IDENTIFYING HABITAT CORRIDORS FOR PALM SPRINGS POCKET MOUSE POPULATIONS

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SUMMARY

The high degree of anthropogenic land cover changes that have occurred in the Coachella Valley over the past four decades resulted in the Palm Springs pocket mouse (PSPM), *Perognathus longimembris bangsii*, being classified as a "species of special concern" by the state of California. The pocket mouse is also one of 27 focal species driving the design of the proposed Coachella Valley Multiple Species Habitat Conservation Plan and Natural Community Conservation Plan. One of the objectives of the Coachella Valley conservation program is to maintain current connectivity between perceived core habitat areas for each species. To help meet that objective for the PSPM we modeled both historic and current suitable habitat for this species. We then determined the extent to which habitat with high suitability for the pocket mice occurs between identified core reserve areas, thus providing an indication of the potential for occupancy within those corridors.

We modeled habitat suitability modeling using a partitioned Mahalanobis D^2 distance statistic to create spatially explicit niche models, describing the distribution of suitable habitat for PSPM remaining within the Coachella Valley. We identified suitable habitat at three levels (low, moderate and high) that described how close the multivariate mean of environmental variables within 150 m x 150 m map cells where the PSPM occur currently or historically aligned with those same variables within map cells covering the entire valley floor. Of the 170,195 ha (420,381 ac) area included in our analysis, historically 39,200 ha were classified as moderately suitable habitat and 31,588 ha were classified as habitat with high suitability for Palm Springs pocket mouse occupancy (leaving 99,407 ha classified as having low habitat suitability). Of that high suitability modeled habitat approximately 25,119 ha (62,043 ac) remains undeveloped. The majority of that habitat modeled with high suitability was located in the northern and western regions of the Coachella Valley. The modeled habitat within and between the Snow Creek, Whitewater Floodplain, Willow Hole, Mission Creek and Thousand Palms/Fan Hill core reserves was all classified as high suitability, indicating Palm Springs pocket mice currently can find habitat within and between each of those core reserves. There are several major roads that potentially compromise the connectivity of the habitat between the core reserves. Our analyses were designed to determine the extent of continuous habitat within and between reserves, not to resolve whether or not that connectivity has been compromised by roads or other anthropogenic structures.

An additional outcome from or live trapping results was that Palm Springs pocket mice were not found in active portions of dry washes, but were common on more stable "benches" within and paralleling those washes. Corridor designs will need to incorporate these bench areas to provide effective connectivity for this species.

INTRODUCTION

Little pocket mice (*Perognathus longimembris)* are restricted to fine sandy soils throughout their distribution (Jameson and Peeters 1988). That edaphic constraint and the disjunct distribution of those soils has likely contributed to a high degree of taxonomic divergence leading to as many as 23 named subspecies throughout the western United States (McKnight 2005). Within the confines of the Coachella Valley, California, the little pocket mouse subspecies is generally accepted as *P.l. bangsi*, the Palm Springs pocket mouse (PSPM), although genetic analyses (Swei et al. 2003, McKnight 2005) indicate complex genetic affinities here. PSPM are found from the San Gorgonio Pass area east to the Little San Bernardino Mountains and south along the eastern edge of the Peninsular Ranges to Borrego Valley where they inhabit flat to gently sloping topography, sparse to moderate vegetative cover, and loosely packed or sandy soils (Dodd 1996). Historically, their range in the Coachella Valley was likely more extensive but their occurrence is now highly fragmented. The Coachella Valley and the San Gorgonio Pass area contains a large portion of the PSPM range, including the western, northern, and eastern limits of its distribution (CVAG, 2006). Anthropogenic habitat modification including habitat fragmentation from agricultural and suburban development and reduced habitat patch size has occurred throughout most of the valley and elsewhere within PSPM distribution. This subspecies is classified as a “sensitive species” by the Bureau of Land Management and a “species of special concern” by the state of California. Additionally, the PSPM is one of 27 focal species driving the design of the proposed Coachella Valley Multiple Species Habitat Conservation Plan and Natural Community Conservation Plan (MSHCP/NCCP). The research presented here was funded through a Local Assistance Grant awarded to the Coachella Valley Association of Governments (CVAG) by the California Department of Fish and Game in support of CVAG’s efforts to design and implement the MSHCP/NCCP.

