10 Guidelines for Ecosystem Researchers

Lessons from Missouri

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In the early 1990s managers in natural resource agencies in Missouri began asking, "How does ecosystem management relate to our current practices? How might we do a better job of managing large ecosystems?" As they started addressing these questions, several points emerged:

- Planning and managing ecosystems requires expertise in more subject areas than any single individual can possess.
- Many ecosystem attributes can be observed only at large scales, like landscapes or watersheds.
- Management issues often involve multiple ownerships.
- New tools are needed to help synthesize information and guide decisionmaking.

The Missouri land managers acknowledged those constraints and began discussing ways to collaborate on ecosystem research and management projects. As with any collaboration, the process has not been quick, simple, or easy. There is no master plan for this work, but rather a series of complementary large-scale research and development efforts to improve both knowledge and tools. The initiatives involve long-term ecosystem experiments and other permanent plot data, synthesis of research results across numerous disciplines, spatial data compilation and analysis, and making ecosystem management responsive to society.

Long-Term Experiments

Missouri Ozark Forest Ecosystem Project. The Missouri Ozark Forest Ecosystem Project is a landscape-scale experiment to evaluate the effects of timber harvest on a wide range of forest characteristics. The study is centered in the heavily forested southeastern Ozarks, and experimental units are nine forest compartments of approximately 1,000 acres each. Each compartment is composed predominantly of mature, second-growth upland oak-hickory forest that has been uncut since 1950. Five years of monitoring preceded the harvest treatments that began in 1996. Three compartments are managed by the clearcutting method, three are managed by the group selection harvest method, and the remaining three compartments are controls, with no timber harvest.

The impetus for this experiment was the need to investigate landscape-scale effects of harvesting practices on the neotropical migrant songbirds that breed in Missouri (Brookshire and Hauser 1993; Kurzejeski et al. 1993). A number of studies have documented high rates of songbird predation and parasitism by cowbirds in mixed forestland and farmland (Robinson et al. 1995; Thompson et al. 1996). The Ozark study area, however, is heavily forested, with comparatively low rates of songbird nest predation and parasitism. How would harvesting affect habitat availability and bird populations? Does harvesting fragment the forest and cause reproductive failure?

The experiment offered the opportunity to examine the effect of harvest practices on other forest characteristics and ecosystem processes as well. Pretreatment and posttreatment monitoring was therefore expanded to include overstory composition and structure, herbaceous vegetation, reptiles and amphibians, small mammals, mast production, down wood, invertebrates in both canopy and litter, fungi and lichens, hydrology and soil processes, tree genetic diversity, and microclimate in the canopy and at the forest floor.

The Missouri Department of Conservation is responsible for executing this study, but the research involves university and USDA Forest Service scientists. Currently, 25 interrelated research studies have been initiated under its umbrella.

Riparian Ecosystem Assessment and Management. The focus of the Riparian Ecosystem Assessment and Management project is the riparian forests in northern Missouri. The watersheds here are subject to a variety of uses and management practices, both silvicultural and agricultural. Vegetation, herpetofauna, small mammals, and avian communities are sampled in this project. In addition, several features particularly relevant to riparian ecosystems are being studied: channel morphology, instream woody debris, soil–ground flora relationships, and sedimentation, nutrient, and chemical inputs from surrounding watersheds.

The projected duration of both the Ozark forest ecosystem project and the riparian experiments is at least a century. Obviously, managers cannot wait until the conclusion of these large-scale experiments before making ecosystem management decisions. Fortunately, these studies have begun to provide information.

Several long-term monitoring studies in Missouri help document how our forests reached their current state and form a baseline against which to evaluate change. Primarily forest inventories and research studies that were started in the 1950s and 1960s, they also include long-term fire records and centuries of fire history that have been recovered from dendrochronology studies (Guyette 1995).

