

HISTORICAL VEGETATION, FUEL LOADS, AND INTEGRATED RESOURCE INFORMATION SYSTEM FOR BRYCE CANYON NATIONAL PARK

DAVID W. ROBERTS ♦ MICHAEL J. JENKINS ♦ DOUG W. WIGHT
DEPARTMENT OF FOREST RESOURCES AND ECOLOGY CENTER
UTAH STATE UNIVERSITY ♦ LOGAN

♦ INTRODUCTION

The composition and distribution of plant communities across a natural landscape is determined by a complex interaction of environment, interspecies relations and disturbance. Environmental factors associated with particular locations, such as precipitation and temperature regimes, limit the species which can occur at a given site to those with a metabolism suited to the environmental conditions. These environmental factors, while variable across the landscape, are relatively constant at a fixed point in space. Consequently, environment acts as a relatively constant constraint on vegetation distribution and composition. Within the usually large set of species which can exist at a given point, interspecies competition further limits the species present at a given time. The ecological characteristics of the species are also rather fixed, and the interspecies relations lead to a fairly directional and predictable change with time, i.e. succession. Disturbance reduces or eliminates some species directly, and leads indirectly to changes in composition through changes in the competitive hierarchy. In contrast to environmental and interspecies effects, the occurrence and effects of disturbance are highly variable, and depend in a complex way on previous disturbance and the current and previous vegetation.

Historically, fire played an enormous role in determining the characteristics of vegetation in western forests. Additionally, fire suppression has

preserved species which would have been reduced or eliminated under a regime of repeated burning, and has led to an increase in fuel loads in many natural communities. The high fuel loads cause relatively severe fires when fires do occur, causing relatively greater disturbance than occurred in the historical past. The results of these high intensity fires are very different from low intensity fires, with increased mortality of even fire-tolerant species, and occasionally catastrophic results.

To evaluate the current landscape with reference to the historic landscape information is needed in several related areas. First, more baseline information is required on the historic vegetation mosaic. Specifically, what was the distribution of plant communities on the historic landscape, and what was the typical composition of these communities? Second, how does the pattern compare to the current pattern and how is this relation affected by the vegetation potential of the environment and the interspecies relations? How can natural ecosystem processes, including fire, be reintroduced so as to return the vegetation mosaic to one more similar to the historic vegetation mosaic? How can the guidelines which emerge from this information be implemented in an operational and spatially-explicit manner? These information needs are best met through a comprehensive information system incorporating the basic ecological relations of the vegetation and environment, fuel load accumulation, and fire behavior models.

◆ OBJECTIVES

The overall objective is to develop a comprehensive computer-based information system to provide spatially explicit information on historic, current, and potential vegetation composition, vegetation response to fire, fuel loads, and predicted fire behavior.

Specifically, the objectives are:

1. To develop a written and pictorial document to portray vegetation change in historical time.
2. To map Bryce Canyon National Park to historic vegetation type by use of relocated historical photographs, inference from similar regions, and results from computer simulations using estimated fire return intervals. The historical vegetation is classified using the successional community type classification employed for the current vegetation map.
3. To map fuel loads and fuel model types throughout Bryce Canyon National Park specifying weights for duff and litter, live and dead herbaceous vegetation, shrubs and small conifers by diameter class, and down woody material.
4. To integrate the fuel and fire response models into the existing vegetation simulation model to improve simulation predictions for different fire regimes.

◆ STUDY AREA

Bryce Canyon National Park occupies an area of approximately 14,250 ha on the east face of the Paunsaugunt Plateau in south central Utah. Bryce Canyon National Park was set aside for the spectacular erosional remnants (Hoodoos) along the scarp of the Plateau, and as a result the Park is generally long and narrow running primarily NNE to SSW. The Park consists of a strip of land on the Plateau top itself (varying from a few to several kilometers in width), the scarp of the Plateau, and a strip of land below the scarp to the east (also varying

from a few to several kilometers in width). For detailed geology, topography, soils, climate, flora, and vegetation see Roberts et al. (1992b).

◆ RESULTS

We relocated two series of historical photographs of Bryce Canyon National Park. All of the retakes were photographed in late summer of 1989. See (Roberts et al. 1992b) for details about photograph reference numbers and exposures for each plate. The first series was shot during 1958 by W. B. Alcorn, and show the general scenery around Bryce Canyon National Park. While these photographs were not georeferenced except in a very general way, four of the photographs included landmarks which could be relocated in the field.

