Mapping habitat and genetic diversity in the Mojave Desert

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USGS
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Questions

What are the best regions in the Mojave to conserve to protect species and genetic diversity and preserve evolutionary potential?

Is dispersed renewable energy and other development compatible with the conservation of desert species and their habitats?

Why focus on genetic diversity?

- Genetic diversity within species represents a fundamental level of biodiversity

- Provides the basis for phenotypic variation and adaptation

- Underlies the processes of lineage diversification and speciation that are evident in patterns of species, community and ecosystem diversity we see today.

- Mapping patterns of genetic diversity across a landscape can help to locate evolutionary “hotspots”-- regions where diversification and speciation may be more likely to occur.

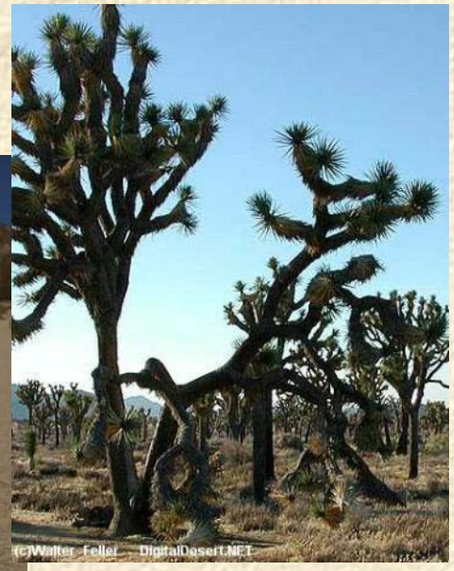
Research Objectives

1. Gather population genetic data from completed studies of desert species

2. Develop habitat suitability models for selected species
   - Gather species presence data
   - Environmental data layers

3. Map and compare patterns of genetic divergence and diversity among species to locate evolutionary hotspots

4. Evaluate in conjunction with current and proposed land use



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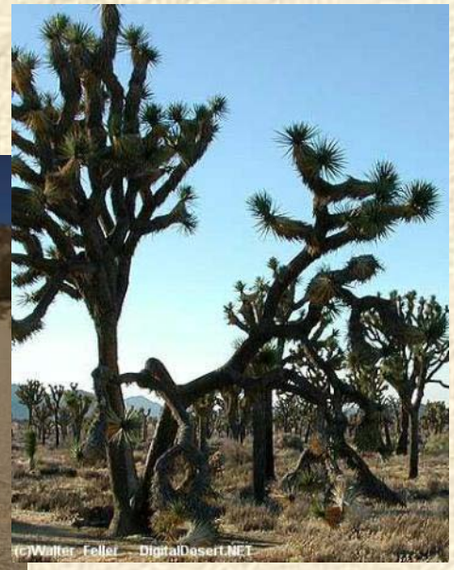

Species

Herpetofauna

1. *Anaxyrus punctatus*
2. *Chionactus occipitalis*
3. *Coluber flagellum*
4. *Crotaphytus bicinctores*
5. *Crotalus cerastes*
6. *Dipsosaurus dorsalis*
7. *Gopherus agassizii*
8. *Lichanura trivirgata*
9. *Plestidon gilberti*
10. *Phrynosoma platyrhinos*
11. *Sauromalus ater*
12. *Sceloporus magister*
13. *Uma scoparia*
14. *Xantusia vigilis*

Invertebrates

15. *Homalonychus selenopoides*
16. *Homalonychus theologus*
17. *Tegeticula antithetica*
18. *Tegeticula synthetica*

Mammals

19. *Chaetodipus penicillatus*
20. *Ovis canadensis*
21. *Perognathus longimembris*
22. *Spermophilus mojavensis*
23. *Thomomys bottae*

Plants

24. *Yucca brevifolia*

- Datasets contained at least 6 collection locations within the Mojave Desert (Average 20 locations)
- Genetic data consisted mainly of mtDNA sequence data with some nuDNA sequences or microsatellite data.

Distribution of Mojave Species

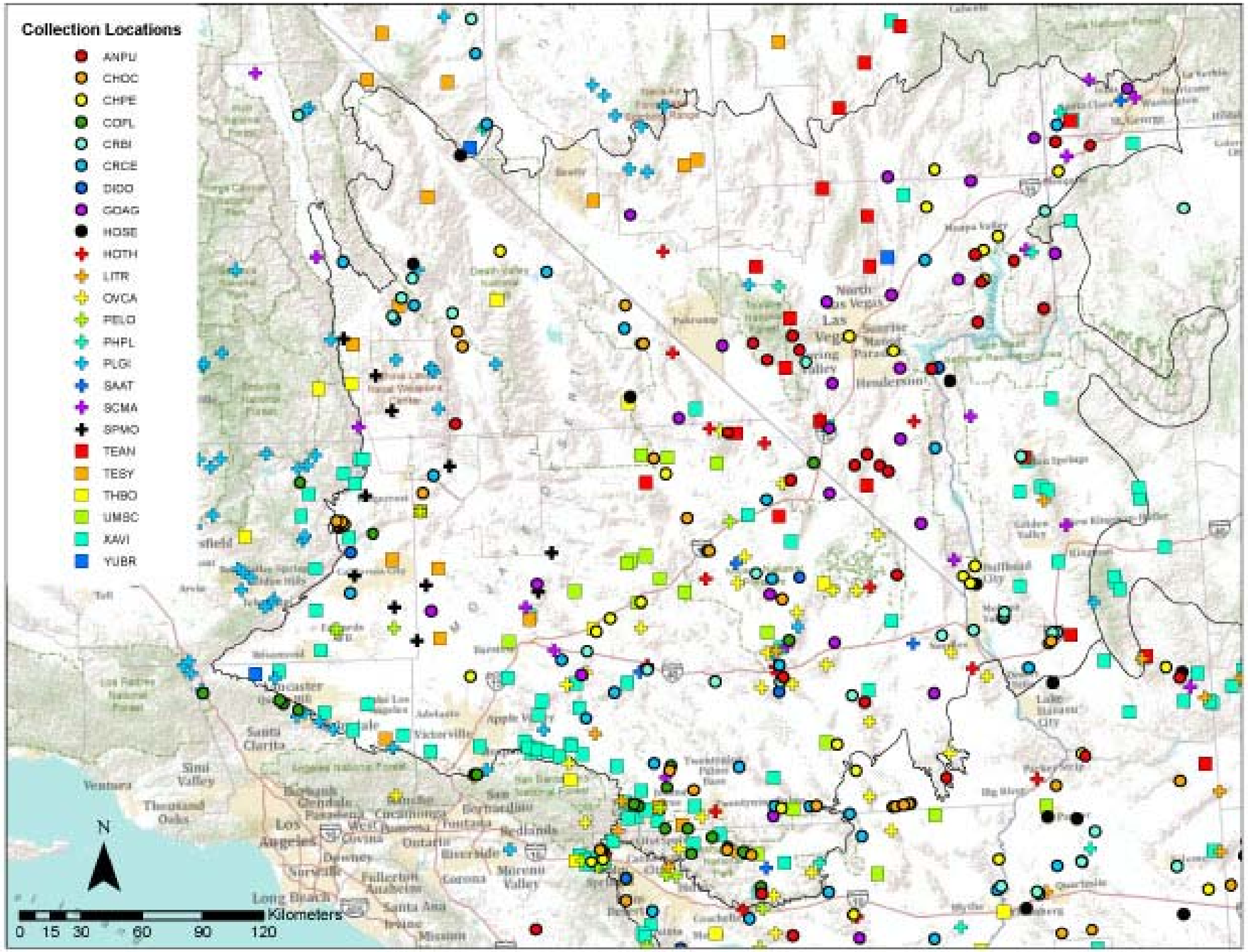

Figure 2-1: Collection locations for genetic datasets across the Mojave Desert.

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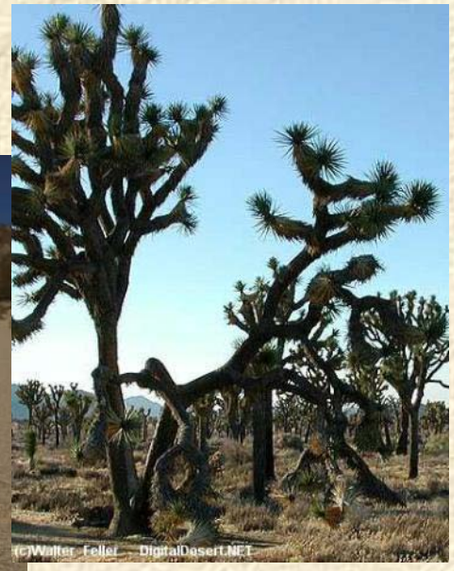

Species Habitat Models

Herpetofauna

1. ***Anaxyrus punctatus***
2. ***Chionactus occipitalis***
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12. ***Sceloporus magister***
13. ***Uma scoparia***
14. ***Xantusia vigilis***

Invertebrates

15. ***Homalonychus selenopoides/theologus***
16. *Tegeticula antithetica*
17. *Tegeticula synthetica*

Mammals

18. ***Chaetodipus penicillatus***
19. *Ovis canadensis**
20. ***Perognathus longimembris***
21. ***Xerospermophilus mojavensis***
22. ***Thomomys bottae***

