LANDSCAPE- AND ECOSYSTEM-LEVEL MANAGEMENT IN WHITEBARK PINE ECOSYSTEMS

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ABSTRACT

To provide adequate resource protection in alpine and subalpine areas, managers need to expand their perspectives and focus on ecosystem and landscape-level management. Single-resource and microsite focuses stymie integrated management and protection plans. A landscape perspective is outlined for the Northern Rocky Mountains, interpreting climatic, landform, topographic, and distribution factors and their relation to vegetation mosaics.

INTRODUCTION

The upper subalpine and alpine zone of the Northern Rocky Mountains has a unique natural vegetation mosaic. This mosaic of forested and nonforested communities differs from the montane forested and nonforested community mosaic that occurs in the next lower elevation zone. The alpine and subalpine community mosaic is a diverse complex of subalpine forest-dominated upland communities, shrub- or herb-dominated upland communities, shrub- or herb-dominated wetland communities, and talus, scree, or rock cliff areas, with sparse vegetation cover.

The types of community mosaics within the alpine/subalpine zone vary by geographic area and type of disturbance history, and are strongly correlated with topography and amount of soil development. A second process of importance is presettlement and postsettlement fire history. Differences between geographic areas exist, both in the natural potential for fire ignition and spread and in the history of fire suppression. A third process that produces different types of mosaics is disturbance by humans, which in this zone, typically includes timber harvest, roads, mining, effects of pollution, effects from recreation, and livestock grazing.

Managers and researchers face a difficult challenge in this zone. It is imperative that we take a landscape perspective and ecosystem management approach to maintain a diversity of productive and functioning ecosystems. Yet the nature of resource advocacy and studies that emphasize small, uniform areas stymie our ability to manage ecosystems at a broad-scale level with an integrated approach. Our basic management objective should be land stewardship that protects the basic ecosystem values of soil, water, air, biotic diversity, and ecological processes, while producing resources for public use. To protect these values and provide resources it is logical to move forward in understanding and implementing an ecosystem management approach at a landscape level.

The understanding of communities and their linkages at a landscape level is a developing science. This paper will provide a landscape perspective of subalpine and alpine ecosystems in the Northern Rocky Mountains, interpret some of the effects of human activities on the landscape mosaic, and identify challenges for managers and researchers to meet to provide sound land stewardship of these ecosystems.

PRIMARY FACTORS OF LANDSCAPE MOSAICS

The pattern, shape, size, and juxtaposition of communities on a landscape are formed or controlled by a variety of factors (Bailey 1988). These factors range from broad-level factors, such as change in climate, to site-specific factors, such as effects of fire, insects, or windthrow (Knight 1987). Broad-level and community-specific factors interact to result in a dynamic pattern of shifting community shapes and sizes. This spatial and temporal pattern is an important component in the development of management strategies.

Geographic and Climatic Patterns

Different geographic areas have different spatial and temporal patterns on their landscapes within the subalpine and alpine zones. Within the Northern Rocky Mountains there is a strong west-to-east longitudinal gradient and a strong south-to-north latitudinal gradient that create different patterns as a result of changing climate conditions (Arno and Hammerly 1984). From west to east, subalpine and alpine climates shift from inland-maritime, to semidesert, to continental influence. From south to north in the Northern Rocky Mountains the lower elevational limits of the subalpine and alpine zones tend to decrease with elevation. However, this can be strongly influenced by local relief and wind patterns.

Landform Patterns

Local landforms and valley to mountaintop relief strongly influence the climate of the subalpine and alpine zones (Arno and Hammerly 1984; Habeck 1987). The

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present landform landscape is an interaction of the landforming process with the geological bedrock and previous landforms (Bailey 1988). In subalpine and alpine areas glaciation is a common important landforming process. Areas that had significant mountain glaciation that covered all aspects differ considerably from areas that had minor mountain glaciation or nivation snow basin action on north slopes, but were not glaciated on alpine plateaus or southerly aspects. Other areas on the northern end of the Northern Rocky Mountains that were strongly influenced by both continental and mountain glaciation have a different landform landscape.

Areas that have low-elevation valleys associated with high-elevation mountains appear to differ significantly in their subalpine and alpine landscape from those areas where the valleys are relatively high elevation and the relief difference from valley to mountaintop is not as great. Those areas that have large relief differences usually have sharper gradients in the alpine and subalpine zone and often have higher precipitation.

Topographic and Edaphic Patterns

Aspect, slope, and soil have a strong influence in the alpine and subalpine zone. The slope, aspect, and position of a community determine microclimatic influences that create a highly complex set of conditions across relatively small land areas. This results in an intricate pattern of variation within and between communities.

Many plants in the subalpine and alpine zone are on the edge of their ecological amplitude. Consequently, minor shifts in soil characteristics that change soil physical and chemical conditions can affect the ability of plants to survive and compete. This results in high variability within and between communities.

