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INSIDE

Science
FINDINGS

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"Science affects the way we think together."
Lewis Thomas

FROM GENES TO LANDSCAPES: CONSERVING BIODIVERSITY AT MULTIPLE SCALES

"Biodiversity, in the simplest terms, is the variety of life and its processes."
Keystone Center 1991

Biodiversity, it seems, has found its place in the public lexicon. It is now widely understood as a thing worth fighting for, even if some enthusiasts still can't actually define it clearly.

So, a definition: biodiversity is a manifestation of genetic diversity, an expression of habitats and their associated assemblages of plants and animals. It is thus the primary raw material constantly being filtered by natural selection, and is therefore central to how biota evolve and adapt through time to changing environmental conditions. But in far too many areas of the United States and the world, we can witness the same scenario: severe and widespread stress on biodiversity resulting from human activities.

If we assume that biodiversity is worth conserving, it is far less clear how we go about actually conserving it. How do you take the whole world into account?

"You prioritize," says Ross Kiester. "You have limited resources to manage a scarce resource, so you prioritize. And to do this well, you need a comprehensive and complete method of deciding how to prioritize."

Ten years ago, Kiester and others recognized that monitoring the threats to biodiversity is obviously a problem too large for any one agency to get its arms around. Thus they formed the Biodiversity Research Consortium (BRC). It was composed of members from 10 to 12 universities, the USDA Forest Service, the Environmental Protection Agency (EPA), and The Nature Conservancy. Kiester is Global Biodiversity

Photo credit: John Hutmacher

The American marten is an example of the terrestrial vertebrates indicated in the hexagonal grid technique used in mapping biodiversity.

IN SUMMARY

Biodiversity has at last become a familiar term outside of scientific circles. Ways of measuring it and mapping it are advancing and becoming more complex, but ways of deciding how to conserve it remain mixed at best, and the resources available to manage diminishing biodiversity are themselves scarce. One significant problem is that policy decisions are frequently at the local scale, whereas biodiversity mapping is more often at the regional or national scale. Building on gap analysis techniques, one hierarchical, objective approach to conserving biodiversity is based on prioritizing sets of species rather than focussing on individual species or whole ecosystems. This method has already been somewhat successful.

Team Leader with the PNW Research Station in Corvallis, Oregon.

The other challenge was that much of the biodiversity research at the time was not policy oriented. “People would agree that the threat to biodiversity was a people problem, then they’d go off and study birds,” he observes wryly. “Stewardship of habitat was then and remains today divided among many landowners, each with a different perspective on risks and values associated with natural ecosystems. In addition, most of the habitat in the United States is privately owned and not subject to similar management goals and policies.”

Science and policy were disconnected, and Kiester and his colleagues wanted to devise a system of prioritization that would bridge those worlds.

KEY FINDINGS

- Maps of spatial patterns of biodiversity at all scales are informative and can sometimes substitute for more detailed and expensive analyses of processes. Hexagonal grids possess the best mapping properties with regard to distortion and efficiency of data use.
- Species are usually the best category of biodiversity response variables. Measuring genetic diversity would be ideal but too expensive. Other entities such as habitat or vegetation classes have an element of arbitrariness that may confuse analyses.
- Species frequently show complementary distributions (different species occur in different regions) meaning that optimizing prioritization of areas can be quite effective.
- The hierarchical approach can integrate biodiversity conservation planning from local to regional and national levels.

SCIENCE = FACTS, POLICY = VALUES

The hierarchy of biodiversity understanding, and of political decision-making, are exactly opposite, Kiester points out. Most often, biodiversity status is captured by scientists at large regional levels, thus at a fairly coarse scale. It is understood, for example, that a certain large watershed has plentiful wildlife and habitat, that another is relatively impoverished, either naturally or by disturbance of some kind, and that a third might be the last stronghold of a certain species of fish.

Most often, however, the decisions about how to conserve existing biodiversity are made at the county level, with small communities of people as the main contributors to decisions, and the chief beneficiaries of sound conservation decisions—or losers if those decisions are lacking.

“It seemed clear that we needed to shift the scale of our studies, for biodiversity funding decisions are frequently based on political considerations, not science,” Kiester says. “What was needed was a method that allowed scientists and policymakers to work together in a policy-oriented way.” To make the connection, in other words, between the value-based local decisions of policymakers and the fact-based regional information produced by scientists.

Amongst existing methods of approaching conservation biology, the two overriding research emphases have been the species based and the ecosystem based. Kiester believes the whole-ecosystem approach tends to leave out too much biodiversity detail, and the species-based approach by definition deals with only a fraction of the whole in its focus on individual species.