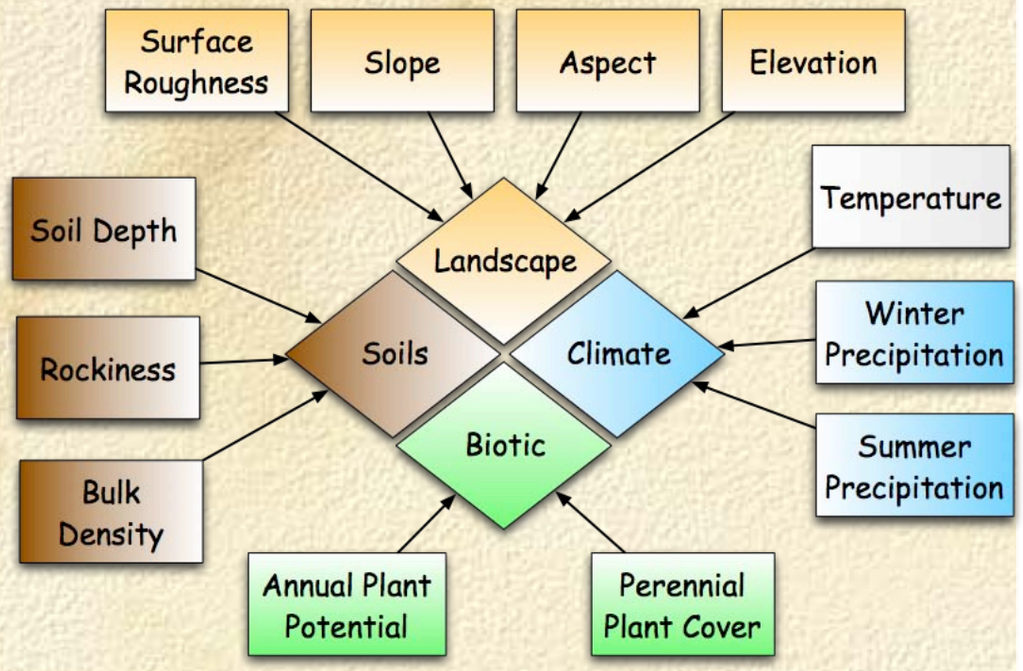
Plants

23. *Yucca brevifolia*

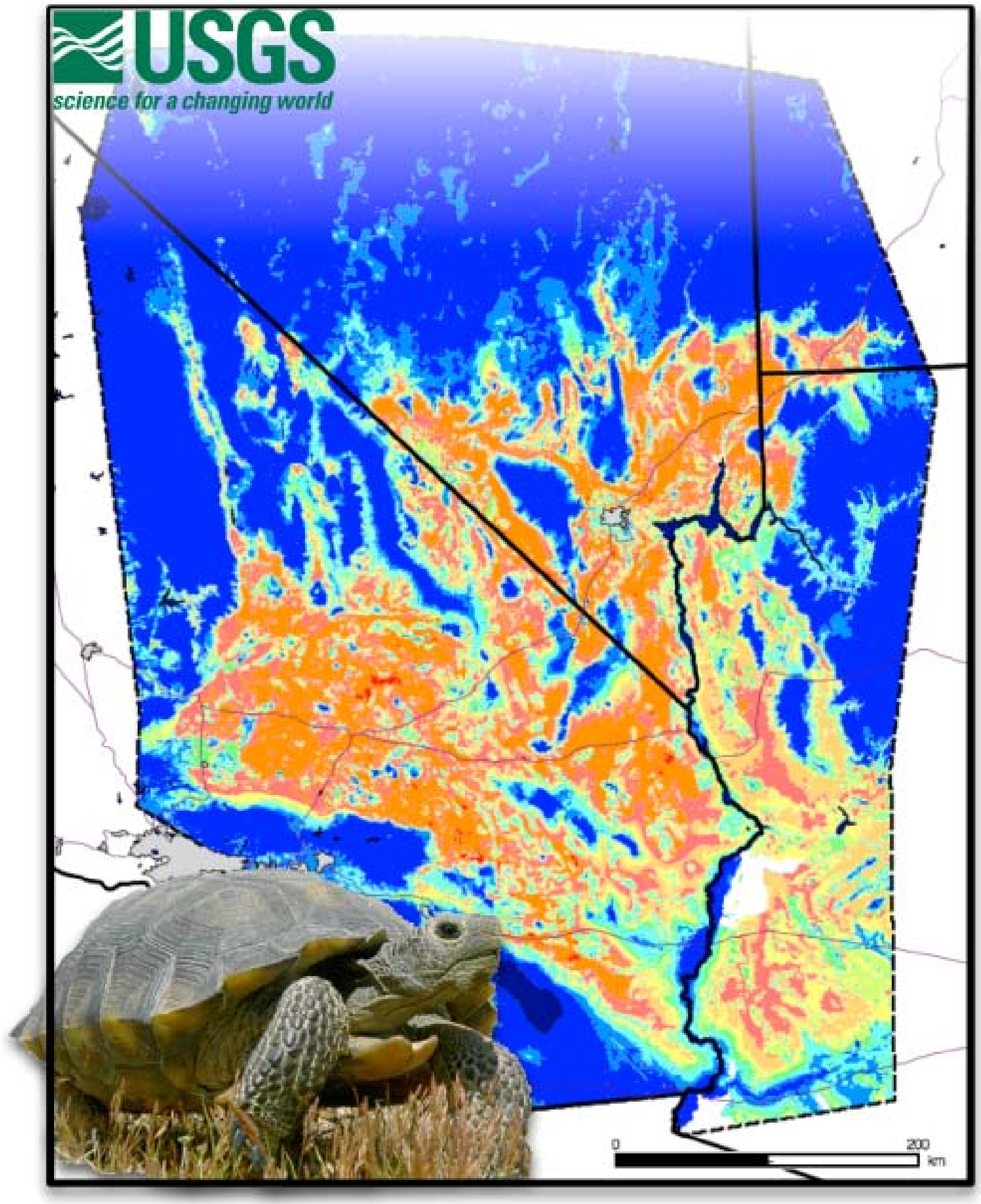
- **Presence data from Museums, USGS, DOD and CDFG databases and from individual researchers.**
- **Locations with less than 1.5 km accuracy discarded.**
- **Between 20 (spiders) and 472 (*Sceloporus*) presence points used per species (Avg = 206)**

* Bighorn: No suitability model available, but used a expert opinion habitat shapefile to mask genetic data

Habitat Suitability Modeling

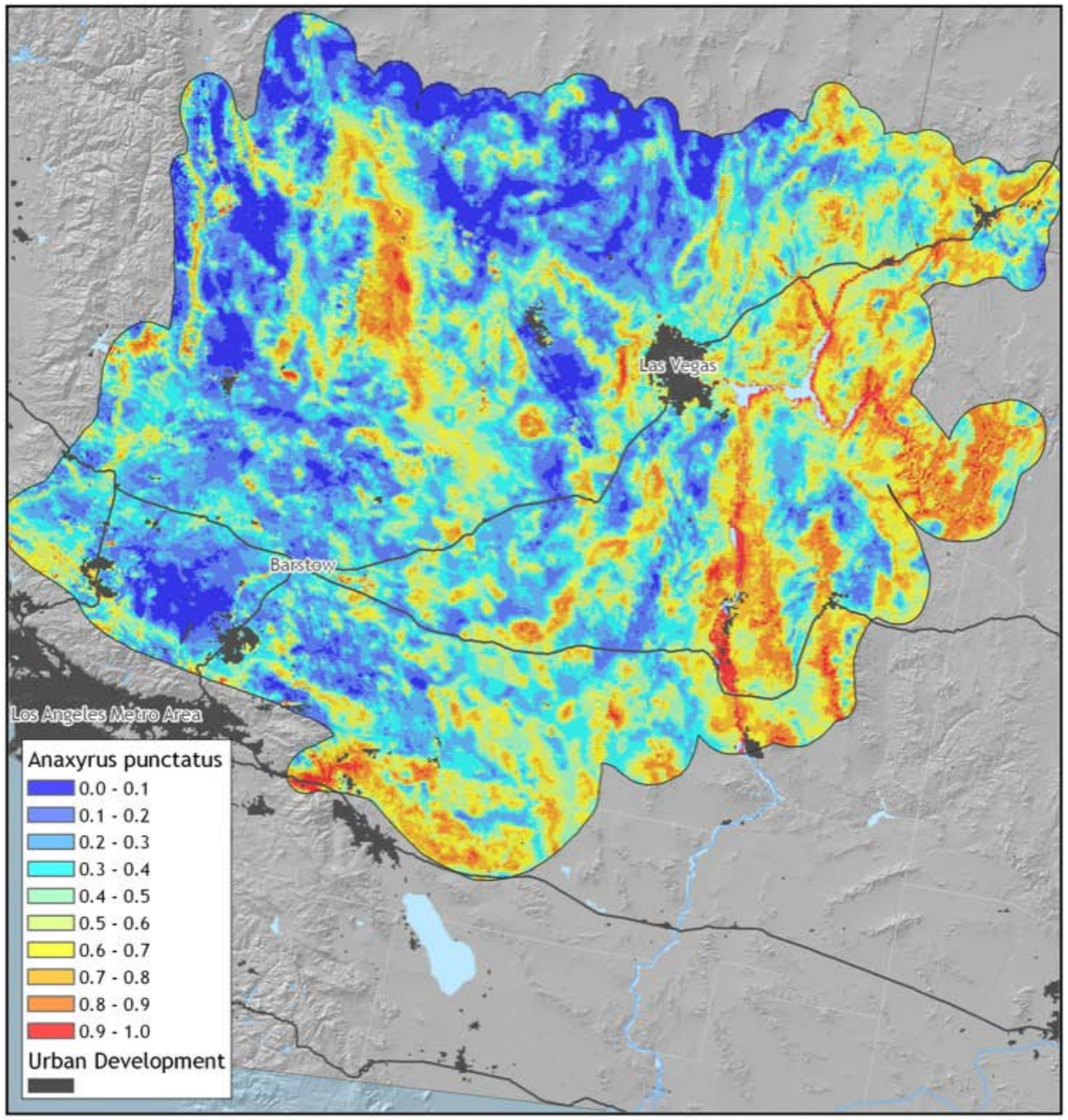


- **Covariates selected based on conceptual models of habitat preference for each species**
- **Modeled using GAMs and Maxent**
- **1 km grid cell size**
- **Model performance evaluated using several metrics with top 18 models evaluated by experts**
- **Model averaging of final suite of top models.**



Nussear et al. 2009

Resulting Probability Models



ANAXYRUS PUNCTATUS HABITAT MAP OF THE MOJAVE DESERT BASIN

1:2,700,000

Kilometers 0 25 50 100 150

USA Contiguous Albers Equal Area Projection
Central Meridian -96.00

Prepared with financial support from the Bureau of Land Management (United States) under agreement L10PG00751.

Digital base map from StreetMap USA available through ESRI.

This map displays habitat suitability for Anaxyrus punctatus in the Mojave Desert Basin. Habitat suitability was assessed using Generalized Additive Models (GAM) and Maximum Entropy (MaxEnt) methods. Occurrence data were compiled from publicly available sources.

