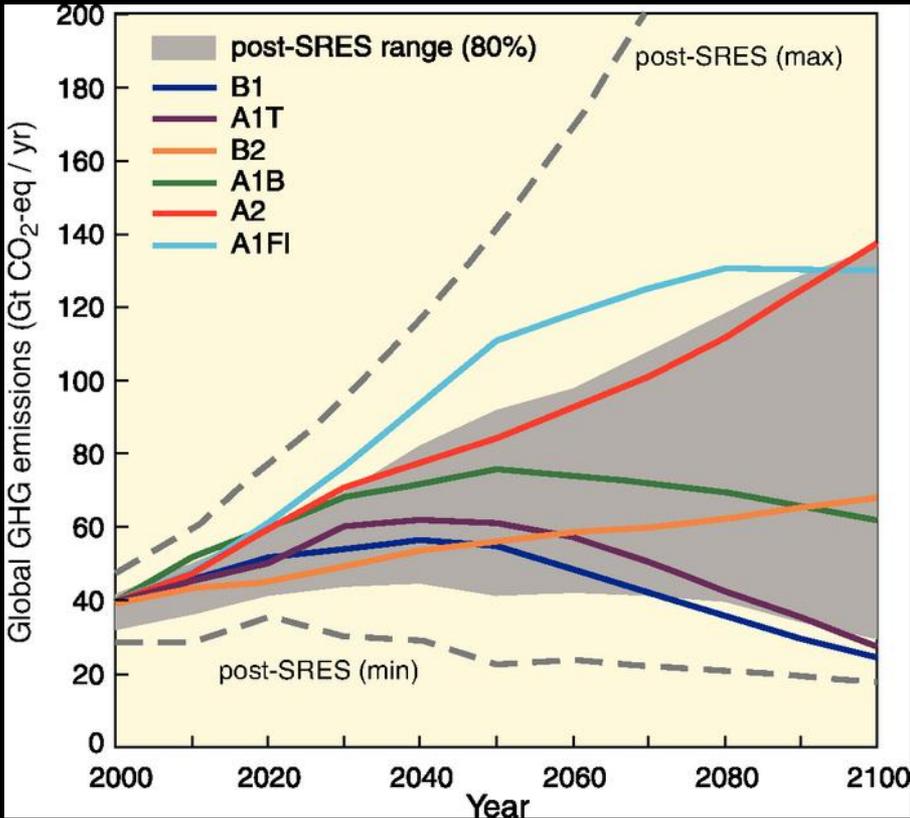


# Amphibian response to climate change in the southeastern US: Identifying species and habitat priorities

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# Uncertainty is ubiquitous



- Conservation decisions must be made now – prior to perfect information
- “Judicious use of model projections at appropriate scales may help us prepare<sup>1</sup>”

# What approach do we take, and at what scale?

- Climate change is a large-scale threat that requires a large-scale approach
- Action plans should be data-driven
  - Qualitative assessment
  - Experimentation
  - Models



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## CONTRIBUTIONS

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Losing the Culture of Ecology

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# Methods for modeling species responses to climate change

- Forecasting distribution responses

## Correlative models:

- Phenomenological
- Relate current distributions to environmental variables

## Mechanistic models:

- Use explicit relationships between environmental variables and organismal performance
- Estimated independently of species current distribution



# Methods for modeling species responses to climate change



**Ecology Letters**  
 Ecology Letters (2010) 13, 1041–1054  
 doi: 10.1111/j.1365-3113.2010.00476.x

**REVIEW AND SYNTHESIS**  
 Can mechanism inform species' distribution models?

Lauren B. Buckley<sup>1</sup>\*, Mark S. Ridgway<sup>2</sup>, Richard S. Stephens<sup>3</sup>, Ian D. Owen<sup>4</sup>, Todd E. Miller<sup>5</sup> and Michael S. Boyer<sup>6</sup>

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**Abstract**  
 Two major approaches address the need to predict species distributions in response to environmental change. Correlative models estimate parameters (phenomenological) by relating current distributions to environmental conditions. By contrast, mechanistic models incorporate explicit relationships between environmental conditions and organismal performance, estimated independently of current distributions. Mechanistic approaches include models that measure environmental conditions via biophysical or resource metrics (e.g. potential duration of activity), models that represent environmental conditions via measures of microclimate and resources, and models that use concepts in life history theory and demography. We compared how two correlative and three mechanistic models predicted the range of one species, a tiger heron (*Ardeotis ibis*), in response to a 3 °C temperature increase and a forest fire (Cajon Grande). Correlative and mechanistic models performed similarly in predicting current distributions, but mechanistic models predicted larger range shifts in response to climate change. Although mechanistic models theoretically should provide more accurate distribution predictions, there is much potential for improving their flexibility and performance.

**Keywords**  
 Biophysical model, climate change, climate envelope model, demography, fundamental niche, physiology, niche and niche, species' range model.

