

# MODELING SPATIAL AND TEMPORAL DYNAMICS OF MONTANE MEADOWS AND BIODIVERSITY IN THE GREATER YELLOWSTONE ECOSYSTEM

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♦ **OBJECTIVE OF RESEARCH**

Our project is an examination of ecological dynamics in the Greater Yellowstone Ecosystem (GYE), concentrating specifically upon the spatial and temporal dynamics of montane meadow communities. We are examining both the abiotic aspects of these communities as well as the biodiversity of plant, bird and butterfly communities. Our long-term goal is to develop predictive species assemblage models based upon landscape level habitat analysis. This involves using intensive, local field sampling to test for relationships between species distribution patterns and remotely sensed data. This research involves several steps: 1) quantifying the spatial and temporal variability in montane meadow communities; 2) developing a spectrally-based spatially-explicit model for predicting plant and animal species diversity patterns in montane meadows; and 3) testing the spectrally-based spatially-explicit model for predicting plant and animal species diversity patterns in montane meadows. Note: Details contained in this report are restricted to year one of a three year grant, so we focus primarily on techniques rather than results.

♦ **PROGRESS SUMMARY:**

We are using a time series of satellite multispectral imagery for monitoring the extent, condition, and spatial pattern of montane meadows on a seasonal and interannual time scale. Field sampling is being used to collect data on the distribution of plant, bird, and butterfly species. Spectrally-based, spatially-explicit models are being developed for six meadow types using a GIS to stratify the study area by topography and geology. We have sampled for two years in two regions of the ecosystem: the northern part of the ecosystem, hereafter termed the Gallatin study area, included the Gallatin National Forest and northwestern portion of Yellowstone National Park; the southern part of the ecosystem, hereafter termed Teton study area, included Grand Teton National Park. Twenty-five sample sites were located in the Tetons and thirty sample sites were located in the Gallatins. Birds, butterflies, and plants were surveyed at each of the sites. Details of the sampling methodology and data analysis are noted below.

## ◆ ACCOMPLISHMENTS AND RESEARCH RESULTS

### MEADOW MAP PRODUCTION

Computer classification of multitemporal SPOT multispectral satellite imagery was used to produce maps of spectrally distinct meadow classes within the Gallatin and Teton study areas. The SPOT satellite remote sensing system records reflected light in three spectral bands (green, red, and near-infrared), with a spatial resolution of 20 m. A summer and a fall date of SPOT multispectral imagery were selected for each study area. A multitemporal approach, using two seasons of data, has been proven in other research to be superior for land use/land cover mapping. Data for May 25 and September 6, 1994 were used for the Gallatin National Forest; data from June 17 and September 3, 1996 were used for the Teton study area. Selection of dates was a function of orbital revisit dates, cloud cover, and availability.

Data were converted from brightness values to units of radiance ( $\text{mW/cm}^2/\text{sr}/\mu\text{m}$ ) and then reflectance. Data were further normalized for differential illumination effects by performing a topographic normalization procedure, using the DEM data re-sampled to 20 m. All satellite imagery were georeferenced to a Universal Transverse Mercator (UTM) coordinate system with a pixel size of 20 m. The three-band multispectral data for the summer and fall dates for each area (Teton and Gallatin) were then combined into a six-band data file for each study area.

An Iterative Self-Organizing Data Analysis (ISODATA) clustering algorithm was applied to each six-band image file to identify spectrally similar pixels. Thirty to fifty initial clusters were specified for the ISODATA clustering, producing a map of spectral classes. Each spectral class was then identified and assigned to an information class representing a vegetation type. Based on spectral similarity, and visual interpretation of the classes with the assistance of aerial photography and knowledge of the study area, the spectral classes were combined to create a five-class map of coniferous forest, water, developed lands, deciduous forest, and non-forested (meadow) vegetation. This five-class map was then recoded to a binary map of meadow/non-meadow, and used to mask the six-band image file, producing a

new image file containing data only for meadow areas. ISODATA clustering was again applied to the masked data to identify spectral differences in the meadow class only, producing a final map of distinct meadow classes. Six non-forested meadow classes, representing a distinct xeric-to-hydric gradient from sedge meadow (M1) to dry grassland with sagebrush (M6) were identified and mapped. FRAGSTATS computer program is being used to analyze landscape differences in meadow size, distance to next meadow of the same type, and type of adjacent habitat between sampling areas. These landscape-level parameters may have significant effects on species distribution at a particular point in the ecosystem.