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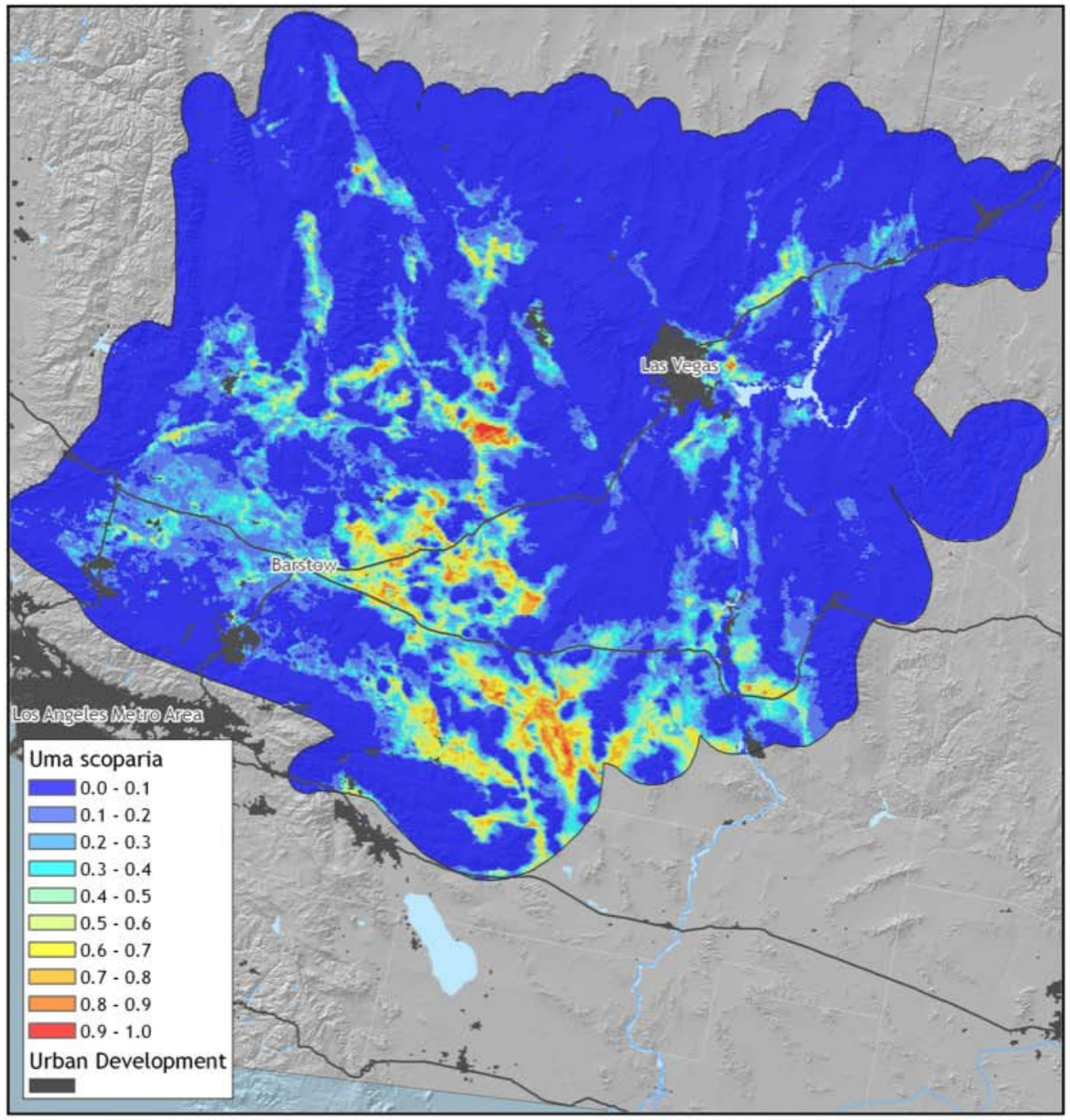

UMA SCOPARIA HABITAT MAP OF THE MOJAVE DESERT BASIN

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Digital base map from StreetMap USA available through ESRI.

This map displays habitat suitability for Uma scoparia in the Mojave Desert Basin. Habitat suitability was assessed using Generalized Additive Models (GAM) and Maximum Entropy (MaxEnt) methods. Occurrence data were compiled from publicly available sources.

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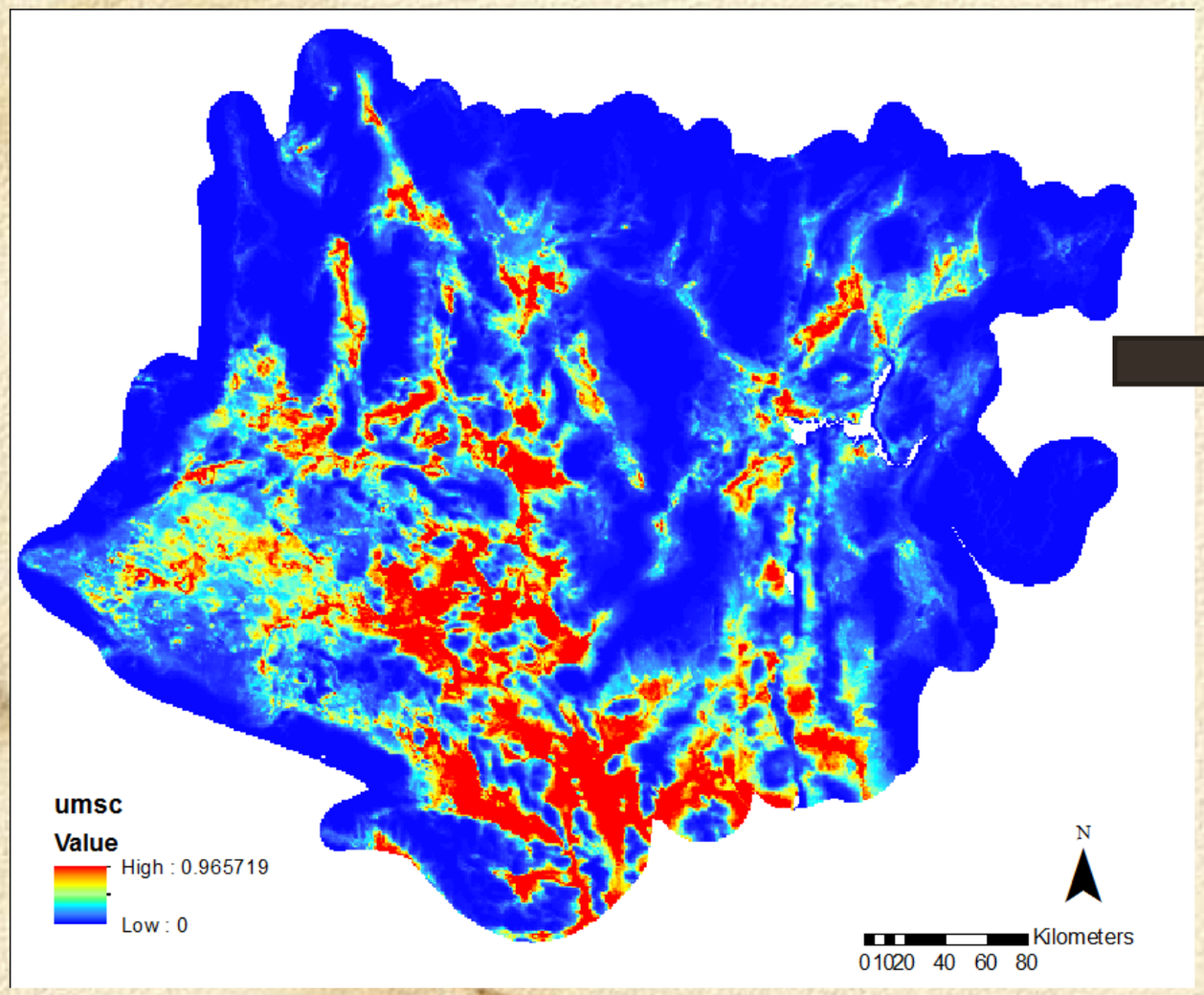
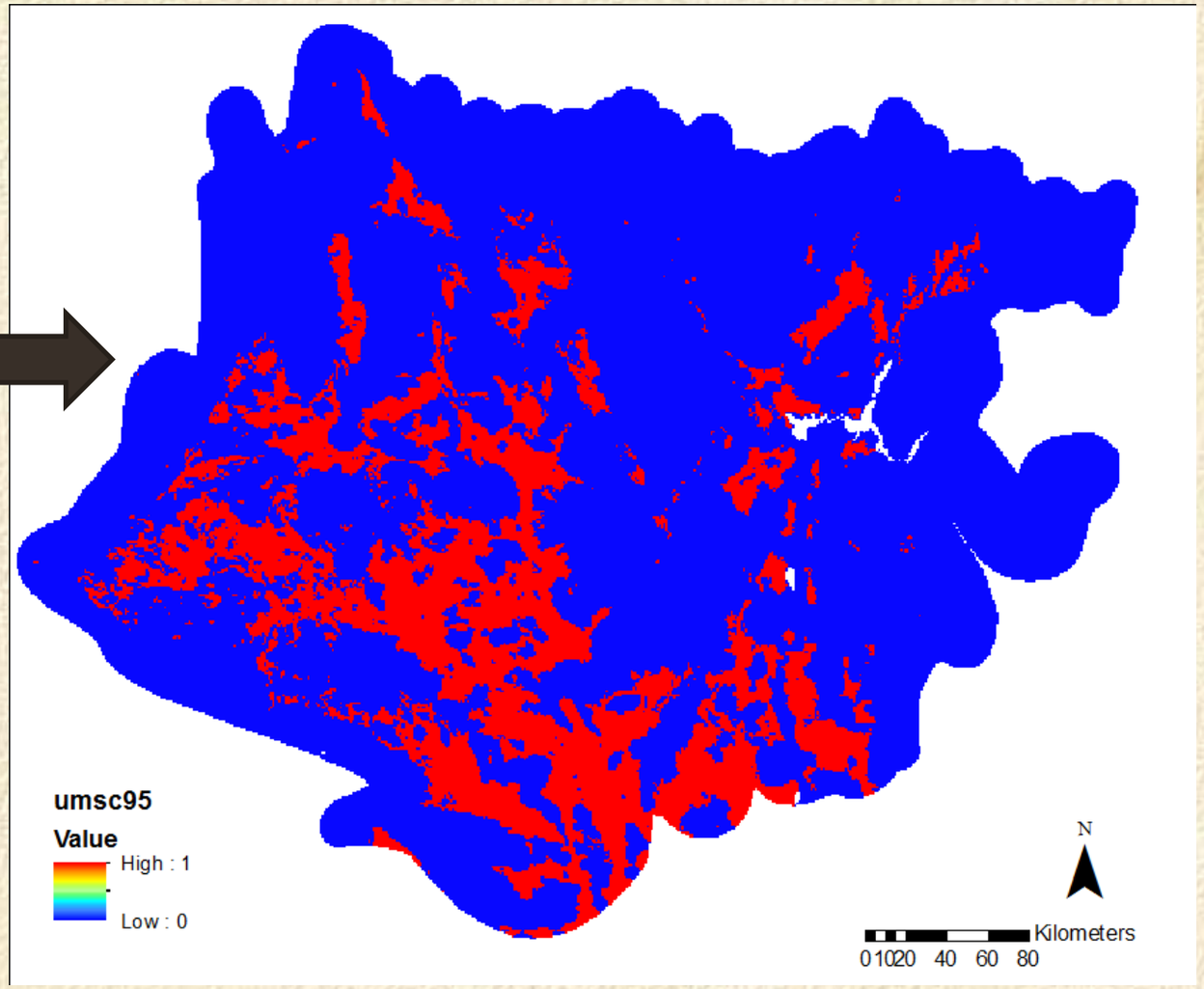
Thresholding and "Species Richness"