The method developed by the BRC pursues a third approach to conservation biology, based on sets of species. As Kiester puts it, they were more interested in the properties of the set than the particular members of the set.

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A MAP OF THE WORLD

Most biodiversity projects today rely on mapping their concepts. Colored patches on maps have become the accepted language. But how do the patches get there, and what do they really represent on the ground?

A research project in Idaho, starting in the early 1990s and using data from the Gap Analysis Program, provides an example of how data are compiled on a biodiversity map. In this case, the goal was to establish where areas existed that were unprotected, and thus at risk of habitat stress. The guiding theory was that it is a better investment to protect a species when it's common than when it becomes threatened or rare, Kiester explains.

Typically, the process begins with vegetation maps, both from field data, and more recently from satellite imagery. Multiple geographic layers are superimposed, and as each new layer is added, the look of the map changes—geographic information systems in action. When vegetation data are combined with physical data such as topography, scientists are able to deduce the kind of habitat present, and thus the animals most likely to be found there.

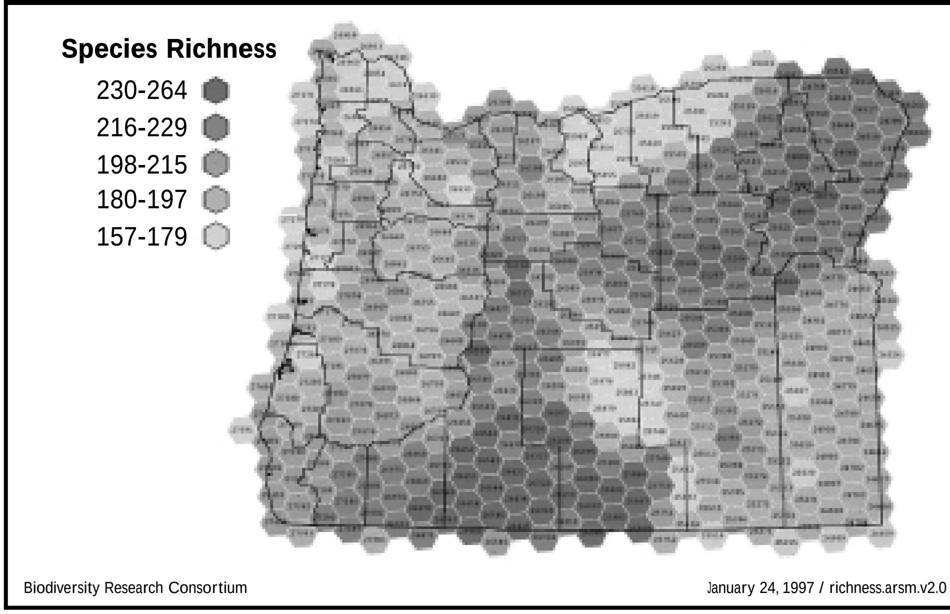
Such data can come from many sources, Kiester explains. Naturalists, museum reports, and scientific literature help capture the birds, mammals, reptiles, amphibians, and fish of an area, as well as the habitats with which they associate, and where they actually live. State fish and game managers, and people associated with The Nature Conservancy's Heritage Program can be particularly helpful in compiling data, he says.

"Once the information is entered into a gap-analysis database, researchers can look at the distribution of vertebrates, species by species, or vegetation, group by group," Kiester explains. "Knowing where certain animals live, the scientists can predict other places where a particular species may thrive." In statewide gap analysis for Idaho, these predictions guided wildlife biologists to previously unknown populations of the Columbian sharp-tailed grouse, a bird under consideration for listing as endangered or threatened in some areas.

LAND MANAGEMENT IMPLICATIONS

- Biodiversity analysis and planning ought to consider including all possible species and not focusing solely on the rare.
- For the National Forest System, biodiversity cannot be managed on a Ranger District by Ranger District basis. There must be a national plan, a regional plan, a Forest plan, and a project plan all working together, or each district will be put in the position of having to do everything, with no overriding context.
- Planning should best include mechanisms for the three-dimensional visualization of alternative futures, which is an effective tool for informing the public about the biodiversity and landscape consequences of their choices.
- Selecting priorities is the business of managers. Testing effects of those priorities on biodiversity is the business of scientists.

ALL TERRESTRIAL VERTEBRATE RICHNESS
28 Amphibians, 28 Reptiles, 252 Birds, 116 Mammals



This figure shows the species richness of the terrestrial vertebrates of Oregon. Each hexagon is about 245 square miles. There are 424 total species.

BROADENING THE DATA REACH

The programs also incorporate species richness by overlaying data about individual species to see where most of them live. This process helps highlight the most biologically diverse areas.

