METRO PULSE

17,000 Species in the Great Smoky Mountains. And Counting.

A project to identify every living thing in the national park has a lot to show for its first decade of work. But where does it go from here?

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You won't see a tardigrade even if you step on one, or 100. The microscopic, eight-legged creatures are only about a half-millimeter long. Yet they are part of the most ambitious scientific endeavor in East Tennessee since the Manhattan Project.

Tardigrades live in wet places like mosses and beach sand. Because of their sectioned, steamer-trunk body and ambling gait, they are colloquially known as water bears or moss piglets. (Their name comes from *tardigrada*, Italian for "slow walker.") But they are among the hardiest life forms on the planet. They depend on fluids for survival, which they extract from plant cells and smaller organisms by piercing the walls with tiny fang-like stylets and sucking out the contents with their tubular mouths. When there aren't fluid sources around, they do something remarkable: They shut down their bodies in a process scientists call cryptobiosis. Curling up into a tiny ball, and filling their cells with a protective, synthesized sugar called trehalose, tardigrades can reduce their metabolic activity by about 99.99 percent. When they next encounter moisture, they can come back to life in just a few hours. Tardigrades have been resuscitated from dried moss that had been sitting in a museum for more than 100 years.

Just as dazzling as their endurance is their range. They have been found 20,000 feet up in the Himalayas, and 13,000 feet down in the ocean, in polar seas and equatorial dunes. And, not surprisingly, in the Great Smoky Mountains National Park. With its abundance of mosses and lichens, and its 55 to 85 inches of rain a year (depending on elevation), the park is a tardigrade's paradise. But if it is easy to assume a widespread and persistent tardigrade population, it has until recently been hard to know much about them. Unlike the park's real bears, whose population is closely tracked, its little water bears went unstudied for decades.

"Before we started, there had only been one published record of tardigrades in the park, and there were three species," says Paul Bartels, a biology professor at Warren Wilson College outside Asheville, N.C. "Now there are 78 species."

The other 75, including 13 previously unknown to science, were identified through years of painstaking work by Bartels and about 50 of his students. How the intrepid undergrads came to be in the Smokies, gathering moss in a literal rather than metaphorical way, is a small part of a much larger story.

It is called the All Taxa Biodiversity Inventory, an overly technical title for a mind-boggling effort. Its significance starts to sink in if you know that Taxa means, basically, biological groups or families, flora or fauna. Any order of living thing. The All at the front end of the name means exactly what it says, as does Inventory. And the third word, Biodiversity, is really the key to the whole effort. The ATBI, now in its 14th year, is an attempt to count and catalog every species of anything living in the Great Smoky Mountains—and to understand how they relate to one another.

That includes the obvious ones everybody knows, the hemlocks and beeches and ash trees and firs, the deer and the trout and the synchronous fireflies. But it also includes the things the average person can't see or doesn't care about: the worms in the soil, the beetles in the leaf piles, the slugs and the snails, and all of the things that those things eat, or that eat them. It includes invasive species like the wooly adelgids that are killing acres of forest with their tree-weakening toxins. And it includes the endangered and the vanishing, like the Indiana bats, threatened by white-nose syndrome, and the furry spruce-fir moss spider, a victim of lost habitat as the park's Fraser firs have fallen prey to pests.

"The problem that parks and natural areas have all over the world is that we only know a small fraction of the species that occur in each one," says Keith Langdon, a Park Service biologist who is in charge of inventory and monitoring for the Smokies. "In places where we have a mandate to protect everything, we need to know what's there."

To date, the ATBI has racked up some impressive-sounding numbers: The number of known species in the park has nearly doubled, from 9,511 to 17,527, and research has so far identified 910 species new to science (including Bartels' tardigrades). The count includes about 3,000 different kinds of beetle, alone. Langdon says that more than 1,000 scientists have been involved, either in field or lab work. And 19 sample plots scattered around the park's 800 square miles have been plumbed in detail from the soil to the treetops. The Great Smoky Mountains is often touted as the most biodiverse national park in America, and its range of elevations and habitats is the reason. As one scientist says, you can study environments from Arkansas to Canada without leaving its boundaries.

But the work is far from finished, and it is getting harder. The funding that got the ATBI started has largely fallen off, and people to do the hands-on research are increasingly difficult to come by. It turns out that for all its scope, the kind of work the project demands is not, in a lot of ways, the kind of work that modern science most values and rewards.

