Mapping habitat and genetic diversity in the desert southwest and potential impacts of utility-scale renewable energy development

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Purpose

- To assist in ongoing ecoregional planning efforts (particularly related to utility scale renewable energy development).
- Assessment of habitat use and genetic structure for multiple species, at an ecoregional scale.
- Funding provided by BLM and USGS
- Work initiated in May 2010

Study Objectives

1. Model the geographic distributions of habitat for a broad taxonomic range of species and evaluate where potential habitats overlap.

2. Assess the levels of genetic diversity (and how it is geographically distributed) across multiple species to map “evolutionary hotspots”.

3. Evaluate habitat distributions and genetic diversity patterns in relation to proposed renewable energy development projects and utility corridors.

Study Area

Mojave Desert Ecoregion

Why focus on genetic diversity?

- Genetic diversity within species represents a fundamental aspect of biodiversity

- Provides the basis for phenotypic variation and adaptation

- Underlies the processes of lineage diversification and speciation as expressed in patterns of species, community and ecosystem diversity.

- Mapping patterns of genetic diversity can help to locate evolutionary "hotspots"-- regions where diversification and speciation are more likely to occur.

Species

Herpetofauna

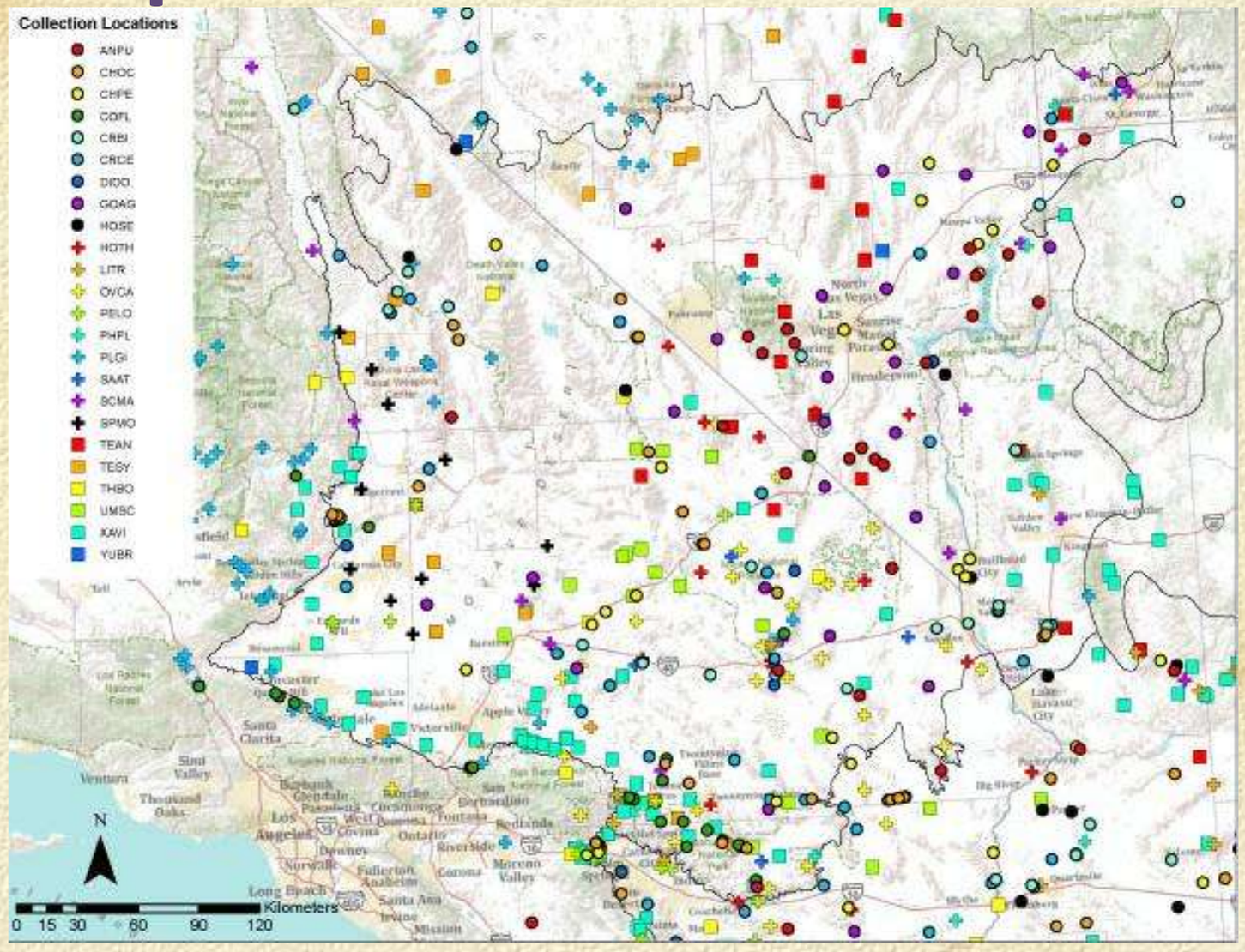
1. *Anaxyrus punctatus*
2. *Chionactus occipitalis*
3. *Crotaphytus bicinctores*
4. *Dipsosaurus dorsalis*
5. *Gopherus agassizii*
6. *Lichanura trivirgata*
7. *Plestiodon gilberti*
8. *Sceloporus magister*
9. *Uma scoparia*
10. *Xantusia vigilis*

Invertebrates

11. *Homalonychus selenopoides*
12. *Homalonychus theologus*

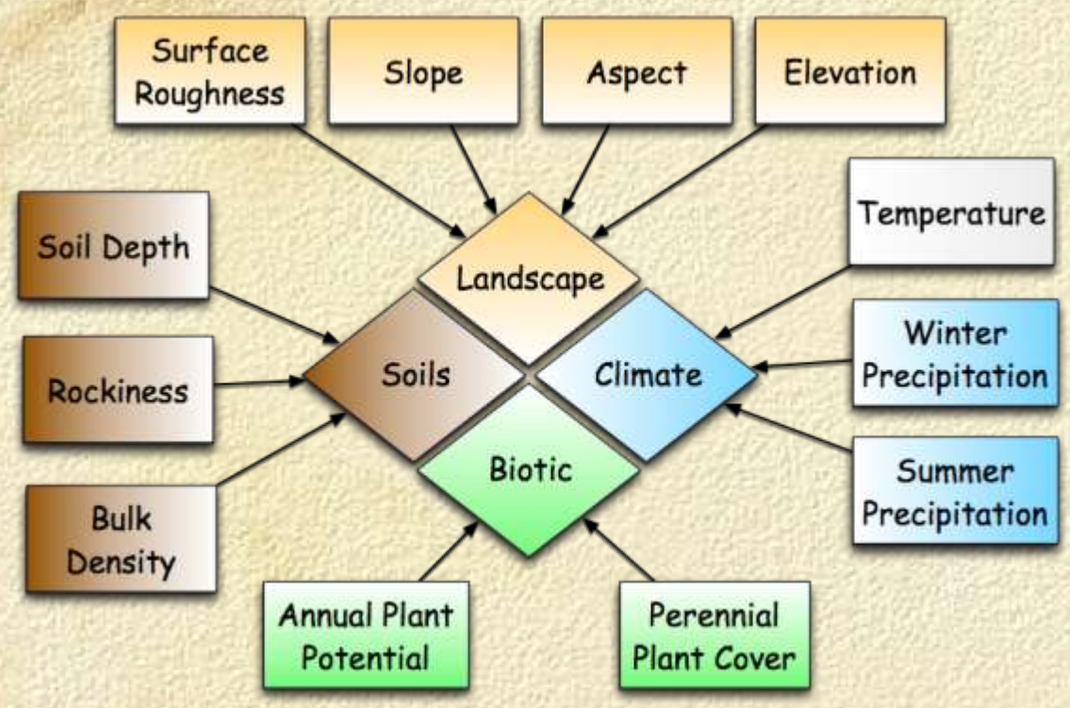
Mammals

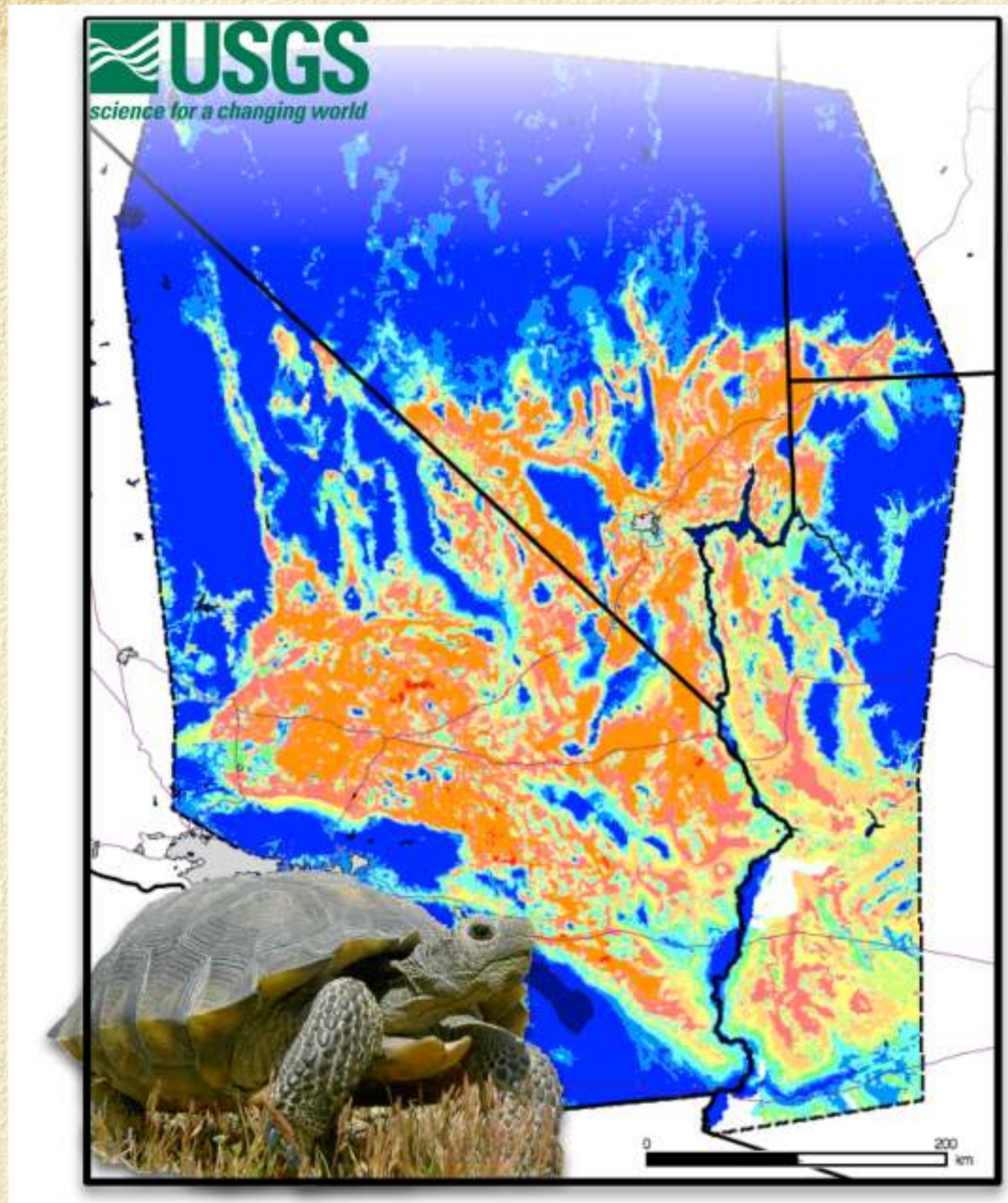
13. *Chaetodipus penicillatus*
14. *Ovis canadensis*
15. *Perognathus longimembris*
16. *Thomomys bottae*
17. *Xerospermophilus mojavensis*



