# Mapping Permeable Landscapes for a Changing Climate in the Eastern US

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The Nature Conservancy, Eastern Conservation Science

# Conservation in a Dynamic World

Species ranges are shifting

Natural communities are changing and reorganizing,

Disturbances are getting more extreme

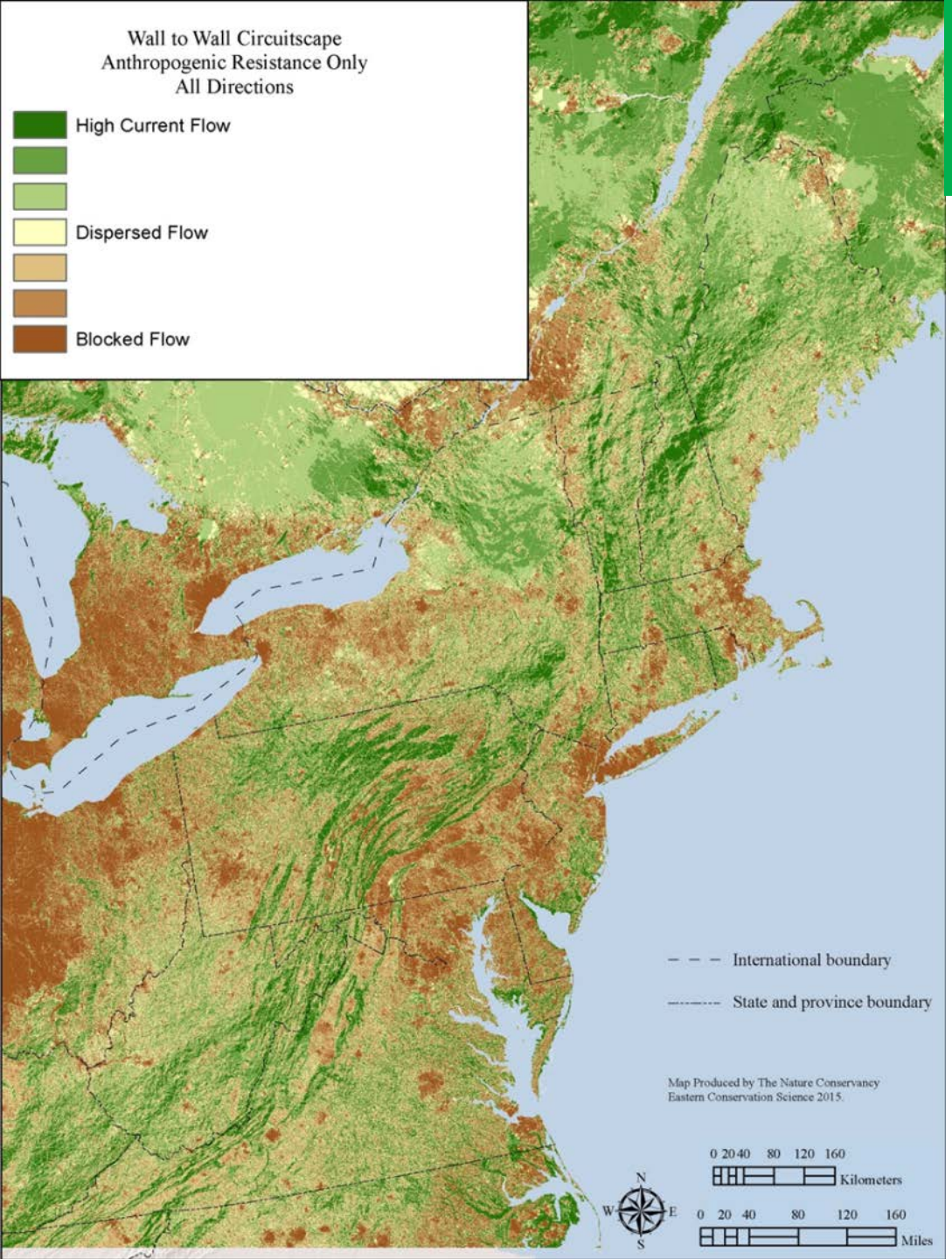
How do we ensure that the landscape remains permeable enough to support large scale rearrangement?

# Terrestrial Movements

Upslope and Northward Range Shifts

Riparian Climate Corridors

# Regional Permeability Wall to Wall Circuitscape:



**Improvements**

NLCD 2011

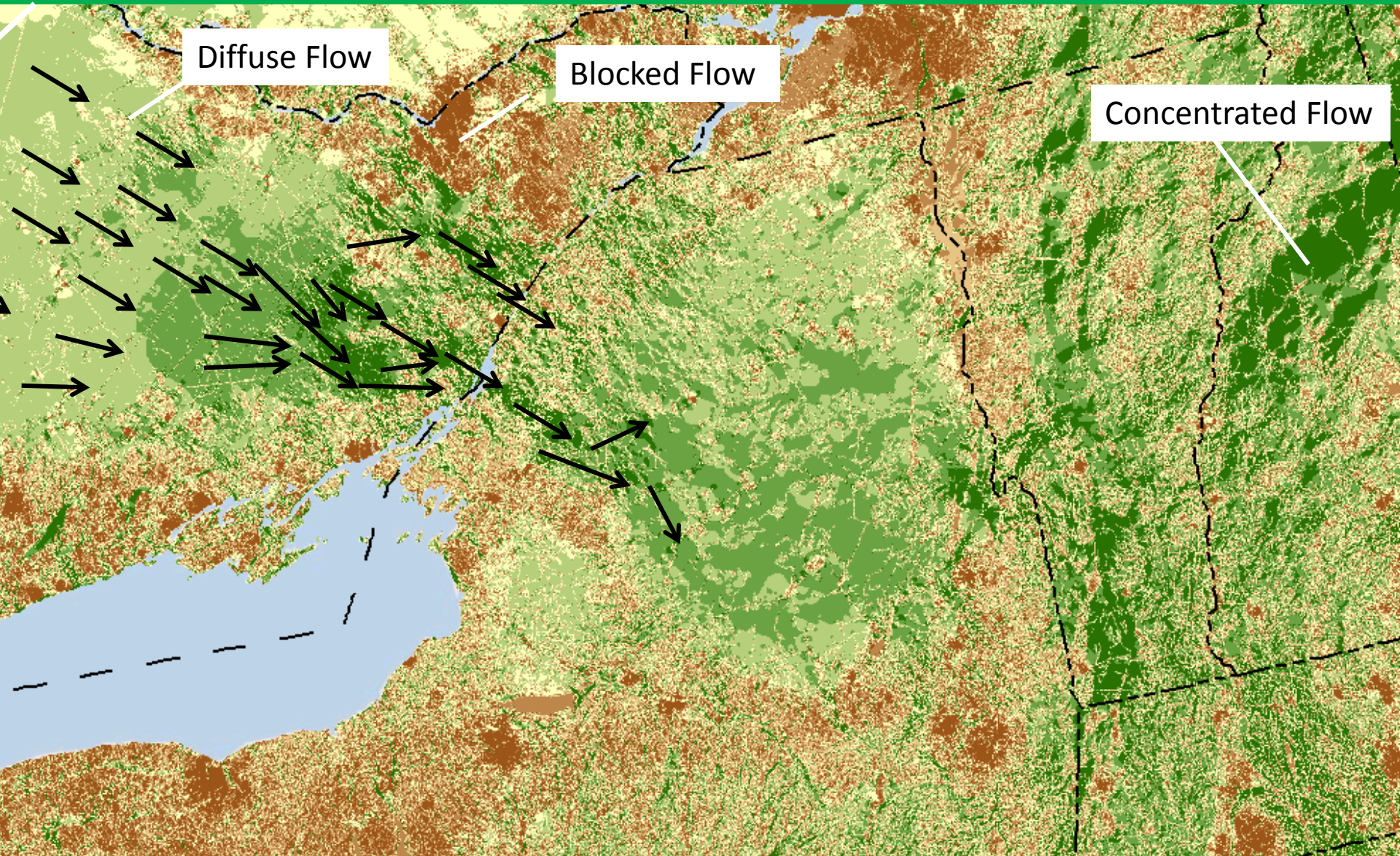
Tiger Roads

Waterbodies and barrens

Boundary/shoreline buffer

Tile assembly

# Wall to Wall Circuitscape: Anthropogenic Resistance



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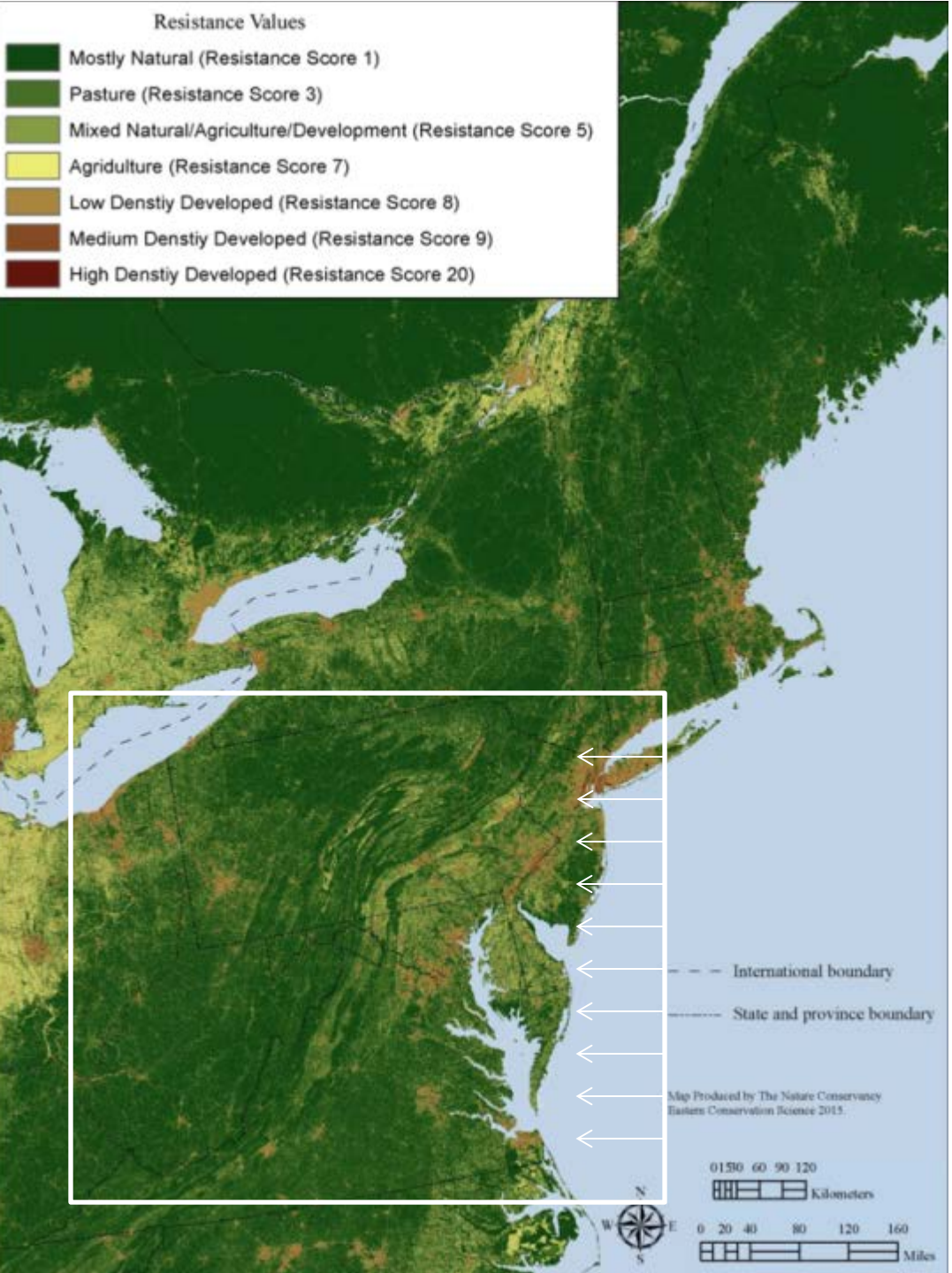


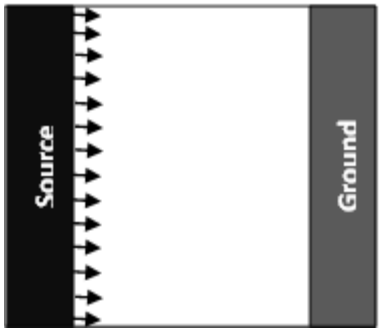


| Landcover description | Resistance | Source |
|---|---|---|
| Developed, Open Space | 8 | NLCD 2011 |
| Developed, Low intensity | 8 | NLCD 2011 |
| Developed, Medium Intensity | 9 | NLCD 2011 |
| Developed, High Intensity | 20 | NLCD 2011 |
| Barren Land, non-natural | 9 | NLCD 2011 |
| Barren Land, natural | 1 | NLCD 2011 |
| Deciduous Forest | 1 | NLCD 2011 |
| Evergreen Forest | 1 | NLCD 2011 |
| Mixed Forest | 1 | NLCD 2011 |
| Shrub/Scrub | 1 | NLCD 2011 |
| Herbaceous | 1 | NLCD 2011 |
| Hay/Pasture | 3 | NLCD 2011 |
| Cultivated Crops | 7 | NLCD 2011 |
| Woody Wetlands | 1 | NLCD 2011 |
| Emergent Herbaceous Wetlands | 1 | NLCD 2011 |
| Open Water, Shoreline Distance <200 m | 1 | NLCD 2011 |
| Open Water, Shoreline Distance 200-400m | 3 | NLCD 2011 |
| Open Water, Shoreline Distance >400 meters | 5 | NLCD 2011 |
| Major Roads | 20 | Tiger 2014 |
| Minor Roads | 10 | Tiger 2014 |
| Transmission Lines | 9 | Ventex 2014 |
| Pipelines | 9 | Ventex 2014 |
| Railroads | 9 | ESRI 2009 |
| Unpaved Roads /Tracks | 1 point added to the above score | OpenStreet Map 2014 |

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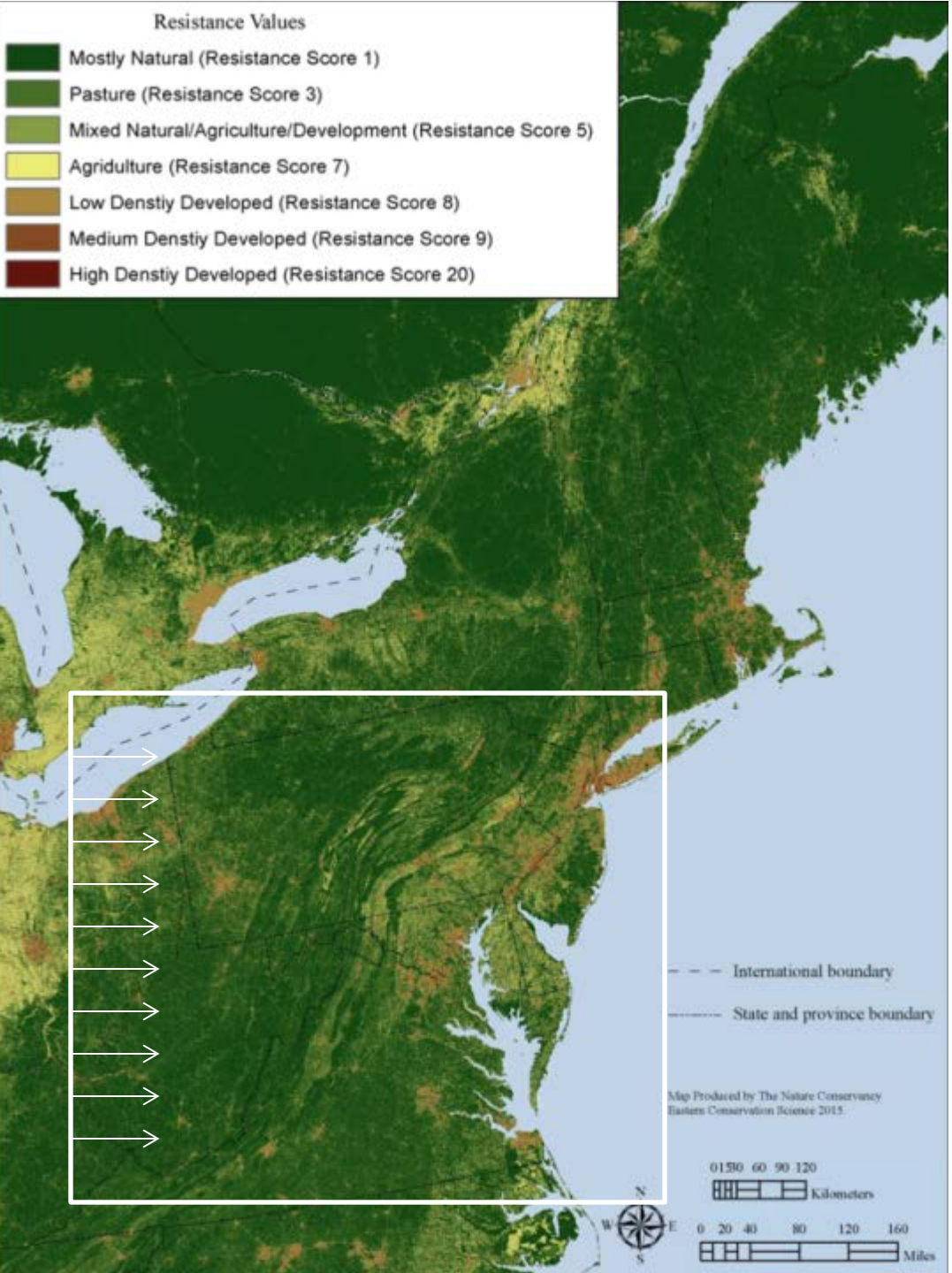


