Using Electrical Circuit Analysis to Map Landscape Connectivity for Wildlife in Vermont

Implications for Transportation Planning and Mitigation

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The Nature Conservancy

Vermont Fish & Wildlife

Photo courtesy of Paul Marangelo, TNC

Vermont Roadways & Impacts

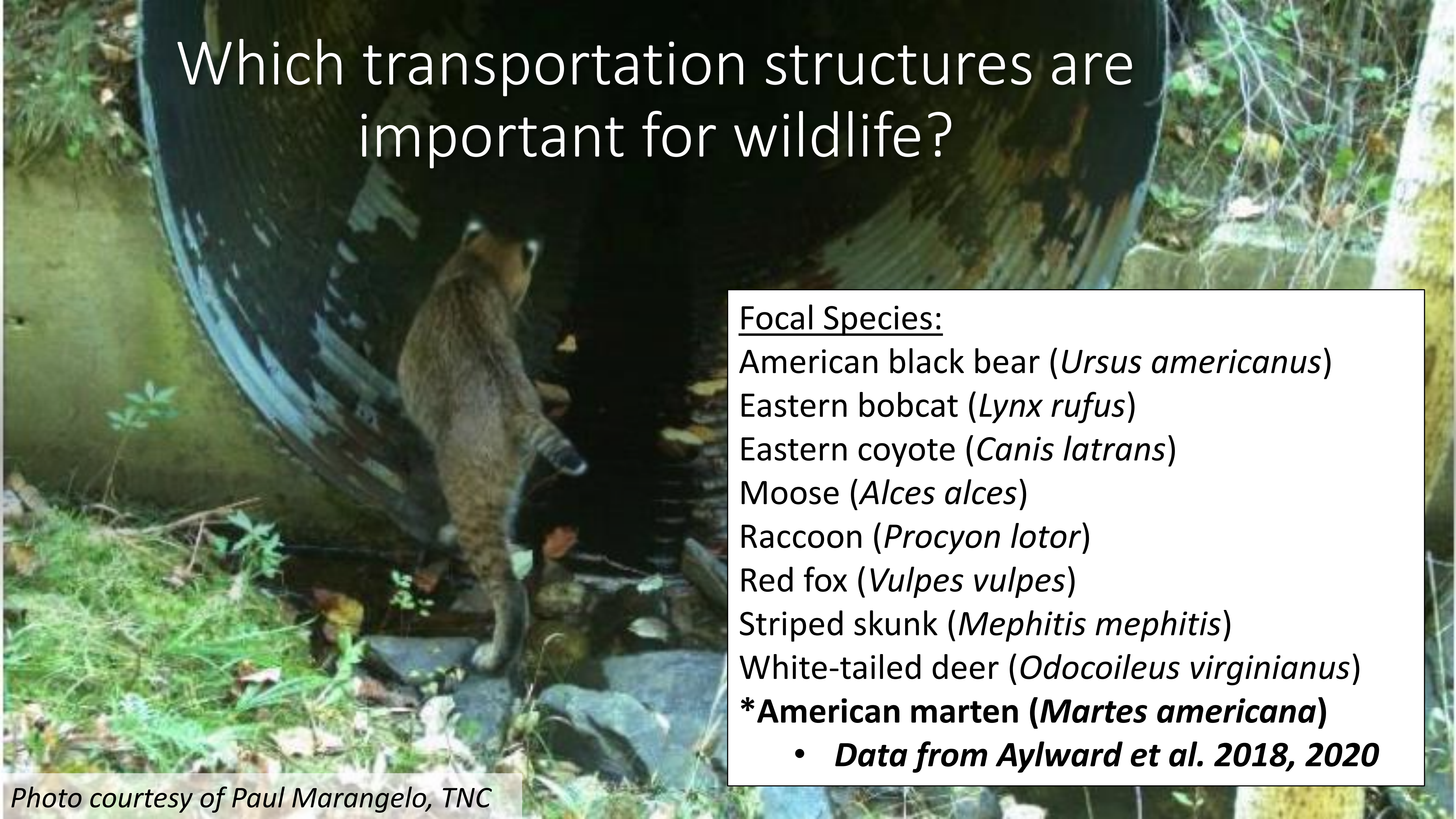
Roads and wildlife:

- Direct mortality (vehicle collisions) ↑
- Habitat fragmentation ↑
- Dispersal ↓
- Genetic exchange ↓
- Range shifts in response to climate change ↓

Vermont:

- 78% forested
- 25,429 km of roadway
- >88,000 transportation structures
  - 6,206 structures >3ft in diameter

Which transportation structures are important for wildlife?