*Ecology Letters* (2010) 13, 1041–1054

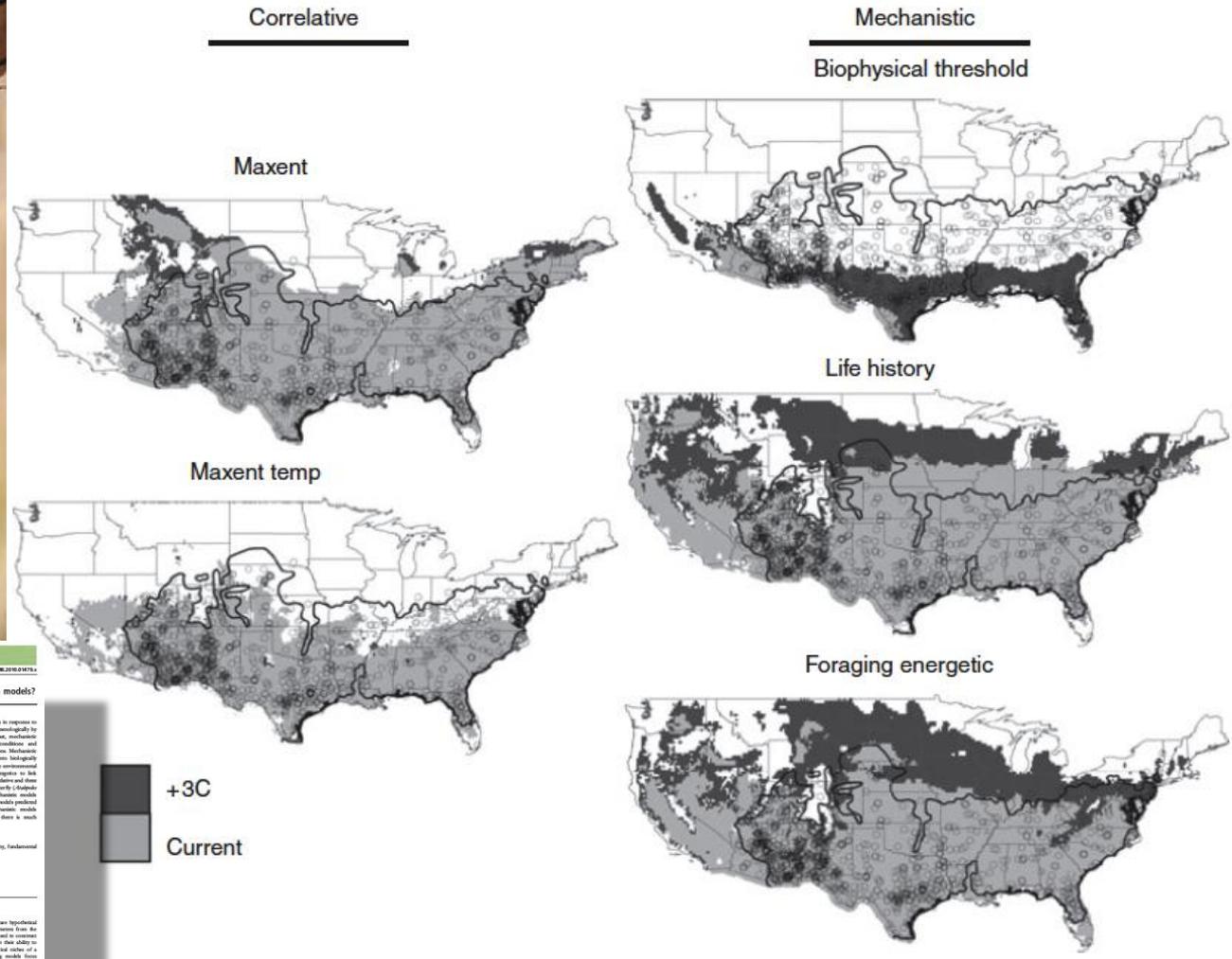


Fig. 1 Range predictions for *Sceloporus undulatus* in current climates (light gray) and predicted range expansions following a uniform 3 °C temperature increase (dark gray). Localities (o) and the atlas range polygon are shown.

# So many problems, so little time

- The southeast represents one of the world's most diverse region for amphibians
  - Nearly 200 species
  - > 50 endemics
- Climate change is likely to result in a loss of climatically suitable habitat for many of these species



# Prioritizing model effort: Expert solicitation

- Surveyed state herpetologists to identify priority species
- Identified results most relevant to wildlife managers



# Climate change vulnerability assessment: target species

Salamanders	Frogs
<i>Ambystoma cingulatum</i> (2)	<i>Hyla andersonii</i> (2)
<i>Ambystoma tigrinum</i>	<i>Lithobates capito</i> (3)
<i>Amphiuma pholeter</i>	<i>Lithobates okaloosae</i>
<i>Aneides aeneus</i> (5)	<i>Lithobates sylvaticus</i>
<i>Cryptobranchus alleganiensis</i> (3)	<i>Pseudacris brachyphona</i>
<i>Desmognathus aeneus</i> (3)	<i>Pseudacris ornata</i>
<i>Desmognathus welteri</i>	
<i>Desmognathus wrighti</i>	
<i>Hemidactylium scutatum</i> (2)	
<i>Necturus alabamensis</i>	
<i>Notophthalmus perstriatus</i> (2)	
<i>Plethodon ventralis</i>	
<i>Plethodon websteri</i> (2)	
<i>Plethodon wehrlei</i> (2)	
<i>Plethodon welleri</i>	

# Location of selected species

Generalist species (n = 5)



S. Apps (n = 6)

Piedmont (n = 2)



Coastal Plain (n = 8)



# Building a correlative model

The screenshot displays the Maximum Entropy Species Distribution Modeling (MaxEnt) software interface, Version 3.3.2. The main window is divided into two primary sections: "Samples" and "Environmental layers".

- Samples Section:** Includes a "File" input field and a "Browse" button.
- Environmental layers Section:** Includes a "Directory/File" input field and a "Browse" button.

Below these sections, there are several configuration options and controls:

- Feature Selection:** A list of features with checkboxes: Linear features, Quadratic features, Product features, Threshold features, Hinge features, and Auto features (checked).
- Modeling Options:** Checkboxes for "Create response curves", "Make pictures of predictions" (checked), and "Do jackknife to measure variable importance".
- Output Settings:** "Output format" is set to "Logistic" and "Output file type" is set to "asc".
- Directories:** Fields for "Output directory" and "Projection layers directory/file", each with a "Browse" button.
- Buttons:** "Run", "Settings", and "Help" buttons are located at the bottom of the main window.

A smaller, semi-transparent version of the same interface is overlaid on the left side of the main window. A large blue curved arrow points from the right side of the main window towards the smaller window, indicating a zoom or focus shift. Another blue curved arrow points from the right side of the main window towards the bottom right corner, highlighting the "Output directory" and "Projection layers directory/file" fields.

On the right side of the main window, there is a legend for the map view, including a north arrow and a legend box with the following items:

- Legend
- background pts
- range (50km buffer)
- range
- boundary

At the bottom of the window, there is a footer with the text "Accepted 30 July 2007" and a small logo for the Center for Conservation and Restoration Science (CCRS).

