Impacts of Land Use and Climate Change on Mojave Desert Tortoise Gene Flow and Corridor Functionality

SERDP Project RC18-C1-1207

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RC-1207: Impacts of Land Use and Climate Change on Mojave Desert Tortoises Gene Flow and Corridor Functionality

Performers: *UNR, USGS*

Technology Focus

- *How will land use and climate change impact Mojave desert tortoise gene flow and corridor functionality?*

Research Objectives

- *Present/future habitat and population connectivity*
- *Gene flow among differing climate futures*
- *Identify species under the desert tortoise 'umbrella'*
- *Installation specific management and strategic partner recommendations*

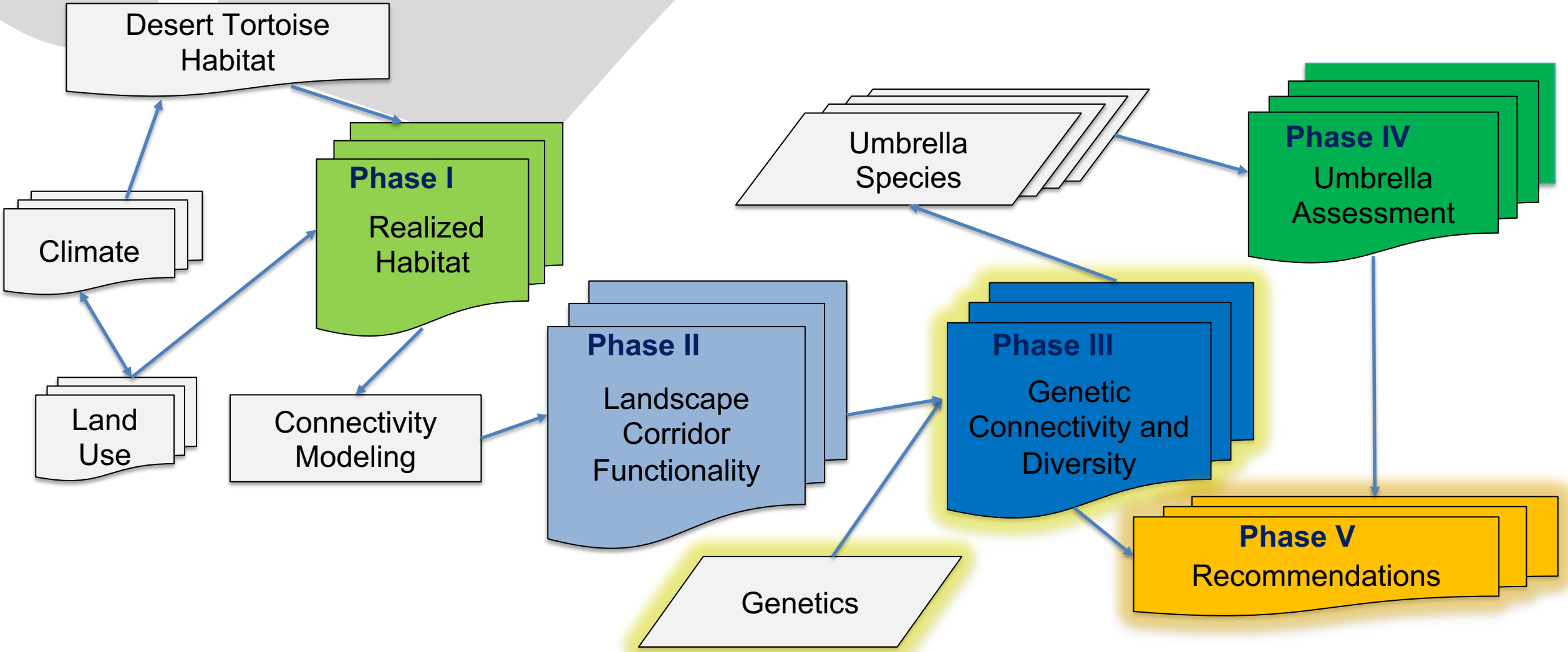
Project Progress and Results

- *Tortoise DNA sequencing, habitat and connectivity under future land use and climate, umbrella assessment*

Technology Transition

- *Assess potential for dynamic land use/climate/impact mapping with DoD installations*

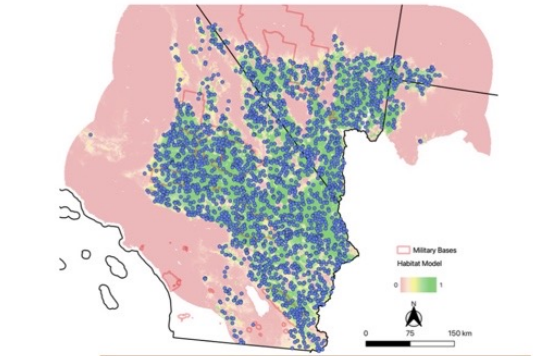
Technical Approach

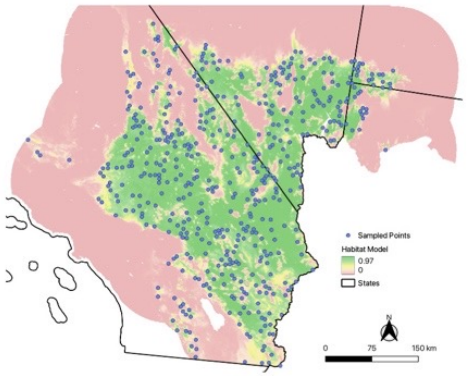


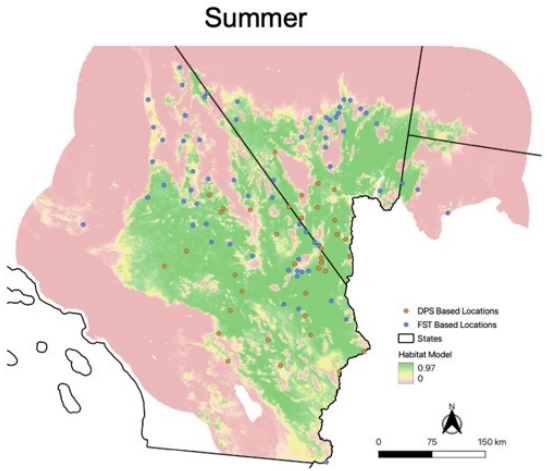
Habitat Modeling

Expanded Dataset of Tortoise Locality data

Sampling Design- Spatial Patterns of Diversity/Connectivity







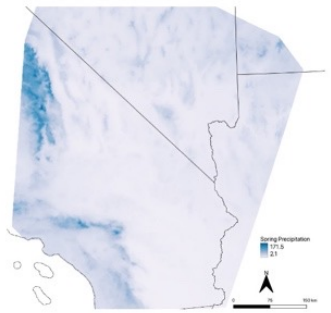
Geographical Space
SDM and distance based

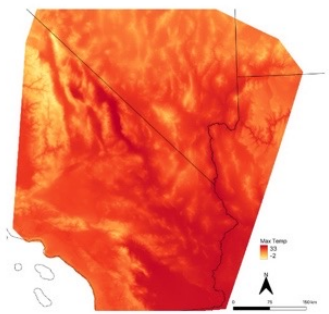
Climate Data
PRISM

Environmental Approach
n = 497

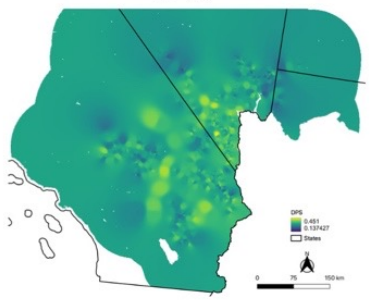
Genetic Approach
Genetic divergence

Sampling Design
n = 124 or 122

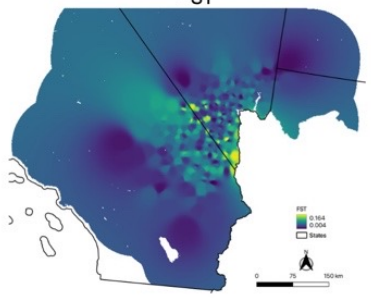




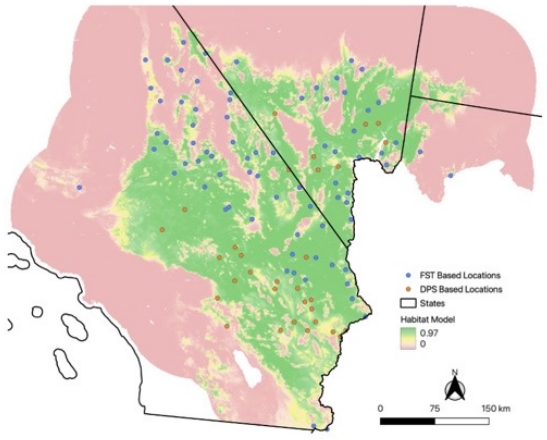
DPS



F_{ST}



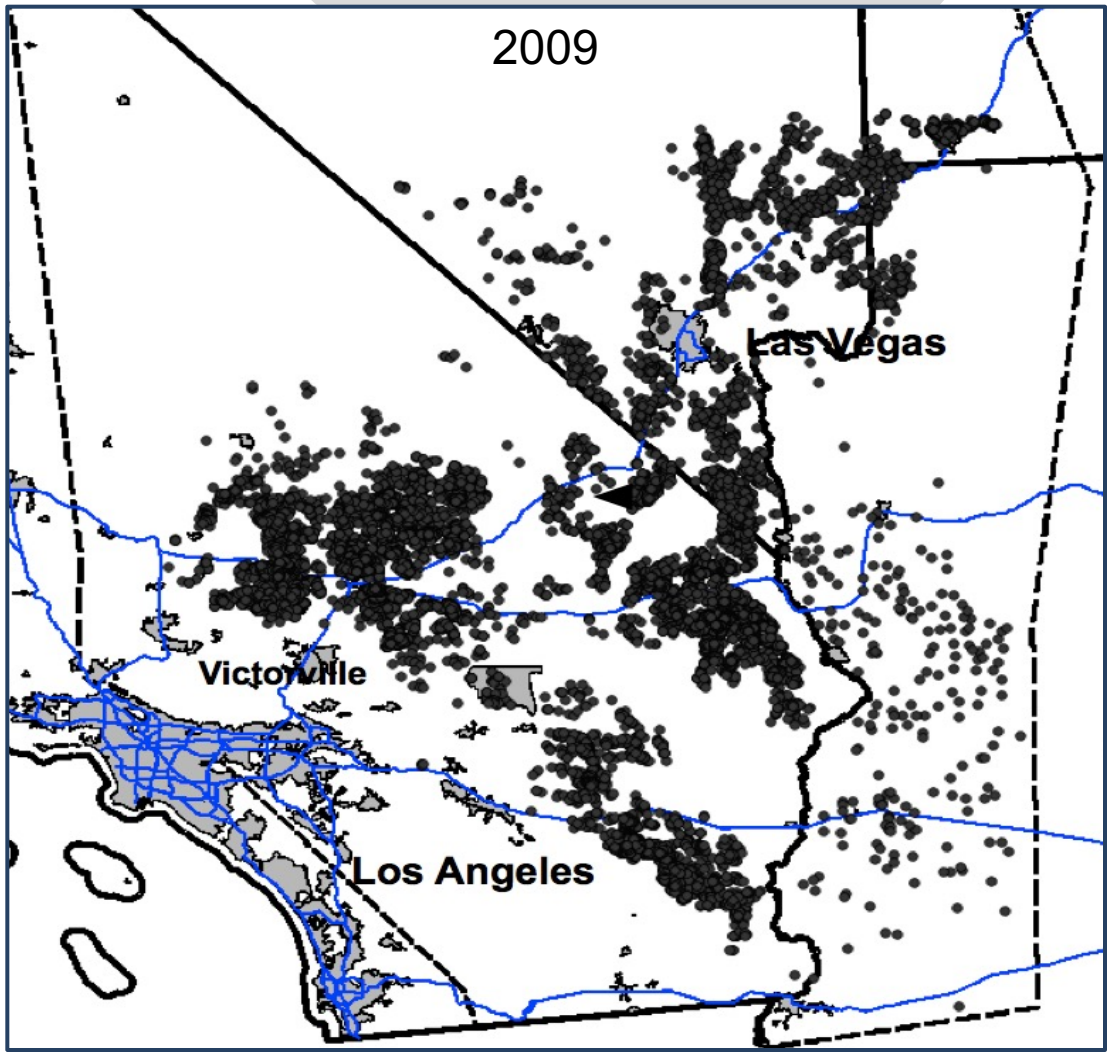
Spring



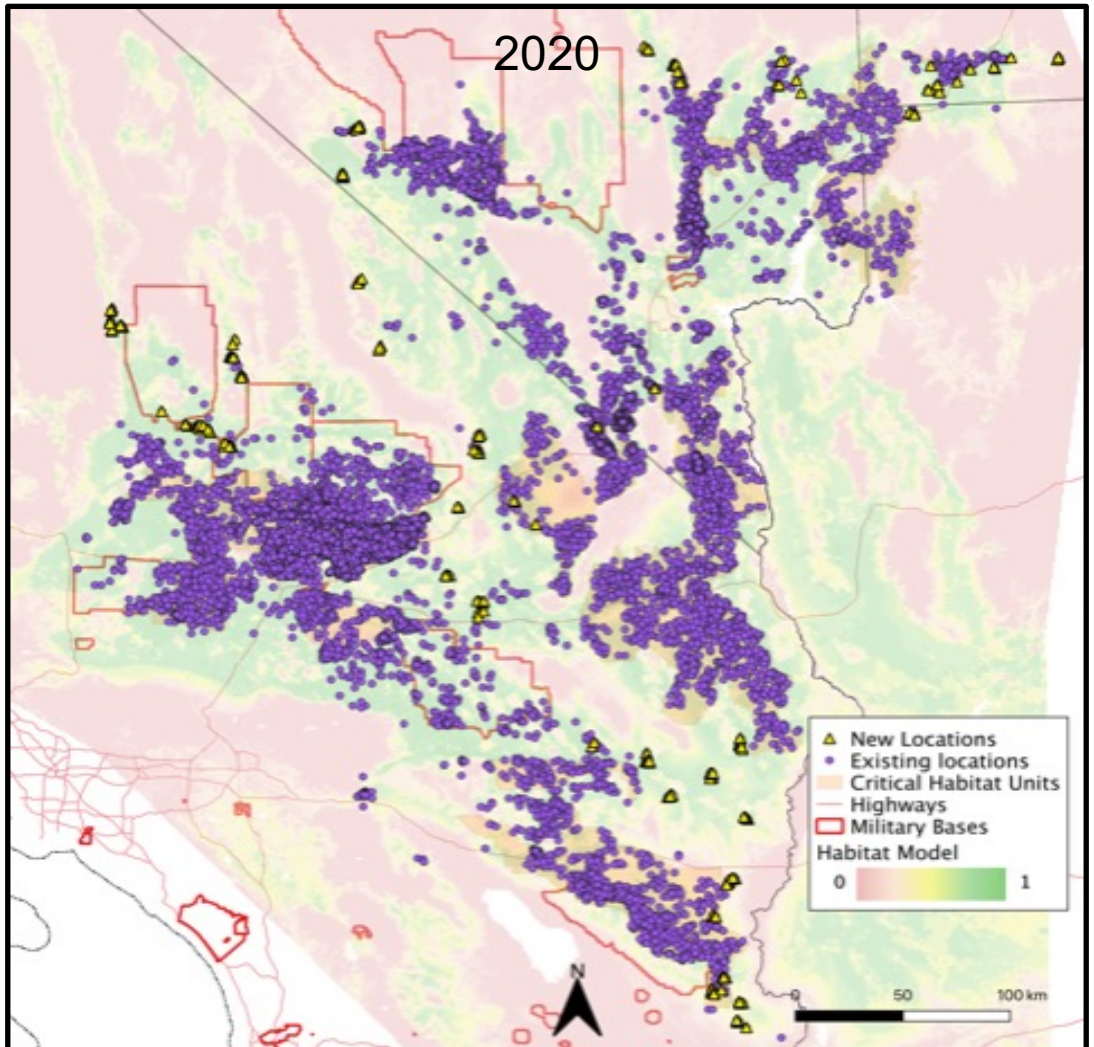
Habitat Modeling (Current Time Period)