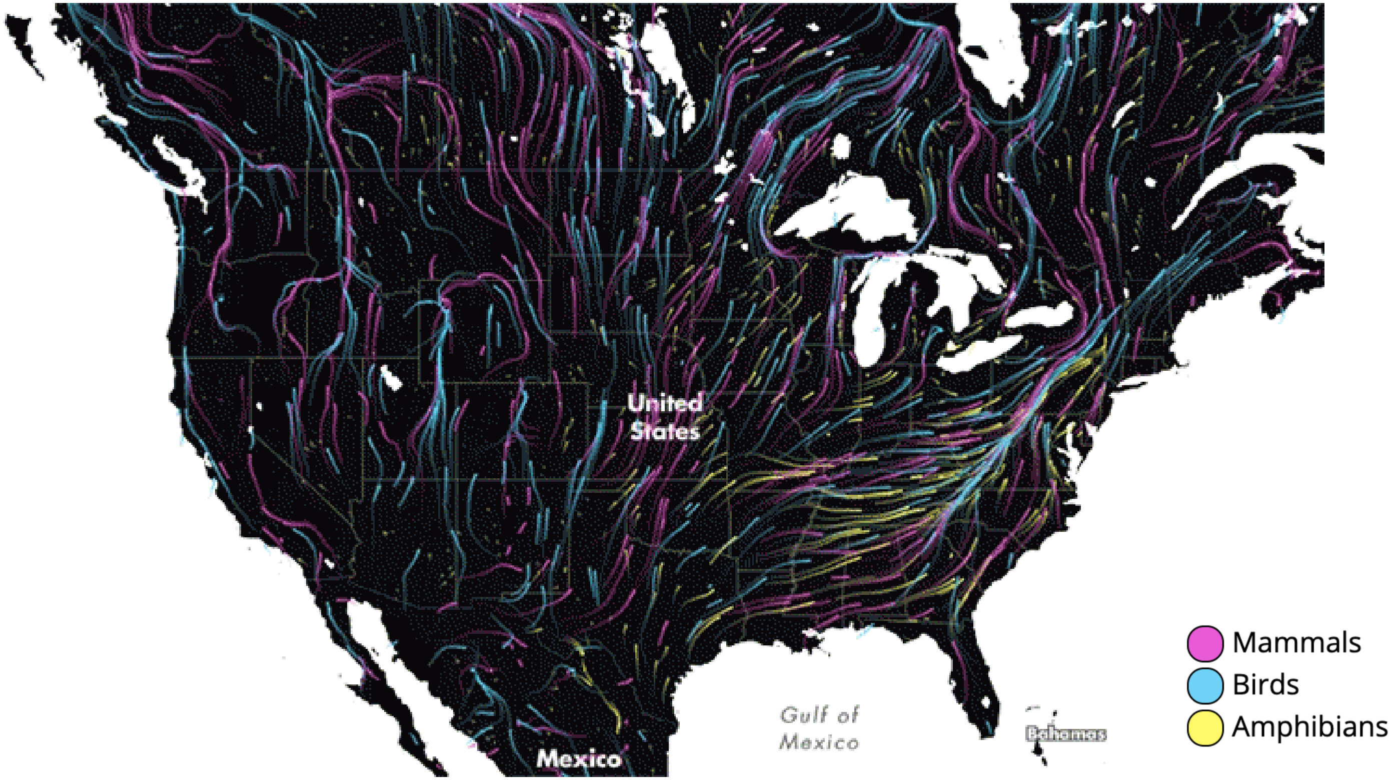
Focal Species:

American black bear (*Ursus americanus*)
Eastern bobcat (*Lynx rufus*)
Eastern coyote (*Canis latrans*)
Moose (*Alces alces*)
Raccoon (*Procyon lotor*)
Red fox (*Vulpes vulpes*)
Striped skunk (*Mephitis mephitis*)
White-tailed deer (*Odocoileus virginianus*)
***American marten (*Martes americana*)**

- ***Data from Aylward et al. 2018, 2020***

Photo courtesy of Paul Marangelo, TNC

Circuit Theory Approach to Connectivity Modeling



Predicted movement paths of 2,954 species under climate change projections, based on research by Lawler et al. 2013 and McGuire et al. 2016. Researchers used circuit theory to model wildlife movement. "Migrations in Motion" map created by Dan Majika, TNC.

- Wildlife movement = electricity
- Landscape = circuit
- Electricity flows through <u>less resistant</u> paths

Omniscape Tool

(McRae et al. 2016)

StructID	LS Current	SS Current	Final Rank
3000100	240	367	1
E4E9F23	211	289	2
2000100	175	233	3
D651EE9	310	78	4
9DDF487	102	57	5

