How does knowledge of intraspecific variation improve our ability to predict geographic distributions? A case study of the eastern fence lizard, *Sceloporus undulatus*

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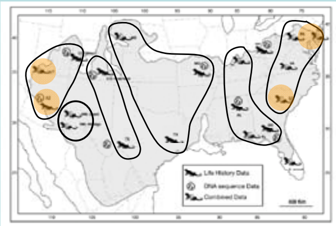
Phylogeography



Left: Phylogenetic analyses of mtDNA identified several clades of *Sceloporus undulatus* that span latitudinal clines (Leaché and Reeder 2002).

• Variation in phenotypes among populations likely influences the distribution of this species and its sensitivity to climate change; a recent mechanistic model of species' distributions enables us to account for such intraspecific variation (Buckley 2008).

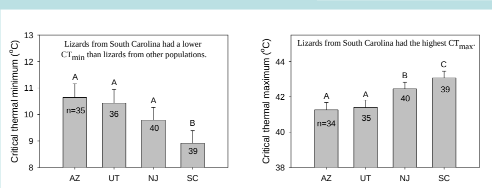
• We quantified thermal physiology of lizards from four populations (highlighted on the map above) and parameterized the mechanistic model to account for intraspecific variation.

Thermal Tolerances and Preferences

• Measures of thermal tolerance are a critical component of most models that predict geographic ranges.

• We measured critical thermal minima and maxima, which are common measures of thermal tolerance.

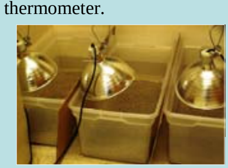
• Critical thermal limits were estimated as the upper and lower temperatures at which a righting response was lost. (heating/cooling rate = 1°C min^{-1})

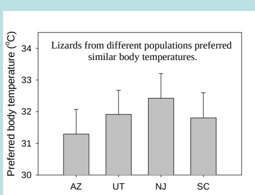


• Preferred body temperatures were measured in a thermal gradient (86 x 40 cm), with a substrate of sand.

• Operative temperatures within the gradient ranged from 24° to 41°C.

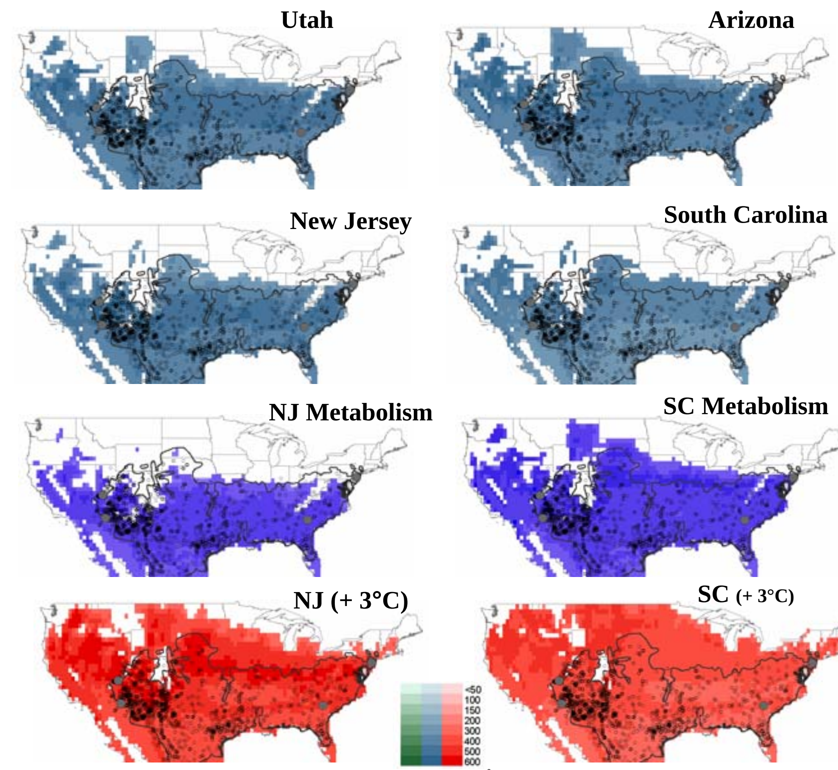
• Body temperature was recorded twice during the day with a cloacal thermometer.





Abstract

Biologists have long recognized that the geographic range of a species expands and contracts in response to environmental change, but predicting such responses remains an elusive goal. Most efforts to predict shifts in species' ranges rely on a correlational approach that assumes environmental tolerances do not vary over space or time. In this approach, species are assumed to track specific environmental conditions across space during climate change. However, geographic variation in phenotypes should influence how subpopulations respond to climate change, leading to predictions that differ from those of correlational models. We adopt a mechanistic approach that accounts for physiological variation among subpopulations of a species. This approach will be exemplified using data from a widespread species, the eastern fence lizard (*Sceloporus undulatus*). We investigate how physiological traits vary across this species' range and ask how this influences the distributional response to climate change. Phylogenetic analyses have defined four major clades in *S. undulatus*, each spanning a latitudinal cline. We use preferred body temperature, critical thermal limits and standard metabolic rates of lizards from four populations representing two clades (eastern and western). These data parameterize a population-specific model of the geographic range. The population-specific model differs from the more common model, in which one assumes all populations possess the same physiological traits. Developing mechanistic models of species' ranges that incorporate geographic variation should improve our ability to predict responses to climate change.



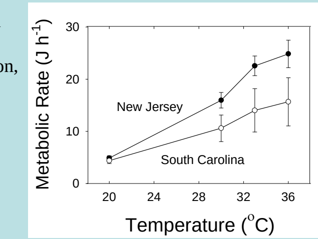
Standard Metabolic Rates

• Because metabolism limits the energy available for reproduction, a mechanistic model must account for the effects of temperature and mass on the standard metabolic rate.

• We measured CO_2 production by flow-through respirometry at body temperatures that span the range observed during activity (20º-36 ºC).

• An ANCOVA for repeated measures was used to estimate effects of population, temperature, and mass on metabolic rate.

• The thermal sensitivity of metabolic rate differed between populations (e.g., see figure on the right).



Linking Physiology and Demography to Geographic Distribution

• Recently, Buckley (2008) linked the thermal physiology of *S. undulatus* to its population dynamics and geographic distribution.

• The model optimizes the energy intake of a territorial, sit-and-wait forager in a thermally heterogeneous environment; energy intake is converted to reproductive output to estimate population density.

• Densities of lizards are projected across a geographic landscape according to local thermal environments.

• The model was parameterized with population-specific means for body size, critical thermal limits, and metabolic rates.

The maps shown on the left depict the predicted ranges of *S. undulatus*.

• Blue maps show predicted distributions based on mean body sizes and critical thermal limits
• Purple maps show predicted distributions based on the mean body sizes, critical thermal limits, and metabolic rates.
• Red maps show predicted distributions based on a warming scenario (3°C-increase in temperature throughout the range).

References

Buckley, L. B. 2008. Linking traits to energetics and populations dynamics to predict lizard ranges in changing environments. *Am. Nat.* 171: E1-E19.

Leaché, A. D. and T. W. Reeder. 2002. Molecular systematics of the eastern fence lizard (*Sceloporus undulatus*): A comparison of parsimony, likelihood, and Bayesian approaches. *Syst. Biol.* 51: 44-68.

Acknowledgments

We thank the ISU School of Graduate Studies for funding, Benjamin Williams for lab assistance, and Mark Carroll, Kacie Ehrenberger, Gary Horn and Zack Walker for field assistance.