"What happens when the hopeful, impossible task runs up against pragmatic reality?"

Bartels says. “That’s the question.”

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In a way, the ATBI seems like the ultimate realization of the classic scientific impulse to sort, categorize, and record the world. From Aristotle’s attempts to classify species (he came up with 540) to the Renaissance zoologist Conrad Gesner’s magisterial *Histories of the Animals* to the explosion of modern biology in the 19th century, there has been a persistent expansion and refinement of human understanding of the life around us. The ATBI, with its digital databases, its cabinets full of plants and animals, and its thousands and thousands of microscope slides, aims for a comprehensive account of one place on the map. An updatable, cross-referenced Book of Creation for the Great Smoky Mountains.

The old-fashioned ambition of the project presents some serious challenges, though. There are, first of all, the unforgiving terms of the mission: Count everything. The name says All, not Some or Most. There is the problem that the natural world does not stand still. Every count is a snapshot of this year, this organism, this place. One of the hopes for the ATBI is that it will make it easier to understand the effects of forces like climate change, air pollution, and invasive species. But those forces are already at work, which means that things already counted have to be monitored and revisited even as the search for new species goes on.

There is the constant question of financing. The project operates with a tiny staff and small pockets of grant money for visiting scientists. And there is that old-fashioned ambition itself. As biology has become increasingly a realm of molecules and genomes, there is less interest in merely observing and classifying.

“A lot of these people are dying off, not being replaced by new generations of authorities,” Langdon says.

Langdon looks like an old-fashioned scientist himself, his trim gray beard and handlebar mustache giving him the bearing of a gentleman about to address the Explorers’ Club. And the ATBI was his idea, or at least doing it here was. Alarmed by threats from assorted invasive species in the 1990s, he reckoned that the only way to measure their impact on local flora and fauna was to first know everything that was out there.

“We found out about a project in Costa Rica that was trying to do that and failed,” he says, sitting in the park’s Twin Creeks Science and Education Center. Behind him, big windows look out on a wooded hill, the trees bright with October color. “So this is the second attempt.”

That first project was spearheaded by Daniel Janzen, a prominent ecologist at the University of Pennsylvania. Janzen, who specializes in butterflies and moths, has spent much of his professional life working in Costa Rica’s Area de Conservación Guanacaste, a national park in the country’s northwest corner. Reached by phone at his university office, after just returning from Central America, Janzen says the ATBI

concept came out of a 1993 meeting of scientists in Philadelphia. They were wrestling with the question of how to figure out what actually lived in large, protected areas—not just out of their own professional curiosity, but as a public service.

“In order to make them be, shall we say, user-friendly for society,” Janzen says, “so that society can go to them and use them and make use of what’s in them, we need to *know* what’s in them. It’s just like a library. If a library’s got a huge number of books, but nobody knows what they are or where they are, what good is a library? It’s just firewood.”

That 1993 meeting proposed a model that became the first ATBI effort, led by Janzen and some colleagues (including his wife and collaborator, Winnie Hallwachs) in Guanacaste. But after rounding up $25 million from government science funds around the world to start the research, they saw the money reappropriated for other conservation efforts after a new administration came to power in Costa Rica. “The lesson we learned was that, if you’re going to do something like this, you need to raise the money in some way that is not controlled by the political process,” Janzen says.

Langdon, who flew down to Costa Rica to meet Janzen a few years later, kept that lesson in mind. When he called together 120 scientists and educators in Gatlinburg in 1997 to talk about starting an ATBI in the park, the first result was the creation of a separate, nonprofit organization to manage the project. Discover Life in America was formed in 1998, with start-up funding largely from the park and its affiliated nonprofits, the Great Smoky Mountain Association and Friends of the Great Smoky Mountains National Park. It is a small operation with just two full-time staffers: a data manager, who organizes and categorizes the massive amounts of information collected by researchers since work started in earnest in 2000, and an executive director. The latter position has been filled for the last four years by Todd Witcher, a robust, bearded outdoorsman who previously taught high school biology and was an educator at Ijams Nature Center. His office is a small house behind the science center, crammed with file folders, maps, reference books, and the accoutrements of field work.

