IMPLEMENTING ADAPTIVE ECOSYSTEM RESTORATION IN WESTERN LONG-NEEDLED PINE FORESTS

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ABSTRACT. This paper discusses the restoration of western long-needled pine ecosystems in general with a focus on developing adaptive ecosystem management projects which will simultaneously restore these ecosystems and advance basic understanding of how these systems operate. The paper begins with some background remarks on ecosystem restoration. Next comes a brief overview of the evolutionary context of long-needled pine forests of western North America. Then I present a broad overview of human caused changes in the structure and function of long-needled pine forests. Next I illustrate these changes for the ponderosa pine forests around Flagstaff, Arizona. Finally, I close with a call for interagency cooperation to implement adaptive ecosystem restoration of western long-needled pine ecosystems at an operational scale.

INTRODUCTION

A fundamental postulate of ecosystem management is that restoring and managing ecosystems consistent with conditions present during their evolutionary history is the most effective strategy for preserving diversity, maintaining endangered species, and avoiding catastrophic disruption of ecosystem functioning (Society for Ecological Restoration, 1993). Ecological restoration rests on the premise that the entire ecosystem will function best under the conditions to which its component organisms have become adapted over evolutionary time. Restoration does not mean that the ecosystem can be returned completely to the presettlement era nor does it imply a rigid, uniform prescription for management of every acre of forest land. In fact, on most of the land, restoration will be used to maximize compatibility between both natural processes and structures and human habitat requirements.

For western long-needled pine forests, ecosystem restoration implies that dense patches of postsettlement trees should be thinned to promote tree and grass growth and vigor; that native grasses, shrubs, and wildflowers be encouraged to provide forage for wild and domestic animals as well as enriching the soil and holding moisture; that a range of tree ages, especially of the oldest trees, be maintained to ensure habitat and genetic diversity; that heavy, unnatural postsettlement fuels be treated and then that prescribed fire be reintroduced on regular intervals to carry out its natural role. Within this broad-based approach, there is room for emphasis on specific goals for timber, range, water, or wildlife and game production, recreational opportunities, and human homesites. As the field trips and talks at this conference have shown we are a long way from healthy ecosystems such as these. Today all resources and ecological processes are suffering from current forest conditions.

AN EVOLUTIONARY CONTEXT

Ponderosa pine is the most widespread member of an ecologically similar group of long-needled pine in the section ponderosae. Principal members of this group are Arizona pine (formerly classified as a five-needled subspecies of ponderosa pine), Durango pine, Apache pine, and Jeffrey pine. These species share the morphological characteristics of having thick bark, protected buds, prolific seed production, longevity, and abundant and highly flammable litterfall, all of which are considered to be adaptations to frequent, low-intensity surface fires. They are analogous to the red pine forests of the Great Lakes region of North America and long-leaf pine of the southeastern United States.

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The earliest paleoecological record of this group of yellow pines comes from 50 million-year-old macrofossils found in British Columbia. Ponderosa pine macrofossils dating from 26.5 million years ago have been found near Creed, Colorado. Throughout the late Pliocene and the Quaternary ice ages species of ponderosa pine/bunchgrass ecosystems have migrated up and down in elevation and latitude tracking favorable climatic conditions. At various points in time, ponderosa pine/bunchgrass communities were much more prevalent, most notably during the Pliocene (2-5 million years ago) when these ecosystems occupied 200-300 million acres of North America and provided extensive habitat for the modern biota of today as well as other some species now extinct, including some species of the prehistoric megafauna such as mammoths, ground sloths, and saber toothed tigers. Clearly, ponderosa pine/bunchgrass ecological systems have coevolved with frequent surface fires and open park-like stand conditions for many millions of years.

Since Pliocene times these forests have provided important evolutionary habitat for an exceptionally diverse biota, much of which appears to be adapted to frequent fire. For the past 10-30 thousand years these forests have been vital resources for numerous human cultures, most recently (1850-present) for Euro-American industrialization.