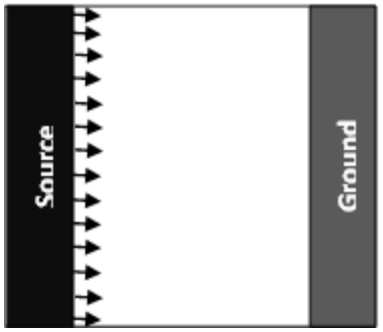


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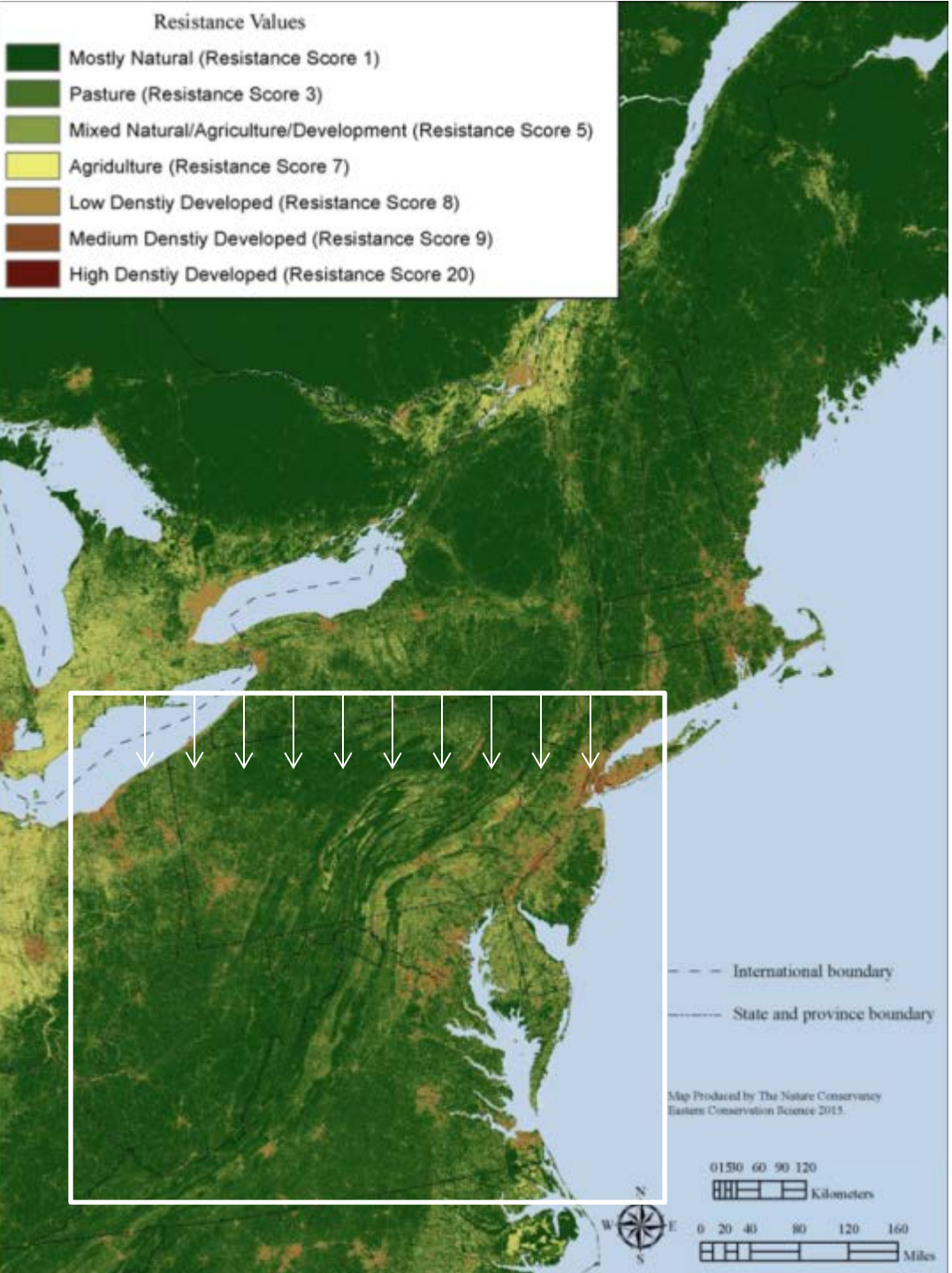


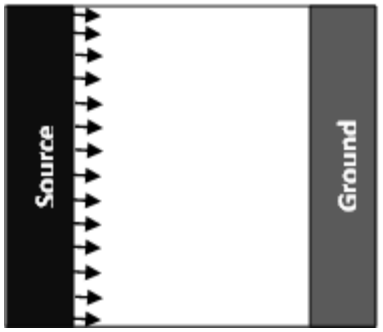


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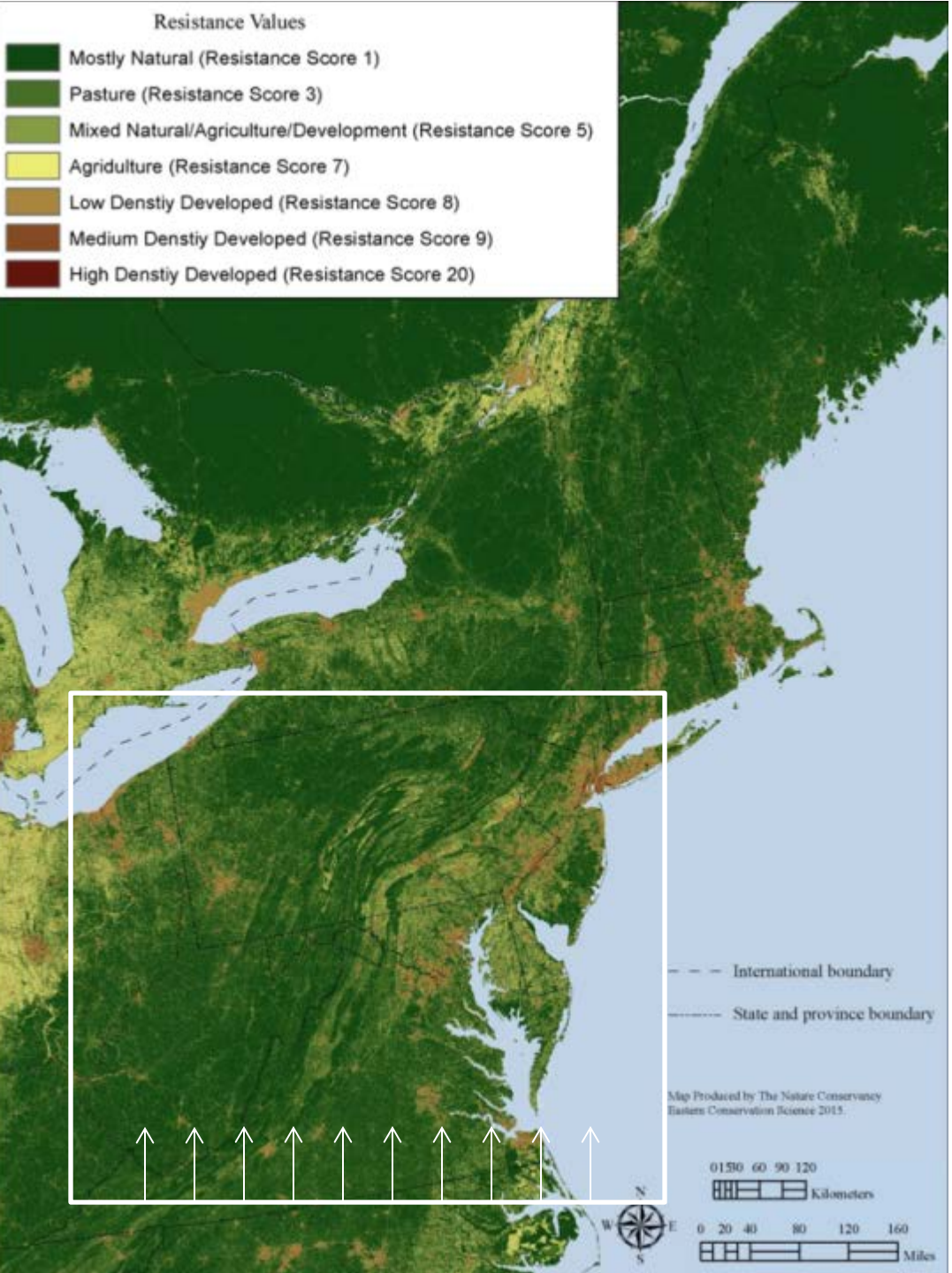


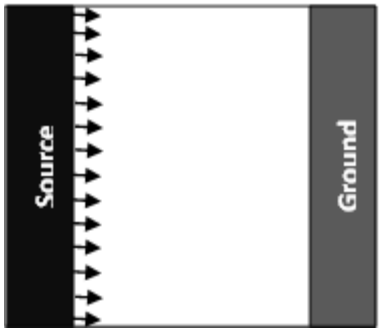


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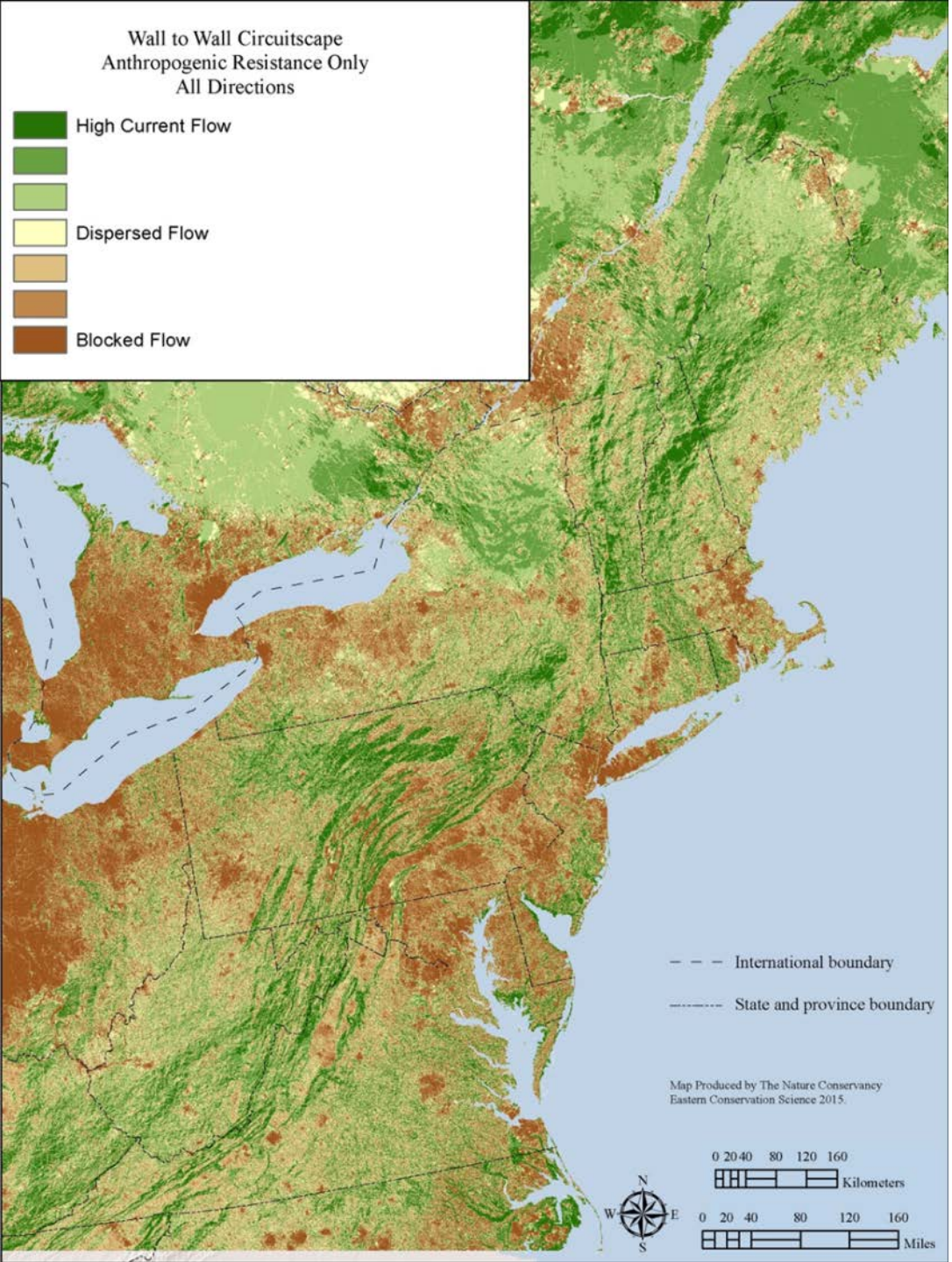



Determine the tile size that best suits your computing resources. This is subject to several interrelated factors: tolerance for seams (Appendix S1), the number of available processors, and per-processor memory (Appendix S3).

↓

Crop the map into square tiles of the determined size. For each tile, add a buffer of the determined size. Fill the buffer with the underlying land-cover data where available. At edges of the study area where there is no available land cover data to use, fill with pixels of values drawn randomly from the resistance map.

↓

For the north-south directional run, place a 1-pixel wide input/output region along the northern edge and another along the southern edge. For the east-west directional run, place 1-pixel wide input/output region along the eastern and western edges.

↓

Run these calculation areas through Circuitscape, in pairwise mode.

↓

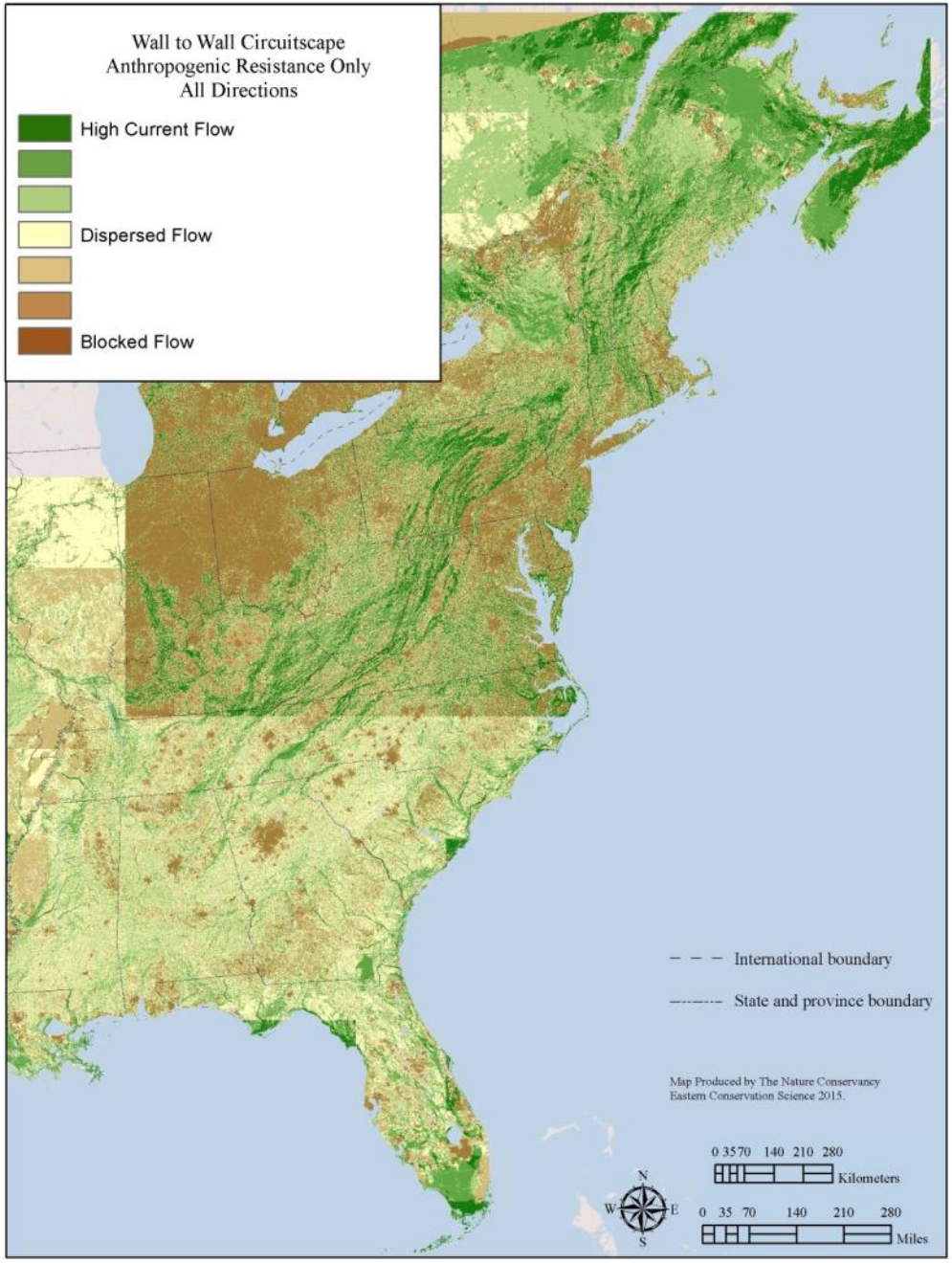
Crop the buffer from around the processed tiles.

↓

Create the mosaic by assembling tiles in their original position.