By adding in land use information—land protected from development, private or public ownership, populated, unpopulated, or scheduled for development—researchers can pinpoint areas of vegetation not protected, species that do not occur frequently, and places rich in biodiversity but vulnerable to development, Kiester says.

Then comes the number crunching, sophisticated number crunching. The mathematical processes, or algorithms, needed to help researchers decide how unprotected species might best be taken care of, required answers to key questions. How widespread does a species or habitat need to be to ensure its viability? How many species do you want to protect? What size parcel of land would form the best unit for analysis?

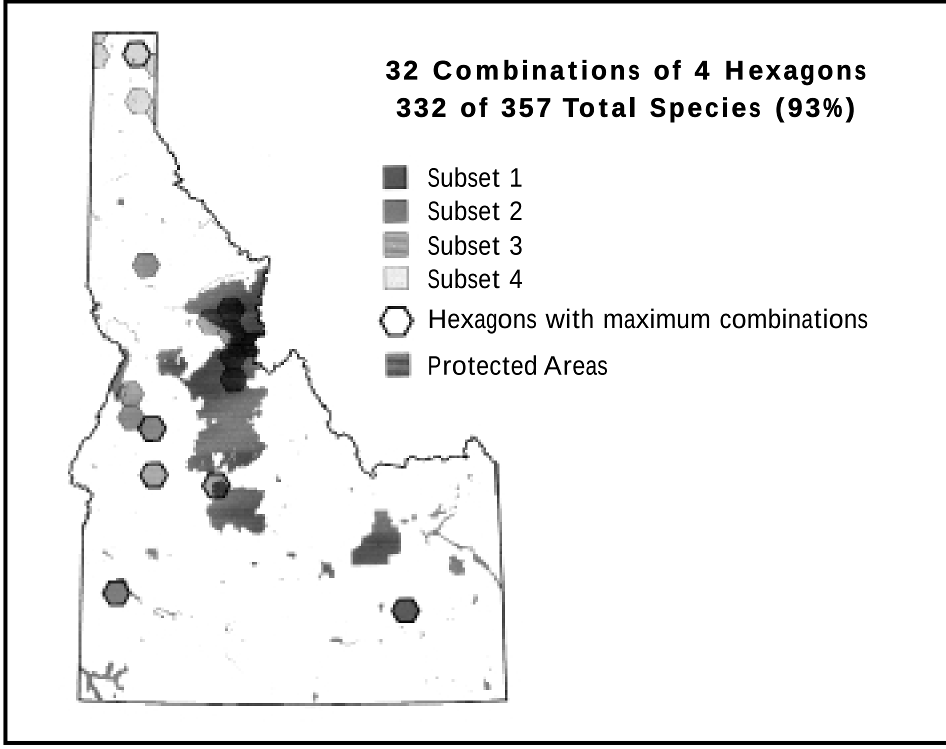
For a midsize carnivore such as a coyote, for example, it was apparent that it needed about 24,700 acres to thrive. The researchers decided that any species needed to be present in at least three areas of that size to be safe; they also recognized that this "averaging" could not properly capture species that needed considerably more or considerably less space.

Mapping of actual species presence on the ground was accurate to within about 247 acres on land, and about 98 acres on waterways, Kiester says. But with a view to a national survey, a coarser grid of about 245 square-mile hexagons was overlaid on their map; this size was chosen as a compromise between being small enough to be useful in management decisions and large enough to represent the variations in patterns of diversity at state and national scales.

"This grid makes the gap maps compatible with standard environmental monitoring and assessment maps generated by the EPA. You then cookie cutter states with this grid to give you a regular structure," Kiester says.

This divided Idaho into 389 hexagons, and computer analyses could identify the hexagons in which new preserves should be established to ensure protection for the greatest number of species. The list of species in each hexagon is a subset of the list for the entire state.

EXACT SET COVERAGE FOR VERTEBRATE SPECIES



The hexagon-combinations method allows a greater degree of coverage of the land to determine where species are, species diversity, and the optimal amount of land needed to ensure species viability.

COUNTING HEXAGONS

For Idaho, Kiester wanted to see mapping coverage for about 95 percent of the state's 357 vertebrates. He requested that the computer find the hexagon with the most species, then the most species-rich pair, threesome, and foursome of hexagons, without requiring that the single most diverse hexagon stay in the group. The combinations of comparisons took 12 hours of supercomputing time but found 32 combinations of four hexagons that protected at least 332 species.

"If this is your definition of biodiversity, then these 32 ways are all equally good, which means you can add other considerations in protecting it, such as land ownership and cost," he says.

