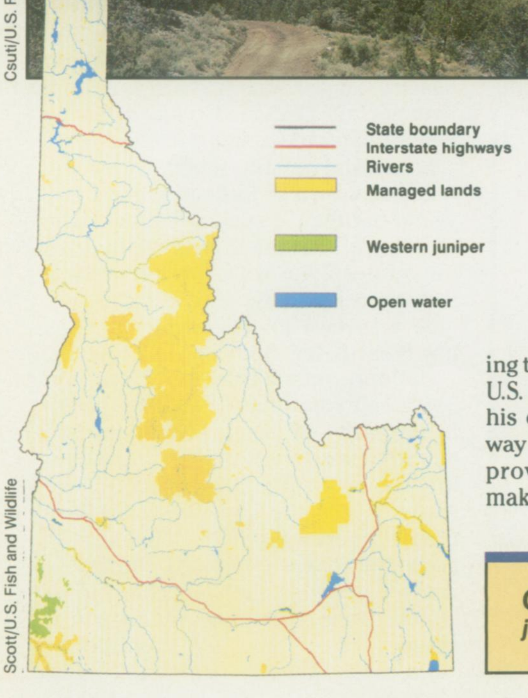
Filling in the Gaps

Computer mapping finds unprotected species

By ELIZABETH PENNISI

Csuti/U.S. Fish and Wildlife



Scott/U.S. Fish and Wildlife

About 150 years ago, artist and naturalist John James Audubon trekked across the American landscape, cataloging the wildlife he encountered and capturing its beauty on canvas. Now a computer is transforming his work, as well as the field observations of countless other biologists, into a much different kind of imagery: complex maps that lay the groundwork for conservationists' attempts to practice preventive medicine.

"The basic assumption is that the time to protect a species is when it's common," says J. Michael Scott, a U.S. Fish and Wildlife Service biologist based at the University of Idaho in Moscow.

History shows that many now-rare plants and animals were common 50, even 20 years ago. Some were so numerous that people considered them pests. But once a plant or animal's numbers dwindle, preventing its extinction can become a very expensive – and sometimes losing – battle, Scott explains. Rather than spend all that money to save just one species, why not protect as many species as possible before they become endangered? In the long run, such preemptive conservation should cost less.

Also, his work in Hawaii monitoring that state's endangered forest birds made Scott realize that, too often, organisms most in need of refuge reside nowhere near protected land. There, just 5 percent of the endangered forest birds lived in forest preserves. "There was a big gap in the conservation lands network," Scott says.

Enter gap analysis, a computer-based technique for locating these holes. Under the auspices of the U.S. Fish and Wildlife Service, Scott and his colleagues have developed this new way of looking at land. They hope it will provide both scientists and policy makers with data to make intelligent compromises for settling the competing land-use needs of people and of plants and animals. Already, by shifting slightly where development occurs, this preemptive approach promises to protect species in ways compatible with human activities.

Just as painters create their particular style by brushing on their canvases layer upon layer of color, gap analysts use computer mapping to superimpose layer upon layer of data. Sophisticated software converts this geographic information into colors or codes and plots those onto a base map, altering the look of the map with each new kind of data added – from vegetation types to population-growth projections. Thus, the images generated can dramatically display the status not just of one species but of entire communities, including the human components.

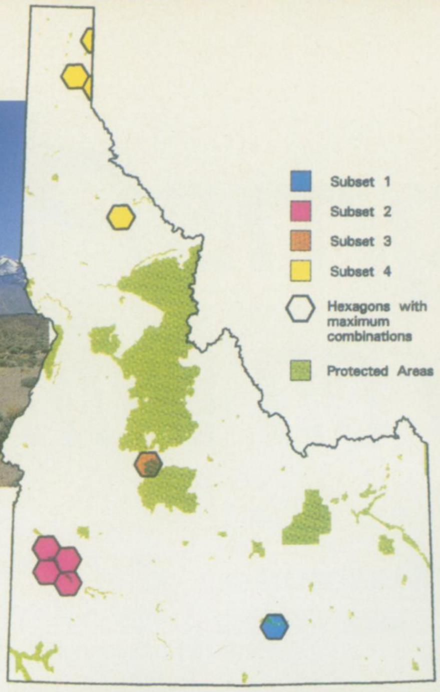
To date, 28 states have begun this approach. Arizona, Utah, Oregon, and Idaho are furthest along; Texas has just started. "And we have more states wanting to do gap [analysis] than we are able to pay for," Scott says.

