Portrait by Ken Richardson

By Brendan Borrell

Grounded.

As climate change sends species scrambling, conservation finds its anchor in geology.

THE CHALLENGE
Global warming is rearranging our ecosystems.

Habitat boundaries and migration patterns are shifting.

Many plants and animals are moving to escape the heat.

THE RESPONSE
Scientist Mark Anderson (left) is looking at landscapes to find natural strongholds.

Mark Anderson is surrounded by maps. He has maps of wetlands and waterways, ridges and valleys, pastures and forests. He has geologic maps that look like watercolors, with pastel pinks and blues swirling from Maine to Alabama, and maps showing habitat disruptions in pointillist detail. They curl up next to the origami moose in his bookcase. They pile up on his desk, next to his latest scientific paper. They plaster the outside of his cubicle, partially obscuring his name and his title, director of conservation science for The Nature Conservancy's Eastern United States division.

Of all these maps, there's one in particular that Anderson and his team have agonized over. It shows all the Conservancy's preserves, easements and land purchases in the eastern United States, more than 6 million acres in total, plotted in green and brown and protected for years to come. In fact, Anderson was one of the field ecologists who, in the early 1990s, came up with a strategy to identify the best places for the Conservancy to protect distinct examples of ecological communities. "Everything was based on the location of where species were at that time," he says. "Then climate change comes along and—whoa!—everything is moving."

Since 1880, average global temperatures have increased 1.5 degrees Fahrenheit, and scientists project that they will rise at least 2 more degrees by the end of the century. This warming trend has led to many ecological shifts. Some species are moving north—or up in elevation—in search of cooler habitat, while others, including invasives, fill the void. Flowers are blooming earlier in the spring and birds migrating south later in the fall. Extreme weather events such as epic droughts and storms are expected to become more common, threatening species that are already struggling to survive.

All this change raises a troubling question for the Conservancy: Even if it has set aside land with the highest levels of plant and animal biodiversity today, how can it guarantee that such a rich ecological community will remain there a century from now?

The answer may be found between the contour lines of Anderson's maps. He champions an unconventional approach to conservation, one that focuses more on the stage than on its actors.

"Species are really tied to physical properties of the landscape," he says, explaining that landforms and elevation play a big role in determining biodiversity. Protecting the most diverse landscapes will help protect biodiversity by offering plants and animals the greatest number of options to cope with a changing climate. He calls these places resilient sites.

His research offers good news for the Conservancy: About half of its preserves rank high on his resiliency scale. And the research will also serve as a helpful signpost for future conservation priorities.

In many ways, Mark Anderson has spent his entire life thinking about resiliency. Now in his 50s, Anderson grew up south of Denver and watched firsthand as some of his old haunts gave way to suburbia. During college he became interested in conservation while working summers at an outdoor school in the Sangre de Cristo Mountains, and he went on to pursue his Ph.D. at the University of New Hampshire.

It was there that he started pondering just how large a plot of forest needed to be to preserve all its species and

HIGH-END REAL ESTATE: Uninterrupted landscapes with lots of ups and downs—like the wind-carved sandstone outcrops of the Conservancy's Bear Rocks Preserve in West Virginia (top), or the granite slopes of New Hampshire's White Mountains—will weather climate change better than flat, fragmented landscapes. As habitats heat up, species can move to higher or more sheltered areas.

NATURAL STRONGHOLDS: Mark Anderson and his team of scientists analyzed the entire eastern United States to see which landscapes offer the most potential for species to adapt as the climate changes. They looked at factors such as geology, elevation, wetland density and habitat connectedness to identify hot spots of resilience. The research will help guide future conservation priorities.

functions indefinitely. He examined historical records in New England, mapping the effects of extreme events such as tornadoes and ice storms. Finding that rare, devastating events could wipe out up to 3,500 acres in one fell swoop, Anderson argued that New England forest reserves needed to be at least 15,000 acres. Even before he turned in his dissertation in 1992, he was offered a job with the Conservancy.

For many years, Anderson's warnings seemed overstated. Then, on June 1, 2011, six tornadoes struck New England, including one that tore through Massachusetts with 160-mile-an-hour winds. The Conservancy's Massachusetts conservation director, Andy Finton, went out to assess the damage at the Brimfield State Forest, a reserve established with the Conservancy's guidance. "The hair stood up on the back of my neck," Finton says. A swath of forest, 39 miles long and half a mile wide, had been leveled along a path that went straight through Brimfield. "It was exactly what Mark had talked about," he says. Luckily, enough standing forest remains in the preserve and surrounding area that it is bouncing back.

By 2008, Anderson was thinking about resiliency in bigger terms, wondering how to succeed at conservation under the looming threat of climate change. The leading approach by ecologists has been to try to predict where individual species will end up in 50 or 100 years. That might make sense for conserving certain charismatic and endangered species—such as wolverines or Atlantic puffins—but how do you protect an entire ecosystem? Anderson realized that if scientists' projections about the climate were off just a little bit, and if their predictions about how species would respond to these changes were also off just a little bit, they might be protecting the wrong places.

He decided to take a step back and look at the drivers of biological diversity in 14 eastern U.S. states and three Canadian provinces. When he plotted the number of plant and animal species against different environmental features, one factor stood above the rest: geology. His research found that states with a greater variety of bedrock types hosted greater biological diversity. And the presence of specific types of bedrock, such as limestone, gave them an extra boost in the number of species.

Anderson's training had taught him the basic ecological tenet that specific species are tied to the landscape. The Tennessee cave salamander needs limestone caves. The serpentine aster grows only on certain serpentine soils. But the relationship Anderson uncovered between diversity and geology was so striking, it led to a kind of epiphany.