Expanded Dataset of Tortoise Locality data

15,311

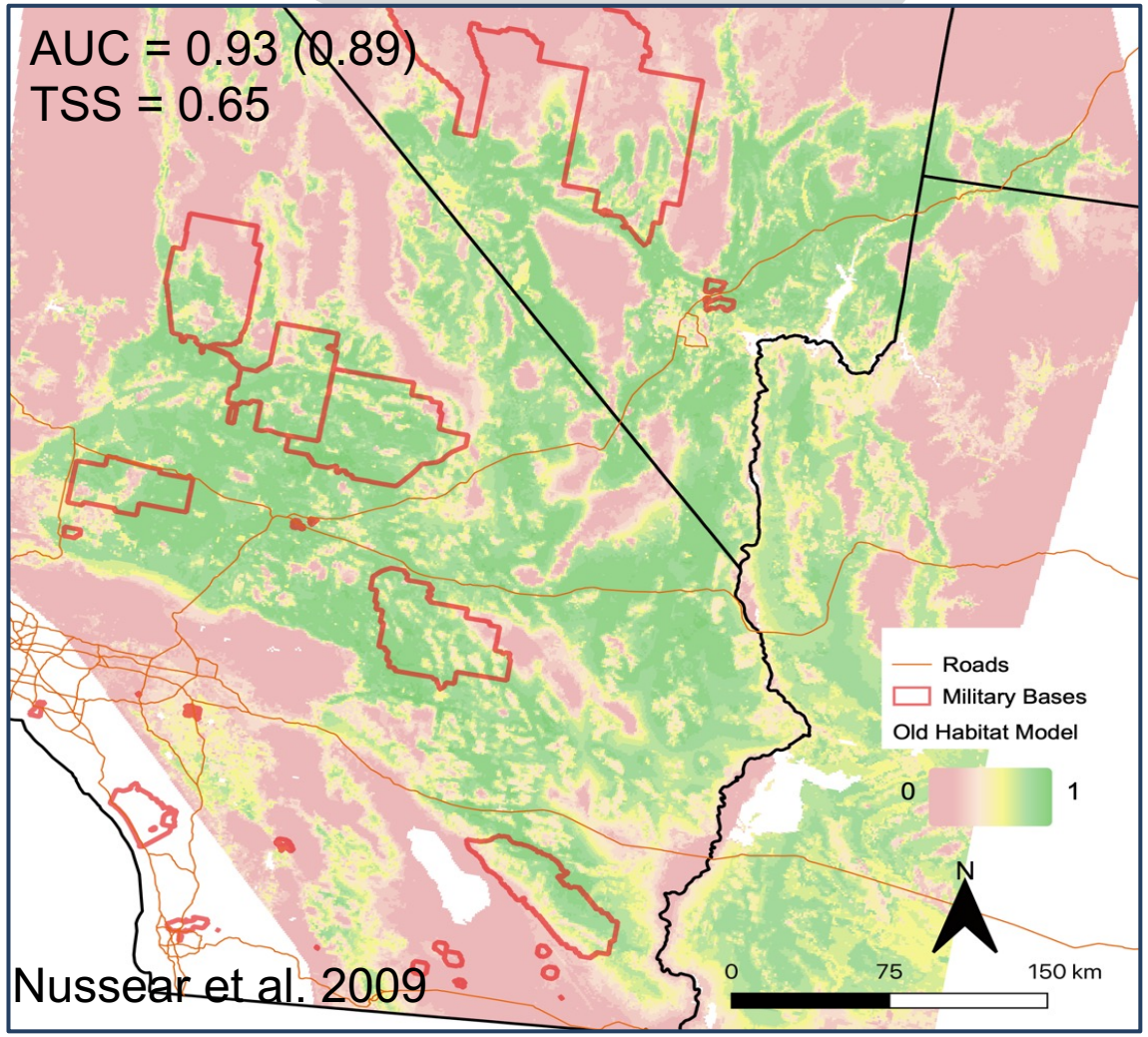


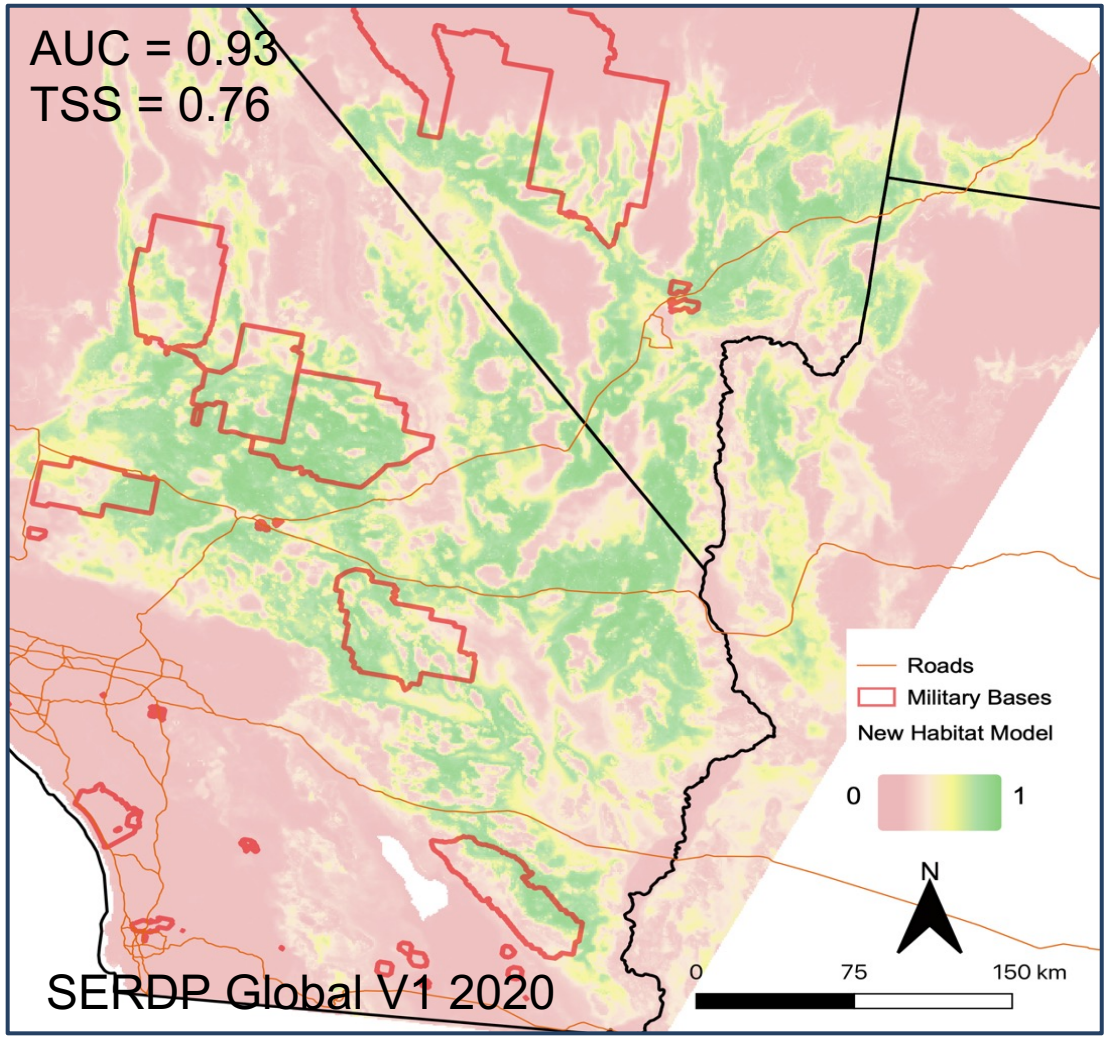
253,360

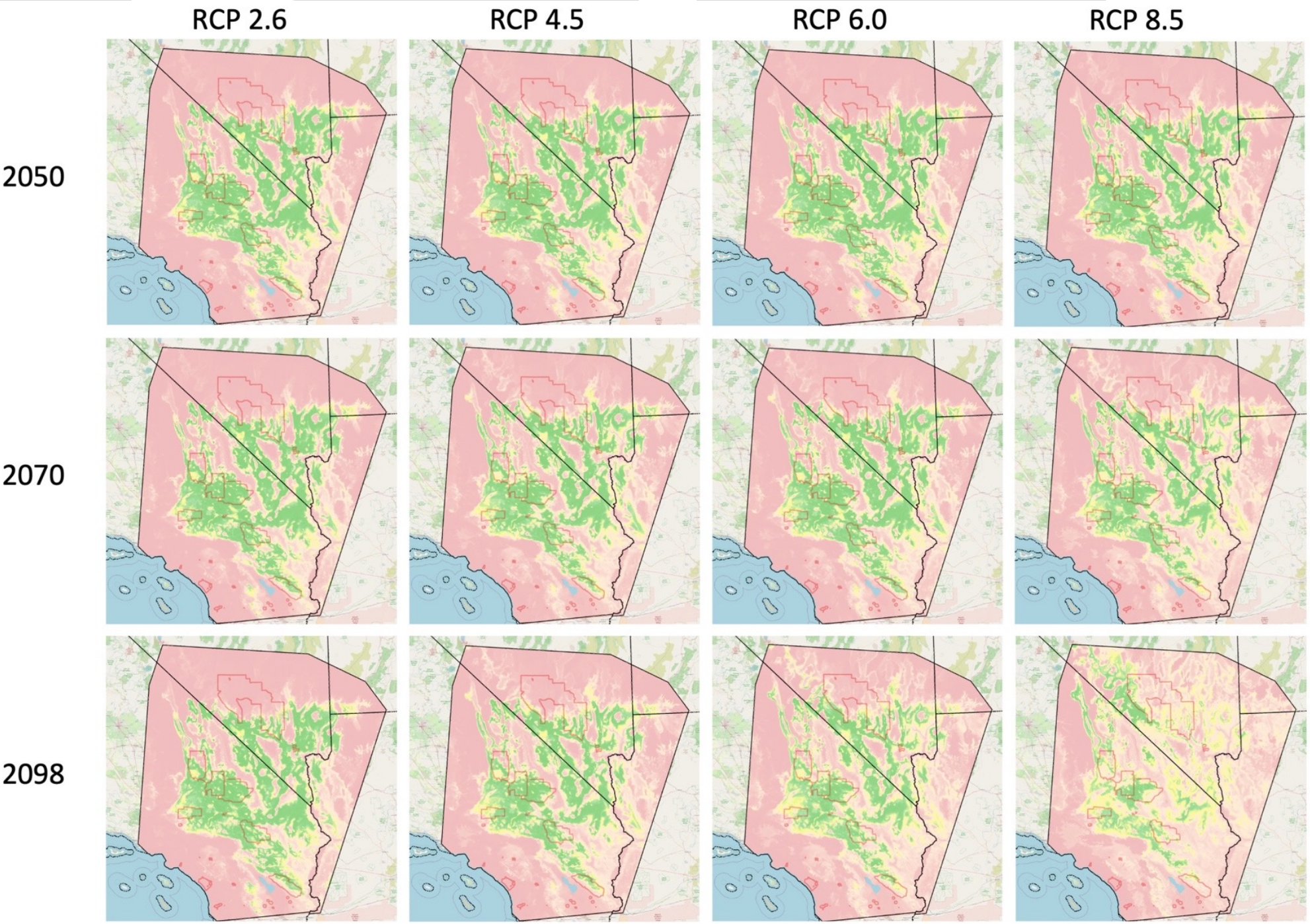


Habitat Modeling (Current Period)

Updated “Global” SDM – Ensemble Approach

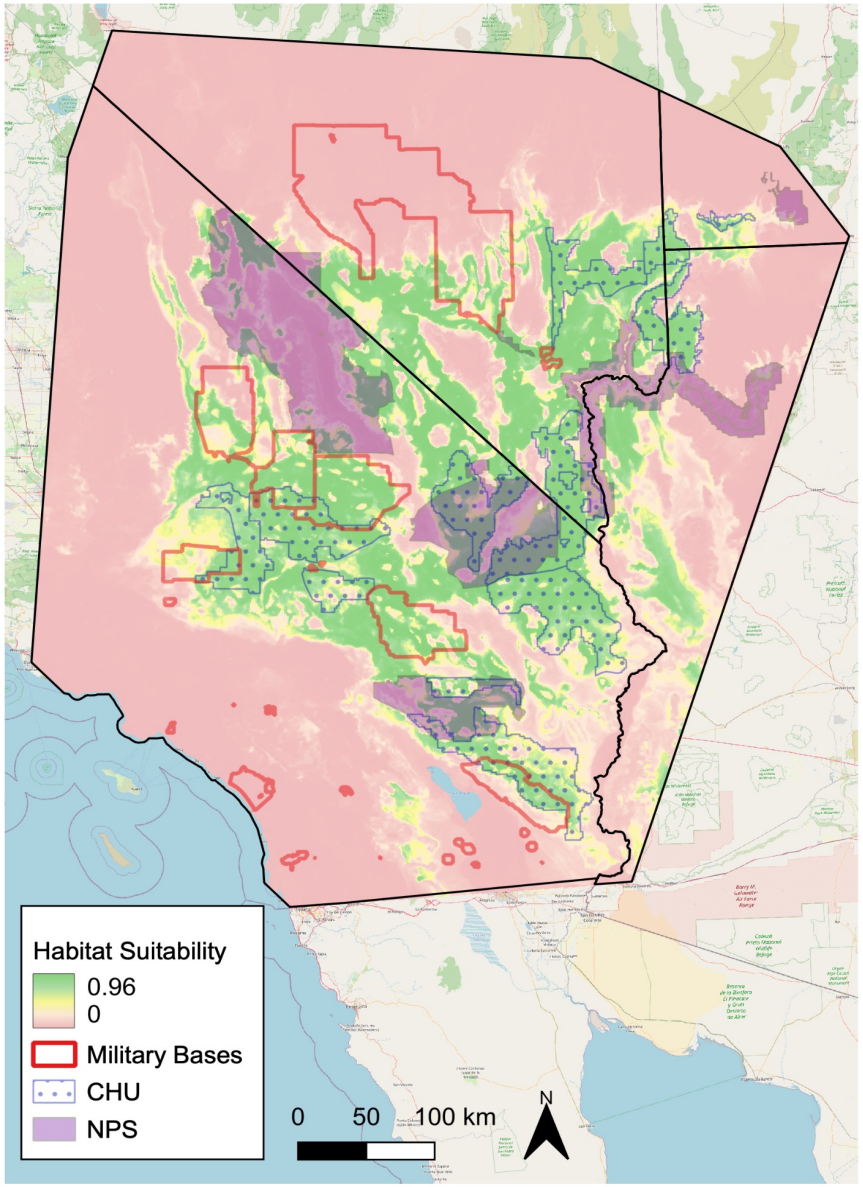


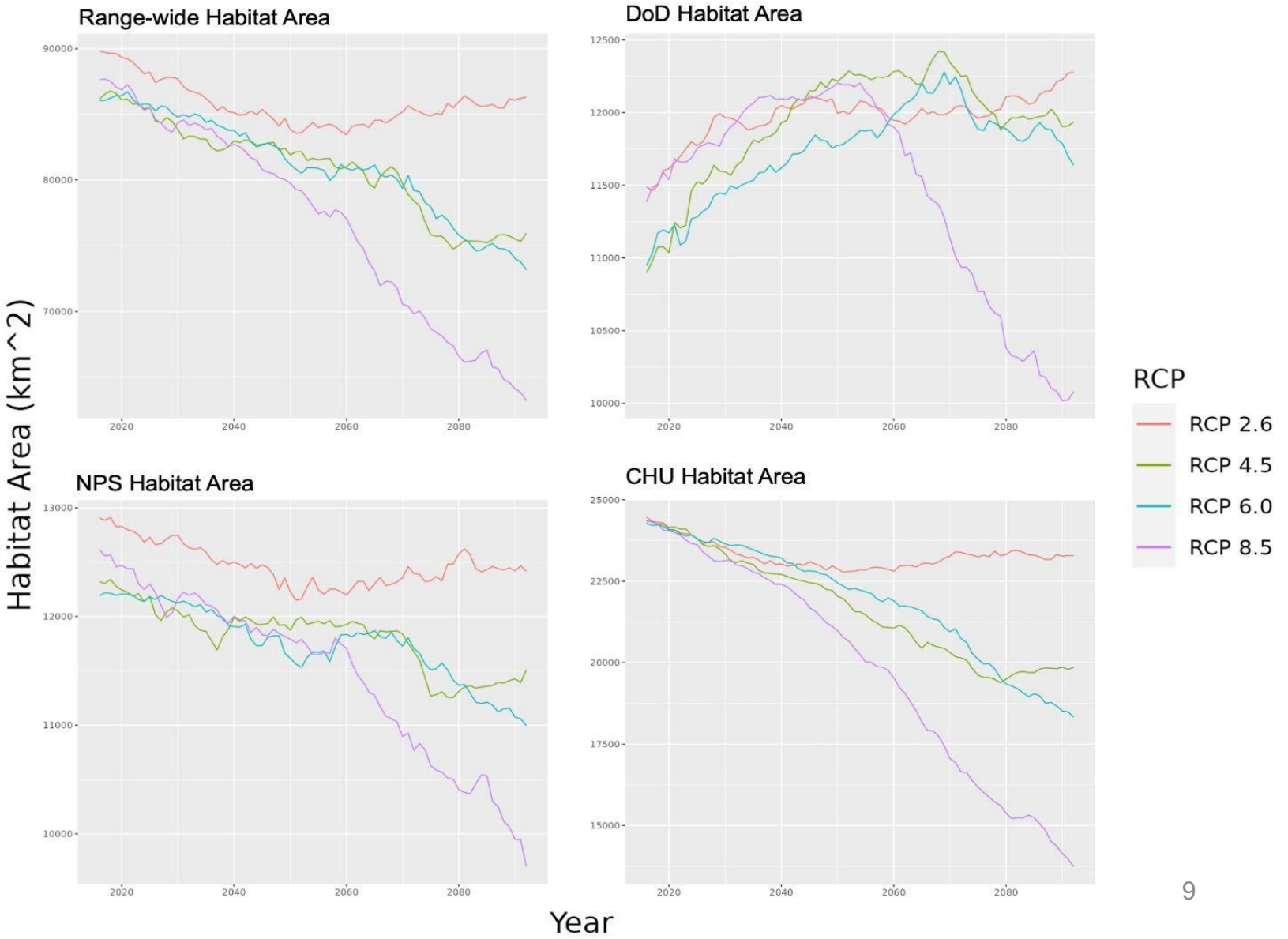




Habitat Modeling (Future Scenarios)

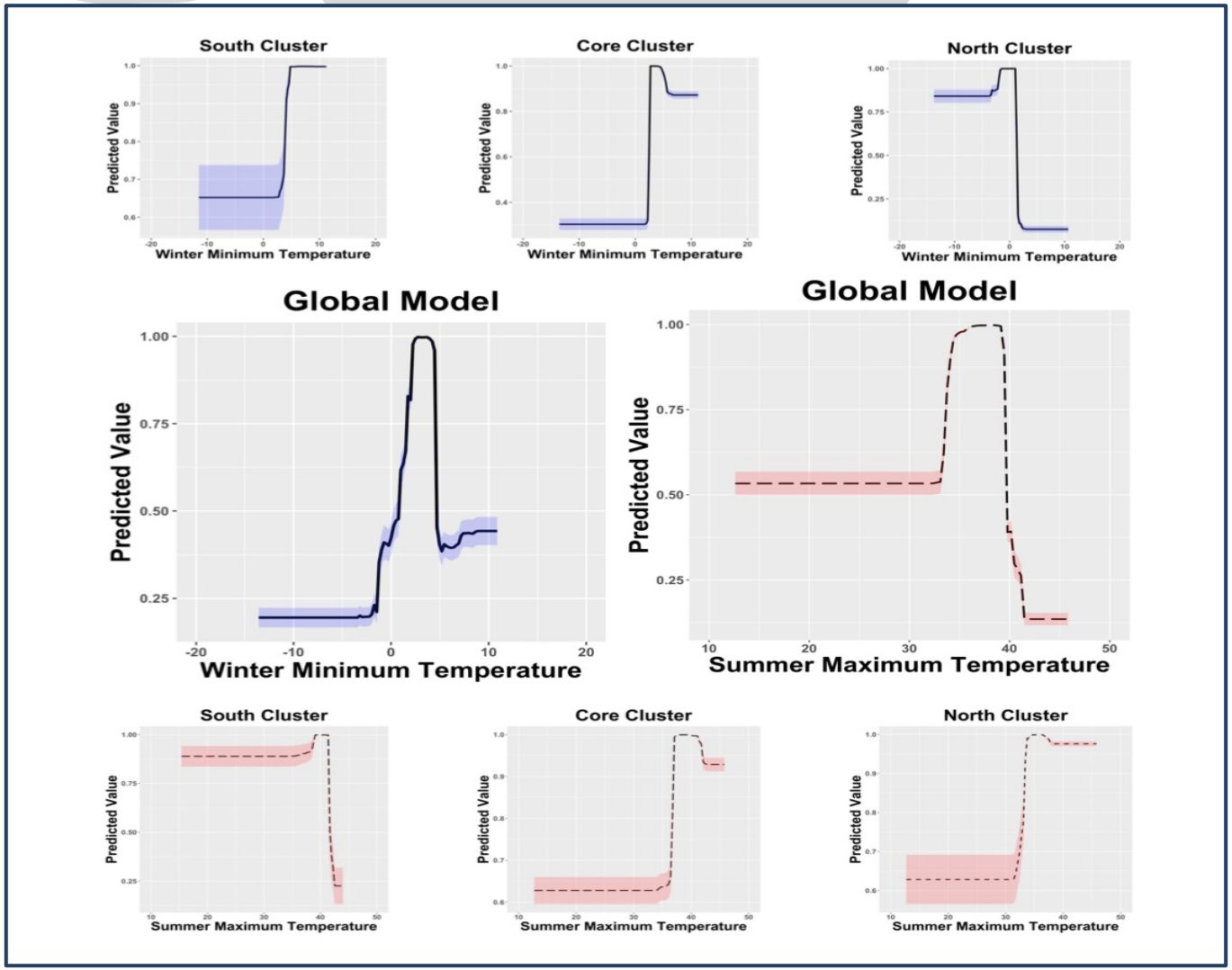
Habitat Area (Future Scenarios)