- **Genetic datasets contained 6 – 80 (Avg. 20) collection locations within the Mojave Desert**
- **Mostly mtDNA sequence data, some DNA sequences & microsatellite data.**
- **Occurrence Points ranged from ~20 - ~500**

Habitat Suitability Model





Inman et al. 2013. Endangered Species Res. 20, 1-18.
Nussear et al. 2009. USGS Open-File Report 2009-1102

Mapping Habitat

- Gathered occurrence records
  - VertNet, HerpNet, MaNIS, California Natural Diversity Database, Joshua Tree National Park, Edwards Airforce Base, the Conservation Biology Institute, USGS

- Selected covariates from 23 habitat variables, using conceptual models of habitat preference

- GAM and MaxEnt Modeling (1 km grid cell), top ranking models averaged into a single habitat map

- Reclassified suitable/unsuitable habitat using 5th percentile of habitat suitability scores from the occurrence localities

** Bighorn: no statistical model available– utilized an expert opinion potential habitat map provided by Kristeen Penrod.

Mapping Evolutionary Hotspots

<u>Genetics Mapped in 3 ways:</u>

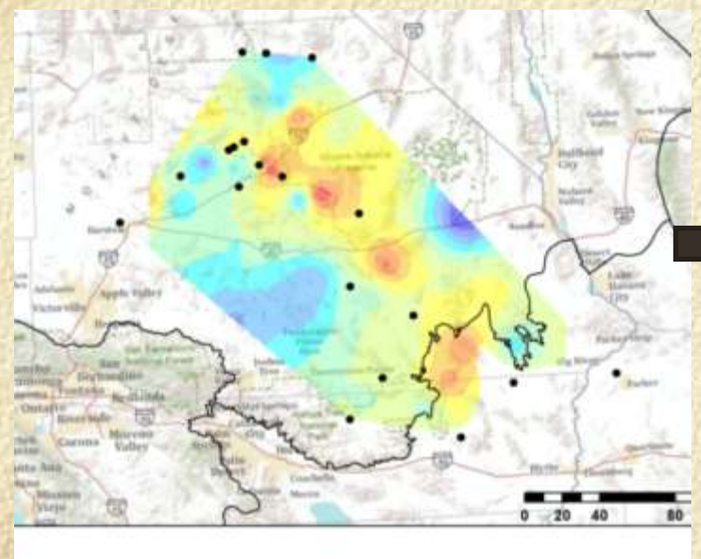
1. **Intrapopulation Gene Diversity /Heterozygosity**
2. **Intrapopulation Sequence Diversity**
3. **Population Divergence**

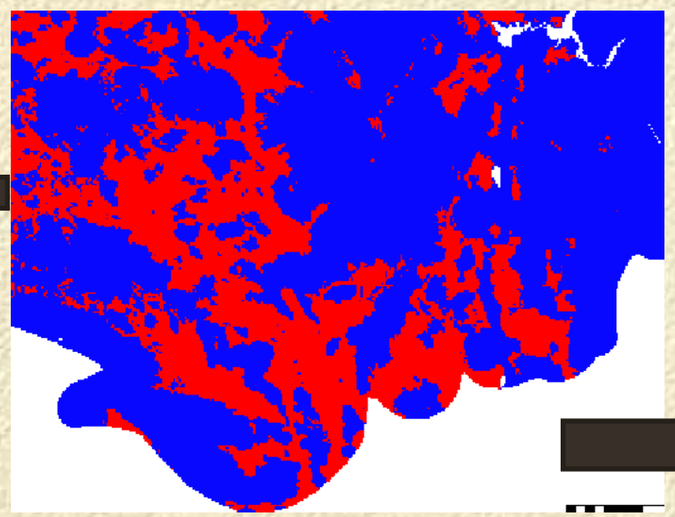
- **Intrapopulation Gene Diversity/ Heterozygosity will emphasize locations with large populations and stability over long periods of time (Refugia).**

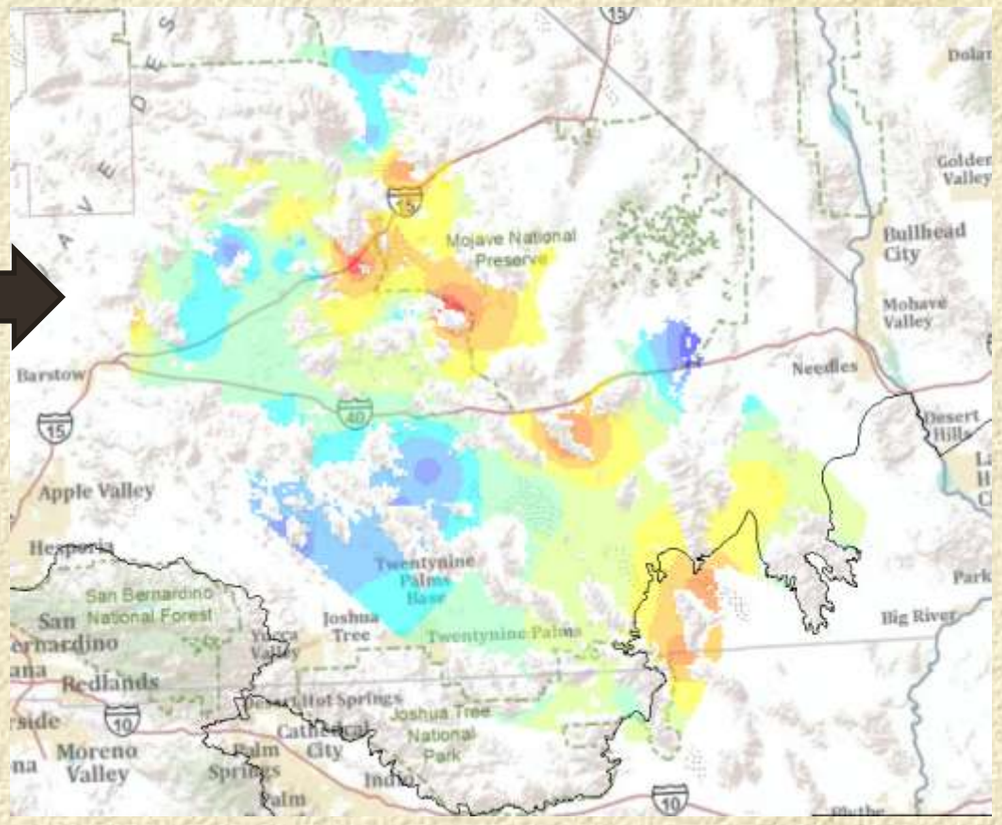
- **Sequence Diversity and Population Divergence will emphasize locations where historical lineages come into contact (Suture Zones)**

Genetic Mapping

- **Values mapped at collection locations or midpoints between collection locations**
- **Inverse Distance Weighted Interpolation**
- **Masked by suitable habitat**

