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ECOSYSTEMS

EDITORIAL

Workshop on Ecosystem Manipulation

This issue of *Ecosystems* highlights the Fourth International Workshop on Ecosystem Manipulation (Jasper National Park, Alberta, Canada, 14–17 October 1998). This was the first workshop on ecosystem experiments to be held outside of North America. In contrast to previous workshops, which focused heavily on acid deposition and air pollution, the Jasper workshop also addressed climate change, food-web and nutrient manipulations, and effects of ultraviolet radiation.

The healthy state of ecosystem experimentation was demonstrated by the 18 lectures and 30 posters presented by 45 participants from several European nations, Canada, and the United States. The schedule allowed ample time for discussion. There was general agreement that large-scale experimentation is essential for understanding and predicting the responses of ecosystems to a changing environment.

Considerable discussion was devoted to replication. Comparisons of whole ecosystems with smaller experimental units showed that often the smaller-scale experiments, while replicable, sacrificed the capacity to predict ecosystem responses. In particular, smaller-scale experiments often ignored top carnivores, animal migrations, key sediment–water or atmosphere–biosphere exchanges, and important physical processes. It was generally agreed that if experiments were replicated, it would be most useful to replicate at different sites. Examples of excellent replication across whole-ecosystem experiments performed in different regions were provided. These included lake acidification studies in Lakes 223 and 302S at the Experimental Lakes Area (ELA) and Little Rock Lake; nutrient experiments in several lakes at ELA, in Wisconsin, and at several other locations; and nitrogen deposition manipulations at several sites throughout Europe.

All long-term ecosystem experiments yielded some totally unforeseen surprises. Ann Hershey described a sudden switch from algae to mosses, with massive impacts on invertebrates, in the Kuparuk River after 10 years of fertilization. Jim Elser showed that trophic cascades could not occur in lakes with chronically low carbon: phosphorus ratios, because a low carbon-phosphorus diet is nutritionally inadequate for the keystone grazer *Daphnia*. Using experimentally enriched lakes in Wisconsin, Daniel Schindler found that trophic cascades control the direction and magnitude of carbon dioxide flow between lakes and the atmosphere. Bridget Emmett showed that carbon:nitrogen ratio of the forest floor could predict nitrate leakage in nitrogen deposition experiments. Results from experiments reported by Sven Jonasson indicated that warming of tundra interacted with fertilization to shift tundra vegetation toward dominance by birch.

Strong hysteresis was common in the recovery of many sites from acidification, including Gårdsjön, Lakes 302 and 223 at ELA, acidified catchments in Norway (the RAIN project), and acid-exclusion experiments at several sites in Europe (the NITREX and EXMAN projects). The ubiquity of large-scale, long-term hysteretic processes suggests that accurate management predictions would be difficult, if not impossible, to obtain by using experiments of small scale or short duration.

Many examples of slow, relentless changes lasting many years were described. Examples included the full response of the nitrogen cycle to phosphorus fertilization in Lake 227 at ELA, the growth of birch in Alaskan tundra, the changes to insect communities of Kuparuk River, and cation depletion in acidified soils. Many studies also suggested that the speed and success of recovery of ecosystems depended on both the severity and the duration of treatment. Depletion of certain key species and soil cations are examples of ecological changes that severely retard the recovery of stressed ecosystems.

It was generally agreed that inferential methods for treating data from unreplicated experiments needed further research and development. Multiple reference systems, randomized intervention analysis, real replication and "pseudo"-replication, time-series analyses, model comparisons, and Bayesian methods were discussed.

It was also agreed that research and method development were needed for "scaling up" results from experimental ecosystems to units that were realistic for management. The NOLSS (Northern Ontario Lake Size Series) study by Everett Fee and Bob Hecky and the European Union models described by Bob Ferrier and Jack Cosby were mentioned as examples. This discussion led naturally to that of the use of ecosystem experiments in policy formation and ecosystem management. Ecosystem experiments have already contributed in central ways to management decisions pertaining to acidification, nitrogen deposition, lake eutrophication, and food-web management.

Suzanne Bayley described a case study of policy applications of ecosystem science. As coauthor of the Banff–Bow Valley Task Force Report, she has addressed the problem of managing ecosystems of the national parks of the Canadian Rockies confronted with rapidly increasing human activity and development. Introduction of exotic aquatic species, destruction of habitats and disruption of travel corridors for large mammals, and elimination of early successional stages of forest vegetation by fire suppression were among the most serious challenges to the task force. The difficulties of implementing the task force recommendations in a politically charged situation are daunting.

This issue of *Ecosystems* presents four papers from the workshop. David Schindler compares the results of whole-lake manipulations to those of mesocosm and bottle experiments at ELA. He finds that small-scale experiments often fail to predict ecosystem responses. Carpenter and colleagues suggest that comparison of multiple working hypotheses is a powerful method of inference for ecosystem experiments. They demonstrate the approach by using time-series analyses of a whole-lake manipulation. Van Breemen and colleagues manipulated CO_2 and temperature in an enclosed catchment. Mobilization of nitrogen increased productivity and stimulated nitrate export in stream water, suggesting a potential connection of ecosystem warming to eutrophication of coastal waters. Emmett and coworkers describe seven ecosystem experiments in northwestern Europe designed to study effects of changing nitrogen deposition. Responses include acidification, changes in water quality, and impacts on tree growth in some sites.

Previous issues of *Ecosystems* included two additional papers from the workshop. Elser and colleagues (volume 1, number 1) described effects of nutrient stoichiometry on trophic cascades in experimental lakes. Wright and coworkers (volume 1, number 2) summarized whole-catchment manipulations showing that global warming may mobilize enough nitrate from soils to offset the effects of policies to reduce nitrogen deposition.

The positive responses of participants and quality of the papers presented suggest that the workshop was a success. We hope that the selection of papers appearing in *Ecosystems* conveys the excitement and enthusiasm for ecosystem experimentation that we experienced in Jasper.

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