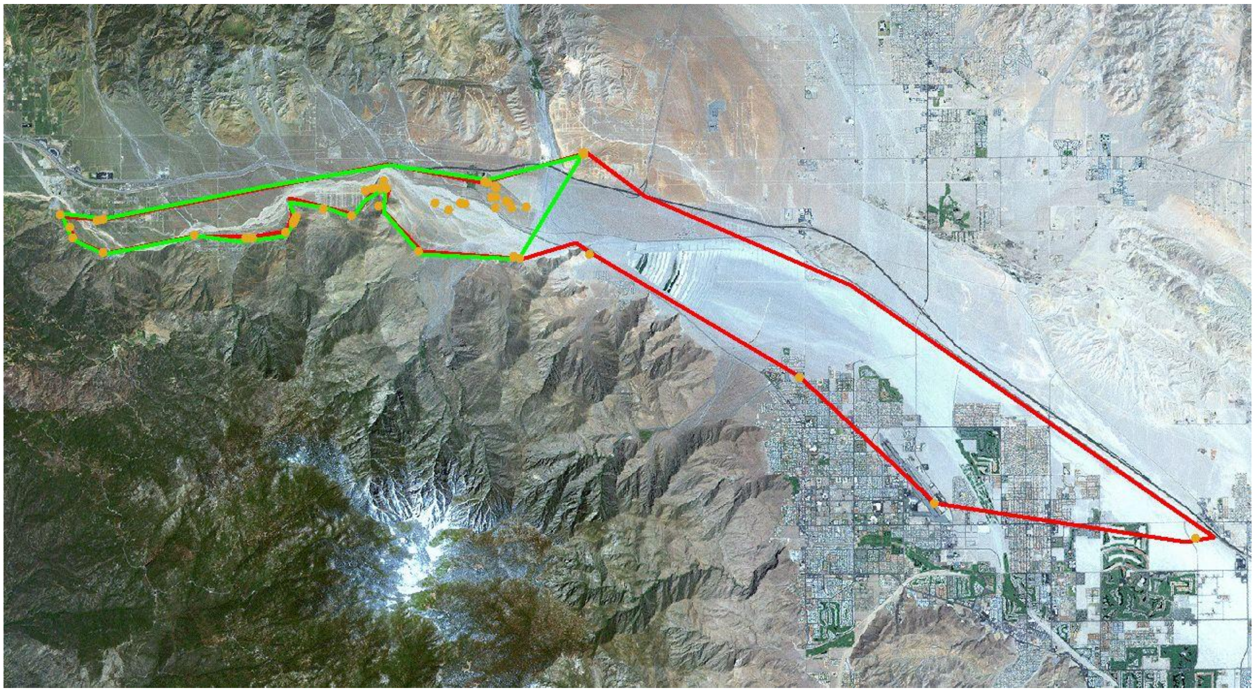

Figure 12. Historic and current distributions of the Coachella Valley Jerusalem cricket, estimated by a minimum convex polygon of known locations. Red polygon approximates the historic distribution; the green polygon approximates its current distribution. Orange circles indicate cricket locations (historic and current).

Accuracy and Survey Methods

Due to the cricket's general rarity, nocturnal behavior and no distinctive or readily observable tracks (as they often occur in more stabilized, coarser aeolian deposits), the same survey approach described for the species above will not work for this species. Previous survey efforts have shown lifting and searching under debris to be an effective detection method (Prentice et al. 2011). However debris is not randomly or regularly distributed across the desert. In order to sample in those areas without extensive debris we have developed a 60 cm x 60 cm cover board – termed a detection tile – design that provides an adequate substitute for debris (Prentice et al. 2011). The tiles are meant to mimic debris, however we found that only by insulating the tiles with sand piled on top and when "irrigating" the area below the tile with water to keep the sand damp, did the detection efficiency approach that of the debris searches. Pitfall traps were time consuming to establish and maintain and had by far the worst detection success. They also had the negative aspect of increasing the mortality rate of any creature that became trapped.