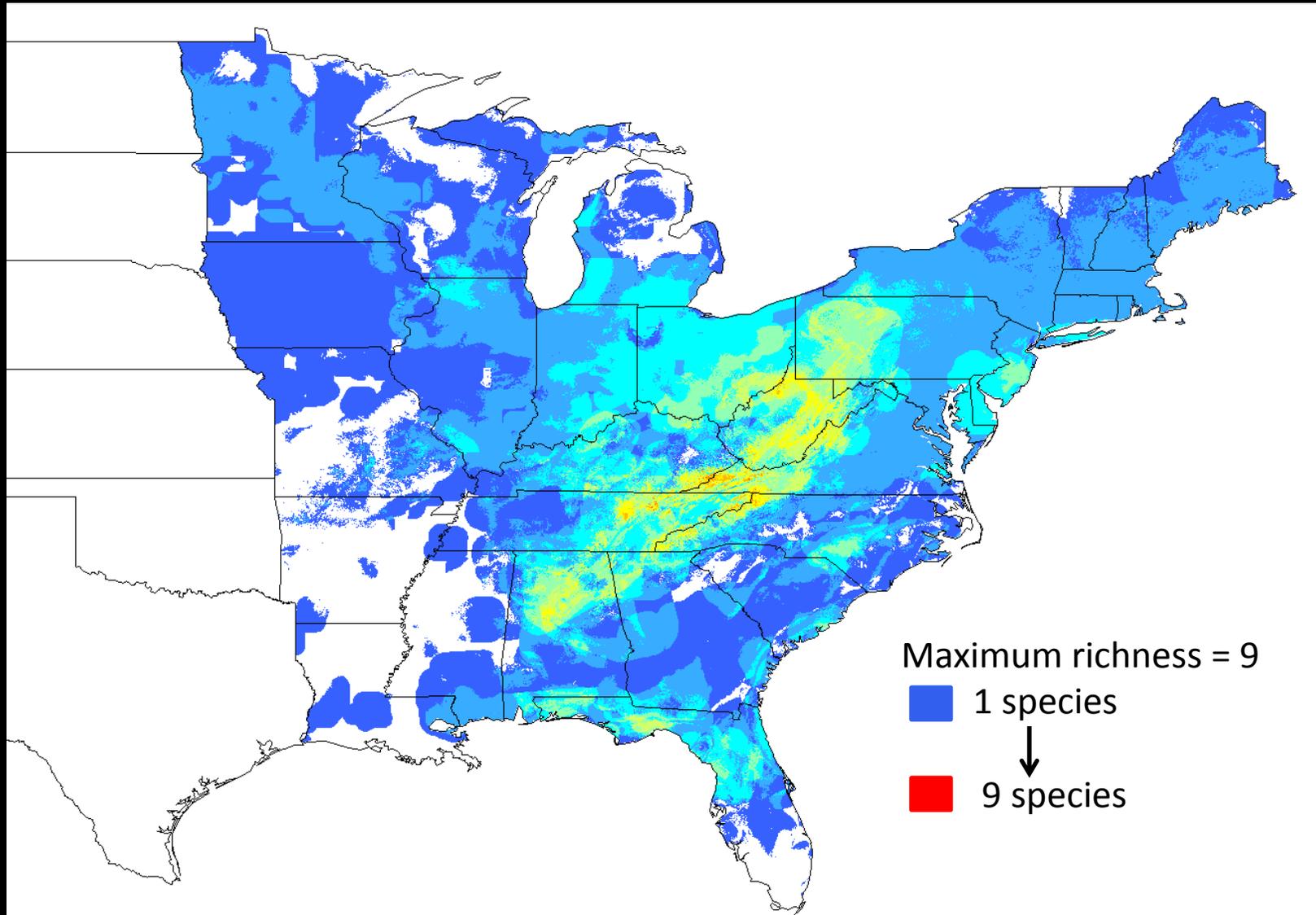
# Building a correlative model

## Output

- Examined species richness and individual species projections
  - A2a and B2a scenarios x 2 GCMs = 4 outcomes
  - Examined 3 thresholds per outcome
  - Generated ensembles of threshold and GCM