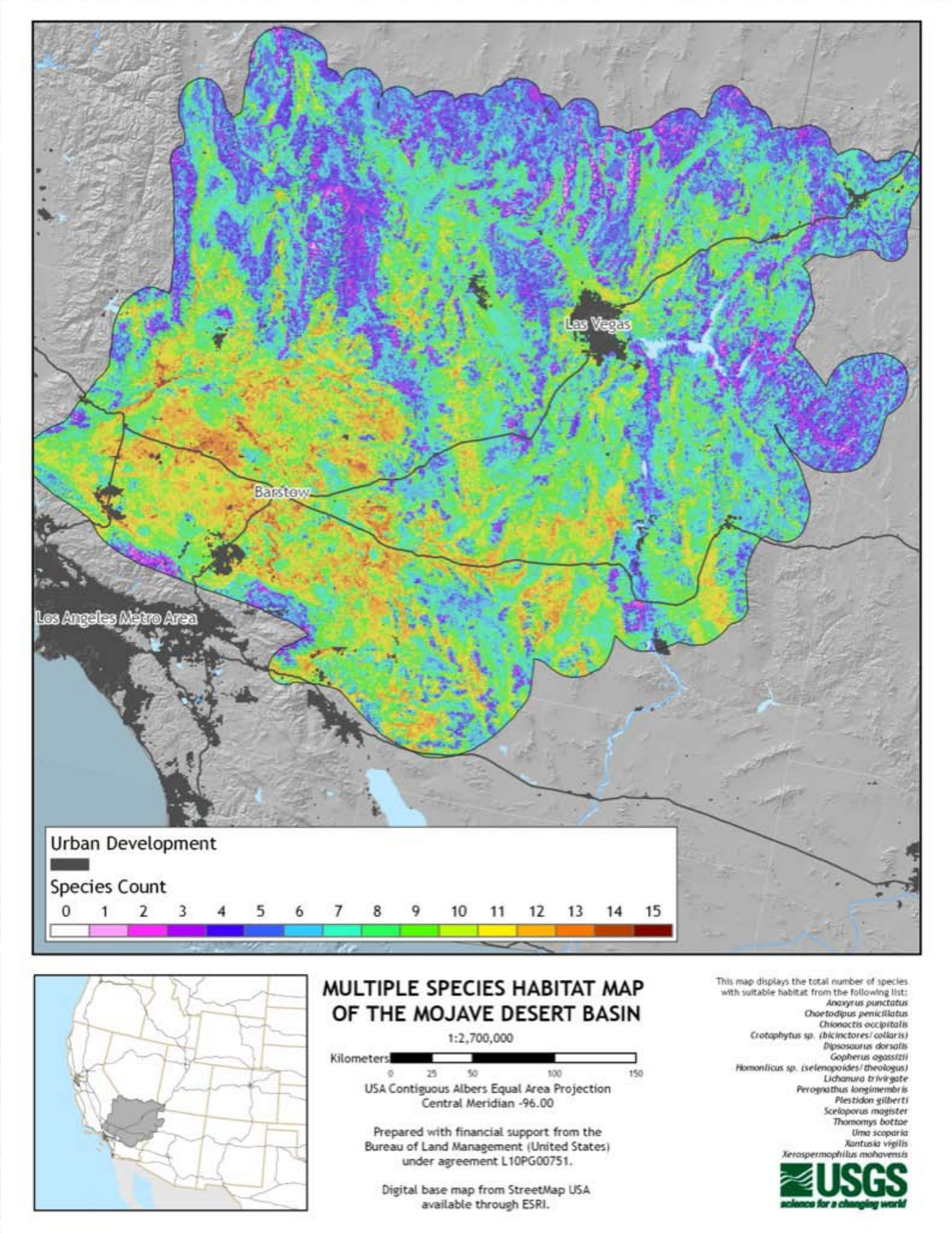
- Final maps were reclassified into high and low habitat suitability using the 5th quartile of habitat suitability scores from the occurrence localities.





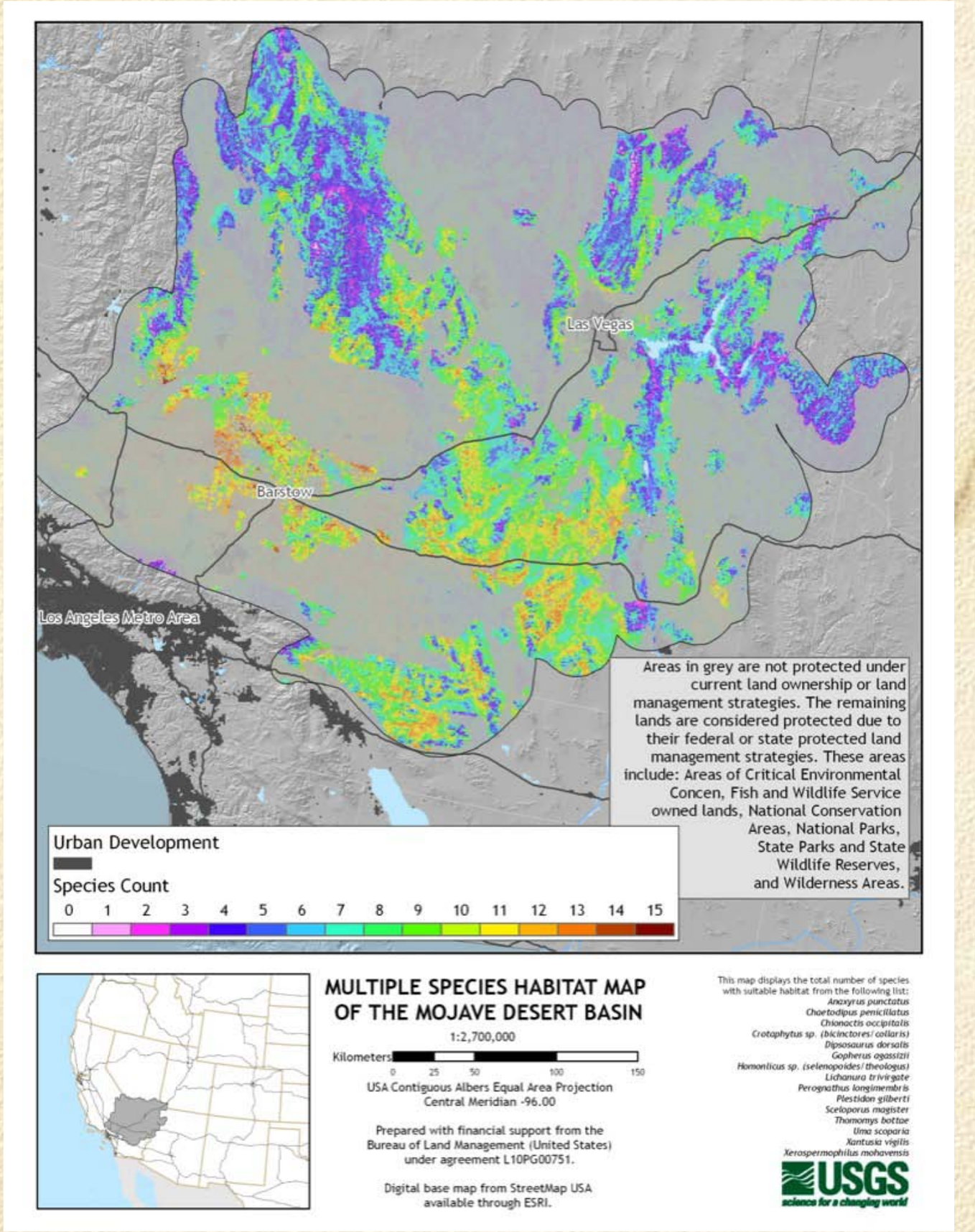
Thresholding and "Species Richness"

- High habitat suitability was summed across all 15 taxa to approximate "species richness".
- Suitable habitat/ species richness concentrated in the western Mojave, valleys and alluvial fans.
- 0.06% study area contained all 15 species
- 22% study area contained 10 or more



Protected Lands Coverage

- "Protected lands": 41%; Areas of critical environmental concern, USFWS lands, Nat'l Conservation Areas, Nat'l Parks, State Parks, State Wildlife Reserves and Wilderness Areas.
- 0.01% of suitable habitat for all 15 species is protected
- 8.5% of suitable habitat for 10 or more species protected