STEP 1

Landscape scale

MODEL LANDSCAPE-WIDE WILDLIFE MOVEMENTS

STEP 2

Structure scale

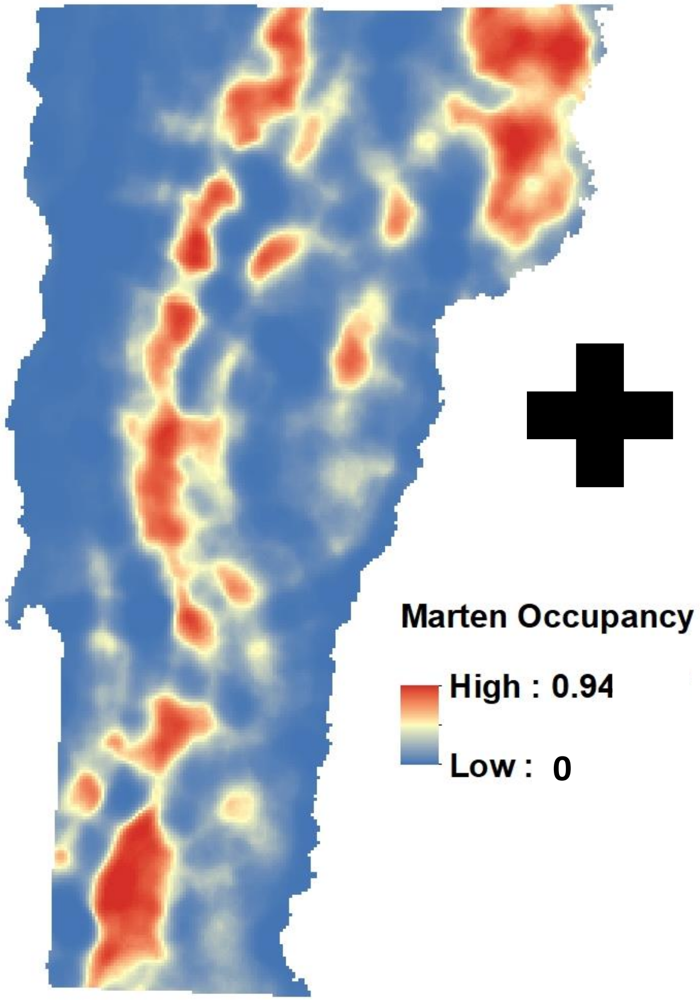
MODEL STRUCTURE-LEVEL WILDLIFE MOVEMENTS

STEP 3

