the Revolutionary Lizard

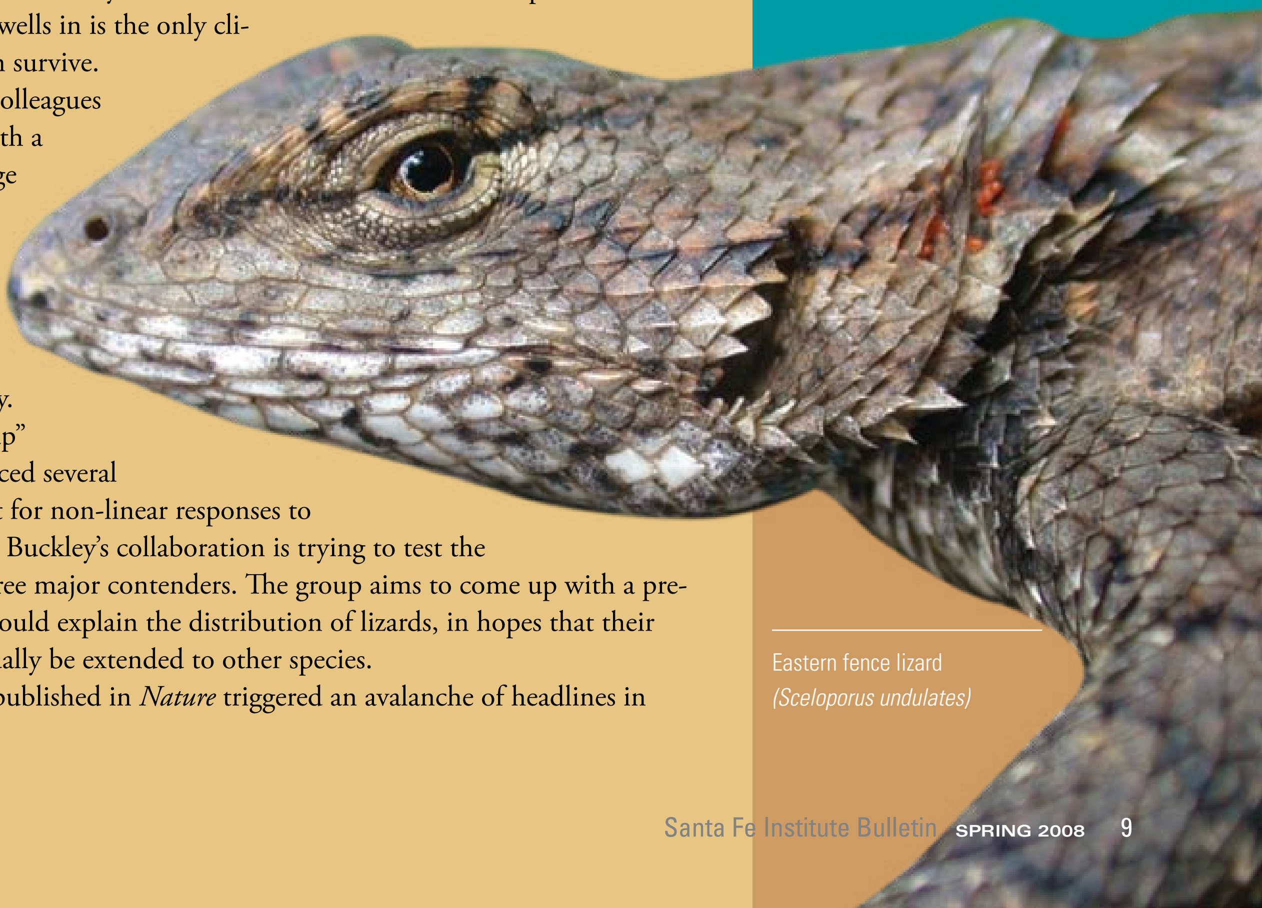
"Who cares about lizards?" Ecology grants usually go to studies of dominant species—large animals that have enough charisma to merit an appearance on *Animal Planet.* So when SFI postdoc Lauren Buckley, along with a group of fellow ecologists, applied for funding to study the eastern fence lizard, she found herself defending the quiet little crawlers. As a result, the humble lizard may change the way ecologists think about global warming.

