Counting Connections: Ecological Thresholds for Anurans in Human-Altered Landscapes

Latornell Conservation Symposium 2025
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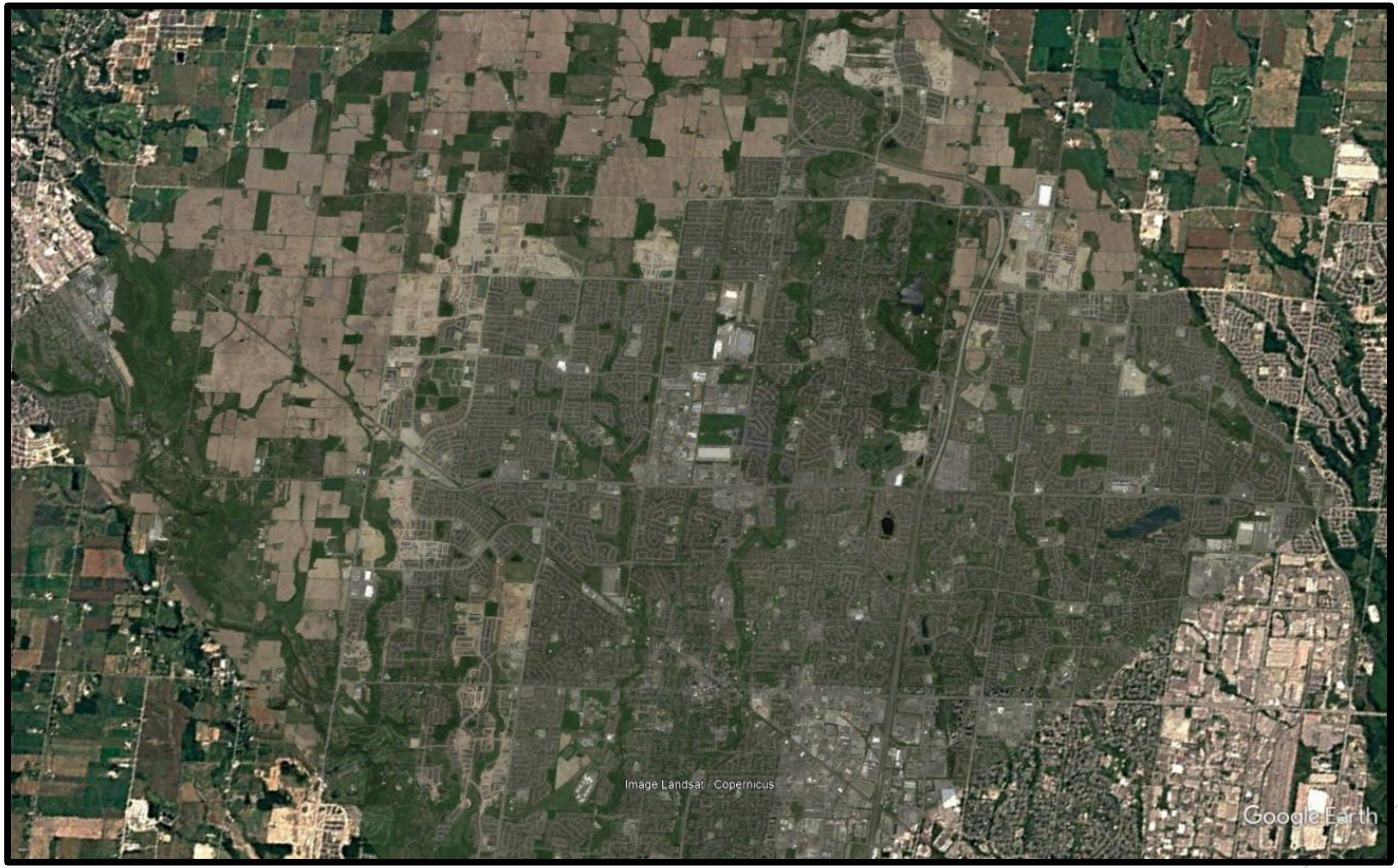
Habitat Connectivity

Urban Expansion and Intensification

Habitat Connectivity

Urban Expansion and Intensification



Habitat Connectivity

Urban Expansion and Intensification

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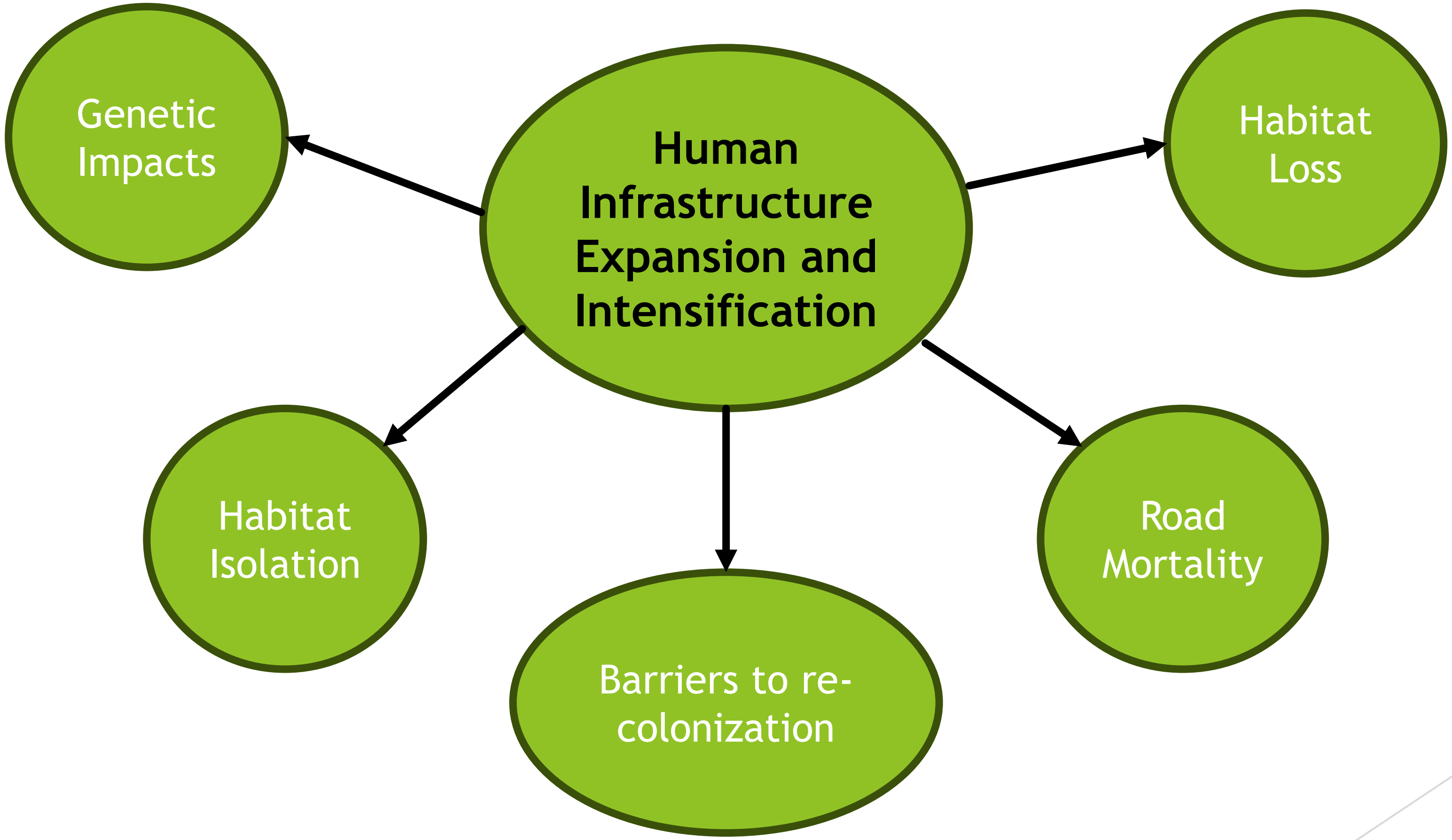


Human Infrastructure Expansion and Intensification

Genetic Impacts

Habitat Loss

Habitat Isolation

Barriers to re-colonization

Road Mortality

Habitat Connectivity

Legislative Approach in Ontario

Planning Act

- Primary land use planning legislation

Provincial Policy Statement

- "Long-term ecological function and biodiversity of natural heritage systems should be maintained…recognizing linkages between and among natural heritage features and areas" (PPS, 2024)

Significant Wildlife Habitat Technical Guide

- Official guidance for evaluating habitat and determining significance (OMNR, 2000)
- Recommendations for movement corridor design are vague

Habitat Connectivity

Anurans as a Model Species

- Highly mobile
- Connections between multiple habitats
- Terrestrial and aquatic
- Easy to monitor
- Vulnerable to road mortality
- Ecological indicators

Anuran Movement Dynamics

Dispersal

- ❖ Newly transformed juveniles
- ❖ Direction, auto-correlated
- ❖ Little land cover selection
- ❖ Instinctual
- ❖ Colonization/re-colonization