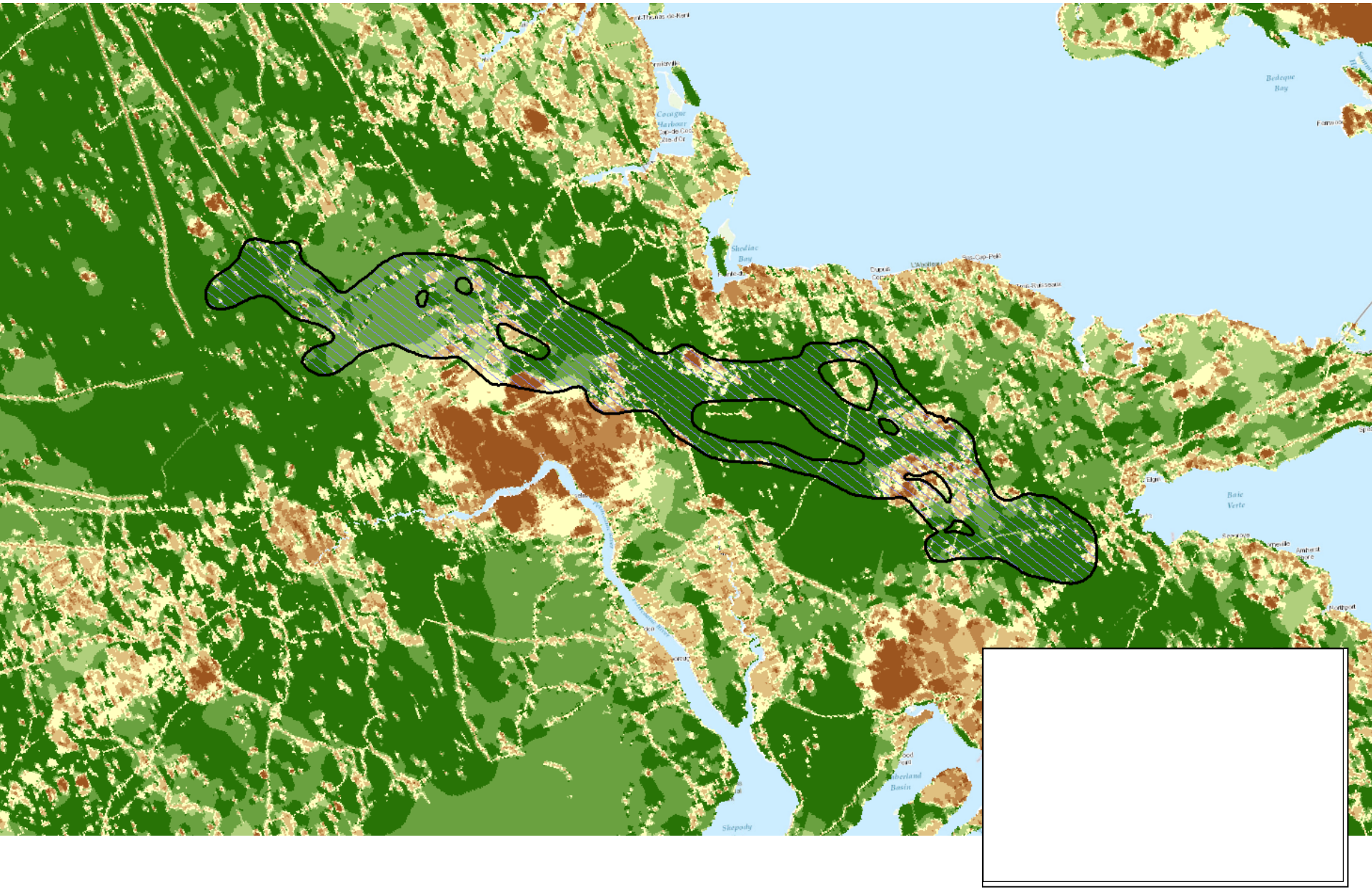
For more detailed methods see:

Pelletier, D., Clark, M., Anderson, M. G., Rayfield, B., Wulder, M. A., & Cardille, J. A. (2014). Applying circuit theory for corridor expansion and management at regional scales: tiling, pinch points, and omnidirectional connectivity. *PloS one*, *9*(1), e84135.

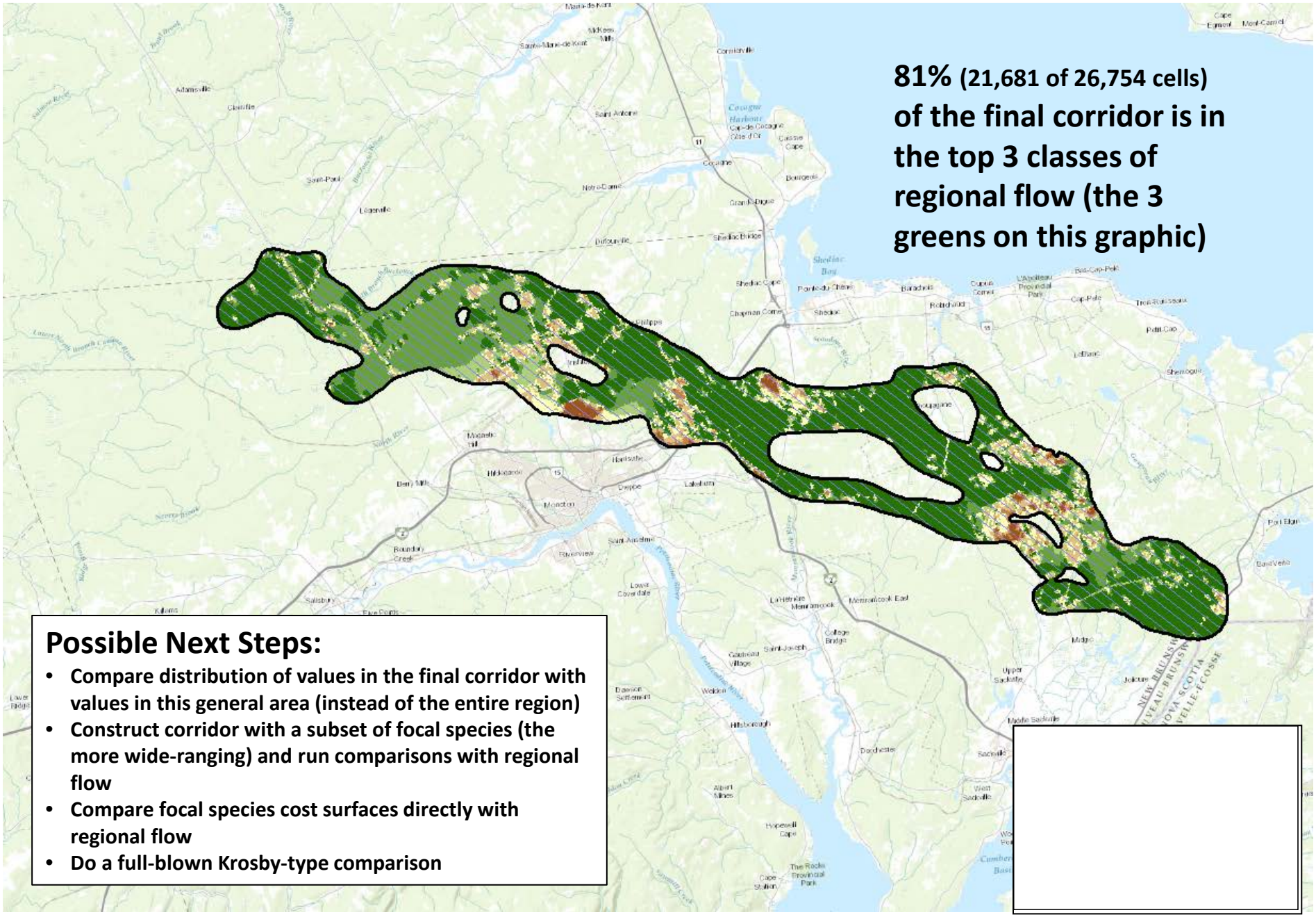

Wall to Wall Circuitscape
Anthropogenic Resistance Only
All Directions
High Current Flow
Dispersed Flow
Blocked Flow
International boundary
State and province boundary
Map Produced by The Nature Conservancy
Eastern Conservation Science 2015.
0 35 70 140 210 280
Kilometers
N
W
E
S
0 35 70 140 210 280
Miles

# Does the model work?

**Analysis results overlaid on Northeast Regional Flow results with final multi-species corridor in black outline with hatching**



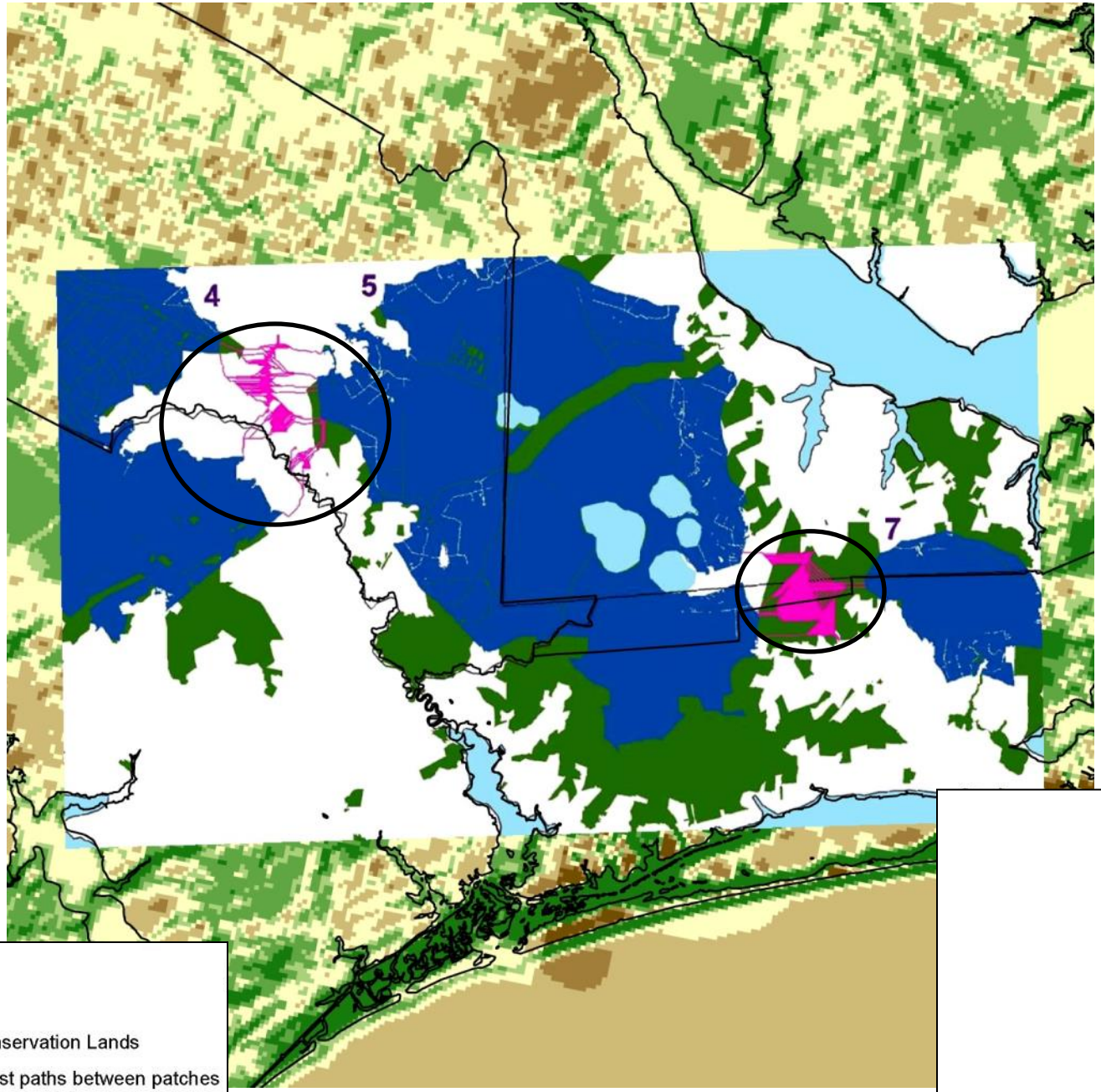
# Quick Quantitative Assessment – extract flow data for final result corridor



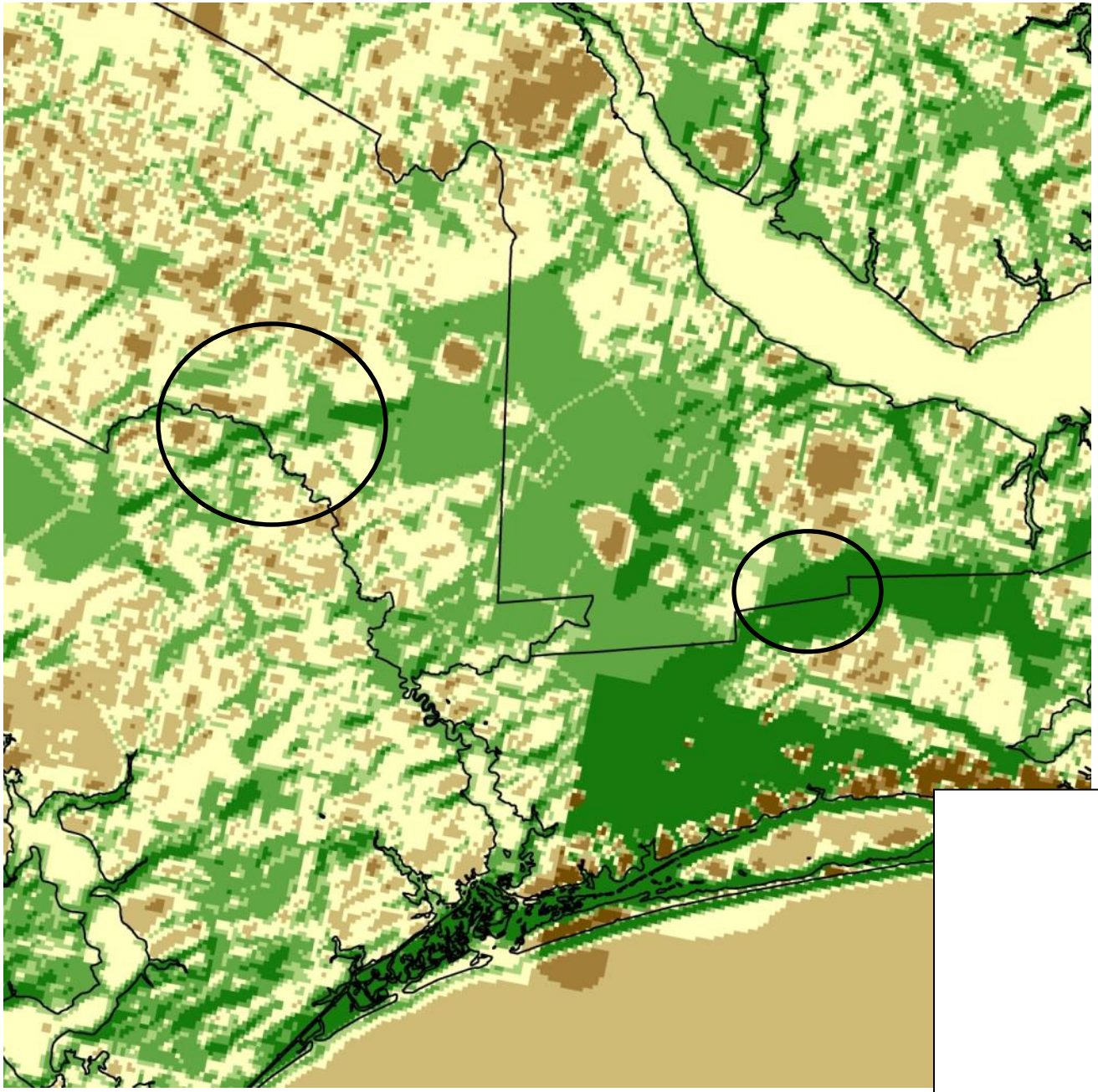

## Possible Next Steps:

- Compare distribution of values in the final corridor with values in this general area (instead of the entire region)
- Construct corridor with a subset of focal species (the more wide-ranging) and run comparisons with regional flow
- Compare focal species cost surfaces directly with regional flow
- Do a full-blown Krosby-type comparison