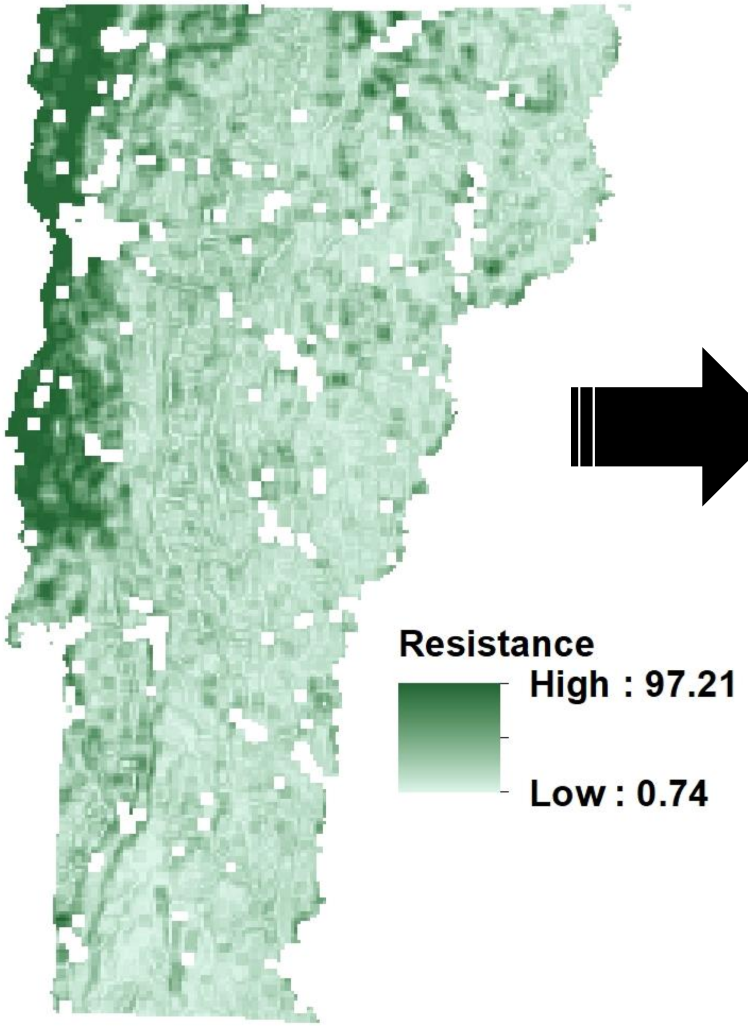
Final ranking

COMBINE BOTH SCALES AND RANK STRUCTURES

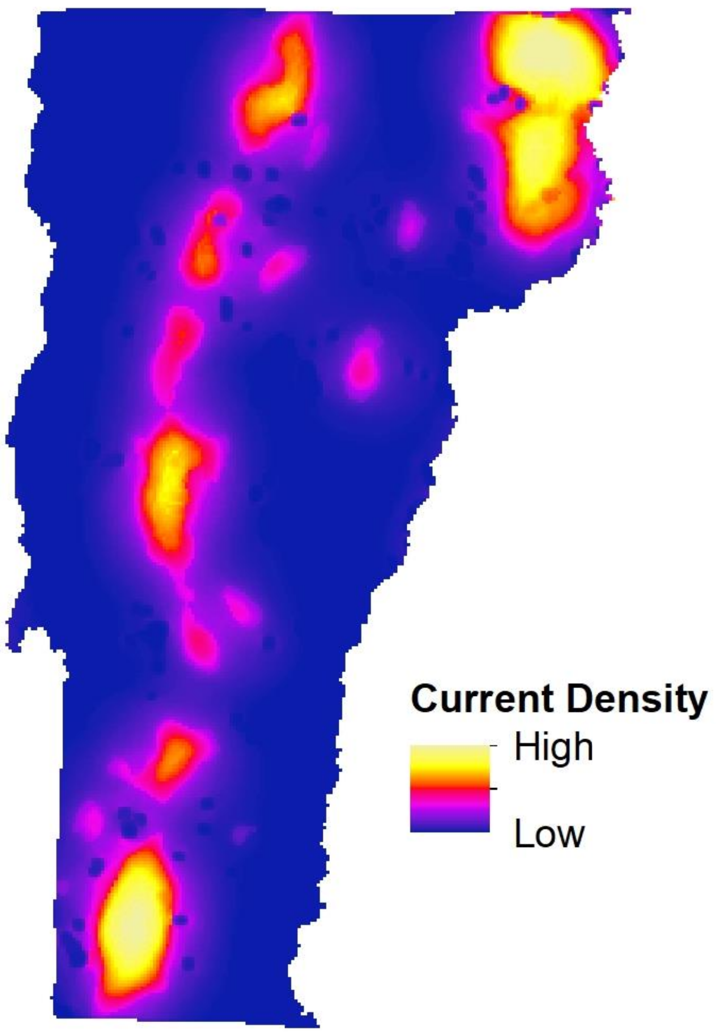
STEP 1: LANDSCAPE SCALE



Wildlife Occurrence