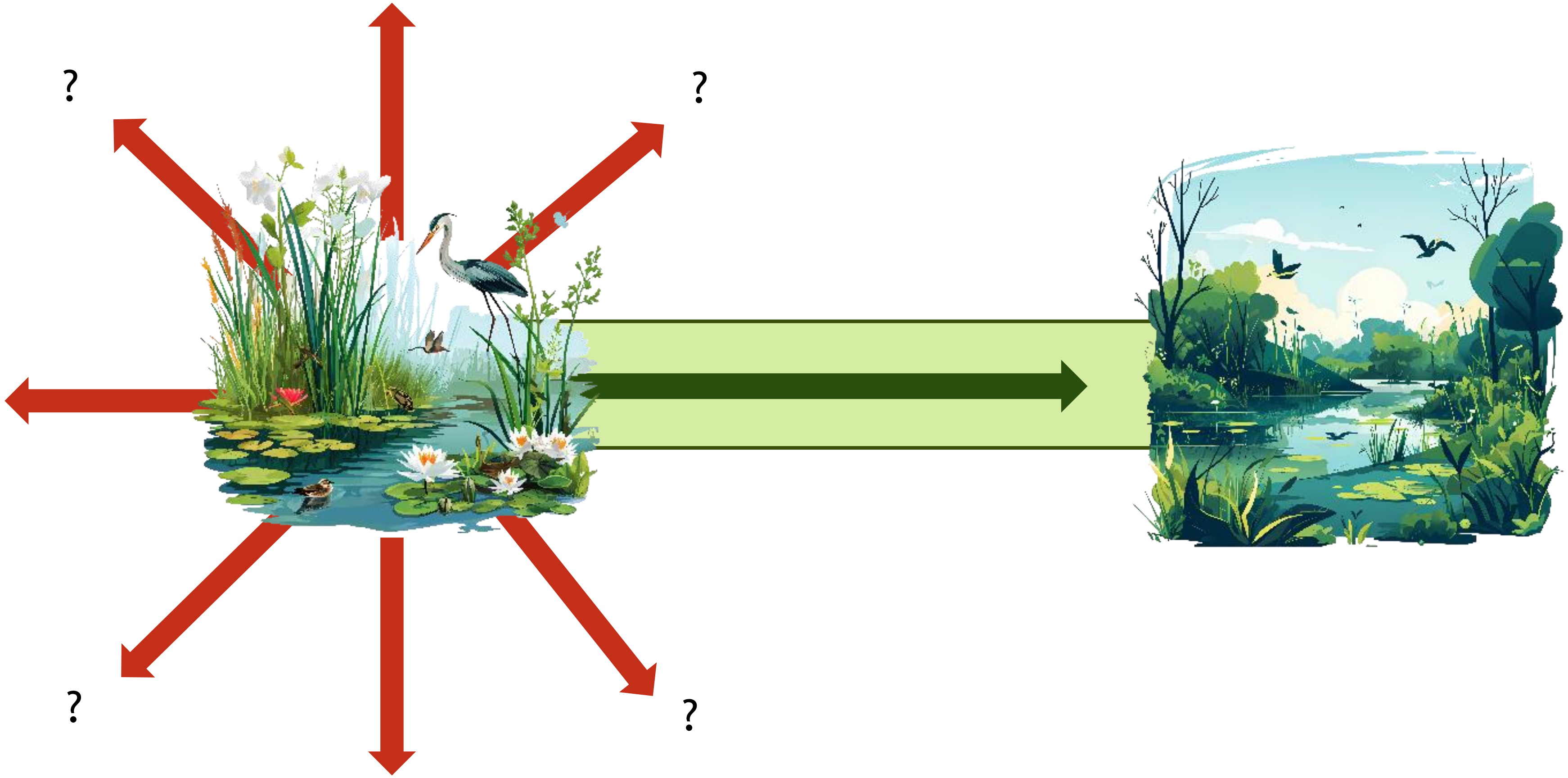
Anuran Movement Dynamics

Migration

- Previously used routes
- Breeding to overwintering
- Adult movement
- Guided, possibly more selective

Identifying Habitat Linkages

Resistance Modelling



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Identifying Habitat Linkages

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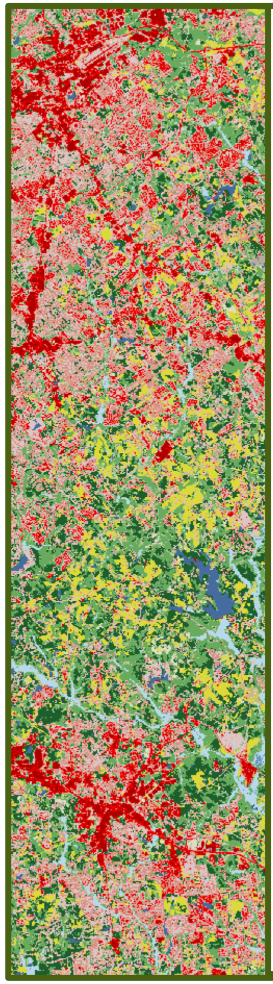
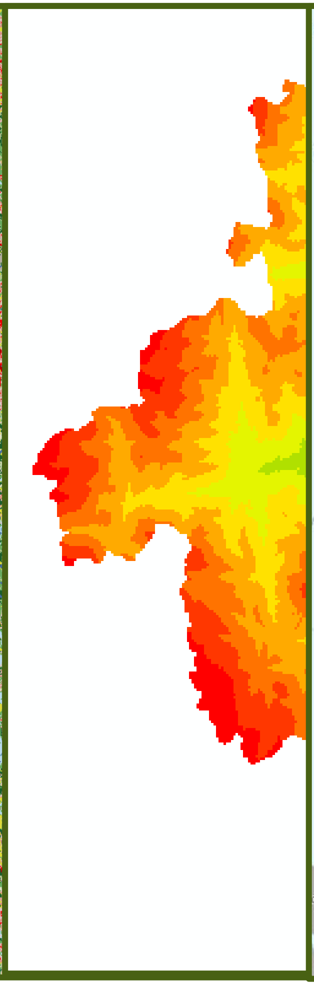
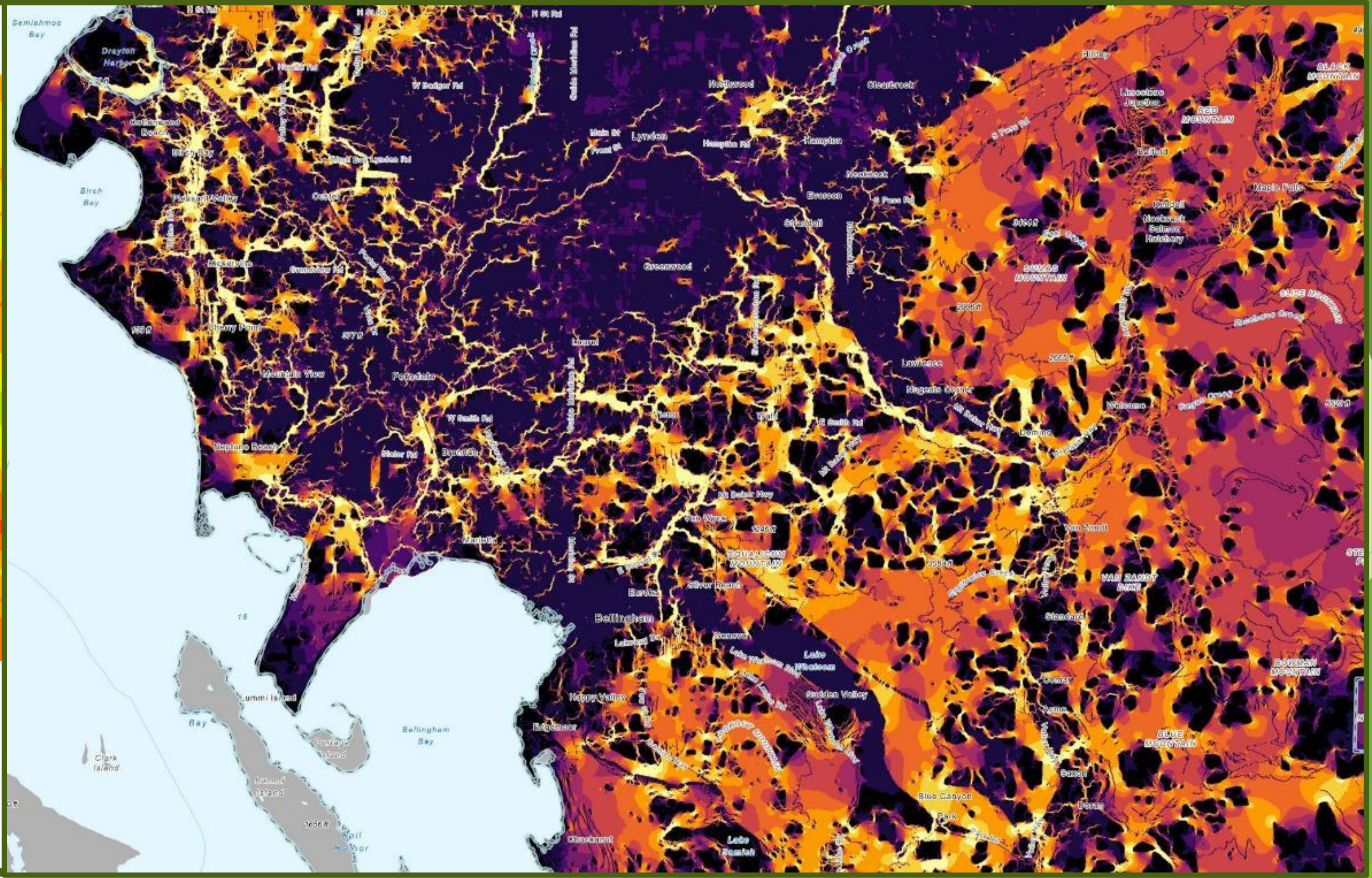
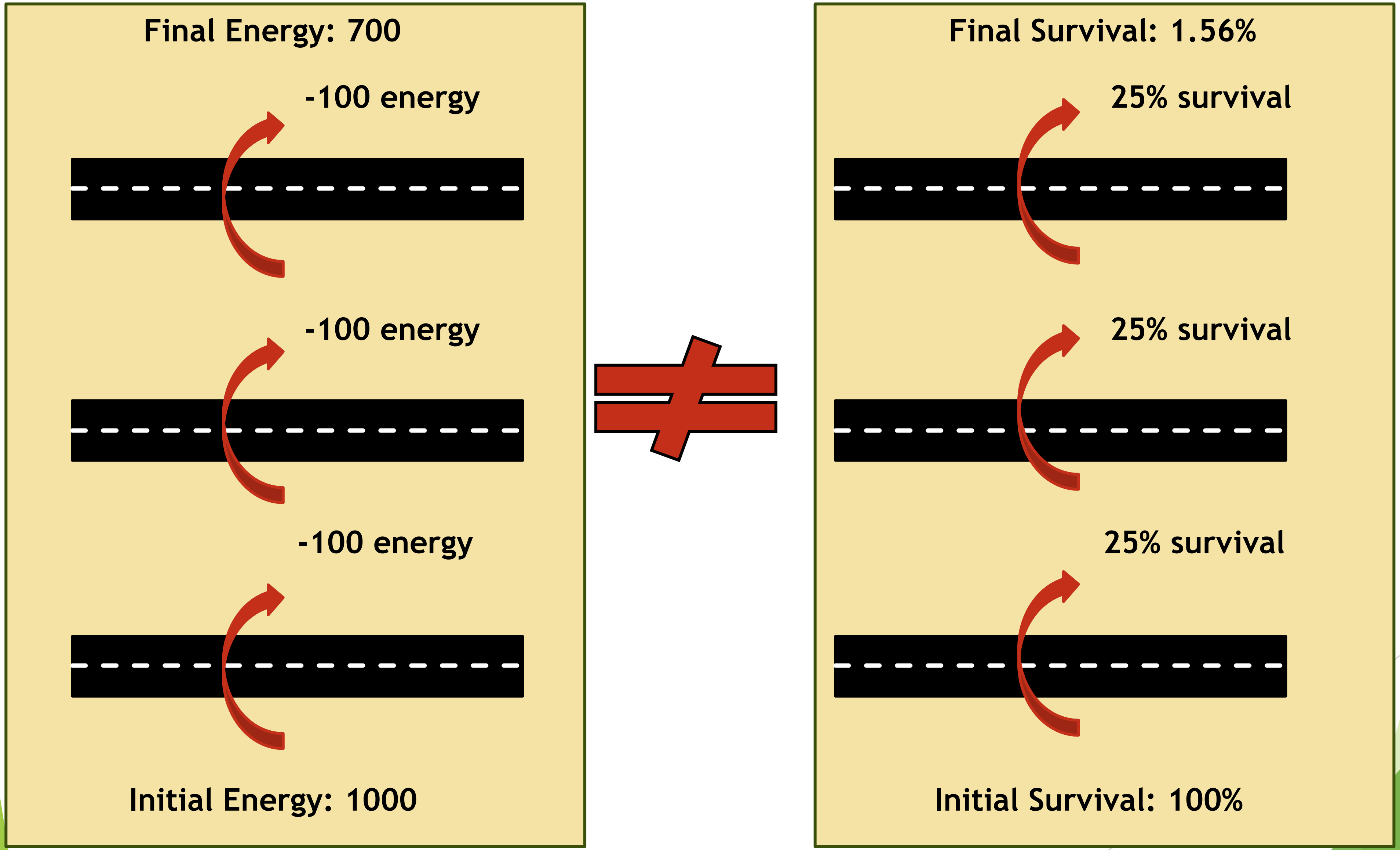