Modeling a species’ habitat begins with identifying variables that constrain its distribution across a heterogeneous landscape (Rotenberry et al. 2002, 2006). Identifying habitat relationships allows us to model suitable habitat available for a species and to describe potential current and historical distributions, leading both to quantifying the extent of a species’ habitat loss, and to identify core sites most suitable for protection strategies. Beyond providing core areas of sufficient size to sustain populations, one of the conservation objectives for the Coachella Valley includes maintaining existing connectivity between core reserve sites. In support of that objective, our tasks included:

- creating habitat suitability maps of historic and current suitability that revises and refines the distribution map for PSPM in the Coachella Valley
- using the model of current habitat suitability, identifying and mapping areas of habitat connectivity between core areas
- mapping potential barriers to movement along those corridors; and
- validating the model statistically and through trapping, and determining whether the PSPM occupies the identified corridors.

The Mahalanobis statistic (Clark et al 1993; Rotenberry et al. 2002, 2006; Browning et al. 2005) results in the calculation of an index of its habitat similarity (HSI), scaled from 0 to 1, for any location within the modeled area. This statistic has several advantages over other spatially explicit modeling approaches, the foremost being that only species presence data are required for the dependent variable. Since only positive occurrence data are required, data can used from a wide range of disparate sources including location records from museums, as long as there is sufficient precision in the site location. This also avoids the uncertain assumption of correct identification of unoccupied habitats (Knick and Rotenberry 1998; Rotenberry et al. 2002; Browning et al. 2005). Another advantage of using the Mahalanobis statistic is that the results may be further refined by partitioning them into separate, additive components (Dunn and Duncan 2000; Rotenberry et al. 2002, 2006). This partitioning is based on a principal components analysis of the variables and observations comprising a calibration dataset. The partition or component with the smallest eigenvalue is associated with the multivariate combination of habitat characteristics that has the least variation among locations, and since they are the most consistent from site to site, may identify those habitat requirements that are most critical to the occurrence of a species. Identifying the variables that demonstrate the least variability may be more appropriate for modeling potential or historic distributions in changing environments (Dunn and Duncan 2000; Rotenberry et al. 2002, 2006). A similar niche modeling effort was recently conducted for both the Coachella Valley fringe-toed lizard, *Uma inornata*, and the flat-tailed horned lizard, *Phrynosoma mcallii*, and yielded accurate models of both current and historic distributions for these species (Barrows et al, 2008).

Corridors and their utility is a much debated topic in conservation biology (Lindemayer and Fischer 2006). The debate is not whether connectivity is important to population sustainability, but whether given corridors function to provide connectivity for specific species or ecological process. Here we assume that, due the small size of PSPM, their movement distances are relatively small. Therefore, our use of the term corridors confined to areas of suitable habitat where PSPM could maintain home ranges. This is in contrast to the use of corridor term for larger mammals, bats and birds, which can traverse expanses of unsuitable habitat relatively rapidly and so would not need to reside within movement corridors. Our assumption for PSPM simplifies corridor identification; potential corridors were mapped as suitable habitat as part of the niche modeling process. With this definition of a suitable corridor (requiring sufficient habitat for occupancy) the separation of core versus corridor habitats becomes muddied. To avoid that confusion, we start with the *a priori* identification of core areas as: 1) Windy Point – Snow Creek; 2) Fault-line dunes – Willow Hole; 3) Whitewater Floodplain Preserve; 4) Thousand Palms Preserve; and 5) the upper Mission Creek and Morongo Wash channels.

METHODS

Our study area was confined a 170,295 ha (420,629 ac.) area of the floor of the Coachella Valley of Riverside County, California, extending south to the county border (Fig. 1). The modeled area corresponded to relatively flat topography and the extent of available soils GIS layers. We collected historic data on PSPM locations from a variety of sources including the University of California Museum of Vertebrate Zoology, California Academy of Sciences, and California Natural Diversity Data Base of the California Department of Fish and Game. All museum locality records and biologists' sighting locations were georeferenced to ≤150 m resolution. Unfortunately many of the older museum records lacked sufficiently accurate location information in order to accurately map historic lizard locations; we were unable to include those data. These records were not collected in a systematic or repeated manner; therefore, they document presence only. These sources yielded 54 spatially non-redundant locations (i.e., locations at least 150 m apart) for PSPM. We used these historic data (ranging from 1908 to 2004) to calibrate and validate the pocket mouse distribution model.

