Standardized. Researchers worldwide add nutrients and measure plots the same way.

NETWORK SCIENCE

Open-Source Ecology Takes Root Across the World

A new collaboration of volunteer research sites is running simple yet powerful experiments to shed light on global change in grasslands

In 2005, a handful of young researchers in Santa Barbara, California, were fed up with their inability to answer a major ecological question by reviewing the literature. So they decided to take matters into their own hands and created a network of small experiments. In the past 6 years, the network has spread to six continents and is now poised to make substantial contributions to ecology. "We're on the edge of something big," says John Orrock of the University of Wisconsin, Madison, a network co-founder.

The half-dozen Ph.D. students and postdocs were part of a workshop at the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara. The group was investigating fundamental influences on the structure of grasslands, such as herbivory and nutrients. Trying to analyze data from far-flung places, the group was stymied by a common obstacle. "It's really frustrating because everyone does their studies differently," says Elizabeth Borer, who is now at the University of Minnesota, Twin Cities.

During a coffee break at NCEAS, Borer and a few others hatched a plan: They would each set up a small research plot, use the same methods, then pool their data. The vision was a network of sites that would be quick and cheap to set up without the need for major grants, enabling simple experiments around the world. "It's like big science on a shoestring," says Scott Collins of the University of New Mexico, Albuquerque, who later joined the network.

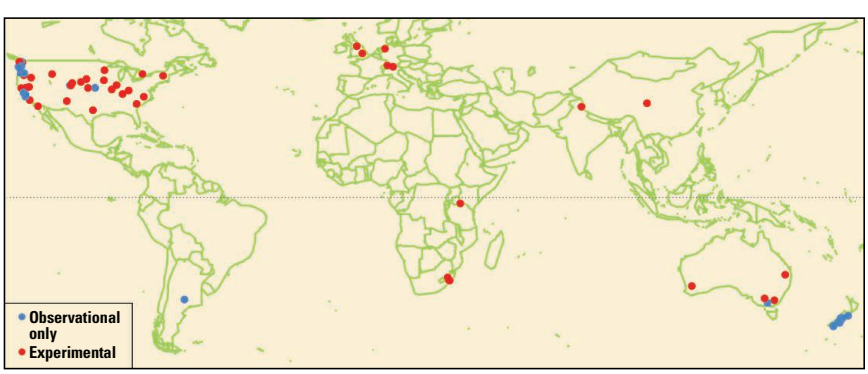
The collaboration, called the Nutrient Network—now known as NutNet—has grown far beyond initial expectations, with scientists volunteering at 68 sites in 12 countries. In part, it's popular because the simple experiments are designed to answer a broad set of questions about how grasslands respond to global change—without disproportionate effort by any one individual. "It's not a brand-new idea, but it's novel that they've pulled it off," says Alan Townsend of the University of Colorado, Boulder, who is not involved. The network also provides an easy way for young faculty members, postdocs, and grad students to get involved in a large collaboration and contribute to high-profile papers.

So far, the effort has been funded with just a single $322,000 grant from the U.S. National Science Foundation (NSF) for coordinating data and analysis, yet already the first few papers have been published over the past year. The most recent, which appeared in *Science* last month (23 September, p. 1750), challenged a long-standing idea in ecology about plant diversity and productivity. Dozens more papers are in the works, and ecologists enthuse about the network's potential for cost-effective, rapid results. "NutNet has tremendously improved on the way we've done things," says Alan Knapp of Colorado State University, Fort Collins, another ecologist who is not involved. "I've been incredibly impressed."

Keep it simple

Research networks aren't new to ecology, of course. The Long Term Ecological Research (LTER) network, for example, is composed of 26 research sites and stations, almost all in the United States, that have been collecting data for 30 years. And construction began this fall on some of the 20 U.S. observatories that will make up the $434 million National Ecological Observatory Network. These hefty networks require a fair amount of money to operate, because staff members collect hundreds of types of data, often year-round.

During the NCEAS workshop, NutNet's founders quickly sketched an alternative vision: Each researcher would conduct the same few experiments



Diversity. NutNet sites include 1747 plant taxa in many ecosystems, such as (see photos, *left to right*) subalpine grassland, alpine meadow, desert, pasture, sagebrush steppe, and savanna.

CREDITS: (TOP LEFT TO RIGHT) JOSLIN MOORE; CHENGJIN CHU; (BOTTOM) ELIZABETH BORER

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in several plots of 25 square meters. They would add combinations of three crucial plant nutrients—nitrogen, phosphorus, and potassium—and they would fence part of the plots to exclude deer, zebras, kangaroos, and other herbivores.