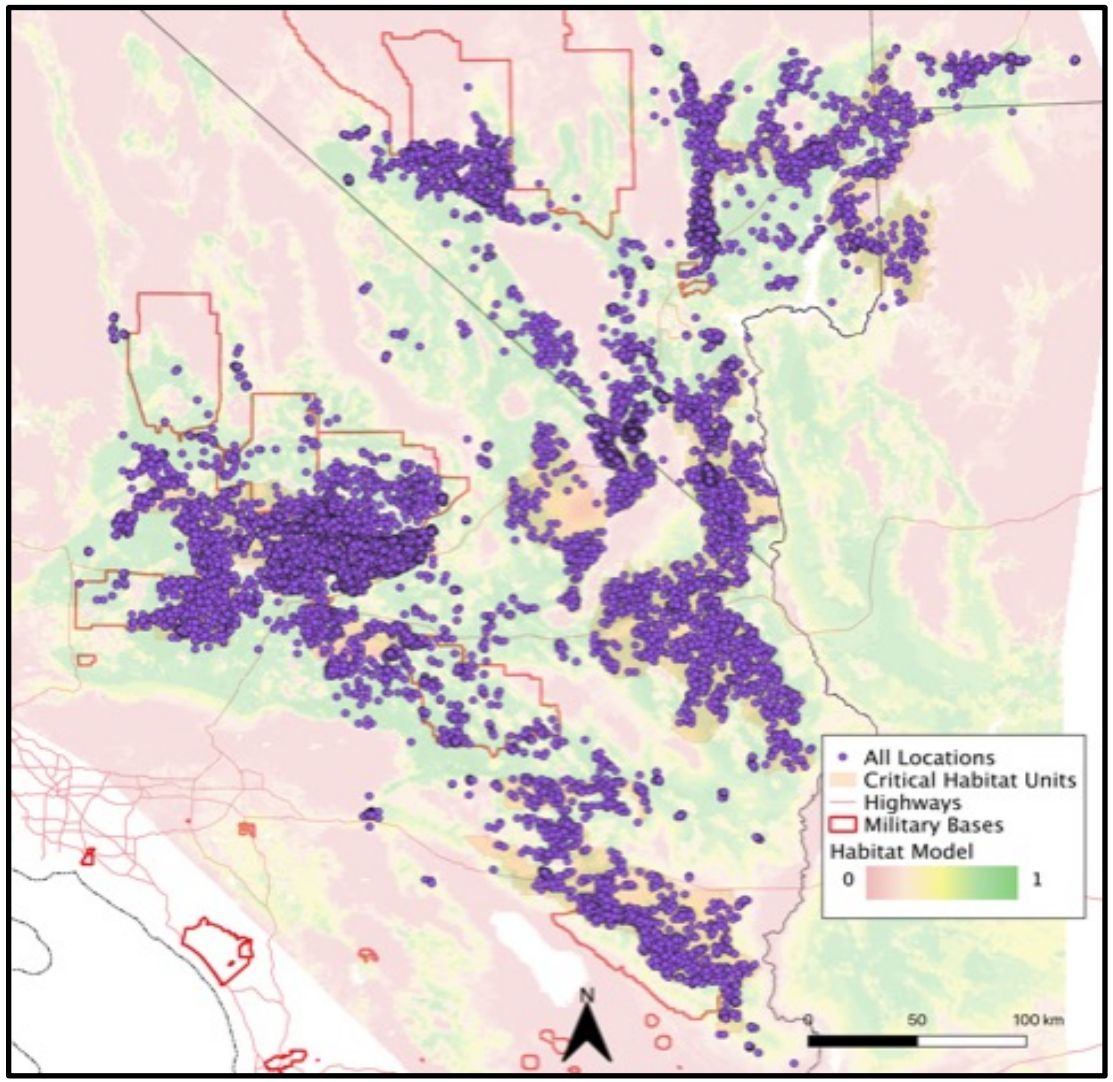




Habitat Modeling (Current Time Period)

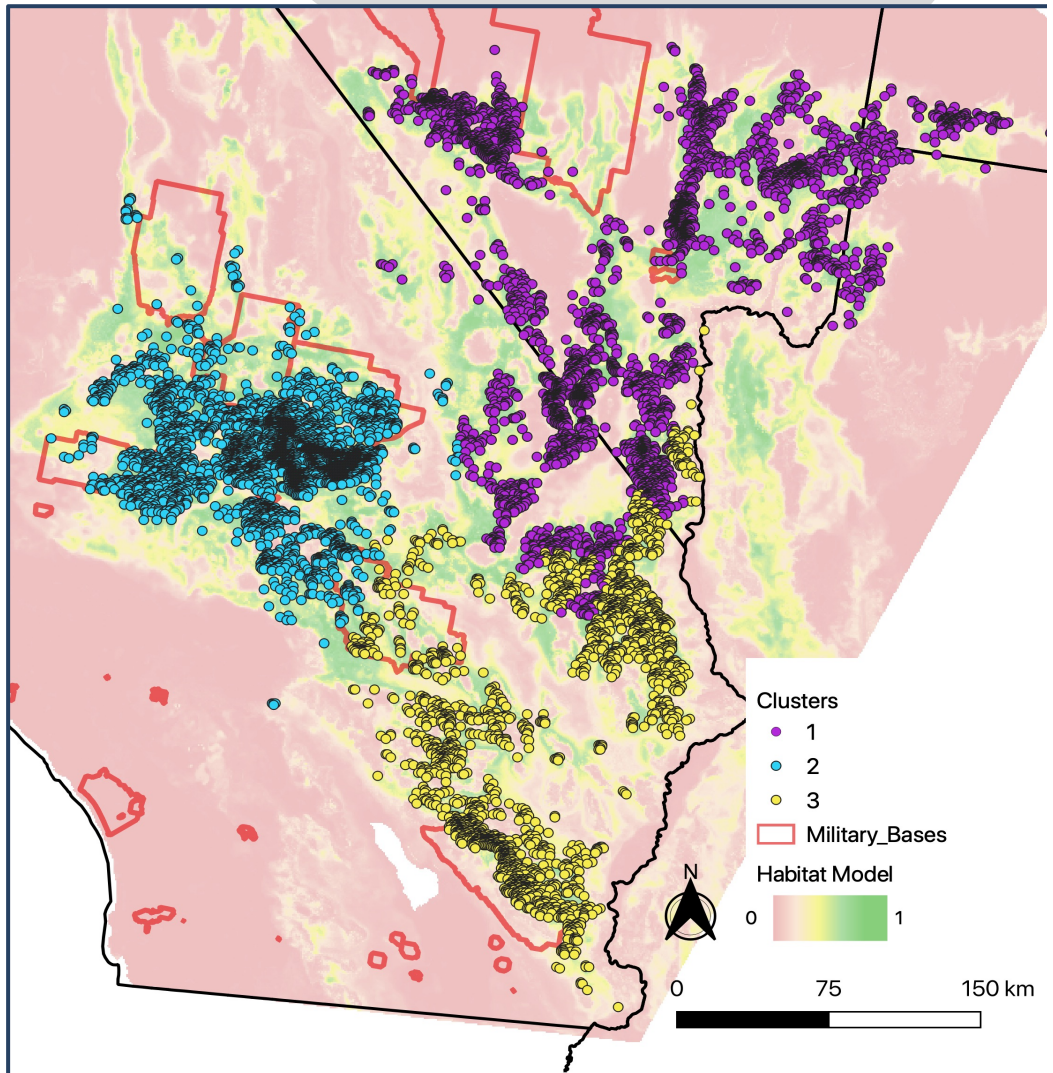
Regionally Weighted Models

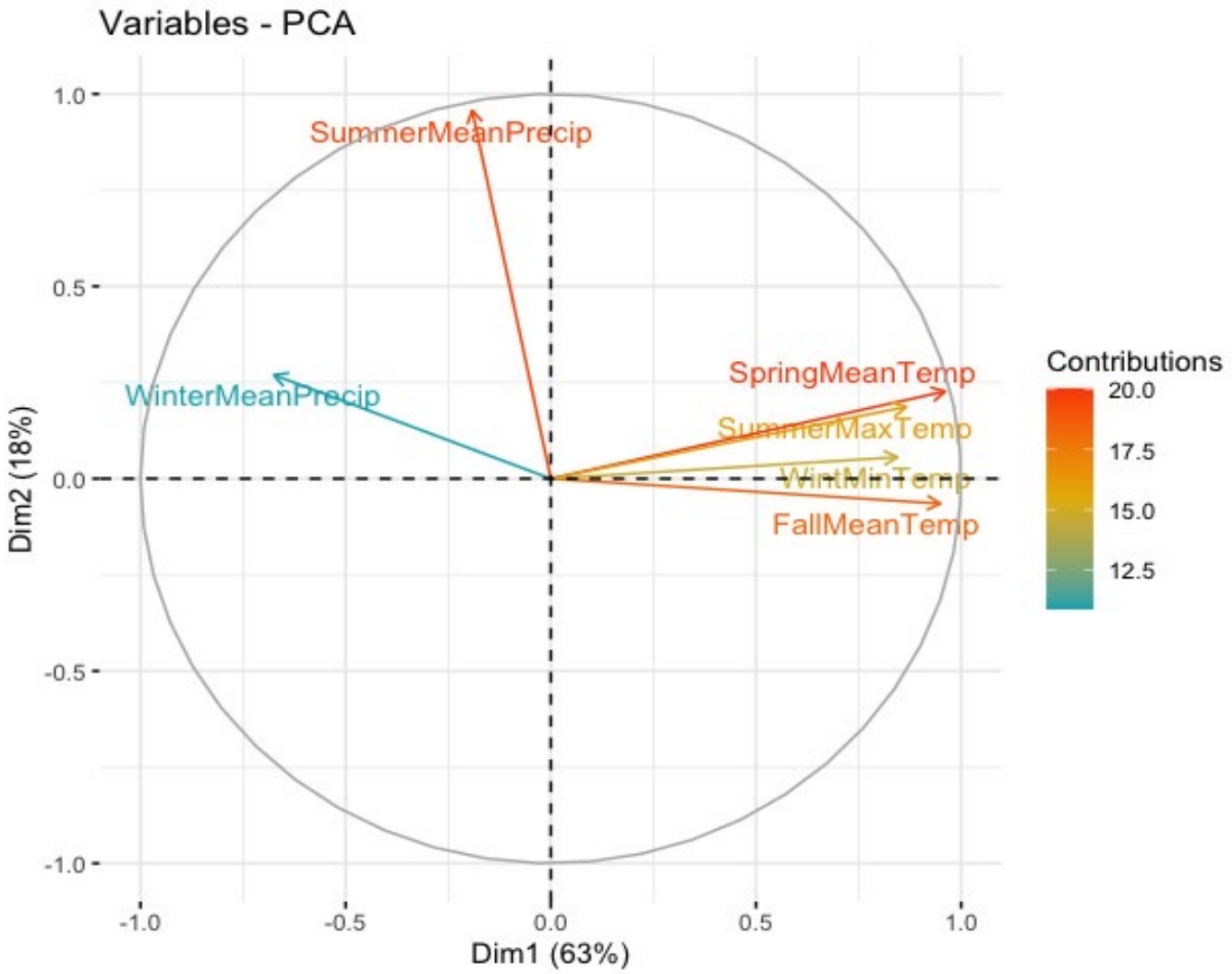




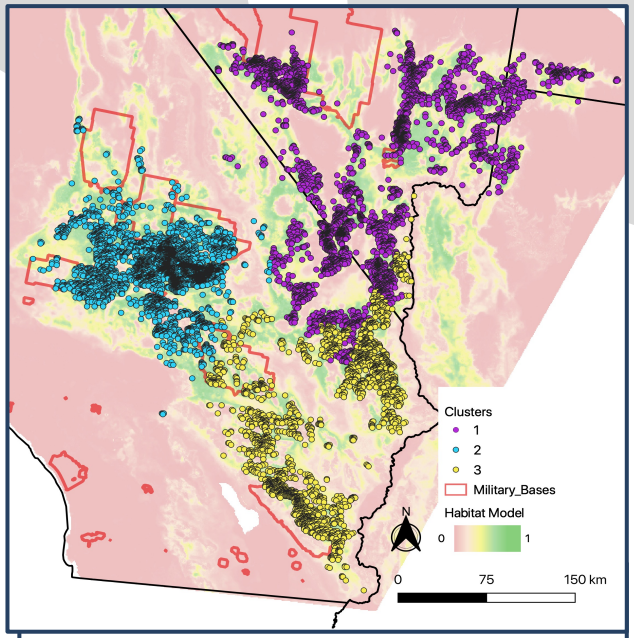
Habitat Modeling (Current Time Period)

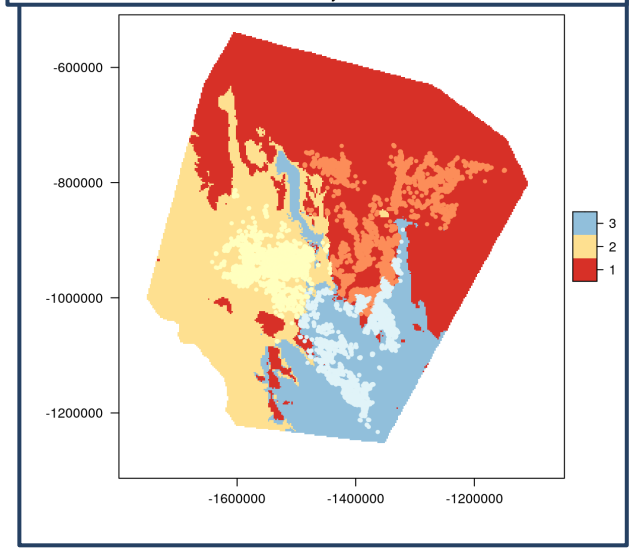
Regionally Weighted Models

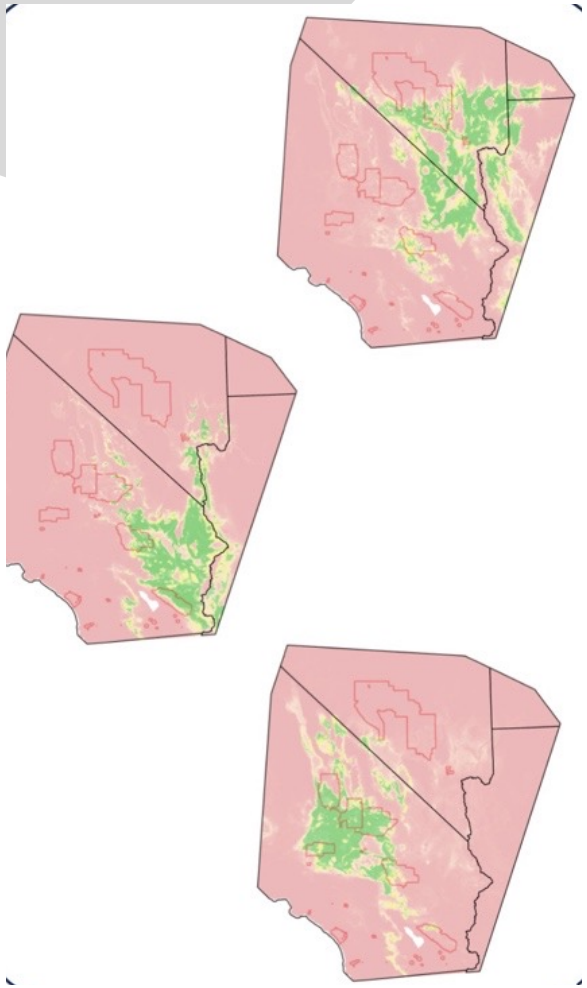




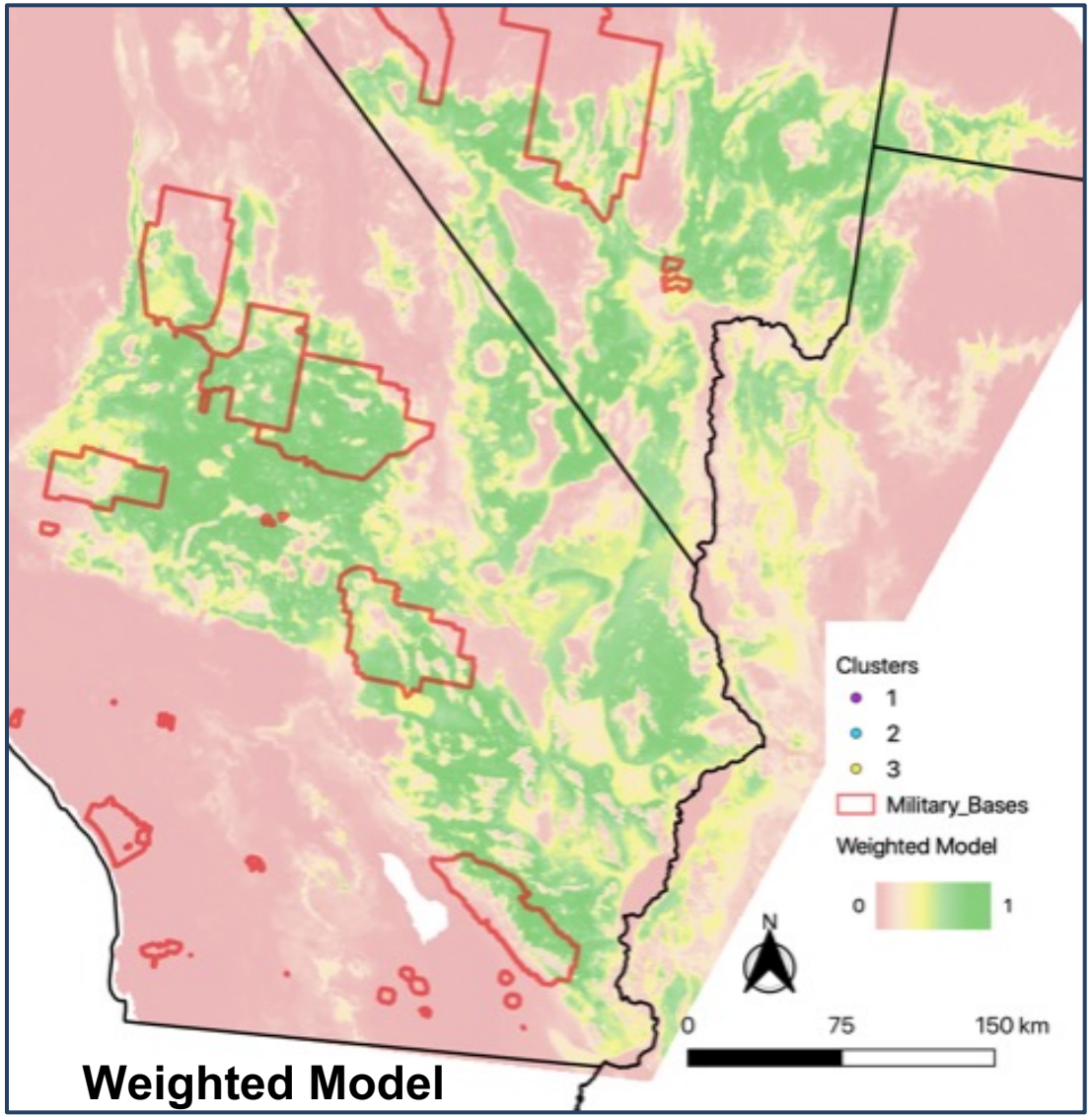
Habitat Modeling (Current Period)