A similar analysis was then done for "needy" species, those that live outside of protected areas. Working on 83 species, the researchers discovered that 79 of these species could be covered in any of 16 combinations of four hexagons. This latter analysis also showed up an area under consideration for set aside: the Snake River Bird of Prey Wilderness Area. The area was contained in four centrally critical hexagons.

"That area was prioritized by the old species-specific way of doing business, and now it turns out to be one of the most important areas for all biodiversity, not just raptors."

What the hexagon-combinations method offers, Kiester notes, is a higher level of objectivity and repeatability that land managers can rely on. Although all three approaches to conservation biology have their strengths and weaknesses, their proponents and detractors, this method cannot be faulted for coverage. "The fact is," he says, "we have literally looked everywhere on the land with this method."

He emphasizes, however, that the three methods are actually complementary: the weaknesses of one are usually covered by the strengths of the others, and use of all three in concert provides a highly comprehensive picture of biodiversity status.

Gap analysis by this method is a starting point, and Kiester and his colleagues readily acknowledge the coarseness of their data. It's a screening process that tells personnel what hotel to check into when they head out into the field to take a closer look, he says.

Such investigators could include biologists, wildlife managers, planners, and lawyers seeking to determine exactly where within the hexagons the needy species live and what boundaries would be optimal for protection.

With this information in hand, the facts of the science can more usefully feed into the values of policy.

INTEGRATING ACROSS SCALES

"The hierarchical structure of biodiversity from global to local patterns and from biomes to individuals indicates that multiple-scale hierarchical approaches are needed for conserving biodiversity," Kiester says. Specifically, biodiversity priorities may be best set at a regional level, but the decisions still will be made county by county.

With the National Forest System (NFS) as an example, he notes the single most important implication is that biodiversity cannot be managed on a Ranger District by Ranger District basis. "There must be a national plan, a regional plan, a Forest plan, and a project plan all working together. Otherwise, each district is put in the position of having to do everything and so the NFS tries to do everything everywhere, with perhaps predictable results."

The combination of best-biodiversity and most-unprotected hexagon combinations selected by computer analyses provides fruitful options for prioritization, which Kiester sees as the sine qua non of biodiversity management and conservation. The direction provided by gap analysis allows other conservation biology research activities to help determine reserve boundaries and the management techniques necessary to maintain viable populations and ecosystem processes.

"Furthermore, whereas gap analysis provides initial prioritization for the use of scarce resources, it does not preclude other kinds of conservation planning," he says. "Rather, it provides a way of calculating the positive cumulative impact of choosing various areas for protection."

PRIORITIES AND DECISIONMAKING

With the emphasis on areas rather than species, a key assumption of the method preferred by Kiester and his colleagues becomes clear: diversity in its own right, not just a selection of individual species, is the target of concern. All native species are assumed to be of equal value.

"These results also showed that endangered species are thinly and relatively evenly distributed, thereby making them poor candidates for the prioritization of all vertebrates," Kiester says. "If the policy goal is to protect threatened and endangered species, then that protection will be virtually case by case, requiring 30 locations in this case. Proactive protection before species become endangered is clearly more effective, with only seven locations required."

An additional dimension of this work lies in the projection of alternative future scenarios, which can be executed in collaboration with landscape planners, local stakeholders, policymakers, and biologists. These alternative futures projects, according to Kiester, provide a reasonable cost method for considering future impacts of human activities on biodiversity. For the futures projections, the researchers assume that projected population growth is correct; from there, given a future, the method can show the impact on biodiversity. "In Oregon, for example, we also can attach a land value model, with which we can ask, what's the cost of land in various areas that would save the greatest amount of biodiversity, thus adding financial considerations to the management decisions."

This approach was incorporated into recent assessments of roadless area planning and impacts on biodiversity (USDA Forest Service 2000) revealing that preserving roadless areas will contribute to preventing vertebrate species from becoming rare enough to be listed as threatened or endangered.

"For this work, we recognize that there is no current quantitative relation between the size of the range of a species and its population viability, except that more is better," Kiester says. "However, policy targets could be set that allow a quantitative comparison of the relative effect of different land use decisions."

What the method most usefully provides, Kiester believes, is a conceptual and spatial framework for decentralizing resource management decisionmaking to more local levels, while maintaining the larger spatial perspectives necessary for sustainable resource use. The researchers involved envision gap data to be an integral part of planning efforts by local, state, and Federal officials, as well as providing a scientific resource. For the global and the local viewpoints and scales are both essential in assessing how best to spend environmental protection or rescue money.

"Funding the conditions that allow species to continue to survive, or otherwise working to that end, allows us to participate in the condition of possibility," he observes.

"Most of us feel that we could never become extinct. The Dodo felt that way too."

William Cuppy

FOR FURTHER READING

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