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Using Satellite Data to Support Fieldwork: Can Species Distributions Be Predicted?

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Abstract

Although species extinction has become a global concern during the last decade, our knowledge of species distribution patterns remains limited. If we don't know where a species has existed historically, we cannot determine if its range is contracting or expanding. This can make it difficult to identify a species as endangered until it is close to extinction. One way to address this problem is to try to predict which species may be at risk based on their habitat distributions.

Keywords

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Disciplines

Animal Sciences | Biodiversity | Ecology and Evolutionary Biology

Comments

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Using Satellite Data to Support Fieldwork

Can species distributions be predicted?

by Diane Debinski

Above: The author, Camille King, Katie Horst, and Liesl Kelly discuss the results of their morning bird census at Twin Cabin Creek. Photos by James Pritchard.

Although species extinction has become a global concern during the last decade, our knowledge of species distribution patterns remains limited. If we don't know where a species has existed historically, we cannot determine if its range is contracting or expanding. This can make it difficult to identify a species as endangered until it is close to extinction. One way to address this problem is to try to predict which species may be at risk based on their habitat distributions.

A variety of on-the-ground techniques has been developed for monitoring species distribution patterns, but they are labor-intensive and costly. After conducting a three-year biodiversity inventory of birds and butterflies throughout the wide array of habitats in Glacier National Park, I became interested in developing methods to make field surveys more efficient and cost effective. Satellite data can be used to identify remotely sensed habitat types based on vegetation density, moisture content, and species composition. I decided to test the use of satellite data in predicting plant and animal species distribution patterns.

Although vertebrate biologists have long used knowledge of an animal's habitat to predict its presence, and more recently used satellite data to identify species-specific habitat sites, the use of remotely sensed habitat types to predict animal species distribution is still unrefined. The Environmental Protection Agency's biodiversity and habitat initiative is investigating the use of low-cost satellite data as an alternative to ground-based habitat assessment.

Our ability to distinguish different vegetation types using only satellite data may be limited. Spectral reflectance patterns are influenced by a combination of topography, moisture, elevation, and vegetation. Proponents of gap analysis (a technique used to compare locations of plant and animal habitats at a study site to those in existing preserves) use LANDSAT Thematic Mapper (TM) imagery to determine the boundaries of vegetation types. Then other data is incorporated (e.g., aerial and high-altitude photography and ground-based vegetation maps and field surveys) to label the vegetation types to series level. A major criticism of this approach has been that gap analysis does not involve enough ground-truthing of information. Even if a habitat appears suitable, we do not know how often a species actually occurs at the predicted site.

Research Objectives

My own goal was not to do away with local field sampling, but to use remotely sensed habitat types and geographic information systems (GIS) analysis to predict species distribution patterns so that fieldwork could be focused on specific sites within the study area. If remotely-sensed habitat types prove to be good predictors of species assemblages, this could provide a more cost-effective technique for monitoring biodiversity than ground-based field work alone. To test this hypothesis, I needed to:

- Determine the extent of the relationship between remotely sensed habitat types and plant and animal species distribution; and
- Test the predictability of species assemblages based on knowledge of this relationship.

The presence of a particular plant species at a specific site can be highly indicative of the particular microhabitat of that site. Because the plant species that provide dominant cover play a major role in determining spectral reflectance patterns, we needed to test the relationship between remotely sensed habitat types and the actual plant community. If plant species distribution could not be predicted using remotely sensed data, relationships between remotely sensed data and animal taxa would be highly unlikely. Thus, a plant survey is the critical link between remotely sensed data, habitat, and other species distribution patterns.

Research Design

My colleagues and I initiated this research to link habitat components (e.g., grasses, forbs, shrubs, and trees) with birds and butterflies. Our study area was the northwest corner of the Yellowstone ecosystem, from Porcupine Creek to Bacon Rind Creek (north/south), and from the crest of the Madison Range to the crest of the Gallatin Range (east/west). This area was chosen to develop our model because it includes a wide range of elevation and moisture gradients and the patchiness of post-fire successional habitats, and because bird and butterfly species lists, including more than 100 species of each, are available for the ecosystem.

Birds were used to test the hypothesis because they are conspicuous, ecologically diverse and use a wide variety of food and other resources, and are often more sensitive to environmental change than other vertebrates. Butterflies were chosen because they are well known taxonomically, easily identified in the field, and their diversity is correlated with underlying plant diversity. Birds and butterflies made a good combination because they are active at different times of the day. Birds were surveyed in the early morning, and butterflies from mid-morning through the afternoon.

Species and Habitat Characterization

The remotely sensed data were clustered into 50 spectrally distinct classes that were evaluated using U.S. Forest Service stand survey maps, aerial photography, and personal knowledge of the study area. A preliminary analysis resulted in a merging of the 50 classes to create five forest habitat types and six meadow habitat types. Mapwork and field surveys were then used to identify five spatially distinct examples of the three mixed conifer-forest and six meadow types, and 100 x 100 m plots were staked out at each of the 45 sites.