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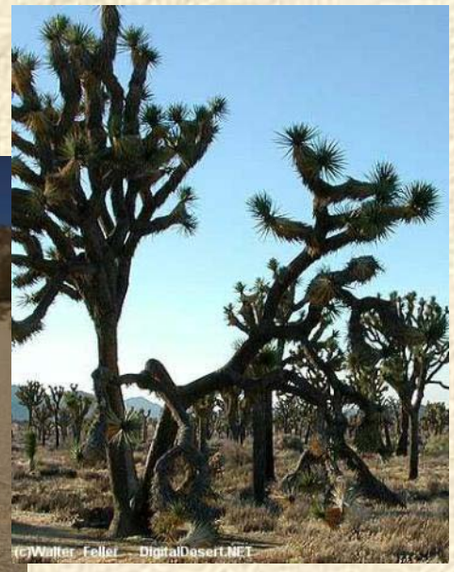
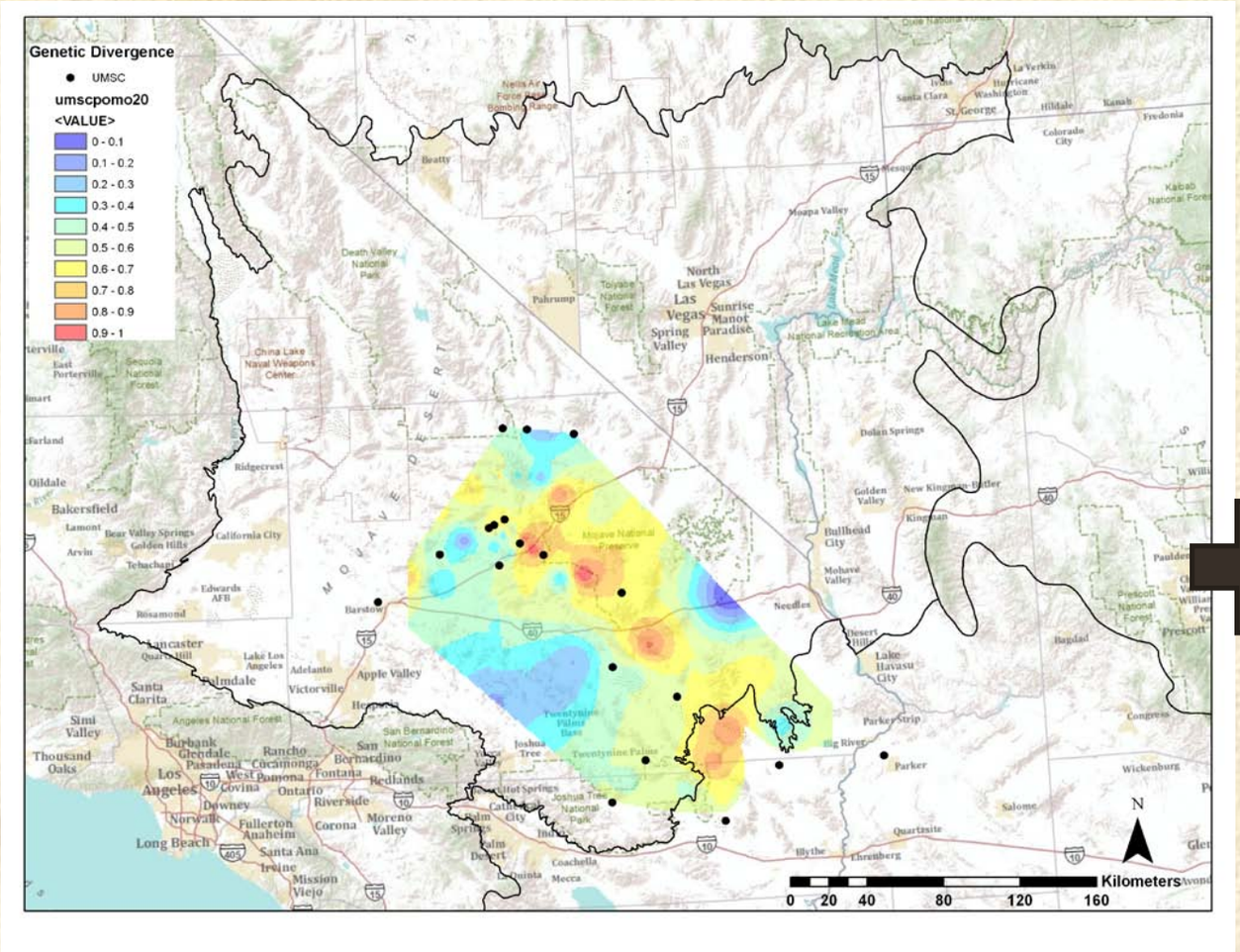
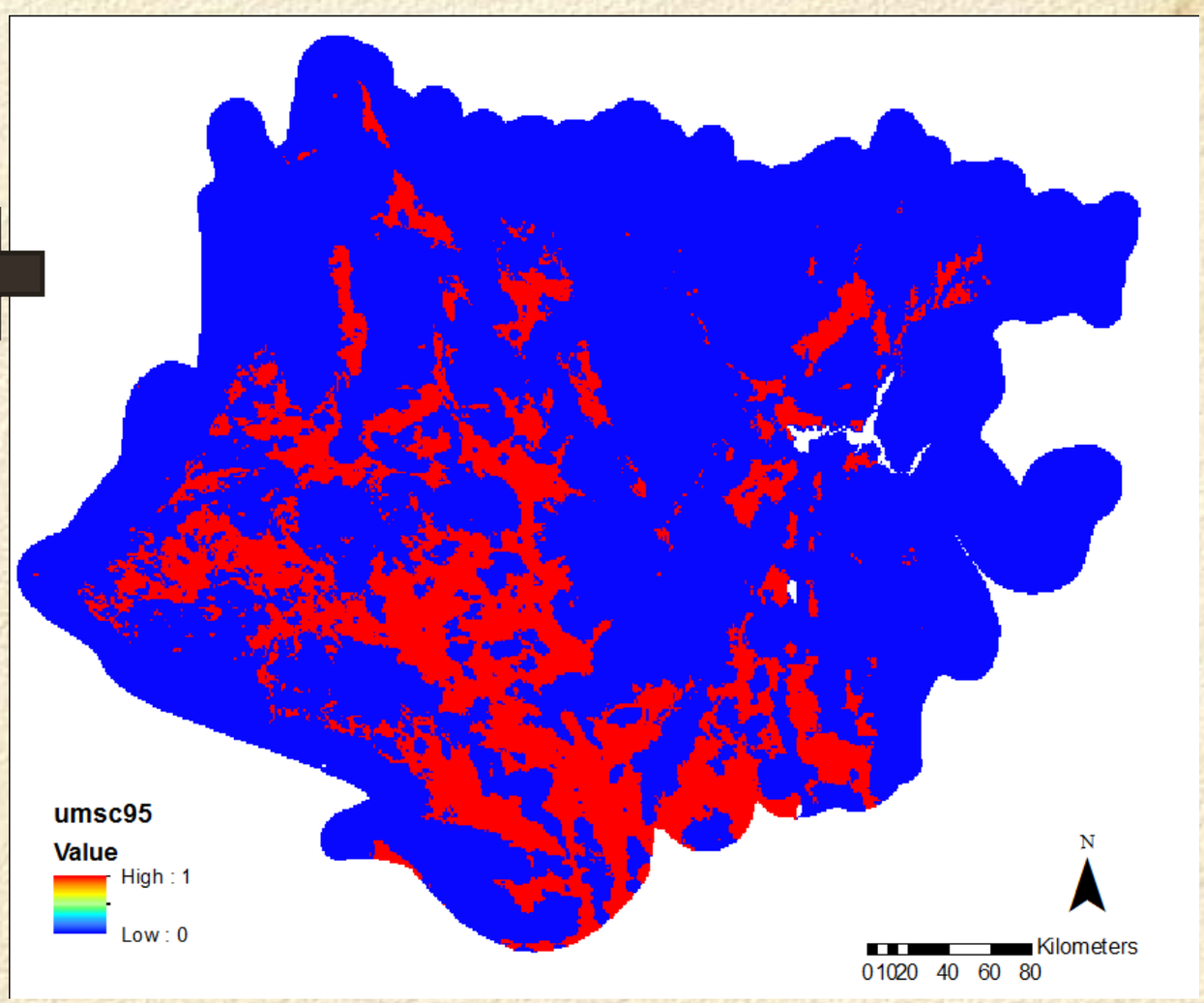


Incorporating Genetic Data

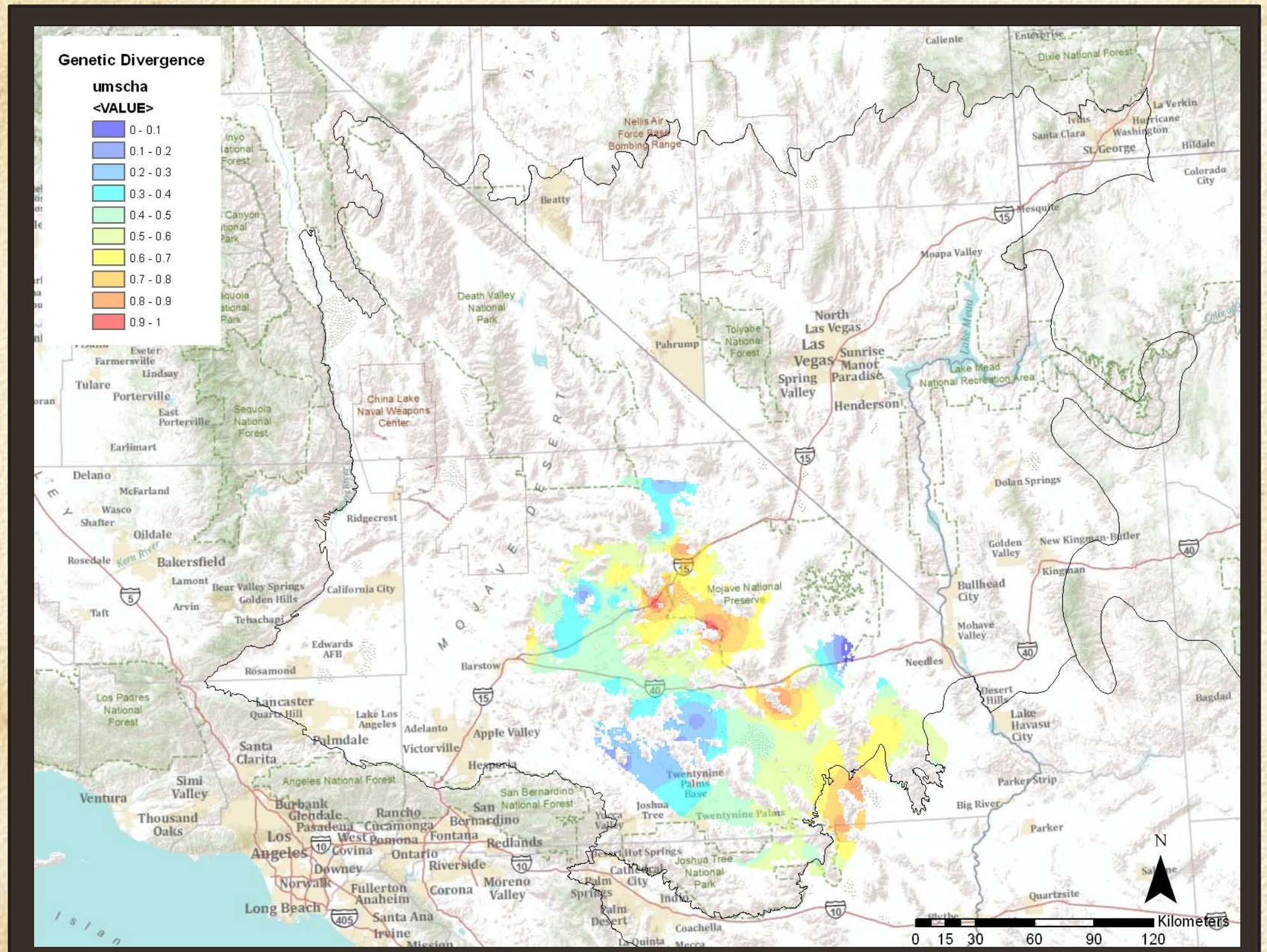
- **Mapped patterns of genetic diversity and divergence and masked these with suitable habitat**