Niche modeling

We used the Mahalanobis distance statistic (D^2) (Clark et al., 1993; Rotenberry et al., 2002; 2006; Browning et al., 2005) to model the distribution historic and currently available suitable habitat for the pocket mouse. The Mahalanobis statistic yields for any location an index of its habitat similarity (HSI) to the multivariate mean of the habitat characteristics at the target species' locations (the calibration data set). We calculated Mahalanobis distances and their partitions with SAS code provided in Rotenberry et al., (2006).

Habitat variables – We selected habitat variables based on our expectation of their likely influence on the distribution of PSPM based on our literature reviews, and their independence from anthropogenic change in the valley. To prevent model over fitting, we maintained a variables-to-observations ratio of 1:10 (one variable per 10 observations). Because the calibration data set contained 40 non-redundant observations, we limited the number of variables to 4-5. We ran partitioned Mahalanobis D^2 models with different suites of abiotic variables describing soils, climate, and elevation.

Variables used to model suitable habitat for PSPM included three soil classifications: Myoma fine sand 5-15% slope (MaD), Myoma fine sand 0-5% slope (MaB), and Carsitas gravelly sand 0-9 % slope (CdC), (Soil Conservation Service, 1980). In addition to the soil variables, elevation and slope calculated from digital elevation models (DEM) (http://prism.oregonstate.edu/docs/meta/ppt_30s_meta.htm, PRISM Group, Oregon State University) were incorporated as independent variables into the models.

For the niche-modeling process a GIS map of the Coachella Valley was uniformly divided into 75,687 150 m x 150 m cells. Each cell was scored for the underlying abiotic environmental variables using a neighborhood analysis; a mean score was generated for the 5 cells that include and abut the cell that contained a species' observation. Cells that contained a species' observation were extracted to create the calibration data set from which a species' habitat model was created. Once a model was created, it was used to calculate HSIs for each Mahalanobis distance partition for every cell on the map. Following Rotenberry et al., (2006), HSI was rescaled to range from 0-1, with 0 being the most dissimilar and 1 being identical to the mean habitat characteristics of PSPM based on the calibration data set. ArcGIS 9.1 (ESRI 2005) was used to provide a spatial model (niche map) of the similarity to the species mean for each cell. These modeled areas were then screened for anthropogenic changes to the soil surface with GIS layers for agricultural development and urban-suburban to derive an estimate of current suitable habitat availability.

Niche model validation – Validation data sets were employed to select which of the model-partitions created in the Mahalanobis niche-modeling process represented the most accurate model. Twenty five percent of the total data set of 54 spatially non-redundant pocket mouse locations (14) were randomly selected and used to independently validate the model developed from the calibration data set (40 locations). Mean HSI values for the validation points were calculated for each partition for each model (each combination of variables). The model partition that yielded the highest mean HSI values for the validation data set was selected as the best performing model.

Live trapping

We conducted live trapping for PSPM to evaluate model predictions of suitable habitat and identify PSPM occupancy along proposed linkage zones. We were limited in the locations for our trapping to public access, public right-of-way, and existing conservation ownership, and so the trapping effort was neither comprehensive in meeting our objectives nor were the trapping locations randomly distributed. We used 9 cm x 7.5 cm x 23 cm (3.5" x 3" x 9") Sherman aluminum traps, each fitted with a "clip-adapter" attached to the trap entrance keep the door from closing snugly and so eliminating tail damage to kangaroo rats, *Dipodomys* spp., caught inadvertently. Each trap was baited with organic dry rolled oats in order to not spread exotic weed seeds sometimes associated with seed mixes. Trapping occurred only when evening temperatures were above 15.5˚C (60˚F), and when wind speeds were below 33km/hr (~20mph) to prevent extensive trap closure, and unnecessary episodes of torpor. All traps were set at or near dusk and then checked and collected at or near midnight so as to reduce potential stress to the trapped animals. Individuals were marked lightly on the ear with a Sharpie ink pen to identify them as recaptures on subsequent trap nights. Once caught individuals quickly had their weight, sex, age, and capture coordinate, as well as the time, temperature, and wind speed recorded before they were released unharmed.