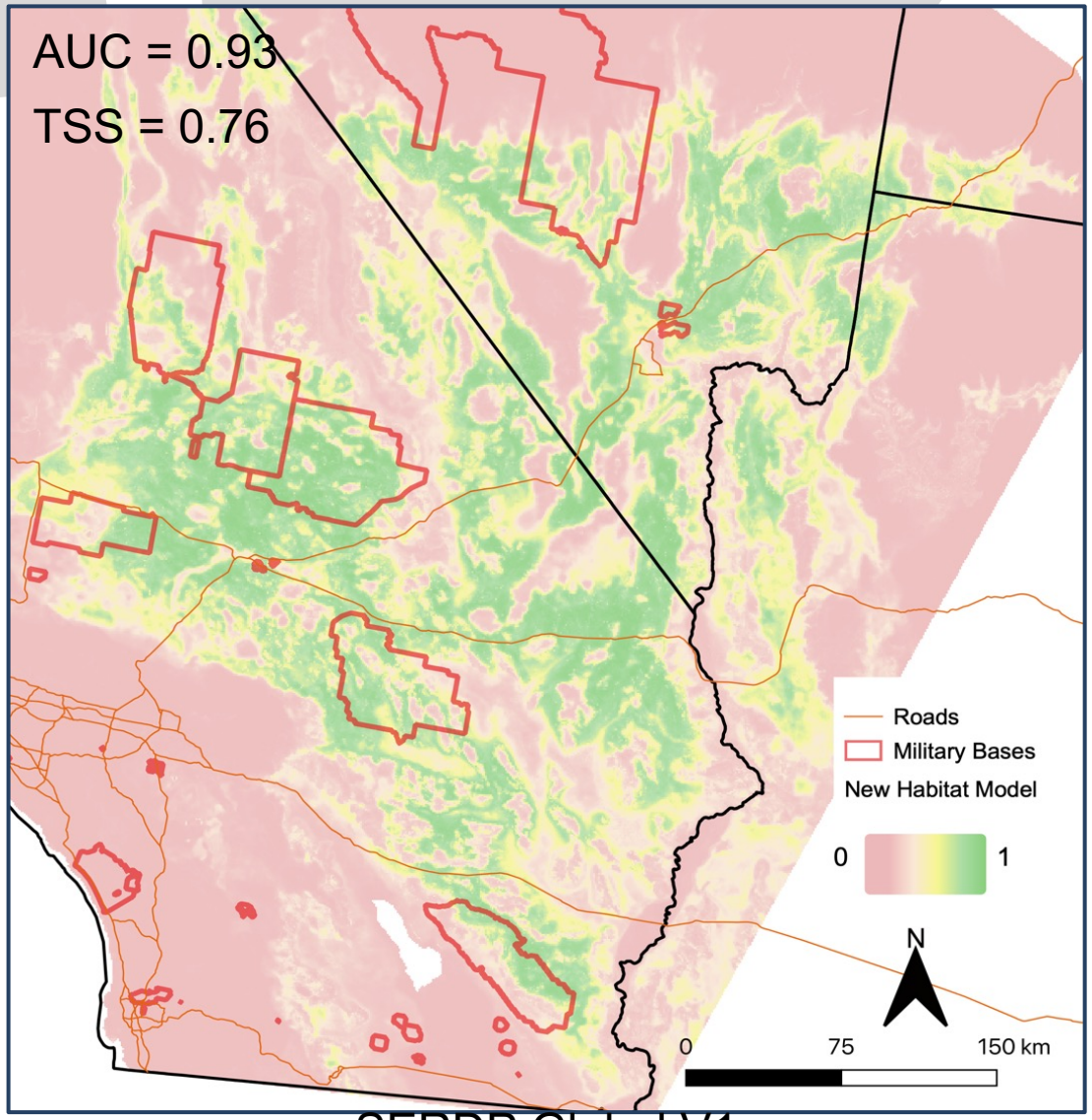


Regionally Weighted Model

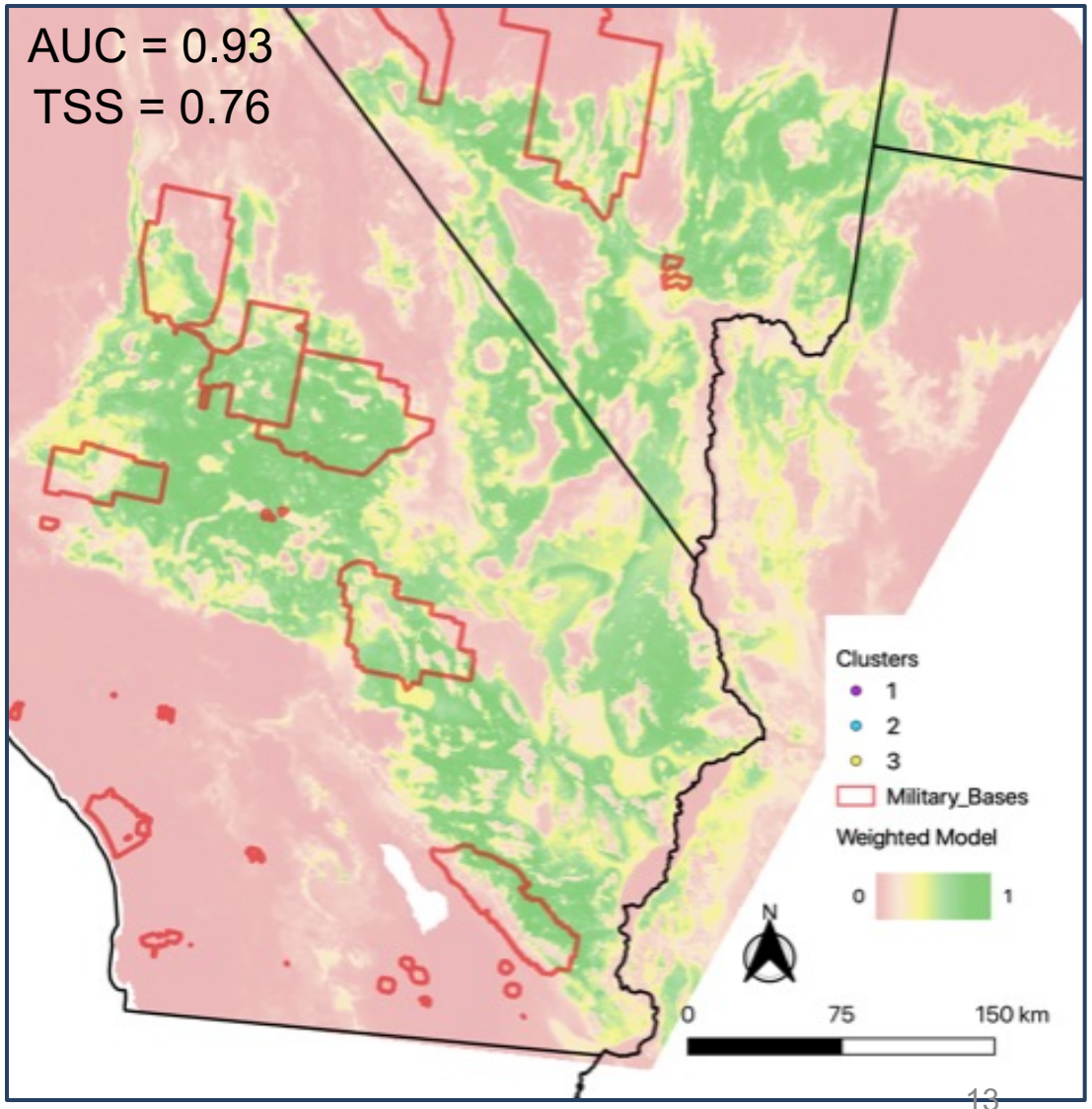


Habitat Modeling (Current Period)

Regionally Weighted Models



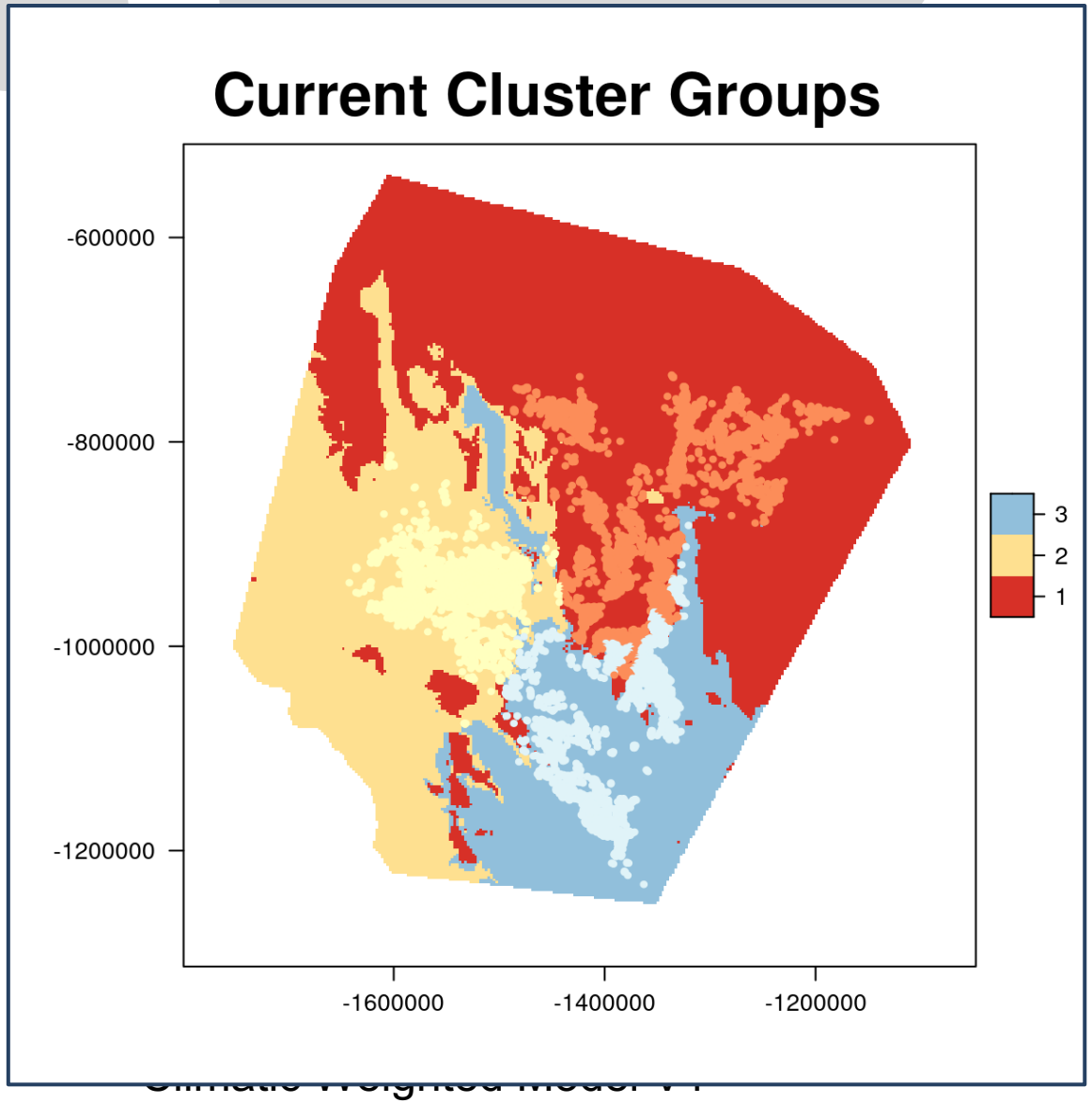
SERDP Global V1

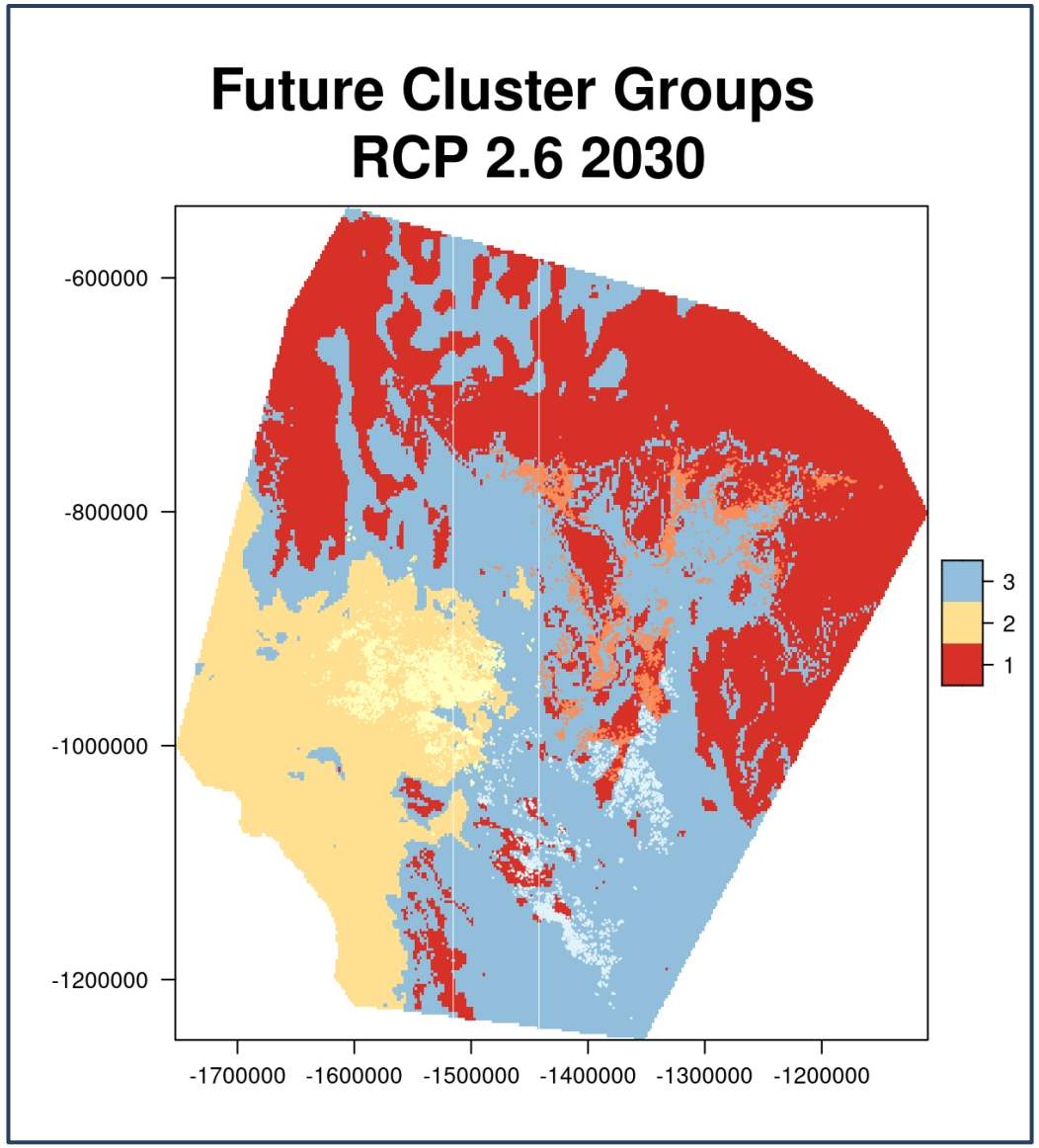


Climatic Weighted Model V1

Habitat Modeling (Future)

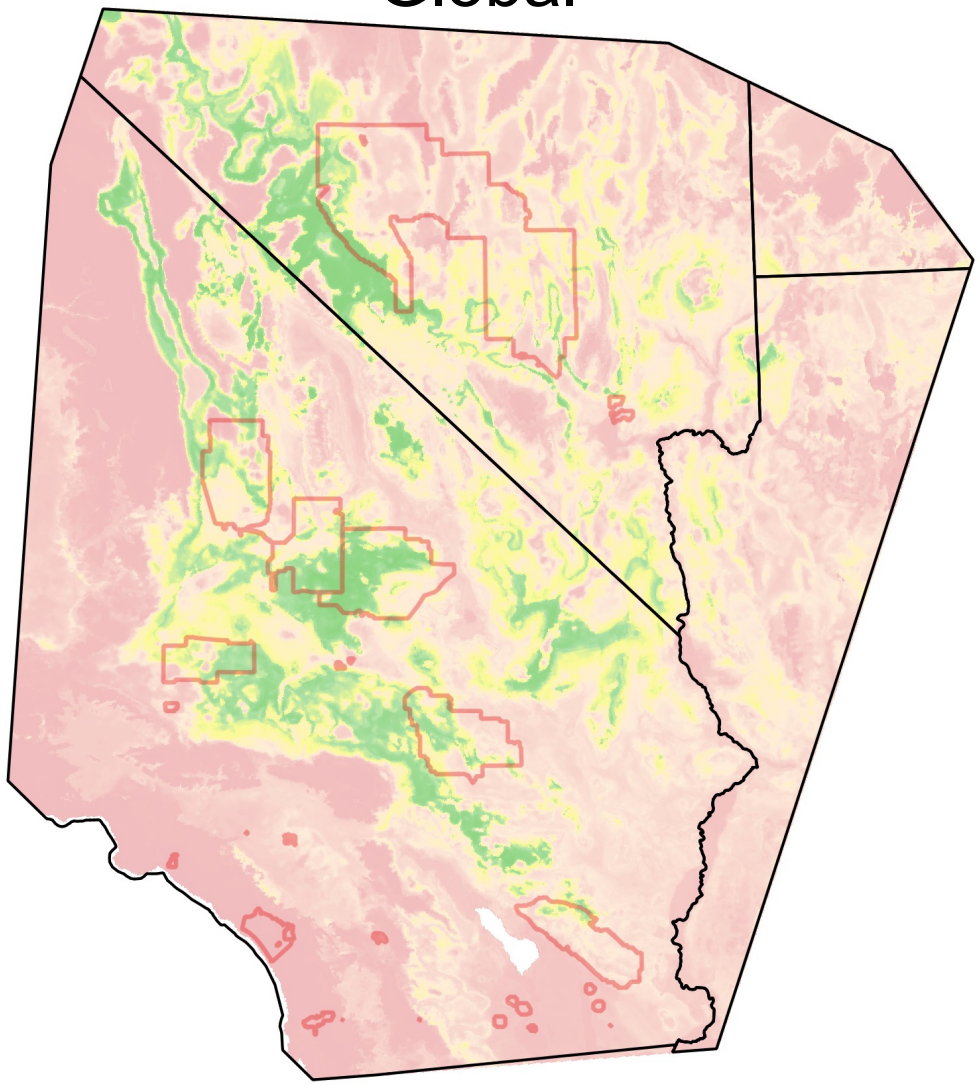
Regionally Weighted Models



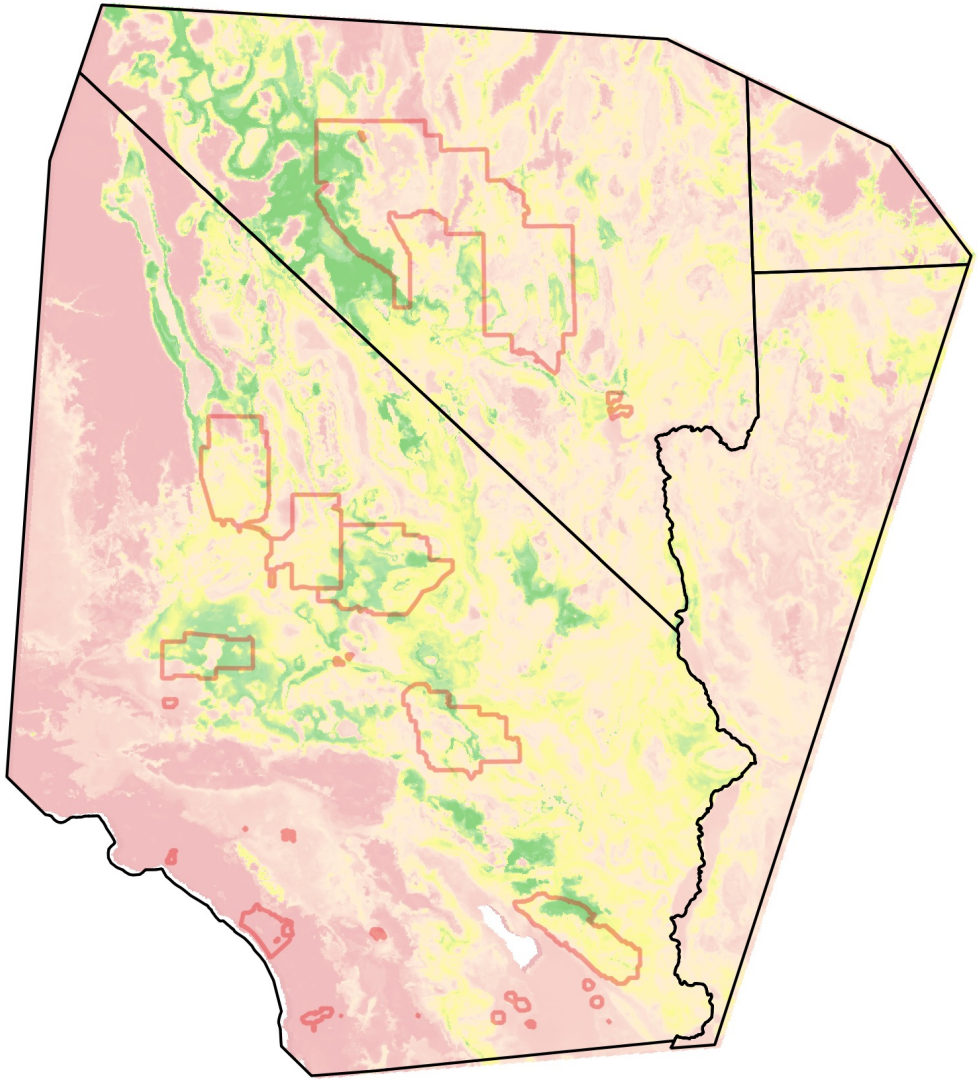


Habitat Modeling (Future RCP 8.5 2099)