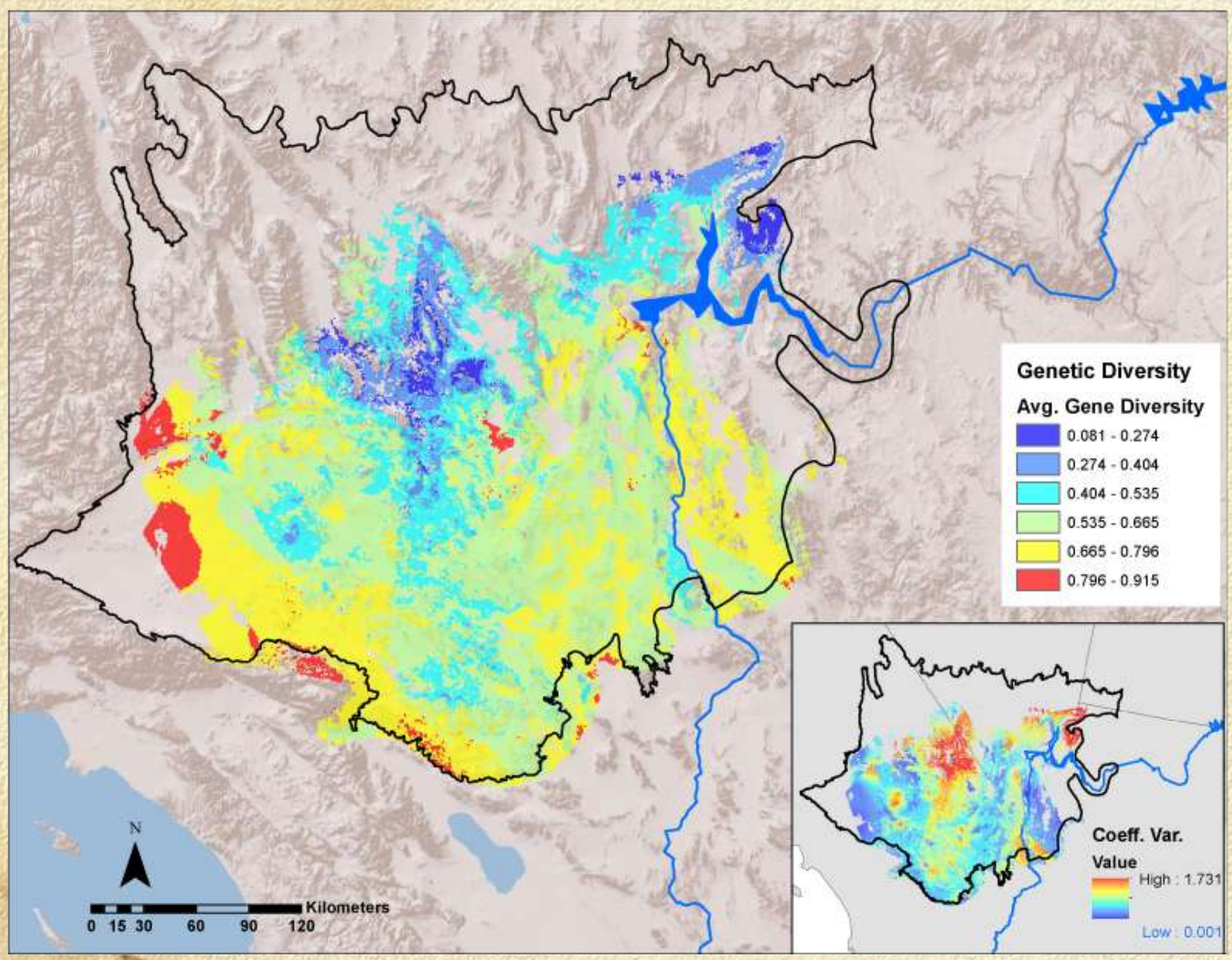




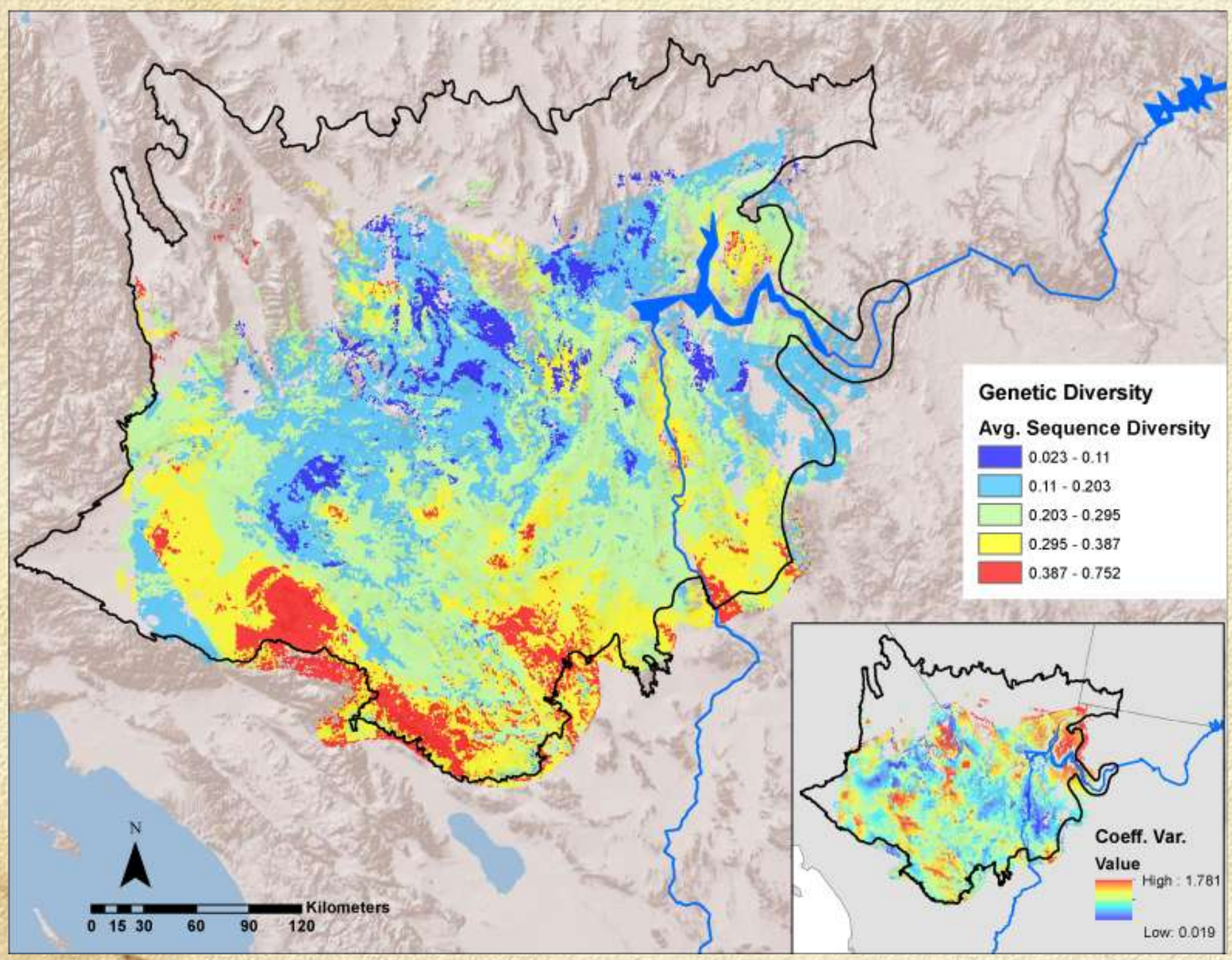


- **Averaged across species**

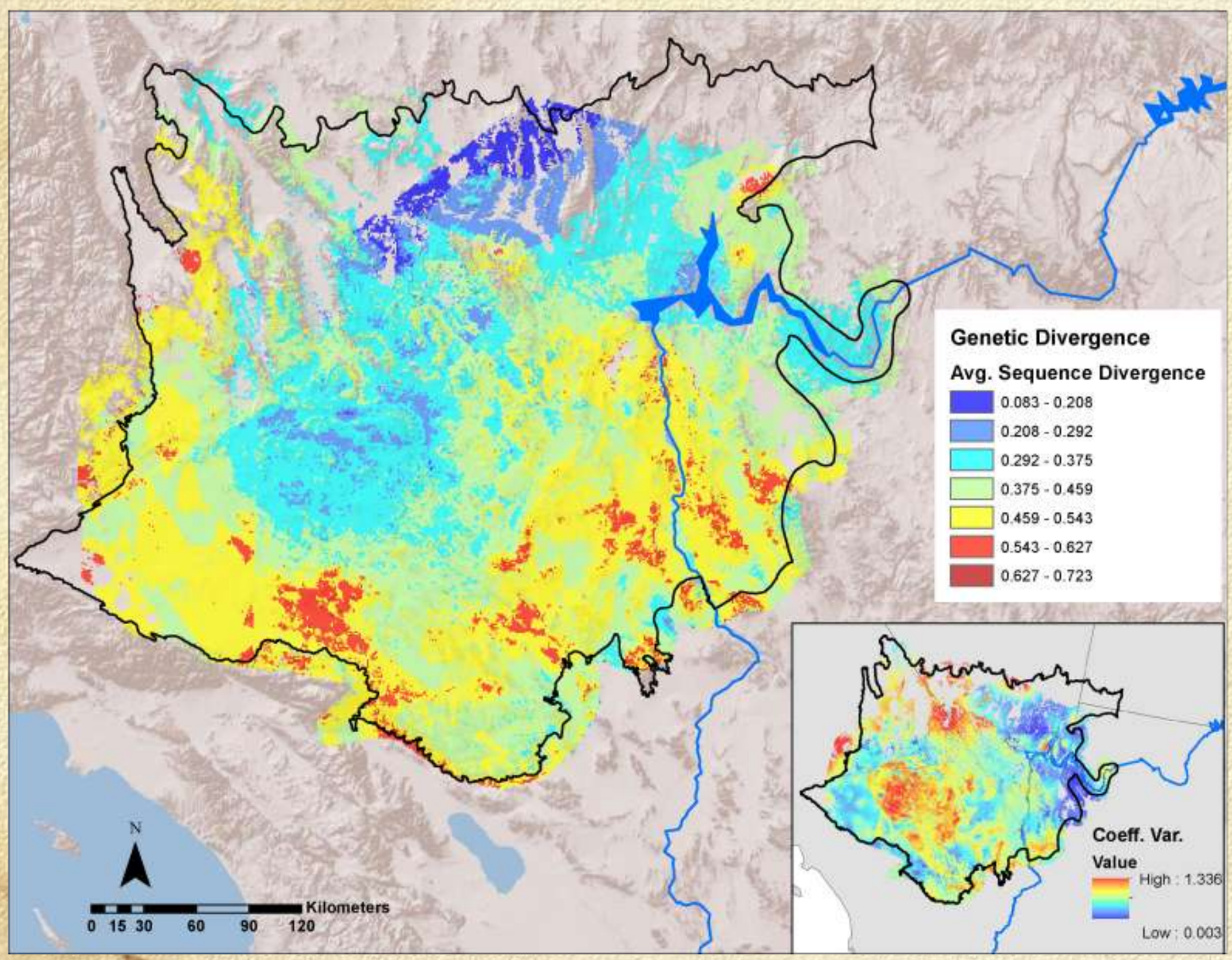
Average Gene Diversity



Average Sequence Diversity



Average Population Divergence



Combined Diversity and Divergence Hotspots

A. Dunmovin-Coso Junction

B. Sierra-Tehachapi Transition

C. Antelope Valley-Mojave