Early human cultures in North American forests supplemented lightning ignitions by using fire as a hunting, gathering, and agricultural tool. Native Americans used fire to extend the range of ponderosa pine parklands into adjacent forest and woodland types (Arno 1985). Soon after Euro-American settlement of the region, a period of intense resource exploitation began during which the ecosystem capital of large old-growth trees and lush herbaceous vegetation generated tremendous wealth for the rapid expansion of the then infant Euro-American economy. However, intensive exploitation exacted its toll on the ecosystem, setting into motion changes which would result in the depauperate conditions we see today.

Postsettlement changes in Southwestern ponderosa pine

Old-growth tree populations and their dependent communities have been, and are continuing to crash precipitously, first from logging and then from competition with irrupting postsettlement tree populations and crownfire. Heavy livestock grazing broke grass fuel continuity and active fire suppression eliminated the presettlement fire regime. In the absence of frequent fires striking changes occurred: tree species less adapted to frequent fire have invaded (at the expense of other plants), and conifer tree biomass, both live and dead, has steadily accumulated, contributing to progressively declining biodiversity, increasing susceptibility to insect and disease epidemics, and supporting a shift from frequent, low intensity surface fires to larger and larger crownfires (Cooper 1960, Covington and Moore 1994b, Swetnam and Baisan 1994).

To a society with high demands for wood products, the increase in tree density at first seemed beneficial to many. However, after 50-70 years of fire exclusion, foresters and ecologists, beginning with Aldo Leopold in the 1930's, began sounding the alarm that fire exclusion in these long-needled pine forests was leading to rapidly accelerating ecological degradation. For example, Harold Weaver in 1943 summarized conditions in eastside Washington ponderosa pine:

> "Dense, even-aged stands of ponderosa-pine reproduction have developed...enormous areas are growing up to dense, even-aged stands of white-fir [sic], Douglas-fir, and incense-cedar [sic] reproduction under the merchantable ponderosa pines...for the past 20 years epidemics of the western pine beetle have killed and are continuing to kill billions of board feet of ponderosa pine worth many millions of dollars. Because of these ecological changes, which are continuing to take place, the fire hazard has increased tremendously. Fires, when they do occur, are exceedingly hot and destructive and are turning extensive areas of forest into brush fields."

Soon other researchers pointed out additional undesirable consequences of fire exclusion in ponderosa pine forests. Studies in Utah (Madany and West 1983, Stein 1987), Montana (Gruell et al. 1982), Idaho (Steele et al. 1986), Washington (Weaver 1943), California (Laudenslayer et al. 1989), and the Southwest (Cooper 1960, Covington and Sackett 1986, Covington and Moore 1994a,b) have shown that increased tree density, fuel loading, and crownfire occurrence are common consequences of fire exclusion throughout the ponderosa pine type.

Various authors (e.g., Arnold 1950, Cooper 1960, Biswell 1972, Weaver 1974, Kilgore 1981, Williams et al. 1993, Covington and Moore 1994a,b) have inferred that associated with these increases in tree density, forest floor depth, and fuel loading in ponderosa pine ecosystems have been:

1. Decreases in soil moisture and nutrient availability;
2. Decreases in net productivity and diversity of herbaceous plants and shrubs;
3. Decreases in tree vigor, especially in the oldest age class of pine;
4. Decreases in animal productivity;
5. Decreases in stream and spring flows;

6. Increases in susceptibility to pine bark beetles; and

7. Increases in fire severity and size.

In sum, the implication is that today's tree densities and fuel loads in ponderosa pine ecosystems are not sustainable. However, with few exceptions these inferences have not been supported by intensive ecosystem management-oriented research.