Natural Disturbance and Cycles

Natural disturbances and successional cycles, or sequences, cause dramatic changes in the spatial and temporal patterns of subalpine and alpine communities. Natural disturbances of fire, wind, drought, severe cold, erosion, animal herbivory, and mortality or reduction in vigor from insect or disease influences all interact to result in dynamic conditions in this zone. Vegetation composition over time, as a result of interacting plant species growth rates, competitive ability, and mortality, also changes over time as influenced by the various disturbance factors. In the subalpine and alpine zones, where plant growth rates are slow and competitive ability is low, disturbance factors are often harsh and play a strong role in maintaining a dynamic set of shifting conditions. But alpine plant communities have a relatively low ability to buffer against these changes, in comparison to lower elevation montane and valley systems.

Landscape Linkages

The mosaic of ecosystems in a landscape has linkages of: (1) snowmelt and water flow, (2) energy state and transfer, (3) nutrient state, cycling, and transfer, (4) animal habitat needs and movement, and (5) buffering from disturbance. In systems such as the subalpine and alpine zones, which are subjected to extreme environmental conditions, these linkages are critical for species and community survival. Changes in community juxtaposition or conditions can shift the environmental balance and negatively affect an associated community to the point where it can no longer survive. An example in the alpine and subalpine zones is the moist herbaceous communities typically associated with the lee side of a patch of subalpine trees or timberline krummholz trees. Removal of the patch of trees through fire or other disturbance eliminates the conditions for snow retention in the adjacent community, which changes the moisture, energy, and temperature conditions in that ecosystem.

Human Disturbance

Impacts from human developments, pollution, and disturbance to natural processes have been relatively low in the subalpine and alpine zones compared to other ecosystems. However, these zones are very sensitive to disturbance by humans, and the consequences are often highly visible. Primary human disturbances that have affected the subalpine and alpine ecosystems involve: (1) mining, (2) oil and gas development, (3) road construction, (4) direct fire suppression impacts, (5) indirect fire suppression effects, (6) domestic livestock grazing, (7) logging, and (8) air pollution and associated global climatic change. Because of the lack of buffering ability in subalpine and alpine ecosystems, the effects of these disturbances are longer, often more drastic, and tend to be more chain-reactive than in other more productive and less fragile ecosystems.

The principal effects of historic natural resource management and development on landscape patterns and linkages have tended to fragment communities that are naturally contiguous and reduce or eliminate corridors or environmental linkages between associated ecosystems (Franklin and Forman 1987; Knight 1987). In contrast, the consequence of fire suppression in relatively natural landscapes has been homogenization. Typical patterns of human developments are straight lines, squares, and rectangles compared to the more natural shapes of nature.

In Europe, long-term human developments have resulted in a lowering of the upper timberline, thus increasing the alpine zone (Douguedroit 1978; Plesnik 1978). This has been primarily caused by tree cutting for use in charcoal burning and by grazing. Some attempts have been made to reforest these areas with subalpine tree species. These attempts have been somewhat successful in establishing trees in this zone, but the resulting forests greatly lack the natural diversity of patterns and associated stability of linked communities.

In the Northern Rockies, historic logging, mining, and livestock overgrazing have locally removed forest subalpine communities and changed community patterns. However, these effects have not been broad scale. Revegetation of sites degraded by mining, roading, and overgrazing has been somewhat successful given the right conditions. It has become apparent that once the shallow topsoil is lost, revegetation of alpine and timberline ecosystems is very difficult. The change in snow accumulation/melt patterns and energy flow from tree removal and soil loss in these ecosystems often create a complete change in the potential vegetation that can grow on the sites.

Disturbances to subalpine forest vegetation from logging and overgrazing set succession back to an early stage. As long as the disturbance has replicated natural events, such as fire or big-game grazing, and no exotic plants have been introduced, succession will usually proceed in a relatively natural fashion. However, successional response in this zone is very slow, even when there has been no effect on soil and microclimate. This slow response usually does not meet management standards for regeneration or for livestock vegetation management trend. There is little that can be done to speed up this response on areas that have been impacted in the past. Future harvest treatments and grazing systems should be designed to better mimic natural disturbances and maintain soil productivity and microclimate conditions.

The results from fire suppression in the subalpine zone are broad scale. Natural fire frequency cycles are relatively long in this zone and successful ignitions are infrequent (Arno 1986; Fischer and Bradley 1987). Consequently, fire suppression has been relatively successful. Since fire frequencies are typically 100 to 300 years, the effects of fire suppression on individual communities have not caused a change from what is present naturally. The primary effect is that the amount of communities in an early seral stage compared to mid and late seral is much less. Consequently, the pattern of communities in this zone is becoming more homogenous; old communities are maintained, while adjacent communities that were once young are now becoming old.

