THE SHAPE OF THINGS TO COME:
A WINDOW INTO DESERT TORTOISE CONNECTIVITY IN AN INCREASINGLY URBAN WORLD

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**Project Purpose & Status**

- Understand the effects of corridors & quantify connectivity in disturbed habitat
- Final report & deliverable submitted

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Genetic Connectivity

- Panmixia
- Isolation-by-Distance
- Isolation
Gene Flow, Barriers, & Corridors

Gene Flow

Gene Flow
Main Connectivity Takeaways

- Effect of population density & addition of corridors
- Impacts of habitat disturbance on population size & gene flow
- Indicators of corridor success/failure
DISTURBANCE & LAG TIMES

Neutral

Clark County

habitat resistance

Current

Future

Time
1 generation

200 generations
Forward-in-Time Simulation Modeling

- Genotypes - 20 microsatellite loci
- Time - 200 tortoise generations
- Resistance surface - 0 to 1
Proof-of-Concept Models

Neutral

Absolute Barrier

Permeable Barrier

Population densities: low (3/km²), moderate (14/km²)
Population & Genetic Analyses

Population Size

Genetic Diversity

Dutcher et al. in review
Hagerty 2008

$H_o \sim 0.8$

Genetic Structure

$ex: K = 2$

Time series

Generation 200
**Population Size & Genetic Diversity**

Moderate Density
(14/km²)

Low Density
(3/km²)
**Population Genetic Structure**

- **Neutral**
  - Moderate: $K = 1$ (14/km²)
  - Low: $K = 3$ (3/km²)

- **Absolute Barrier**
  - $K = 2$

- **Permeable Barrier**
  - $K = 2$
**TAKEAWAY:**

**Effect of Population Density & Addition of Corridors**

- The addition of corridors improves connectivity.
- Higher densities improves connectivity.
- 1 migrant/generation → former gene flow.
**Clark County Modeled Landscape Locations**

- **Locations:** 17
- **Area of each:** 525 to 625 km²
- **Density:** 1 to 24/km²
RESISTANCE SURFACES

Adapted from Nussear et al. 2009

Clark County

Neutral Current Future

habitats resistance
Bounding the Landscape

Jean/Roach

Laughlin

Jean/Roach
RESISTANCE SURFACES

Laughlin

Jean/Roach

Current

Future
**Population Size & Genetic Diversity**

Laughlin

Jean/Roach
**Population Genetic Structure**

- **Neutral**
  - Laughlin: $K = 2$
  - Jean/Roach: $K = 2$

- **Current**
  - Laughlin: $K = 3$
  - Jean/Roach: $K = 2$

- **Future**
  - Laughlin: $K = 3$
  - Jean/Roach: $K = 3$
**Takeaway: Impact of Disturbance on Population Size & Gene Flow**

- Disturbance reduces population size, diversity, & connectivity
- Pay attention to population size

Photo courtesy of USGS
**Corridor Success Index (CSI)**

- **Neutral Landscape**: $F_{ST} = 0.002$
- **Absolute Barrier**: $F_{ST} = 0.014$

The CSI index is used to measure the success of corridors in facilitating gene flow. A lower $F_{ST}$ value indicates better connectivity, with Neutral Landscape showing a lower value compared to Absolute Barrier, suggesting better genetic connectivity in the former scenario.
High Levels of Genetic Connectivity ($\text{CSI} = 0.7-1$)

Current
- Laughlin
- Eldorado Valley
- Trout Canyon
- Sandy Valley
- Searchlight
- Indian Springs
- Las Vegas North
- Coyote Springs
- Moapa Valley

Future
- Laughlin
- Eldorado Valley
- Trout Canyon
- Searchlight
- Indian Springs
- Moapa Valley

Habitat resistance
**Intermediate Connectivity (CSI = 0.35-0.69)**

**Current**
- BCCE
- Dry Lake
- Mesquite

**Future**
- Dry Lake
- Mesquite
- Coyote Springs
- Sandy Valley
Low/No Connectivity (CSI < 0.35)

Current
- Ivanpah Valley
- Las Vegas West
- Las Vegas East
- Red Rock
- Jean/Roach

Future
- Ivanpah Valley
- Las Vegas West
- Las Vegas East
- Red Rock
- Jean/Roach
- BCCE
- Moapa Valley
- Las Vegas North

Habitat resistance
Landscape Metrics

- Number of habitat patches – measure of fragmentation
- Percent habitat area – measure of habitat loss
**Fragmentation & Connectivity**

Increasing Fragmentation

- Loss of Individuals
- Loss of Genetic Diversity
- Increase in Genetic Differentiation

Number of Suitable Habitat Patches
Habitat Loss & Connectivity

- Loss of Individuals
- Loss of Genetic Diversity
- Increase in Genetic Differentiation

Graphs showing the relationship between habitat loss and genetic metrics:

- Loss of Individuals vs. % Suitable Habitat Area
- Loss of Genetic Diversity vs. % Suitable Habitat Area
- Increase in Genetic Differentiation vs. % Suitable Habitat Area

Increasing Habitat
Habitat Loss & Fragmentation
**Takeaway:** Indicators of Corridor Success/Failure

- More habitat + less fragmentation = more connectivity
- Landscape dependent individual management units

Photo courtesy of USGS
Management Recommendations

- Low/no connectivity landscapes – prioritize for restoration
- Intermediate connectivity – strategically restore connectivity
- High connectivity – maintain existing habitat
Thank you

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Population & Genetic Analyses

Population Size

- $N = 10$

Genetic Diversity

- $H_0 \sim 0.8$

Genetic Differentiation

- $F_{st} \sim 0$
- $F_{st} > 0$

Genetic Structure

- $K = 2$

Time series

Generation 200
Population, Heterozygosity, & Differentiation

Moderate Density

Low Density
Population, Heterozygosity, & Differentiation

Laughlin

Jean/Roach