Habitat types were based on remote sensing cluster analysis, followed by ground-truthing with USFS stand-survey maps and aerial photos.

During the summers of 1993-1995, we inventoried each site for vegetation, butterflies, and birds.

- Trees were sampled by establishing a 100-m transect on one side of each plot and surveying every tree within 3 m on either side of the transect line for species and diameter at breast height.
- Meadows were sampled by estimating total cover for each plant class (forbs, grasses, and shrubs) within 25 one-m^2 plots, placed evenly along a 100-m transect. For comparison purposes, coverage estimates were also made for each class using a 100 x 100 m plot at each site.
- Birds were surveyed in 35 plots comprising three forest types (F1-F3) and five meadow types (M2-M6). We conducted aural and visual surveys using two groups of two observers moving systematically through the plots for 45 minutes. Sampling was repeated three times in

REMOTELY SENSED HABITAT TYPES

Forest	
F	Mixed conifer forest: lodgepole pine (*Pinus contorta*), Englemann spruce (*Picea englemanni*), and Douglas-fir (*Pseudotsuga menzezii*)
F3	High density
F2	Lower density
F1	Fairly sparse
DF	Douglas-fir
WB	Whitebark pine (*Pinus albicalus)*
Meadow	
M1	Hydric/lush meadow
M2-M4	Decreasing moisture gradient
M5	Moist sagebrush/cinquefoil meadow
M6	Xeric, mostly dry sagebrush shrubland

each plot during the summer of 1993.

- Butterflies were surveyed in 30 meadow sites (five of each of the M1-M6 types). Three people netted and released butterflies for 20 minutes in three randomly selected 50 x 50 m subplots. Sampling was repeated two or three times in each subplot during the summers of 1993 and 1995. Butterflies were not surveyed in forests due to their low density there and the difficulty of maneuvering with nets.

Comparing Satellite Data to Field Observations

There appeared to be significant relationships between remotely sensed data and the vegetation we found in our field observations, and these impressions were quantified. through statistical analysis, which showed several important relationships between satellite data and species distribution patterns of vegetation, birds, and butterflies.

Vegetation. Field surveys in 1993 validated the vegetation density, composition, and moisture gradients expected from the satellite data. For example, forest density decreased from F1 to F3 forests, and F3 forests tended to be located on steep, north-facing slopes. M1 and M2 meadows were characterized by sedges and grasses that prefer wet sites, and M3 meadows by willow thickets and flowering vegetation, while M4, M5, and M6 meadows were characterized by a progression of plants that tended towards the drier end of the moisture spectrum (e.g., sagebrush, fescue, brome, sedum, and aster). I will focus here, however, on the results of the animal data.

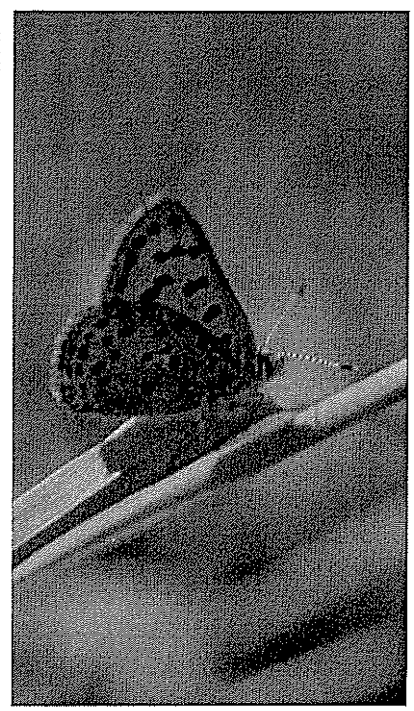
Birds. A total of 74 bird species and 42 butterfly species were observed during the surveys. Several species of birds exhibited a preference for one or more of the remotely-sensed habitat types. The frequency of seven bird species (mountain chickadee, brown creeper, American crow, orange-crowned warbler, hermit thrush, American robin, and song sparrow) was significantly different in the forest versus meadow habitat types. Except for the song sparrow, all of these species preferred the forest habitat types. This is what we would have predicted, for song sparrows are typically found in wet meadows, while the other birds are forest dwellers. When habitats were clumped into broad categories, preferences were as follows:

Butterfly surveys can be an aerobic sport. Here Camille King goes for the gusto in chasing down a vigorous swallowtail.

- The mountain chickadee, which is usually found in coniferous forests, preferred the forest habitat types to the meadow habitat types.
- The song sparrow and rufous-sided towhee preferred M1-M2, the wet willow meadows.
- The dark-eyed junco, which is usually found in forest or forest-edge habitats, preferred the forest habitat types to the meadow habitat types.
- The violet-green swallow, which is found in a variety of habitats including towns, preferred M5-M6 meadows.
- The hairy woodpecker, which is often found in medium moisture meadows with aspen stands or dead standing timber, preferred medium to drier meadows (M3-M4).
- The American robin and red-breasted nuthatch preferred F3, the denser forest, while the ruby-crowned kinglet preferred F1, the more open forest.

