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Profile of Monica G. Turner

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In October 1988, ecologist Monica Turner rode in a helicopter over Yellowstone National Park and glimpsed the aftermath of unprecedented destruction. Earlier that summer, a severe drought triggered the largest fires the region had seen in two centuries, and by the time the fires abated, over one-third of the park had been consumed by the flames. As Turner flew overhead, looking at the charred, and in some places still smoldering, landscape, she did not see desolation and death. Instead, she saw transition and rebirth.

The Yellowstone fires gave Turner, the Eugene P. Odum Professor of Ecology at the University of Wisconsin–Madison (Madison, WI), a grand opportunity. A few years earlier, Turner had joined a nascent scientific movement termed landscape ecology, a subdiscipline of ecology and geography examining the large-scale relationships among the land, its resources, and the organisms that inhabit it. Turner was particularly interested in the dynamics of heterogeneous landscapes, such as what causes spatial patterning and how it is important ecologically, and the fires at Yellowstone presented a natural experiment unfolding before her eyes.

"I was expecting that the fire damage would be uniform," says Turner. "Instead, I could see this rich mosaic of burnt and unburnt patches next to each other. These were exactly the types of patterns that I could generate with computer models." Turner has made frequent return visits since 1988, and much of her research has examined the numerous players involved in the fire recovery process. These factors include growth and competition among reestablishing plants, the movement and foraging patterns of elk, and whole-system carbon dynamics. "As a landscape for study, Yellowstone has just been phenomenal," says Turner, "and I think that our work over the years has shown how well adapted the landscape is to these major fires. They are not ecological catastrophes by any stretch of the imagination."

In her Inaugural Article in this issue of PNAS (1), Turner, elected to the National Academy of Sciences (NAS) in 2004, looks at processes driven by some of the smaller, but no less important, Yellowstone inhabitants: microbes. Turner and her colleagues discuss how a severe fire affected nitrogen availability in the soil, noting that for the first few years post-fire, microbes turn the ground into a nitrogen sink, principally through extensive ammonium immobilization.

Monica G. Turner

Birth of a Movement

The suburbs of Long Island just outside of New York City, where Turner grew up, may not seem like the ideal setting to raise a nature lover. However, frequent summer camping trips across the northeastern United States spurred in Turner a fascination with the outdoors. By the time she started college at Fordham University (New York, NY) in the Bronx in 1976, Turner had narrowed down her career aspirations to becoming either a veterinarian or a forest ranger. Fordham's biology program was oriented toward premedical studies, so Turner did not attend many classes that could help her decide between her two career choices. However, the summer between her sophomore and junior years, she found an opportunity to work for the Student Conservation Association and was placed in Yellowstone National Park as an interpretive ranger.

"I had never been out of the northeast before that," she says, "but the experience was just phenomenal. I was stationed at Old Faithful, and had to give the evening campfire talks and the Twilight on Geyser Hill walk and also work in the visitor's center. By the end, I had learned so much and loved it that I decided against the veterinary path and to pursue something in ecology."

Convincing others of this idea was a bit more difficult, as Turner recalls. Her undergraduate department chair tried to steer her toward medical school, saying there were no jobs or money for ecologists. Undaunted, Turner applied to graduate ecology programs, including the University of Georgia (Athens, GA), where Eugene Odum, a pioneer in ecosystems research and author of the classic textbook *Fundamentals of Ecology* (2), was a professor. Turner actually overlooked University of Georgia's acceptance letter in her mail and initially decided to attend Boston University (Boston, MA), but when she later received a call from the University of Georgia asking whether she would like to visit the campus, she decided to go. "And I just really enjoyed it," she says. "I was so impressed with all the work that was going on down there that I changed my decision quickly" and attended the University of Georgia.

Although the campus, ecology program, and faculty at the University of Georgia greatly impressed Turner, the thought of long years of graduate research was not particularly appealing. Her first taste of independent research had been her senior honors thesis on phytoplankton growth in Long Island Sound, which primarily taught her that she did not like sitting in front of microscopes. "When I started graduate school, I really just wanted to teach at a small college and be a park ranger in the summers. I was going to do the research only because I needed to in order to get the degree," she confesses. But as she progressed through graduate school, her attitude began to change.