In a preliminary study to determine the best detection methodology we conducted a total of 2158 searches under random debris, 1389 searches under detection tiles, and 240 searches in pitfall traps (Prentice et al. 2011). Overall detections were very low, 1.9% of the debris yielded a cricket, 1.0 % of the detection tiles, and 0.4 % of the pitfalls. When both the weather/soil moisture was suitable for above ground cricket activity and the searches were within the crickets' occupied range (i.e. at least one cricket was found at the site and day being surveyed), the success rate under debris rose to 16.0% and under detection tiles rose to 2.9%. Only one cricket was ever detected using pitfalls so a similar comparison for that method was not possible. Not only were there more crickets detected with this method but the cost other than the labor for conducting the search was essentially zero.

Detections appeared to vary with soil moisture, so when the sand below the debris dried out days or weeks after a rain event, detections approached zero. For example, twenty-three days after the last heavy rain, over 50 pieces of debris were upended along a sandy, little-used dirt road resulting in no CVJC captures. The sand beneath all lifted pieces was quite dry. Two weeks later, following a heavy rain on the previous day, approximately 20 pieces of debris were overturned along the same road, resulting in the discovery of four CVJCs. The ground surface beneath all debris articles was quite moist. All of the objects under which CVJCs were found had previously been upended on the previous survey. Surveys should occur in January and February, when soil moisture is more likely to be high.

Sampling Habitat Heterogeneity

Debris searches are opportunistic, and occur wherever there is accumulated solid debris (even small items, even cow dung can yield crickets). Detection tiles are envisioned to fill in surveying gaps to better define the distribution and habitat characteristics of this species. As such they are not randomly placed. Where occurrence data from a site/habitat type is desired, a cluster of 4-6 tiles is placed. The resulting data are limited to presence/absence and a defined distribution. This species may be particularly sensitive to drought-related climate change effects and so documentation of changes in its distribution is critical.

Limit Observer Impacts

Surveying under debris and/or detection tiles has no known effect on survivorship as long as the debris is carefully replaced. In previous surveys individual crickets were repeatedly observed under the same debris. Other potential methods, including pitfalls (very low detection rates) and excavating root areas (presumed even lower detection rates) increase the rate of cricket mortality.

Putting Survey Data in an Ecological Context

Habitat Measures – GPS location, a sand sample, and vegetation type data are collected for each survey site.

DATA ANALYSES

When developing analytic methods, one must keep in mind research objectives. 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. The typical analyses applied to data from monitoring focuses on the first of these objectives, i.e., addressing whether $N_t^1 \neq N_t^2$ or $N_t^1 = N_t^2$. However, quantification of extinction risk requires data that are difficult to acquire and therefore often unavailable (i.e., population viability analysis requires precise estimates of survivorship and fecundity). Furthermore, such an analysis would not identify population drivers (objective 2), which would lead to management actions (Barrows and Allen 2007b). We instead focus our analyses, at least initially, on identification of variables that affect variation in abundance or at least are correlated with abundance over time and space. This approach allows analysis of spatial and temporal variation in relative abundance, which is easier to acquire than precise estimates of actual abundance and other demographic parameters. Once the driving factors underlying population change are identified, we will be in a position to evaluate the extent to which these factors reflect natural processes, to which species are more likely adapted, versus anthropogenic-induced processes, which may require management activities. If anthropogenic stressors are identified as population drivers, more detailed demographic studies of stressed species in conjunction with adaptive management may be conducted.

