BIODIVERSITY AND REMOTELY SENSED HABITAT TYPES: A COMPARISON OF MONTANE MEADOWS IN THE GALLATIN RANGE, MT AND IN GRAND TETON NATIONAL PARK, WY

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✦ INTRODUCTION

During the last decade, many approaches to biodiversity analysis have relied on the use of GIS (Geographic Information Systems) and remotely sensed data to categorize habitats, and then predict species assemblages expected to be found in those habitats. For example, Gap analysis uses predictions based on knowledge of the geographical limits of a species' distribution, ecological limiting factors, and habitat preferences (Scott et al. 1993). The goal of Gap analysis is to compare locations of plant and animal habitats to those of existing preserves, thereby identifying geographical gaps in habitat and/or species protection. One problem with this approach to conservation planning is that Gap analysis has not been extensively tested to determine the accuracy of its predictions (Flather et al. 1995).

Thus, an important parallel approach to Gap analysis, which we describe here, involves assessing statistical relationships between species distribution patterns and remotely sensed habitat types. For the past several years, we have used plants and butterflies as taxonomic test groups to examine these relationships. Because the plant species with dominant cover play a major role in determining the spectral reflectance patterns recorded by multispectral scanners, we felt that it was imperative to test the relationship between the remotely sensed habitat types and the plant community. Butterfly species were chosen because they are moderately host-specific insects, and their diversity may be correlated with underlying plant diversity. We have found that many of the butterfly and plant species of montane meadow communities show significant differences in distribution among remotely sensed habitat types (Debinski 1996, Jakubauskas et al. 1996).

Here, we pose the question whether species-habitat relationships (based on remotely sensed habitat categorization of montane meadows) in one part of the Greater Yellowstone Ecosystem will hold in another area of the ecosystem. The long-term goal of our research is to use known species-habitat relationships to predict species distribution patterns in unsurveyed sites. The test of geographic limits of species-habitat relationships is the first step in our analysis. More extensive data will be collected during 1997-1998, allowing for a more rigorous comparisons.

✦ STUDY AREA

The study areas for this research project included a 32,000 ha. area in the Gallatin and Madison Ranges (hereafter referred to as the Gallatins) and a similar size area in Grand Teton National Park (hereafter referred to as the Tetons). Meadow habitat types within the ecosystem range from hydric willow (*Salix* spp.) and sedge (*Carex* spp.) meadows to high-altitude tundra and rock meadows (Knight, 1994). The Greater Yellowstone Ecosystem was chosen because it is one of the largest intact ecosystems in the continental U.S., and species/habitat relationships were therefore expected to be less affected by human disturbance.

✦ METHODS

The methodology for this study was directed toward producing maps of spectrally distinct meadow vegetation classes similar to those produced for Gap analysis. Landsat Thematic Mapper (TM) data are being used for vegetation mapping in the majority of state Gap analysis projects. TM data records reflected light in six spectral bands (blue, green, red, near-infrared, and two mid infrared), with spatial resolution of 30 m and on a scale of 0-255 (0 indicates no light reflected by the object and 255 is maximum separation). The red and infrared bands of TM data have been found to be particularly useful for vegetation mapping.

Satellite data of the study areas were converted from brightness values to units of radiance (mW/cm2/sr/um) (Markham and Barker 1986) and georeferenced to a Universal Transverse Mercator (UTM) coordinate system. To identify areas with similar spectral reflectance characteristics, an iterative euclidean distance clustering algorithm was applied to create preliminary spectrally distinct classes. Spectral classes were identified and assigned to a specific vegetation (or non-vegetation) class with the aid of aerial photos, U.S. Forest Service stand survey maps, and personal knowledge of the study area. Non-vegetated areas (e.g., water bodies, roads, developed areas) were not included in the final vegetation map. In the Gallatins, the meadow classes were defined along an apparent moisture gradient from wet sedge meadow (M1) to dry grassland with sagebrush (M6). In the south (Tetons), the meadows were characterized from M1-M7 because the driest meadow was slightly different from those in the north. The M4 meadow type was discarded in the Tetons because it was found to represent pasture land. Thus, the classes correspond between the north and the south except for M7 meadow which was absent in the north and the M4 meadow which was absent in the south.

Since class polygons smaller than 1 ha would be difficult to locate with confidence in the field, the final vegetation map was generalized to a minimum mapping unit of 1 ha (approximately 11 TM pixels). To facilitate location of study sites during fieldwork, the map was plotted on translucent Mylar, allowing overlays onto 1:24,000 topographic maps of the study region. We inventoried five spatially distinct examples of each of the M1-M6 habitats in the Gallatins in 1993-95 and five spatially distinct examples of M1-M3 and M5-M7 habitats in the Tetons in 1996 (total sites = 60). Sample sites were located in the field with the aid of aerial photography, 1:24,000 USGS topographic maps, a global positioning device, and compass readings from identifiable landmarks.