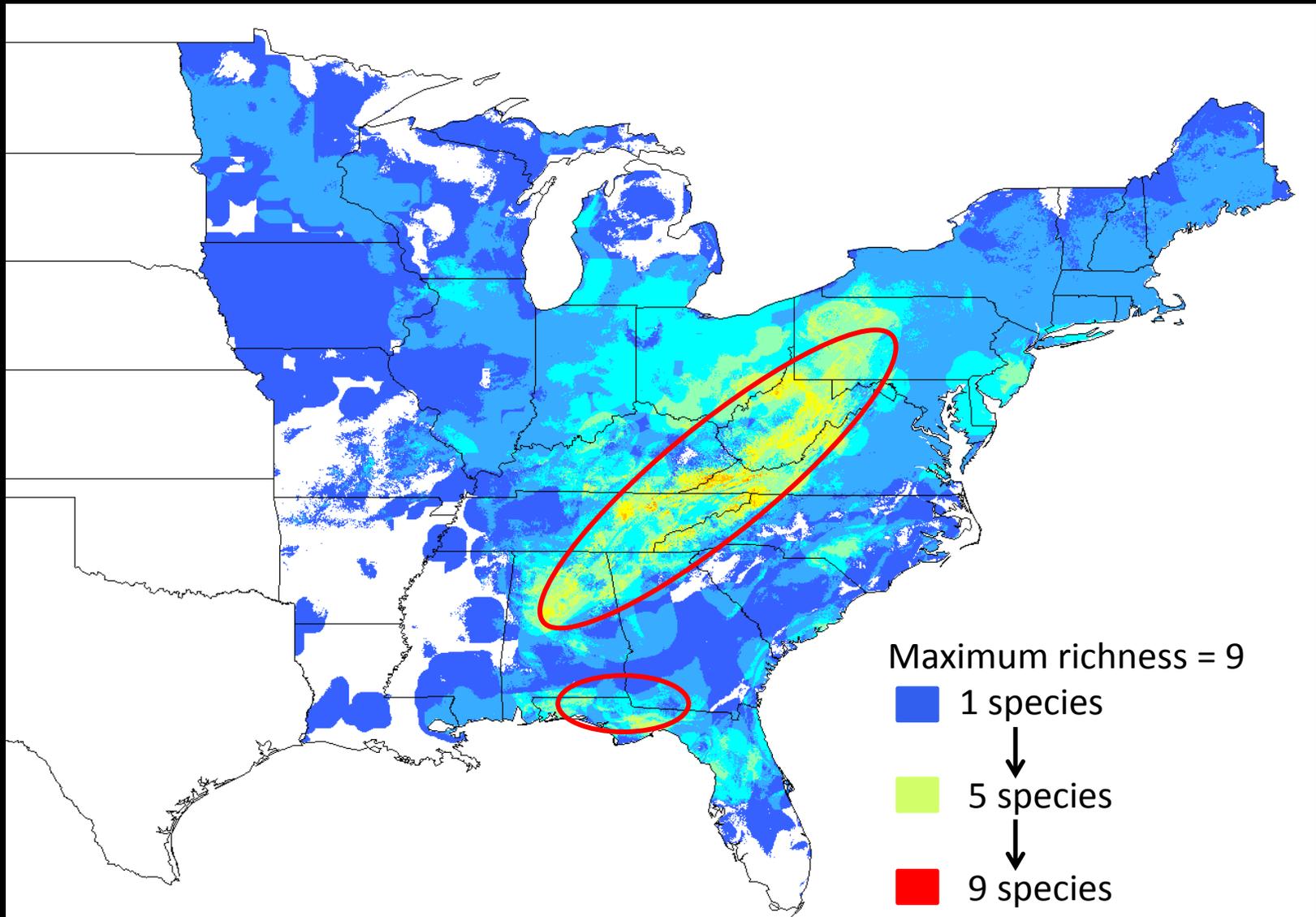
# Identifying sensitive areas

## Current species richness (F10)



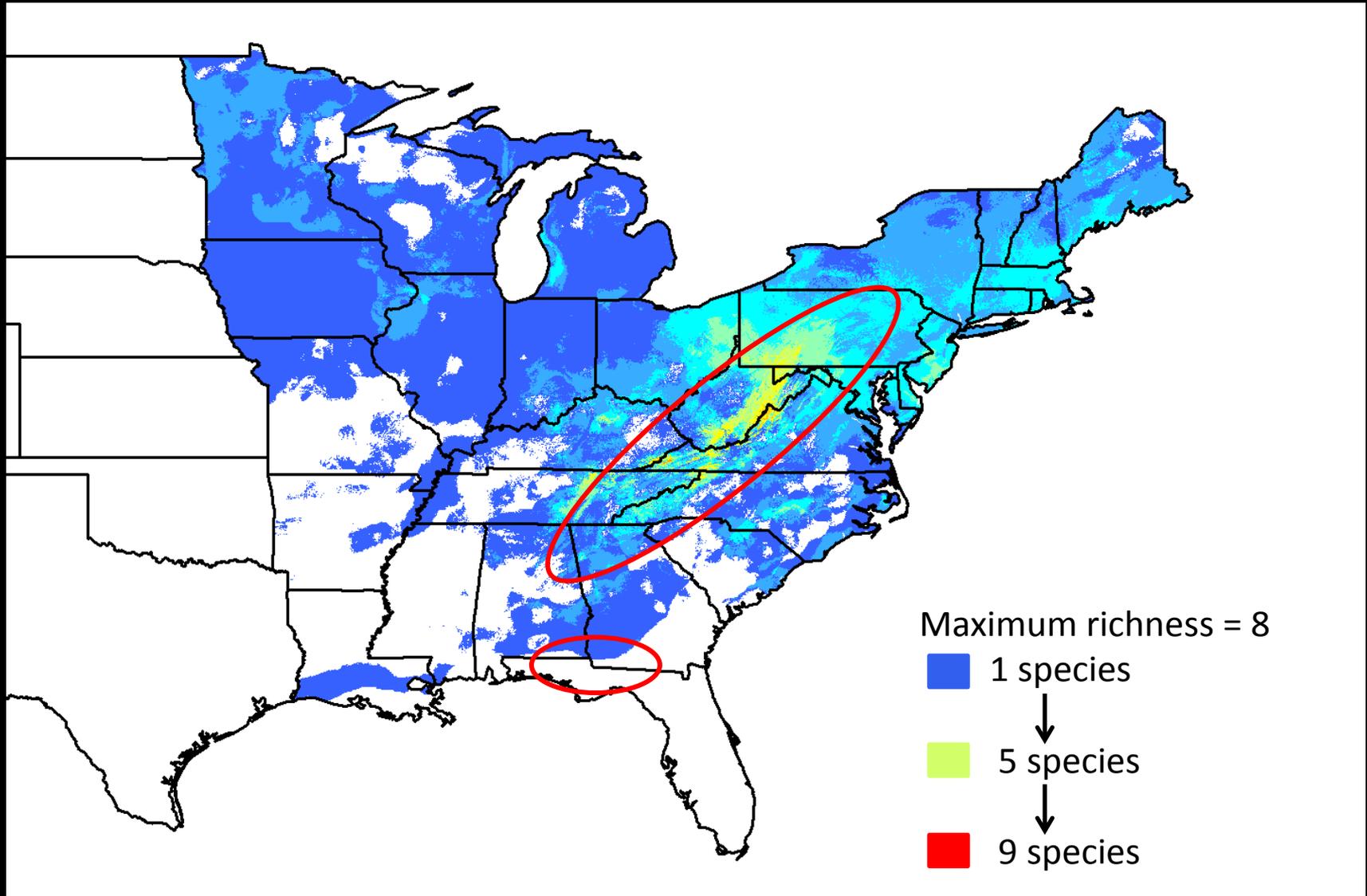
# Identifying sensitive areas

## Current species richness (F10)



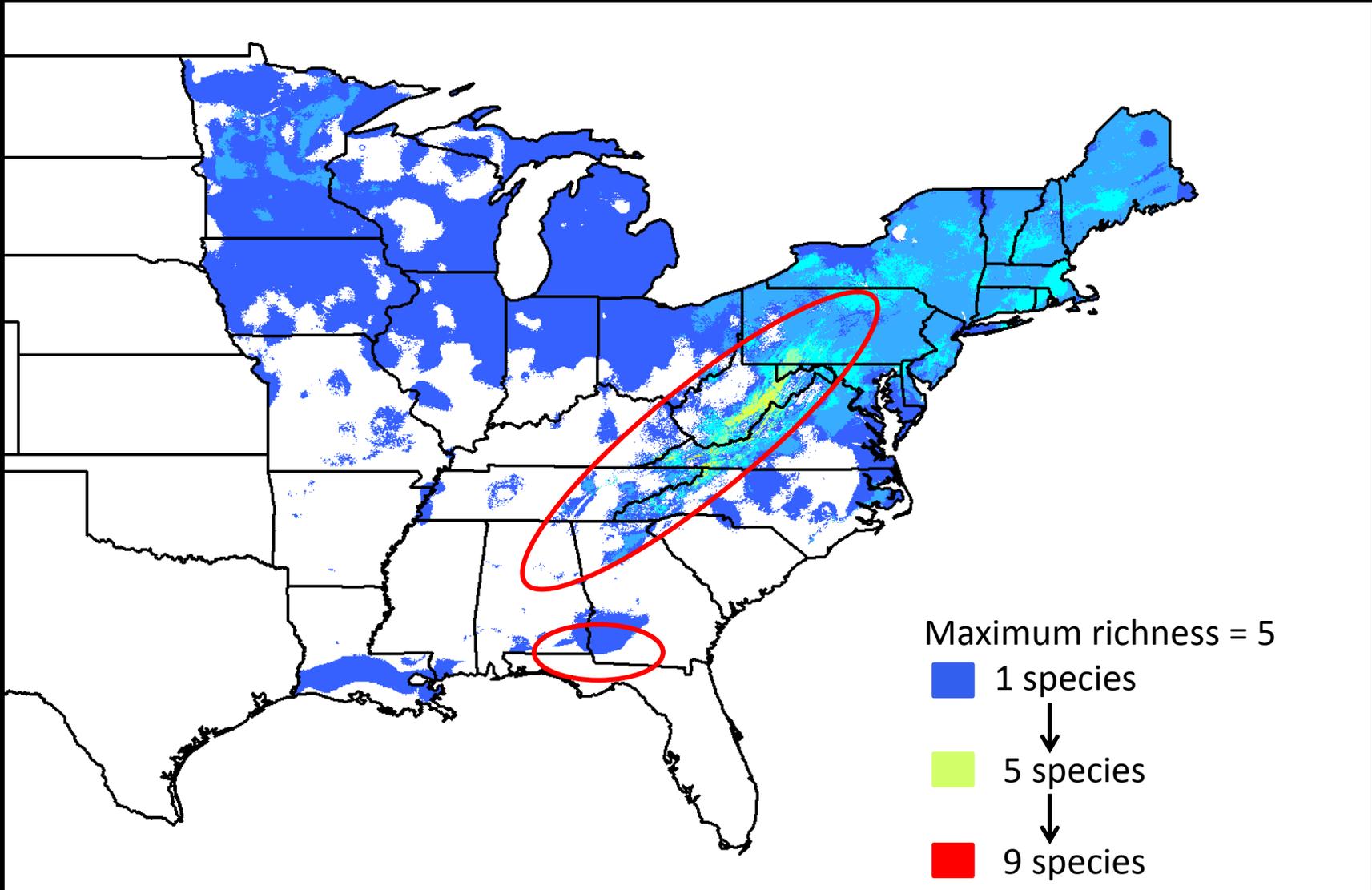
# Identifying sensitive areas

## Hadley B2a 2020 species richness (F10)



# Identifying sensitive areas

## Hadley B2a 2050 species richness (F10)



# Identifying sensitive species: species w/ 100% projected loss of suitable habitat

Species	Hadley						Canadian						# of "extinction" scenarios
	A2a			B2a			A2a			B2a			
	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	
<i>Ambystoma cingulatum</i>	■	■	■	■	■	■	■	■	■	■	■	■	12
<i>Lithobates okaloosae</i>	■	■	■	■	■	■	■	■	■	■	■	■	12
<i>Necturus alabamensis</i>	■	■	■	■	■	■	■	■	■	■	■	■	12
<i>Plethodon websteri</i>	■	■	■	□	□	□	■	■	■	■	■	■	10
<i>Plethodon ventralis</i>	■	■	■	■	■	■	□	□	□	■	■	■	9
<i>Amphiuma pholeter</i>	■	■	■	■	■	■	■	■	■	■	■	■	6
<i>Desmognathus wrighti</i>	■	■	■	■	■	■	■	■	■	■	■	■	6
<i>Lithobates capito</i>	■	■	■	■	■	■	■	■	■	■	■	■	6
<i>Desmognathus welteri</i>	■	■	■	■	■	■	■	■	■	■	■	■	4
<i>Notophthalmus perstriatus</i>	■	■	■	■	■	■	■	■	■	■	■	■	4
<i>Desmognathus aeneus</i>	■	■	■	■	■	■	■	■	■	■	■	■	3
<i>Hyla andersonii</i>	■	■	■	■	■	■	■	■	■	■	■	■	2
<i>Plethodon wehrlei</i>	■	■	■	■	■	■	■	■	■	■	■	■	1
<i>Plethodon welleri</i>	■	■	■	■	■	■	■	■	■	■	■	■	1

# Identifying sensitive species: species w/ 100% projected loss of suitable habitat

Species	Hadley						Canadian						# of "extinction" scenarios
	A2a			B2a			A2a			B2a			
	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	
<i>Ambystoma cingulatum</i>													12
<i>Lithobates okaloosae</i>													12
<i>Necturus alabamensis</i>													12
<i>Plethodon websteri</i>				0.98	0.98								10
<i>Plethodon ventralis</i>							0.97	0.97	0.95				9
<i>Amphiuma pholeter</i>							0.82	0.80	-1.56	0.99	0.99	0.89	6
<i>Desmognathus wrighti</i>							0.96	0.99	0.96	0.96	0.99	0.98	6