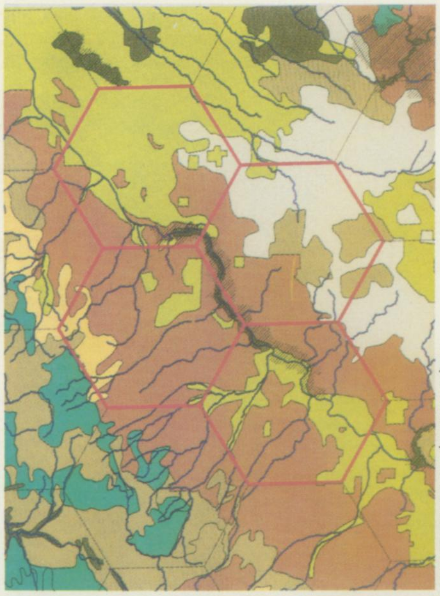
To begin a gap analysis, researchers first have their computer sketch in vegetation types based on satellite images and on existing vegetation maps. To do regional gap analysis across state boundaries, a common way of classifying and presenting the information was needed. Scott and his colleagues have set up standards to do that, a difficult task given that everyone involved has a particular way of looking at things. For vegetation, gap analysts and the Nature Conservancy agreed to follow definitions set by the United Nations Educational, Scientific, and Cultural Organization for naturally occurring groups of plants, usually with one type of tree, shrub, or grass dominating.

These groups tend to occur in conjunction with particular animals, depending on the topography of the land in which the vegetation occurs. Thus, combining vegetation data, as indicated by the satellite maps, and physical data, such as topography, enables scientists to deduce the kind of habitat present and, from that, the animals most likely to be found there,

Gap map (left) reveals that no protected areas in Idaho include western juniper woodlands (top).

Csuti





Maps: Kiester/U.S. Forest Service

"Exact-set" gap analysis comes up with 16 four-hexagon combinations that will cover 79 of 83 unprotected vertebrates. Each set must include one hexagon of each color. Enlarging the red hexagons shows that they contain different vegetation classes (solid colors), waterways (dark blue), and the Snake River Birds of Prey Wilderness Study Area (cross-hatched) that would be evaluated for different land uses. These hexagons also contain places covered with shadscale scrub, a salt-desert shrub.

Scott explains.

To expedite the process of assessing the variety of plants and animals present — biodiversity — the researchers decided to include data just about vertebrates, and more recently butterflies, assuming that the two groups are a good measure of overall biodiversity.

To verify this assumption and to check that the data they're compiling matches what exists in the landscape, gap researchers visit different parts of their states. But for the most part, they rely on observations made by a century of Audubon's successors. "In a lot of states, a lot of the information is already out there," Scott says.

Gap data collectors survey existing museum records and scientific literature for reports about that state's birds, mammals, reptiles, amphibians, and fish; the habitats they associate with; and where these animals actually live. They also investigate the vegetation types, procuring data that help them fill in details not picked up by satellite sensing.

At the same time, these researchers tap local experts, in particular state fish and game managers and people involved with the state's Heritage Program. That program, set up across the country by the Nature Conservancy, tracks rare and endangered species in each state.