The change partially arose from her dissertation work on the interactions between wildfires and the grazing of feral horses on Cumberland Island National Seashore in Saint Marys, GA (3). But another factor was the start of the new ecological movement of landscape ecology. "In the early 1980s, landscape ecology was emerging in Europe, and my doctoral advisor, Frank Golley, was one of the few U.S. scientists who attended some of their meetings," she says. "Whenever he came back, he would tell all of us about the goings on." Turner was enthralled by the concepts of this field, and after finishing her Ph.D. in ecology in 1985, she stayed at the University of Georgia as a postdoctoral researcher. She worked with Odum to examine the changes in land use in the Georgia landscape, one of the earliest U.S. landscape ecology studies (4, 5).

Together with Golley, Turner helped organize the first American meeting for landscape ecology in 1986. "This was an exciting moment," she says, "because for the first time ecologists from different places came together to meaningfully consider what it means to have spatial variation in the environment and what implications this has for the functioning of ecosystems, the movement patterns and survival of organisms, and community-

This is a Profile of a recently elected member of the National Academy of Sciences to accompany the member's Inaugural Article on page 4782.

level interactions. I was lucky to have my interests coincide with the beginnings of this new way of thinking."

Initially however, this new direction of study hit a few bumps in the road. "Many early studies were difficult to publish," says Turner, who wrote an article favoring landscape ecology as a discipline (6). "People called it pseudoscience because of the absence of replicability, and reviewers would say it's impossible to do ecology at these scales." One of Turner's own papers on how the size and timing of disturbance events could affect landscape equilibrium was rejected three times before being published (7). Two decades later, as Turner prepares to host the upcoming 2008 Landscape Ecology meeting in Madison, WI, she has an opportunity to reflect on the growth of this discipline. "It's certainly taken off quite well," she says, echoing her review in the journal *Landscape Ecology* (8). "Now you can find it spread across ecology. If you go to ESA [Ecological Society of America] meetings, landscape ecology is everywhere."

Return to Old Faithful

In 1987, Turner completed her postdoctoral research and moved to Oak Ridge National Laboratory (Oak Ridge, TN) in eastern Tennessee as a staff scientist. Perhaps underscoring the allure and unpredictability of science, Turner, who just a few years before had envisioned teaching at a small college, was now engaged in full-time research at a large institute. "It was a fabulous time. I was there for 7 years, and during that time our group developed some of the important simulation models and key concepts in landscape ecology, things like the fact that you can have thresholds in the connectivity of habitats across landscapes, or a series of predictions we made for species movement patterns and the spread of disturbances," she says.

While working on a theoretical model on how heterogeneous landscapes influence the movement of disturbances (9), Turner reconnected with Bill Romme, who she had first met at the inaugural landscape ecology meeting. "I was interested in finding a real landscape in which to study my model, and Bill had done all the fire-history work at Yellowstone. His work was some of the first that applied quantitative measures used in species diversity toward landscape," she says. The two agreed to collaborate and use his data with her model. But when she flew out to Yellowstone in 1988 to meet him and tour the park, she saw the fire damage and realized that they had been given a fresh palette to work with. The Yellowstone fires would provide study opportunities and surprises for years to come.

One of Turner's major projects in Yellowstone was examining the regrowth of lodgepole pine, the dominant tree species in the park. When Turner, along with Romme and Bob Gardner, set up their early studies, they picked three geographic sites that were expected to serve as replicate locations. Instead, they unwittingly captured the spectrum of an unusual gradient in seed abundance. "Lodgepole pines have a trait in their cones known as serotiny," explains Turner. "The cones stay closed until they're heated by a fire, at which point they release their seeds. So the trees store their seeds in the canopy." It seemed natural that the study patches, all burnt forest, would come back in a similar fashion. "Instead, we had areas ranging from almost no trees, to areas that are so dense you can barely even walk through them," she says. Although lodgepole pines are known not to all bear serotinous cones, Turner's work demonstrated that the value could range from 0% to 100% in one region, resulting in enormous differences in post-fire tree density in what was thought to be a relatively simple ecological system (10). Although denser forests will eventually thin out and thinner ones build up, Turner notes that this significant heterogeneity in regrowth will influence the landscape for decades to come.