The second series of photographs were shot by Dr. Hale Buchanan as part of his dissertation research in the year 1959. These photographs are typically of subjects closer to the camera, and show more detail but less overview than those by Alcorn. A total of 15 of Buchanan's photographs were relocated; 13 of those locations are presented in (Roberts et al. 1992b).

RECONSTRUCTING THE HISTORICAL VEGETATION OF BRYCE CANYON

Estimating the historical vegetation of Bryce Canyon required integrating information from three sources: (1) historical photographs, (2) computer simulation model outputs, and (3) inference from local and regional fire history studies.

In general, the vegetation of Bryce Canyon has shown a steady successional development throughout the Park. The rates and extent of this development, however, vary considerably depending primarily on the number of species adapted to specific environments and the relative moisture availability on specific sites. Because more moist sites are more productive, they generally proceed faster than drier sites. Accordingly, the results will be discussed roughly in order of available moisture for those community types where sufficient information exists to estimate the historic vegetation.

In the lower areas of the Park on xeric non-



Plate 13A. Mixed Forest on Whiteman Bench (Roberts et al. 1992b)



Plate 13B. Mixed Forest on Whiteman Bench (Roberts et al. 1992b)

The most noticeable element of change is the presence of two large down trees in foreground and mid-ground. Several of the trees in the original photograph are now dead. Some filling of the meadow is evident.

forest sites relatively little change has occurred. These sites, mostly BIG SAGEBRUSH/FOUR-WING SALT BUSH and CORYMB BUCHWHEAT/SALINA WILDRYE community types, probably do not burn often due to the isolated location and relatively low fuel loads. Buchanan (1960) discusses the grazing impacts on these areas, and it is probably true that some increase in shrubs occurred at the expense of palatable grasses during this grazing, but there is no strong evidence that the existing community has not recovered from the grazing in the past. Occasional trespass grazing still occurs on these sites, but the overall impact on the vegetation is small.

The flood-plain communities along the streams below the Breaks have been and are still subjected to a regime of alternating high sediment deposition and erosion (Buchanan 1960). Accordingly, these sites form a dynamic system of shifting vegetation, and are vegetated primarily by short-lived opportunistic species or long-lived woody plants such as ponderosa pine that withstand burial of the lower trunk. The environment on these sites is controlled primarily by the geology and climate, and has probably not been significantly affected by either changes in the fire or grazing regime.

The majority of the area below the rim of the plateau is dominated by the PINYON PINE / UTAH JUNIPER community type. In this type the photographic evidence suggests that slow but steady increases in the basal area occurred for both pinyon pine and Utah juniper. An analysis of fire scats and tree age class distributions in this type (Roberts et al. 1992a) shows that fires have been relatively infrequent for the last several hundred years, and that the current vegetation is probably typical of the historical vegetation, although slightly denser. We do not believe that Park management has significantly influenced the pinyon juniper woodlands in Bryce Canyon National Park.

Above the rim the non-forest communities are dominated by the BLACK SAGE/NEEDLE-AND-THREAD community type. This community type was subjected to some grazing pressure up until fairly recently (Buchanan 1960), but has probably not significantly changed due to this influence. Clearly, this community type has not burned often in the recent past, as the dominant black sage is sensitive to fire. There is evidence of invasion of the BLACK SAGE/NEEDLE-AND-THREAD community type by

ponderosa pine in the vicinity of the administration building, possibly as a consequence of fire suppression (Wight 1989). However, our impression is that this area has changed relatively little in historic time.

The lower elevation forest communities are dominated by ponderosa pine and Rocky Mountain juniper woodlands and forests. Here both the photographic evidence and the community composition indicate significant changes in historic times. Where in the past the regeneration has been primarily episodic with few cohorts escaping the frequent fires to achieve sufficient size to become fire resistant, we now observe significant waves of tree regeneration for much of the last 100 years. Where we would expect relatively sparse woodlands of mostly large ponderosa pine we now see relatively few large ponderosa pine in the overstory with abundant saplings and small trees in the understory. The community type classification is insensitive to the overall increase in tree abundance, however, and shows no change due to this increase alone. While ponderosa pine is relatively fire resistant, Rocky Mountain Juniper is much less so. In the absence of fire Rocky Mountain juniper appears to have increased its abundance throughout the ponderosa pine forest. Accordingly, we believe that fairly large areas (approximately 1800 ha) of PONDEROSA PINE/PONDEROSA PINE community have shifted to the ROCKY MOUNTAIN JUNIPER/PONDEROSA PINE community type in the recent past.