Areas within the Coachella Valley where we conducted PSPM live trapping included Mission Creek, Fault line Dunes, Tipton Road, Upper Thousand Palms Canyon, Whitewater Floodplain Preserve, the Palm Springs Amtrak Station, and Dos Palmas. Within these areas, 32 sites were selected to test for the presence/absence of the Palm Springs Pocket Mouse. At each site, 20 Sherman traps were laid in four clusters, with clusters at least 250 meters apart. The spacing allowed us to evaluate PSPM presence or absence within varying habitat, slope, and soil types (for a total of 80 traps /site). Our objective was to determine presence, not abundance or density, so the same location was trapped for up to three successive nights or until a PSPM was captured. Once a PSPM was captured, trapping at that location ceased and our trapping efforts were directed to a new location. Since our tapping at any one location was not exhaustive we accept that PSPM may well have been present at locations where, after three nights of trapping we did not find them. However at the locations where they were found to be present, they were invariably captured the first night of trapping. Species were identifications were based on diagnostic hind foot and ear measurements along with pelage color. Trapping was conducted under CDFG Permit # 008781 and UC AUP Permit # A-20070022 and followed the ASM preliminary guidelines for field work in Mammology (American Society of Mammologists, 1998).

RESULTS

The best performing Mahalanobis D^2 model consisted of soil and topography variables; Myoma fine sand 5-15% slope (MaD), Myoma fine sand 0-5% slope (MaB), and Carsitas gravelly sand 0-9 %, along with elevation and slope. Other variables, including mean maximum temperature in July, mean minimum temperature in January, along with vegetation community types, including ephemeral aeolian sand fields, stabilized sand fields, Sonoran creosote bush scrub, and Sonoran mixed woody and succulent scrub, all of which occurred at PSPM locations, were tried in multiple combinations with and without the soils variables, but no variable combination performed as well as the soils-elevation-slope model. The soil type most commonly occurring at or near cells occupied by PSPM and used for calibrating the model was Carsitas gravely sand (typically fine alluvial sands), followed by Myoma fine sand with 0-5% slope, corresponding to stabilized aeolian sand fields. Myoma fine sand 5-15% slope, (active dunes), had the least occupancy rate of the soils types used in our niche model. The mean slope was just under 2%, indicating flat terrain.

The mean HSI value for the cells of the independent validation data set was 0.796. The high mean HSI of the occupied cells used for validation indicated the model correctly identified cells with high suitability for PSPM. Our analysis resulted in a niche model that identified approximately 41% of our 170,295 ha study area as having potential PSPM habitat with HSI values ≥ 0.333 (moderate habitat suitability), and 18% of the area with HSI values ≥ 0.666

(high habitat suitability) prior to anthropogenic land cover changes of the past roughly 100 years (Table 1). Current potential PSPM habitat with HSI values ≥ 0.666 covers 15% of our study area.

Table 1. Modeled areas for historic and recent extents of suitable habitat for the Palm Springs pocket mouse.

Historic Modeled Area HSI ≥ 0.333 < 0.666	Historic Modeled Area HSI ≥ 0.666	Current Modeled Area HSI ≥ 0.666
39,200 ha	31,588 ha	25,119 ha 20% loss

The spatial model resulting from our Mahalanobis D^2 analysis indicated the majority of the highest ranking PSPM habitat historically as well as currently occurring in the northern and western-most portions of the Coachella Valley (Figs. 1 and 2). Historically there was contiguous modeled PSPM habitat extending south on the eastern and western edges of the Coachella Valley extending to and bordering the Salton Sea. The relative lack of modeled habitat with high suitability in the center of the valley (Fig. 1) corresponds to active aeolian sand dunes and the historic extent of Lake Cahuilla. Currently that southern modeled habitat is no longer contiguous (Fig. 2). A closer view of the northern-western portion of the Coachella Valley shows contiguous habitat still exists between four of the five proposed core habitat reserves proposed in that region (Fig. 3). However, there are numerous roads, including an 8-lane Interstate Freeway that compromise the effectiveness of that connectivity.

Our live trapping resulted in positive PSPM captures at 66% of the locations trapped (Table 2). Three areas yielded no PSPM captures: 1) the Dos Palmas Access Road; 2) the Indian Avenue-Train Station; and 3) the Whitewater Floodplain Preserve. The Dos Palmas Access Road was modeled to have lower and patchier habitat suitability. The locations at Indian Avenue and the Whitewater Floodplain Reserve were among the windiest locations that were trapped, and also had the coarsest gravel and rock underneath the ephemeral aeolian sand. At both these locations several individuals of the Desert pocket mouse (*Chaetodipus pencillatus*) and the Merriam's kangaroo rat (*Dipodomys merriami*) were captured.