Butterflies. Ten species were found in all meadow habitat types, while another ten species were each found in only one meadow type. Thirteen species showed significant preferences for one or more specific habitat types, including several species that were found only in extremely wet or dry meadows.

- Five species preferred M1-M3 habitat types (wet meadows). The Yellowstone Checkerspot *(Euphydryas gillettii)*, a species that typically prefers wet sedge meadows, was found only in M1 meadows (see cover photo). This butterfly lays its eggs only on a shrub called black twinberry (*Lonicera involucrata*), and only if the shrub is in a wet meadows. Checkerspot populations appear to be declining, and may become a species of concern in future years. Other moisture-loving species that showed significant preferences for M1 and M2 meadows included the greenish clover blue *(Plebejus saepiolus)* and four medium-size orange butterflies in the family Nymphalidae: the western meadow fritillary *(Boloria epithore)*, the silver meadow fritillary *(Boloria selene)*, the bog fritillary *(Boloria frigga)*, and the painted lady *(Vanessa cardui)*. The host plants of the fritillaries and the blue include willows, violets, legumes; the painted lady is more of a generalist.
- Four species preferred M4-M6 habitat types (dry meadows). Species such as the lupine blue (*Plebejus icariodes*), the ringlet (*Coenonympha inornata*), and the Mormon fritillary (*Speyeria mormonia*) showed preferences for M5 and M6 meadows. These species are typically found in



Some butterflies are more reclusive than others. Shown here is Lyceana mariposa, *the Mariposa Copper.*

Diane Debinski carefully examines a butterfly for identification prior to releasing it.

Katie Horst measures out the 100x 100m plot and stakes flags preparing for a census at Twin Cabin Creek.

sagebrush habitats and span a range of colors (tan, orange, and blue) and sizes. Their host plants include legumes, violets, and grasses.

- Four species preferred M3 or M4 habitat types (intermediate-moisture meadows), which were characterized by diverse flowering plants such as wild geranium, strawberry, prairie smoke and cinquefoil, but sometimes had a few sagebrush or willow as well. Butterflies found in these meadows included Sara's orange tip (*Anthocharis sara*), the orange sulfur (*Colias eurytheme*), the small wood nymph (*Cercyonis oetus*), and the dappled marble (*Euchloe ausonides*). All of these species are medium in body size and light in color. Their host plants include legumes, mustards, and grasses.

How Effective is the Use of Satellite Data?

We expected satellite data to be a relatively good predictor of vegetation, and this expectation was met by our data analysis. All of the plant species with minimum cover (at least 5 percent in at least one plot) showed a statistically significant difference among the remotely-sensed meadow habitat types. Forest habitat types were significantly different with respect to both density (F1 being lowest and F3 being highest) and species composition.

The next step was to determine whether satellite data could be correlated with distributions of selected animal taxa. Several species of birds and butterflies were associated with one or more remotely sensed habitat types. In some cases, our data showed that a species preferred a broad category of habitats (e.g., forest vs. meadow). In other cases, species distinguished among finer gradations of habitats (e.g., wet meadows vs. dry meadows). Several species, including the Yellowstone Checkerspot, showed a preference for one specific kind of meadow or forest. All of the species-habitat relationships we observed make sense given known species-habitat preferences.

Plants were much more highly correlated with remotely sensed habitat types than were animals. This can be explained by several factors: (1) the remote sensing image is reflecting the actual presence of these plants on the ground; (2) plant data are measured in terms of coverage while animal data are measured as presence or absence; and (3) plants are stationary on the landscape, whereas animals move through the landscape and may or may not be present when the data are collected.

Many factors besides vegetation type affect species presence and can cloud the observed relationship between species and vegetation. Even if a habitat appears suitable for it, a species may not be present because of historical factors (e.g., hunting) or competition with other species. In addition, species found in a wide range of habitat types will not demonstrate a statistical correlation with one specific habitat type. Many bird and butterfly species fit into this "generalist" category. Species that were found in only a few sites, on the other hand, do not provide enough data for rigorous statistical relationships. Thus, in order to predict where one might find a species using remote sensing and GIS methods, a species must be common enough and its habitat specific enough to exhibit a significant relationship with one or more remotely sensed habitat types. Our next step will be to use the models developed in Yellowstone to predict the species distribution patterns in Grand Teton National Park. The test of our predictive models will begin during the 1996 field season.

In summary, remote sensing will be helpful in locating possible sites for rare species with known habitat associations (e.g., a species restricted to dense forest or wet meadows) by identifying the portions of an ecosystem in which the species' habitat is likely to be found. This technique could also be valuable in setting up programs to monitor the effects of global climate change on the distribution of certain species. However, the limitations of this technique must be recognized; extremely rare species and species that are not habitat-specific will continue to require monitoring through more field-intensive methods.

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Diane Debinski is an assistant professor in the Department of Animal Ecology at Iowa State University. This article reflects her special interest in conservation biology and biodiversity assessment.