D. Ord Mtns-Lucerne Valley

E. Indio Hills- Little San Bern Mtns

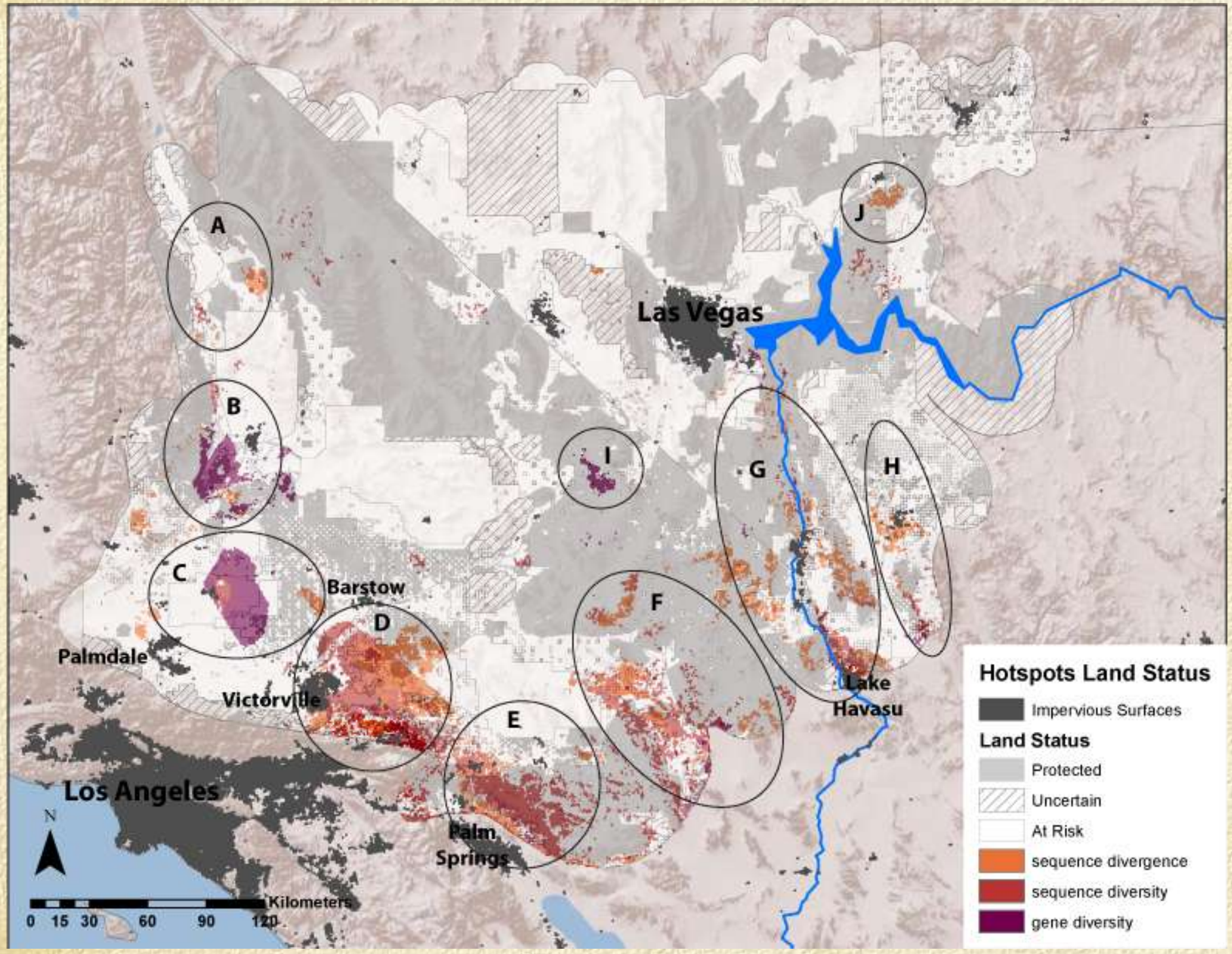
F. Pluvial Lakes

G. Colorado River Mtns

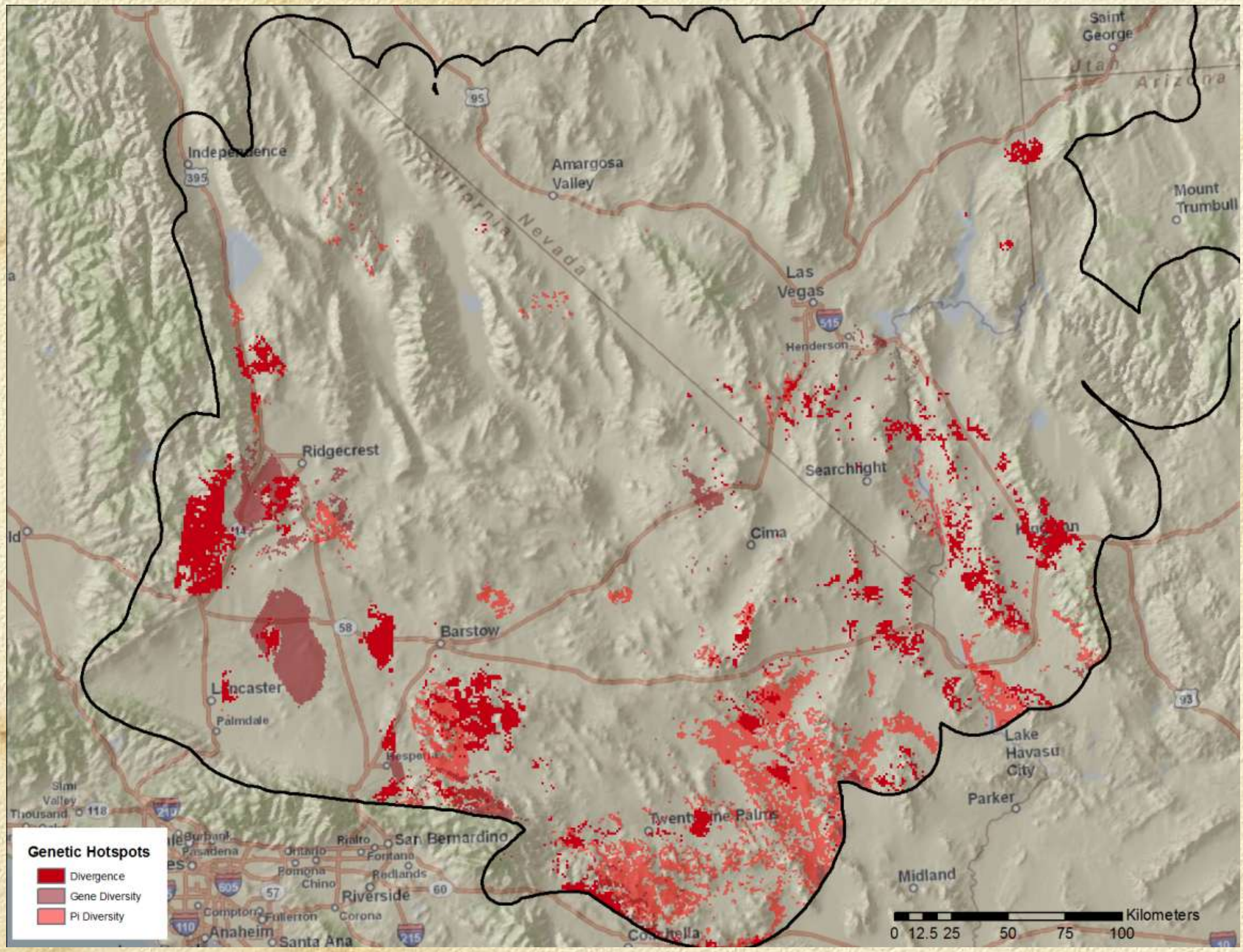
H. Sacramento-Detrital Valleys

I. Ivanpah Valley

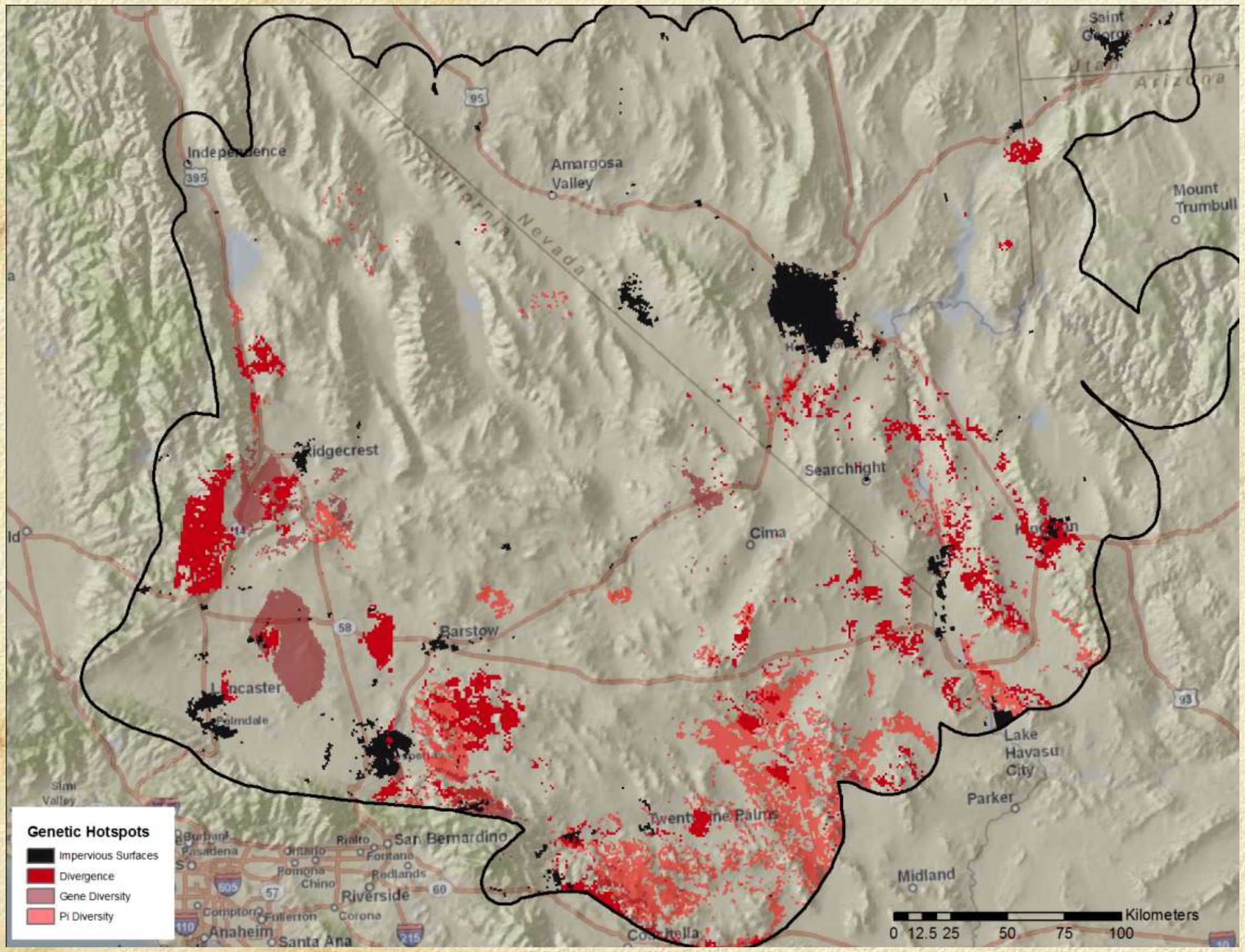
J. Virgin Mtns



Renewable Development and Hotspots

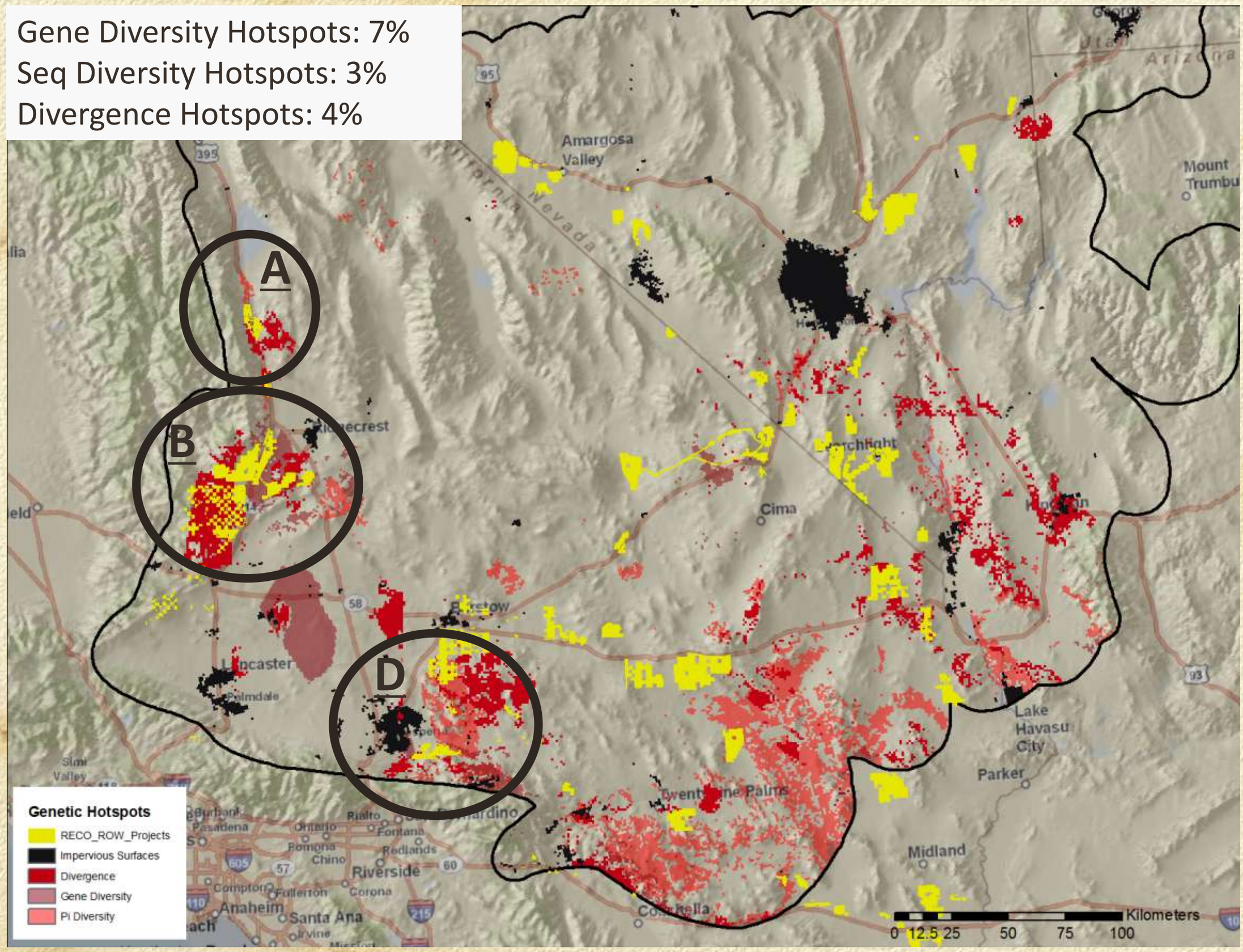