Incorporating Genetic Data

- **Clipped to the extent of genetic sampling and high suitable habitat**



Genetic Mapping

Genetics Mapped in 3 ways:

1. **Population Divergence (mapped at midpoints among sites)**
2. **Intrapopulation Sequence Diversity**
   - **Measures differences among gene copies as the number of bases they differ by**
3. **Intrapopulation Gene Diversity /Heterozygosity**

Genetic Mapping

- **Population Divergence and Sequence Diversity will emphasize locations where historical lineages come into contact (Suture Zones)**
- **Intrapopulation Gene Diversity/ Heterozygosity will also emphasize locations with large populations and stability over long periods of time (Refugia).**

Average Population Divergence

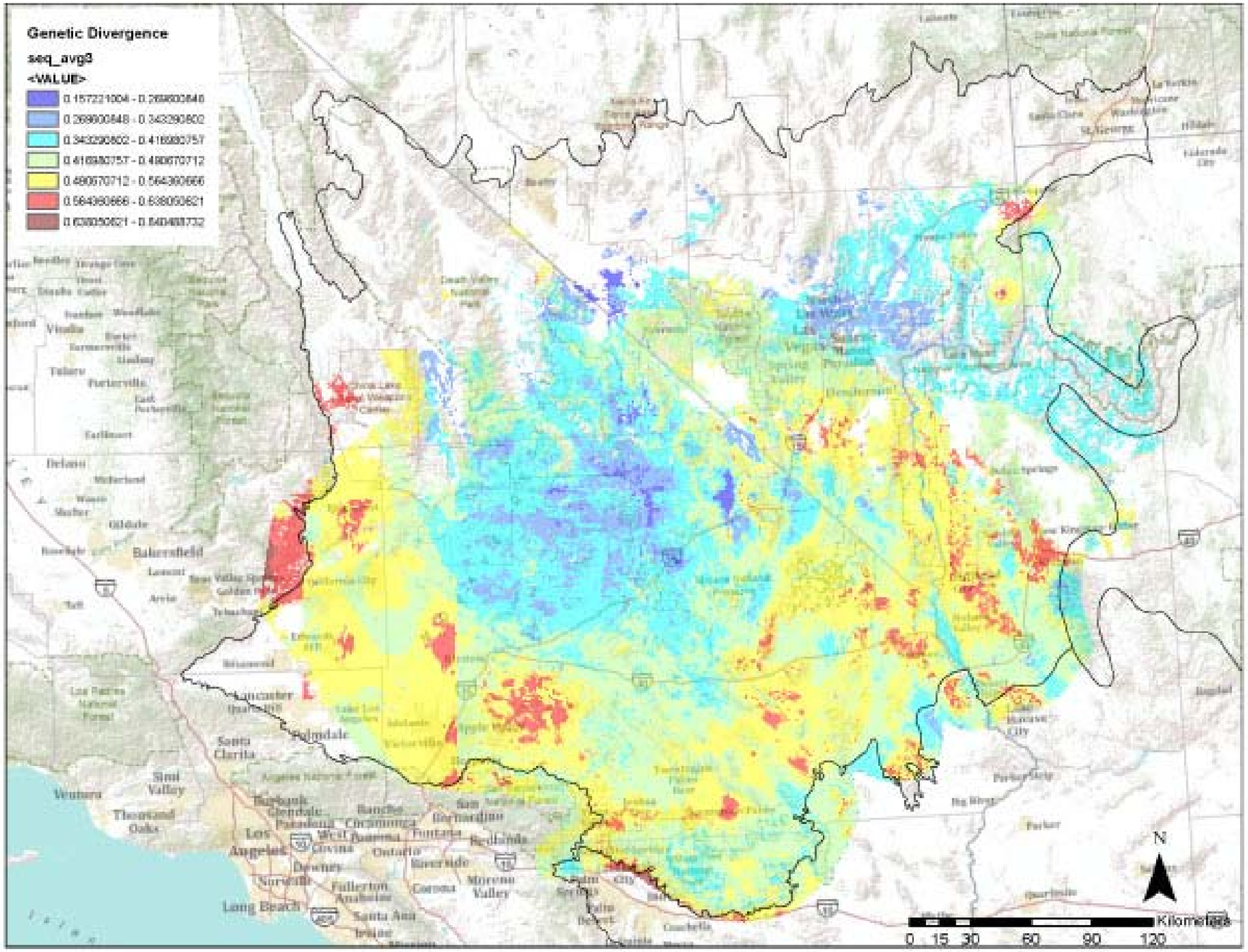


Figure 2-2: Average genetic divergence landscape for 15 species across the Mojave Desert. Areas of greatest divergence (1.5 standard deviations greater than the mean value) are highlighted in red.

Average Sequence Diversity

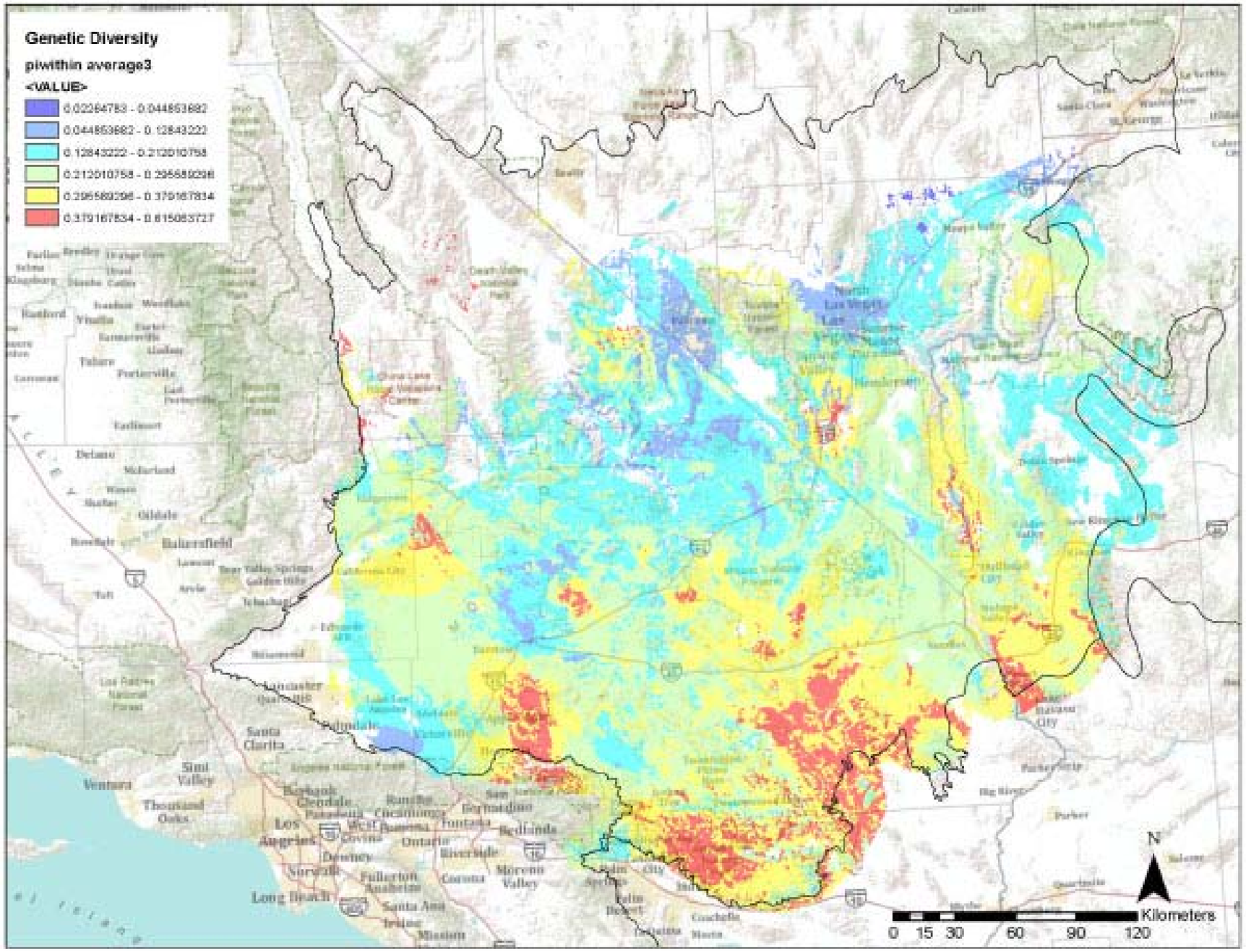


Figure 2-5: Average π diversity landscape for 13 species across the Mojave Desert. Areas of greatest diversity (1.5 standard deviations greater than the mean value) are highlighted in red.