Identifying Habitat Linkages

Resistance Modelling



Final Energy: 700

-100 energy

-100 energy

-100 energy

Initial Energy: 1000

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Final Survival: 1.56%

25% survival

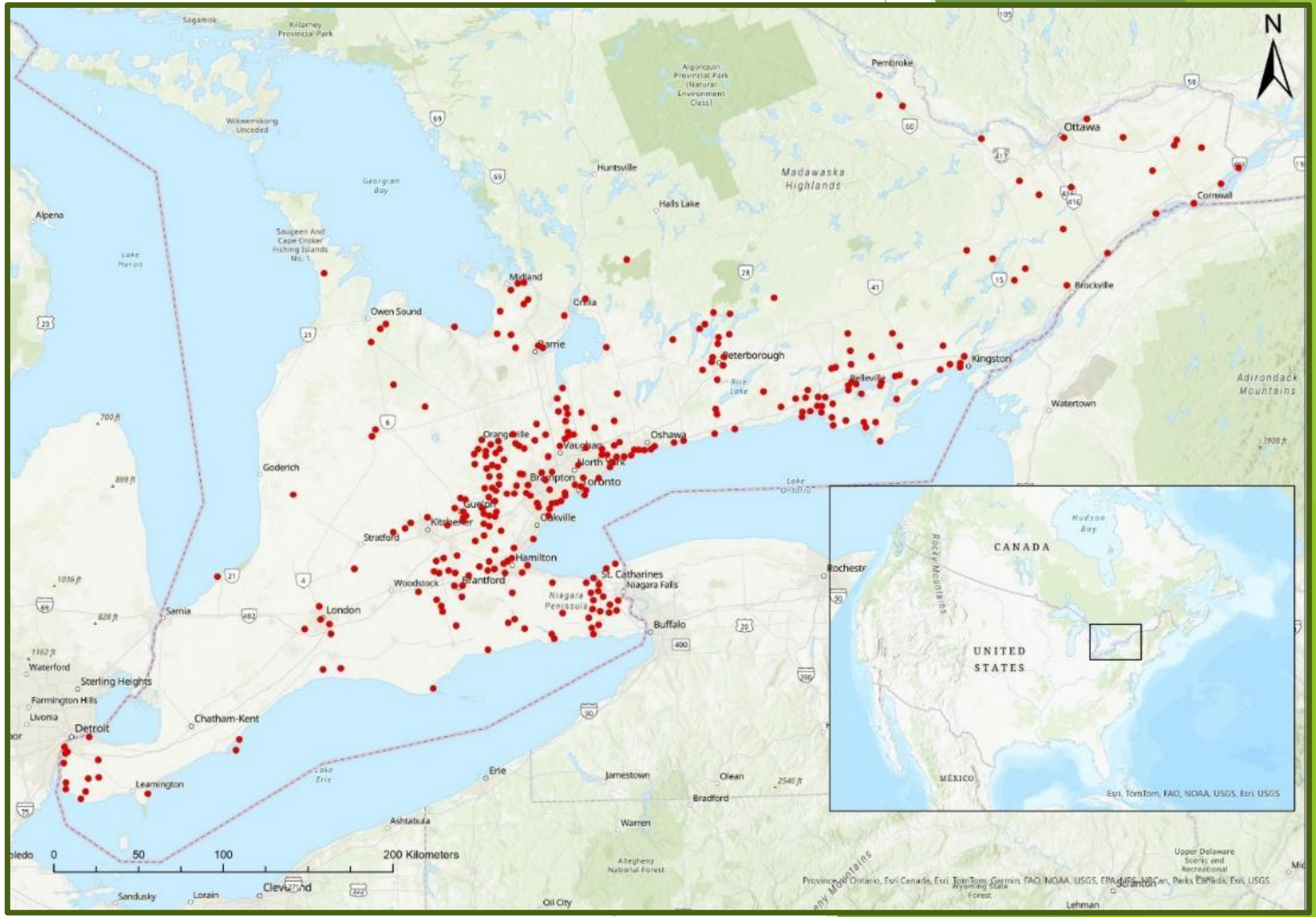
25% survival

25% survival

Initial Survival: 100%

Anuran Acoustic Data

Amphibian Marsh Monitoring Database



Connectivity Metric Design

Newly-transformed Juvenile Dispersal

- ❖ Number of wedges with accessible marsh
- ❖ 12 wedges of 60° arcs and overlapping width
- ❖ Accessibility modelled using a cost distance surface
- ❖ 3 maximum movement distances: 1000m, 2500m, 5000m

Connectivity Metric Design

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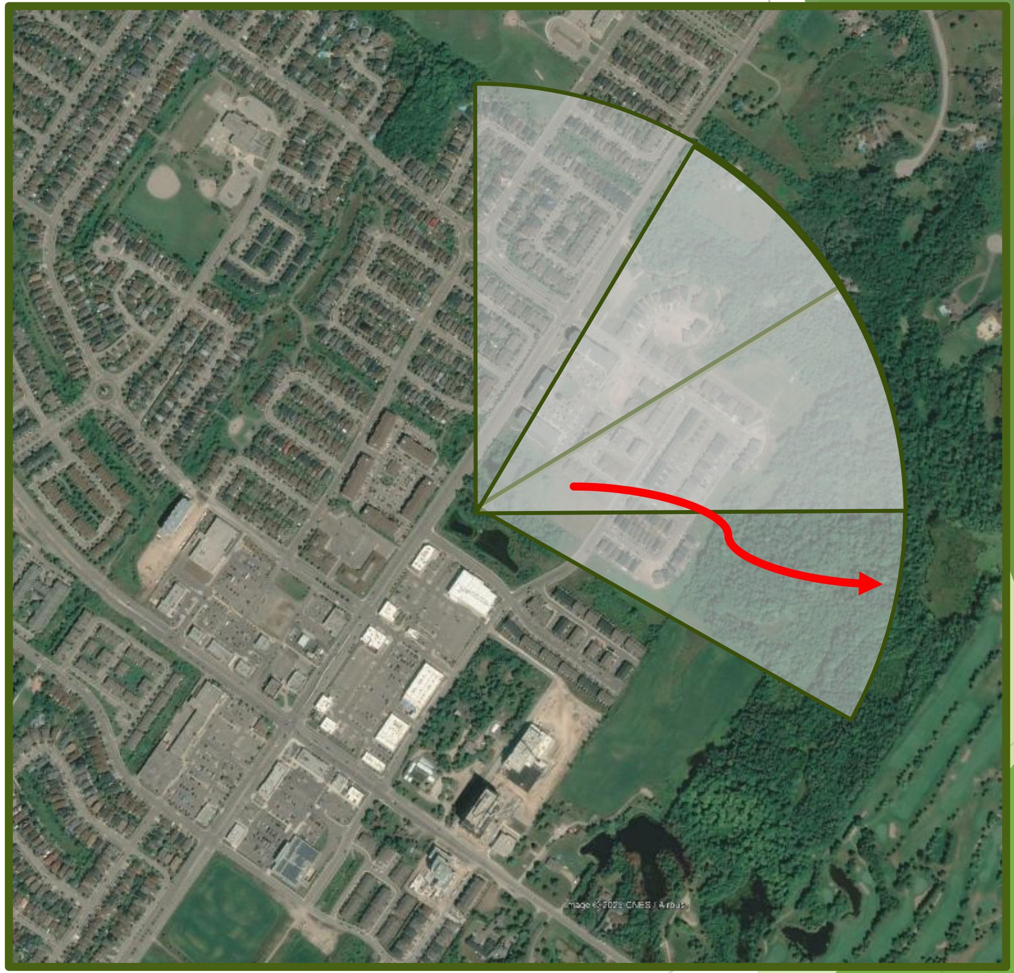