Impervious Surfaces



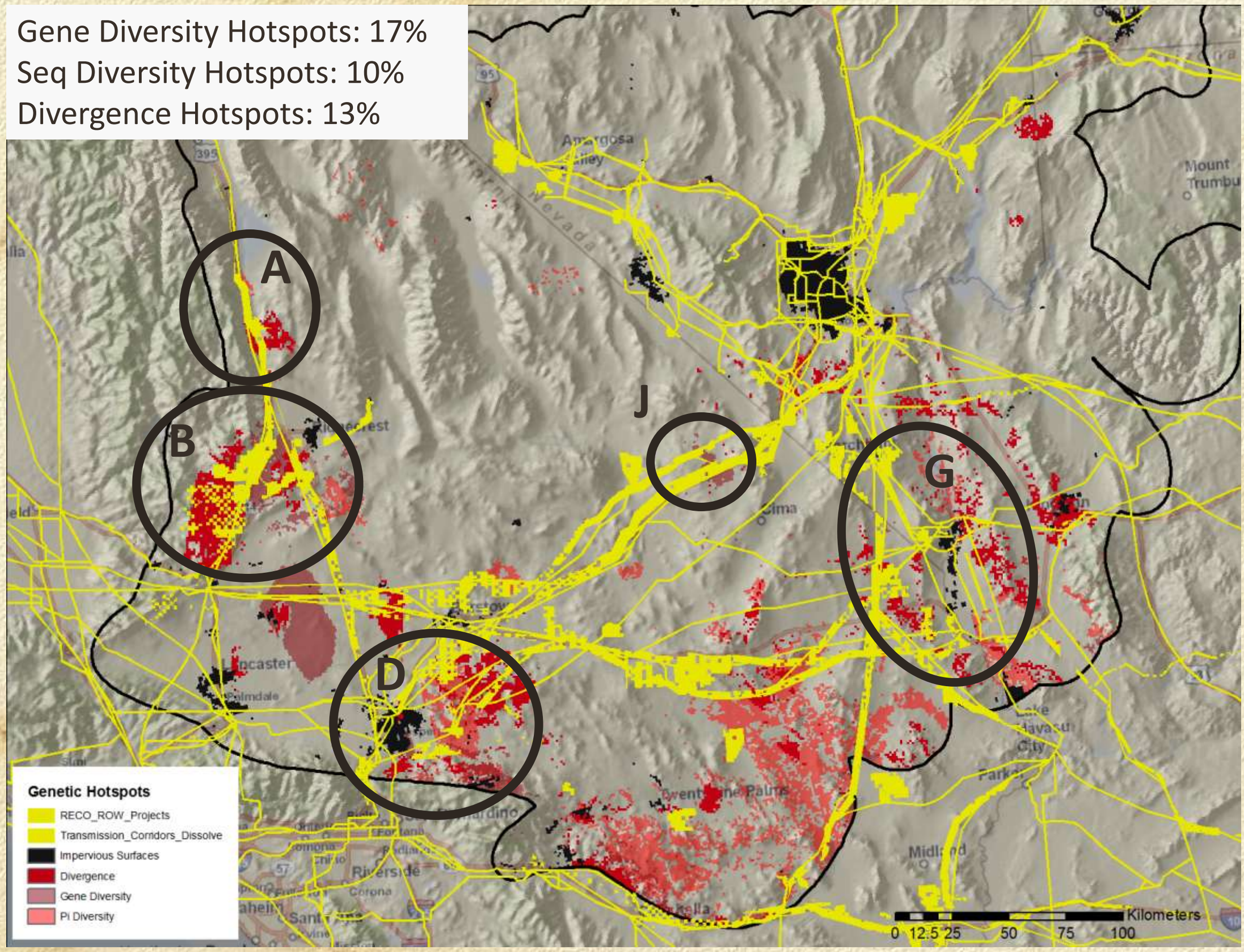
Renewable Energy Projects

Gene Diversity Hotspots: 7%
Seq Diversity Hotspots: 3%
Divergence Hotspots: 4%



Projects and Transmission Lines

Gene Diversity Hotspots: 17%
Seq Diversity Hotspots: 10%
Divergence Hotspots: 13%



Ranking species by potential loss of suitable habitat and genetic diversity due to renewables