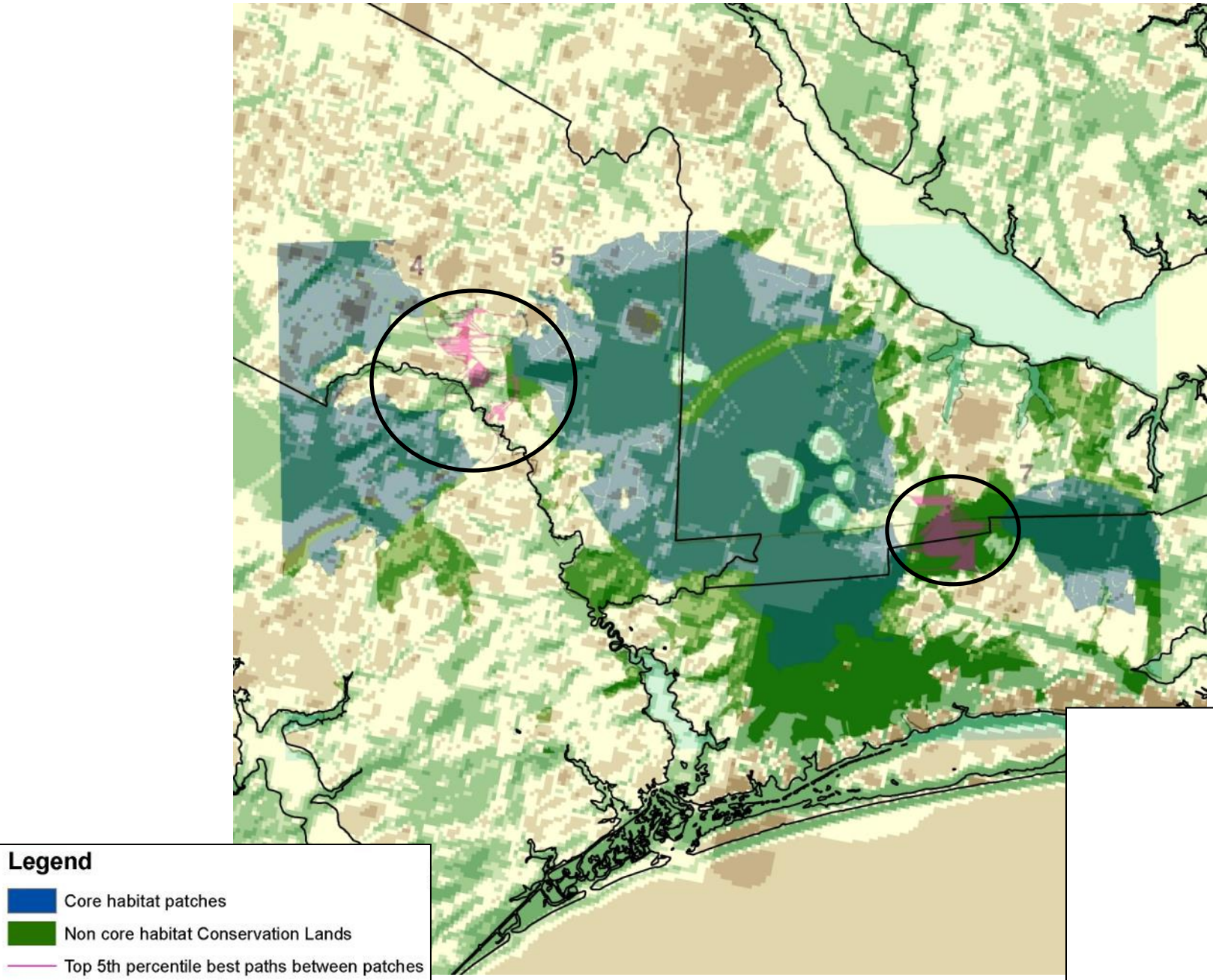
# Analysis results overlaid on SE Resilience Regional Flow results with key connectivity areas circled



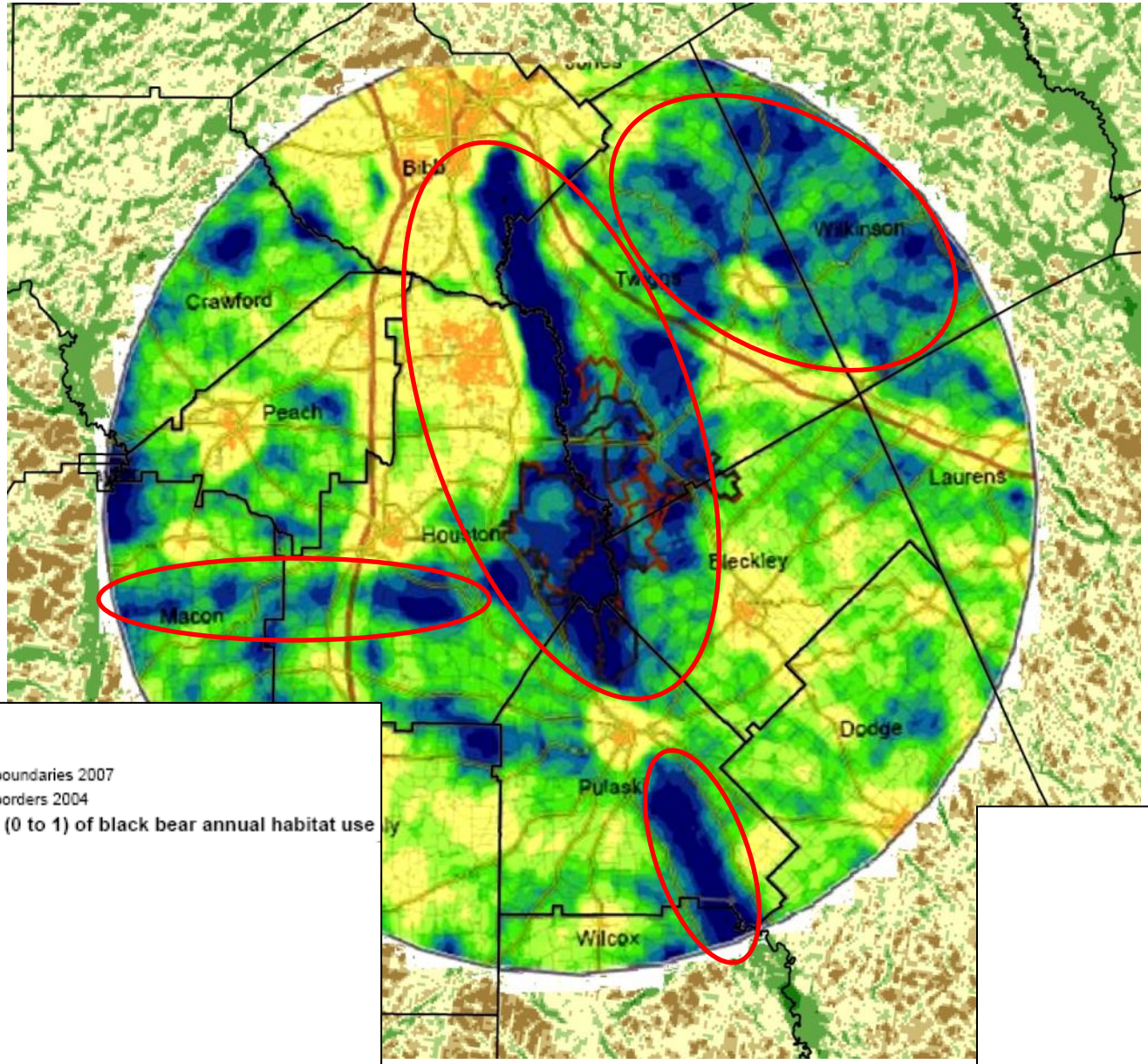
# SE Resilience Regional Flow results with key connectivity areas circled



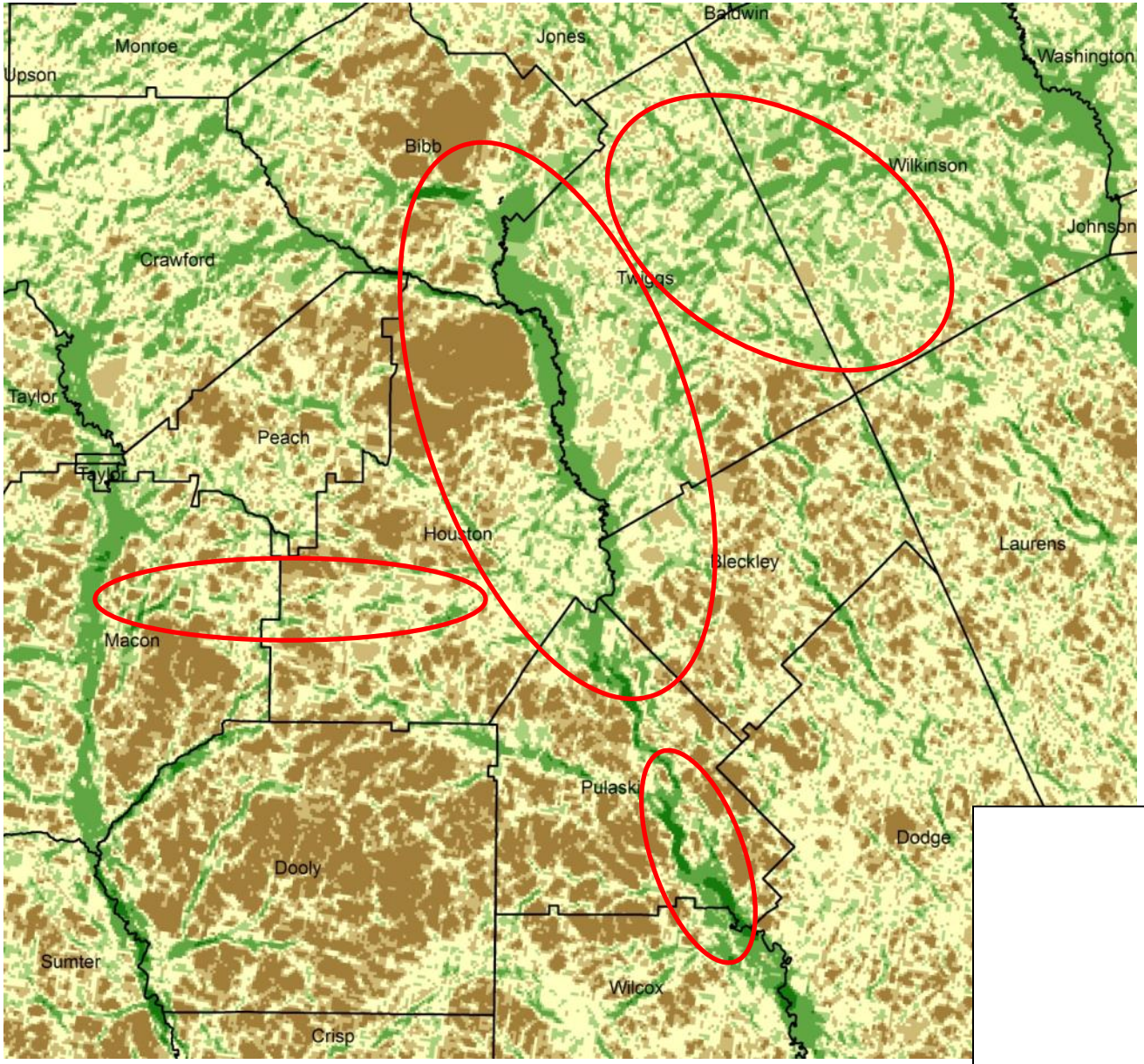
# SE Resilience Regional Flow results (40% transparency) overlaid on Shaffer results



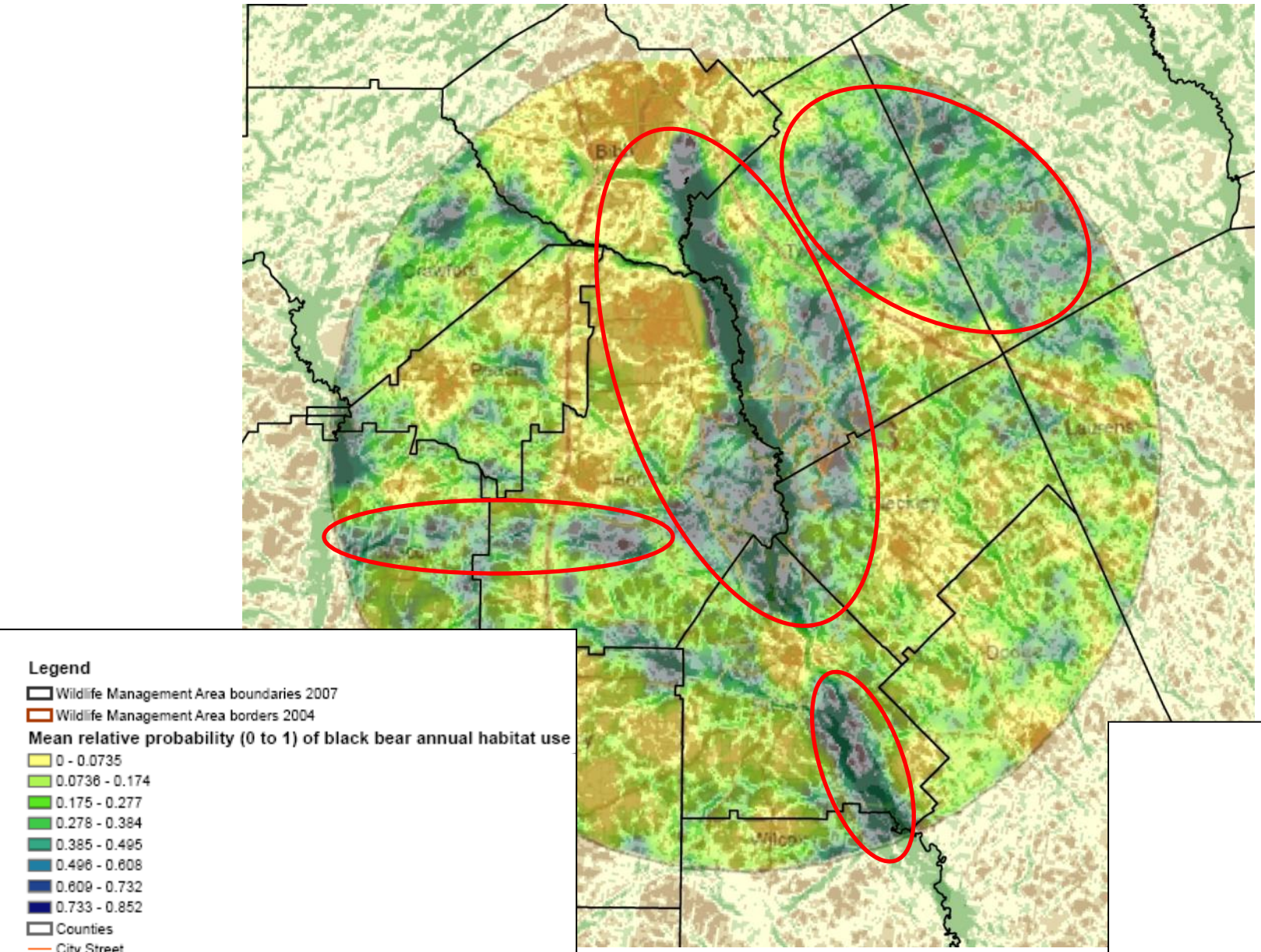
# Analysis results overlaid on SE Resilience Regional Flow results with key connectivity areas circled



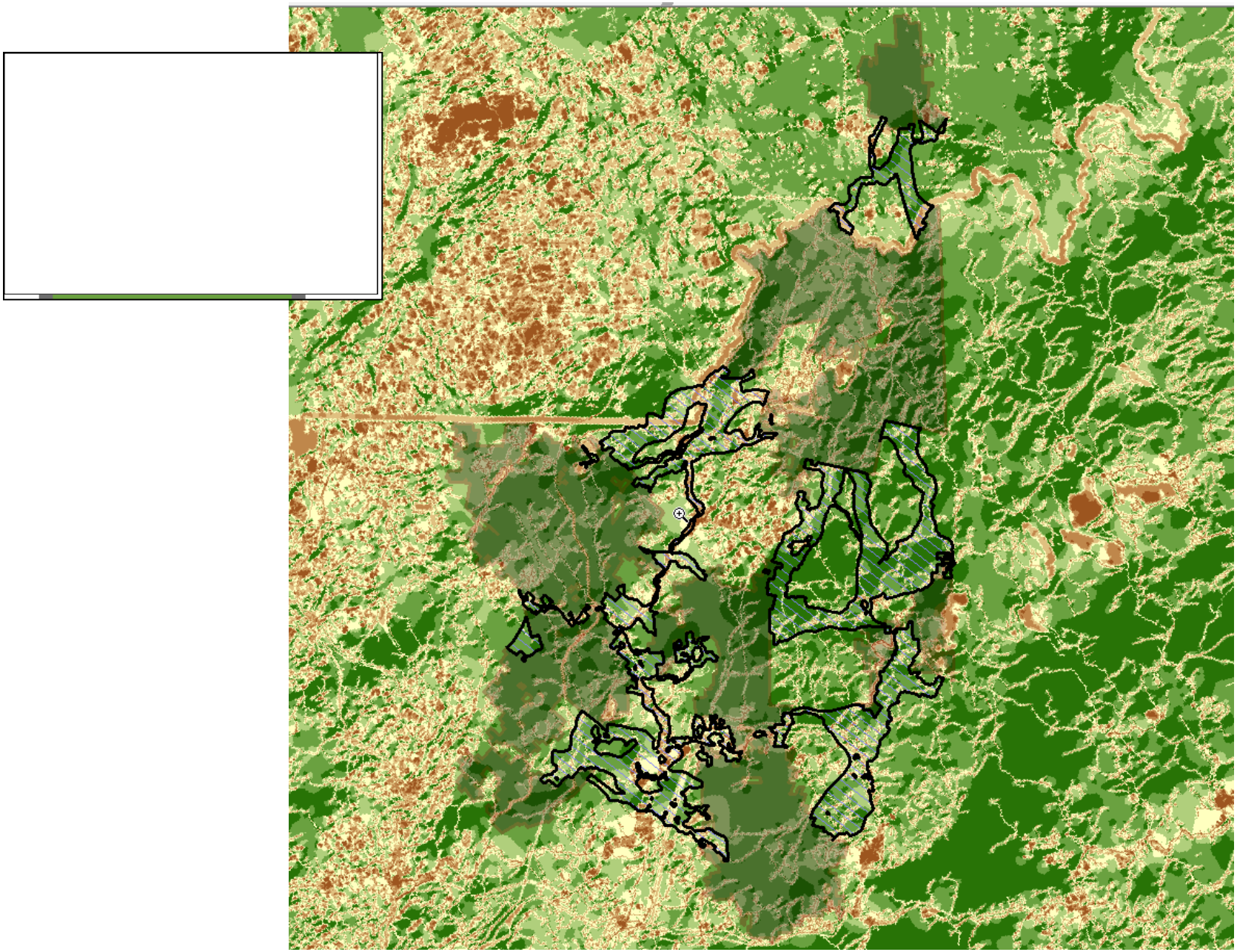
# SE Resilience Regional Flow results with key connectivity areas circled