The group aims to come up with a predictive model that could explain the distribution of lizards, in hopes that their methods will eventually be extended to other species.

Buckley and her collaborators are developing a new approach to one of the central objectives in ecology—modeling how wildlife responds to climate change. Most of the current climate-change models fail to explain non-linear migration patterns that have been observed so far, because they assume that as certain temperature zones move north or south, the flora and fauna that inhabit those zones will follow linearly. The models are based on the assumption that the climate an animal dwells in is the only climate in which it can survive.

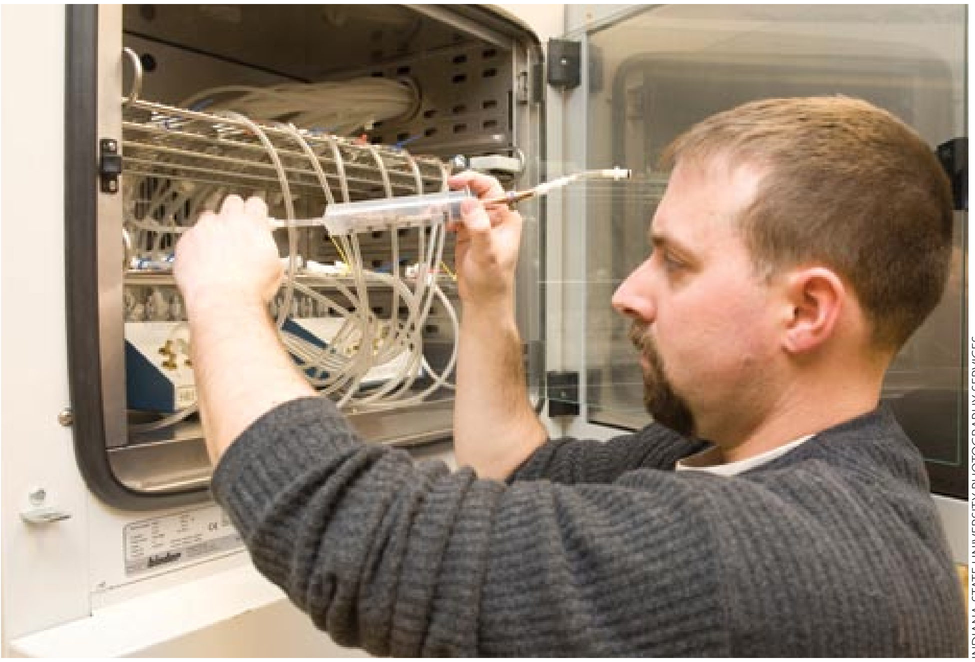
Buckley and her colleagues hope to come up with a better climate-change model that will predict where organisms can live based on how they forage, reproduce, and use energy. The new, "bottom up" approach has produced several models that account for non-linear responses to climate change, and Buckley's collaboration is trying to test the relative merits of three major contenders. The group aims to come up with a predictive model that could explain the distribution of lizards, in hopes that their methods will eventually be extended to other species.

In 2004, a study published in *Nature* triggered an avalanche of headlines in



WILL COOK; DUKE UNIVERSITY

Eastern fence lizard
(Sceloporus undulates)



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Physiological data collection allows ecologists to examine how the variation in physiology across an organism's distribution allows it to live in a diversity of environments. Here, Indiana State University graduate student Joe Ehrenberger loads a fence lizard into a metabolic chamber.

the popular press. "Scientists Predict Widespread Extinction by Global Warming" was the headline that ran in *The New York Times;* "Climate Risk to 'Million Species'" on *BBC News Online;* and "By 2050 Warming to Doom Million Species, Study Says" on *National Geographic News.* The study estimated the future distributions of plant and animal species using a correlative technique called climate envelope modeling (CEM). The technique infers species' environmental tolerance from the temperature, precipitation, and seasonality in their present-day surroundings.