SPECIES AND HABITAT CHARACTERIZATION IN SAMPLE SITES

Meadow vegetation was surveyed in 20 x 20 m plots. The Gallatins were surveyed in 1995 and the Tetons were surveyed in 1996. Each plot was surveyed for total coverage on a per species basis for all grasses, forbs, and shrubs. Plant taxonomy followed Dorn (1984). Species cover was determined by visually estimating the sum of the greatest spread of foliage for each species in each plot (Daubenmire 1959). In cases where species identification was problematic due to the seasonal sampling time or taxonomic difficulties, species were lumped by genus to calculate a total cover for the genus rather than the species.

Presence/absence data were collected for butterflies in the Gallatins during 1993 and 1995 and in the Tetons in 1996. Butterflies were surveyed on sunny days from 1000-1630 hrs. employing previously developed methods (Debinski and Brussard 1992). Taxonomy followed Scott (1986). Surveys were conducted for 20 min. periods by netting and releasing in 50 x 50 m plots. Surveys were repeated a minimum of three times at each site in the Gallatins. In the Tetons, surveys were conducted for 30 minutes, but replicated only twice due to a limited field season. Stepwise discriminant analysis of the butterfly data was conducted by using a modified presence/absence matrix that weighted the number of species occurrences relative to the number of times a site was surveyed. Each species/site combination was scored as $p_{ij} = m_{ij}/n_j$, where m_{ij} is the number of occurrences for species i, and n_j is the total number of samples taken at site j.

✦ RESULTS

Analysis of the grass, forb, and shrub cover data revealed similarities in the major genera, but large differences in species distribution patterns between the Gallatins and the Tetons. There were also major differences among meadow types within each region. Vegetation characterizing M1 and M2 meadows in both areas included *Carex* spp. and *Juncus* spp. and there was often some standing water. M1 meadows in the Tetons were dominated bay *Salix* spp. M2 meadows in both areas had a high cover of *Poa* spp. M3 meadows in the Gallatins were characterized by high cover of *Salix* spp. and *Fragaria* spp. and tended to be located near streams; in the Tetons, *Poa pratensis* and *Artemesia tridentata* were more common. M4 meadows were only surveyed in the Gallatins. They were of medium moisture with *Stipa richardsonii*, *Bromus* spp., and mixed herbaceous vegetation (e.g., *Potentilla* spp., *Lupinus argenteus*, *Geum triflorum*, and *Geranium* spp.). M5 meadows in both the Gallatins and Tetons had a mixture of *Artemesia tridentata*, *Agropyron* spp., and mixed herbaceous vegetation. M6 meadows in both areas were characteristically xeric, rocky, and dominated by *Artemesia tridentata*, *Festuca* spp., and bare ground. In the Gallatins, this meadow type tended to occur on south-facing slopes, whereas in the Tetons, it was found on large, open flats. M7 meadows were only found in the Tetons on highly eroded, steep slopes. The major cover species were *Agropyron* spp. and *Artemesia tridentata*.

Overall, the 30 sites sampled in the Gallatins yielded 193 total plant species, whereas 160 species were found in the Tetons. For each of the meadow types that were in common (M1, M2, M3, M5, M6), there were a larger number of plant species found in the Tetons (Table 1). It was difficult to conduct statistical analyses of the plant communities due to the fact that while genera were often similar, most of the species were different by M-type in the Gallatins versus the Tetons. For example, M1's in both the Gallatins and the Tetons had *Scirpus* sp., *Carex* sp., *Salix* sp., and *Poa* sp. comprising a major portion of the coverage. However, the species differed between the areas and the species with the highest cover also differed between areas.

Table 1. Comparison of total species richness of grasses, shrubs, and forbs by meadow type between the Gallatins and the Tetons. Meadow types range from M1 (hydric) to M7 (xeric). The M4 class did not exist in the Tetons and the M7 class did not exist in the Gallatins, so the species richness in each of these categories is a blank.