# SE Resilience Regional Flow results (40% transparency) overlaid on Cook results

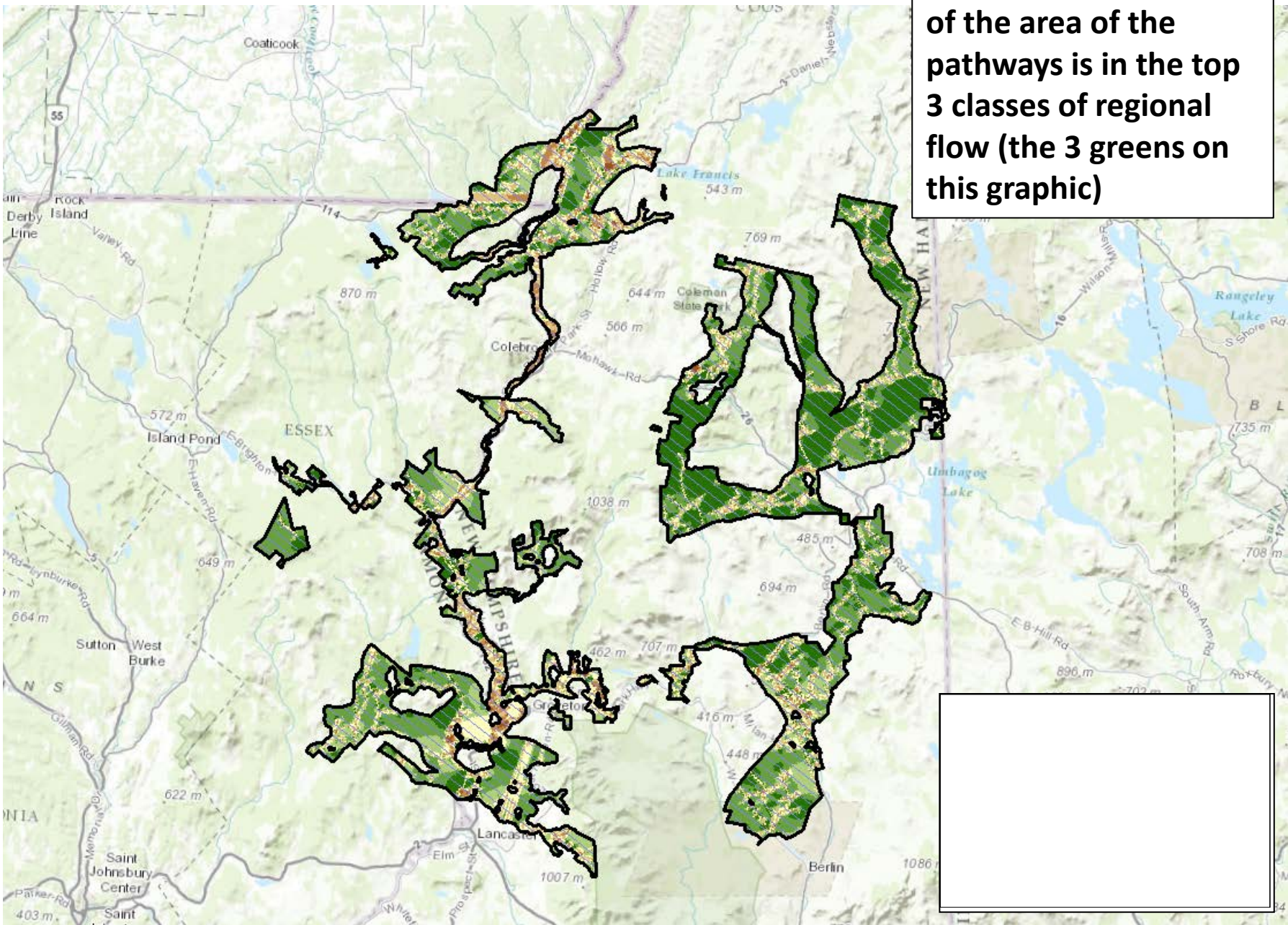


**Analysis results overlaid on Northeast Regional Flow results with final structural pathways in black outline with hatching – landscape conservation areas (places being connected) are in grey wash**



# Quick Quantitative Assessment – extract flow data for structural pathways

**70% (30,364 of 43,715 cells) of the area of the pathways is in the top 3 classes of regional flow (the 3 greens on this graphic)**



Regional Flow Qualitative Assessment Summary*

70% of study sites had Good Agreement - 30% of study sites had Moderate Agreement

| Study | Good | Moderate | Poor | Notes |
|---|---|---|---|---|
| Shaffer Red Wolf (NC) | X | | | |
| Cook Black Bears Site 1 (GA) | X | | | |
| Cook Black Bears Site 2 (GA) | X | | | |
| Guthrie Black Bears Site 1 (FL) | X | | | |
| Guthrie Black Bears Site 2 (FL) | X | | | |
| Guthrie Black Bears Site 3 (FL) | X | | | |
| Manen Black Bears Site 1 (NC) | | X | | 1992 LULC |
| Manen Black Bears Site 2 | X | | | |
| Thatcher Florida Panther Site 1 (FL) | X | | | |
| Dixon Black Bears Site 1 (FL) | | X | | |
| Dixon Black Bears Site 2 (FL) | X | | | |
| Jones Black Bears (NC) | X | | | |
| Breckheimer Habitat Connectivity (NC) | | X | | |
| Simon RCW (NC) | X | | | |
| Trainor RCW (NC) | X | | | |
| Gruber Swallow Tailed Kites (FL) | | X | | |
| Chignecto Isthmus (NB and NS) | X | | | |
| SCI – Northern Green Mountains (VT) | | X | | |
| SCI – NW Kingdom /North NH (VT and NH) | | X | | |

# Can Climate Change be incorporated into the Regional Permeability Model?

# Range Shifts: 51 studies, 1457 species

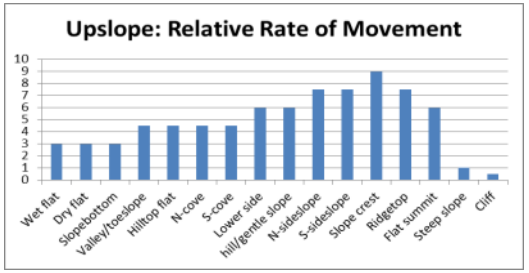
| **Elevational range shifts** | | | Adapted from Chen et al. 2011 | | | |
|---|---|---|---|---|---|---|
| **Taxon** | **# of Species** | **Duration (yrs)** | **Mean ORS** | **Min ORS** | **Max ORS** | **# Studies** |
| Invertebra | 554 | 20-42 yrs | 37.7 | 7.4 | 108.6 | 5 |
| fish | 15 | 25 yrs | 32.7 | 32.7 | 32.7 | 1 |
| herptiles | 30 | 10 yrs | 65.3 | 65.3 | 65.3 | 1 |
| birds | 326 | 11-25 yrs | -4.75 | -19.3 | 7.6 | 4 |
| mammals | 37 | 25-88 yrs | 50 | 31 | 69 | 2 |
| plants | 495 | 22-94 yrs | 62.4 | 21 | 89 | 7 |
| **Median shift 11 m uphill / decade, Mean Shift 12.2 m uphill /decade** | | | | | | 20 |
| **Latitudinal range shifts** | | | | | | |
| **Taxon** | **# of Species** | **Duration (yrs)** | **Mean ORS** | **Min ORS** | **Max ORS** | **# Studies** |
| Invertebra | 332 | 8-25 yrs | 59.1 | 7.9 | 104.2 | 3 |
| fish | 15 | 25 yrs | 47.2 | 47.2 | 47.2 | 1 |
| birds | 361 | 12-31 yrs | 24.2 | 3.6 | 46 | 4 |
| mammals | 9 | 25 yrs | 22.4 | 22.4 | 22.4 | 1 |
| algae | 37 | 50 yrs | 61.4 | 61.4 | 61.4 | 1 |
| **Median shift 16.9 km northward / decade, Mean Shift 17.6 km northward** | | | | | | 10 |

# Population movement

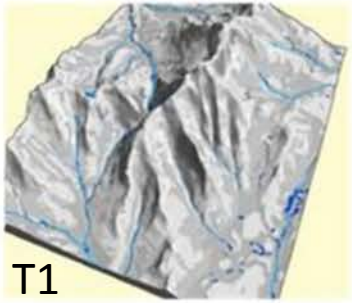
- upslope
  (11 m/decade)

- northward
  (17 km /decade)

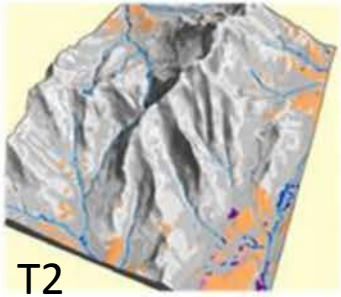
Gain is highest on sideslopes. Flats -are easy to move across but offer little climate gain Steep slopes are the reverse.



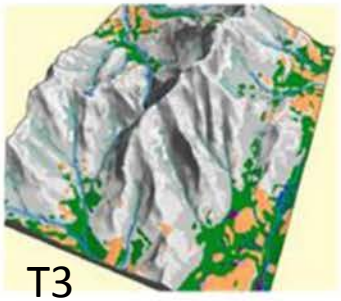

Streams & wetland



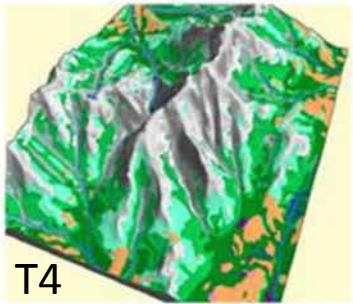

Flats & low hills



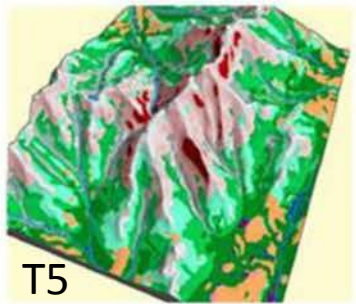

Coves and draws



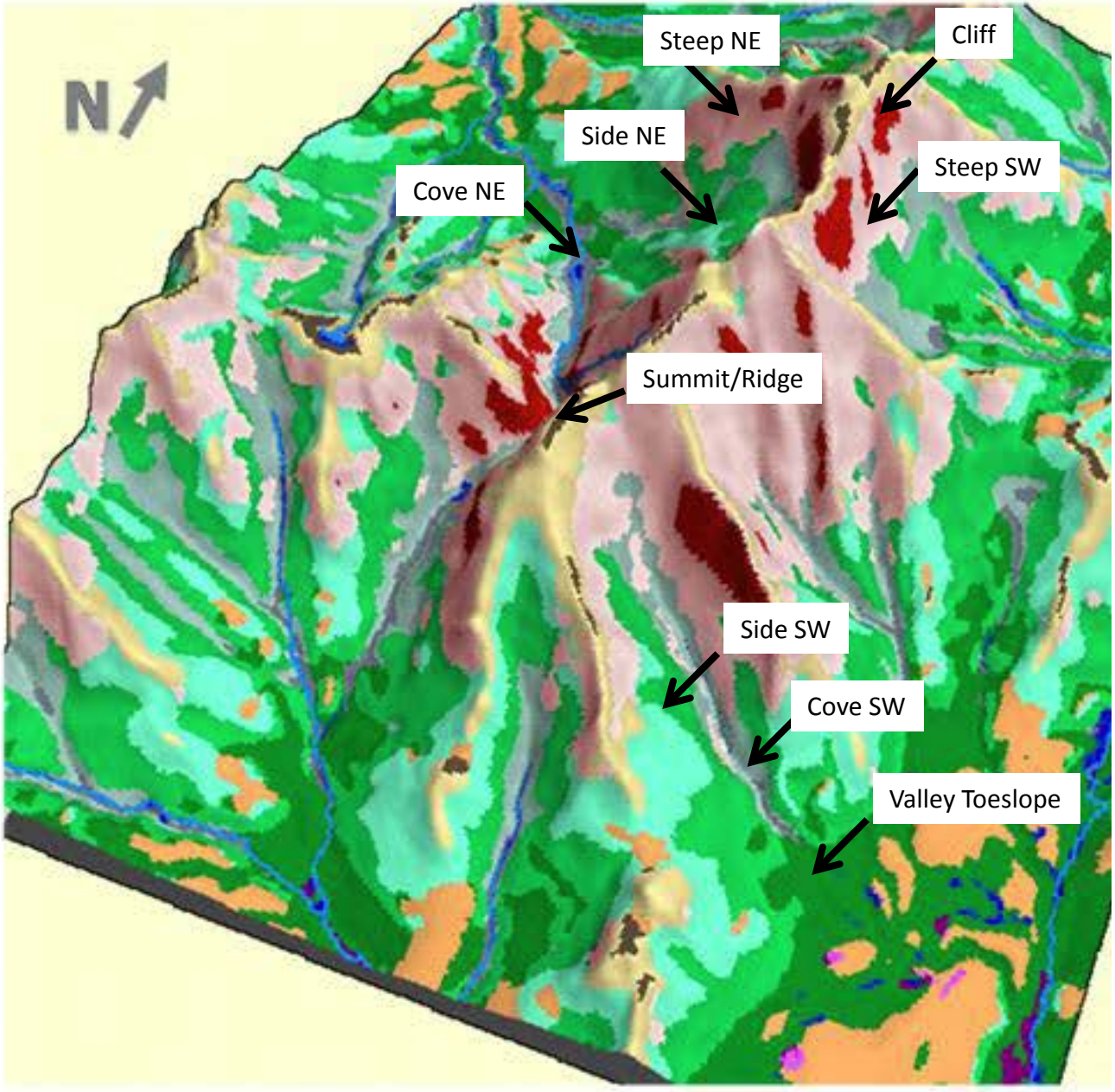

Side slopes




Cliff and steep slope



# SLOPING LANDFORMS




**Cliff**, Peregrine falcon, Golden eagle, Fragrant cliff fern, smooth cliff fern

**Steep slope SW:** timber rattlesnake, Allegheny woodrat, Purple Clematis

**Steep slope NE**: coal skink, rounded dogwood, american harebell, carolina saxifrage

**Sideslope SW:** Kate's Mt clover, shale barren rock cress, SB evening primrose copperhead, N spring salamander, E. rat snake

**Sideslope NE** : American ginseng, N and E small footed Myotis, goldies fern, green salamander. Allegheny vine. VA flying squirrel

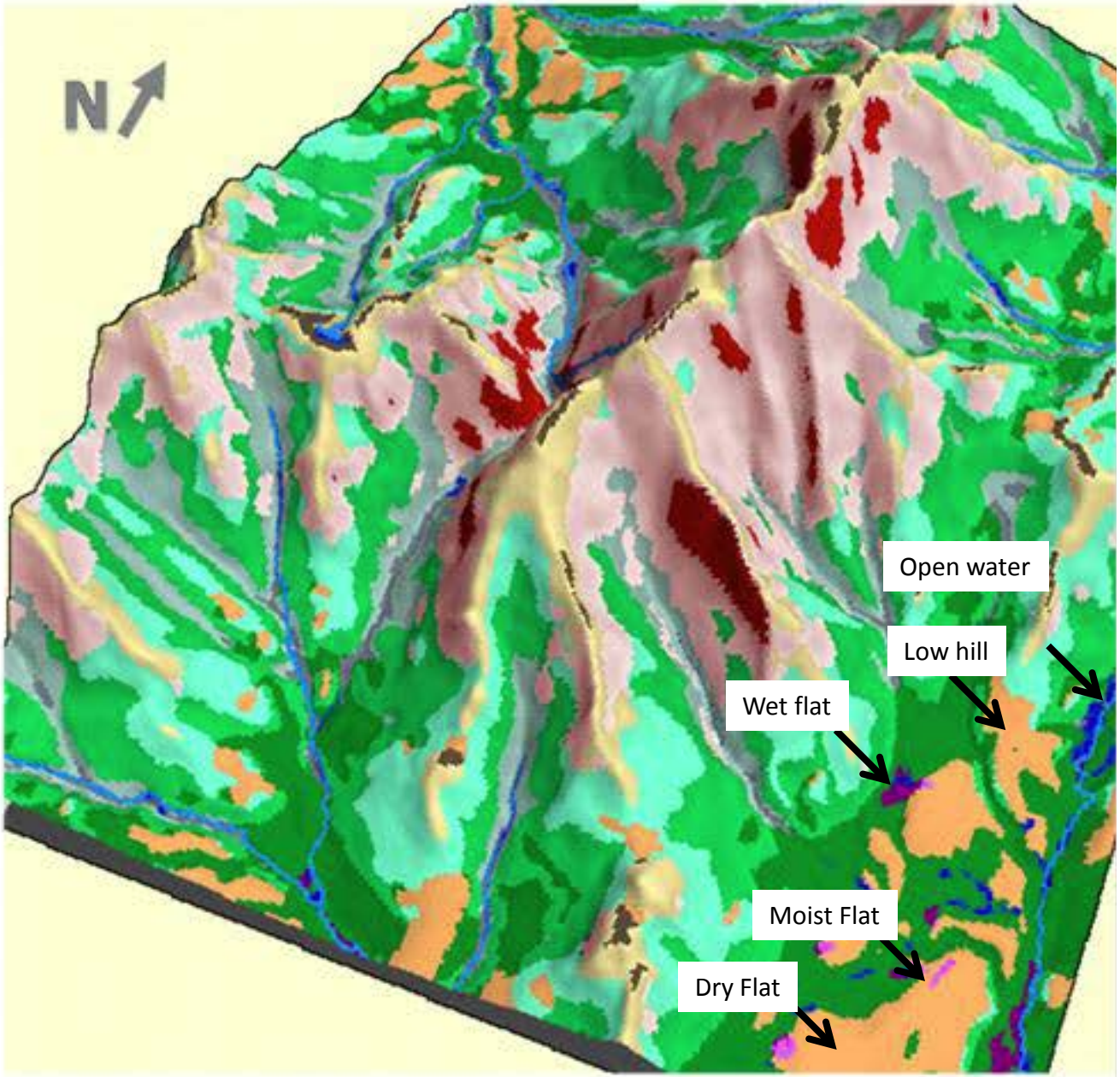
**Cove SW**: Blackbelly Salamander, Bristly Black Currant, Clasping Twisted-stalk, S rock vole, Loesel's Twayblade