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Connectivity Metric Design

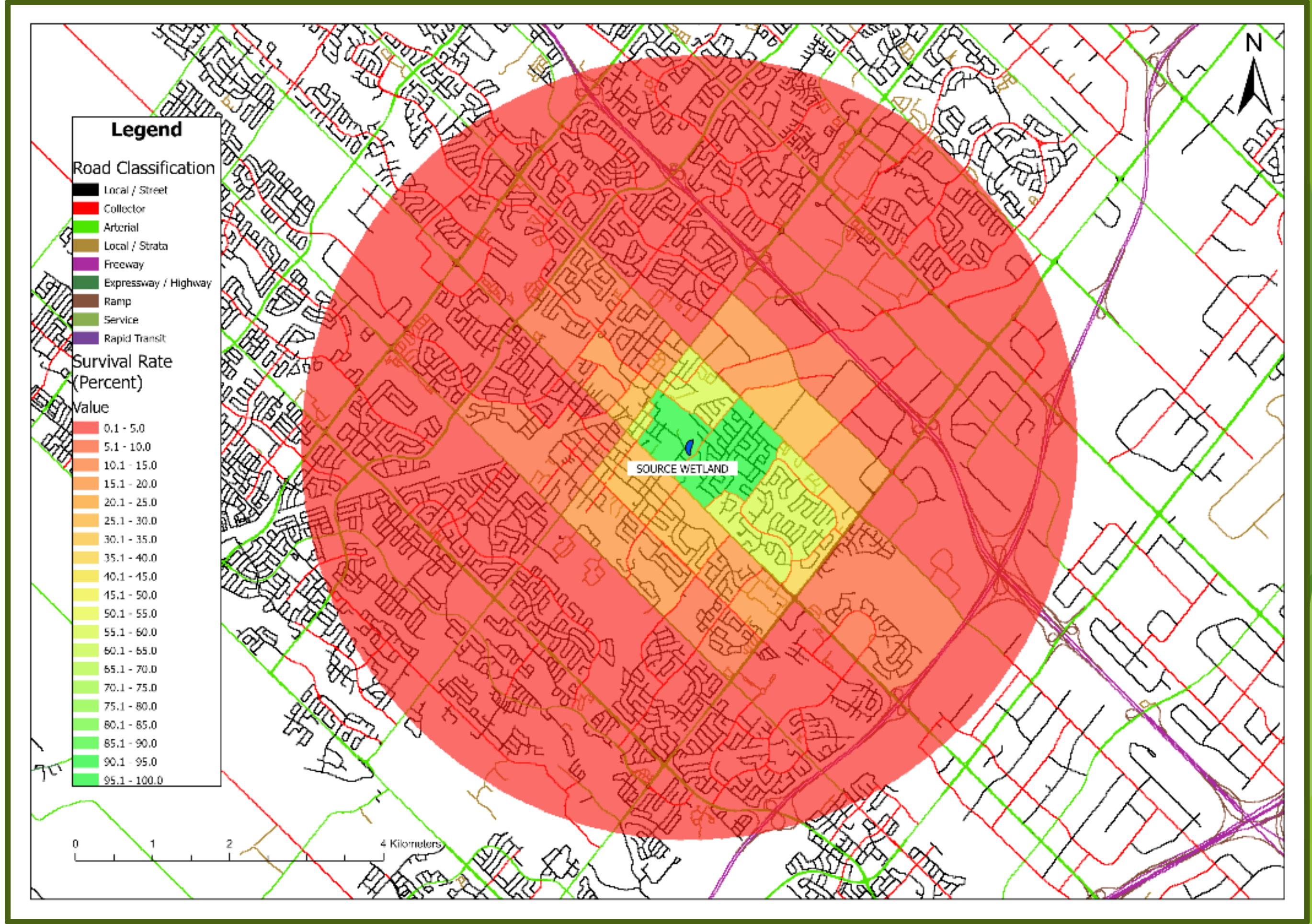
Adult Migration (Overwintering to Breeding)

- Sum of forest pixels scaled by remaining “energy”
- 3 maximum movement distances: 500m, 1000m, 3000m
- Land cover assigned values according to resistance to movement
- Building footprints treated as absolute barriers to movement

Connectivity Metric Design

Road Crossing Survival

- ❖ Sum of marsh pixels with at least 5% survival rate
- ❖ Roads assigned values based on crossing survival rate
- ❖ Cost distance tool altered to use multiplication instead of addition (i.e. exponential vs linear decreases in survival)
- ❖ 3 maximum movement distances: 1000m, 2500m, 5000m



Statistical Analysis

Generalized Additive Models (GAMs)

- Generalized Additive Models (GAMs)
  - Binomial family (presence/absence)
  - Deviance explained (%) and Akaike Information Criterion (AIC)

- Multi-variable models
  - All possible combinations tested
  - Only one variable from each metric in each model (maximum 4 in one model)

Statistical Analysis

Generalized Additive Models (GAMs)

Frequency significant variables in top models

Species (Deviance explained)	**Dispersal**	**Overwintering**	**Survival**	**Land Cover**
Green Frog (14% - 17%)	2500m	-	1000m	Urban
Wood Frog (14% - 15%)	-	Variable	-	Urban
Leopard Frog (17% - 18%)	1000m	-	1000m	Urban
American Toad (4% - 13%)	Variable	-	-	-
Spring Peeper (41% - 43%)	Variable	3000m	5000m	Natural
Gray Treefrog (47% – 48%)	1000m	3000m	5000m	Natural

Statistical Analysis

Piecewise Regression

Statistical Approach

- Data organization
  - 10 bins and 20 bins
  - Dispersal metric limited to 13 bins

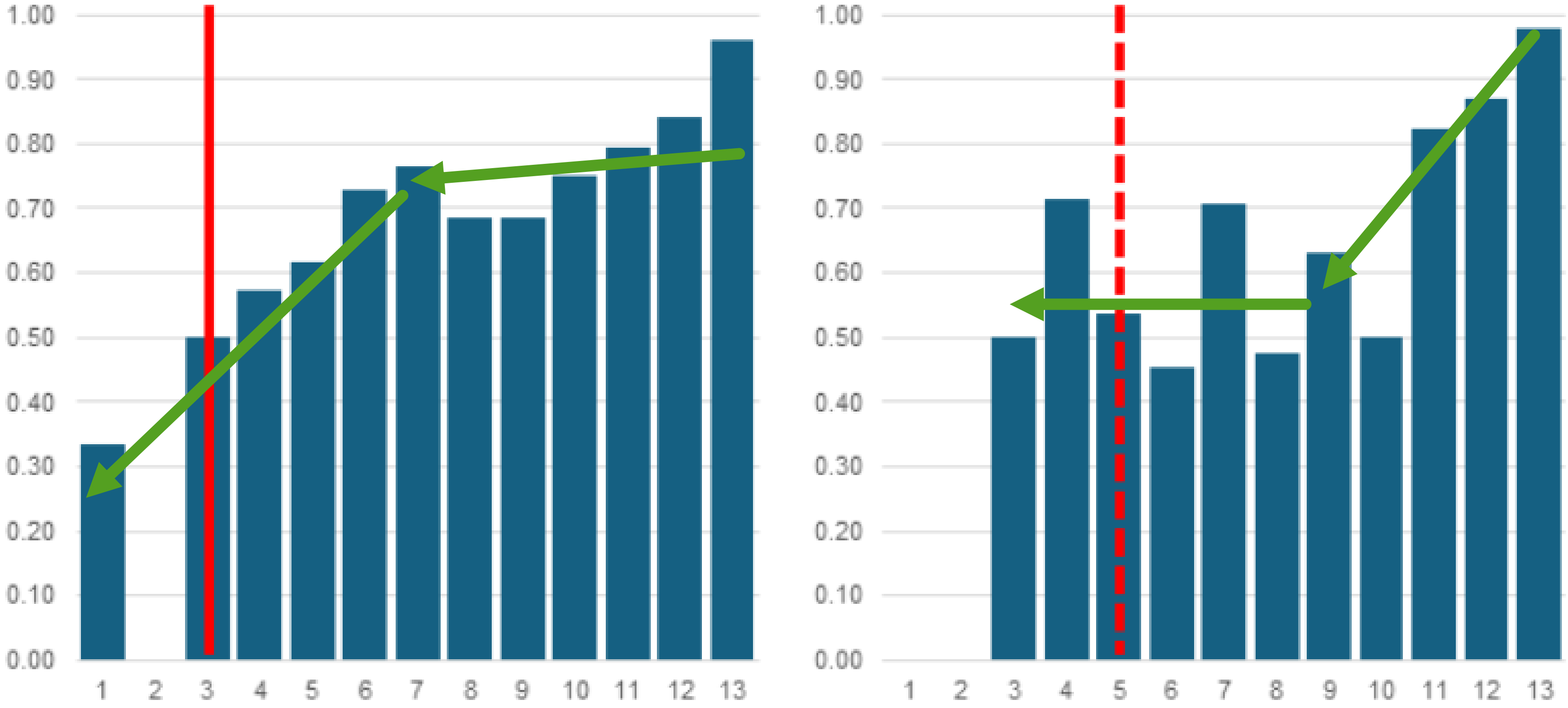
- Statistical analysis
  - Piece wise regression (r.segmented) to identify breakpoints
  - Davies p-value ($p=0.05$) to test for significance