Predicting Outcomes

Synthesizing the knowledge obtained in the current ecosystem research projects with existing scientific knowledge of midwestern forests will provide insight into the landscape-scale implications of management decisions. Most silvicultural research, for example, is applicable to the stand (roughly 10 to 20 acres in Missouri) and to a rotation (roughly a century). Wildlife populations and their responses to changes in habitat, however, operate in different scales. Compare the longevity and reproductive rates of mice, deer, bears, and migratory songbirds. Then consider the distances they travel to feed and breed: a few yards for mice, a few miles for deer, hundreds of miles for bears, and thousands of miles for birds. Human response to forest change may also involve different spatial scales and vary in duration from an immediate emotional reaction to a lifetime of observations and experience.

Monitoring the effects of timber-harvesting practices on neotropical migrant songbirds like the worm-eating warbler, researchers from a range of disciplines work together to understand the complex ways in which an ecosystem responds to disturbances. Forest fragmentation has led to a rise in nest predation by cowbirds.

Predicting the multiple response of even a few populations that operate on different spatial and temporal scales is complex; it requires predicting both where and when landscape disturbances are likely, far into the future. Analyses are complicated because plants and animals operate in vastly different spatial scales. For real landscapes the analysis can be done using spatially explicit simulation model-

Photos by Jim Rathert, Missouri Department of Conservation ing—starting with a map and predicting how that landscape will change over time with various assumed disturbance regimes.

Wind, fire, and harvesting are the major disturbances shaping Missouri forests. Of these, wind is strictly natural; fire and harvesting are regulated to varying degrees by humans. All three factors can greatly affect the species composition and structure of vegetation across the landscape. These in turn influence the expected response of wildlife populations and of the people who have social or economic interests in the forest.

In 1994 the North Central Forest Experiment Station, in Columbia, Missouri, began a research project to develop tools suitable for predicting the response of hardwood ecosystems to disturbance by wind, fire, and harvesting. This research was initially implemented in the Missouri Ozarks to take advantage of the large information base developed in the Ozark forest ecosystem project, Mark Twain National Forest studies, and other data-intensive, long-term research and monitoring projects. Because the modeling approach is spatially explicit, it requires mapped landscapes that can be manipulated and displayed by a geographic information system (GIS). Furthermore, because the model simulates harvesting practices, the digitized maps must include stand boundaries. The largest mapped landscapes in Missouri are the Mark Twain National Forest and Missouri Department of Conservation lands in the southeastern Ozarks.

Conceptually, constructing a landscape-scale simulation model is simple:

Step 1. Begin with a mapped landscape showing current vegetation, ecological classification or site quality, stand boundaries, management units, and other significant physical characteristics, such as roads, water, topography, and ownership.


Jim Rathert, Missouri Department of Conservation

Cindy Becker, an employee of the Missouri Department of Conservation, is determining percentage coverage by species for all plants less than one meter tall in a one-meter-square plot—an initial stage in constructing a landscape-scale simulation model.

Step 2. For a short period (typically one year or one decade), simulate the amount and location of disturbance by wind, fire, and harvesting.

Step 3. Estimate the changes in the composition, structure, and landscape-scale spatial arrangement of vegetation resulting from the disturbance.

Step 4. Estimate the changes in product outputs, wildlife populations, human reactions, and other aspects as they relate to predicted vegetation composition, structure, and spatial pattern.

Step 5. Update maps to reflect all expected changes over the time interval.

Step 6. Return to step 2 and repeat.

In practice, realistically simulating wind, fire, and harvesting across a landscape is complicated. Predicting vegetation response to disturbances and predicting the subsequent response of wildlife and humans to changes is also complex. However, we know at least a little about most such relationships and considerably more about others, such as how oak forests respond to harvesting.

We are relying on the LANDIS simulation software (Mladenoff et al. 1996) to simulate spatially explicit disturbance regimes and related vegetation response. A series of supplemental models are being developed to estimate response of human and wildlife populations to alternative types, amounts, and patterns of disturbance.