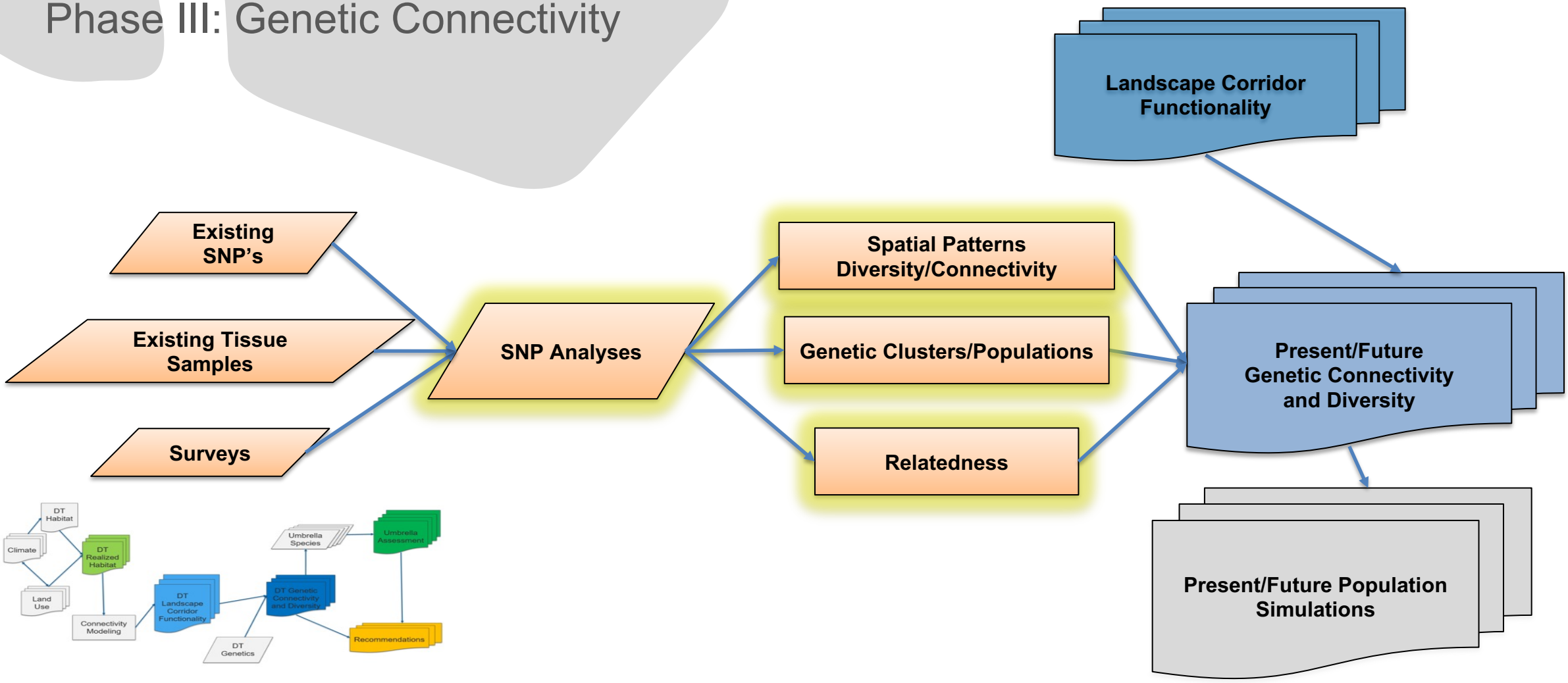
Global



Regional Weighted

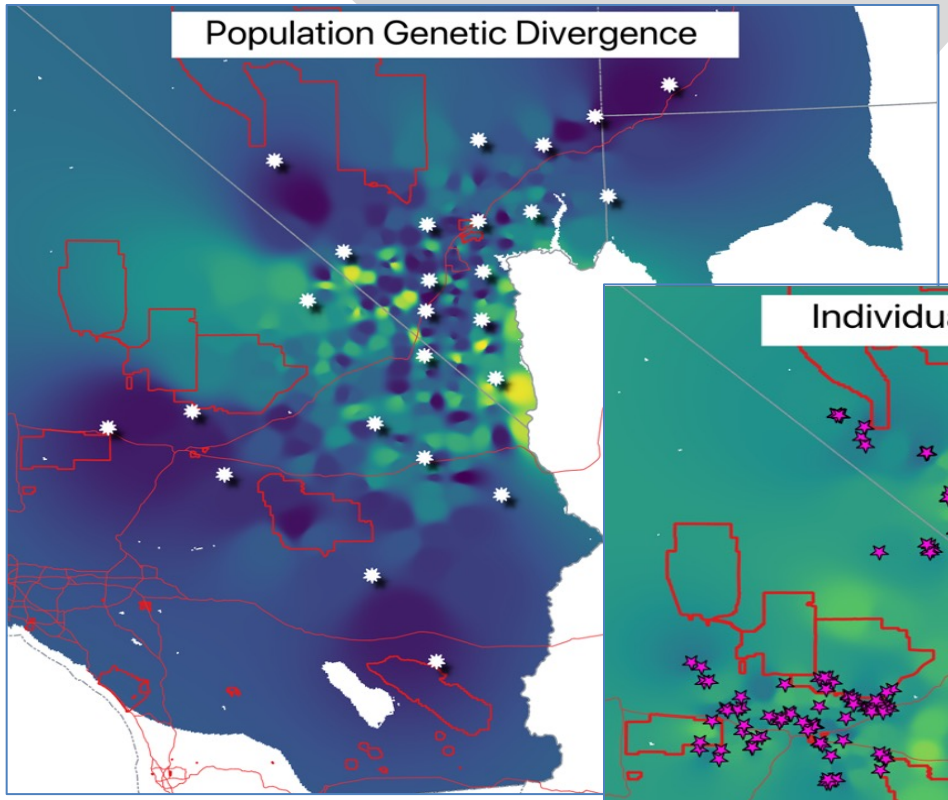


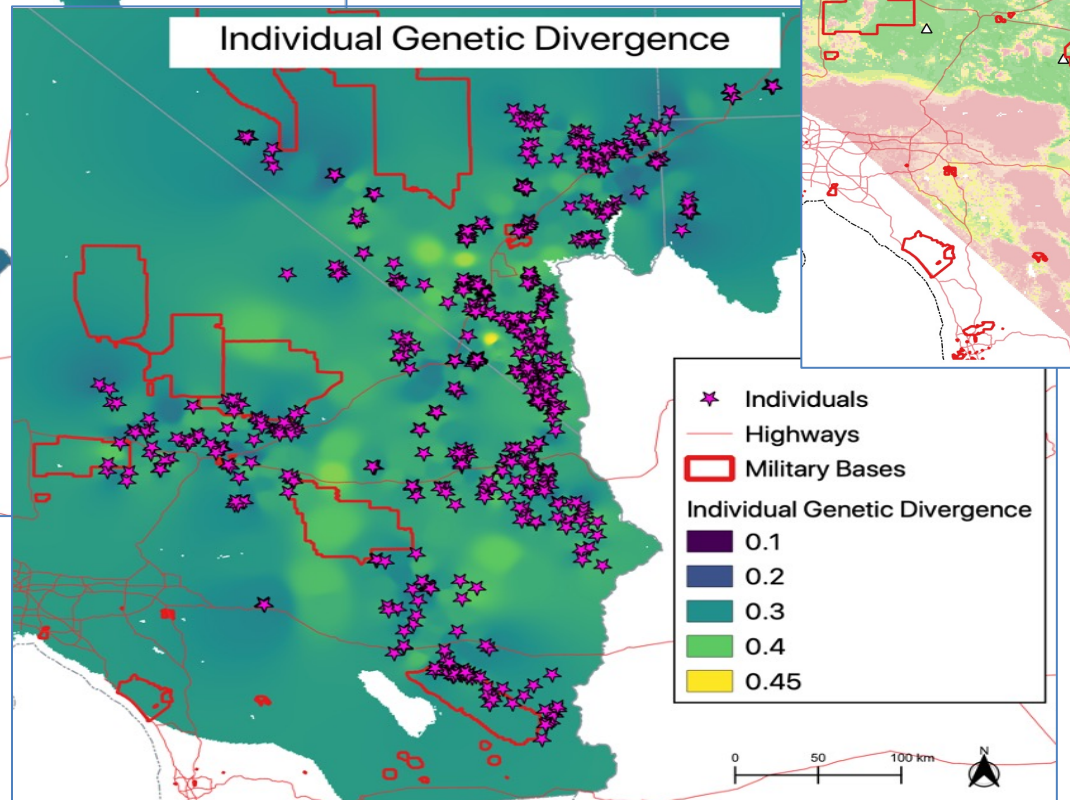
Phase III: Genetic Connectivity

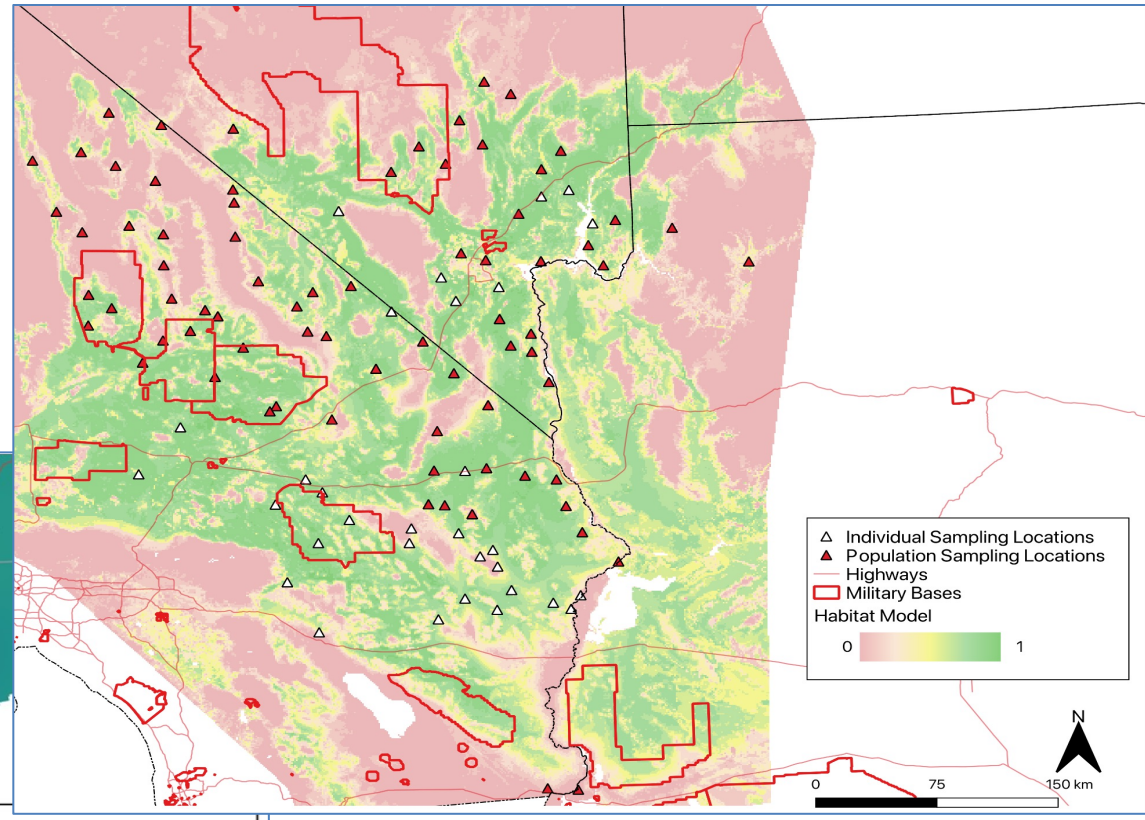


Sampling - Spatial Patterns of Diversity/Connectivity

Sampling Methods

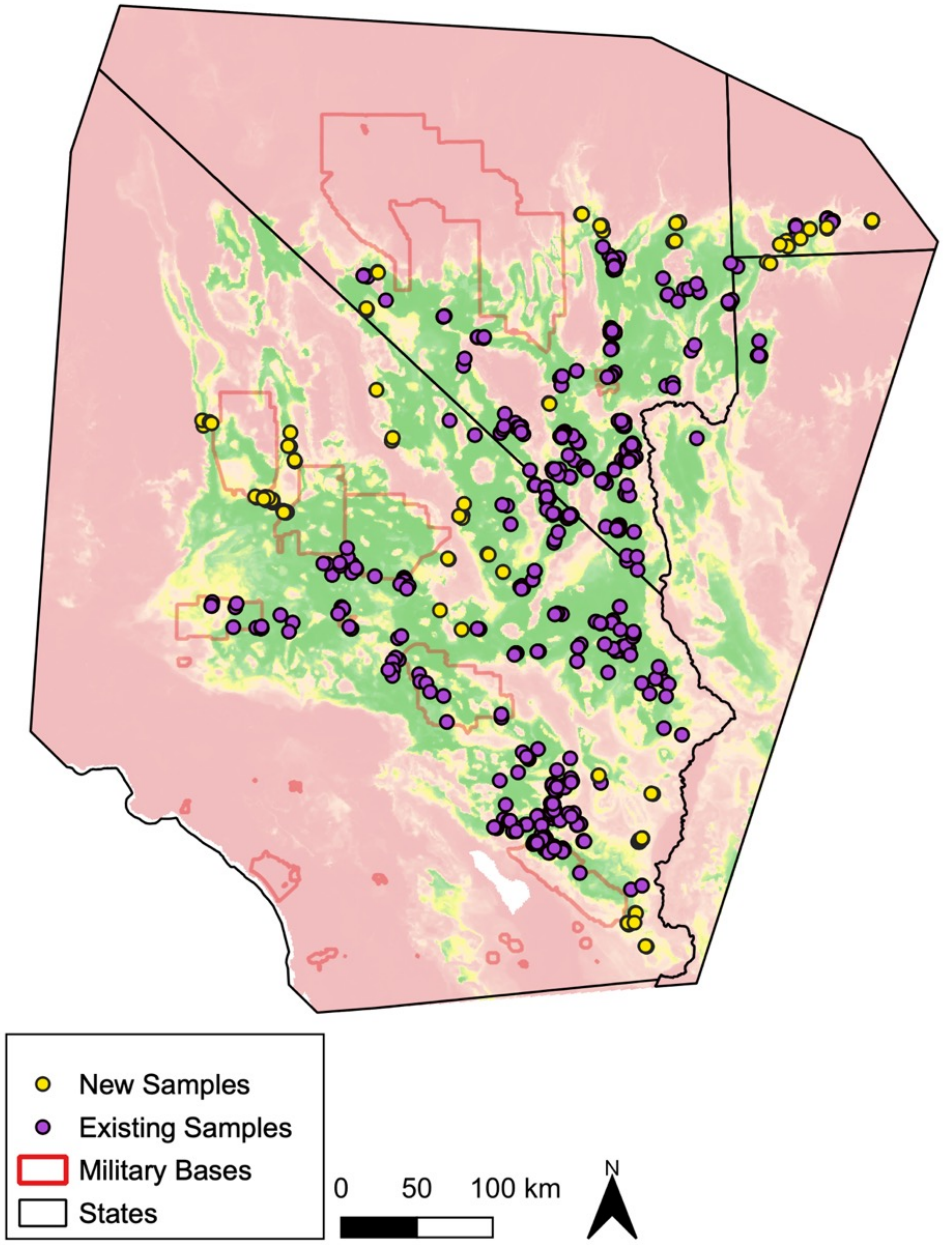






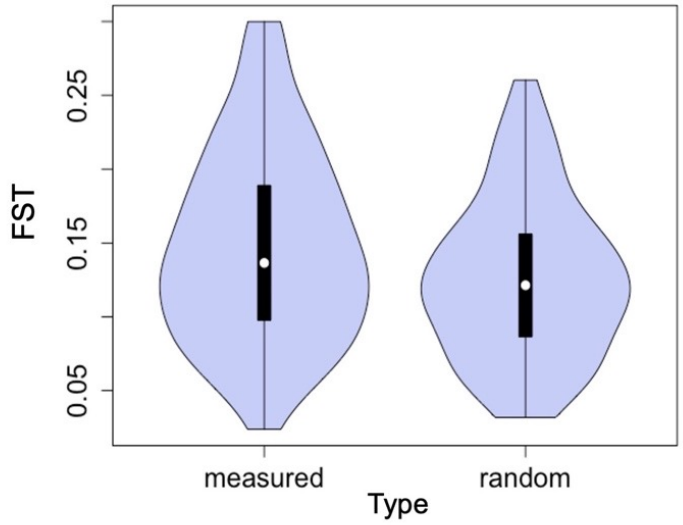
Sampling points were identified based on genetic divergence using Hagery et al. 2010 and Nussear et al. 2009

Spatial Patterns of Diversity/Connectivity

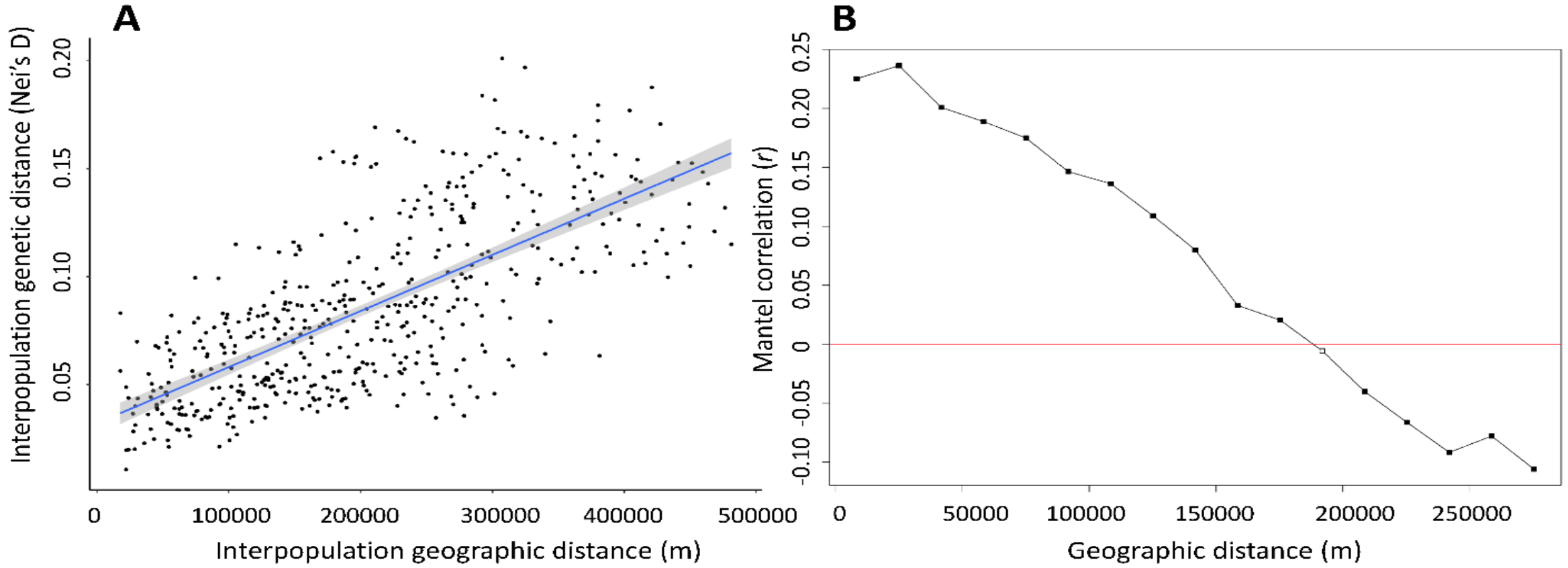


Final Genetic Data Selection

- Analysis of genetic divergence across the Mojave Desert was used to identify existing samples for this study (*n* = 494)

