and no multiple sequence alignment with phylogenetic trees to interpret.

A variety of tools already exist that assign taxonomies to individual reads. But for taxonomic profiling of, say, large clinical microbiome samples, as from the Human Microbiome Project, most of these may be too slow. Segata *et al.*[1] report benchmarking MetaPhlAn against six popular methods, all alignment based, nucleotide word frequency based (also called 'compositional') or hybrid (combining both approaches). All six methods attempt to assign every read. The next best to MetaPhlAn in speed, PhyloPythiaS[2], was 50-fold slower, whereas PhymmBL[3], which was comparable to MetaPhlAn in accuracy, was several times slower yet. A competing fast method, MetaPhyler[4], is based on BLAST searches against a manually curated list of lineage-specific versions of 31 widely distributed genes, and it similarly avoids classifying most reads. It was not explicitly compared to MetaPhlAn.

Two additional recent methods, both based on statistical mixture models, illustrate evolving approaches to abundance estimation. Taxy[5] examines oligonucleotide distributions for a sample as a whole and makes clade abundance estimates for a metagenome in just minutes while making no individual read assignments at all, but its use was described only for coarse-grained divisions, to the phylum or class level. GRAMMy[6], which can build its analysis on per-read classifications made by other pipelines, claims that its mixture model greatly reduces the amount of input data needed to estimate taxonomic abundances to a desired accuracy, an alternative approach to reducing computational costs.

Methods based on 16S rRNA gene sequencing still maintain a cost advantage, and they perform better at community profiling if a significant fraction of the analyzed community has no closely related reference genome. But continual advances in tool development, falling sequencing costs and new reference genomes from underrepresented lineages make metagenomic shotgun sequencing increasingly attractive.

### COMPETING FINANCIAL INTERESTS

The authors declare no competing financial interests.

PUBLISHED ONLINE 10 JUNE 2012; HTTP://WWW.NATURE.COM/DOIFINDER/10.1038/NMETH.2080


1. Segata, N. *et al. Nat. Methods* 811–814 (2012).
2. McHardy, A.C., Martín, H.G., Tsirigos, A., Hugenholtz, P. & Rigoutsos, I. *Nat. Methods* **4**, 63–72 (2007).
3. Brady, A. & Salzberg, S. *Nat. Methods* **6**, 673–676 (2009).
4. Liu, B., Gibbons, T., Ghodsi, M., Treangen, T. & Pop, M. *BMC Genomics* **12** (suppl. 2), S4 (2011).
5. Meinicke, P., Aßhauer, K.P. & Lingner, T. *Bioinformatics* **27**, 1618–1624 (2011).
6. Xia, L.C., Cram, J.A., Chen, T., Fuhrman, J.A. & Sun, F. *PLoS ONE* **6**, e27992 (2011).