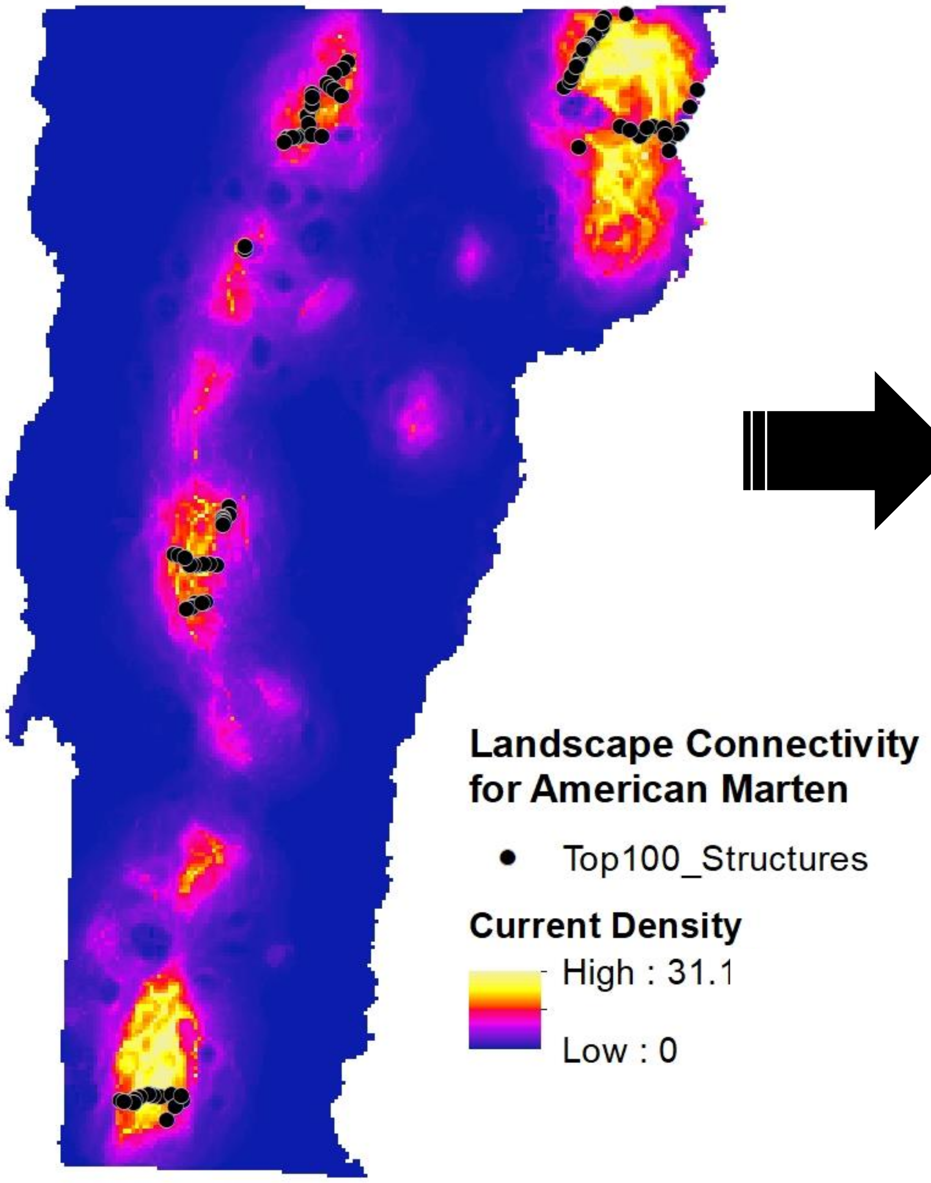


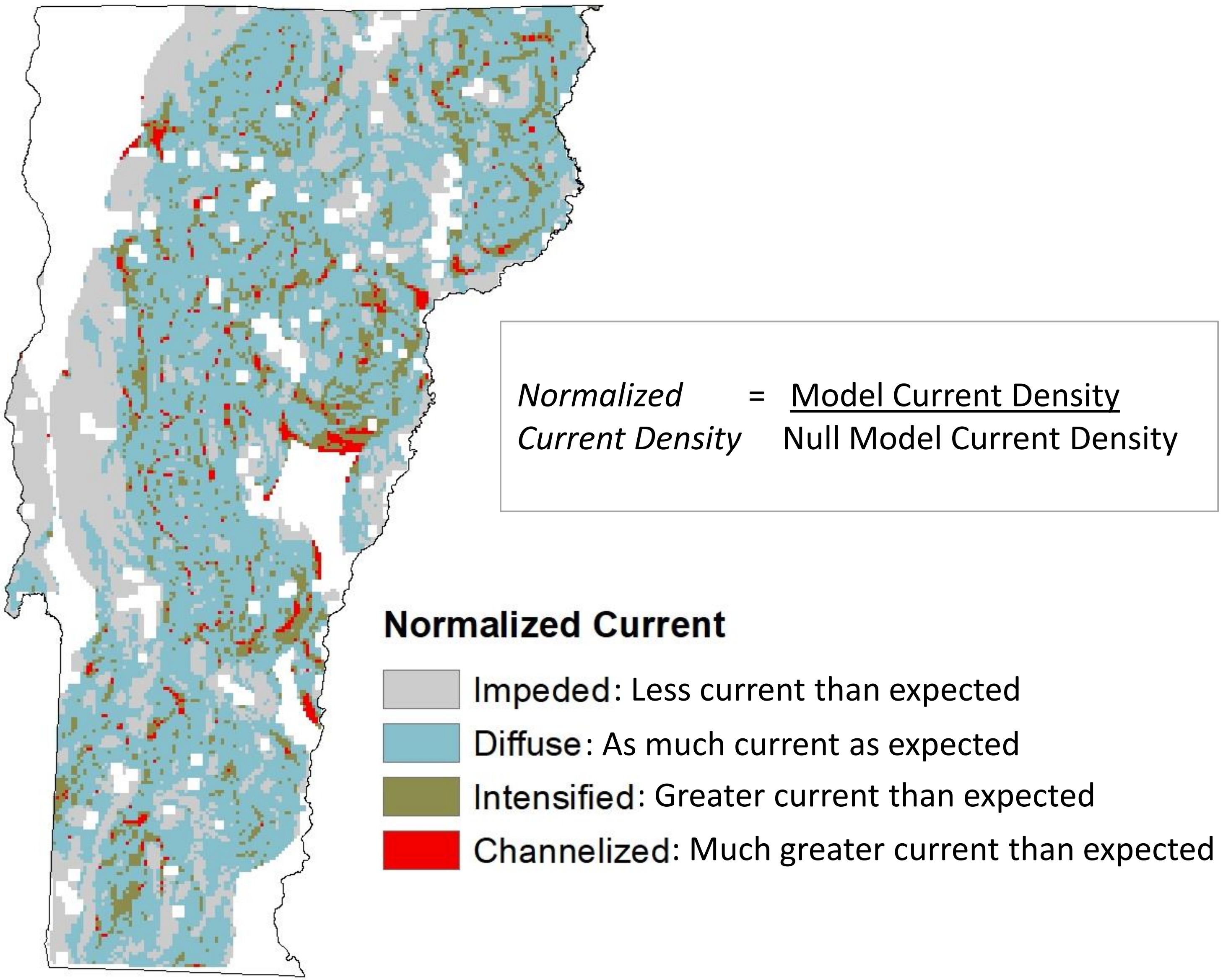
Landscape Resistance



Wildlife Movement Flow

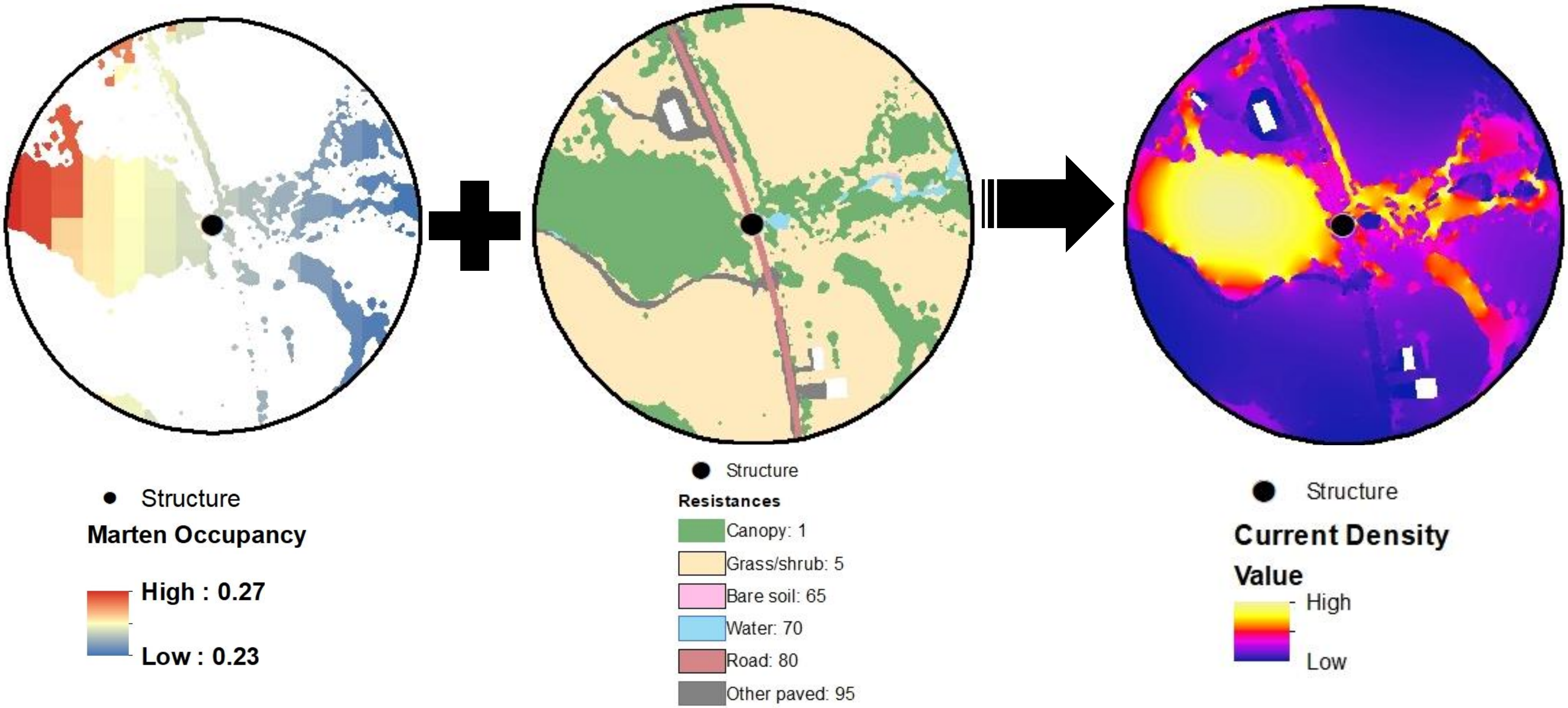