- Breakpoints plotted and visually inspected

Ecological Threshold Results

Connectivity Metrics

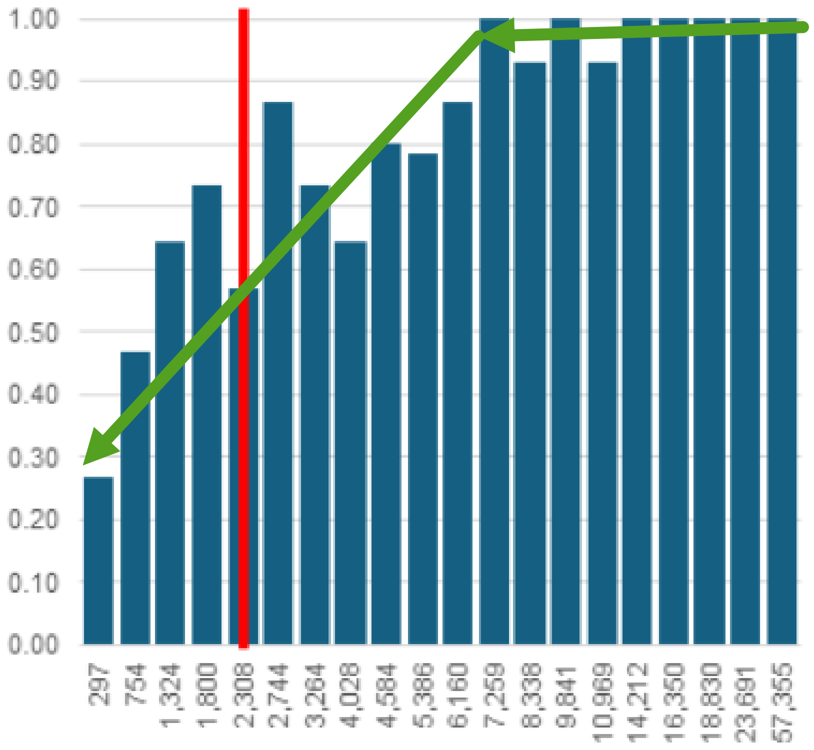
Dispersal Metric @ 5000m

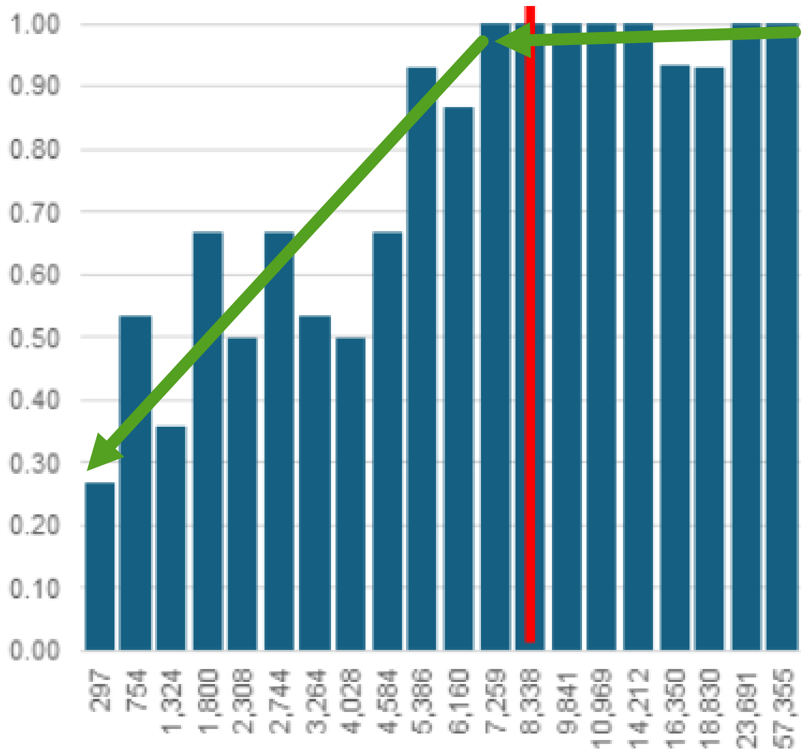


Ecological Threshold Results

Connectivity Metrics

Overwintering Metric @ 3000m

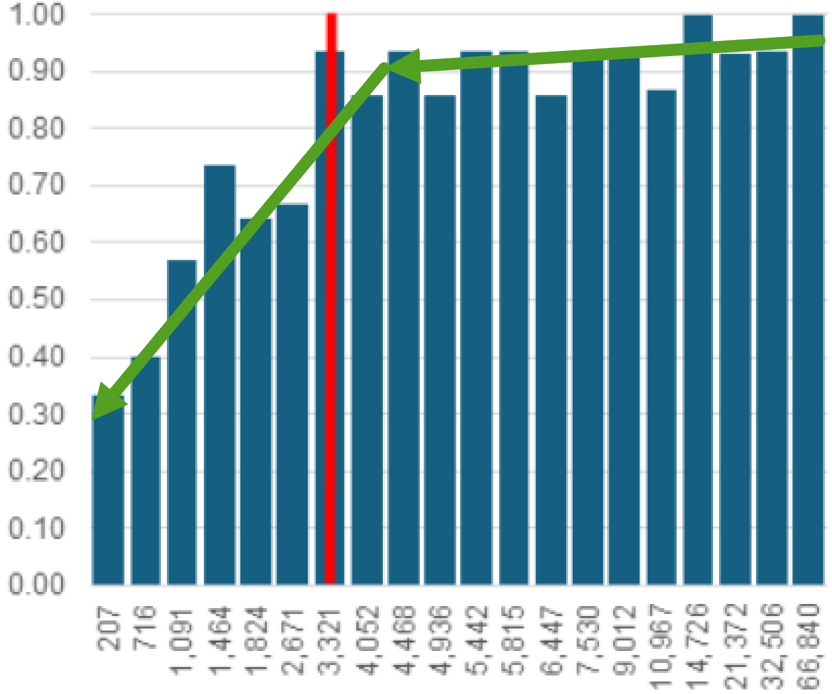


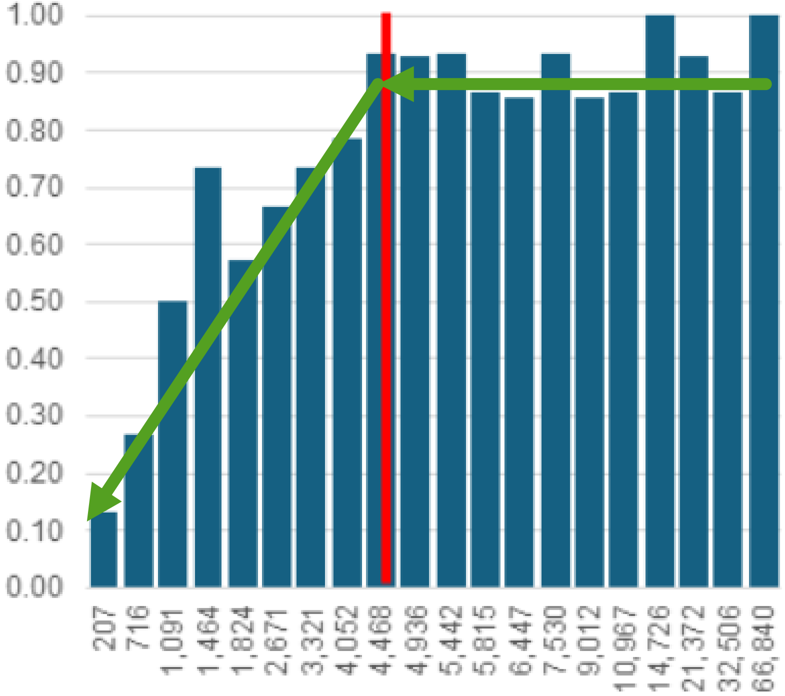


Ecological Threshold Results

Connectivity Metrics

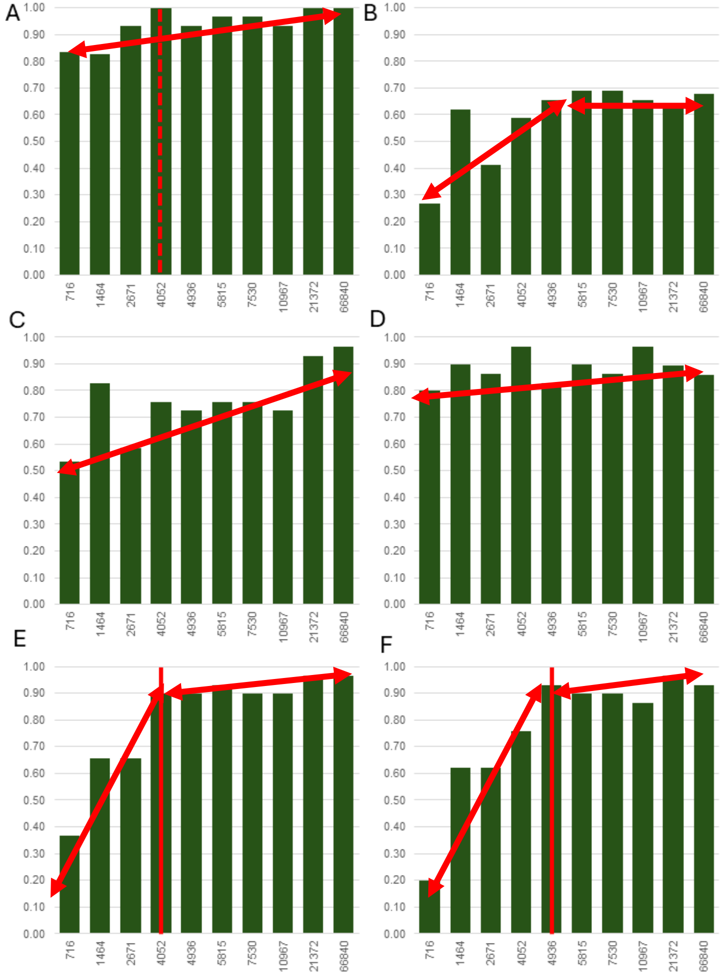
Road Crossing Survival Metric @ 5000m