**Cove NE:** Mountain Bugbane Long Beech-fern, Wild Hydrangea, Lesser Pyrola, longtailed salamander

**Summit/Slope crest**: Bicknells thrush, alpine blueberry, Bigelow sedge, Cheat mt salamander, Greater straw sedge

**Valley/Toeslope**: Small whorled pogonia, Marbled and Jefferson Salamander, Barbed-bristle Bulrush, Appalachian Blue Violet, Mitchell's Satyr

# FLAT LANDFORMS




**Low Hill (Flat)**, Northern Pinesnake, Grasshopper Sparrow, Whip-poor-will, Sandplain Gerardia, Nuttall's Milkwort

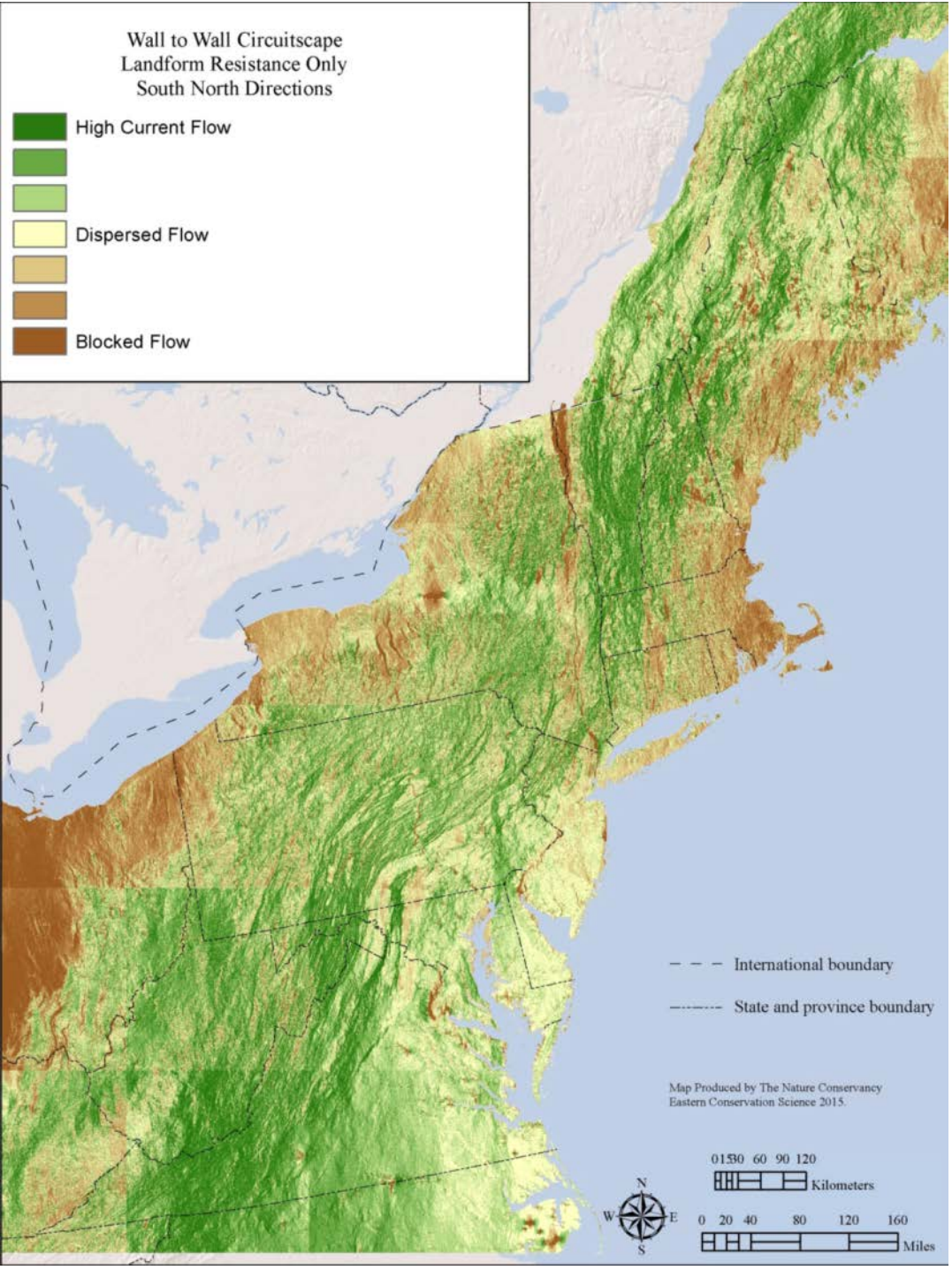
**Low hill (Gentle slope) :** Sand Violet, Broom Crowberry, Michaux's Sumac, Pale Corydalis, Beardgrass, Dickcissel

**Dry flat**: Red Milkweed, Slender Nutrush,Migrant Loggerhead Shrike, Woolly Chaffhead, Baltimore Checkerspot

**Moist Flat**t: E. Box Turtle, E. Silvery Aster, Eastern Spadefoot, Brown Thrasher, Northern Blazingstar, Tiger salamander

**Wet flat:** Wood Turtle, Spotted Turtle Blanding's Turtle, Pine Barrens Treefrog, Barred Owl, American bittern, Four-toed Salamander, Swamp pink, Arethusa, Bog turtle, Showy Lady's-slipper, Long's Bulrush, Asa Gray's Sedge

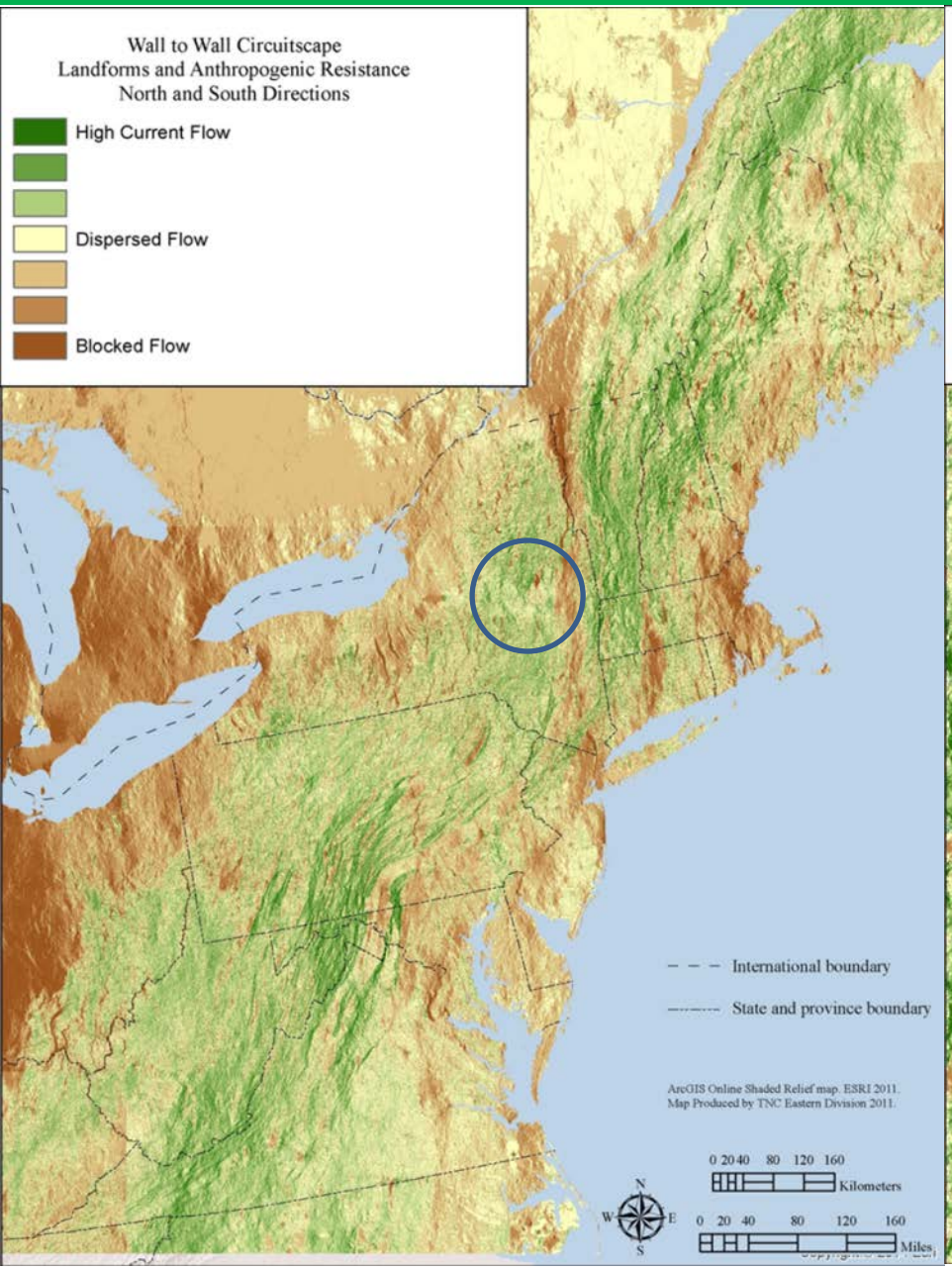
**Open Water / Shore** : Common Loon Yellow Lampmussel, Plymouth Gentian, Algae-like Pondweed, Eastern Pond Mussel, Tidewater Mucket, Quill-leaf Arrowhead

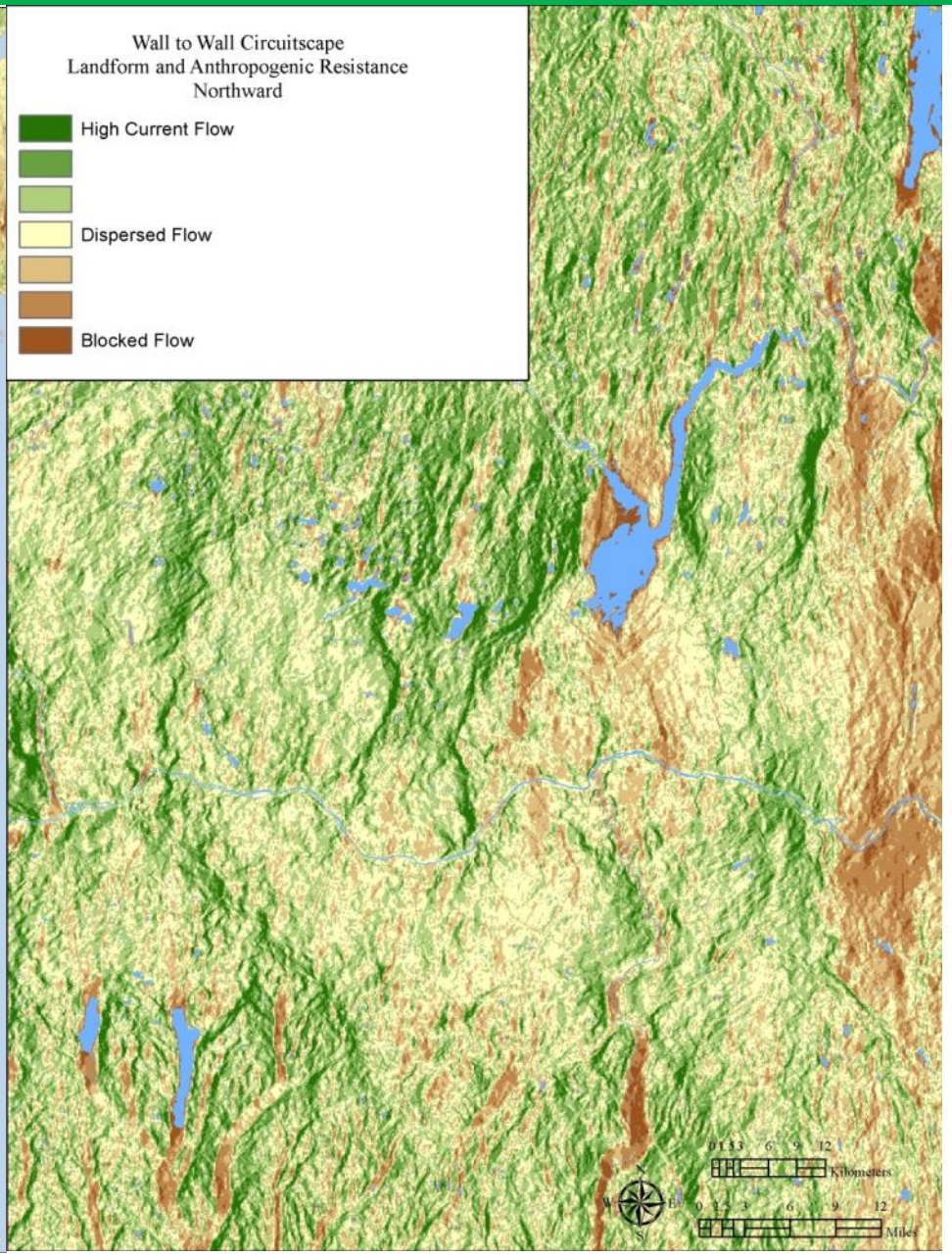



# Upslope & Northward Model

Current flows **Northward** through areas steep enough to provide temperature differences but not too steep to restrict movement.

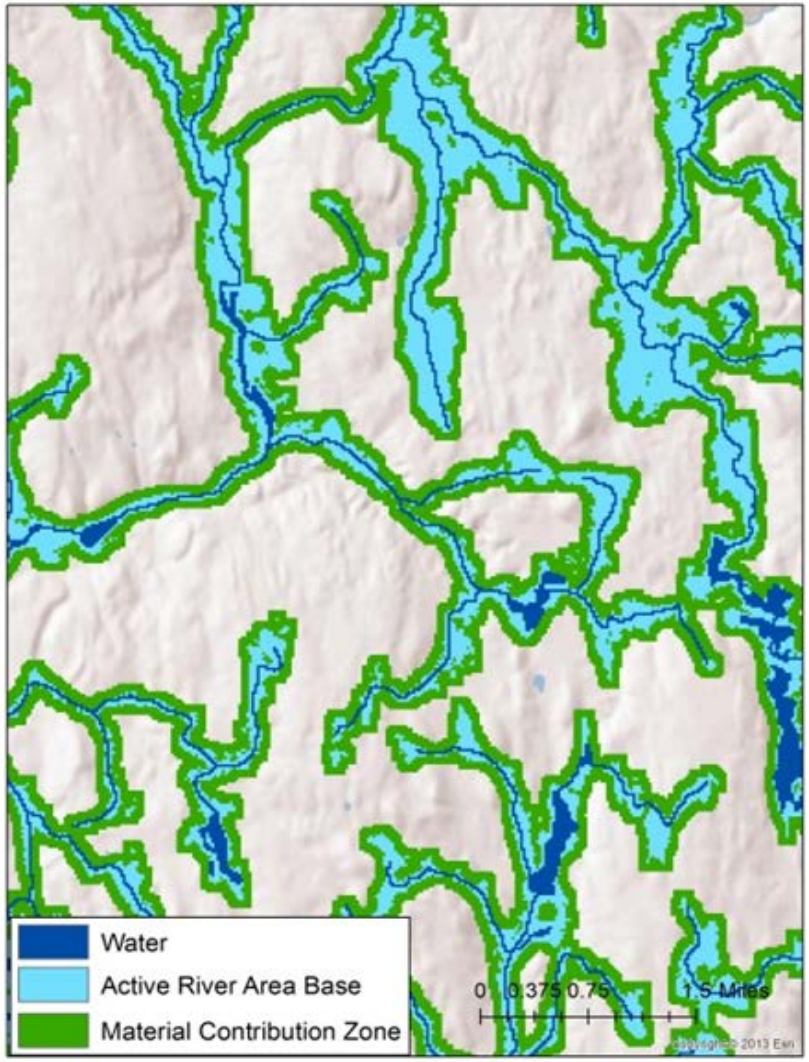
# Anthropogenic Resistance
# Upslope & Northward