By measuring changes in biomass and species composition, they would try to tease apart the relative impact of herbivores and nutrients on the structure of the community. "Ecologists have been fascinated by this question for a long time," Orrock says. Moreover, the experiments simulate the impacts of anthropogenic global change. Nutrient levels have been boosted dramatically by fertilizers and pollution from fossil fuels. At the same time, humans have altered the density of herbivores in many places through farming or indirectly by hunting of predators.

"We're out to change the culture."

—ELIZABETH BORER, UNIVERSITY OF MINNESOTA, TWIN CITIES

Several attendees at the NCEAS workshop immediately volunteered to participate. One of the first was Helmut Hillebrand of the Carl von Ossietzky University of Oldenburg in Germany, who set up a NutNet site, even though he's a plankton ecologist. "I think it's the next generation of ecological experiments," he says. The site he started is located in an old field 5 minutes from his parents' house, so he drops by to collect data while visiting.

Borer and the others also invited a few colleagues to join, and the idea began to spread by word of mouth. Sensing potential, the group sent an e-mail in November 2006 to just about every grassland ecologist they knew. By the time data started arriving the next year, there were 51 sites.

Members of the network agree to submit data immediately to a central database. All participants—now about 100, including a dozen or so graduate students—have access to the data. Simply by contributing data, they can be an author on high-profile papers that address the project's big questions. The network is already making a mark: Last month's paper in *Science* showed that a textbook idea about the relationship between plant productivity and species richness in fact occurs rarely. Other key papers, based on the experimental results of adding nutrients and excluding herbivores, are still being written.

NutNet participants must propose papers on additional ideas to the whole group. The goal is to avoid duplication and allow other members to contribute to analysis or writing the manuscript. Jennifer Firn of the Queensland University of Technology in Brisbane, Australia, for example, wanted to look at invasive species in the plots. "The process of turning this idea into a paper was the best learning experience I have ever had," says Firn, who became an assistant professor in February. "I had more than 30 authors and co-authors, so it meant so much advice and expertise were available." Published in *Ecology Letters* in March, the paper showed that non-native plants, some invasive, don't all spread like the worst weeds. Instead, most species in the NutNet plots were about as common in their new environment as in their native range. That suggests that regulators of plant imports might want to focus on screening out plants that are highly abundant overseas.

Network members decide among themselves what kinds of additional data to gather. "This is like an indie garage band, a cooperative without all the top-down headaches," says co-founder W. Stanley Harpole, an assistant professor at Iowa State University in Ames. (Others make analogies to the development of open-source software or start-up companies.) Eighteen members are analyzing regular deliveries from other participants, who collect everything from soil microbes to arthropods and leaf litter. "It is simple, mail-order sampling," says co-founder Eric Seabloom of the University of Minnesota, Twin Cities. "The person in the field doesn't have to do that much."

"This is like an indie garage band."

—STAN HARPOLE, IOWA STATE UNIVERSITY

Facing the future

An all-volunteer approach may have its limitations, however. So far, the majority of sites are in the United States. Peter Adler of Utah State University in Logan, a co-founder, says the group tried to recruit scientists in South America without much success. "Maybe it's just [bad] luck," he says. Townsend expects that more researchers in less developed countries will eventually sign up, as word spreads about the network and its publications. Earlier this month, several sites in India agreed to provide observational data, and a few more will also conduct experiments.

A larger question is how long a volunteer effort can be sustained. "In absence of external funding, I fear that the good will of those individuals and their institutions may not persist," says Michael Willig of the University of Connecticut, Storrs, who is not a participant in the network. But co-founder Melinda Smith of Yale University predicts that interest will remain high as long as the network produces high-impact papers. Harpole points out that each plot has space reserved for experiments not yet planned. "We're banking for the future," he says.

The looming danger is the expiration of the NSF grant in January 2013. These funds pay for collaboration meetings and for a postdoc, Eric Lind of the University of Minnesota, Twin Cities, who runs the central database. "The death of the Nutrient Network will be when the funding for that postdoc position runs out," Adler says. The steering committee hopes to cover those expenses with future research grants for more ambitious analyses.

Even if the NutNet peters out, the founders hope it will be a model. To Borer, the success so far shows that individual scientists at any stage of their career can help answer big questions even if they haven't landed a major grant. "We're out to change the culture," she says. "The success of this model could empower other groups to address equally important ecological problems at a global scale."

–ERIK STOKSTAD

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