Though CEMs are the principle models ecologists use to predict how wildlife will respond to climate change, Buckley and others criticize them for being too simplistic. CEMs assume that the climates in which species currently live are the only climates in which they *can* live, and that if those climates shift or disappear, the species will follow. Yet there is evidence that species do not simply follow a single set of climactic conditions; data that lepidopterists have collected over the past century indicates that certain butterfly species in Europe have remained stable in the face of a mean temperature increase of 0.8 degrees centigrade, whereas other species shifted northward. An analysis of fossilized mammal remains similarly shows that different species shifted in different directions and at different times during a climate change in the late Quaternary period. CEMs can neither predict nor explain such non-linear behavior.

Buckley's team of ecologists pursues a new way of modeling. They aim to predict species ranges based on how animals metabolize energy and collectively behave, and in what temperatures they can gather food and reproduce. Buckley calls it mechanistic modeling. And building a mechanistic model requires not only a new mathematical approach, but extensive data collection and experimentation to ascertain the physiology of the animals in question.

The physiological data for the lizard model will come from a laboratory at Indiana State University. There, ecologist Michael Angilletta and his grad students lower fence lizards into special chambers that measure oxygen consumption. They record the reptiles' feeding rates, and heat and cool them to find the temperature range at which they remain active. Over the next few years, Angilletta will collect such data from eight different lizard populations.

Once he knows whether lizards collected from different environments have different sensitivities to temperature, he will present the data to Buckley, who will use it to model the species' environmental ranges. "It takes a lot more time than gathering data from the literature," Angilletta explains. "The mechanistic modeling is obviously going to take more data because you can't just get the data from museum records online. You have to collect data on physiology, which is expensive and time consuming."

The time-consuming data collection will hopefully give the ecologists a basis for modeling the extent to which the lizards are able to adapt to their environment. Buckley says that the physiological data is important because it indicates the ability of an organism to change: "We're trying to model the process of evolution, but as a first step, we are examining how the variation in physiology across an organism's distribution allows it to live in a diversity of environments."

The group aims not only to produce a good mechanistic model for how lizards respond to climate change, but also to get a sense of how many variables a model needs in order to be predictive. Too few variables make a model inaccurate, while too many make it impractical. Using Angilletta's data, the group will test three models of varying degrees of complexity, the practical and the predictive. All three of the models represent radical departures from the traditional climate-envelope models. Buckley illustrates the radical departure in a paper that will soon be published in *American Naturalist.* In the paper, she compares a mechanistic model with a climate-envelope model by using each to "predict" the current distributions of North American lizards. The maps in the paper reveal a significant difference between the old and new models, and higher overall predictive success for the mechanistic model. Buckley explains that the paper demonstrates that considering a lizard's biology is important when predicting its distribution. "A central goal of the group's research," she writes, "is to incorporate more biology, such as how organisms interact, move, and evolve, into distribution models."

Buckley is also leading a broader, multidisciplinary collaboration of about a dozen researchers aiming to produce mechanistic distribution models for organisms as diverse as plants, fish, birds, and mammals. The group will meet twice a year at the National Center for Ecological Synthesis in California and the National Evolutionary Synthesis Center in North Carolina.

They hope the distributional models will be available to other ecologists by October 2009. "All the people who are independently working on mechanistic modeling are going to be in tune with one another, which I think is very cool," Angilletta says. "If the exercise turns out to be useful and can show that these mechanistic models are more valuable than, say, a climate-envelope model, the way of thinking will spread and other people will go out and tailor the math to their particular systems."—*Jenna Beck*

BELOW: Range predictions for the fence lizard vary when including population body size (green), population body size and life history (blue), and with a 3° C temperature increase (red).