Ecological Threshold Results

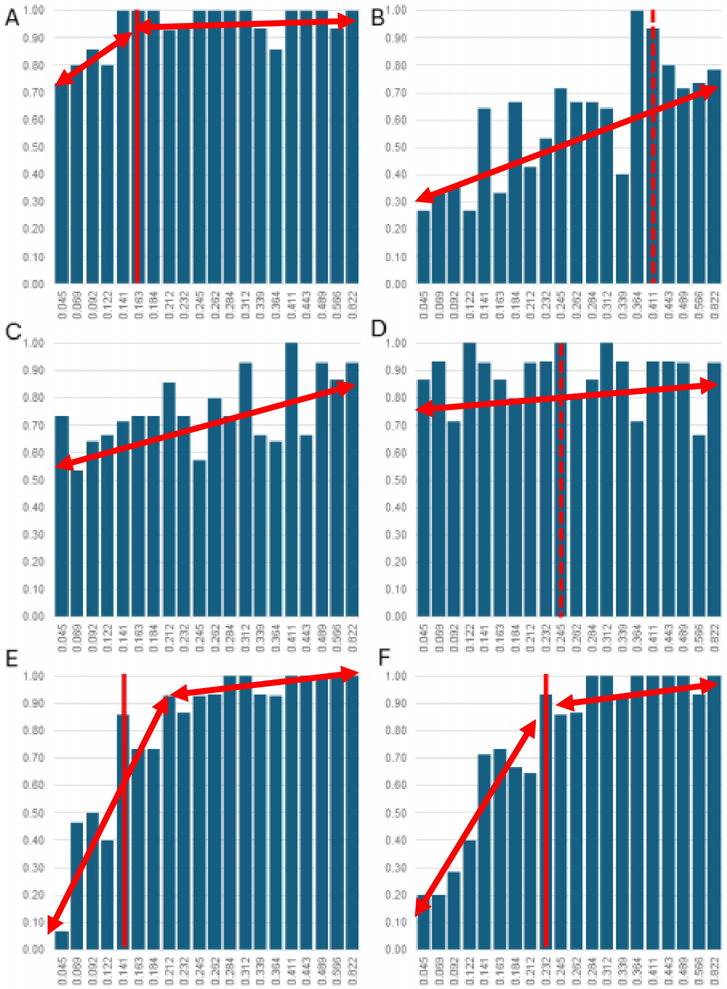
Connectivity Metrics



Road Crossing Survival (5000m)

Ecological Threshold Results

Land Cover Composition



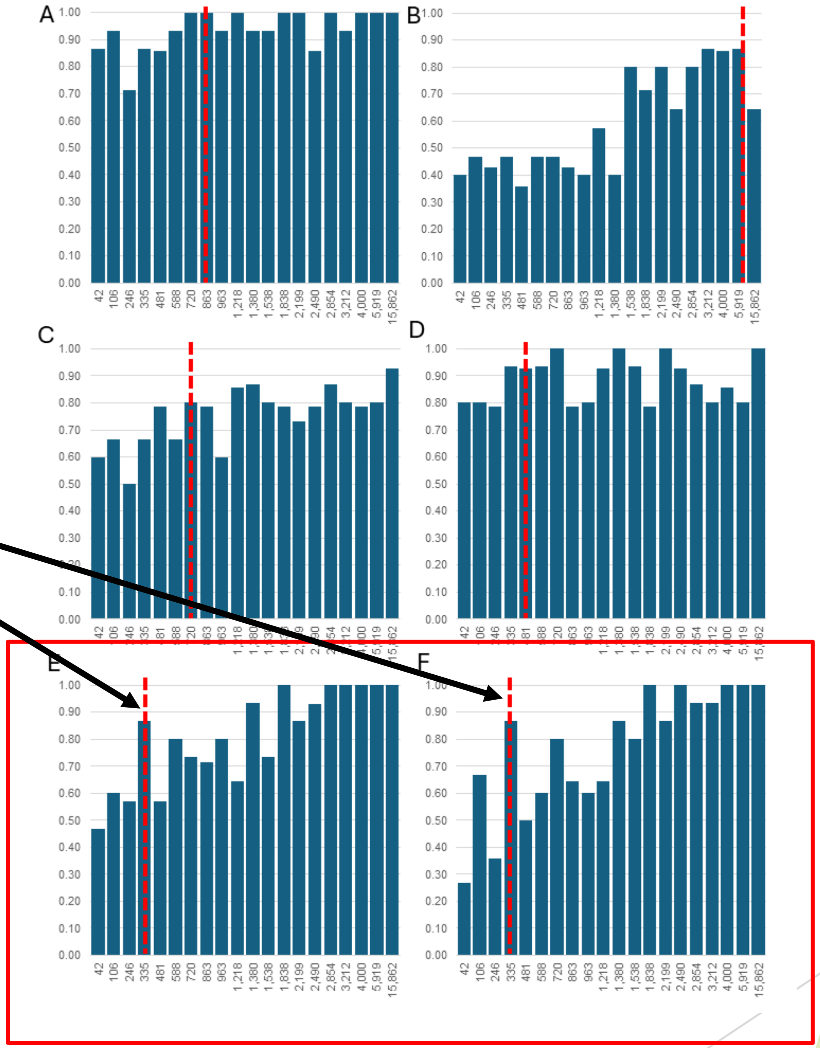
Forest and Wetland Cover (3000m)

Ecological Threshold Results

Location of Thresholds

- Local maxima and minima affecting threshold identification (see SPPE and GRTR), especially in the 20-bin analysis

- Visual inspection critical; breakpoints, even significant ones, sometimes don’t hold up visually