The design of our live trapping protocol allowed us to evaluate the occurrence of PSPM associated with the proposed corridor for this species along Mission Creek as well as the buffer zone and banks. PSPM were trapped at each of the four locations selected along that corridor Mission Creek 1, 2, 3, and faultline-powerline locations). At these locations, half of the traps were placed within the dry wash area, and half were placed on the bank above. We also trapped locations in increasing distance from Mission Creek with each location 250m from the last. PSPM were only trapped on the more stabilized benches and bank areas near the creek, but were not captured in the active wash channel. In the faultline-powerline locations, PSPM were captured on the final night, at the farthest location from the dunes, but still on the bank of dry wash drainage. This was also the case in Upper Thousand Palms Canyon, where a PSPM was caught just outside a dry wash drainage area, upon the bank where the soil was more compact and gravelly.

Discussion

Dodd (1996, 1997) conducted extensive trapping for this species within the Coachella Valley and surrounding region, and found much higher PSPM densities in the northern and western Coachella Valley. These results, supported by our own trapping data, support the patterns of suitable habitat indicated by our niche model. Dodd (1996, 1999) did record PSPM at the three locations where we failed to detect them, but only after > 1000-2000 trap nights, compared to the ≤ 240 trap nights we spent at any one location.

Other Coachella Valley floor species, such as the Coachella Valley fringe-toed lizard, *Uma inornata*, and flat-tailed horned lizard, *Phrynosoma mcallii*, have both lost > 90% of their historic suitable habitat (Barrows et al. 2008). In comparison, a much greater extent of suitable PSPM habitat remains undeveloped. Additionally, as suitable PSPM habitat appears much less tied to retaining active aeolian and fluvial sand transport processes, the extent those processes have already been compromised should have less negative impact on the sustainability of PSPM populations than it has on the two lizards.

Our niche model, coupled with the results of others (Dodd, 1996, 1999), indicates that PSPM typically occur on alluvial fans with loose sands often intermixed with coarser gravel. PSPM densities are highest in the relatively cool/mesic climate regime of the western and northern Coachella Valley, but they continue to occur at low densities in the more stabilized aeolian sand communities, and more extreme conditions of the southern valley and east into Shavers Valley (Dodd 1999). Our results indicate that PSPM avoid the more dynamic active sand dunes that once occupied much of the center of the Coachella Valley, and are less abundant on very active ephemeral sand fields and dry washes. It is not clear whether it is the degree of surface disturbance, fewer clay-sized particles in the sediments that would promote burrow integrity, distribution of food resources, vegetation cover, or some other variable which PSPM are avoiding in these areas. Whatever the ultimate cause, this observed pattern has implications to the potential effectiveness of corridors designated to ensure connectivity of protected PSPM populations.

Based on our niche model, remaining suitable habitat for the PSPM in the southern Coachella Valley consists of patches of varying size, with historic levels of connectivity lost largely due to agricultural land conversion. In contrast the apparent extent and level of modeled habitat suitability and contiguity of that habitat in the northern and western portions of the Coachella Valley remains intact. The lack of discrete habitat patches there indicates that historically this area would have likely supported a single, interacting PSPM population. More recent anthropogenic road development and urbanization have partitioned this landscape. The extent to which roadways create barriers to small mammal movements has been examined in other species, but not PSPM. Those studies have shown that roads constitute significant but permeable barriers for those species and road types analyzed (Clark et al. 2001, McGregor et al. 2008). Our analyses were designed to identify the distribution and relative suitability of habitat for PSPM along potential corridors; we did not examine the effect of barriers such as roadways on the effectiveness of those corridors to provide connectivity for PSPM.

The conservation design for PSPM and other species in the northern and western Coachella Valley has been to create habitat reserves that encompass the habitat variation of that original landscape and that were sufficiently large as to be able to independently sustain PSPM populations, but to also retain whatever inter-reserve connectivity remained (CVAG 2006). The five core reserves that were designated each included between 1000-4500 ha of PSPM habitat (CVAG 2006). Based on reported PSPM densities (Chew and Butterworth 1964, Dodd 1996), these reserves could support PSPM populations ranging from 5,800 (Thousand Palms) to 74,000 (Snow Creek). Interstate 10, an 8-lane freeway, likely creates an impermeable barrier to PSPM unless they are able to navigate culverts that span the roadway's width. The connectivity between the Snow Creek-Windy Point and Whitewater floodplain core reserves, and the Willow Hole-Faultline Dunes and Upper Mission Creek-Morongo Wash core reserves may still be intact if PSPM can cross the several 2-lane roads that bisect those corridors. Both of these corridors have additional important functions of sand transport to aeolian sand habitats, but our trapping results demonstrated that to also serve as connectivity for PSPM populations, continuous less disturbed habitats in buffer areas adjacent to the main flood channels will also require protection.