Meadow Type	Tetons (1996)	Gallatins (1995)
M1	48	27
M2	69	39
M3	85	36
M4	--	34
M5	88	35
M6	53	29
M7	72	--
Total	160	193

A total of 42 butterfly species were observed during the surveys in the Gallatins and the Tetons. However, only 28 (67%) of these species were seen in both sites (Table 2). Approximately one-third of the butterfly species in both sites showed significant differences in distribution among remotely sensed habitats, but less than half of these were the same species in both the north and the south (*Plebejus saepiolus*, *Boloria selene*, *Euphydryas gillettii*, and *Coenonympha inornata*). In the remaining cases, two species of the same genus often showed up as significant, but one species would show up in the Gallatins and another species of that same genus was significant in the Tetons. For example, *Colias interior* was significantly related to dry meadows in the Tetons, but *Colias eurytheme* was the species found to be correlated with medium moisture meadows in the Gallatins. Comparing M-types, we found that M3 meadows had the highest species richness and the highest similarity in species composition between the Gallatins and the Tetons. All meadows showed a Jaccard's similarity index for butterfly species between the Gallatins and Tetons of approximately 40% (M1: 0.39, M2: 0.39, M3: 0.44, M4: 0.395, and M6: 0.382).

Table 2. Comparison of the butterfly species observed during 1993-1996 in the Gallatins and Grand Teton National Parks. Meadow types surveyed range from M1 (hydric) to M7 (xeric)..

Species	Grand Tetons	Yellowstone
Parnassius clodius	X	
Parnassius phoebus	X	X
Papilio zelicaon	X	X
Papilio glaucus	X	
Papilio eurymedon	X	
Pieris occidentalis	X	
Pieris napi	X	X
Colias interior	X	X
Anthocharis sara	X	X
Euchloe ausonia	X	X
Harkenclenus titus	X	
Lycaena cupreus	X	X
Gaeides xanthoides	X	X
Lycaena heteronea	X	X
Lycaena helloides	X	X
Epidemia nivalis	X	
Plebejus saepiolus	X	X
Plebejus icarioides	X	X
Plebejus acmon	X	X
Plebejus glandon	X	X
Plebejus melissa	X	
Glaucopsyche lygdamus	X	
Glaucopsyche piasus	X	
Limenitis weidemeyerii	X	
Nymphalis milberti	X	X
Charidryas palla	X	X
Phyciodes tharos	X	X
Phyciodes campestris	X	X
Euphydryas gillettii	X	X
Euphydryas editha	X	
Boloria selene	X	X
Boloria epithore	X	X
Speyeria callippe	X	
Speyeria egleis	X	
Speyeria atlantis	X	X
Speyeria hydaspe	X	X
Speyeria mormonia	X	X
Speyeria cybele	X	
Coenonympha haydenii	X	X
Coenonympha inornata	X	X
Cercyonis oetus	X	X
Erebia epipsodea	X	X
Pieris protodice		X
Colias eurytheme		X
Colias philodice		X
Colias pelidne		X
Lycaena mariposa		X
Euphilotes enoptes		X
Vanessa cardui		X
Polygonia faunus		X
Boloria frigga		X
Oeneis uhleri		X
Vanessa atalanta		X
Nymphalis vau-album		X
Vanessa annabella		X

✦ DISCUSSION

The comparisons of the two areas (Gallatins versus the Tetons) showed a moderate level of species similarity in both the plant and the butterfly community. However, the comparisons are confounded by the fact that the data were collected in different years. The implication is that some plant species could have been less visible, or certain butterfly species might not have been observed due to phenological differences in emergence time. Plant identification was also better in 1996 than in earlier years because of lumping of certain genera (*Bromus*, *Asters*, *Poa* spp.), although this lumping was taken into consideration in the calculation of total plant species richness (i.e., Teton plant data were lumped accordingly in Table 1). Overall the data indicate that there is considerable diversity within each site and between areas. In comparisons on a species basis, it is obvious that genera with high coverage values (*Festuca*, *Artemesia*, *Carex*, *Salix*) in the Gallatins also had high coverage in the Tetons. However, for *Carex* and *Salix* spp., it may be different species within the genus that are dominant.

Some of the differences between butterfly communities in the Gallatins relative to the Tetons may be explained by a shorter sampling period in the southern sites. If we had had a longer field season in the Tetons, the similarity of the species lists would probably have been higher. For example, we probably missed seeing early-emerging species such as *Anthocarus sara* in the Tetons because we were not present to sample in the early summer season. However, given the fact that both sites had the same number of species despite a shorter sampling time in the Tetons, one would expect that if both sites were sampled with equal effort, species richness would be higher in the Tetons.

In summary, the species similarity of the butterfly communities within meadow types and between regions is approximately 40%. The similarity of the plant community is probably within the same range as the butterflies, but we could not calculate a similarity coefficient from our data. It is not surprising that there are some differences, because the two areas are 120 miles apart, and the meadows in the Gallatins tend to be smaller in size than the Tetons. M3 meadows showed the highest species diversity in both areas and both taxonomic groups. The Teton meadows supported a higher diversity of plants and may support a higher diversity of butterfly species. Fieldwork in 1997 and 1998 will allow us to examine these differences more closely because we will sample both areas each year.

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