We envision exploring the factors driving population heterogeneity and dynamics in a regression context. For example, we might examine how spatial or temporal heterogeneity in relative abundance (Y) is related to independent variables representing hypothesized population drivers using a linear regression model, $Y = \alpha + \beta_1 * X_1 + \beta_2 * X_2 + \beta_3 * X_3 \ldots$, where α is a constant and β_i are coefficients describing the magnitude of effects of population drivers on population size. Examples of where this approach has already been successfully applied include fringe-toed and flat-tailed horned lizards (Barrows 2006, Barrows and Allen 2009, Barrows and Allen 2010). Alternatively, for relatively rare or sparsely distributed species, we may instead examine the distribution of the species among plots (i.e., presence/absence) using logistic regression or related models (see Royle and Dorazio 2008). These models require specific assumptions, such as homogeneity of variance across levels of explanatory variables and normality of the deviations between observed and model-predicted values for linear regression. Ecological data routinely violate such assumptions, but recent advances have yielded a variety of alternative analytic methods for a wide range of data structures (Clark 2007, Bolker 2008). Although we have some idea of the types of statistical models that may be useful for addressing certain questions, we do not have complete *a priori* knowledge of how data will be structured until it has been collected. Therefore, we will select regression models best suited to analyzing particular datasets following initial exploratory examination of data structure once the data have been collected. Often multiple models are suited to a given dataset. We will explore the relative importance of various model structures, as well as combinations of independent variables representing various hypotheses, within an information theoretic framework (Burnham and Anderson 2002).

When designing a study and analyzing data, researchers should be concerned with whether there will be or are enough data to address the research questions at hand. This concern is ideally addressed during study design, at which point power analyses may be applied to calculate the necessary sample sizes to address questions of interest (Hayek and Buzas 1997). To conduct a power analysis, a researcher must have in mind a particular effect size that he/she is interested in documenting. However, as is often the case in ecological studies, the precise hypotheses and predictions necessary to conduct power analyses are not available for most of the questions guiding this study. Therefore we use the general rule-of-thumb for multivariate analyses of keeping the ratio between the number of independent variables and the number of observations ≤ 1:10. 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. We anticipate, at least initially, using measurements for individual plots as our unit of observation. Thus, a given model could contain a maximum of one independent variable for every 10 plots. Portions of this protocol involve taking multiple measurements per plot. Since we do not expect measurements to be independent of each other within a plot, an average value for each measurement will be calculated for each plot, resulting in a final measurement that should be reasonably representative of the plot. Since, we have not conducted *a priori* power analyses (except see for temporal dynamics in fringe-toed lizard populations; see *Biotic Monitoring Methodology* for reptiles), we will consider a lack of statistical power to be a potential explanation for any results from these initial 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 in an adaptive fashion. *Post hoc* power analyses based on preliminary data could be used to inform the design of follow-up studies.

Our study design is particularly well-suited to identifying potential scale-dependencies of population drivers. Population responses to environmental heterogeneity are often scale-dependent (Wiens et al. 1986), and we have no *a priori* basis upon which to expect species-environmental sensitivities to arise at any particular scale (e.g., plot-, dune- [patch-], conservation-unit- [reserve-], community-, or landscape-scale). Our use of a stratified random array of permanent plots allows analysis of population sensitivities to environmental change at multiple spatial scales. In addition, individual movement or dispersal between adjacent localities could drown out local-scale environmental effects on population size. Such spatial autocorrelation in local abundance could be accounted for by including model parameters associated with the identity of plot clusters and the spatial coordinates of plots in regression models. Spatial autocorrelation would significantly reduce our statistical power to detect local-scale environmental effects, so the presence of spatial autocorrelation could necessitate follow-up studies. Identifying scale dependencies and elucidating which spatial-scale population drivers exist and are operating would be critical for making well-informed management decisions.

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APPENDICES – DATA SHEET FORMATS