# Riparian Climate Corridors

# Riparian Climate Corridors




**Riparian areas**

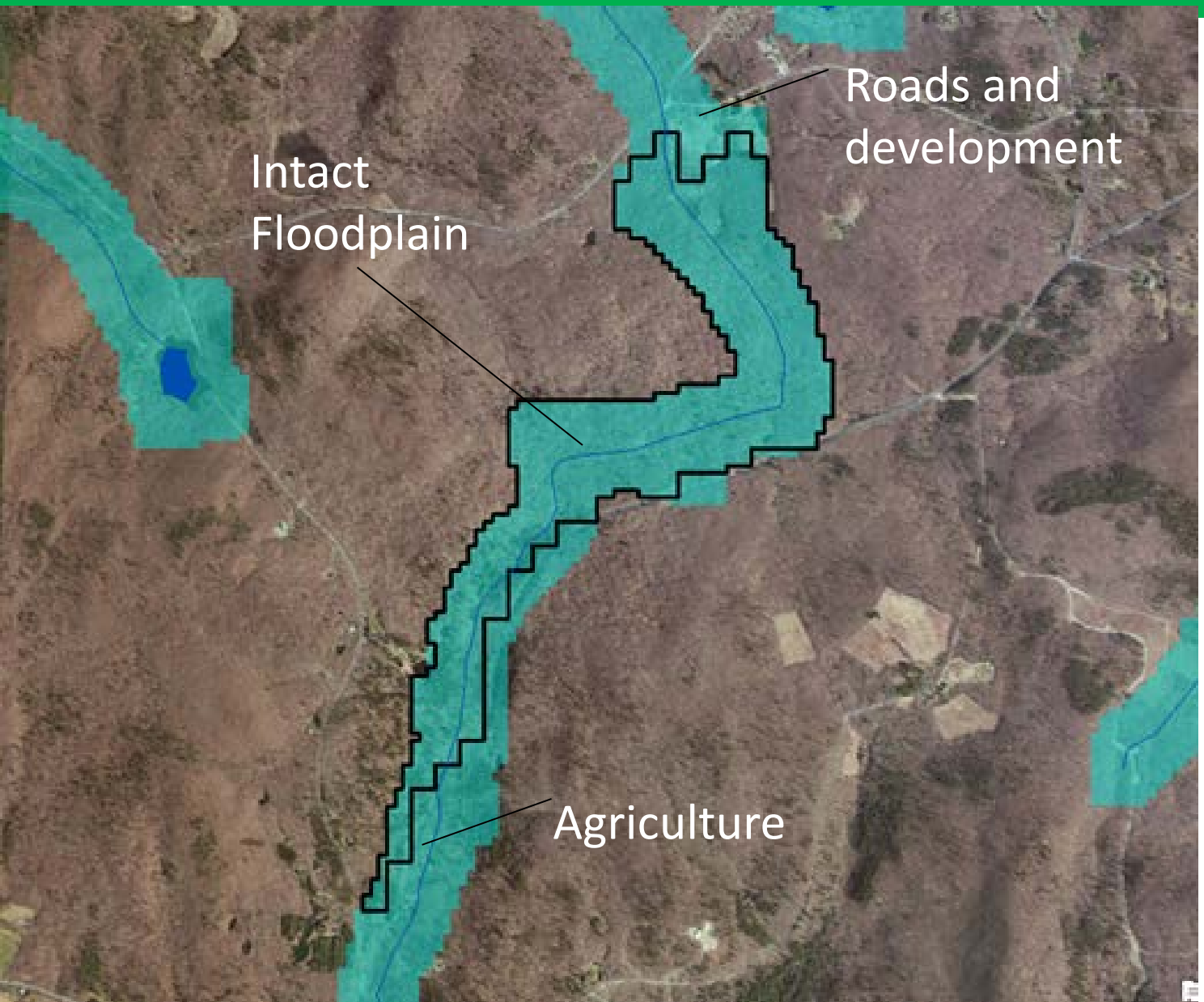
- contain cool, moist micro-climates relative to surrounding areas

- span climatic gradients

- have high levels of biodiversity and provide benefits to upland and aquatic species

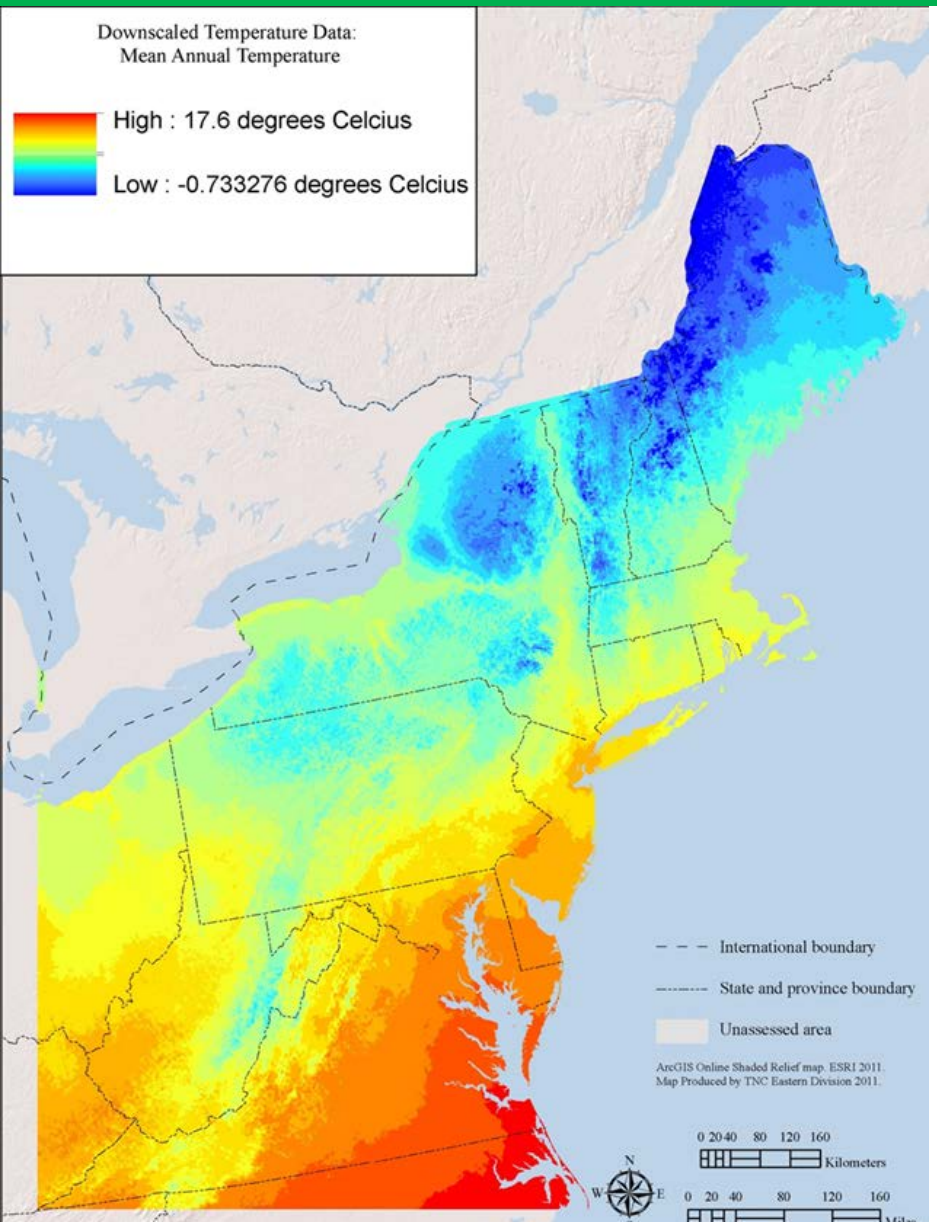
Krosby et al. 2013

# Stretches of Connected Floodplain Habitat

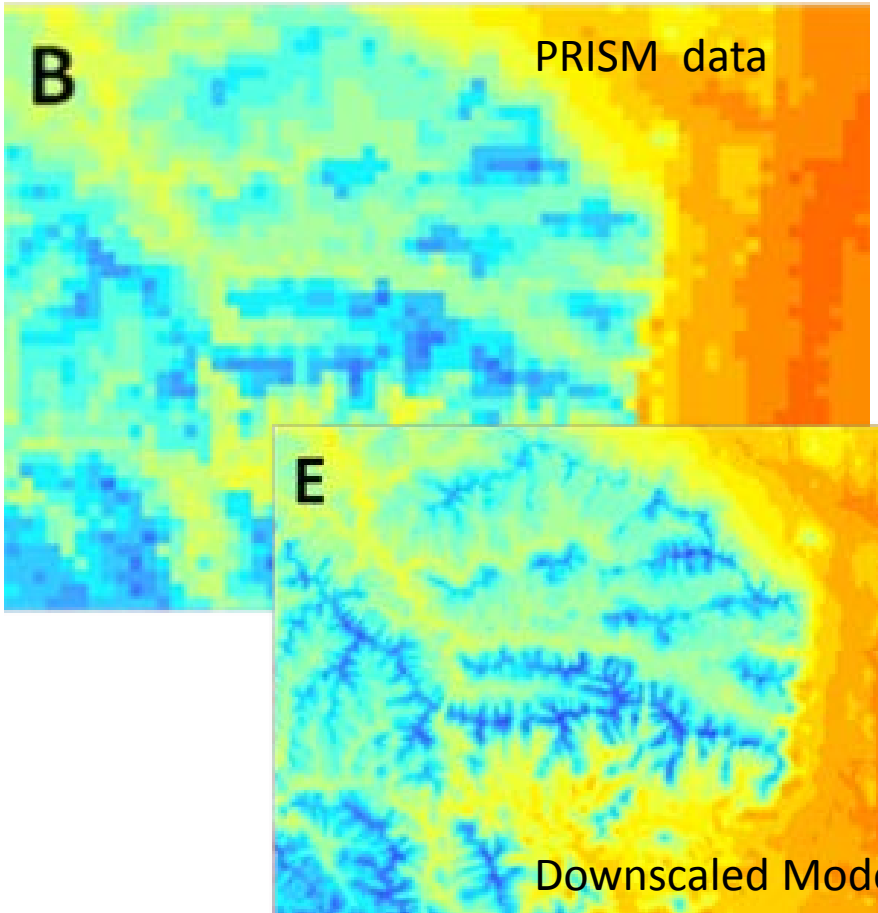



How much temperature change is available to species moving within this intact unit of floodplain?

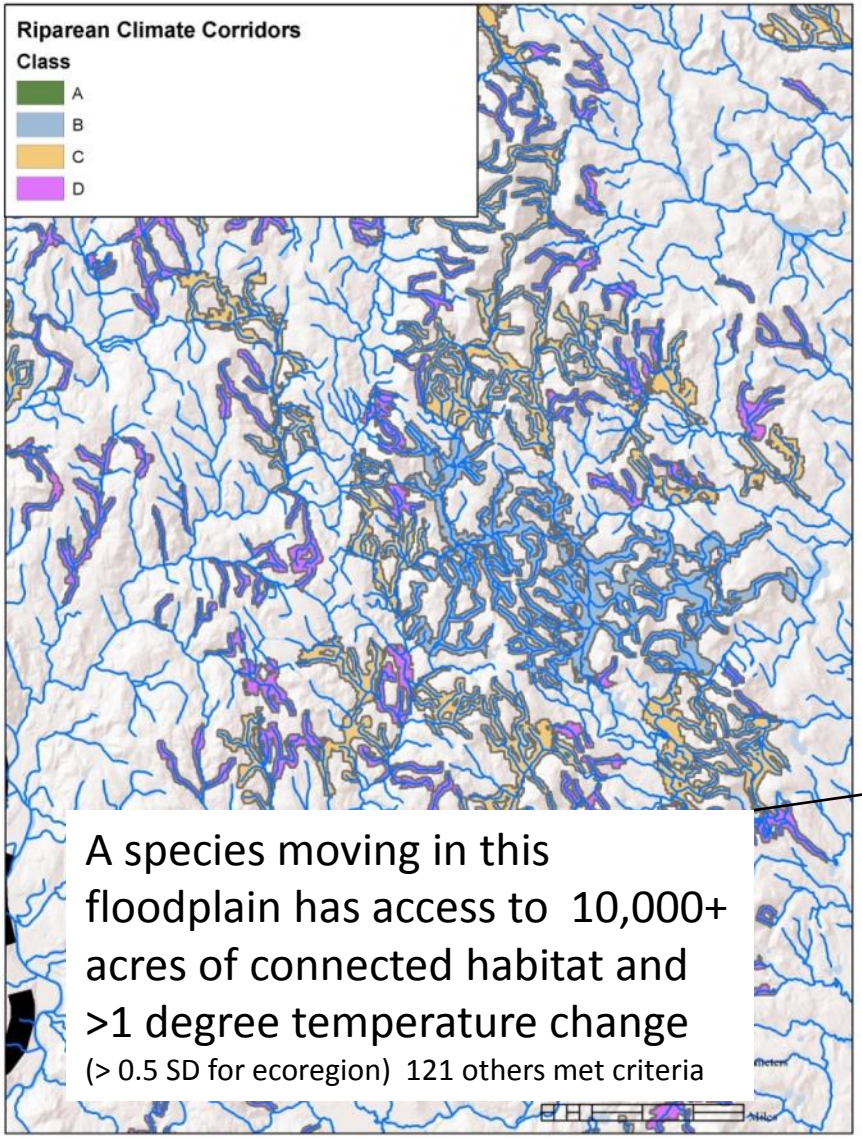
# Downscaled Temperature Model




To measure temperature change in the floodplain we created a downscaled temperature model of mean annual temperature following Wang et al 2011.



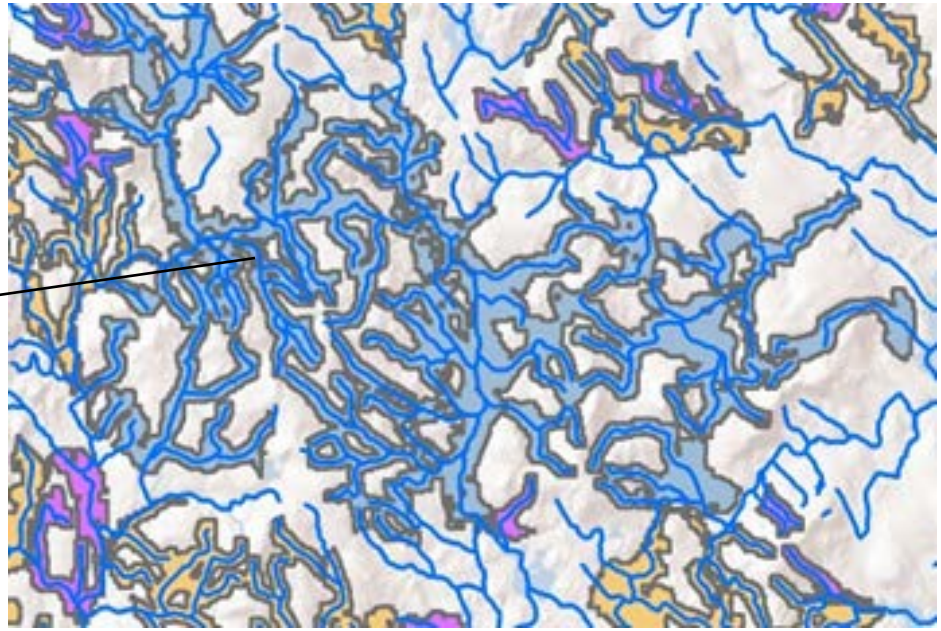
# Riparian Climate Corridors



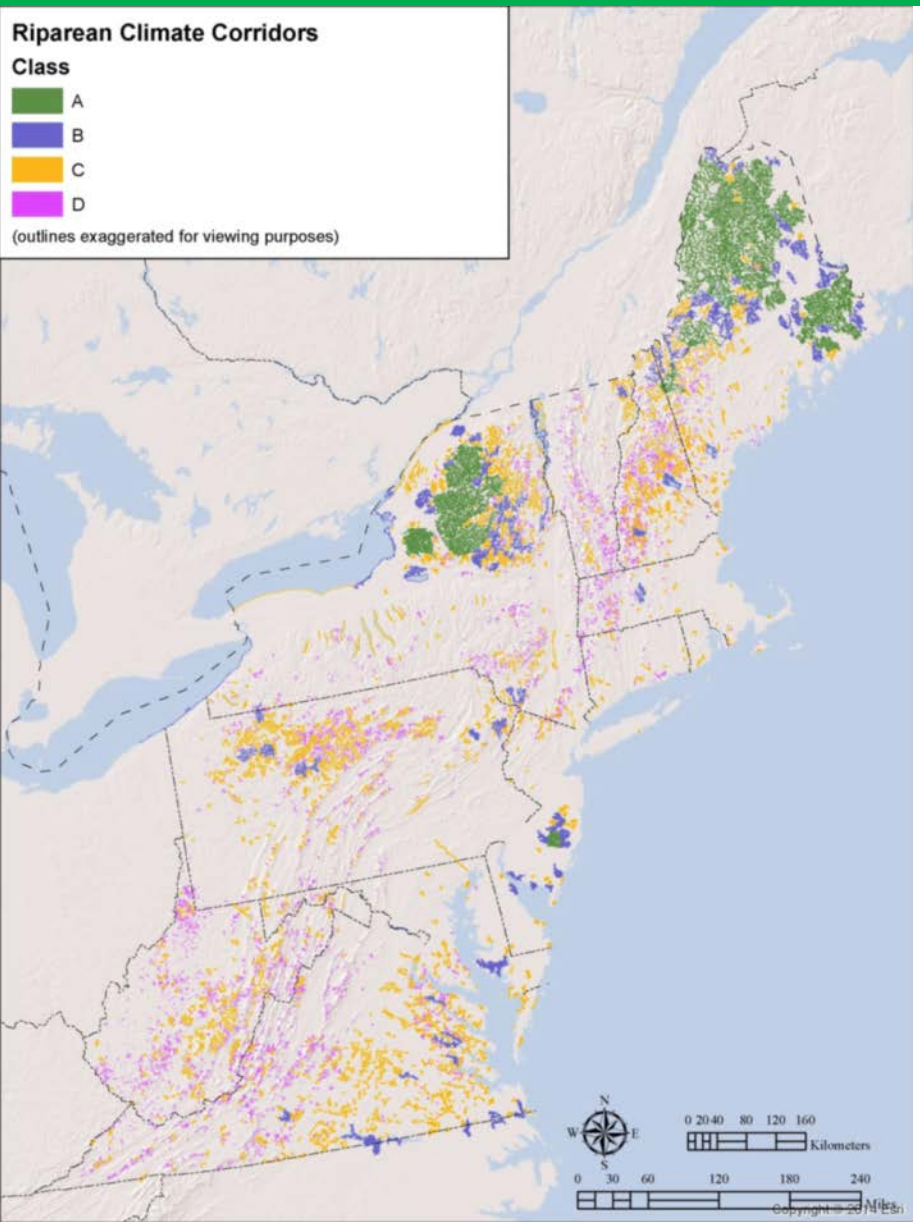

A species moving in this floodplain has access to 10,000+ acres of connected habitat and >1 degree temperature change
(> 0.5 SD for ecoregion) 121 others met criteria

For each floodplain unit we measured:

- Size
- Amount of Temperature Change
- Connectedness
- also canopy cover and wetlands