<i>Lithobates capito</i>	0.96			0.96	0.98		0.99			0.93	0.98		6
<i>Desmognathus welteri</i>	0.91	0.91	0.90	0.90	0.90	0.87				0.97	0.98		4
<i>Notophthalmus perstriatus</i>	0.96	0.99		0.93	0.99		0.97	0.94	0.79	0.99			4
<i>Desmognathus aeneus</i>	0.95	0.95	0.93	0.93	0.93	0.91	0.97	0.98	0.96				3
<i>Hyla andersonii</i>	0.83	0.83	0.83	0.87	0.92	0.93	0.98			0.94	0.95	0.98	2
<i>Plethodon wehrlei</i>	0.92	0.93	0.95	0.89	0.94	0.99	0.94	0.99		0.73	0.80	0.87	1
<i>Plethodon welleri</i>	0.81	0.96	0.99	0.74	0.90	0.99	0.96	0.99		0.86	0.95	0.97	1

# Identifying sensitive species: species w/ 100% projected loss of suitable habitat

Species	Hadley						Canadian						# of "extinction" scenarios
	A2a			B2a			A2a			B2a			
	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	
<i>Ambystoma cingulatum</i>													12
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<i>Desmognathus wrighti</i>							0.96	0.99	0.96	0.96	0.99	0.98	6
<i>Lithobates capito</i>	0.96			0.96	0.98		0.99			0.93	0.98		6
<i>Desmognathus welteri</i>	0.91	0.91	0.90	0.90	0.90	0.87				0.97	0.98		4
<i>Notophthalmus perstriatus</i>	0.96	0.99		0.93	0.99		0.97	0.94	0.79	0.99			4
<i>Desmognathus aeneus</i>	0.95	0.95	0.93	0.93	0.93	0.91	0.97	0.98	0.96				3
<i>Hyla andersonii</i>	0.83	0.83	0.83	0.87	0.92	0.93	0.98			0.94	0.95	0.98	2
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<i>Plethodon welleri</i>	0.81	0.96	0.99	0.74	0.90	0.99	0.96	0.99		0.86	0.95	0.97	1

= Coastal Plain

# Identifying sensitive species: species w/ 100% projected loss of suitable habitat

Species	Hadley						Canadian						# of "extinction" scenarios	
	A2a			B2a			A2a			B2a				
	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR		
<i>Ambystoma cingulatum</i>													12	
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<i>Plethodon wehrlei</i>	0.92	0.93	0.95	0.89	0.94	0.99	0.94	0.99			0.73	0.80	0.87	1
<i>Plethodon welleri</i>	0.81	0.96	0.99	0.74	0.90	0.99	0.96	0.99			0.86	0.95	0.97	1