# Connecting ecology and conservation through experiment

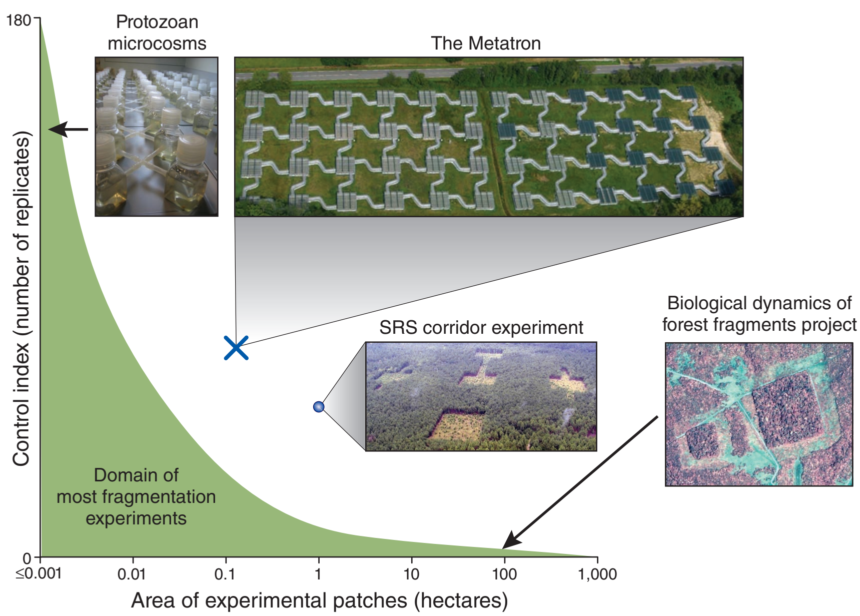
Nick M Haddad

**An experimental infrastructure consisting of environmentally controlled and spatially linked habitat patches permits studies on terrestrial animal dispersal at an unprecedented scale for an experiment with such strict control.**

To understand the central trade-off in experiments in spatial ecology, consider how to create an experiment, a true experiment with full replication and control, for populations of bears or birds. It is much easier to imagine a controlled experiment for populations of protozoans in bottles or for plants in small grassland plots. Yet these experimental settings lack the realism and complexity of landscapes traversed by larger organisms.

There is a strong trade-off in ecology between the spatial extent of studies and the ability to exert experimental control[1] (**Fig. 1**). In this issue of *Nature Methods*, Legrand *et al.*[2] report a new experimental infrastructure, called the Metatron, that is remarkable for the control it achieves over a relatively large area.

The Metatron consists of 48 enclosed habitat patches, each 100 square meters in area




Microcosm, N.M. Haddad; Metatron, Q. Benard; SRS Corridor Experiment, E. Damschen

**Figure 1** | The relationship between the size of study areas and the degree of experimental control in spatial ecology studies. Figure modified from ref. 1. Nearly all experiments from spatial ecology fall within the shaded area. The Metatron is remarkable for its combination of large patches and strict control. SRS, Savannah River Site.

Nick M. Haddad is in the Department of Biology, North Carolina State University, Raleigh, North Carolina, USA.
e-mail: nick_haddad@ncsu.edu

and 200 cubic meters in volume. The experimental patches are subjected to strict control: each is covered with insect mesh and sealed below ground with a plastic barrier to retain organisms, and the patches are equipped with shutters to block the sun's rays when necessary. An impressive array of sensors and recording systems allow precise control of the environment in each patch, including temperature, light intensity, precipitation and humidity. These environmental variables are fundamental to ecological systems, but they are often difficult to vary at such large scales outside a lab setting without unintentionally altering other aspects of the environment. The Metatron is hard-wired to maintain precise control.

What makes the Metatron most exciting is its ability to control the physical connections between patches, and thus the dispersal of organisms. Dispersal links spatially discrete populations and gives rise to complex dynamics found in spatially subdivided 'metapopulations'—where, for example, dispersal may allow populations to occupy poor-quality (sink) habitats—or 'meta-communities', where dispersal may increase the diversity and alter the composition of ecological communities. Like the habitat patches, experimental corridors between patches in the Metatron are covered and controlled. Each corridor consists of a pair of chutes that can be opened or closed at either end, permitting studies of dispersal in either direction between patches. The Metatron thereby provides ecology researchers with a resource they have long needed: a large experimental infrastructure that allows them to test ecological theories that incorporate dispersal.

The Metatron opens new avenues for bridging basic and applied ecology. Habitat loss and fragmentation are the key threats to loss of biodiversity[3]. The most popular conservation strategy to overcome the negative effects of habitat fragmentation is to connect habitat patches in managed natural areas with corridors such as those modeled in the Metatron. Conservation corridors may be as small as road overpasses, urban greenways or riparian buffers, or as large as the 2,000-mile-long Yellowstone to Yukon Conservation Initiative. Although corridors have been shown to increase dispersal for a variety of organisms[4], there are virtually no tests of the central tenet of corridor theory: that higher dispersal will increase persistence of rare populations. The Metatron offers an experimental structure to test this function of corridors.