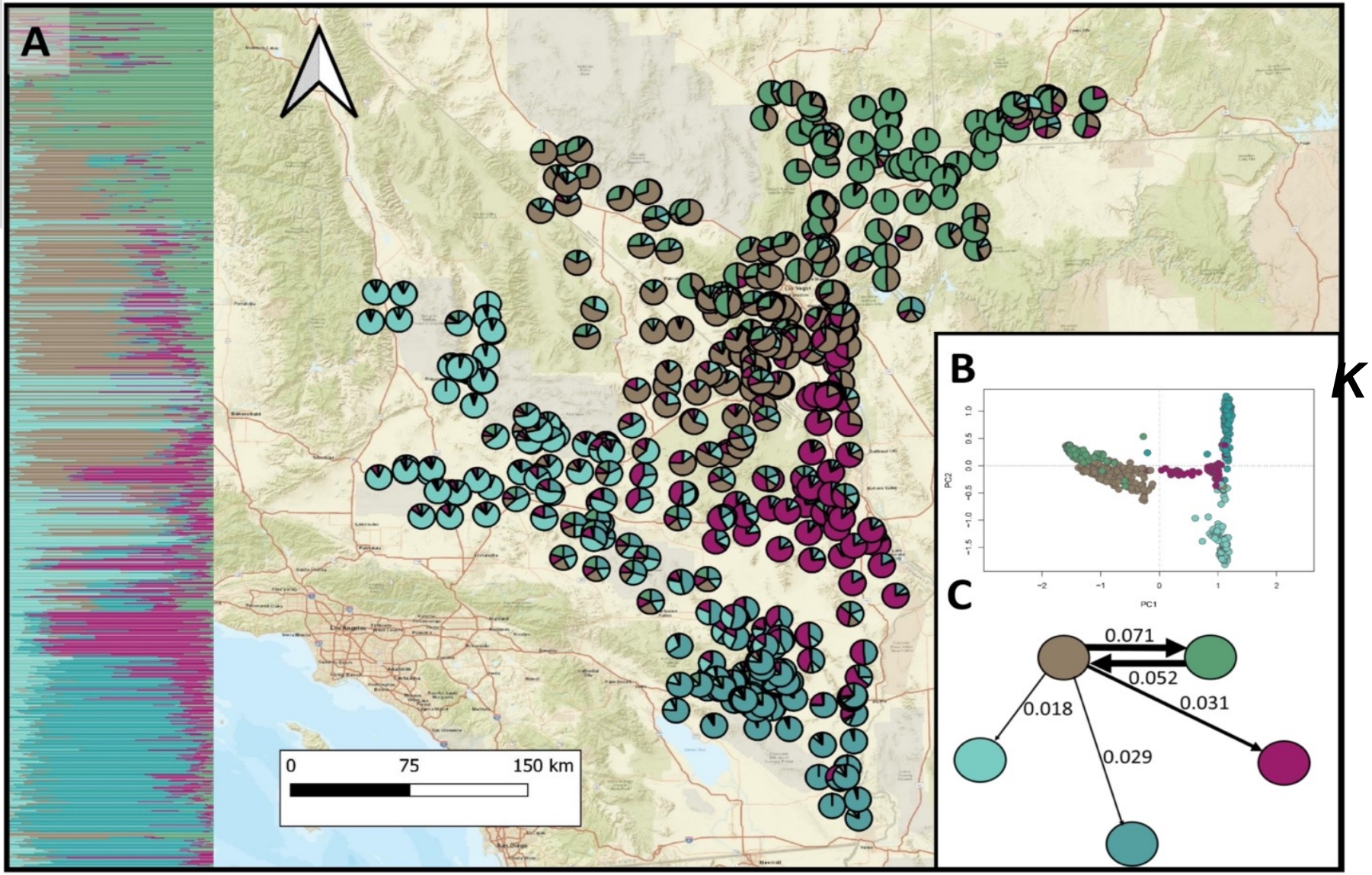


Spatial Patterns of Diversity/Connectivity



- **(A) Inter-population geographic distance plotted against genetic distance**
- **(B) Mantel correlogram of spatial trends between inter-individual genetic and geographic distances**
- **Classic pattern of isolation by distance**

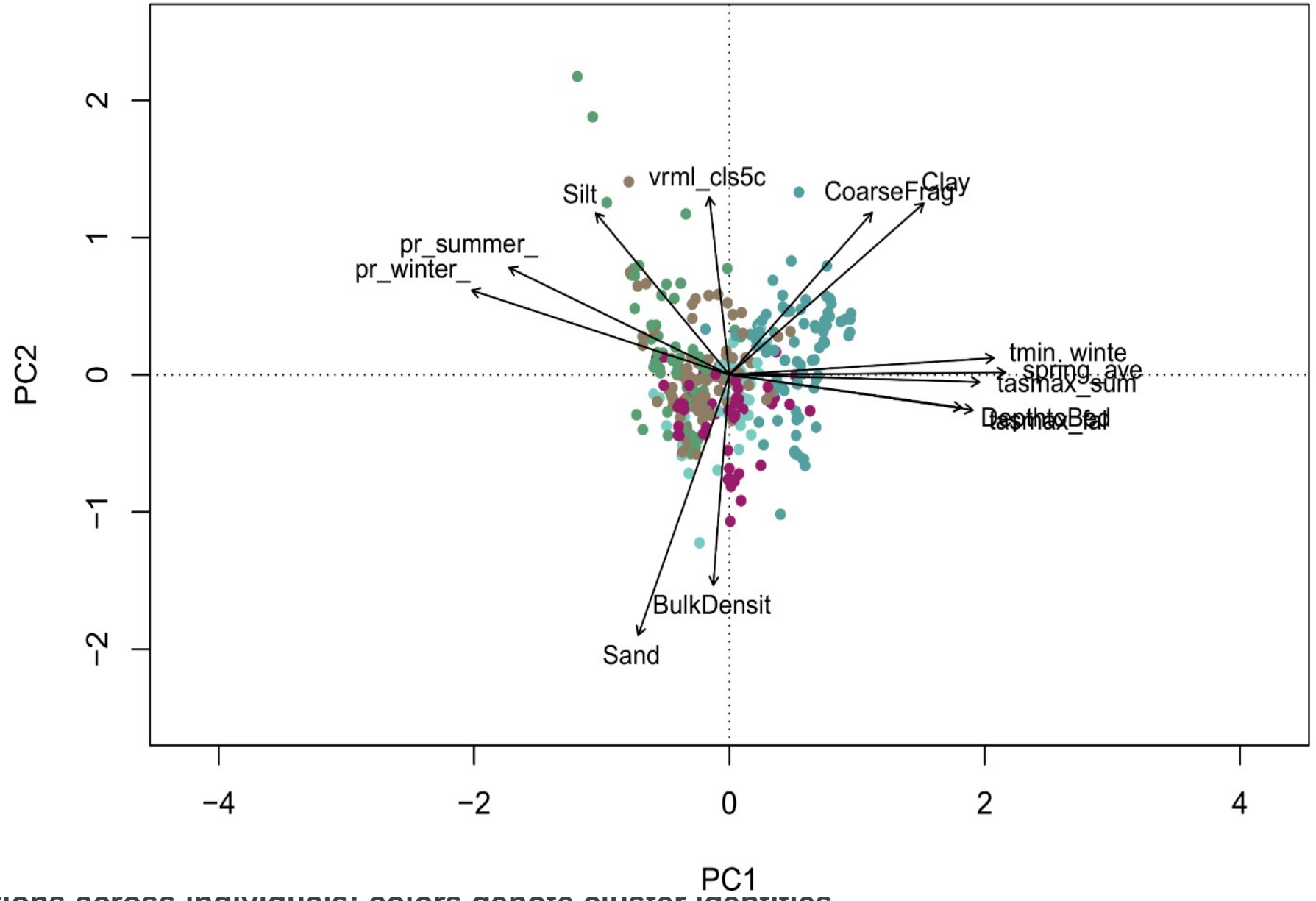
Genetic Clusters/Populations



***K* = 5**

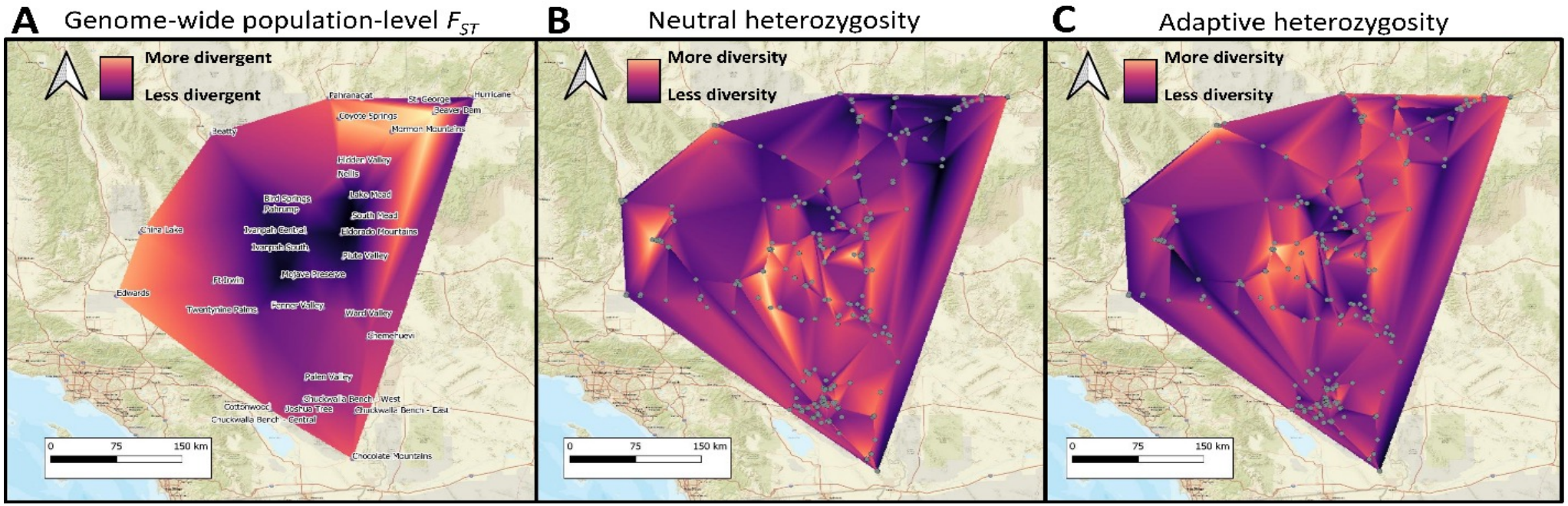
- Spatial patterns in genetic clusters (sNMF); pie charts represent individual admixture proportions
- (A) Barplot of individual-level admixture
- (B) PCA plot (imputed allele frequency matrix); points are colored to match the primary cluster
- (C) Generational migration rates between genetic clusters (BayesAss3); line width scaled to the magnitude of migration; migration rates > 0.01 are displayed

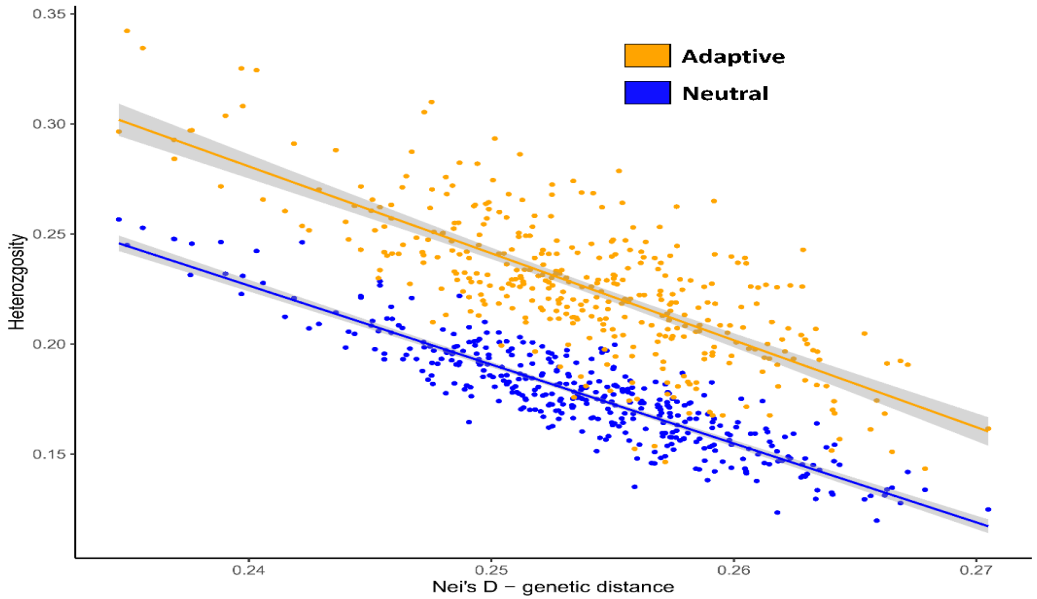
Adaptive Genetic Associations with Climatic Variables



- **PCA of environmental associations across individuals; colors denote cluster identities**
- **pRDA identified 653 SNPs that may be under divergent selection/are adaptive**

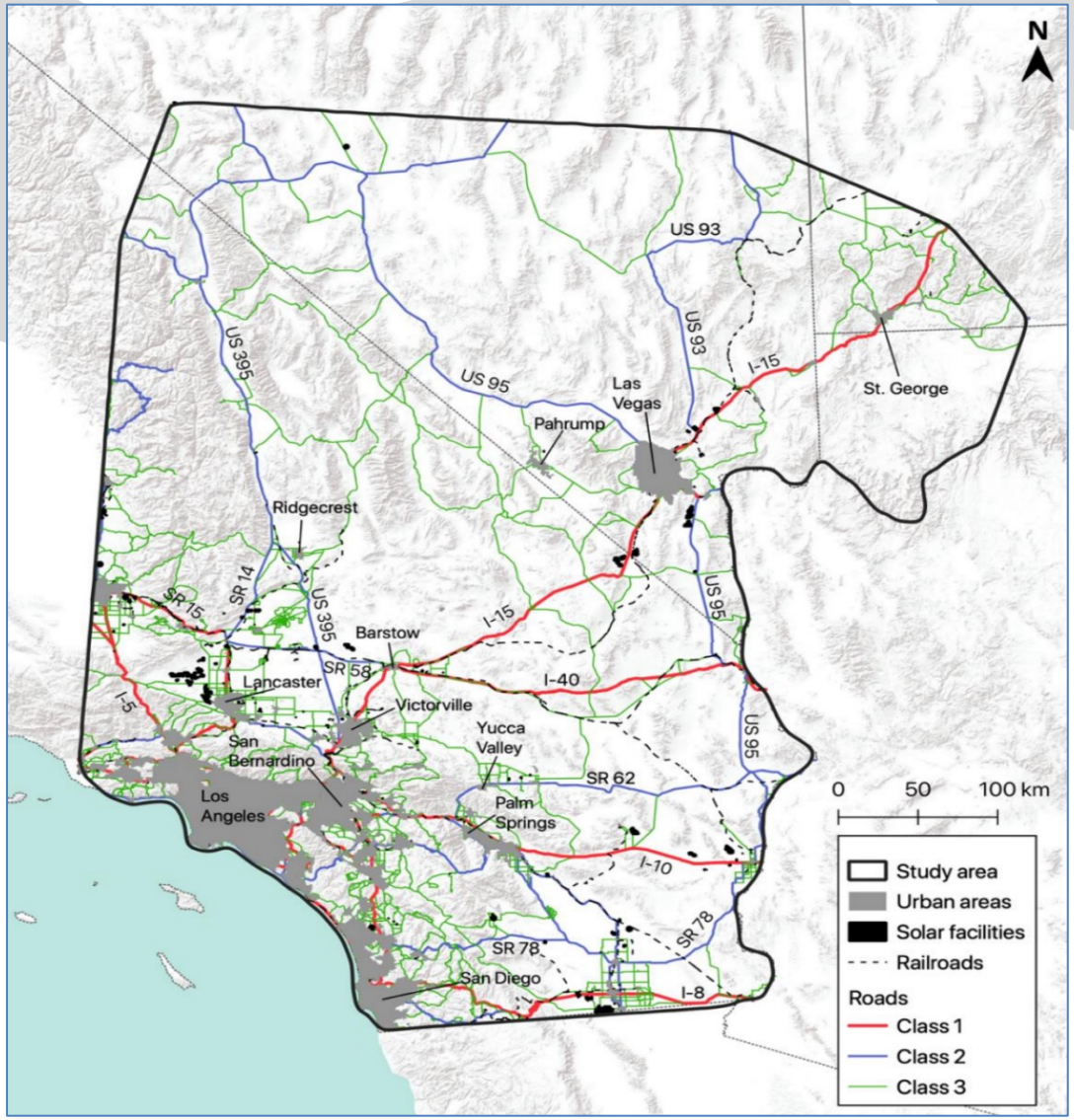
Spatial Patterns Diversity/Connectivity

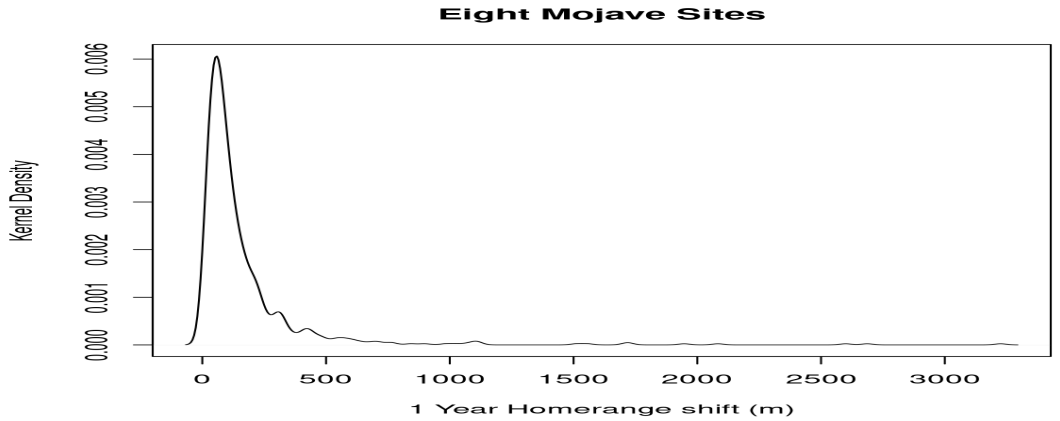




- **Higher gene flow resulted in higher adaptive genetic variation compared to neutral loci**
- **Adaptive genetic diversity is strongest in the northeast Mojave (high divergence and migration)**
- **Neutral genetic diversity is strongest in the central Mojave (low divergence, high gene flow)**