Table 2. Summary of live trapping results for PSPM.

Date	PSPM Capture	General Location	UTMNAD27E	UTMNAD27N
	-	Dos Palmas	604384	3707045
	-	Dos Palmas	604667	3707048
	-	Dos Palmas	604973	3707057
	-	Dos Palmas	605238	3707070
	-	Indian Ave - Train Station	541741	3750684
	-	Indian Ave - Train Station	541988	3750529
	-	Indian Ave - Train Station	541987	3750529
4/24/2008	X	Faultline-Powerline road	544935	3751542
4/24/2008	X	Faultline-Powerline road	544923	3751544
4/24/2008	X	Faultline-Powerline road	544922	3751561
4/24/2008	X	Faultline-Powerline road	544940	3751581
4/24/2008	X	Faultline-Powerline road	544923	3751588
4/24/2008	X	Faultline-Powerline road	545746	3751752
4/24/2008	X	Faultline-Powerline road	544737	3751773
	-	Faultline-Powerline road	544524	3751956
	-	Faultline-Powerline road	544330	3752141
	-	Mission Creek 1	539337	3760804
6/4/2008	X	Mission Creek 1	539391	3761100
	-	Mission Creek 1	539135	3761116
	-	Mission Creek 1	538900	3761233
	-	Mission Creek 2	541730	3759124
	-	Mission Creek 2	541553	3759339
	-	Mission Creek 2	541342	3759542
6/11/2008	X	Mission Creek 2	541101	3759665
	-	Mission Creek 3	539491	3761330
6/2/2008	X	Mission Creek 3	537401	3761740
	-	Mission Creek 3	537112	3761760
6/2/2008	X	Mission Creek 3	536872	3761826
	-	Mission Creek 3	536598	3761886
6/17/2008	X	Tipton Road	532834	3751563
6/17/2008	X	Tipton Road	532834	3751563
6/17/2008	X	Tipton Road	532554	3751620
6/17/2008	X	Tipton Road	532552	3751621
	-	Tipton Road	532135	3751948
	-	Tipton Road	532345	3751763
6/17/2008	X	Tipton Road	532565	3761617
	-	Whitewater Floodplain Preserve	545699	3748543
	-	Whitewater Floodplain Preserve	545428	3748568
	-	Whitewater Floodplain Preserve	545177	3748709
3/26/2008	X	Upper Thousand Palms Canyon	564643	3748422

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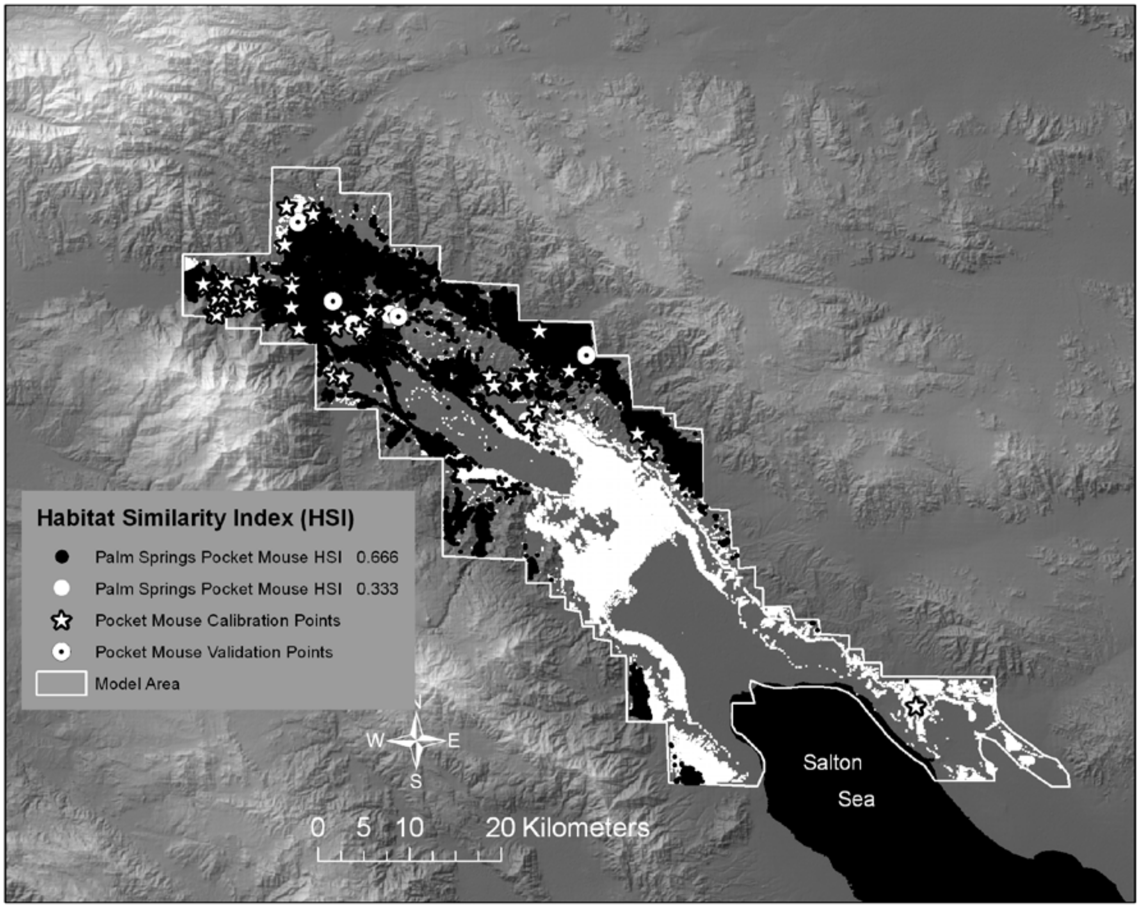