### SELECTION OF SAMPLING SITES

Because 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 25 pixels, or 1 ha. Final maps were plotted on translucent paper at a scale of 1:24,000 for overlay onto topographic maps of the study area. Mapwork and field surveys were used to identify five spatially distinct examples of each meadow type. Sample sites were located in the field with the aid of global positioning devices, aerial photography, topographic maps, and compass readings from identifiable landmarks. Particular care was taken to ensure that sites were located in the center of a class.

We had originally intended to stratify meadows by size classes, but this was not possible because several of the M-types did not exist within a broad range of sizes. However, we did stratify by northern and southern portion of the ecosystem. There were some problems associated with the M4 classification in the Teton study area. Field investigations in late May indicated that areas mapped as M4 meadow types were in fact groves of aspen (*Populus tremuloides*) with dense herbaceous understories. These groves were not identifiable as such on the satellite imagery. Since the focus of this research was on non-forested montane meadows, and there is no close corollary to these groves in the Gallatin study area (aspen is nearly nonexistent in that area), the M4 type was eliminated from the Teton study area, and sampling proceeded in the remaining five meadow types. Thus we established 55 sampling sites (two study areas, six habitat types, five replicates per habitat type (except for M4's in Teton)).

## ESTABLISHMENT OF SAMPLING SITES

A single point was established at each of the fifty-five sample sites. This point was located in an area reasonably typical (not anomalous) for each particular meadow, and in smaller meadow polygons was located near the center of the meadow so as to avoid edge effects. This point is the northwest corner of the 20 x 20 m plot used for botanical and biomass sampling. All 20 x 20 m plots were laid along cardinal directions for consistency. The 20 x 20 m plot was then established using four steps: First, the southwest corner was established by measuring 20 m due south from the northwest corner, second, the approximate location of the southeast corner was located by measuring 20 m due east from the southwest corner, third, triangulation was used to insure that the plot was square, and the southeast corner was located correctly. A hypotenuse of 28.3 m was measured from the northwest corner to the southeast. The southeast corner was established where the hypotenuse met the 20 m measurement from step two. Finally, the approximate location of the northeast corner was located by measuring 20 m due north from the southeast corner. Once again, triangulation was used to insure that the plot was square. The northeast corner was established at the point 20 m from the southeast corner and 20 m from the northwest corner. A 100 x 100 m plot was overlaid upon the 20 x 20 m plot, using the NW corner of the smaller plot as the center point. One of the four 50 x 50 m quadrats within the 100 x 100 m area was randomly selected to be used as the butterfly survey plot. Bird surveys were conducted in a 50 m radius circular plots using the midpoint of the 100 x 100 m plot and flags were used to mark edges of the circular plot in at least 3 of the cardinal directions. Observers surveying birds stood just off the center of the 100 x 100 m point, to avoid packing down the plants in the vegetation plots.

Each of the fifty-five 20 m by 20 m plots sampled was marked to facilitate relocation of plots in subsequent years. The northwest corner of each plot was marked with a 1.25 m steel or wooden post. All four corners of each plot were marked with a 0.3 m piece of buried steel rebar, which can be relocated with a metal detector. Because each plot is permanent and can be relocated, data can be used to track individual plants and species over time. A permanent and repeatable technique helps to insure that year to year species changes are indeed due to shifts in plant community composition rather than sampling error.

## BIOPHYSICAL AND SPECTRAL FIELD SAMPLING

Biomass measurements were made in July for both Teton and Gallatin study areas. Measurements were scheduled to be coincident with satellite overpass days when possible. For each plot, three 0.20x0.50 m (0.1 m<sup>2</sup>) quadrats were spaced at 10.0 m intervals along the northern edge of each 20x20 m plot. All aboveground green photosynthetically active vegetation within each quadrat was clipped, sorted by life form/category (grasses, forbs, and shrubs), placed in paper bags, and immediately weighed in the field using spring scales to the nearest 1.0 gram to determine "wet" weight. In the lab, bags were dried in a laboratory oven at 100 for 48 hours, and weighed again to determine "dry" weight and percent moisture by life form.