Sharing Data

Ecosystem management and research requires assessment of patterns and trends at large spatial scales. This is often most efficiently accomplished with a combination of GIS software, satellite imagery, and digitized maps with linked databases. For spatial analysis, many resource management and research organizations need basic data layers, including satellite images, road networks, waterways, political boundaries, hypsography (elevation), ecological classification units, aerial photography, and a wide variety of composites or derived products based on these data. Given the equipment and training needed to acquire such products and the mosaic of ownership patterns in the state, a shared approach to developing data layers and products seemed prudent. Ten state and federal agencies therefore formed the Missouri Resource Assessment Partnership, which will compile, develop, and distribute digital spatial data for natural resource management and research in the state.

At the landscape scale, the combined effects of management decisions directly and indirectly affect many people. The Missouri Department of Conservation initiated a planning process called Coordinated Resource Management to facilitate setting multidisciplinary resource management priorities. The process involves defining resource management goals for the major ecoregions of the state and determining how agency activities can be tailored to achieve those goals. The process does not dictate management for private lands. Rather, it determines how public lands might best be managed to contribute to regional goals.

Guidelines

Forest ecosystems are extremely complex. There is little reason to think that we will resolve the scientific and social issues surrounding ecosystem management in the next decade or even the next century. Nevertheless, progress is being made in many areas that support ecosystem management: ecosystem processes, assessment of human response to forest management activities, and forest change involving multiple attributes at multiple spatial and temporal scales.

Virtually any research activity related to the physical, biological, or social dimensions of forests and forestry falls in the realm of ecosystem management. How then can we allocate our efforts in ecosystem management so that the results are cohesive and relevant to management issues? We believe there are several principles that help define productive research for ecosystem management. Our involvement with the ecosystem management and research projects based in Missouri has led us to 10 recommendations:

1 Management and research must deal with large landscapes. This is not to say we should ignore smaller-scale phenomena, but at some point we must look at the forest across thousands, tens of thousands, or hundreds of thousands of acres. Some important processes are readily observed only at the landscape scale—patterns of forest distribution, composition, and structure; patterns of natural disturbance; movement and habitat use by large mammals, including humans. The cumulative effects of processes that typically function at smaller scales, such as stand-level silvicultural treatments, can be observed only if we step back to take that wide-angle view of the forest.

2 We must be concerned with long timeframes. Just as the extent, structure, and condition of midwestern forests today have been determined by harvesting practices that took place a century ago, so the impact of current management activities will persist at least a century into the future.

3 We must consider both where and when we create a disturbance. There are important spatial and temporal components associated with any forest management activity or any natural disturbance. If, for example, our management activities will disturb half the acreage in a given landscape over the next century, it makes a difference whether affected acres are contiguous or dispersed and whether the disturbance occurs in a single year or is spread over the full century.

4 We have enough scientific knowledge to start managing ecosystems. We will never fully understand all aspects of forest ecosystems. It is a fallacy to believe that we will someday understand forest ecosystems completely, and it is wrong to suggest that we cannot manage them until we do. Since we know a great deal about some parts of forest ecosystems and at least a little about most, a prudent approach is to begin by using the best science we have, even as we continue our research.

5 We must synthesize the results of research that addresses many different ecosystem attributes and processes. This is extraordinarily important. Only by combining what we know about ecosystem components and ecosystem processes can we arrive at a more complete understanding of how ecosystems work and how they respond to disturbance. Synthesis also serves to identify the major gaps in our knowledge.

6 The complexity associated with ecosystem management is so great that we must employ mathematical models. Tracking details, measuring interactions and tradeoffs, dealing with long timeframes, dealing simultaneously with many species, and mapping the results all require the use of computer models.

7 We must facilitate cooperation and collaboration. The complexity of forest ecosystems requires the attention of teams of scientists and managers representing a wide range of expertise.