Figure 1. Mahalanobis D^2 niche model of the historic extent of suitable habitat for the Palm Springs pocket mouse in the Coachella Valley.

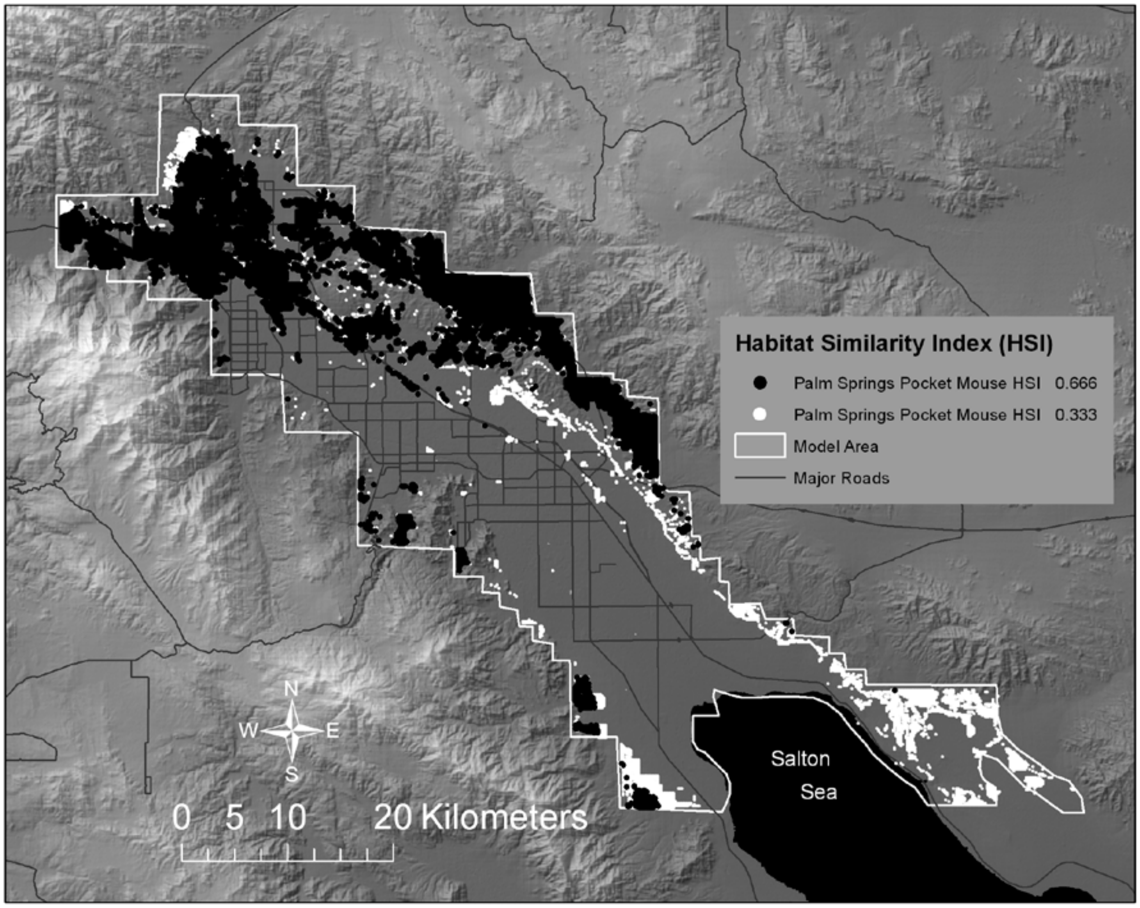

Figure 2. Current extent of modeled suitable habitat for the Palm Springs pocket mouse in the Coachella Valley. Historic niche model was screened with the current extent of suburban development and agriculture.