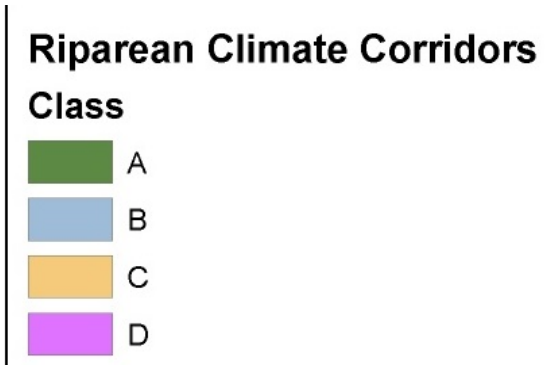


# Riparian Climate Corridors

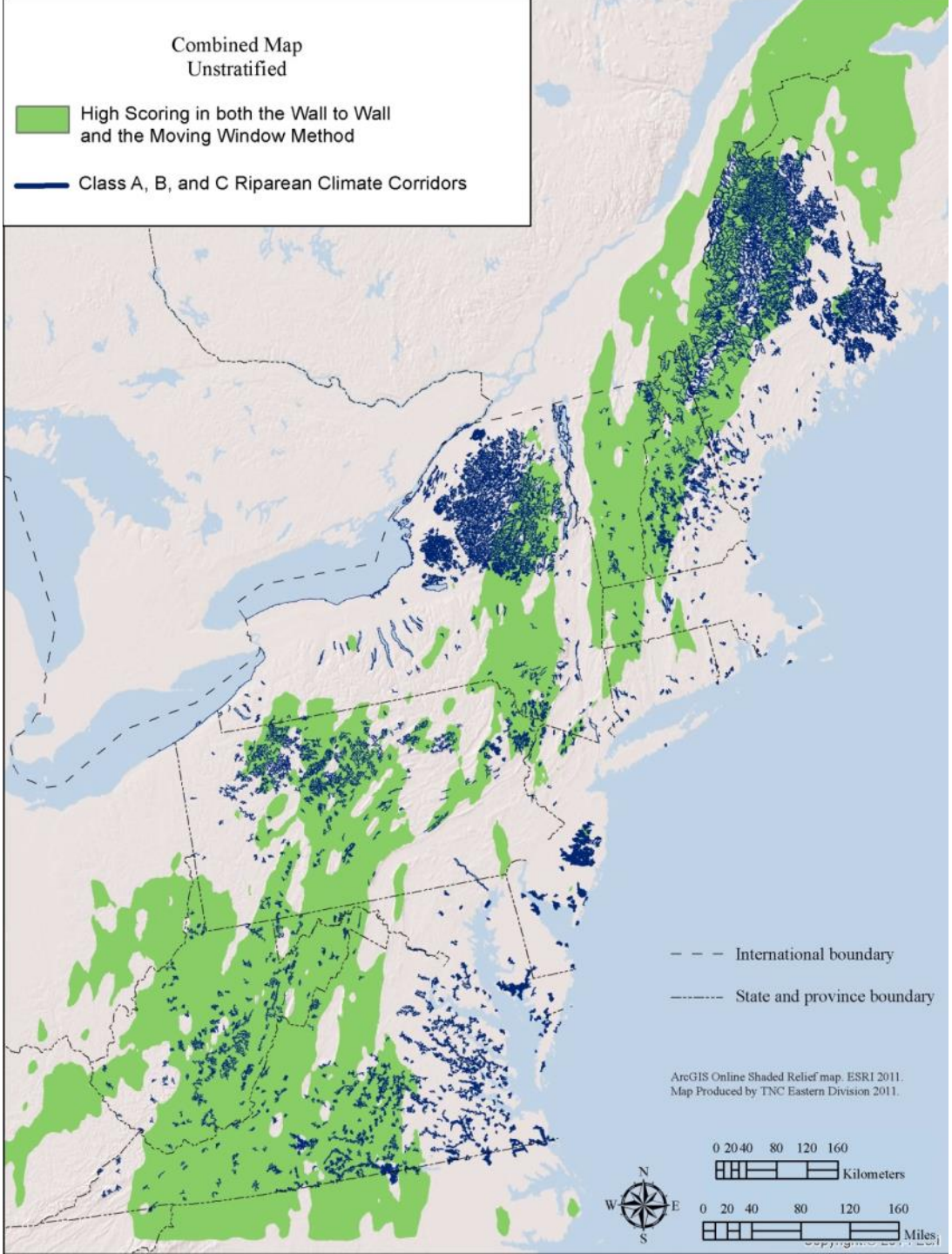


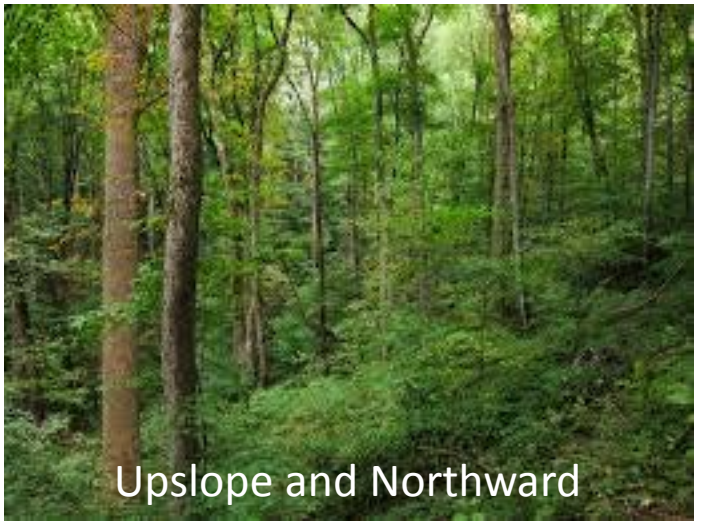

Areas with above average temperature scores were sorted into 4 Classes:

- >50,000 acres and >0.5 SD T
- >10,000 acres and > 0.5 SD T
- >1000 acres and >1 SD T
- >100 acres and >2 SD T

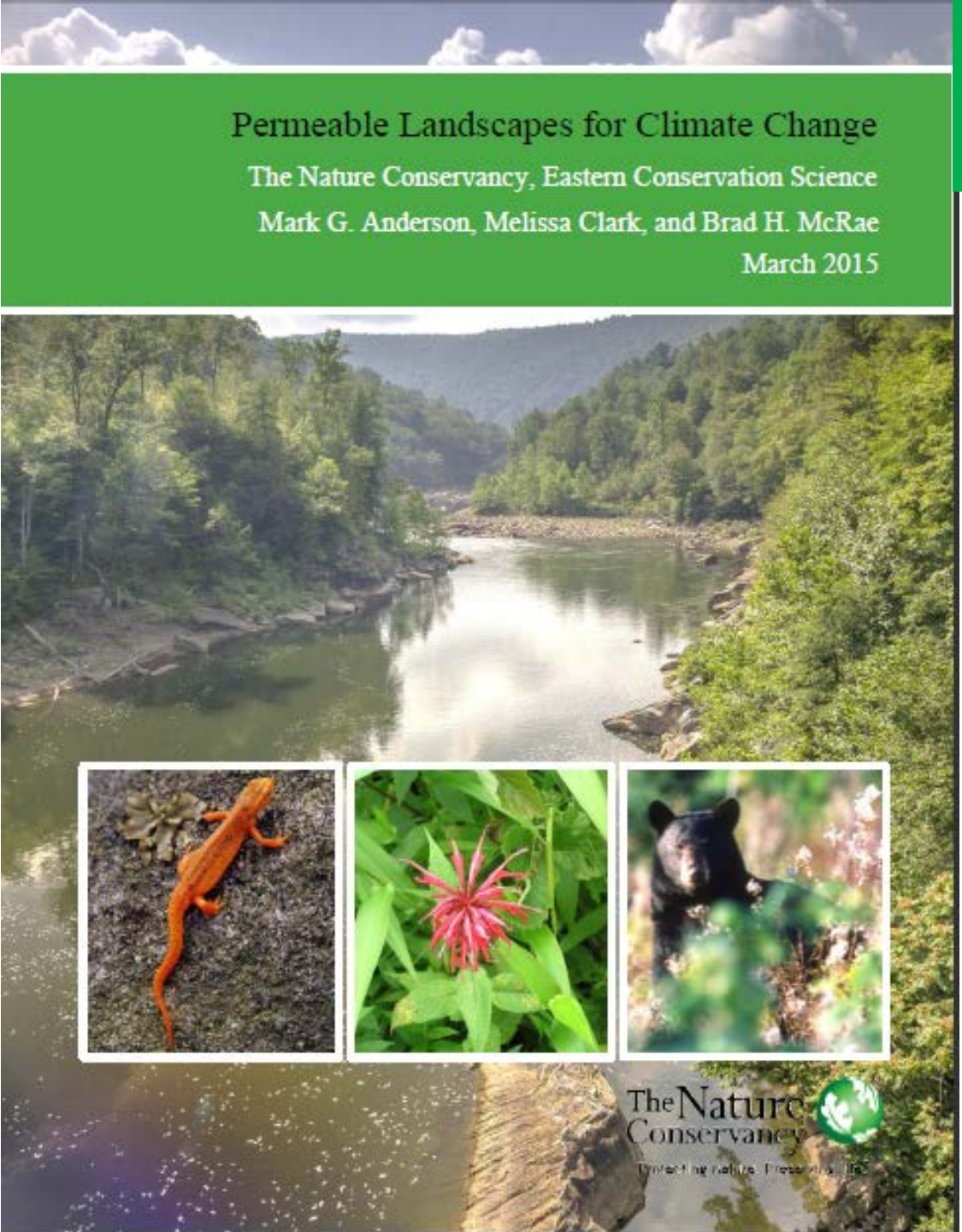


# Overlap


Combined Map
Unstratified
High Scoring in both the Wall to Wall and the Moving Window Method
Class A, B, and C Riparean Climate Corridors
International boundary
State and province boundary
ArcGIS Online Shaded Relief map. ESRI 2011.
Map Produced by TNC Eastern Division 2011.
0 20 40 80 120 160
Kilometers
0 20 40 80 120 160
Miles
N
W
E
S


Upslope and Northward

Riparian Climate Corridors




# Thank You!

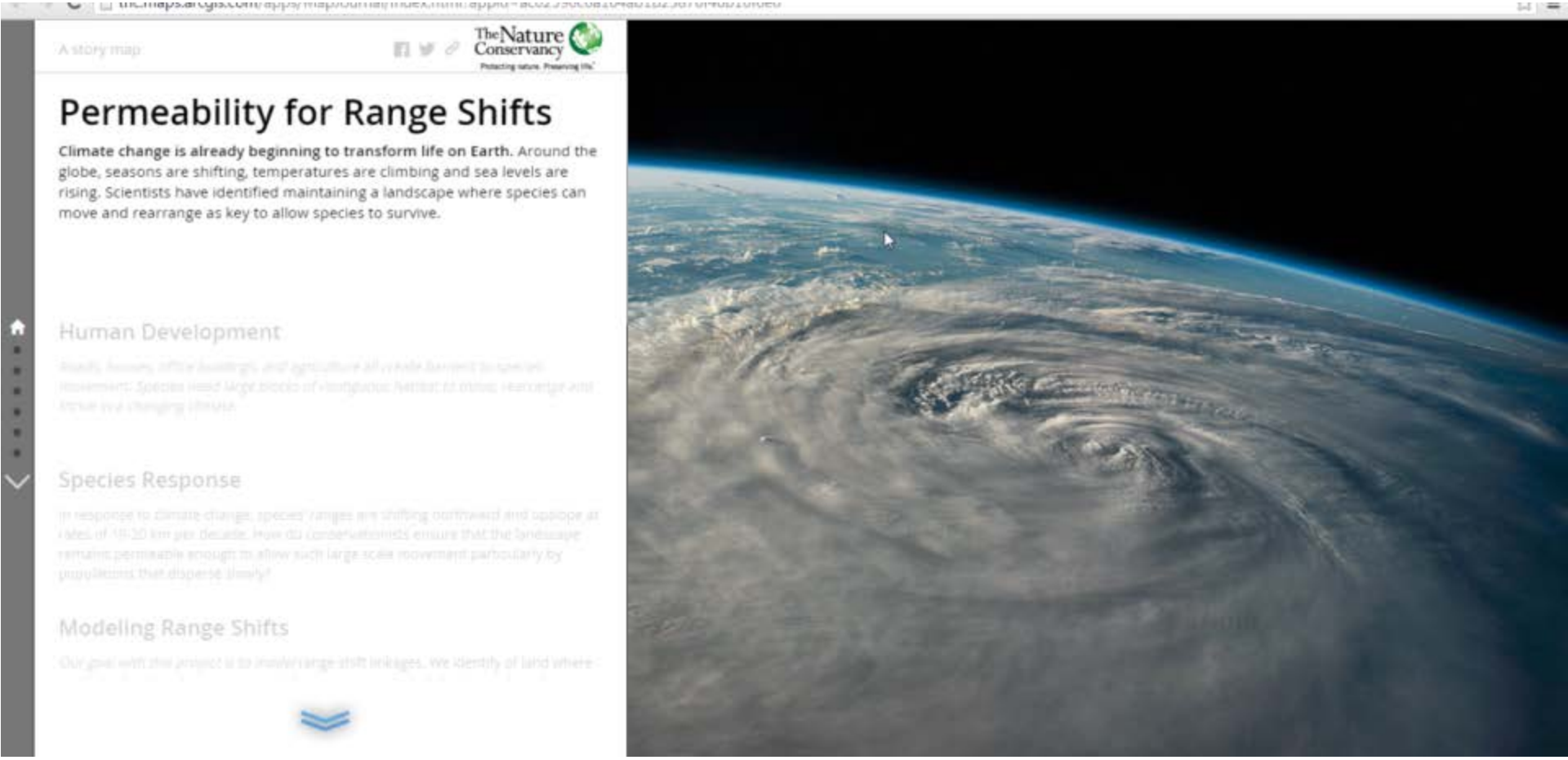
**WEB SITE**

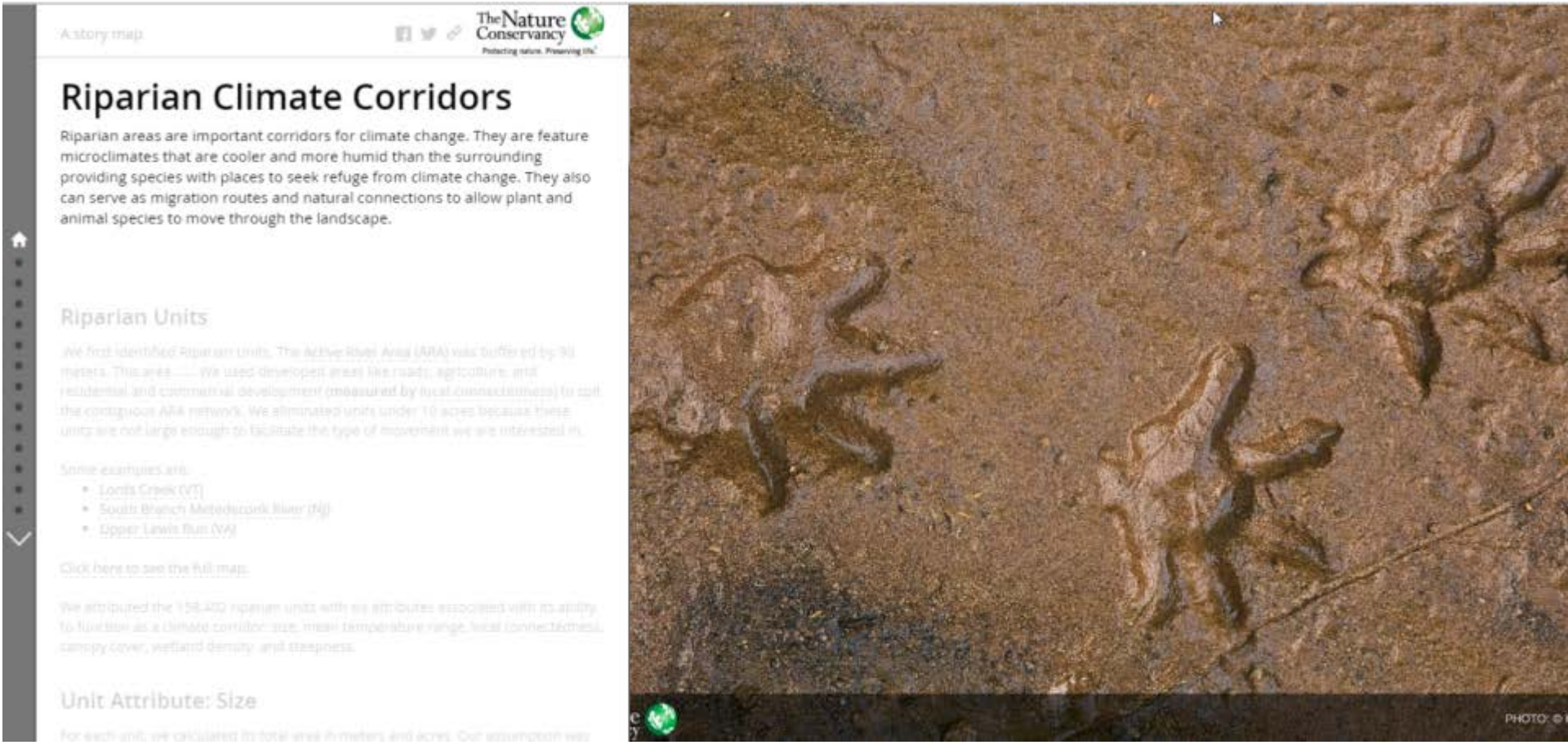
**Conservation Gateway**

Funded with support from the NA LCC and TNC

# Riparian Climate Corridors Story Map

http://arcg.is/1dXPzYY



# Riparian Climate Corridors Story Map

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