8 Researchers must share sites so that they can integrate their findings and investigate change in each ecosystem component over multiple spatial and temporal scales. Agencies must therefore make long-term commitments to maintain research sites as well as to fund basic site measurements. As long as a base level of measurements exists, the marginal cost of additional projects is quite low.

9 We must simultaneously focus our collaborative research efforts on real landscapes. This is the ultimate test of our work. Only when experts from many fields apply their collective wisdom to the same piece of land over the same timeframe will we increase our understanding of the interactions and tradeoffs. Purely theoretical approaches to ecosystem management research have great merit, but ultimately the evaluation must be in the field.

10 We must remember that people are part of the ecosystem. Human activity has left an indelible mark on our forest resources, and people's desire to either instigate or eliminate future disturbances will also have long-lasting effects. Ultimately, it is people who decide which forest practices are acceptable. Our role as scientists and practitioners must be to (a) identify and discourage those activities that will likely cause short-term or long-term ecosystem degradation, (b) clarify the tradeoffs among the array of acceptable management alternatives, and (c) identify and encourage the alternatives that will likely produce the desired outcomes.

That list captures many of the important guidelines for ecosystem management research in Missouri, yet none are specific to the Midwest. We suggest they serve as a basis for discussions about research priorities in other regions. The approach taken in Missouri is certainly not the only option for conducting ecosystem management and related research, but we believe it is working well.

We emphasize the benefits of collaboration when attempting landscape-level ecosystem research. Ecosystem analyses are so complicated that few people have the breadth of knowledge to accomplish the work on their own. A cooperative approach becomes the obvious alternative, but it requires people with both technical skills and cooperative attitudes. Five years ago we would not have been able to predict the high level of energy and resources devoted to ecosystem management and research projects in Missouri. Participants are committed to sharing expertise, information, and resources. The net result is a synergistic consortium of scientists and managers addressing landscapes and ecosystems. JOF

Literature Cited

BROOKSHIRE, B., and C. HAUSER. 1993. The Missouri Forest Ecosystem Project. In *Proceedings, 9th Central Hardwood Forest Conference,* eds A.R. Gillespie, G.R. Parker, P.E. Pope, and G Rink, 289–307. General Technical Report NC-161. St. Paul: USDA Forest Service.

GUYETTE, R. 1995. *A history of wildland fire in the current river watershed.* Report prepared for the Missouri Department of Conservation, The Ozark National Scenic Riverways, and The National Park Service Climate Change Program. Columbia: University of Missouri–Columbia.

KURZEJESKI, E.W., R.L. CLAWSON, R.B. RENKEN, S.L. SHERIFF, L.D. VANGILDER, C.C. HAUSER, and J. FAABORG. 1993. Experimental evaluation of forest management: The Missouri Ozark Forest Ecosystem Project. In *Transactions of the 58th North American Wildlife and Natural Resources Conference.* Washington, DC: Wildlife Management Institute.

MLADENOFF, D.J., G.E. HOST, J. BOEDER, and T.R. CROW. 1996. LANDIS: A spatial model of forest landscape disturbance, succession, and management. In *GIS and environmental modeling: Progress and research issues,* eds. M F Goodchild, L.T. Steyaert, B.O. Parks, C. Johnston, D. Maidment, M. Crane, and S Glendinning, 175–79. Fort Collins, CO: GIS World Books.

ROBINSON, S.K., F.R. THOMPSON III, T.M. DONOVAN, D.R. WHITEHEAD, and J. FAABORG. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267 1,987–990.

THOMPSON III, F.R., S.K. ROBINSON, T.M DONOVAN, J. FAABORG, D.R. WHITEHEAD, and

D.R. LARSEN. 1996. Biogeographic, landscape, and local factors affecting cowbird abundance and host parasitism levels. In *Ecology and management of cowbirds*, eds. T. Cook, S.K. Robinson, S.I. Rothstien, S.G. Sealy, and J.N. Smith. Austin: University of Texas Press.

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