Spectral reflectance readings were taken using an Analytical Spectral Devices (ASD) spectroradiometer, recording electromagnetic energy reflected by the surface over the range 0.3265 - 1.05533 m (visible and near-infrared light) in 512 discrete spectral bands. Measurements were taken for each of the twenty 1x1 m quadrats used for botanical assessment. Ten spectroradiometer scans per quadrat were acquired and internally averaged by the system to determine spectral reflectance. All sites were sampled between 0900 and 1550 hours local solar time. A white reference calibration reading was made at the start of each plot to normalize all reflectance values to a common standard. Sites in Teton study area were sampled during the period July 3-5 (coincident with SPOT satellite image acquisition) and on July 8, 9, 14, 15, and 19 for the Gallatin study area. Poor weather in the Gallatin study area necessitated an extended sampling period, but a majority of sites were sampled on July 14, date of the SPOT satellite overpass for Gallatin, or July 15.

## VEGETATION SAMPLING TECHNIQUES

Twenty 1m<sup>2</sup> quadrats were located systematically within each 20 x 20 m plot. The quadrats were arranged in four belt transects of five quadrats each. All belt transects ran west to east, and quadrats were 4 m apart. Field measuring tapes were laid in a grid-like fashion to insure correct locations of transects and quadrats. The first transect was located along the line between the northwest and northeast corners of the 20 x 20 m plot. The second, third and fourth transects were respectively located 5

m, 10 m, and 15 m south of the first transect. Along each transect, the northwest corner of the 1 m<sup>2</sup> quadrats were located at 3 m, 7m, 11 m, and 15 m from the east edge of the 20 x 20 m plot. The nested sampling design allows for detailed data collection within the 20 x 20 m plot, and the systematic layout insures that the quadrats are relocatable and sampling can be accurately repeated in subsequent years.

For each 1 m<sup>2</sup> quadrat, the aerial percent cover of all plant species was estimated during our July sampling period to derive a measure of plant species composition. Aerial cover estimations were conducted using a modified Daubenmire (1959) method in which estimations were made to the nearest percent. The combined cover of litter and bare ground was also estimated using estimated percent cover. This sampling technique is advantageous because it provides a measure of both species richness and species abundance. Percent cover provides valuable data since it can indicate both plant size and number of individuals.

All plants were identified to species in the field or given appropriate field names. Voucher specimen were collected for all species so that accurate identifications could be made. Species that were difficult to identify are being reviewed by botanists at the University of Kansas Herbarium where the vouchers will be housed. After the 1 m<sup>2</sup> plots were sampled, the entire 20 x 20 m plot and the 100 x 100 m plot were sampled for cover. This sampling provides us with data at 3 scales and with the middle scale (20 x 20 m), being of the actual pixel size of the remote sensing.

#### SPECIES AND HABITAT CHARACTERIZATION IN SAMPLE SITES: BIRDS AND BUTTERFLIES

Abundance data were collected for butterflies and birds in each of the sampling sites. Birds were surveyed between 0530-1030 hrs using point counts in 100 m diameter circular plots. Two observers were present for each 15 min survey. One point count was conducted at each site. Butterflies were surveyed between 0930-1630 hrs by two people netting for 20 minutes in each 50 x 50 m plot. Each butterfly was placed in a glassine envelope and at the end of the survey all individuals of each species were tallied and most were released. A subset of butterflies were taken as voucher specimens. Bird data were collected at each site on three dates (during June 1-July 17). Butterfly data were collected on

four dates (during June 1 -Aug. 15) in each region. Data collections in each of the two areas (Gallatin vs. Teton study area) alternated every two weeks to ensure that species with phenologically different emergence times or activity periods would be included in both data sets. All specimens were identified to species in the field or given appropriate field names. Voucher specimens of butterflies were collected so that accurate identifications could be made. Species that are difficult to identify are being reviewed by Steve Kohler, an authority on Montana lepidopterans. Voucher specimens are housed at Iowa State University.

#### QUALITY CONTROL

All sampling sites have been permanently marked (see Establishment of Sampling Sites). At the start of sampling of each site, the entire crew of botanists, birders, lepidopterists, etc. discussed the species they expected to find and how they could be identified (see grant proposal for details of training). Sampling of each taxonomic group was always conducted with a partner to allow for discussion of each species identification and/or cover value. Voucher specimens were taken for all species of plants and most species of lepidoptera. Multiple vouchers were taken for problematic groups. Data collected were reviewed each day to make sure data sheets were legible and filled out properly. All data forms were copied and are being housed in multiple locations. Data are currently being entered and will be checked by a different person.

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#### ◆ LITERATURE CITED

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