Intensive development and management by humans usually result in a reduction of genetic and species diversity. In the subalpine and alpine zones of Europe this has been a significant result from long-term degradation of these environments (Douguedroit 1978; Plesnik 1978). Many species have become extinct, and the diversity of species in existing communities is much lower than in similar natural communities.

In the Northern Rocky Mountains there have been relatively few plant species extinctions in the alpine or subalpine zones that have been caused by human developments or management. In localized communities that have had severe impacts from mining, road building, or overgrazing there has been significant loss in species diversity. Where exotic species have been introduced, there is little chance for the native species to compete and reestablish dominance through succession.

There is little doubt that pollution is affecting our natural communities (Mintzer 1988; Perry and Maghembe 1989). There is ample evidence that acid rain and other pollutants are reaching all environments on earth. Some ecosystems have the ability to buffer these pollutants and will not be strongly affected. Ecosystems at extremes, such as the subalpine and alpine zones, that have little buffering ability, are typically the first to demonstrate effects of these pollutants. There is little agreement on how global climates may change. However, it is generally agreed that climates will become more extreme even if there is little change in the averages. The subalpine and alpine climates will be more sensitive to this change and communities may show the effects. These ecosystems should make excellent monitoring sites that would be sensitive to changes in air pollutant levels and climates.

EVALUATION AREAS

Three areas were selected on a west-to-east gradient at approximately 46 °N. latitude across the Northern Rocky Mountains. All areas have had varying degrees of mountain glaciation and have subalpine and alpine vegetation, with some communities dominated by whitebark pine (*Pinus albicaulis*). Areas were mapped and map photo interpretation types were correlated with available ground data. The furthest west area is an area on the south end of the Seven Devils Mountains of north-central Idaho, which lies between the Snake River to the west and the Little Salmon River to the east. The second area, which is in west-central Montana, near the Continental Divide, is in the Bitterroot Range, and is called the Piquette Mountain area. This area lies between the East Fork and West Fork of the Bitterroot River. The third area is in south-central Montana, west of the Boulder River, and is called the Meatrack-Carbonate area.

The three areas all have had historic sheep grazing impacts, but adequate areas were left ungrazed to compare disturbed to natural vegetation. All three areas also have had some disturbance from past exploratory mining, but this is relatively minor when compared to the size of the total area.

Table 1 shows a comparison of various environmental and landscape factors based on a preliminary assessment. A final assessment will be published at a later date based on additional ground data and correlation.

Climates of the three areas make a transition from strong maritime influence on the west to the continental climate of the Meatrack-Carbonate area on the east. The Seven Devils site has strong evidence of glacial cutting or deposition on most of the area. The Piquette Mountain area shows evidence of glaciation primarily on the northerly aspects and on south aspects at the highest elevations. Both of these areas have alpine communities that are on steep slopes or in cirque basins. The Meatrack-Carbonate area has strong evidence of glaciation on the north aspects and some south aspects, but large areas of high-elevation alpine plateaus remain above the glacial cirques.

The area with the highest relief is the Seven Devils area with a low of 1,600 ft at the Snake River to a high of about 8,500 ft. The other areas have differences of relief of about 5,000 ft; the Meatrack-Carbonate rises almost 2,000 ft higher than the Piquette Mountain area.

Potential vegetation indicated a strong dominance by forest communities in the Piquette Mountain area compared to approximately an even split between forest potential and nonforest potential on the Seven Devils area. The Meatrack-Carbonate area showed strong dominance by herbaceous communities. This is probably correlated with the low precipitation and continental climatic regime. The presence of subalpine shrub types, primarily

Table 1—Environmental and landscape factors for three subalpine/alpine areas in the Northern Rocky Mountains

Factor	Area		
	Meatrack-Carbonate	S. Seven Devils	Piquette Mt.
Climate type	Inland-maritime	Inland-maritime	Continental
Valley elevation (ft)	1,600	3,500	5,500
High elevation (ft)	8,500	8,600	10,500
Percent mt. glaciation	85	50	35
Percent subalpine forest potential	45	60	30
Percent subalpine herb potential	15	15	30
Percent subalpine shrub potential	15	5	0
Percent timberline krummholz	5	2	10
Percent alpine herb-shrub potential	5	3	15
Percent rock, scree, and cliff	15	15	15
SI(50) SAF ABLA/VASC HT	44	33	22
BA (ft^2) ABLA/VASC HT	115	145	175
Herb-shrub foliage production (lb)	955	785	1,060

mountain sagebrush (*Artemisia tridentata vaseyana*), appeared to be strong to the west and decreased to the east. All areas had approximately the same amount of rock, scree, and cliffs.