"For every animal, I can lead you to the direct reference [about its whereabouts]," says Thomas C. Edwards, a Fish and Wildlife Service biologist based at Utah State University in Logan. "We're almost compulsive about this." The researchers are so thorough because they know that not everyone thinks one can use vegetation to predict where animals live. "It's a little weak from a scientific standpoint," he says. "But from a wildlife standpoint, a lot of sound management has occurred using these habitat relations."

Once the information is entered into a gap-analysis database, researchers can look at the distributions of vertebrates, species by species, or vegetation, group by group. Knowing where certain animals live, the scientists can predict other places where a particular species may thrive. In Idaho, the maps helped guide wildlife biologists to undiscovered populations of the Columbian sharp-tailed grouse, a bird under consideration for being listed as endangered or threatened in parts of the United States, says Blair A. Csuti, who works with Scott.

"We're finding we're somewhere between 80 and 90 percent accurate [in our predictions]," Scott adds.

In addition, the computer can calculate species richness by essentially overlaying all the data about individual species to see where most of them live. Thus, wildlife managers can better locate their state's biologically diverse areas, Scott says.

Then the researchers can paint in land-use information. Their computers can show what land is protected from development; whether an area is privately or publicly held; and whether it is populated, unpopulated, or scheduled for development.

These results pinpoint vegetation types not protected, species that do not occur very frequently, and places rich in biological diversity but vulnerable to development. "You can see what's taken care of and what isn't," Csuti says.

Such work revealed that Idaho possesses 65 native vegetation types, but 27 have less than 10 percent of their area within protected boundaries and six have none. One of those poorly represented in Idaho reserves is the western juniper, often considered an impediment to grazing but also — as gap data revealed — an important rest stop for migrating songbirds, Scott notes.

Next comes the hard part: harnessing mathematical procedures, or algorithms, to help researchers determine ways to take care of the unprotected habitats and species. First, Scott's group had to decide how widespread a species or habitat needed to be to ensure its viability. They also had to figure out how many species they wanted to protect and what size parcels of land would form the best unit for analysis.

On the basis of results indicating that mid-size carnivores such as coyotes need at least 10,000 hectares to thrive, the gap experts decided that any species needed to be present in at least three areas that big to be safe. "Those species that are found in one area are far more vulnerable than those found in multiple areas," Scott points out.

By calling for the computer to draw a map that would include 95 percent of the species, the researchers decided they could establish a reasonably broad protective network. Then they could examine the individual status of the remaining 5 percent, most likely rare or endangered organisms possibly located only in small, scattered pockets.

Continued on p.251

Continued from p.249

Scott's team maps the vegetation and species distributions to within 100 hectares on land and within 40 hectares on waterways. But for eventually doing analyses on a national scale, they decided to overlay a coarser grid of 635-square-kilometer hexagons. This grid makes the gap maps compatible with environmental monitoring and assessment maps generated by the Environmental Protection Agency, says A. Ross Kiester of the U.S. Department of Agriculture (USDA) Forest Service in Corvallis, Ore. "You cookie-cutter [states] with this grid; that gives a regular structure," he adds. Thus, Idaho divides into 389 hexagons, for example. The analyses then identify the hexagons in which new preserves should be established to ensure protection for most of the species.

For Idaho, Kiester first looked for coverage for about 95 percent of the state's 357 vertebrates. To do this, he asked the computer to find the hexagon with the most species and then identify the most species-rich pair, threesome, and foursome, without necessarily keeping the single most diverse hexagon in the group. The computer does this by comparing every possible two-, three-, and four-hexagon grouping – a computational nightmare that took almost 12 hours of supercomputing time. But this so-called exact-set coverage found 32 combinations of four hexagons that protected at least 332 species, says Kiester.

"If this is your definition of biodiversity, then these 32 ways are all equally good, which means you can [take into account] other considerations, such as land ownership and cost," says Kiester.

He and Csuti then took a simpler route, performing a similar analysis but just for "needy" species – those that did not already live in protected areas. For this, they considered 83 species. The analysis showed that 79 of these species could be covered in any of 16 combinations of four hexagons, Csuti reported in June at the annual meeting of the Society for Conservation Biology, held in Tempe, Ariz. The maps pointed out that many of the needy animals lived in a salt-desert scrub habitat, which tends to lie outside protected areas.