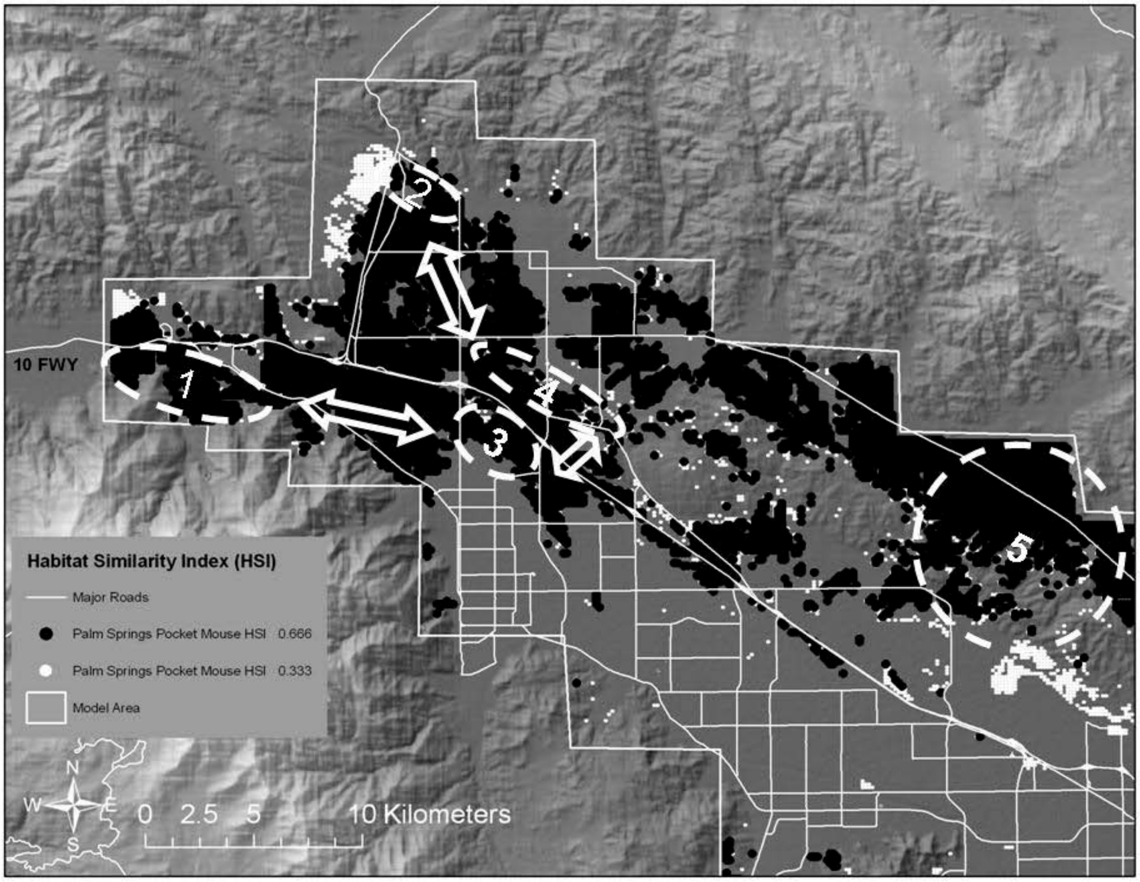

Figure 3. Closer view of the modeled suitable habitat for the Palm Springs Pocket mouse in the northern and western portion of the Coachella Valley. Proposed core habitat areas are delineated as: 1) Snow Creek; 2) upper Mission Creek and Morongo Washes; 3) Whitewater floodplain; 4) Willow Hole-Fault line Dunes; and 5) upper Thousand Palms Canyon-Fan Hill. Arrows indicate potential zones of connectivity between core reserves as well as showing potential road barriers to that connectivity.

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