STEP 1: LANDSCAPE SCALE



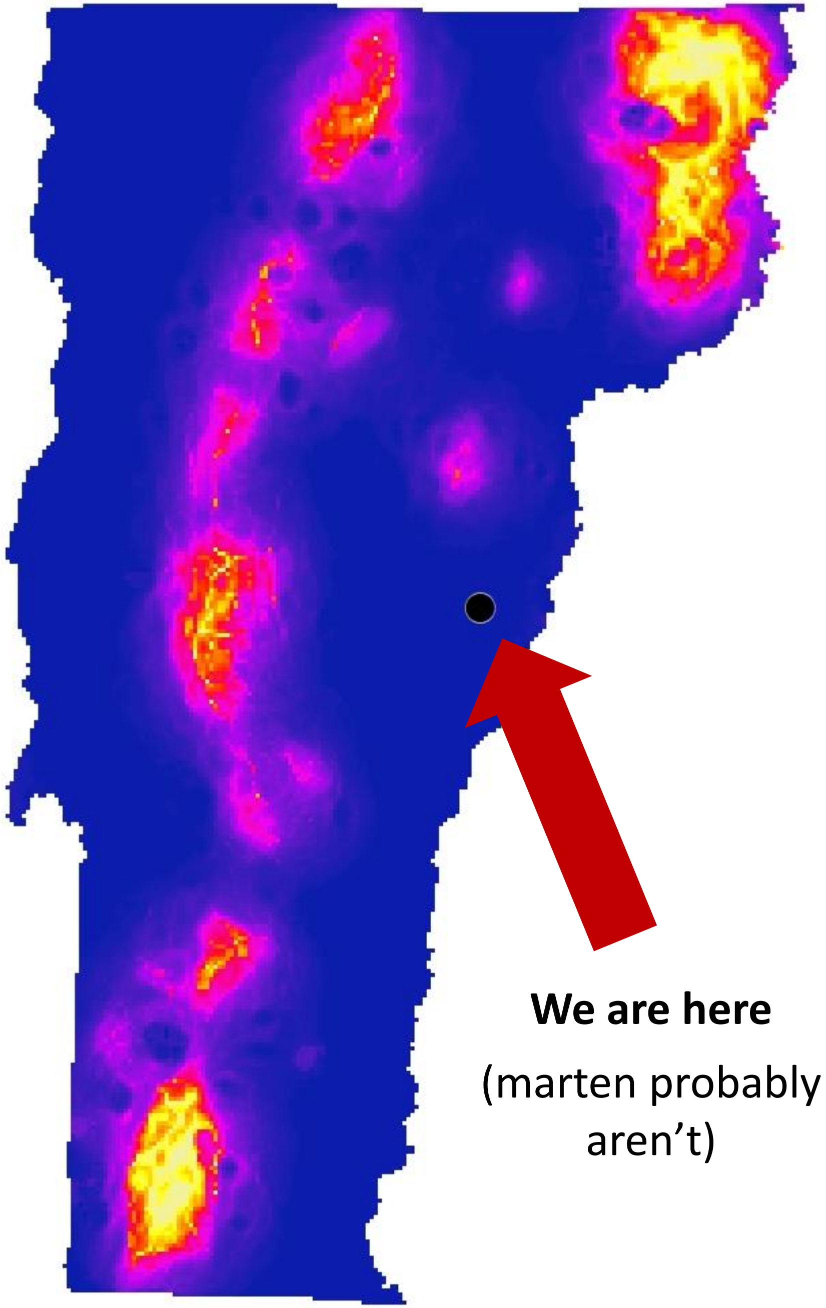


$$\textit{Normalized Current Density} = \frac{\text{Model Current Density}}{\text{Null Model Current Density}}$$