= Coastal Plain

= Piedmont

# Identifying sensitive species: species w/ 100% projected loss of suitable habitat

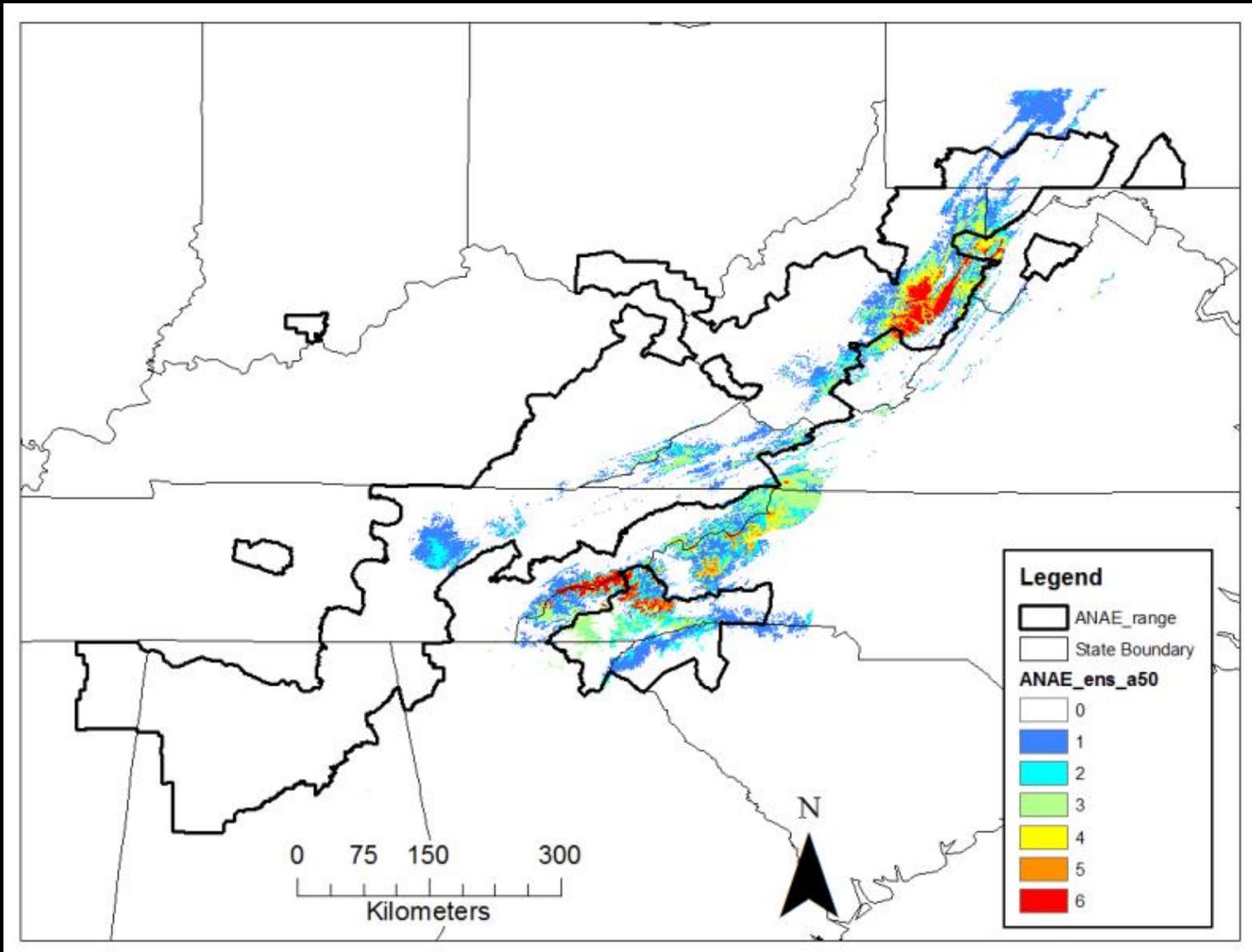
Species	Hadley						Canadian						# of "extinction" scenarios
	A2a			B2a			A2a			B2a			
	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	MTP	F10	MTR	
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<i>Desmognathus aeneus</i>	0.95	0.95	0.93	0.93	0.93	0.91	0.97	0.98	0.96				3
<i>Hyla andersonii</i>	0.83	0.83	0.83	0.87	0.92	0.93	0.98			0.94	0.95	0.98	2
<i>Plethodon wehrlei</i>	0.92	0.93	0.95	0.89	0.94	0.99	0.94	0.99		0.73	0.80	0.87	1
<i>Plethodon welleri</i>	0.81	0.96	0.99	0.74	0.90	0.99	0.96	0.99		0.86	0.95	0.97	1