With increasing moisture ponderosa pine and Rocky Mountain juniper are joined by Douglas-fir. Throughout the Douglas-fir series (sites where Douglas-fir is the expected climax dominant) evidence of fire is observed. On sites with an understory dominated by greenleaf manzanita, evidence of fire is abundant (Roberts et al. 1992a). Fire suppression over the last 100 years appears to have increased the abundance of relatively fire sensitive Douglas-fir on these sites at the expense of ponderosa pine (Roberts et al. 1992a). Accordingly, we believe that areas (approximately 540 ha) previously in the PONDEROSA PINE/PONDEROSA PINE community type have shifted to the PONDEROSA PINE/DOUGLAS-FIR community type in the recent past.

On still more mesic sites white fir joins the

other conifers, and quaking aspen occurs. White fir is the least fire tolerant conifer, and quaking aspen stems (but not root systems) are extremely fire sensitive. The two species differ, however, in their response to the fire regime. Frequent fires serve to regenerate the aspen, which would otherwise succumb to competition from the more shade tolerant conifers. Thus fire is essential for maintaining aspen on these landscapes. In contrast, frequent fires tend to remove white fir from an area, and may reduce the seed source for this species to the point that white fir may be eliminated from an area by frequent fires. In the absence of fire, white fir is the most shade tolerant species and will come to dominate most sites.

Evidence of fire in the white fir series (areas where white fir is the expected climax dominant) in Bryce Canyon National Park is variable (Roberts et al. 1992a). On most sites with understories dominated by greenleaf manzanita, snowberry, or Oregon grape (*Mahonia repens*), evidence of fire is generally present. On more mesic sites with understories dominated by common juniper (*Juniperus communis*) evidence of fire is lacking. Evaluation of the historic photographs and analysis of the age class distributions (Roberts et al. 1992a) demonstrates that throughout these mesic sites quaking aspen is succumbing to competition from conifers and being lost. Additionally, white fir appears to the species exhibiting the greatest increase in abundance. Accordingly, we believe that many areas which may once have had quaking aspen now have none, and that other areas where aspen was dominant or abundant now have relatively small amounts of aspen left. Accordingly, we believe that areas in the QUAKING ASPEN/QUAKING ASPEN and QUAKING ASPEN/PONDEROSA PINE community types (approximately 110 ha) have been significantly reduced in area, and have converted into QUAKING ASPEN/WHITE FIR, PONDEROSA PINE/WHITE FIR, or DOUGLAS-FIR/WHITE FIR community types.

Other areas in the white fir series lack aspen, and were probably historically dominated by ponderosa pine. These areas have experienced a decrease in regeneration of the relatively shade intolerant, fire tolerant ponderosa pine and an increase in the abundance of white fir. Accordingly, we believe that relatively large areas (approximately 1600 ha) have converted from the PONDEROSA PINE/PONDEROSA PINE and PONDEROSA

PINE/DOUGLAS-FIR community types to the PONDEROSA PINE/WHITE FIR community type.

In summary, successional development in the absence of fire has modified the Bryce Canyon Landscape to a significant extent. On dry sites, this development has been relatively slow, and species conversion has not generally occurred. On more moist sites the development has been significantly faster and species conversion has been common. Generally, there has been a decrease in quaking aspen and an increase in white fir across these mesic sites.