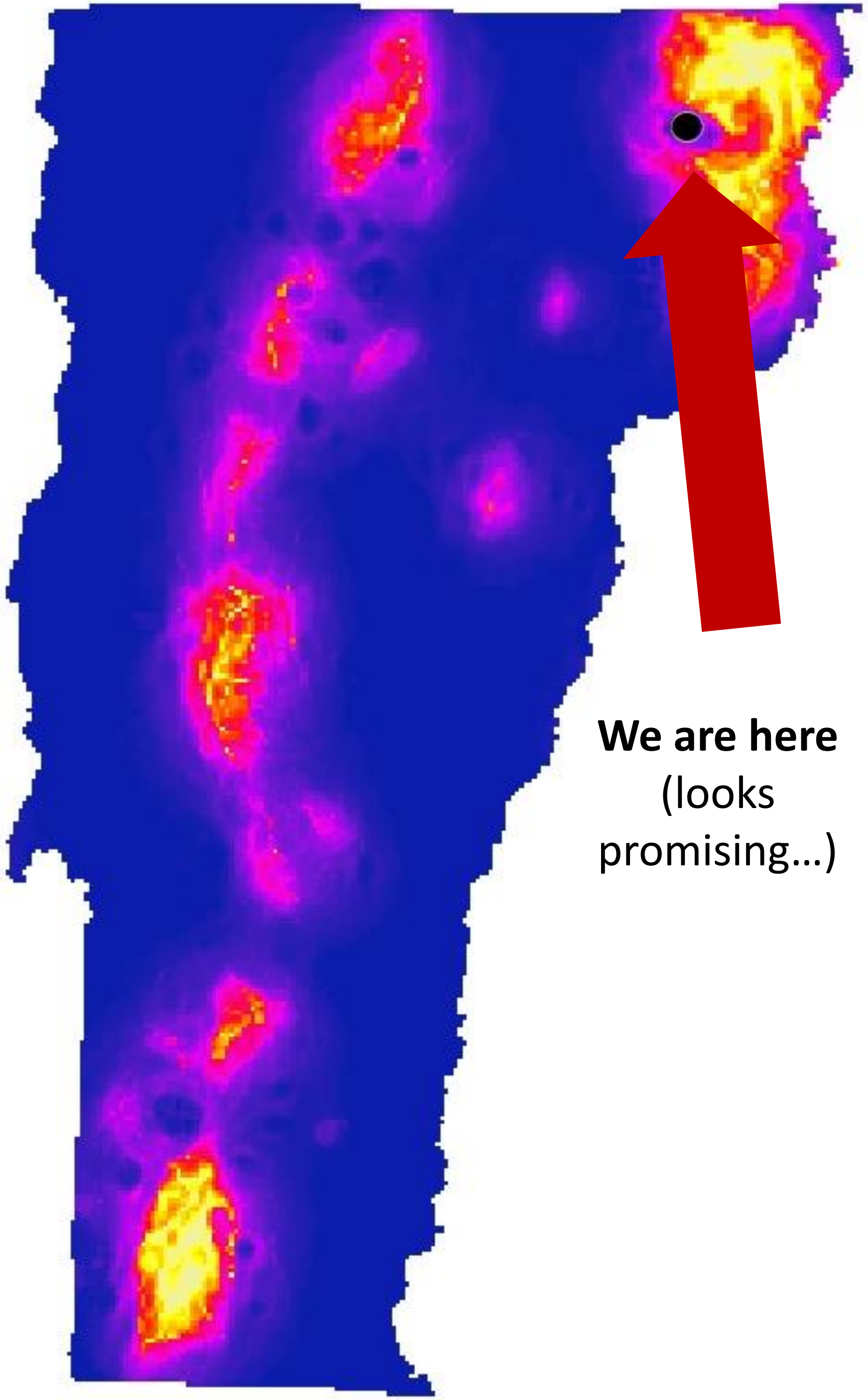
STEP 2: STRUCTURE SCALE



STEP 3: COMBINING SCALES & RANKING STRUCTURES



STEP 3: COMBINING SCALES & RANKING STRUCTURES



We are here
(looks promising…)