They also revealed that in Idaho, four very critical hexagons included the Snake River Bird of Prey Wilderness Area, a parcel that Congress set aside for conservation in September. "That area was prioritized by the old [species-specific] way of doing business," says Kiester. "Now it turns out to be one of the most important areas for all biodiversity."

"By providing that information, we're giving the land manager something to work with," Scott adds. "He or she has a clear-cut decision [to make]." Lawmakers debating the status of the Snake River area knew that more than raptors were at stake. Also, thanks to the Idaho gap map, the Bureau of Land Management (BLM) and the military may agree to shift a proposed bombing site on BLM land to a less biologically diverse section.

Critics are quick to point out that gap analysis provides a relatively crude approximation of what lives where and of the existing biological diversity. And Scott agrees, adding that people using the technique need to be careful not to try to push the data beyond this coarse level. However, he sees the approach and its results as a starting point that will make it easier for others to decide where to do more detailed studies.

"Gap is a screening process," says Kiester. "It tells you what hotel to check into." Lawyers, biologists, wildlife managers, and planners know to head for those hexagons to determine where in those areas needy species live and to figure out boundaries for any protected parcels.

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> *—A. Ross Kiester*

Also, not all solutions will require just four hexagons, and considering combinations of five or more gets exponentially more difficult, even for the smartest computers, Kiester notes. For example, to protect most of Idaho's different types of vegetation, planners will need to set up preserves in 31 hexagons, his analysis shows. Also, while Idaho's vertebrates tended to roam over large areas, places like Arizona and Florida contain many species that exist in isolated spots scattered throughout the state. Figuring out how to cover enough of these species could be daunting for both conservationists and the computer.

Even gap researchers are still debating some aspects of the technique. For one thing, some species may need less than 10,000 hectares to ensure their survival, while others may need more, says Edwards. For another, he and his colleagues have not tried to pick out new preserve sites, in part because they do not have easy access to the massive computing power required to perform the analysis and in part because they think the scientific community has not yet settled on the best way to do that type of analysis. "The results are very algorithm-dependent," says Edwards, adding that he will wait until the Idaho results pass muster with scientific peers before following that state's lead.

But already, the preliminary gap work is proving worthwhile, Edwards says. "At the state level, this is viewed more as an environmental information system that can be of use [to] many agencies on a local scale," he explains. "The gap analysis concept is simply one of many applications of the data." Biologists, or anyone with access to the computer communications network called Internet, can now call up Utah's gap data. With a few strokes on a keyboard, one can examine whether two birds tend to occur together, for example, or what types of habitat they occupy.

As more states finish compiling this information, Edwards will incorporate those data to create regional and national maps. Then, ideally, each state will update its gap data and do a new analysis every decade, in parallel with new U.S. census information, Scott says. Eventually, he envisions gap data to be an integral part of planning efforts by local, state, and federal officials as well as a scientific resource.

Scott's vision closely parallels that of the National Biological Survey, a new federal office established by Interior Secretary Bruce Babbitt. He created the survey to consolidate and reorganize his department's biological research. "The major scientific task we face is integrating all of these disparate efforts," Babbitt told a congressional committee in September. "All of these disparate efforts [need to be] related in a way that makes them useful." Making an analogy to the U.S. Geological Survey, Babbitt suggested that public and private interest groups would more likely accept research results as unbiased from this new agency, in part because it has no regulatory role and in part because of its broad scientific base.

Already NBS has brought into its fold people, such as Edwards, who are spearheading gap analysis. And Babbitt considers gap analysis to be the heart and soul of what this organization will try to accomplish.

"To some extent," says Scott, "if proactive efforts such as gap [analysis] had been funded earlier, we probably wouldn't need the National Biological Survey." □