Connectivity Modeling

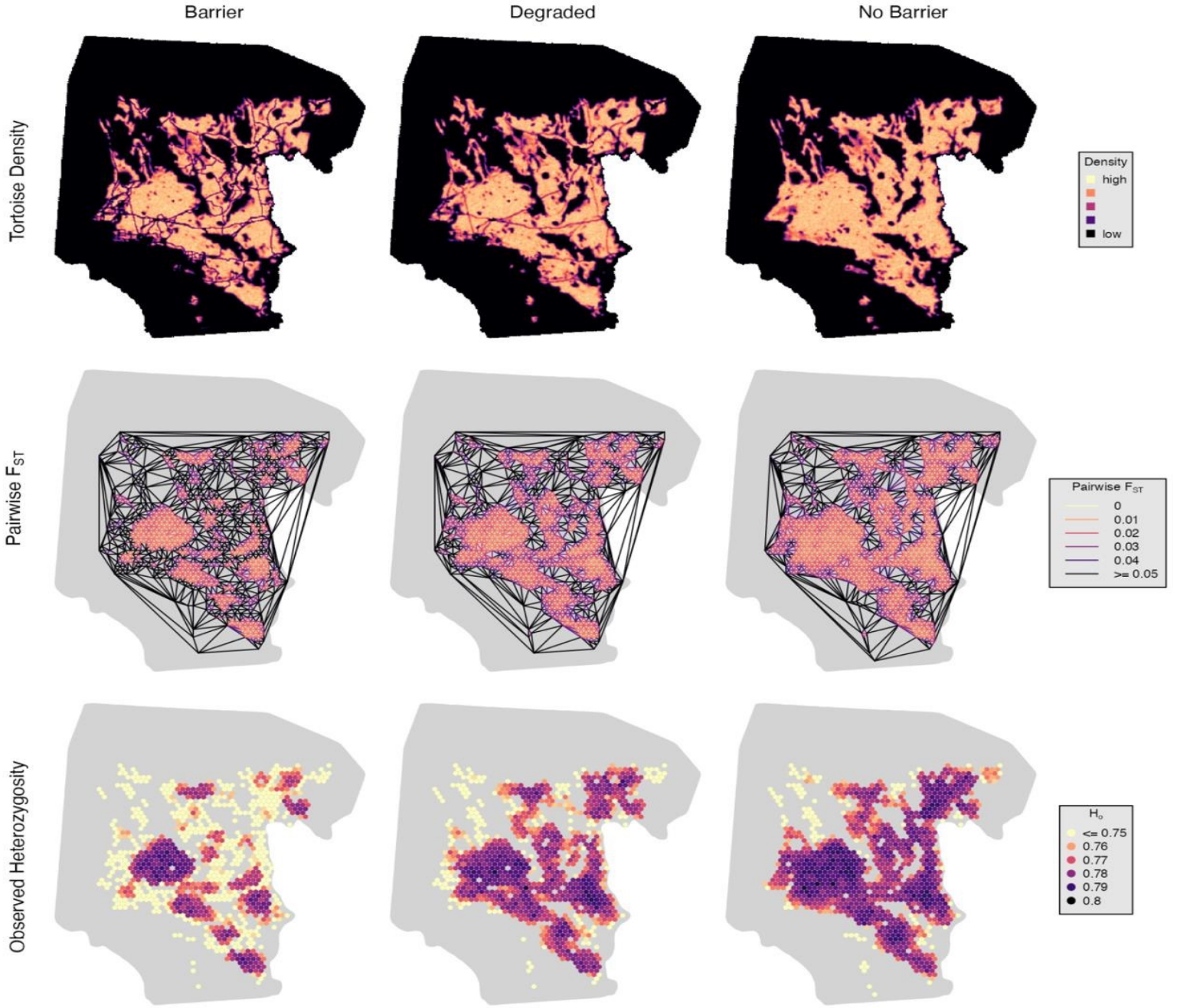




- **Modeled population effects in habitat impacted by barriers to movement (urban areas, roads and railroads); compared to unimpacted landscapes; treated as both full and leaky barriers**
- **Simulations used agent based models; 10,000 year iterations; 10 repetitions each**
- **Empirically based estimates for mortality, reproductive, and dispersal rates**

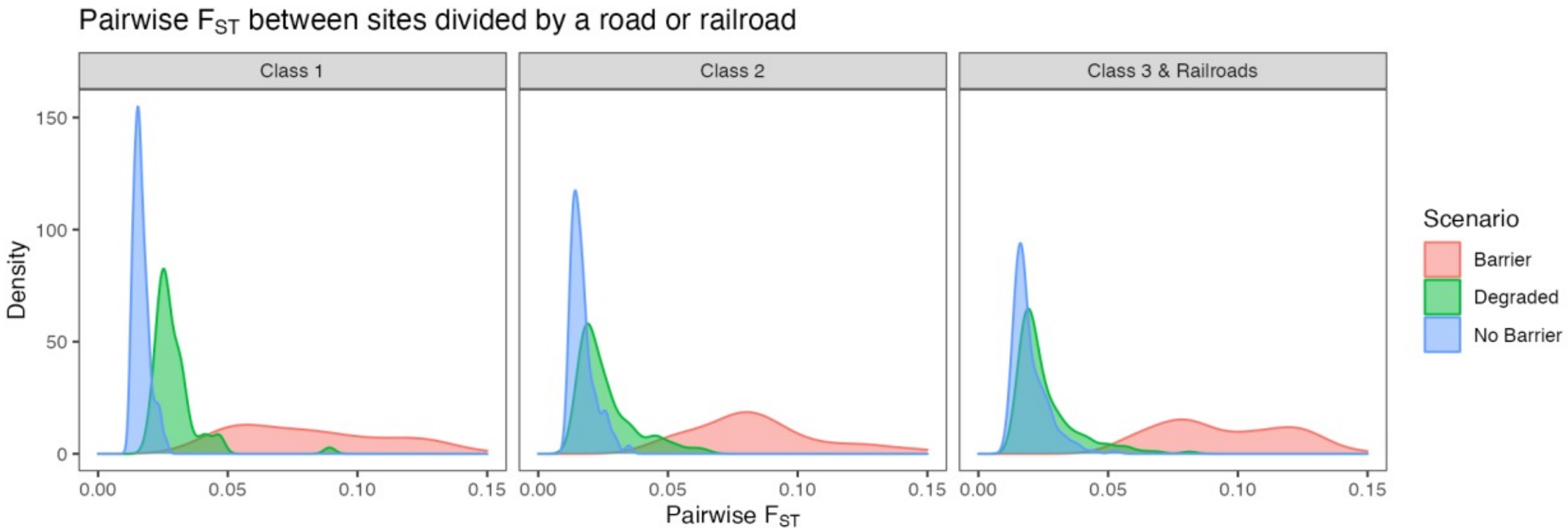
Connectivity Modeling

- **The “no barrier” scenario had the lowest F_{ST} (0.042), highest H_o (0.772), and highest population number**
- **Changes to H_o affected edge regions disproportionately; these areas showed higher adaptive genetic potential and less habitat loss**

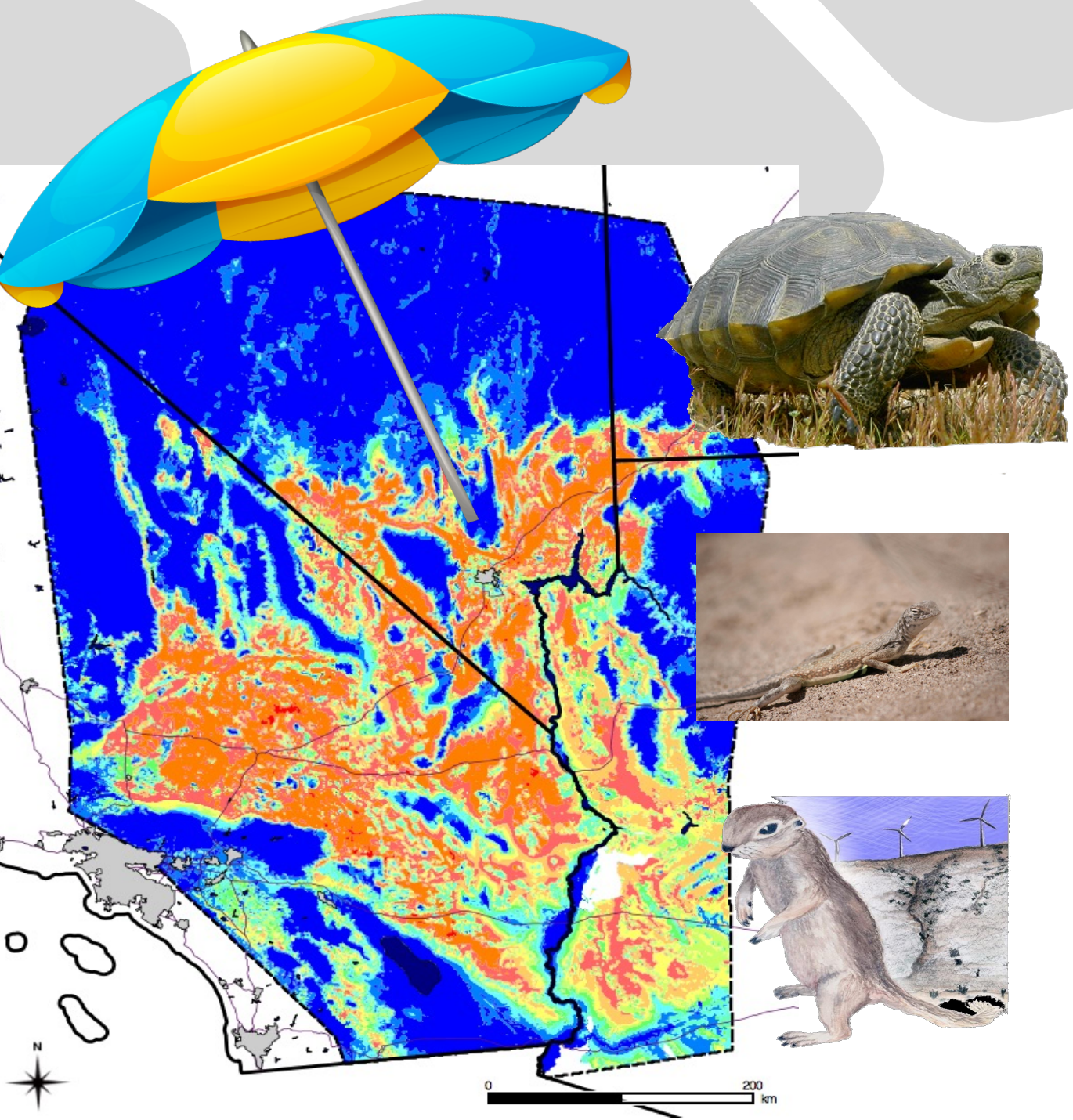


Connectivity Modeling

- **Pairwise comparisons of regions affected by barriers show the relative impacts of different barrier permeability**
- **All were found to significantly reduce genetic connectivity**
- **More restrictive roadways resulted in the highest level of impact**



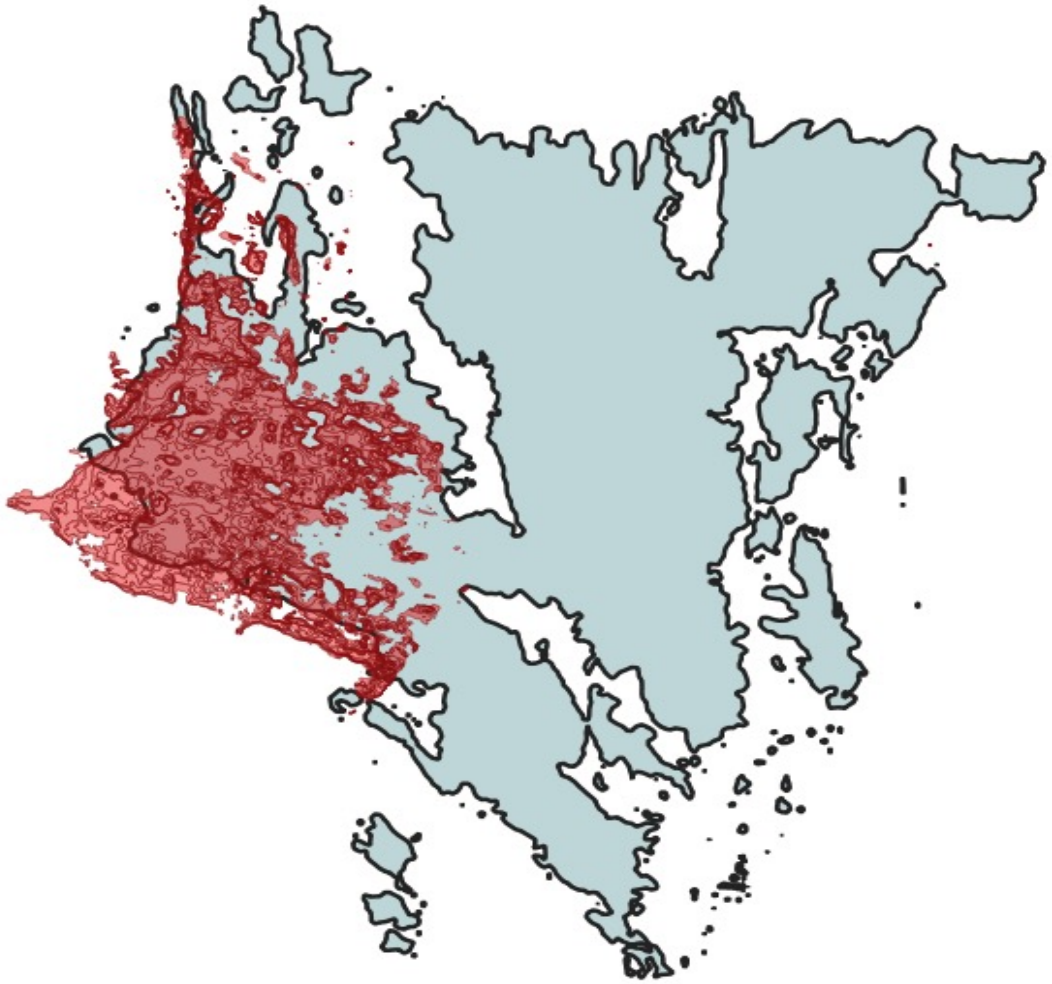
Umbrella Assessment

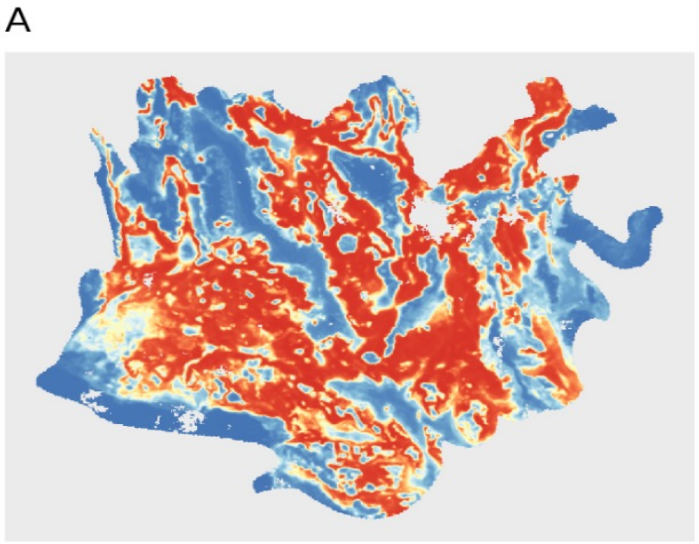


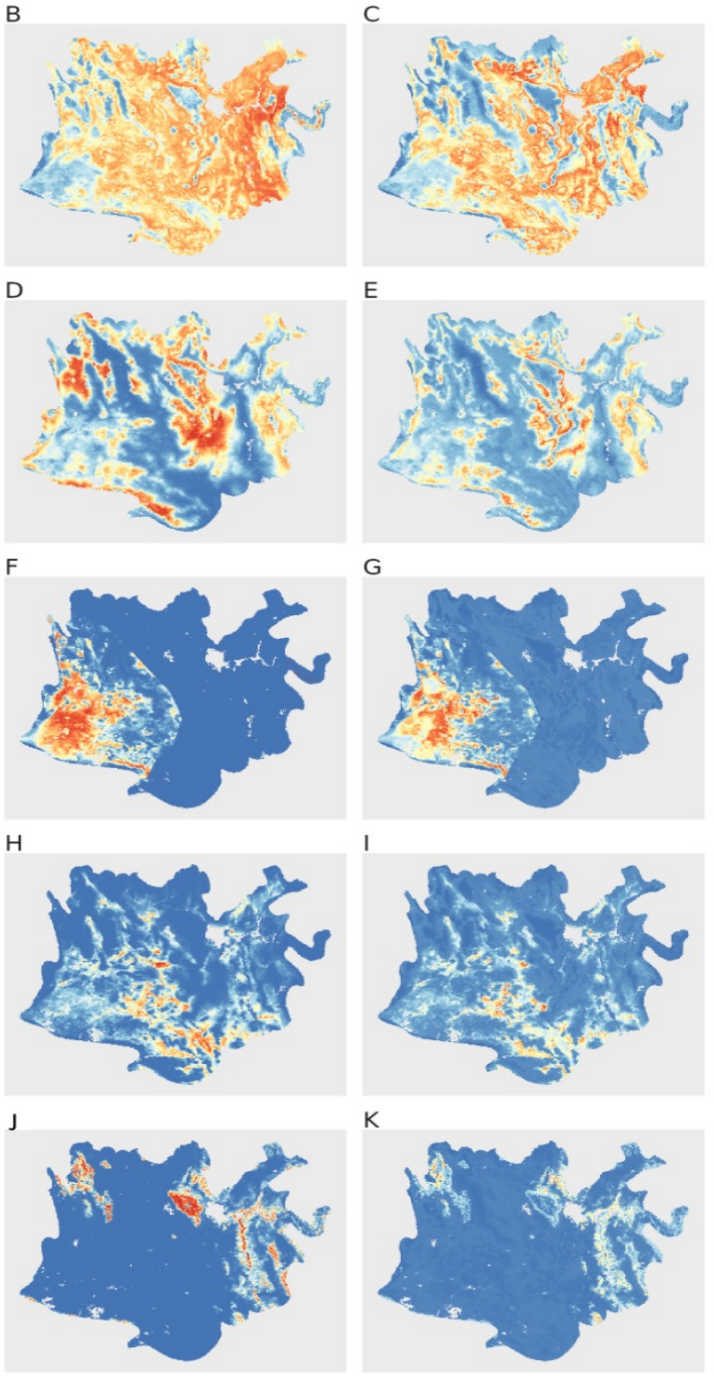
Umbrella Assessment

- **Acquired distribution models for 113 species**
- **Developed a continuous umbrella metric to determine the overlap of habitat for tortoises with other species in the Mojave**
- **Evaluated areas of highly suitable habitat for these species within tortoise habitat**