Average Intrapopulation Gene Diversity

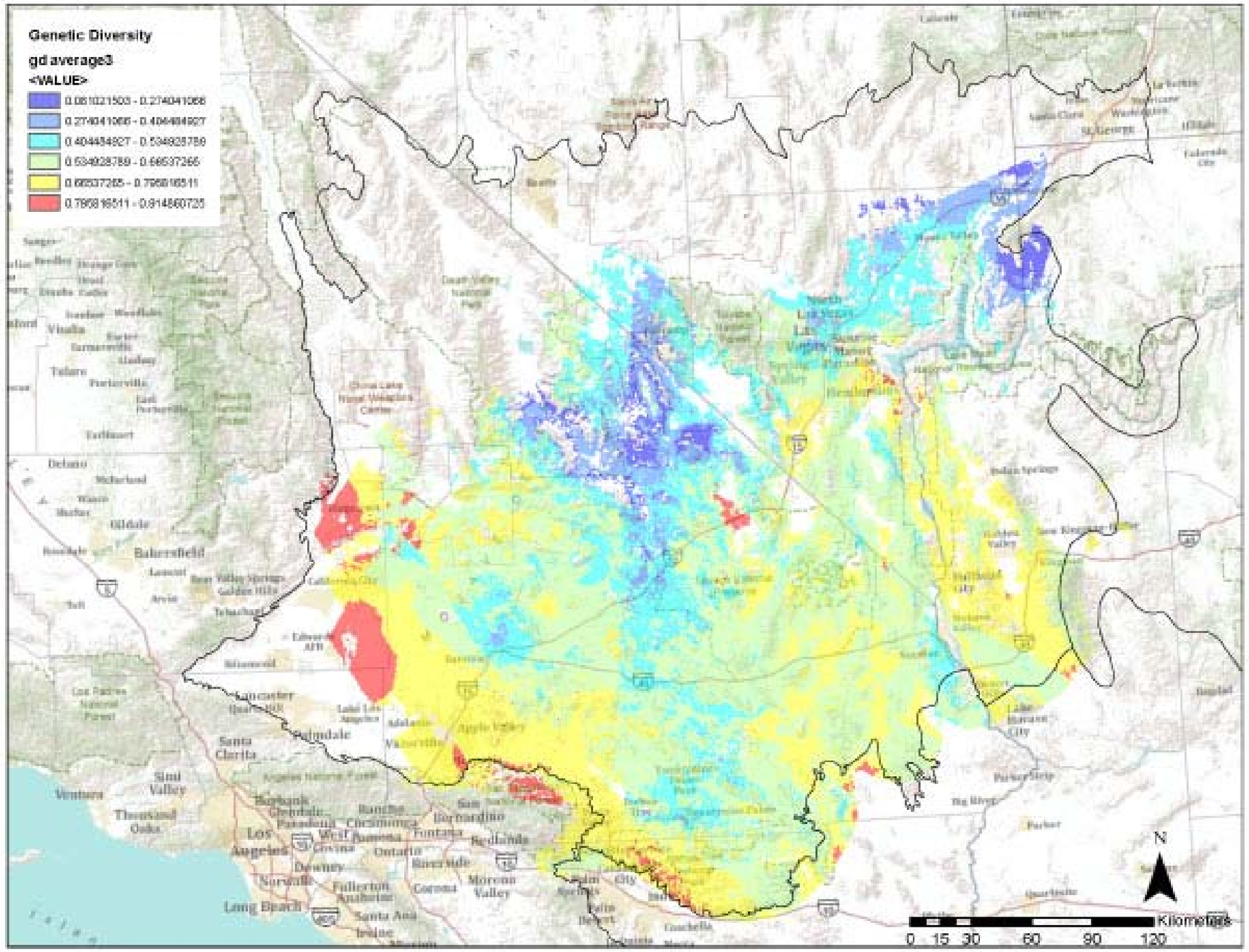


Figure 2-7: Average gene diversity landscape for 13 species across the Mojave Desert. Areas of greatest diversity (1.5 standard deviations greater than the mean value) are highlighted in red.

Combined Diversity and Divergence Hotspots

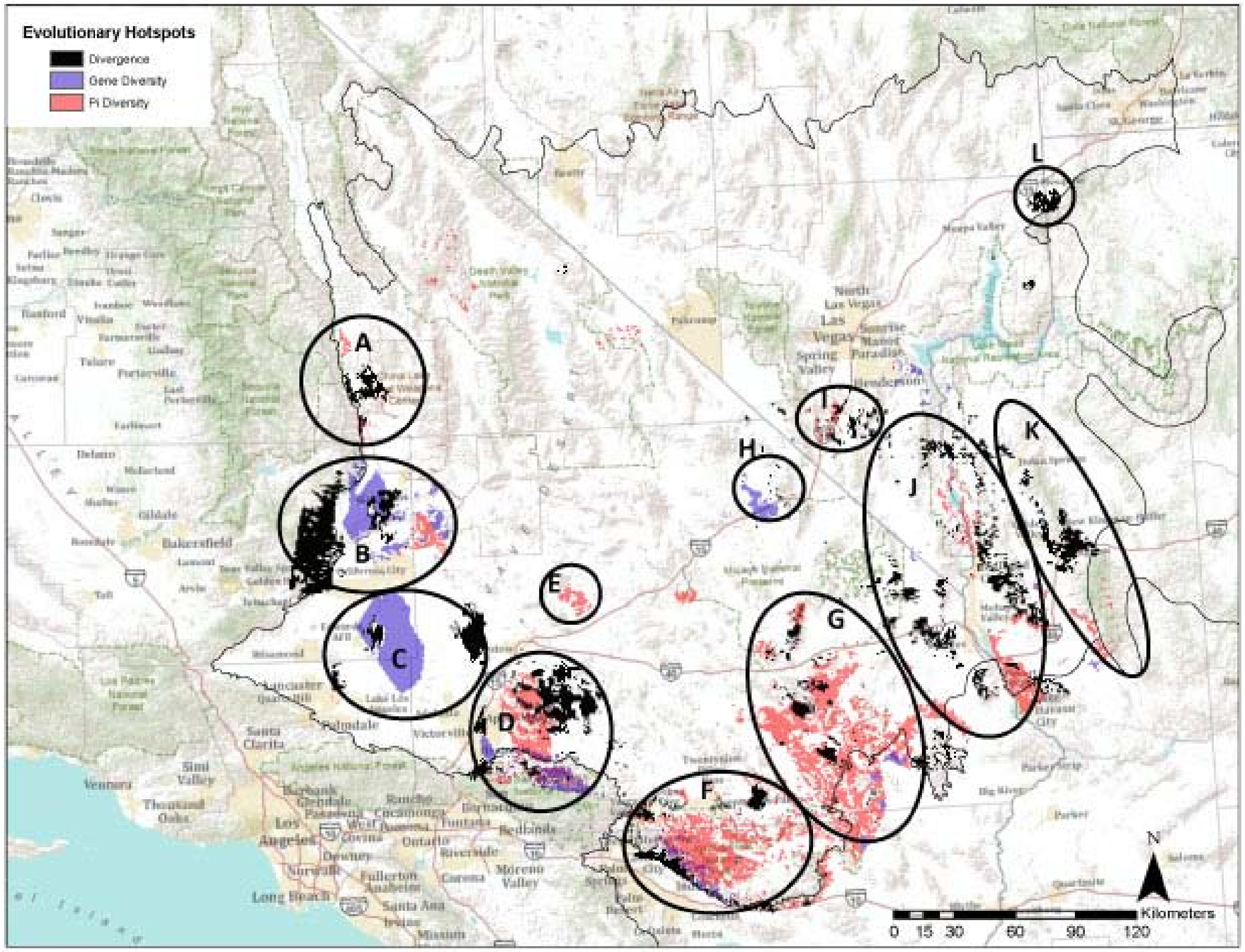


Figure 2-3: Hotspots of genetic divergence and diversity (defined as greater than 1.5 standard deviations above the mean) labeled by region.

Protected Lands

- 38% High Population Divergence
- 52% High intrapop divergence
- 29% High intrapop Gene Diversity

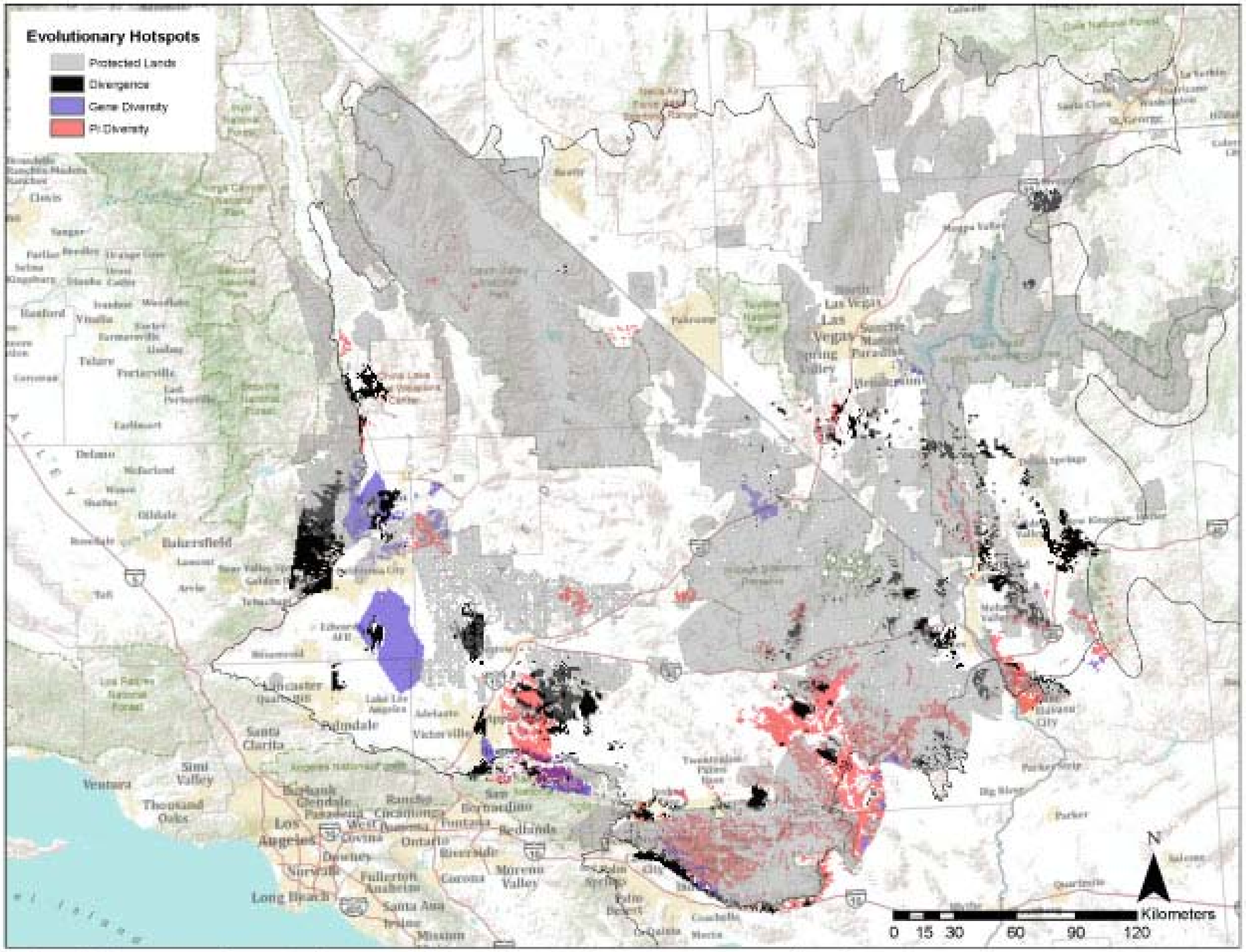


Figure 2-9 Hotspots of genetic diversity and divergence overlayed with protected lands.