MAPPING THE HISTORIC VEGETATION OF BRYCE CANYON

The map of historical vegetation of Bryce Canyon was prepared by converting an existing digital community type map of Bryce Canyon (Roberts et al. 1992a) according to the information described above. Specifically, we converted:

- 1) ROCKY MOUNTAIN JUNIPER/PONDEROSA PINE to PONDEROSA PINE/PONDEROSA PINE
- 2) PONDEROSA PINE/DOUGLAS-FIR to PONDEROSA PINE/PONDEROSA PINE
- 3) PONDEROSA PINE/WHITE FIR to PONDEROSA PINE/PONDEROSA PINE
- 4) ROCKY MOUNTAIN JUNIPER/WHITE FIR to PONDEROSA PINE/WHITE FIR
- 5) DOUGLAS-FIR/WHITE FIR to PONDEROSA PINE/WHITE FIR
- 6) LIMBER PINE/WHITE FIR to PONDEROSA PINE/WHITE FIR
- 7) QUAKING ASPEN/DOUGLAS-FIR to QUAKING ASPEN/PONDEROSA PINE
- 8) QUAKING ASPEN/WHITE FIR to QUAKING ASPEN/PONDEROSA PINE
- 9) QUAKING ASPEN/BLUE SPRUCE to QUAKING ASPEN/QUAKING ASPEN

After conversion of specific community types we dissolved the boundaries between polygons which were previously different community types but which

had been converted to the same community type. The map shows that the historic vegetation of Bryce Canyon was probably much simpler than that which occurs at present (Roberts et al. 1992a). Specifically, where currently six different community types in aggregate cover over 80% of the Park (Roberts et al. 1992a), on the historic map only three community types are sufficient in aggregate to cover greater than 85% of the Park.

Additionally, on the current community type map a total of 27 community types occur; on the historic map that number is reduced to 20. As a basis for comparing landscape diversity, we calculated the fraction of the Park area in each community type for each map and then calculated a Shannon-Weiner diversity index on those fractions. Where the current community type map has a diversity of 2.1205, the historic map has a diversity of only 1.4559.

The primary reason for this simplification is a homogenization of the landscape with frequent fires. Ponderosa pine is the dominant species on drier forest sites regardless of fire regime. On wetter sites ponderosa pine is the dominant species with frequent fire, while white fir is the dominant species in the absence of fire. Accordingly, frequent fires increase the similarity of wet and dry sites by favoring the dominance of ponderosa pine. While absence of fire appears to have reduced the abundance of quaking aspen, and thus reduced diversity, it has more than offset this reduction by allowing for the differentiation of wet sites into different community types. Theoretically, with continued fire suppression landscape diversity will again go down, when white fir dominates all the mesic sites, but this may never occur.

MAPPING FUEL LOADS AND FUEL MODELS THROUGHOUT BRYCE CANYON

Fuel loads were estimated for each fuel class in each community type. Because of the number of potential fuel maps, we did not produce individual fuel load maps. Rather, we added the fuel load data to the community type map data base. Fuel class load can be found by determining the community type and looking up the fuel load values in (Roberts et al. 1992b). Since each community type corresponds to a specific fuel type, we constructed a fuel type map for Bryce Canyon by recoding the community type

map to fuel type and dissolving boundaries between adjacent polygons which converted to the same fuel type.

INTEGRATING THE FUEL MODEL AND FIRE BEHAVIOR

Predictions into the Simulation Model

Roberts et al. (1992a) described a vital attributes-based forest simulation developed for Bryce Canyon. A key element of the model is that fire intensities are estimated for each habitat type as a function of fuel accumulation, which is in turn estimated from site productivity and time since last fire. In the initial development of the model the fire severities were estimated qualitatively from minimal data.

The key to integrating the fuel load and fire behavior predictions from this study into the simulation model is cross-referencing the community types. Specifically, each community type belongs to a specific fuel type with characteristic fuel loads by fuel class, rates of spread, and fire intensity. Each community type also occupies a specific position in the successional development of communities on each habitat type. Accordingly, it is possible to estimate the time at which each community type occurs in the successional development of specific habitat types from the succession model, and to employ the fuel load estimates from this study as the available fuel in the simulation model.

The fuel load program provides specific values for fuel loads in each fuel class, and the fire behavior program predicts specific values for rate of spread and fire intensity under specific environmental conditions. Unfortunately these values do directly relate to biological response of vegetation. Accordingly, the successional simulation model was used to estimate years of transition from one community type to another, and the fuel model data were used to estimate qualitatively the biological response of the simulated tree species. Despite the lack of quantitative correspondence, the fuel load data resulted in a significant improvement to the behavior of the succession model.

◆ **LITERATURE CITED**

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