“I basically write grants and deal with the scientists and try to raise money and work with the park,” Witcher says. His job includes everything from trying to find someone with a boat to take visiting researchers across Fontana Lake to hosting monthly “sorting events,” where volunteers come in and help organize specimen samples into groups for later study.

For several years, with budgets between $200,000 and $300,000, Discover Life provided mini-grants to bring in specialists in particular areas for a few days or weeks of research. That’s fallen off recently as the park has directed money to more pressing needs: “Trails falling down the mountain, hemlocks, getting water quality data,” Langdon offers as examples. So Witcher is looking for new sources to keep the inventory going.

"We're still in the throes of figuring that out," he says. "Where our best funding sources are, how to survive hardships like we're going through right now." He's hoping for a bump in local and national recognition next March, when the renowned biologist E.O. Wilson comes to deliver the keynote address at Discover Life's annual conference.

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"So this is the park," Nate Sanders says, pointing to a computer screen in his lab at the University of Tennessee's Knoxville campus. "And the redder colors show you where there are more individuals of this species. Like here, for the hairy woodpecker, it's most common on these high elevations and ridgetops. But then the downy woodpecker is most common in Cades Cove."

The screen shows dozens of tiny maps of the Great Smoky Mountains National Park, with the park's familiar topography in blue, spattered by blobs of red and yellow. Each map documents one species of bird or tree. "And so one of the things we're working on doing is essentially stacking all of these maps up," Sanders says. "So then you can say, where white ash occurs, is that also where the indigo bunting occurs?" (The indigo bunting is a small, migratory bird, with males of the vivid color indicated by the name.) "And are the places that have lots of different trees the same places that have lots of different birds?"

The maps were compiled by a UT post-doctoral student, and they're just one of many projects Sanders and his students have undertaken as part of the ATBI. Sanders is an ecologist who specializes in biodiversity, and when he arrived at UT in 2004 from Humboldt State in California, one of the first things he did was get in touch with Discover Life in America. "At the time it was the only thing like it in the world," he says. "It was a great opportunity."

Sanders is doing what you might call second-level ATBI work: Taking some of the data already collected on those 17,527 species and trying to understand what it means. "What we've done is try to figure out why species are where they are," he says. "One of the things we focused on early on is, how does temperature relate to biodiversity?" Warmer places tend to have more species than colder places. So what, Sanders asks, are the implications of climate change for any particular location? If, for example, new species start to move into an area because it is now warmer than before, what will that mean for the species already there?

"One pretty cool example is that most of the plant species that you see in the Great Smoky Mountains National Park rely on ants to disperse their seeds," Sanders says. "So one of the things we did was just put out seeds and look at what happened to them. And 166 out of 167 times, one ant species carried the seed away. So even though there there's a lot of biodiversity in the Smokies, there's some species that do a lot." If one of those super-species was threatened by changes in its habitat, it could have wide-ranging consequences.

About a 10-minute walk from Sanders' lab is Ernest Bernard's office in the Plant Biotechnology Building, on UT's Agriculture Campus. As the drawings of hairy bugs on a drafting table by his desk indicate, Bernard specializes in small, scrabbling things. He has been involved with the ATBI since the kick-off meeting in 1998, and served eight years on the Discover Life board of directors (he was board chair for three of those years).

"When we find increasing biodiversity, it means we have increasing links between all of these species," Bernard says. "The web of life out there is much more complicated. Every species you add in, you add in another set of interactions with everything else."

At the ground level, he has concentrated on some of the park's least-visible inhabitants: tiny, six-legged creatures called springtails that are insect-like but not technically insects; nematodes, better known as roundworms; and protura, eyeless, wingless crawlers less than 2 millimeters long.

"We know a lot about the big, conspicuous species," Bernard says. "We know very little about the small, inconspicuous ones. And yet these species probably have, as a whole, important functions in the maintenance of healthy ecosystems."

The scrutiny has yielded plenty of discoveries. In springtails alone, Bernard has more than quadrupled the number of species identified in the park, to 240, and 60 of those were previously unrecorded anywhere.

"This project always surprises me," he says. "Once we started looking closely at some less disturbed areas of the park, we began finding species of soil insects whose closest relatives are in South America. From some grasslands down near the southern end of the park, near Cherokee, we had a springtail that its closest relatives are in Europe."