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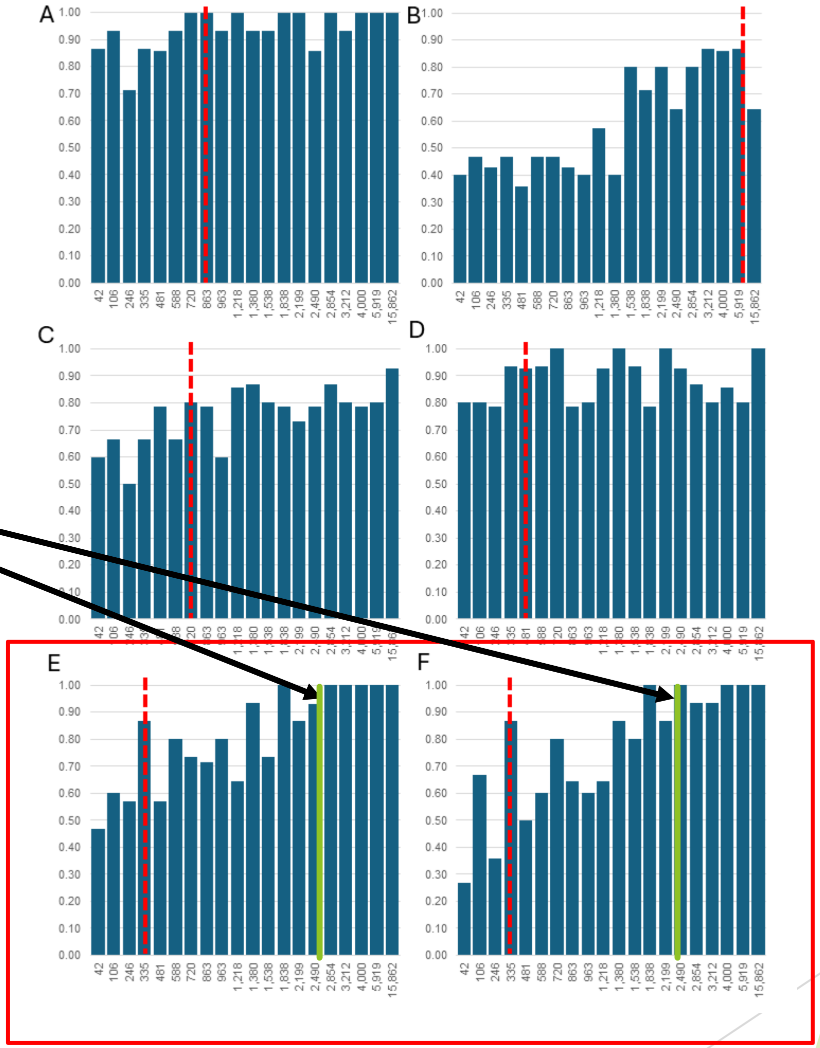
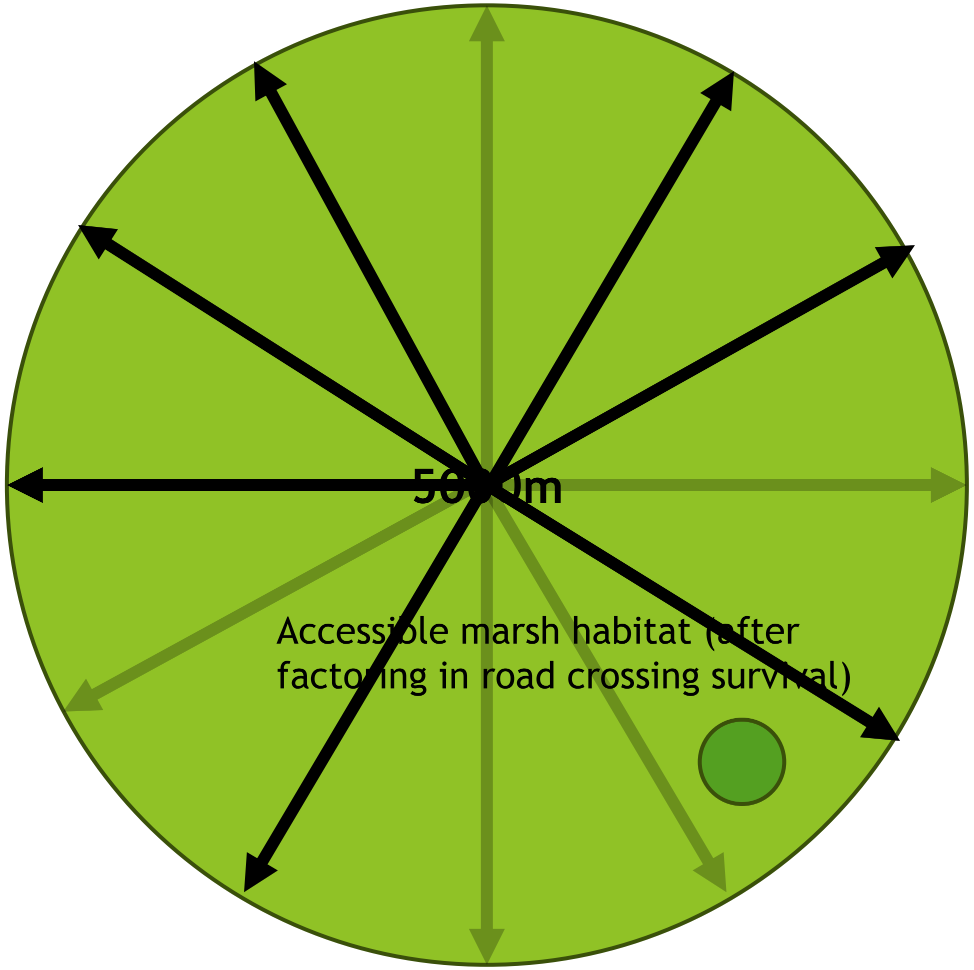


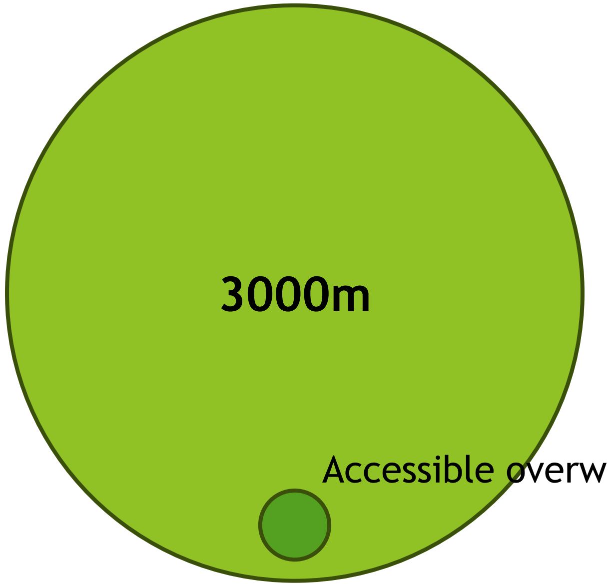
Ecological Threshold Visualizations

Spring Peeper

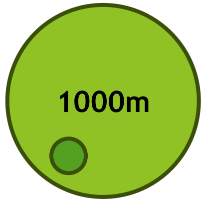


Accessible marsh habitat (after factoring in road crossing survival)

Number of directions with accessible marsh habitat



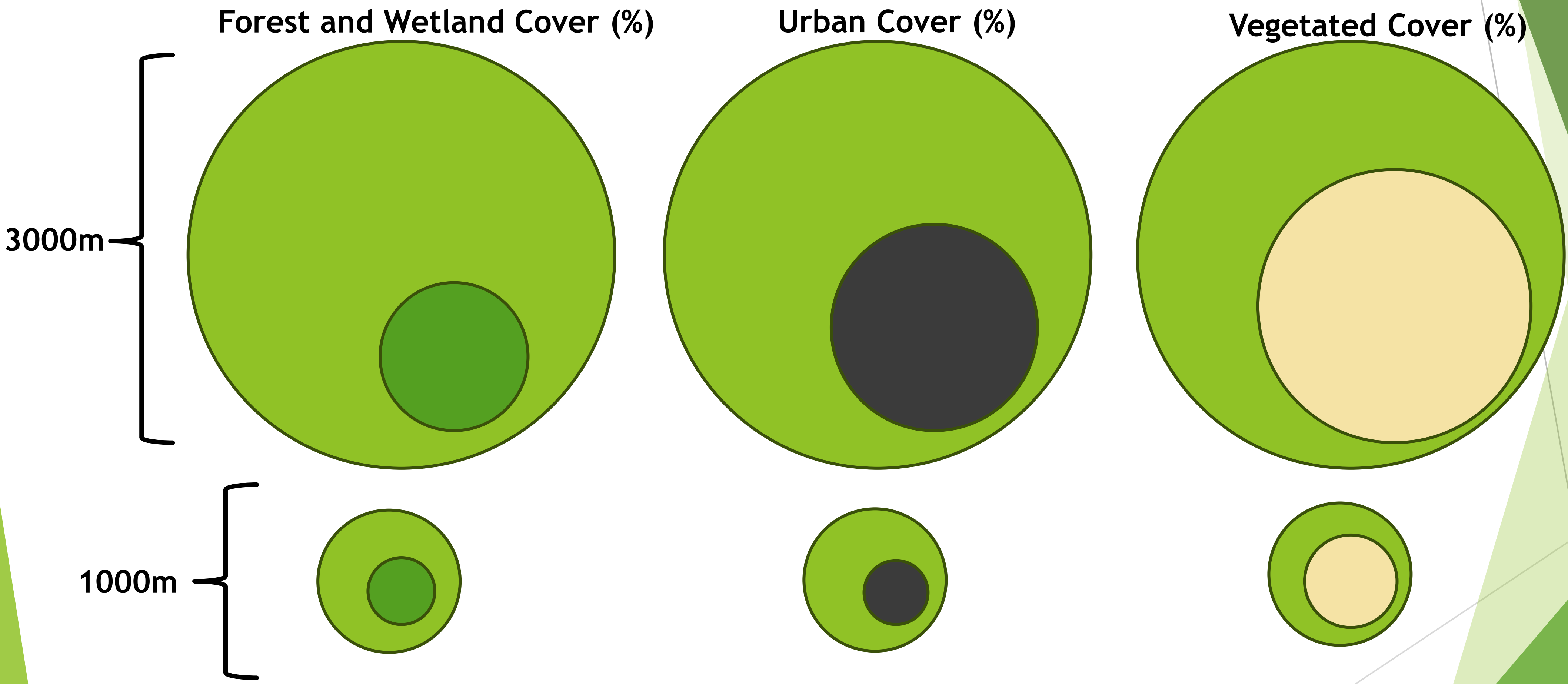
Accessible overwintering habitat



Accessible marsh habitat (after factoring in road crossing survival)