Corridors are created to address another environmental change: climate change[5]. We already know that species are shifting their ranges upward and poleward in response to warming temperatures[6]. These shifts, however, are almost certain to be blocked by changing and more intense land uses that will create further barriers to migration. Corridors such as Yellowstone to Yukon that connect warmer to cooler regions may facilitate range shifts and may increase the persistence of populations that become locally extinct owing to more extreme environmental fluctuations—for example, in temperature or precipitation. This role of corridors has proven difficult to verify in natural landscapes. Because of its ability to control temperature and other environmental variation (for example, greater variation in rainfall), the Metatron provides a setting to test how climate gradients and variation interact with corridors to affect population and community persistence.

The Metatron can be used in novel ways that are unthinkable in less-controlled environments. For decades, conservation biologists have fretted about the role of corridors in promoting the spread and impact of invasive species[7]. Largely because experiments to test the effects of new introductions in real landscapes are unethical, there has never been an adequate demonstration that corridors actually have these negative effects. This could now be tested. Thinking even more broadly and unconventionally, the Metatron could be used to investigate the introduction of genetically modified (GM) species into existing populations. Beyond GM crops, new forms of plants and animals are being created for the purpose of reducing disease vectors (a current emphasis is on mosquitoes) or eradicating invasives that harm native species (such as invasive mice or rats)[8]. These organisms have the potential to disrupt food webs or displace desirable species. The Metatron offers an arena to ethically and rigorously test for the ecosystem-wide impacts of GM species.

A challenge for the Metatron will be to introduce plants and animals whose dispersal ranges match the size of the experimental infrastructure. In this regard, of the two species studied in the paper in this issue, lizards appear to be a good match for the experiment, whereas butterflies—the particular species studied is capable of dispersal over fields larger than the area covered by the whole experiment—do not. As I have argued elsewhere, ecologists have a tendency to select species whose dispersal ranges are too large and whose dynamics are too fast for their experimental system[9]. Although this has the attraction of providing results more quickly, there is a danger in selecting species that are mismatched to the size of the experiment: many smaller controlled experiments of habitat fragmentation and corridors have produced results that differ from (and underpredict) results in larger, uncontrolled landscapes[10]. The control afforded by the Metatron gives rise to the opportunity to introduce species whose dispersal is infrequent at the scale of the patches and corridors.

The choice of appropriate study species becomes particularly complex as the Metatron expands its scope to entire communities. Used appropriately, the Metatron will succeed in fulfilling its greatest potential: to disentangle the complex and competing theories about the factors that structure spatial communities as well as the factors that maintain community diversity and function. By achieving this goal, the Metatron will enable rigorous testing of the core ideas that guide large-scale conservation in a changing world.

**COMPETING FINANCIAL INTERESTS**
The author declares no competing financial interests.

1. Debinski, D.M. & Holt, R.D. *Conserv. Biol.* **14**, 342–355 (2000).
2. Legrand, D. *et al. Nat. Methods* **9**, 828–833 (2012).
3. Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E. *Bioscience* **48**, 607–615 (1998).
4. Haddad, N.M. *et al. Ecology* **84**, 609–615 (2003).
5. Krosby, M., Tewksbury, J., Haddad, N.M. & Hoekstra, J. *Conserv. Biol.* **24**, 1686–1689 (2010).
6. Chen, I.-C., Hill, J.K., Ohlemüller, R., Roy, D.B. & Thomas, C.D. *Science* **333**, 1024–1026 (2011).
7. Simberloff, D. & Cox, J. *Conserv. Biol.* **1**, 63–71 (1987).
8. Gould, F. *Evolution* **62**, 500–510 (2008).
9. Haddad, N.M. & Tewksbury, J.J. in *Connectivity Conservation* (eds. Crooks, K.R. & Sanjayan, M.) Ch. 16, 390–415 (Cambridge Univ. Press, 2006).
10. Gilbert-Norton, L., Stevens, J.R. & Beard, K.H. *Conserv. Biol.* **24**, 660–668 (2010).