"I was lucky to have my interests coincide with the beginnings of [a] new way of thinking."

Another tree species provided an even bigger surprise. During the first post-fire field season in Yellowstone in 1989, Turner stumbled upon a number of unidentified plants with little green leaves that she did not pay much mind. "When we came back in 1990, some of these plants had woody stems, and we keyed them out to be aspen," she says, "and we thought, that has to be wrong, but we keyed them out again, and they were still aspen (11). We excavated some, and there were no roots. These were seedlings!" These tiny trees were startling because ecologists had been taught that western aspen have not reproduced by seed in over 10,000 years. The individual trees that come and go in an area typically share the same root system and are genetic clones.

"That led us to look at the distribution of these seedlings, whether or not the aspen could grow into new clones that might change the pattern of vegetation across the landscape, and where their parents came from," Turner says. Although elk, which love to eat aspen, and the dominant lodgepole pine will prevent most of these seedlings from reaching adulthood, Turner thinks a few may survive long enough to keep the species primed, and she is hoping to obtain additional research funding to track this cohort of aspen.

In addition to the trees and the elk that like to eat them, Turner has recently begun studying some of the less-conspicuous denizens of the park, in an effort to bring this field back to its roots. "In North America, landscape ecology evolved out of the ecosystem ecology community," she says, "but as it has grown, it's placed more of an emphasis on organisms and less on ecosystem processes, and we need to reestablish the connection between those two."

Turner focuses on the process of nitrogen recycling in her PNAS Inaugural Article (1). Examining another severe stand-replacing fire that occurred at Yellowstone in 2000 as the baseline, she looked at how nitrogen pools and mineralization varied in the first four succession years. She found that a relatively large amount of ammonium depletion occurs during this time, especially during the first year, and that microbial immobilization of ammonium plays a key role during initial succession. Considering the large scale of landscape ecology, studying microbially driven processes can be tricky and expensive, according to Turner, but it is an important piece of the puzzle of how landscapes function.

Human Touch

The pristine landscape of Yellowstone National Park provides researchers like Turner with a natural laboratory where they can study ecosystems that have encountered minimal human influence. However, a large focus of landscape ecology when it emerged in Europe was the interaction between humans and natural resources, and as North America continues its population boom, especially in the west and south, these relationships require further exploration.

"We really need more attention on how to establish sustainable patterns of development that are sensitive to both the needs of the human population and the integrity of our ecological system," says Turner. Although she enjoys her annual visits to the undisturbed wilderness of Yellowstone, she has also spent the last decade investigating land use and resource conversion in Wisconsin and western North Carolina.

As a scientist at Oak Ridge National Laboratory, Turner began a project on the spatial distribution of land use in forests of the southern Appalachian Mountains (12). She examined the counterintuitive correlation of increased population and increased forest cover. "Back in the 1800s, there was tremendous forest clearing for agriculture in these areas. Now we have forests regrowing, and people putting their houses under the canopy," she explains. After she moved to Wisconsin in 1994, she began a long-term project on lakefront development with fellow ecologist and NAS member Steven Carpenter. Turner and Carpenter are examining how clearing fallen trees from the shoreline affects the dynamics at the water's edge (13).

In the future, the human element will likely add another layer to Turner's work on ecological disturbances. "As we continue to deal with the effects of global warming, I think we are going to see an increasing frequency, severity, and range of disturbances, which will produce much more interaction," she says. As an example, she notes that many forests have experienced an increase in both forest fires and insect disturbances, such as bark beetles, in recent years. "What's the interaction there? What's the consequence for future patterns of ecosystem functioning? And naturally, what is the appropriate human response?" Turner asks.

Determining the answer to the last question undoubtedly will prove tricky, because it will require balancing the needs of humans against trends that will not prove easy to reverse. Despite this somewhat sobering thought, Turner is eager and enthused to push forward in her research. "I'm still amazed that I get paid to do what I do," she says. "I can't ever imagine doing anything else. It's so much fun, that when I'm out there, I sometimes forget that I'm not on vacation."

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