Site index and basal area of subalpine fir (*Abies lasiocarpa*) were evaluated on a subalpine fir/grouse whortleberry habitat type (Pfister and others 1977; Steele and others 1981) on all three areas for similar aspects. There is considerable difference in soils between the three areas. Site index (SI) generally decreased from west to east for subalpine fir, as would be expected, making the transition to a drier and more continental climate. Basal area generally increased from west to east, and no correlation can be drawn since this attribute is probably more highly correlated to past stand history than to the environment. Production of annual herb and shrub foliage (lb/acre) was evaluated on an elk sedge/Idaho fescue grassland type for all three areas. This value should generally increase in correlation with continental climate, but there was considerable difference in soils and precipitation.

A preliminary assessment of polygon shape and size was also conducted for the three areas. These preliminary values are presented in table 2.

Size and shape of polygons for different vegetation types were highly variable between the areas and showed no strong correlation with the west to east climatic trends. Size, shape, and juxtaposition appear to be highly correlated to local factors of landform, topography, soils, and historic disturbance. Table 3 shows a relative correlation of these factors for the three areas that were evaluated. Fire appears to be a much stronger component in the Seven Devils and Piquette Mountain areas compared to the Meatrack-Carbonate area. However, that may be an incorrect conclusion, since although fires may be less frequent in the Meatrack-Carbonate area, they may just as strongly control size and shape over the long term.

Methods for assessing these correlations are relatively rough and need to be refined to better identify controlling factors and explain variability. Statistical parameters to describe variability are difficult to assess, since none of the factors can be considered to have normal distributions. Frequency statistics appear to be the primary attributes that are descriptive and have meaning for making management assessments and recommendations.

Table 2—Polygon size and shape factors for three subalpine/alpine areas in the Northern Rocky Mountains

Factor	Area		
	Meatrack-Carbonate	S. Seven Devils	Piquette Mt.
Polygon shape			
Subalpine forest types			
Mean size (acres)	45	80	20
Percent linear	30	45	15
Percent octagonal	35	20	40
Percent elliptical or oblong	25	25	30
Percent rotund	5	0	10
Percent irregular	5	10	5
Percent rectangular	0	0	0
Whitebark pine types			
Mean size (acres)	35	10	15
Percent linear	40	85	25
Percent octagonal	40	5	15
Percent elliptical or oblong	0	0	20

Table 3—Percent correlation of factors controlling polygon size and shape for three subalpine/alpine areas in the Northern Rocky Mountains

Factor	Area		
	Meatrack-Carbonate	S. Seven Devils	Piquette Mt.
	Percent		
Geoclimatic	5	5	5
Landform	15	30	30
Topography	15	25	30
Soils	20	5	15
Disturbance	45	35	20

MANAGEMENT AND RESEARCH CHALLENGES

There are many challenges for management and research in the subalpine and alpine ecosystems. We need to evaluate our ability to manage ecosystems from a landscape and vegetation perspective. Do we have the technology and the philosophy to take this approach? Another way to ask this question is "do we see the ecosystem for the trees?" If we had all the data we needed to describe ecosystems from a landscape perspective, would we have the techniques to analyze those data? We need to develop the ability to assess natural mosaics relative to "human activity" mosaics and determine the positives and negatives of various combinations of vegetation types, their size and shape, their juxtaposition, and associated corridors or linkages.

Now more than ever, managers must develop an ecosystem philosophy for management. The number one objective for managers of public lands should be to provide land management and stewardship that protect and enhance basic values (soil, water, air, biotic diversity, natural processes), while producing resources for public use.

On the forefront of management and research challenges is the need to take an ecosystem and landscape approach to assessing management alternatives. Managers must develop their abilities to analyze ecosystems and develop integrated alternatives, rather than being advocates for their own specialty. Specific resource advocacy is a detriment to an ecosystem approach and results in interdisciplinary team members "whipsawing" each other from defensive to offensive, and alternatives to mitigation.

To develop effective management alternatives and understand their potential effects, management needs to be able to extrapolate to large-scale areas. Present research is often done at a micro scale, and management lacks the tools to interpret the results at a large scale. Research needs to develop the relationship between predicting results for a site to extrapolation for an ecosystem.

Research should begin developing technology to assess spatial and temporal changes and assess how these changes might affect resource outputs, community linkages, and ecosystem stability. Without this technology it will be difficult to develop viable ecosystem management alternatives that will provide for conservation of natural processes, landscapes, ecosystems, species, and genetic resources. With this technology managers can develop prescriptions for landscapes versus stands or communities.

To summarize, the challenge to managers is to expand their perspective to the ecosystem and be their own conscience for protection of basic ecosystem values. The challenge to researchers is to improve our ability to extrapolate results, and assess alternatives and affects, in the realms of both spatial and temporal landscapes.

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