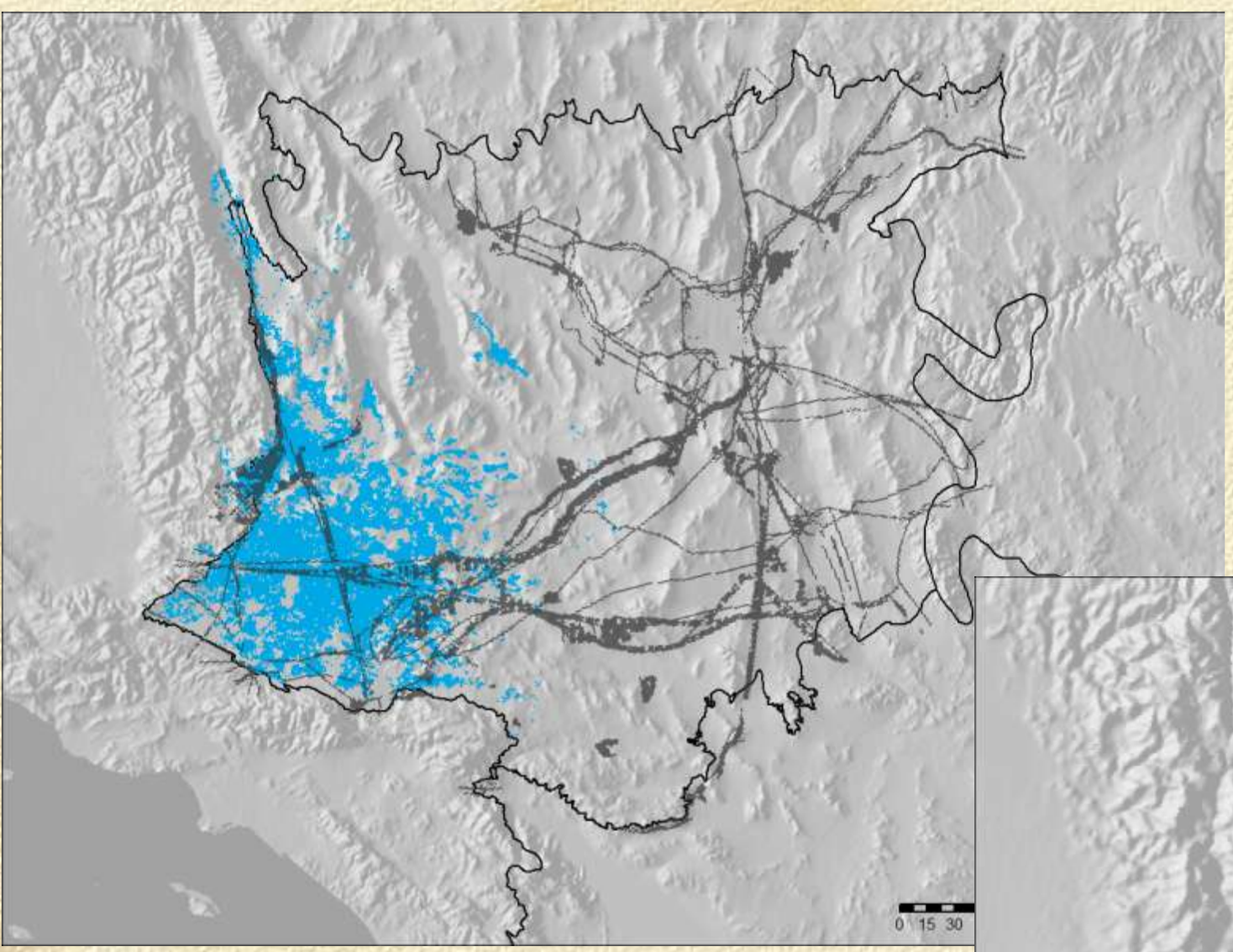
- Percentage of suitable habitat falling within development footprint vs. remaining area
- Mean habitat suitability and gene diversity scores within footprint vs. remaining area
- Ranked species by relative loss

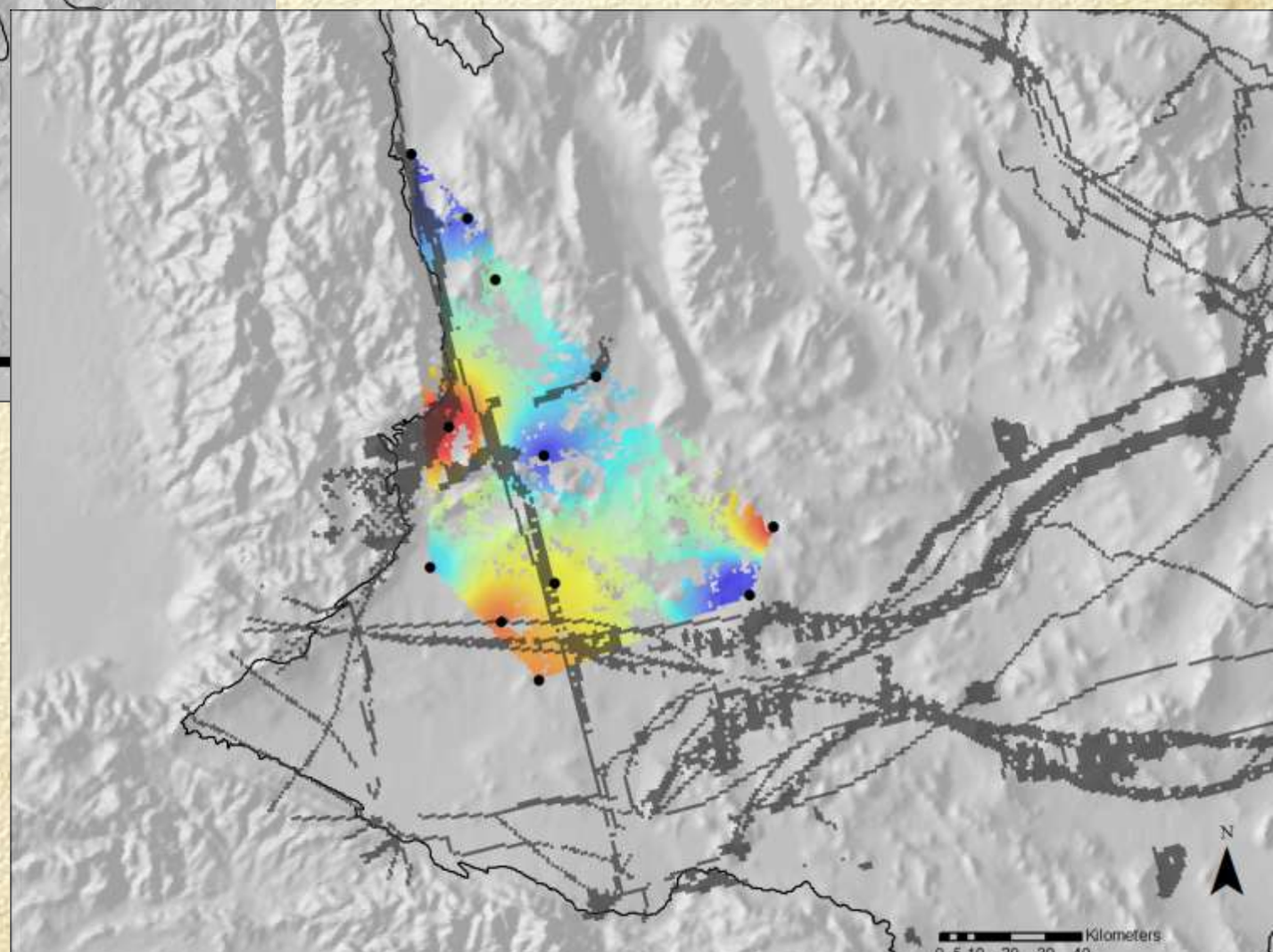
Potential loss of suitable habitat and genetic diversity

	Habitat Area	Habitat Suitability			Gene Diversity		
	% Loss Suitable habitat	Study Area	Energy & Corridors	Rank Ratio	Study Area	Energy & Corridors	Rank Ratio
Species		Mean Habitat Score			Mean Gene Diversity		
Xerospermophilus mohavensis	**17%**	**0.16**	**0.25**	**1.54**	**0.53**	**0.62**	**1.17**
Uma scoparia	**16%**	**0.11**	**0.16**	**1.55**	0.44	0.41	0.93
Gopherus agassizii	**15%**	**0.48**	**0.68**	**1.41**	**0.67**	**0.7**	**1.04**
Chionactis occipitalis	14%	0.35	0.49	1.39	0.66	0.67	1.02
Chaetodipus penicillatus	14%	0.21	0.27	1.28	0.69	0.68	0.99
Dipsosaurus dorsalis	13%	0.39	0.51	1.31	-	-	-
*Homalonychus selenopoides**	13%	0.23	0.28	1.20	**0.53**	**0.58**	**1.09**
*Homalonychus theologus**	-	-	-	-	**0.25**	**0.26**	**1.04**
Perognathus longimembris	11%	0.39	0.42	1.08	-	-	-
Thomoys bottae	11%	0.26	0.27	1.04	-	-	-
Xantusia vigilis	10%	0.40	0.43	1.07	**0.53**	**0.58**	**1.09**
Lichanura trivirgata	11%	0.33	0.35	1.05	-	-	-
Sceloporus magister	10%	0.44	0.45	1.03	0.91	0.92	1.01
Anaxyrus punctatus	9%	0.42	0.39	0.91	0.53	0.53	1
Crotaphytus bicinctores	8%	0.48	0.45	0.93	0.77	0.76	0.99
Plestiodon gilberti	6%	0.19	0.13	0.71	0.84	0.85	1.01

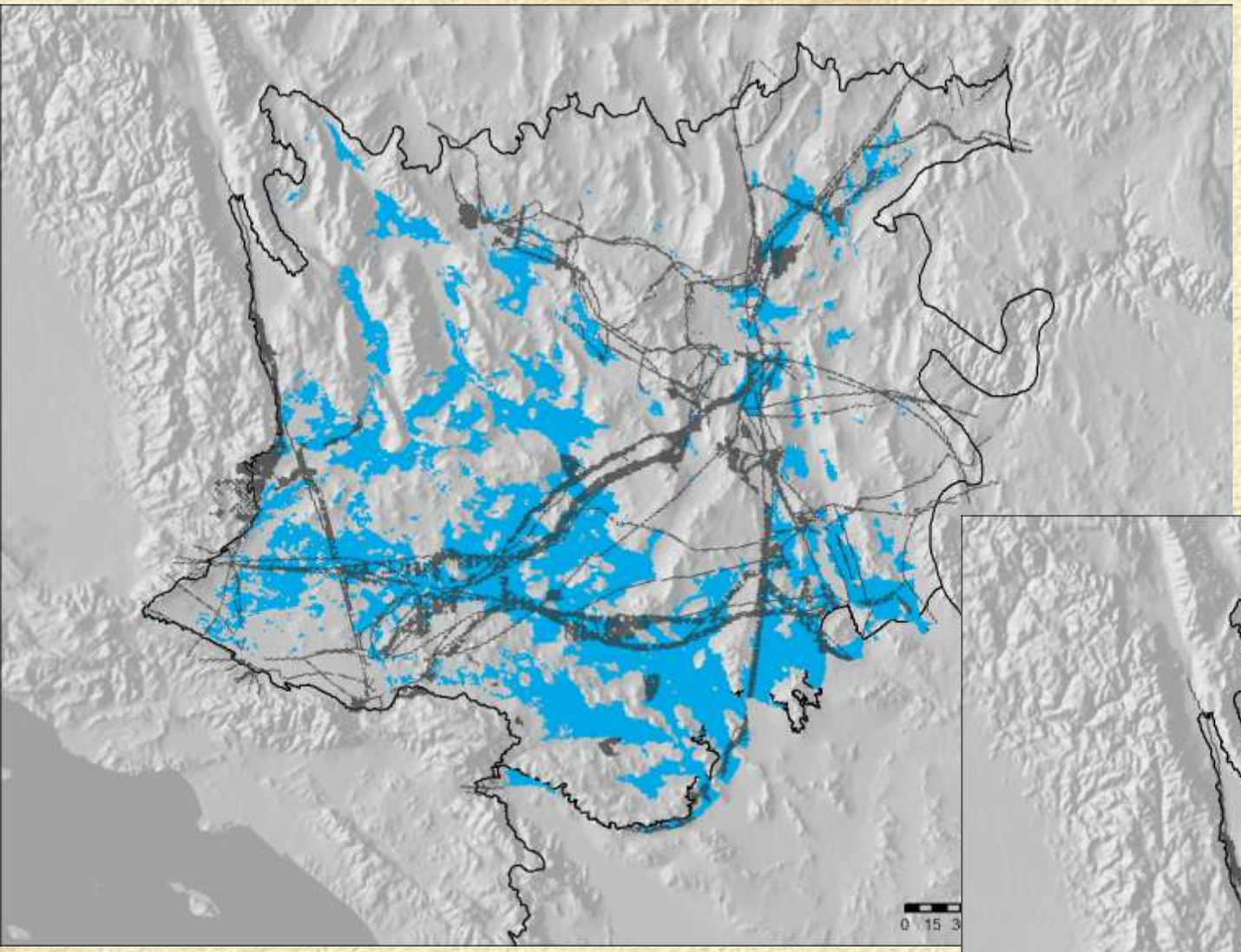
**H selenopoides and theologus were combined for SDM*