The scientists involved in the early ATBI meetings made a back-of-the-napkin guess that the park might have 100,000 species. But 11-plus years of work haven't pushed the total to anywhere close to that. "That 100,000 figure has stuck with us and haunted us," Langdon says. "But there's no scientific basis for that. We're at 17,000. So if it was 100,000 and we went out and collected 10 species at random, you'd think eight of them would be new to the park. That's not what the way it is. So I think it's a lot less than that. On the other hand, there are some groups that we haven't even scratched yet."

The ATBI has made some progress by recruiting volunteers. That's how Bartels got involved. A retired professor at East Tennessee State University had agreed to look at tardigrade samples from the park, if someone else would collect and sort them. Bartels had read about the ATBI and thought it would be a good project for his students. When he called to volunteer, he was assigned tardigrades. Over 10 years, his students have collected 15,000 specimens.

"We've developed a key to all the tardigrades in the Smokies that's an online, easy to use key," Bartels says. "So anybody that wants to go in now and do ecological work or

assessments of whatever impacts they're interested in, now has a tool that they can use and do that. They don't have to start from scratch."

Thirteen of his students have done their senior research projects on aspects of the project, and a few have been inspired to do graduate work in the same area. It is just the kind of outreach Janzen envisioned as part of the ATBI concept, a way to open up science and nature to anyone. Bartels says, "It's really exciting for students to realize that we don't know everything, we're really ignorant, and that there's a lot to be discovered."

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Todd Witcher is standing in a hillside forest high up in the Smokies, off a trail between Newfound Gap and Clingman's Dome. All around him are the smooth, gray barks of beech trees. This is a beech gap, interrupting the march of fir trees above 5,000 feet, one of several such islands scattered through the park. They tend to occur in dips on south-facing slopes, and because they are isolated from each other they provide readymade study sites.

Specifically, the park is concerned about the spread of beech bark disease, a one-two punch delivered by an insect (the beech scale, which bores into the trees) and a fungus (which invades the holes left by the scale). This particular gap is so far free of the disease, which is why it's one of three being rigorously studied in the ATBI.

"One of the urgencies is before infestation, to have a baseline of what's supposed to be here, and what could be lost," Witcher says. Trained volunteers come up here in spring, summer, and fall to collect samples of insects on the bark and anything in the surrounding leaf litter of eight designated beech trees (and eight non-beech "control" trees).

The study hints at the long-term goals of the ATBI. Even if a truly complete inventory was completed, the threats to the park's many ecosystems would mandate continual revisits and resampling.

"In the inventory, we're finding out what's there," Bernard says. "But equally important then is monitoring. Being able to go back and check and see if changes have occurred."

But that will require ongoing resources. Witcher says Discover Life's board, originally heavily populated by scientists, is diversifying to focus more on fund-raising. Some participants are getting creative; in one program, scientists are offering to name some of the abundant new species after generous donors. (Bernard has already led the way, naming a new springtail with a purplish, spotted back for the Tennessee senator who helped secure some federal financing for the project. As of 2006, the park is home to Cosberella lamaralexanderi.)

All the challenges notwithstanding, Janzen says he hopes more parks around the United States and the world undertake ATBIs in coming years. "China talked about

doing a project, but I don't know if any ever happened," he says. "Sweden is basically doing an ATBI of the whole country. Aside from that, I can't name another place that has taken on the whole thing seriously."

One thing working in the concept's favor is technology. The computing power necessary to sort and store all the data is much cheaper and more accessible than it was when Janzen first tried to plan an inventory. There's also the potential to equip future volunteers and scientists with instant identification tools. "Everybody walks around with a cell-phone camera now," Janzen says. "Today it's much easier to turn a person into being a biodiversity inventory person, just with the tools they have in their pockets."

However the ATBI continues, scientists involved in it share a conviction that its continuation is crucial—to understanding what is in the Great Smoky Mountains, and where and why, but by extension also to understanding more about life everywhere on the planet.

"One of the big questions is, if you understand one thing, do you understand many other things?" Sanders says. "Everyone who's worked there has worked on their favorite group of organisms. Now that I think that I understand something about the ants, does what I've learned there apply at all to the lichens? I don't really know yet."

He adds, "I think it's just been an incredible test bed to understand the diversity of life on earth."