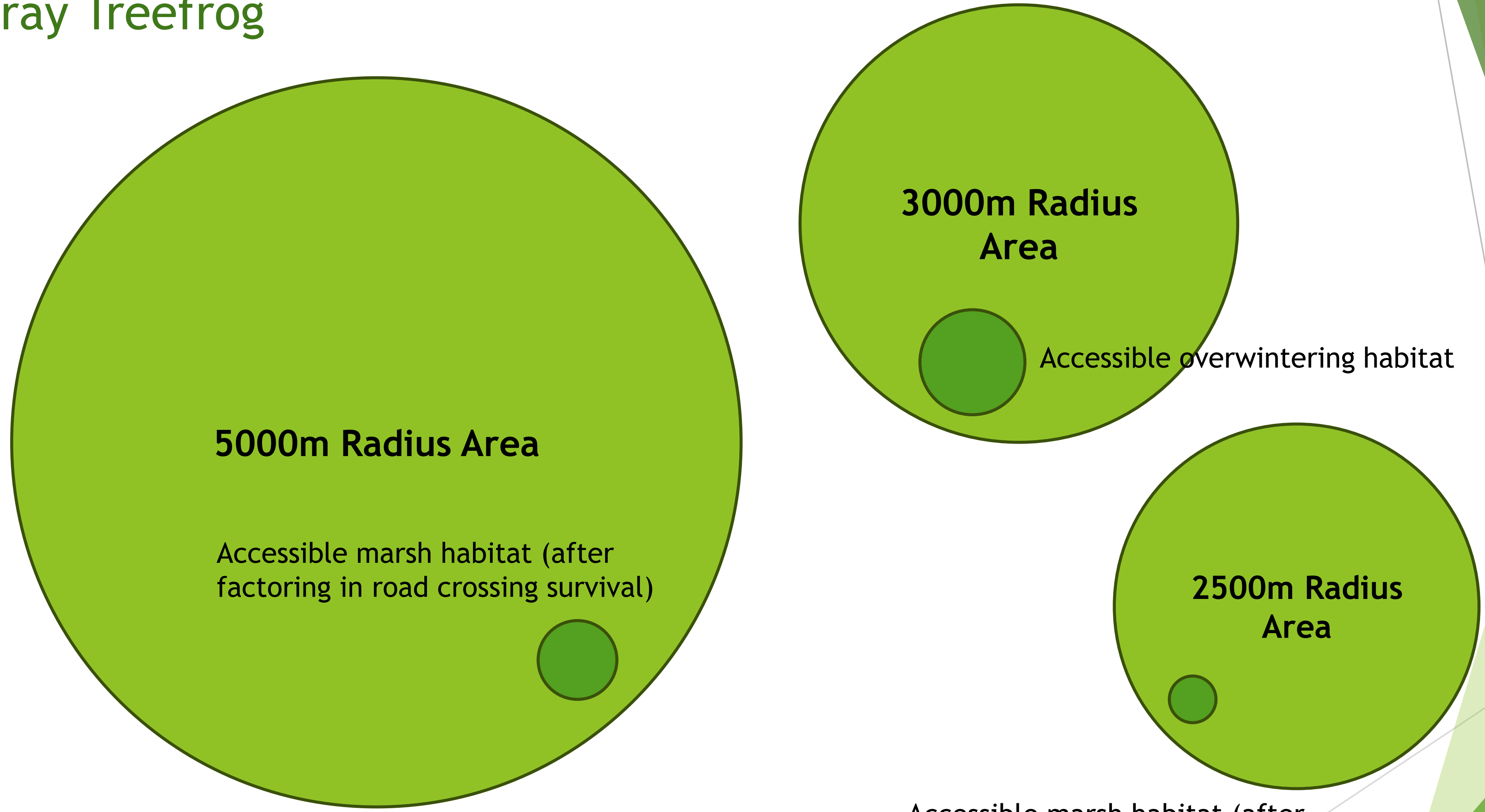
Ecological Threshold Visualizations

Spring Peeper



Ecological Threshold Visualizations

Gray Treefrog



5000m Radius Area

Accessible marsh habitat (after factoring in road crossing survival)

3000m Radius Area

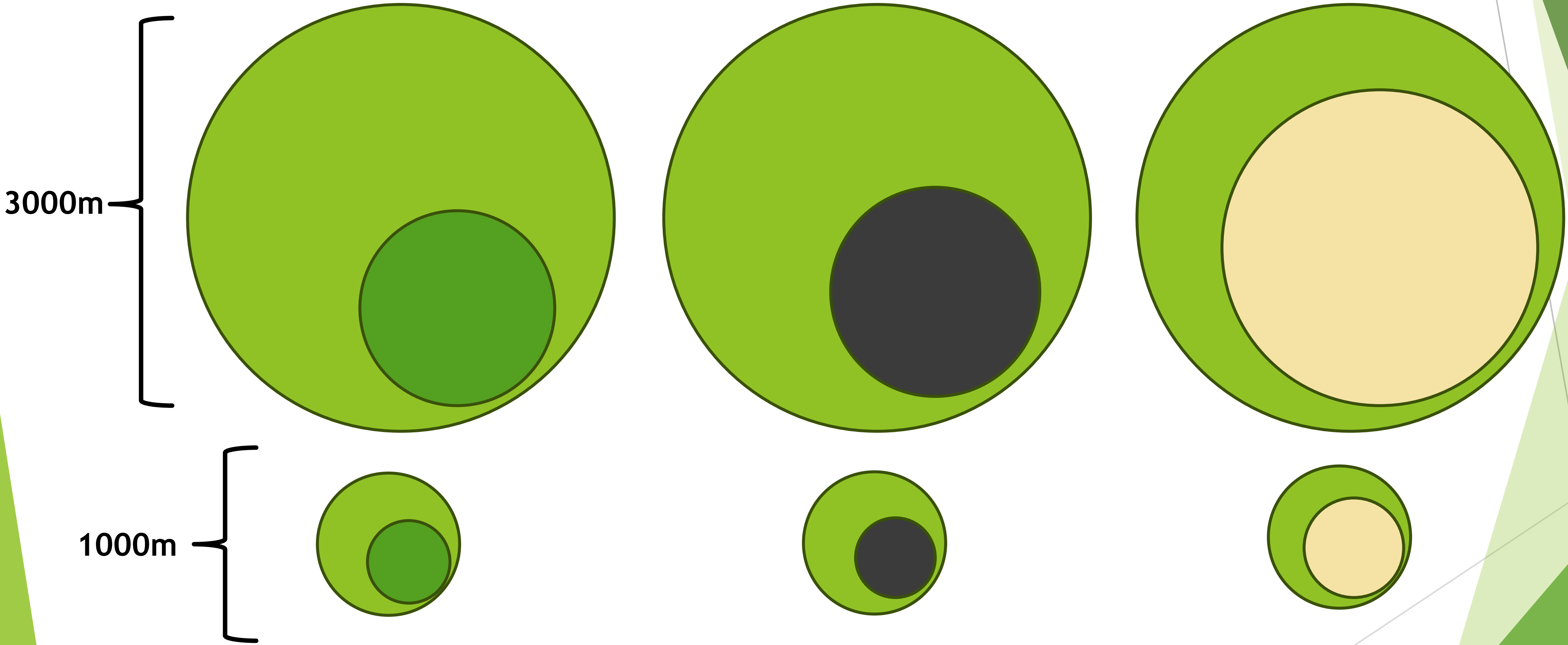
Accessible overwintering habitat

2500m Radius Area

Accessible marsh habitat (after factoring in road crossing survival)

Ecological Threshold Visualizations

Gray Treefrog



Forest and Wetland Cover (%)

Urban Cover (%)

Vegetated Cover (%)

3000m

1000m

Key Take-aways

Species-specific Effects

- Notably higher performance with the hylid species (spring peeper and gray treefrog) compared to the other four species

- Spring peepers have previously been identified as strong indicators of ecosystem health/biodiversity (Price et al., 2007)

- Design of some metrics may be less suitable for certain species
  - E.g. wood frogs prefer ephemeral ponds (Porej et al., 2004; Coster et al., 2014)

  - E.g. American toads are generalists (Lehtinen et al., 1999; Houlahan and Findlay, 2003; Rubbo and Kiesecker, 2004)

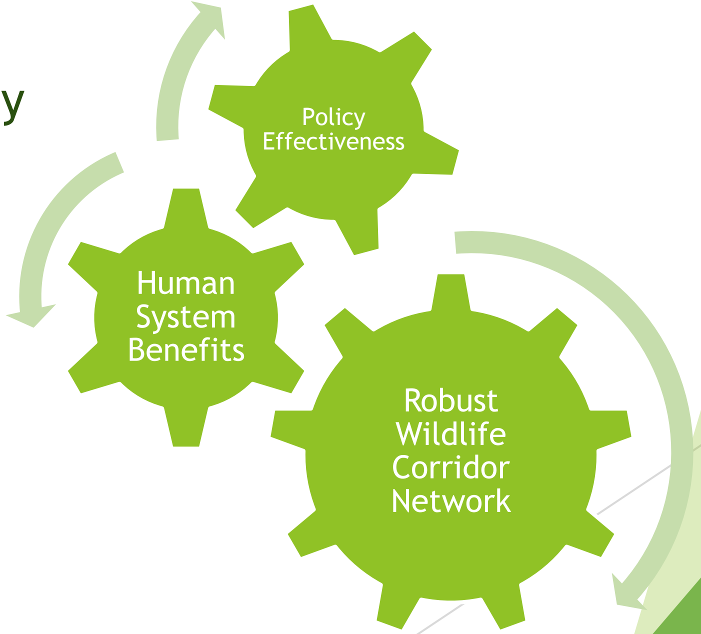
Key Take-aways

Improvements and Future Work

- **Dispersal connectivity metric:**
    - Add and test more “slices” for effect of added resolution
    - Increase resistance laterally from centre of wedge to simulate auto-correlated movement
    - Not just marsh, but swamp/ephemeral ponds too
- **Road crossing survival metric:**
    - Improve understanding of real-world survival rates when crossing roads
    - Reduce reliance on assumptions of traffic rates (use local rates)
    - Not just marsh, but swamp/ephemeral ponds too

Conclusions and Implications

- ❖ Opportunities for future connectivity modelling specific to anurans and other species groups with limited navigational competency (reptiles, snakes)
- ❖ Thresholds can help guide conservation planning for a robust and connected wildlife corridor network
- ❖ Associated benefits to human systems
  - ❖ Urban planning: density, transportation, livability
  - ❖ Health: recreation, air and water quality
  - ❖ Policy: pollutant control, GHG, biodiversity

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Thank you!

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