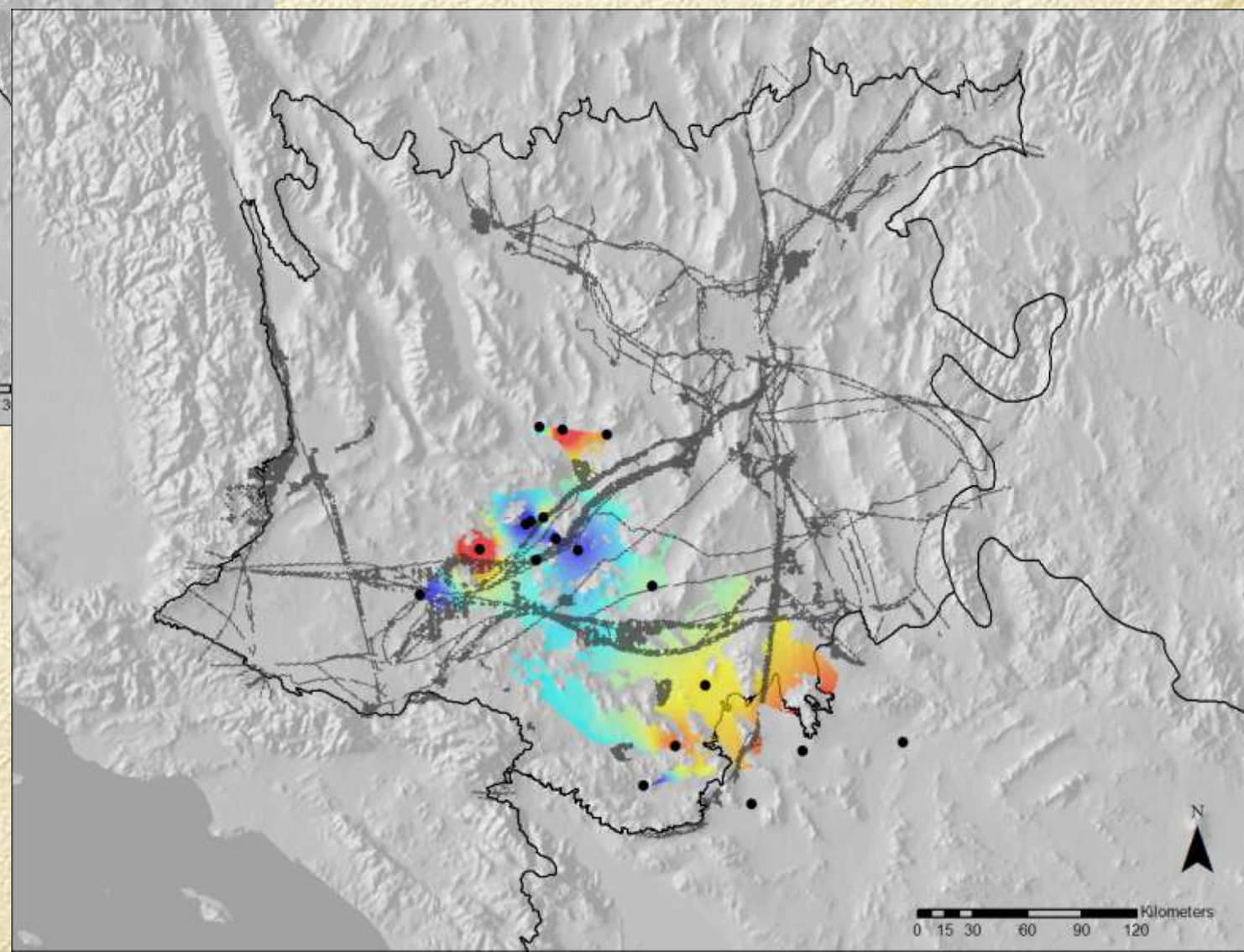
Mohave Ground Squirrel



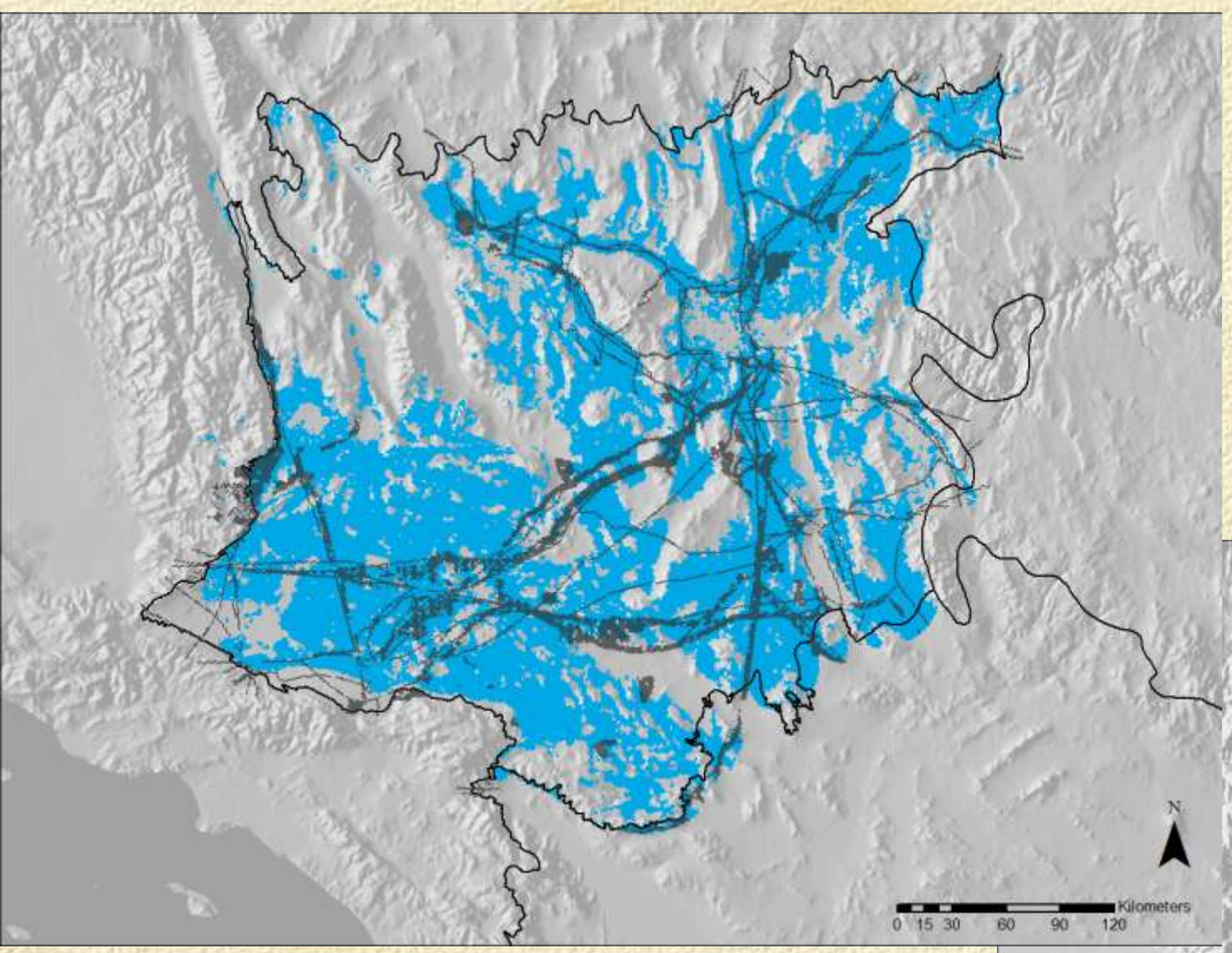


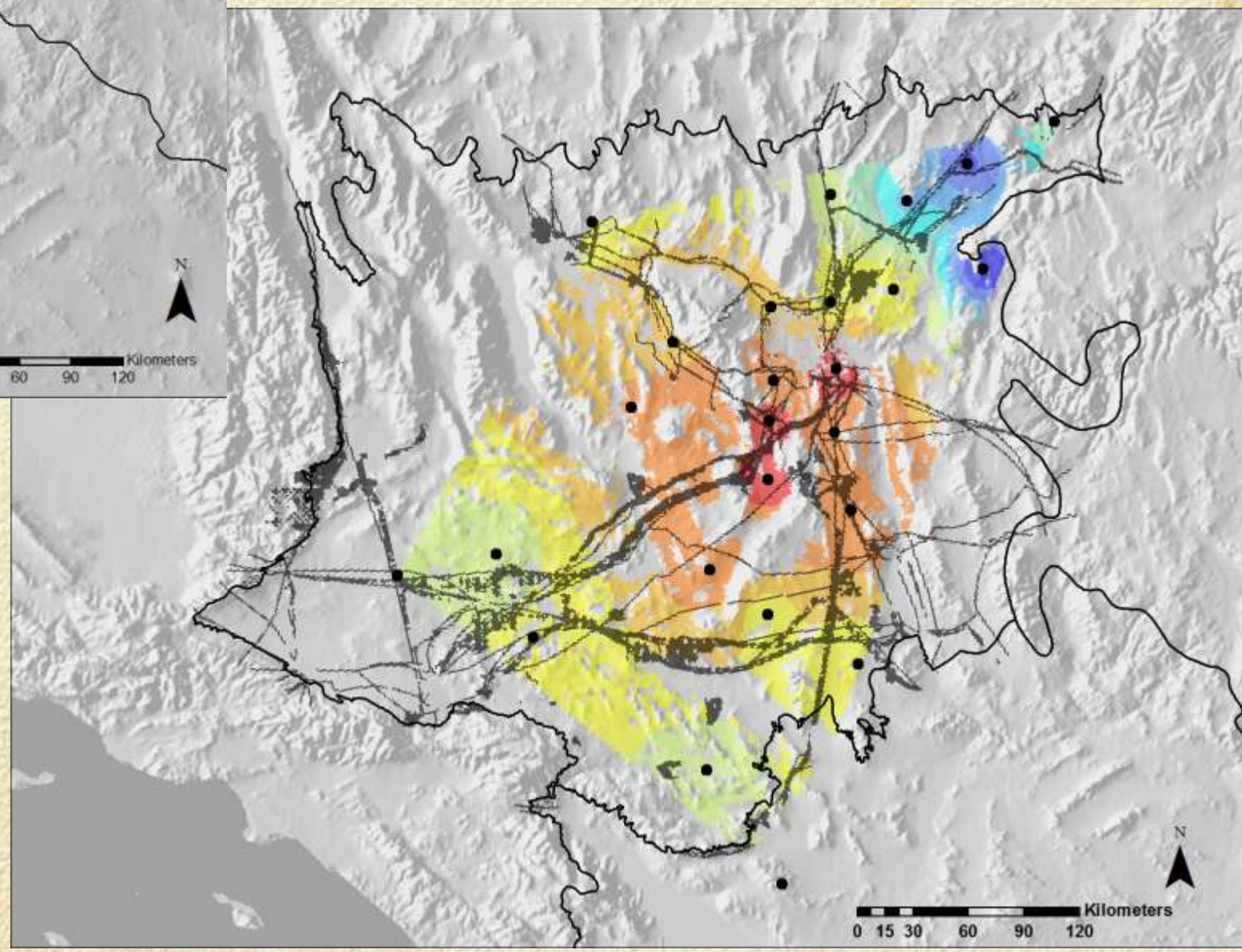
Mojave Fringe-Toed Lizard



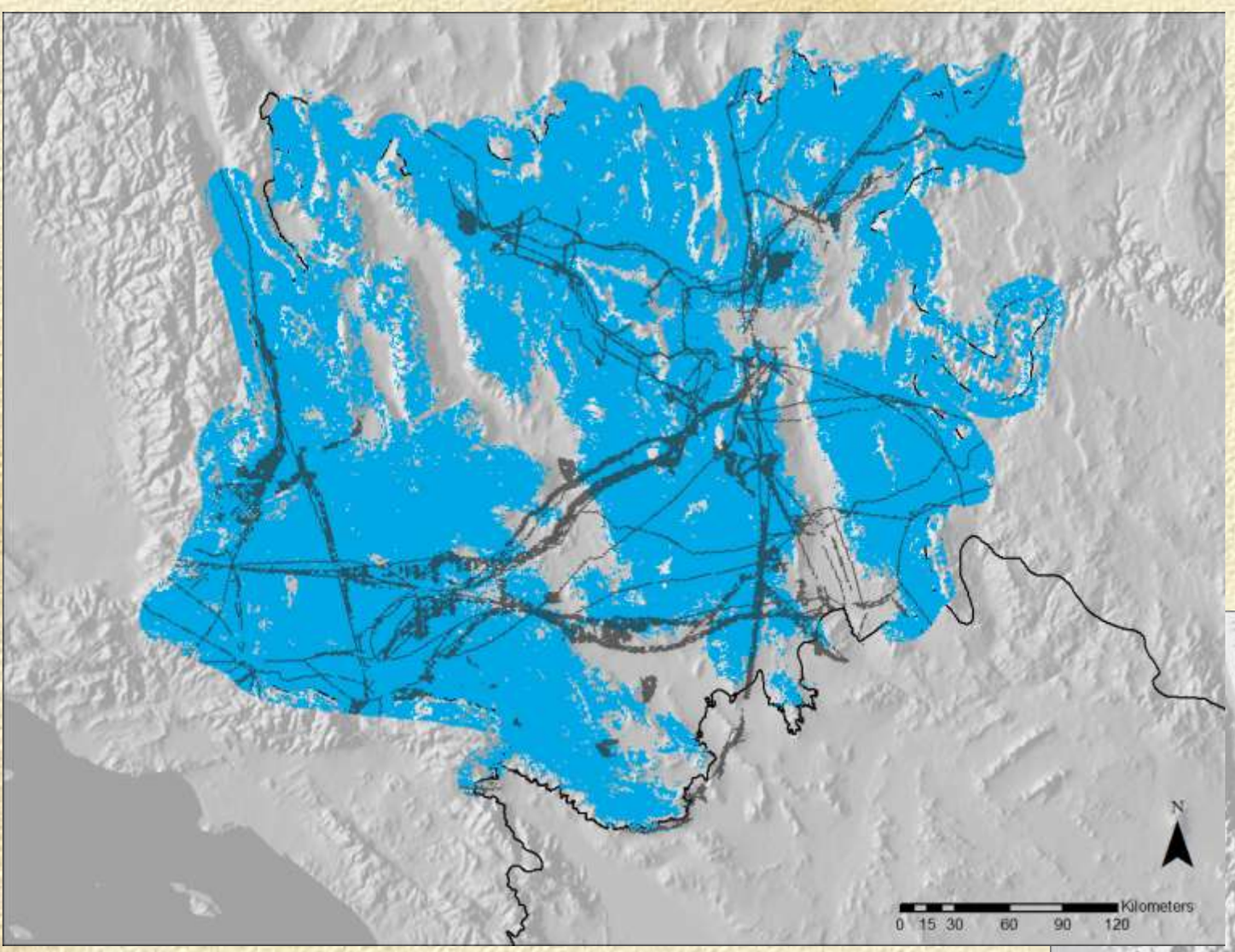


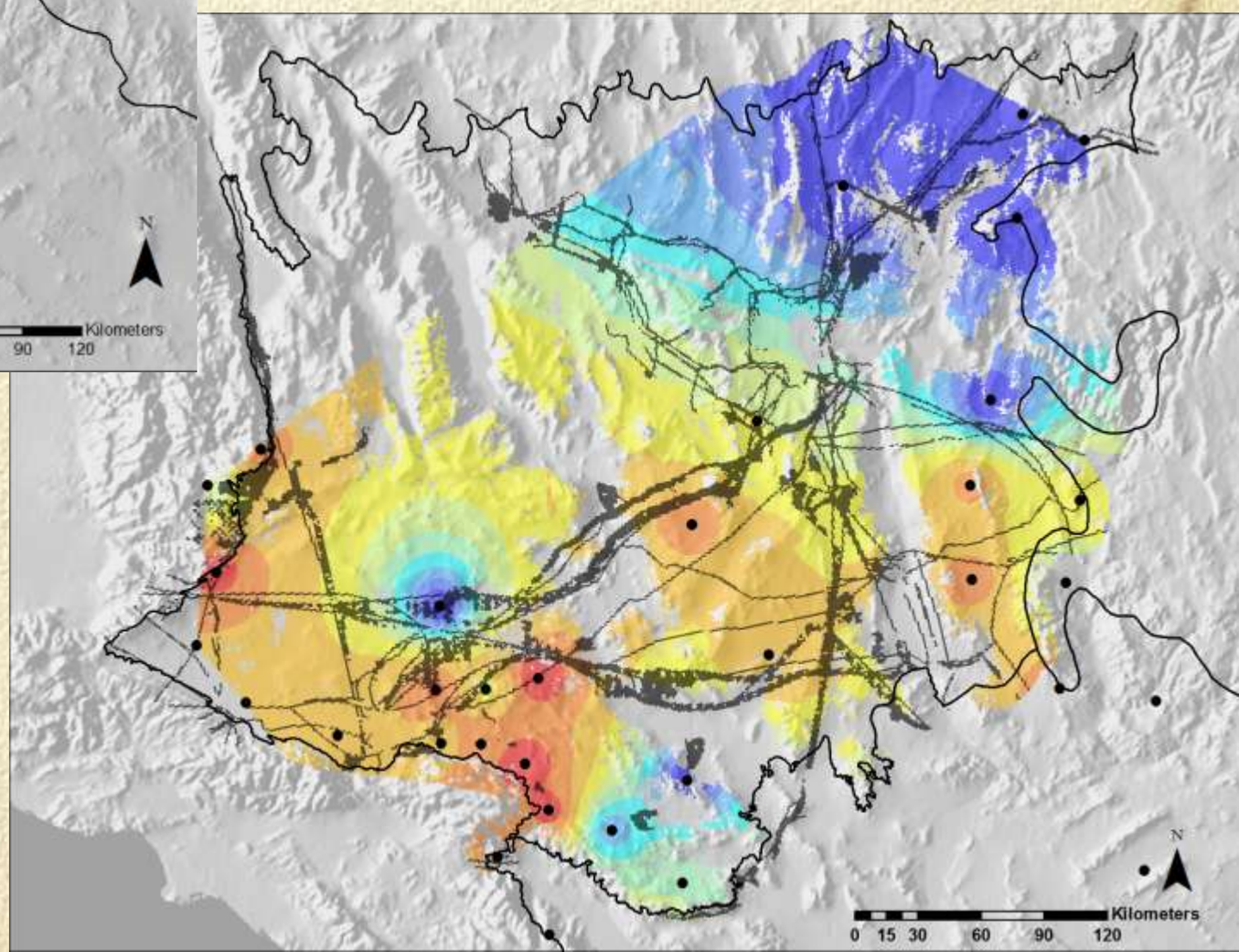
Desert Tortoise





Desert Night Lizard





Future Efforts

- Add additional species
- Collect multi-locus genetic data to better estimate intra-population diversity
- Predictive models of habitat suitability and genetic diversity under future climate change scenarios

Vandergast et al. 2013. Evolutionary hotspots in the Mojave Desert. Diversity 5:293-319.

Wood et al. 2012. Comparative phylogeography reveals deep lineages and regional evolutionary hotspots in the Mojave and Sonoran Deserts. Diversity and Distributions DOI: 10.1111/ddi.12022:1-16.

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