Utility Scale Renewable Energy development

- Utility-scale solar energy development under review and study in 6 western states: AZ, CA, CO, NV, NM, UT

- Mojave identified as one of the best locations for solar development, particularly in the western Mojave where transmission line access is greater.

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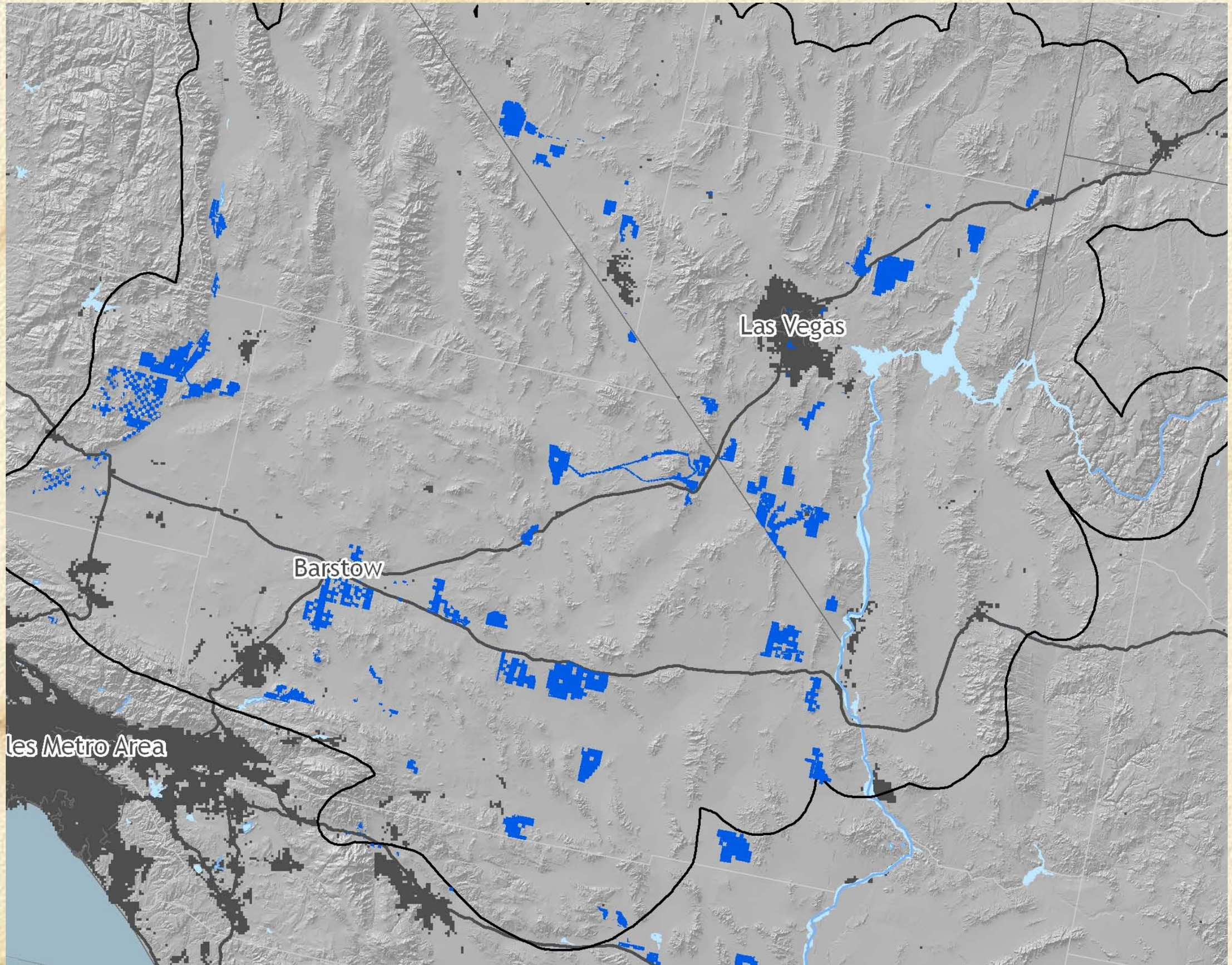
- Collected footprints for verified, approved and pending renewable energy projects in CA and NV. Shown in **BLUE.**

- Transmission corridors from section 368 of the 2005 Energy Policy Act of 2005, CDD Designated Utility Corridors, and CDD Contingent Utility Corridors. Shown in **WHITE**.

Utility Scale Renewable Energy development



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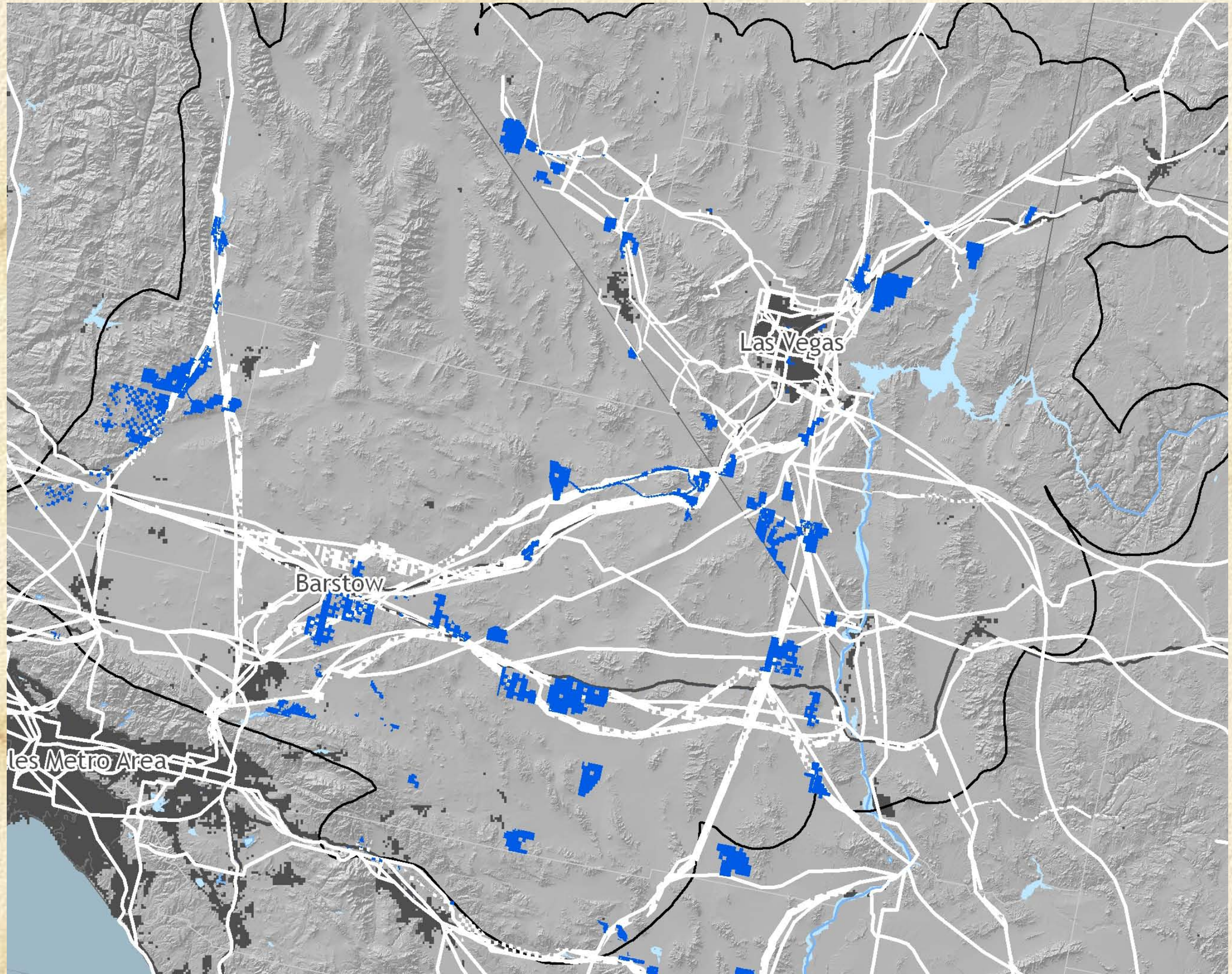
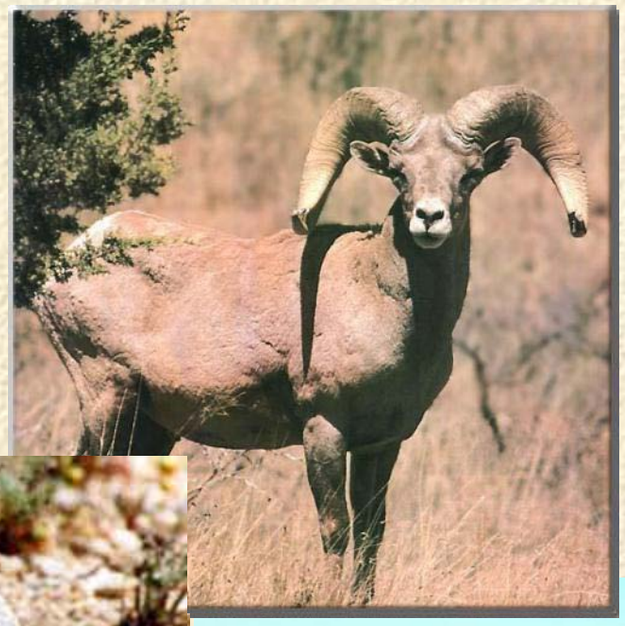


Future Work

- Overlay and evaluate species richness and genetic maps with renewable energy development footprints
- Complete Habitat Suitability Modeling for 7 remaining species
- Add additional collection locations/genetic data where warranted
- Model distributions under climate change