Umbrella Assessment

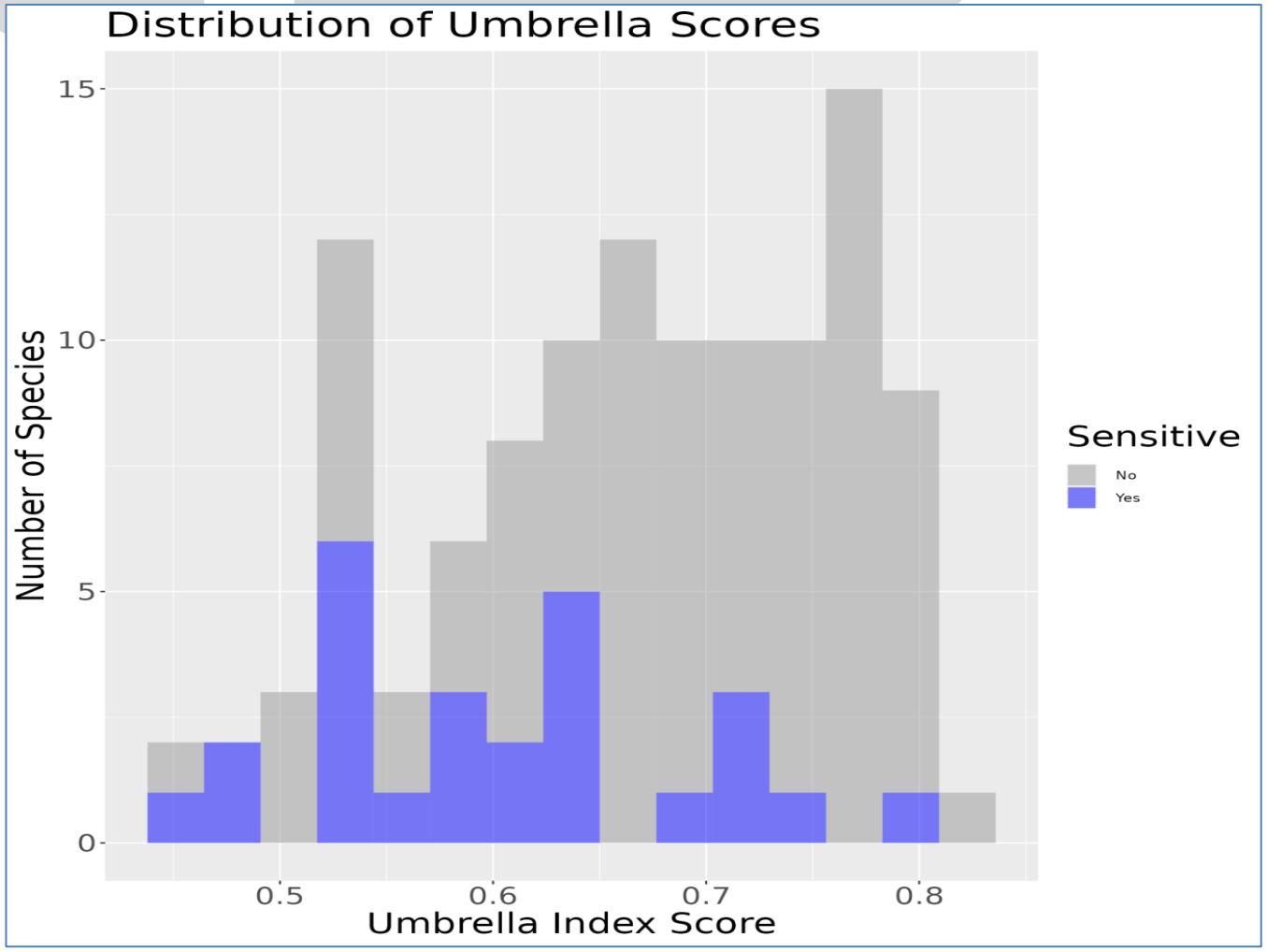




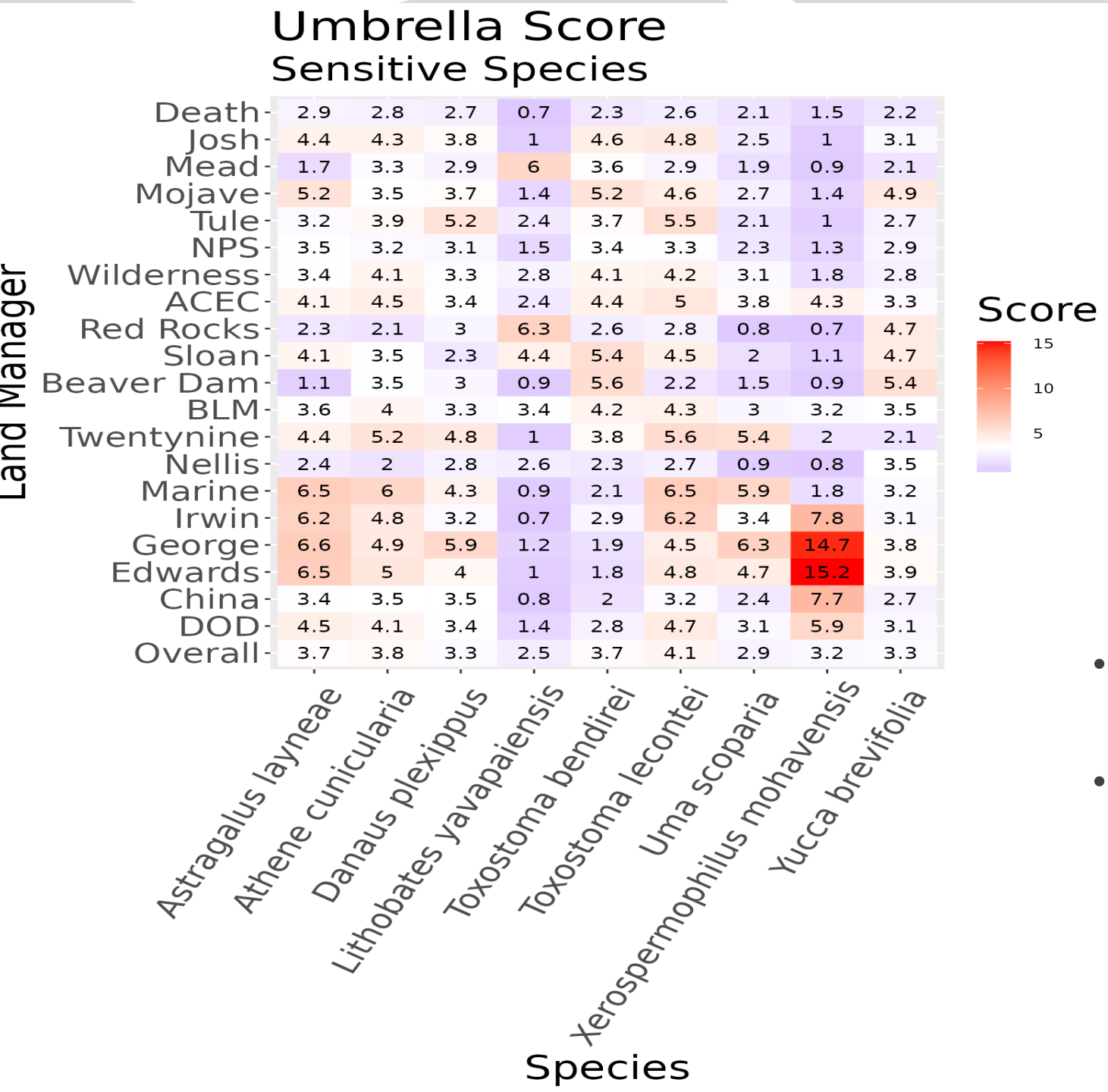


- **Commonly used methods do not consider the joint value of overlapping habitat, nor the difference in extent of habitat**

Umbrella Assessment



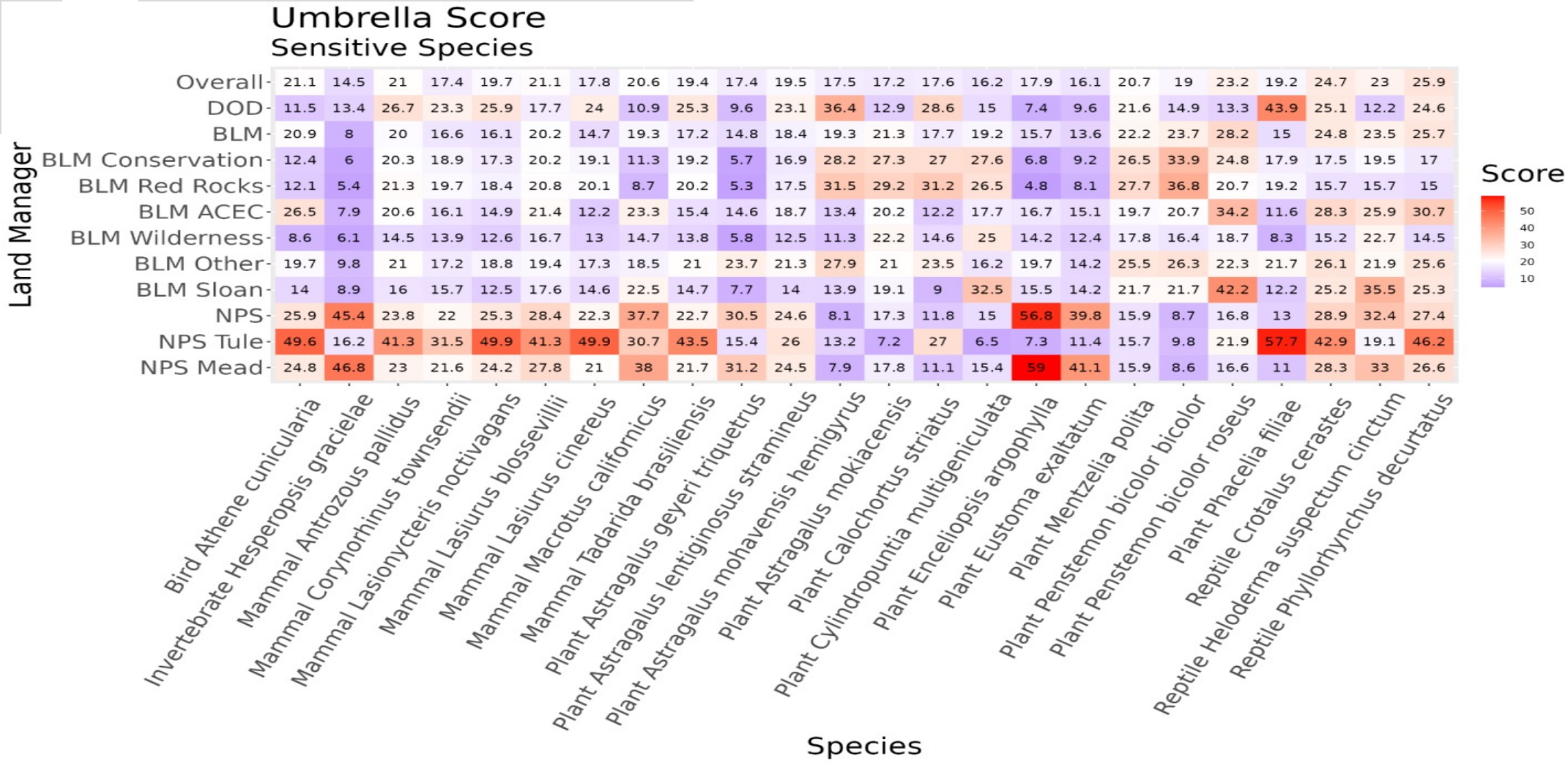
- **Species distribution models for 113 species**
  - **26 of conservation concern (IUCN, federal, state or agency)**
  - **17 modeled to the extent of Clark County extent, Nevada**
  - **9 modeled to the extent of the Mojave**
- **Species of conservation concern had relatively lower overall umbrella scores**



Umbrella Assessment

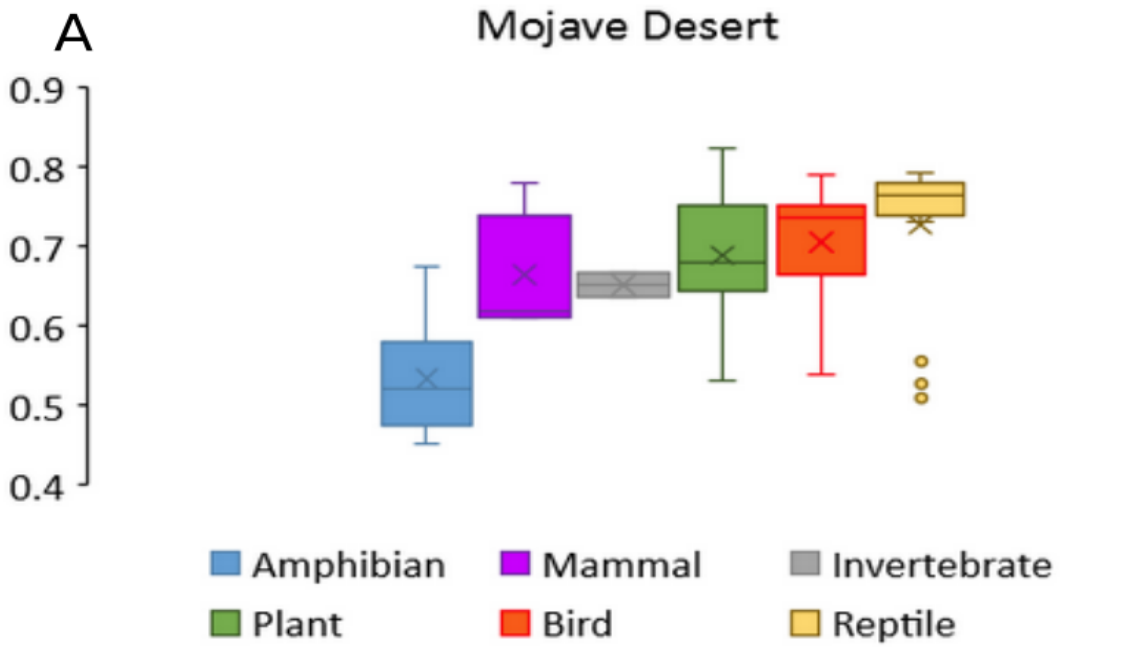
- **Umbrella scores differed between land management entities**
- **DoD lands showed some of the highest umbrella scores**
  - **Key species: Lane Mountain Milkvetch, Le Contes Thrasher, Fringe toed lizard, Mohave Ground Squirrel**

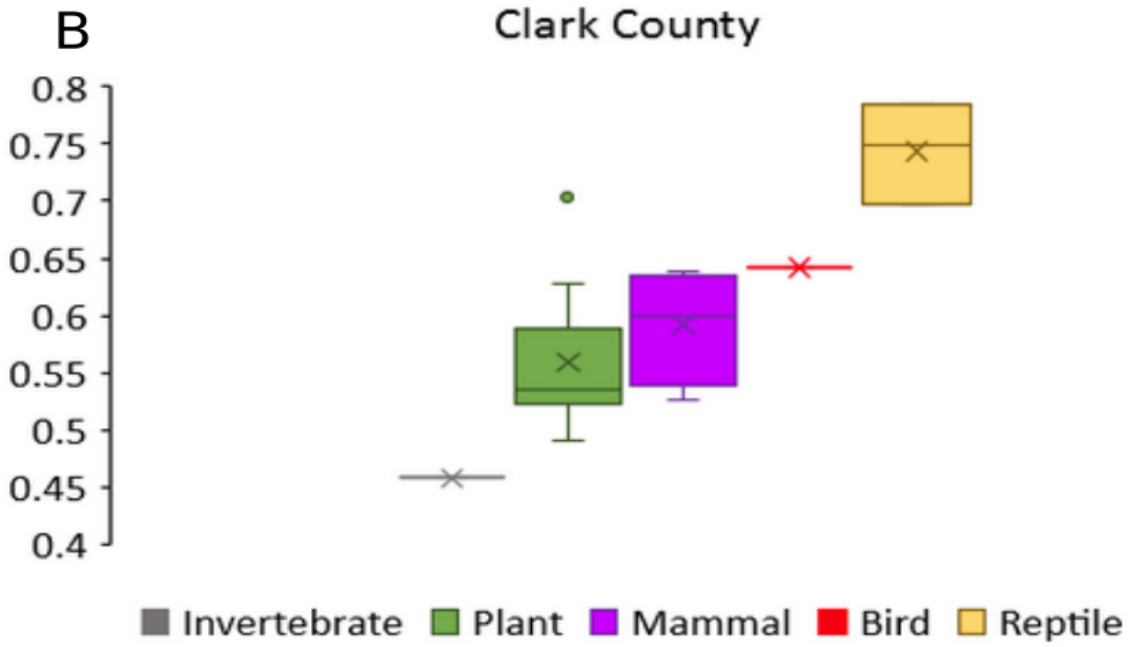
Umbrella Assessment



- **Clark County, Nevada had a great number of species modeled, less on DoD administered lands**
- **NPS had much higher umbrella scores overall; DoD showed higher values for two plant species**

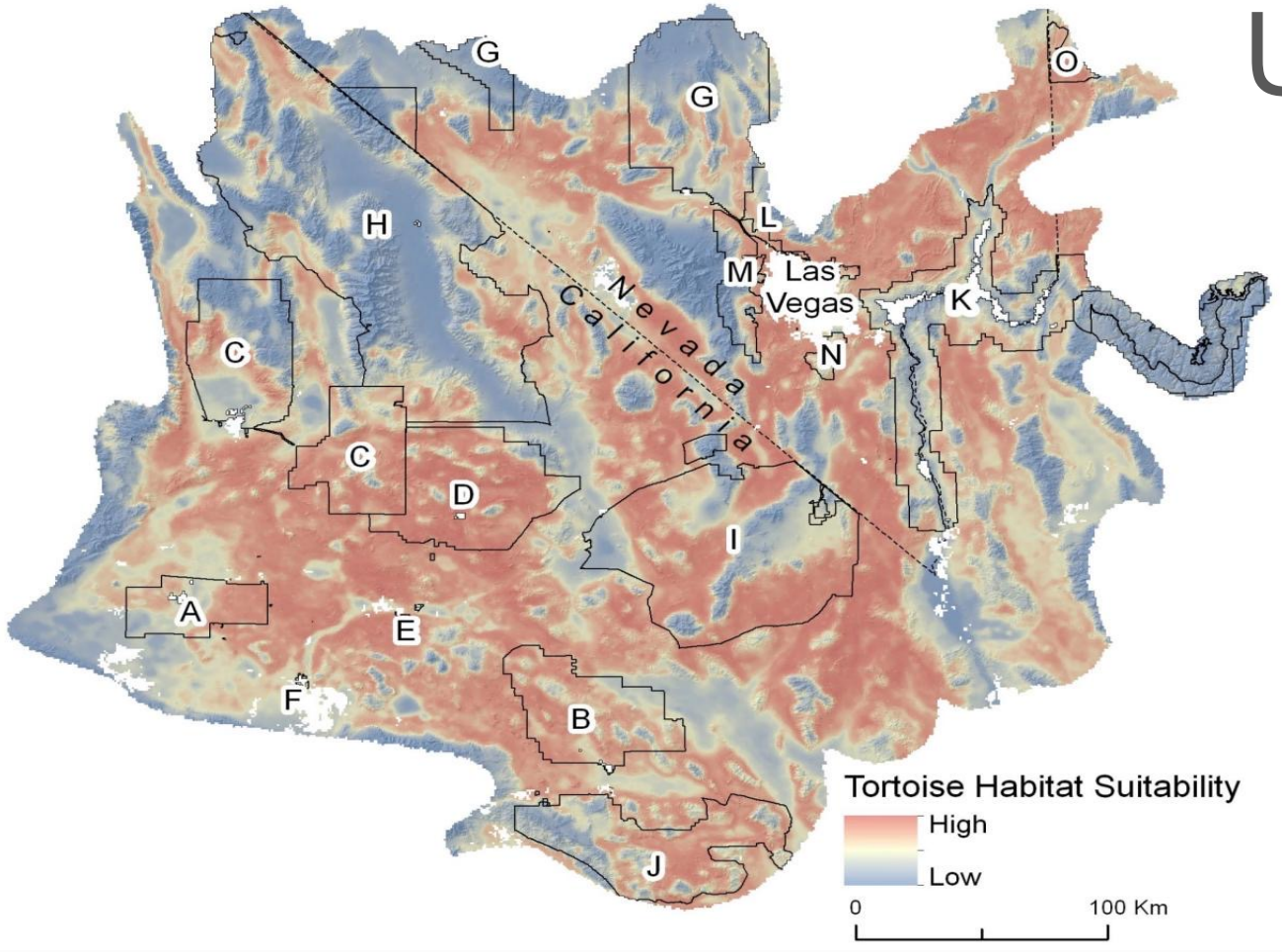
Umbrella Assessment





- **Umbrella scores differed among taxonomic groups**
  - **Amphibians had lower scores in the Mojave**
  - **Invertebrates had lower scores in Clark County, Nevada**
  - **Reptiles had the highest umbrella scores for both regions, followed by birds, mammals, and plants**

Umbrella Assessment



- **The tortoise has high umbrella scores for many species of concern throughout its range**
- **DoD lands are prevalent in the western extent of tortoise habitat and have higher scores for several species of concern**
- **Umbrella concepts only work if conservation actions are upheld/implemented; this is not the case for much of the Mojave**

Key Points

- Desert tortoises exhibit genetic structure among populations that has been formed through their existence in a connected landscape
- Current and future habitats are impacted (i.e. lost and degraded) by anthropogenic barriers that will reduce connectivity among tortoise populations
- Climate change will reduce the extent tortoise habitat overall, with losses generally associated with higher RCP forcing scenarios (4.5, 6.0 and 8.5), however DoD lands are expected to increase in desert tortoise habitat area - making them key in the sustainment of DT in the future
- DT do have high overlap with many other sensitive species, and DoD lands tend to have higher overall Umbrella scores with those species. This suggests that DoD efforts to conserve DT habitat will benefit many other species.