= Coastal Plain

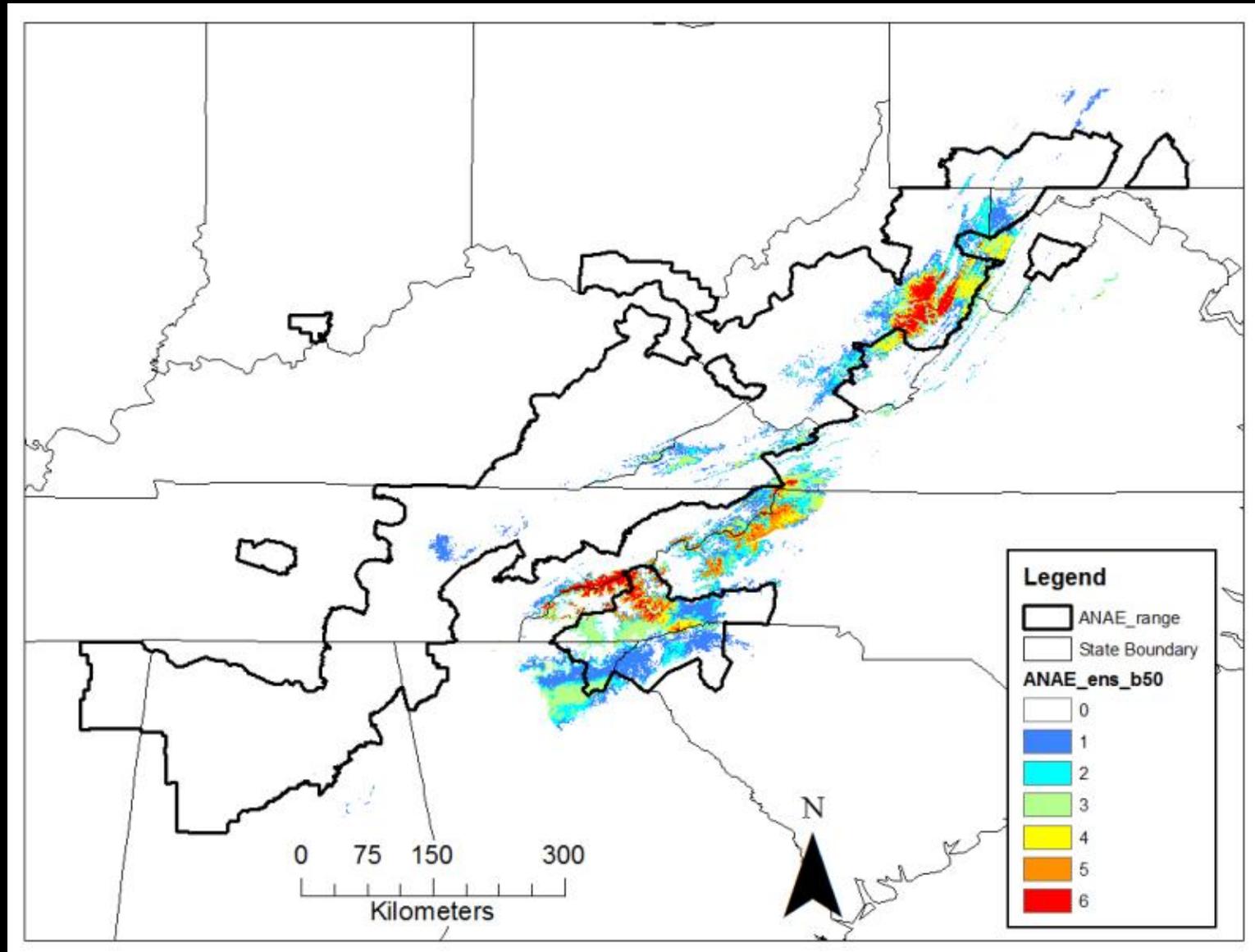
= Piedmont

= Appalachian Mnts

# *Aneides aeneus* – Ensemble A2a 2050

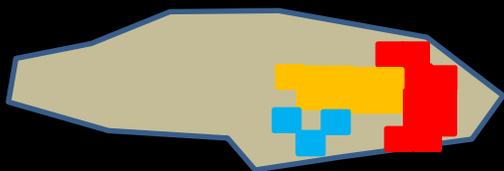


# *Aneides aeneus* – Ensemble B2a 2050

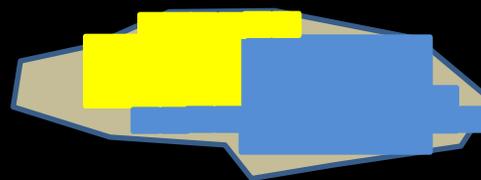


# Prioritizing protected areas (Identifying climate refugia for a species)

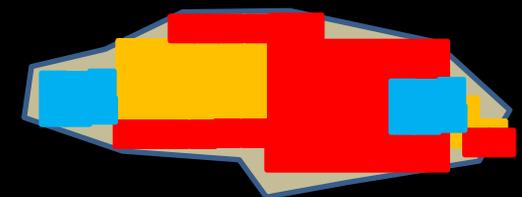
Primary Designation Type	Primary Designation Name	Area (ha)	B2a Percent	B2a Weighted Avg	A2a Percent	A2a Weighted Avg
<b>Alabama</b>						
State Resort Park	Cheaha Resort SP	802	0.90	0.35	0.20	0.10
Wilderness Area (USFS)	Cheaha Wilderness	2,964	0.35	0.17	0.03	0.01
National Forest (USFS)	Talladega National Forest	162,802	0.01	0.00	0.00	0.00
<b>Georgia</b>						
State Park	Don Carter SP	476	1.00	0.50	0.00	0.00
State WMA	Lula Tract WMA	499	1.00	0.50	0.00	0.00



VS



VS



# Model summary

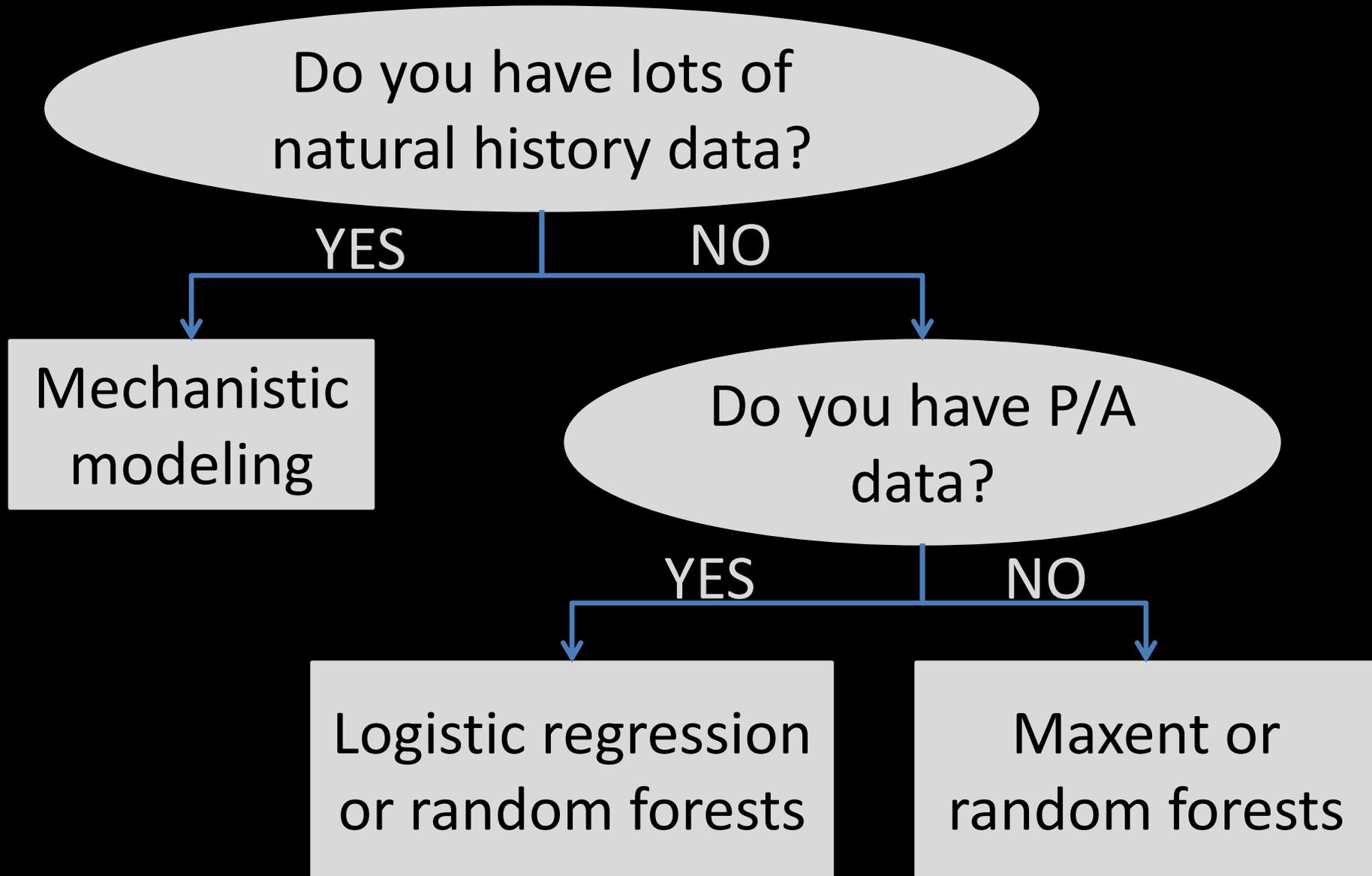
- Coastal Plain habitats shift in suitability as much as other hotspots (southern Apps)
- Over half of the modeled species are projected to lose\*  $\geq 90\%$  of currently suitable habitat
- Individual species models can be ensembled
  - Identification of protected areas that may provide management opportunities
  - Quantification of uncertainty