Appendix 1- Vertebrates

PLOT CLUSTER:									
DATE:									
OBSERVERS:									
WEATHER & NOTES:									
	TIME START:								
	TIME END:								
	Plot Number:								
REPTILES - Tracks = (A=adults or H=hatchlings when applicable) Sightings = S (incl. perpendicular distance from plot center line)									
CV Fringe-toed Lizard	Tracks								
	Sighting								
Flat-tailed Horned Lizard	Tracks								
	Sighting								
Desert Horned Lizard	Tracks								
	Sighting								
Desert Iguana	Tracks								
	Sighting								
Zebra-tailed Lizard	Tracks								
	Sighting								
Western Whiptail	Tracks								
	Sighting								
Side-blotched Lizard	Tracks								
	Sighting								
Leopard Lizard	Tracks								
	Sighting								
Long-tailed Brush Lizard	Tracks								
	Sighting								
Banded Gecko	Tracks								
	Sighting								
Sidewinder	Tracks								
	Sighting								
Shovel-nosed Snake	Tracks								
	Sighting								
Coachwhip	Tracks								
	Sighting								
Other (specify)	Tracks								
	Sighting								
MAMMALS - Tracks = T, Vocals = V Sightings = S									
RT Ground Squirrel	T/V/S								
Desert K-rat (LG)	T/S								
Merriam's K-rat (SM)	T/S								
Palm Springs P-mouse (SM)	T/S								
Desert Pocket Mouse (LG)	T/S								
Jackrabbit	T/S								
Cottontail	T/S								
Kit Fox	T/S								
Coyote/Dog	T/S								
Woodrat	T/S								
Oher mammals (specify)	T/S								
INSECTS - (burrow)									
Sand treader Cricket									
BIRDS - Tracks = T Vocals = V Sightings = S (incl. distance)									
Kestrel	T/V/S								
Mourning Dove	T/V/S								
Roadrunner	T/V/S								
Raven	T/V/S								
Verdin	T/V/S								
Shrike	T/V/S								
Mockingbird	T/V/S								
LeConte's Thrasher	T/V/S								
House Finch	T/V/S								
Burrowing Owl	T/V/S								
Western Meadowlark	T/V/S								
Horned Lark									
Other birds (specify)	T/V/S								

Appendix 2 - Perennial Plant Datasheet

Plot:													
DATE:	INDIVIDUAL HEIGHT (CM)												
ASTRAGALUS LENTIGINOSUS													
AMBROSIA DUMOSA													
ATRIPLEX CANESCENS													
ATRIPLEX POLYCARPA													
CROTON CALIFORNICUS													
ENCELIA FARINOSA													
ENCELIA FRUTESCENS													
EPHEDRA NEVANDENSIS													
HYMENOCLEA SALSOLA													
ISOMERIS ARBOREA													
KRAMERIA GRAYI													
LARREA TRIDENTATA													
LEPIDOSPARTUM SQUAMATUM													
PETALONYX THURBERI													
PSOROTHAMNUS ABORESCENS													
PSOROTHAMNUS EMORYI													
STEPHANOMERIA SP.													
PROSOPIS GLANDULOSA													
TAMARIX SP.													
other:													

Appendix 3 – Annual Plant Datasheet

Plot:												
Date:												
SPECIES - No. of individuals / % COVER	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**
ABRONIA VILLOSA												
sand verbena												
ACHNATHERUM HYMENOIDES												
rice grass												
ACHYRONYCHIA COOPERI												
frost mat												
AMBROSIA ACANTHICARPA												
sand bur												
ASTRAGALUS ARIDUS												
milkvetch												
ASTRAGALUS LENTIGINOSUS												
cv milkvetch												
BAILEYA PAUCIRADIATA												
lax flower												
BRASSICA TOURNEFORTII												
Sahara mustard												
CAMISSONIA BOOTHII												
Booth's primrose												
CAMISSONIA CLAVIFORMIS												
brown-eyed primrose												
CHAENACTIS FREMONTII												
pincushion plant												
CHAMAESYCE ALBOMARGINATA												
sand mat												
CRYPTANTHA SP.												
DICORIA CANESCENS												
bug seed												
DITHYREA CALIFORNICA												
spectacle pod												
EREMALCHE EXILIS												
dune mallow												
ERIOPHYLLUM WALLACEI												
wooly daisy												
ERODIUM CICUTARIUM												
storks bill												
ERODIUM TEXANUM												
native storks bill												
GERAEA CANESCENS												
desert sunflower												
LOESELIASTRUM MATTHEWSII												
desert calico												
LOTUS STRIGOSUS												
LUPINUS ARIZONICA												
MALACOTHRIX GLABRATA												
desert dandelion												
MENTZELIA ALBICAULIS												
sand blazing star												
NICOTIANA OBTUSIFOLIA												
OENOTHERA DELTOIDES												
dune primrose												
PALAFOXIA ARIDA												
spanish needle												
PLANTAGO OVATA												
RAFINESQUIA NEOMEXICANA												
desert chickory												
SALSOLA TRAGUS												
tumbleweed												
SALVIA COLUMBARIAE												
chia												
SCHISMUS BARBATUS												
SISYMBRIUM SP.												
mustard												
STEPHANOMERIA EXIGUA												
STILLINGIA LINEARIFOLIA												