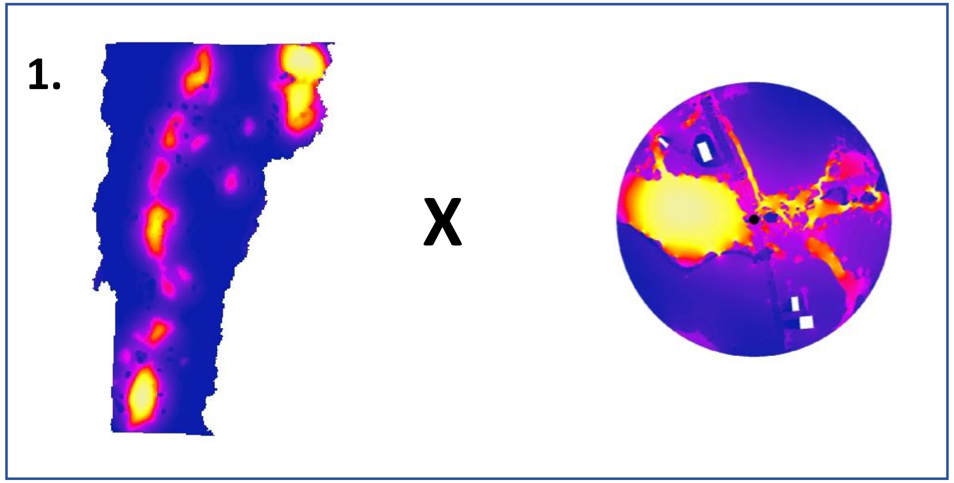
STEP 3: COMBINING SCALES & RANKING STRUCTURES

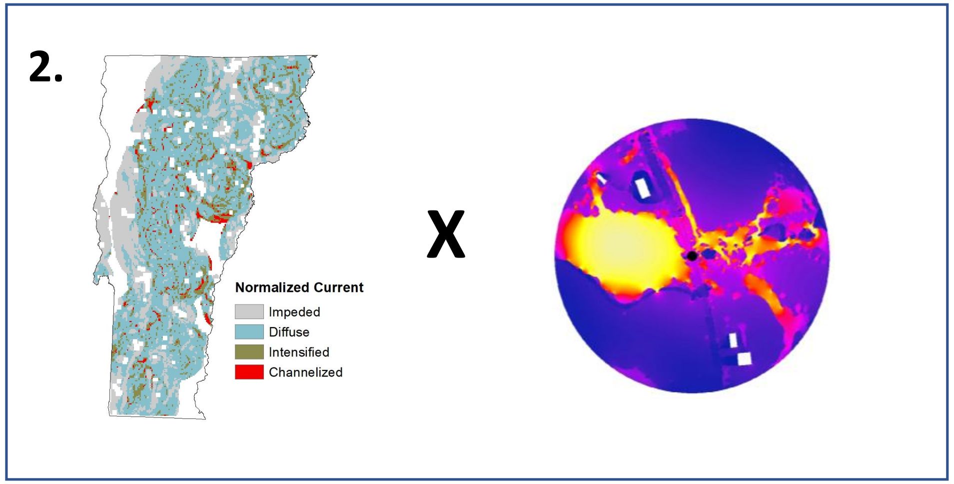
OPTIONS:

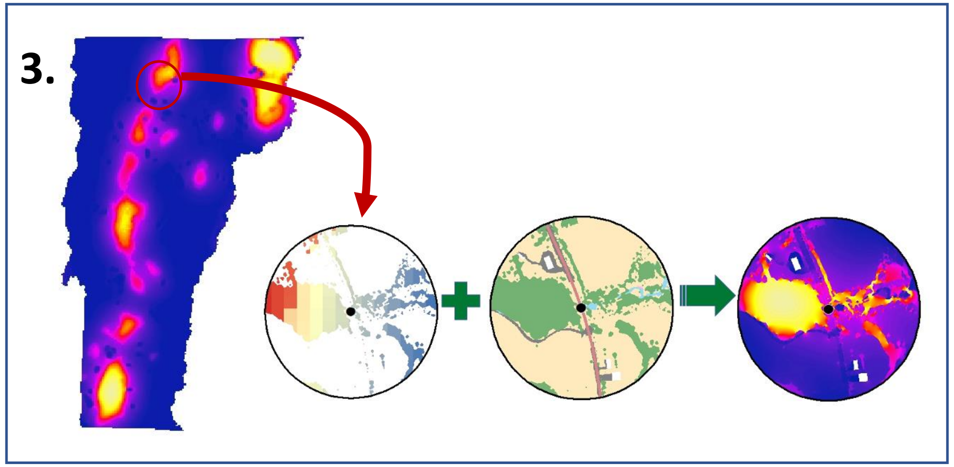
1. Landscape scale current density **x** structure-scale current density
2. Landscape scale current category (weighted) **x** structure current density
3. Landscape scale current as source input for structure-scale
4. Bayesian approach

VALIDATION:

- Camera data
- Roadkill data







Implications

- **Prioritize funding**
- **Structure improvements**: shelving, substrate, shape/size/type of culverts, vegetation/cover near structure, etc.
- **Cost-effective analysis**
  - Collecting new movement data is expensive!
  - Model connectivity across broad area for multiple species

Other uses of circuit theory modeling:

A new model of landscape-scale fire connectivity applied to resource and fire management in the Sonoran Desert, USA

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> PLoS One. 2017 May 2;12(5):e0176960. doi: 10.1371/journal.pone.0176960. eCollection 2017.

Simulating the spread of selection-driven genotypes using landscape resistance models for desert bighorn sheep

Tyler G Creech [1], Clinton W Epps [1], Erin L Landguth [2], John D Wehausen [3], Rachel S Crowhurst [1], Brandon Holton [4], Ryan J Monello [5]

Early modern human dispersal from Africa: genomic evidence for multiple waves of migration

Francesca Tassi, Silvia Ghirotto, Massimo Mezzavilla, Sibelle Torres Vilaça, Lisa De Santi & Guido Barbujani

Investigative Genetics **6**, Article number: 13 (2015) | Cite this article

Connecting today's climates to future climate analogs to facilitate movement of species under climate change

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Circuit-theory applications to connectivity science and conservation

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Questions?

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