# Climate change and conservation planning

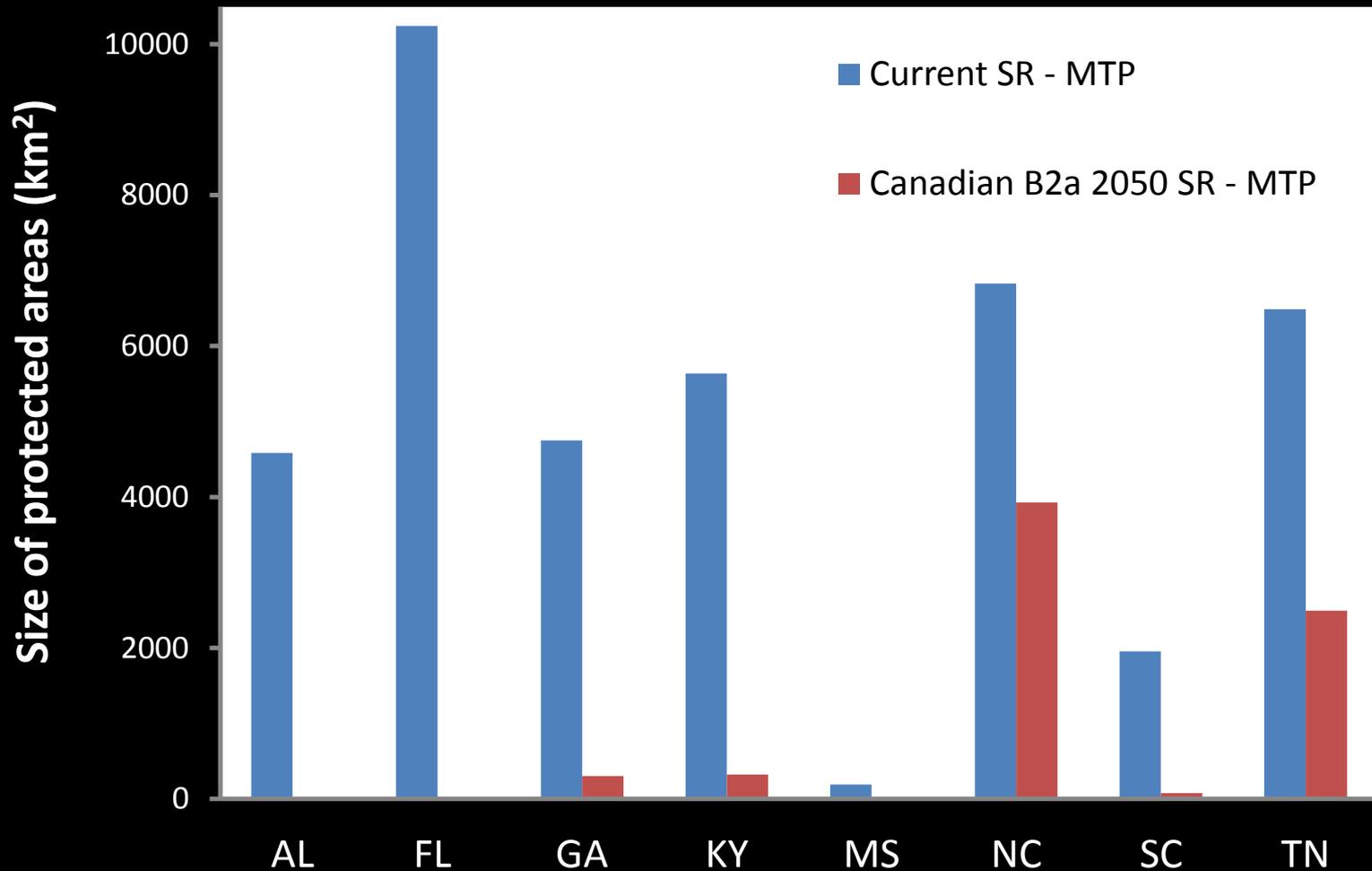
- Downscaled models with ecologically-relevant predictors are essential
- Importance of uncertainty is recognized, but it is often considered difficult to incorporate
- Developing ensembled projections that distill uncertainty down to a few synthetic products will make it more user friendly

# Selecting a SDM approach



# Conservation opportunities

## MTP threshold (liberal)



# Planning for climate change

- Forecasting species responses to climate change is a necessary evil.

## Necessary because:

- Provide stakeholders with planning tools when developing action plans.
  - Identify species that might shift status unexpectedly.
  - Help prioritize allocation of resources, management activities, and areas.

# Planning for climate change

- Forecasting species responses to climate change is a necessary evil.

## Necessary because:

- Provide stakeholders with planning tools when developing action plans.
  - Identify species that might shift status unexpectedly.
  - Help prioritize allocation of resources, management activities, and areas.

## Evil because:

- Fraught with assumptions and uncertainties that make forecasts challenging.
- “Alternative models can be so variable as to compromise their usefulness for guiding decisions.”

# Building a correlative model

- Collected locality data from HerpNet and state-managed collections
- Background points limited to buffered species range
- Selected 12 ecologically relevant bioclim variables
- Used Maxent to construct habitat suitability models
- Examined species richness and individual species projections
  - A2a and B2a scenarios x 2 GCMs = 4 outcomes
  - Examined 3 thresholds per outcome
  - Generated ensembles of threshold and GCM