"Climate might change the details of which species are in a particular region, but what's really driving the overall number of species is the number of different environments they have," he says. "If we want to conserve all the diversity in the Northeast in a continually changing climate, we have to make sure we have a conservation based strongly on geology."

To demonstrate what he means by this, Anderson pulls up a satellite image of the New Jersey Pine Barrens on his laptop: a sandy coastal plain dense with pine forests and a winding network of dark, slow-moving rivers. It's hard to believe that such a wilderness exists less than 100 miles from the skyscrapers of New York and Philadelphia.

Both the New Jersey Pine Barrens and nearby Delaware have the same type of geology—coarse sediment deposited on the plain by ancient glaciers. But the two areas make for a stark contrast. Delaware is flat and fragmented by roads. "It's vulnerable to climate change," Anderson notes. By contrast, in the New Jersey Pine Barrens, where the Conservancy holds several preserves, including the Forked River Mountain Preserve, the landscape is rippled with uninterrupted hummocks and ridges that give species access to a wide variety of microclimates. In other words, it's more resilient. "A hundred years from now, these two areas are going to diverge," he says.

> If scientists' predictions about how species would respond to changes were off just a little bit, they might be protecting the wrong places.

To help the Conservancy prepare for such changes, Anderson and his team have analyzed the entire eastern United States in terms of resiliency. His maps highlight the areas that have the greatest amount of topographic complexity, such as the shady slopes, moist flats and hilltops that provide options for, say, ferns in need of humid soil or salamanders hunting for cooler climes. Since these options are useful only if they are accessible, the analysis also looked at how well connected these habitats are to one another.

Anderson has discovered that about 47 percent of the land the Conservancy has already protected in the eastern United States ranks above average in resiliency.

Q&A

Lynn Scarlett led the Interior Department's first Climate Change Task Force while serving as deputy secretary from 2005 to 2009. Last year, she joined the Conservancy, where as managing director for public policy she helps assess the effects of climate change on conservation efforts.

Q: With weather patterns changing, sea level rising, and species moving into new regions, what do you think conservation means today?
A: For most of the 20th century, we thought of conservation in terms of islands of protected areas: "Here's an important spot. Protect it." In this era of rapid change, those anchor places may be important, but we also need to be thinking about connectivity. We want places that are connected both by latitude and by elevation, so that species have an opportunity to move if changing habitat conditions necessitate that. We need to work across communities and incorporate entire landscapes and watersheds in our plans.

Q: Reducing carbon emissions depends on developing renewable energy. How can we do that without threatening species and ecosystems?
A: It gets back to the "whole systems" approach. Let's look at a great big space, identify places with high solar or wind energy potential, and ask where those overlap with critical water supplies and places of high biodiversity so development can be steered accordingly. These are things we're doing both here in the United States and as far away as Mongolia.

Q: How does the Conservancy help influence public policy about climate change?
A: I think our environmental agencies have gone through a transformation in the past decade or so: Climate considerations are now stitched into everything. The Conservancy has been really influential in that process because we have a huge group of scientists who can help understand these challenges. We also have a great history of partnerships on the ground. When you put together our science, collaboration and strategic investment capacity, the Conservancy positions itself as a leader in helping public agencies and others figure out what to do and where to go.

However, he has also identified geological "stages" that are underrepresented in the Conservancy's portfolio. For example, areas with chalky, limestone soil often harbor high diversity but have largely been converted to agriculture because they are so fertile.

Rodney Bartgis, the Conservancy's West Virginia director, has been using Anderson's resiliency analysis to target protection and restoration efforts in forests that overlie limestone soil (see "Flying High," April/May 2014). Recently, his team acquired a 555-acre conservation easement that connects two larger blocks of land in the Monongahela National Forest. "The positive impacts of making investments in these places are going to be long-lasting," he says. This easement not only scores high in climate resiliency, but also increases habitat connectedness throughout the region.

Others outside the Conservancy have also been drawing on the mapping tools created by Anderson and his team. "It has given us an important way to think about resilience in the Northeast," says Andrew Milliken, an ecologist who leads the North Atlantic Landscape Conservation Cooperative for the U.S. Fish and Wildlife Service. "For me, it's always made a lot of sense."

What Anderson finds most gratifying is the spread of his resiliency approach to other organizations and government agencies. The Doris Duke Charitable Foundation supported Anderson's initial mapping in the Northeast and Middle Atlantic, which was published two years ago. He has since expanded the effort to include the Southeast. Last year, the foundation established a $6 million fund to protect climate-resilient sites in the Northeast and help 1,500 local and regional land trusts use Anderson's tools. "Our initiative is about moving the science into mainstream conservation practice," says David Ray of the Open Space Institute, which is charged with managing the fund.

CLICK

To read Anderson's scientific papers and to see more maps, visit: nature.org/resilience.

Meanwhile, Steve Buttrick, the Conservancy's director of conservation science in Oregon, has been adapting the resiliency analysis to the Northwest. Scientists are also working on maps for northern California and even China.

After 23 years in Boston, Anderson can't help turning to a baseball analogy to explain the long-term benefits of approaching conservation from the ground up. In his telling, the geology of a region is like the baseball diamond, which stays the same season after season. The species are the players, which are constantly changing and moving to different teams. Although there may be times when conservationists need to focus on specific players, they should ultimately be more concerned about protecting the fields. "As much as we like the players, we know they won't stay the same forever," Anderson says. "They are going to move on." ▪