STILLINGIA SPINULOSA												
TIQUILIA PLICATA												
Other												
UNKNOWN												
% BARE GROUND												
% VEG COVER												
% dune sand												
% silt												
% gravel												
% rock												

Appendix 4 – Arthropod Datasheet

Date																								
Plot Cluster																								
Plot																								
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
% filled with sand																								
ANTS																								
Messor perganderi																								
Myrmecocystus flaviceps																								
Myrmecocystus kennedyi																								
Myrmecocystus tenuinodis																								
Pogonomyrmex californicus																								
Pogonomyrmex magnacanthus																								
Dorymyrmex sp.																								
Forelius pruinosus																								
Pheidole barbata																								
Solenopsis xyloni																								
BEETLES																								
Anobiidae																								
Niptus venticulus																								
Carabidae																								
Carabid larva																								
Calosoma pravicollis																								
Calosoma larvae																								
Tetragonoderus pallidus																								
Chrysomelidae sp.																								
Coccinellidae sp.- (lady bug)																								
Curculionidae																								
Ophryastes desertus																								
Ophryastes varius																								
Trigonoscuta imbricata																								
Dermestidae - *Novelsis picta*																								
Elateridae sp.																								
Meloidae sp.																								
Cysteodemus armatus																								
Phodaga alticeps - wing lifter																								
Melyridae sp.																								
Scarabaeiidae - *Diplotaxis fimbriata*																								
Anomalia flavila																								
Tenebrionidae sp.																								
Tenebrionidae larva																								
Araeoschizus hardyi																								
Asbolus laevis																								
Asbolus verrucosa																								
Asidina confluens																								
Batulius setosus																								
Batuloides obesus																								
Cheriodes californica																								
Chilometopon abnorme																								
Chilometopon brachystomum																								
Chilometopon pallidum																								
Cnemodinus testaceos																								
Cryptoglossa muricata																								
Edrotes barrowsi																								
Edrotes ventricosus																								
Eleodes armata																								
Embaphion depressum																								
Eupsophulus castaneus																								
Eusattus dificilis																								

Eustattus dubious																								
Metaponium sp.																								
Notibius puberulus																								
Telabis aliena																								
Trichiasida hirsuta																								
Triorophus laevis																								
Ulus crasus																								
Zopheridae																								
Zopherus sp.																								
Coleoptera sp.																								
SPIDERS																								
Araneae - Caponiidae - *Tarsonops* sp.																								
Araneae - Miturgidae - *Syspira* sp.																								
Araneae - Oonopidae - *Oonops* sp.																								
Araneae - Pholcidae - *Psilochorus* sp.																								
Araneae - Theridiidae - *Steatoda fulva*																								
Araneae - unidentified spider																								
OTHERS																								
Acari - Mite																								
Blattaria-*Averivaga*-sand roach																								
Collembola sp. - springtails																								
Dermaptera sp. - earwigs																								
Diplopoda - millipedes																								
Diptera sp.																								
Hemiptera																								
Homoptera																								
Hymenoptera sp.																								
Hymenoptera - Bradynobaenidae																								
Hymenoptera - Mutillidae - velvet ants																								
Neuroptera - Myrmeliontidae - Ant lion																								
Orthoptera -sand-treader cricket																								
Orthoptera sp.																								
Scorpiones- Smeringurus mesaensis																								
Scorpiones-Vaejovis sp.																								
Scorpiones sp.																								
Solifugae - solpugid																								
Thysanura - silverfish A (silver)																								
Thysanura - silverfish B (gold)																								
Misc sp.																								