Public recognition of the severity of these ecological changes has led to considerable debate over implications of various management scenarios (including no action) on ecosystem health and sustainability. Furthermore, researchers, other natural resource professionals, and the lay public are embroiled in an often rancorous debate over what, if anything, should be done. Concerns about overcutting of old-growth trees (or for some factions practically any commodity uses of forestlands) has led some environmental groups and some scientists to argue against any role for mechanical treatments in restoration of ponderosa pine ecosystem health. However, others point to evidence that without mechanical treatment to reduce unnatural fuel loads, the ensuing fires, even under controlled conditions, can kill old-growth trees and other vegetation, and cause such intense soil heating that restoration of natural conditions is retarded, if not precluded, for the foreseeable future (see review by Covington et al. 1994). Aldo Leopold suggested several lines of evidence for a potential synergy between innovative commodity resource uses and restoration and maintenance of ecosystem health:

> "... Leopold set out to define conservation in the following terms: as 'a universal symbiosis with land, economic and aesthetic, public and private;' as 'a protest against destructive land use;' as an effort 'to preserve both utility and beauty;' as 'a positive exercise of skill and insight, not merely a negative exercise of abstinence and caution;' and, finally, as 'a state of harmony between men and land.'" (passage from Callicott 1994).

However, objective scientific data to support such management actions are inadequate.

Systematic field research in combination with synthesis from existing knowledge can help fill this information gap by providing a sound scientific basis for evaluating the consequences of various ecosystem management options and designing adaptive ecosystem management projects. It is a fairly straightforward task to determine the effects of wildfires, prescribed fire, understory thinning, and bark beetle-induced tree mortality on key ecosystem and human resource characteristics of long-needled pine ecosystems. Collection of field data in combination with synthesis of historical data and ecologically-based response functions can be used to examine the relative effects of fire, cutting, and bark beetle infestation treatments on:

1. Tree composition, density, spatial pattern, size, age structure, growth efficiency, and biomass;
2. Fuel composition and structure;
3. Herbaceous and shrub composition and biomass; and
4. Selected wildlife and human habitat values.

Because ecosystem management uses the concept of the range of natural or historical variability as a key reference point (Morgan et al. 1994), a fundamental comparison should be analysis of treatment effects in relation to conditions which prevailed before disruption of the natural fire regime in these forests.

Examples of Restoration at Work

The impacts of Euro-American settlement in ponderosa pine ecosystems has been devastating to the native biota. The basic chain of events, familiar to us all, consisted of cutting out the old-growth trees, extirpation of predators, introduction and subsequent irruption of livestock populations, and as a consequence, disruption of natural fire regimes.

Dendrochronological analysis of multiple fire scars from the Chimney Spring Interval Burning Study Area 7 miles north of Flagstaff indicates that the average fire interval on this site was 2.3 years before fire regime disruption in 1877 (Dieterich 1980). Beginning in 1877 thousands of head of cattle were introduced into the area. The ensuing overgrazing eliminated the herbaceous fuels which had carried fires across the landscape holding pine populations in check.

With the completion of the transcontinental railroad in 1882, logging began in earnest in the Flagstaff vicinity. Thus began a population crash of the largest and oldest trees which continues to the present. The next event was an irruption of dense forest stands and a crash of herb- and shrub-based food webs. These tree population irruptions are apparent not only at the landscape level but also within stands. Photo series from a restoration study at the Pearson Natural Area north of Flagstaff show open forest conditions in 1909, the seedling population explosion by 1938, and the dense sapling and pole thickets of today which compete with the old-growth trees and provide ladder fuels for fires to reach their crowns (Covington and Moore 1994a). Similar photo series are available from Montana, Oregon, South Dakota, California, and elsewhere. The upshot of this tree population irruption has been the conversion of diverse park-like stands to dense forests. In a very real sense what we have witnessed throughout the western long-needled pine forests is the flip-side of forest fragmentation: the fragmentation of the once vast herbaceous and shrub vegetation which once served as the surface matrix for these diverse and productive parklike pine forests. From a biodiversity standpoint, these tree population irruptions have caused a tremendous simplification of net primary productivity to the point at which today virtually all is concentrated in trees.

The reconstructed sequence of events for the Bar-M study area 25 miles south of Flagstaff is instructive (Covington and Moore 1994a). Steadily increasing tree density has lead to increasing crown closure, a continuous fuel ladder, heavy forest floor accumulations, and a crash of herbaceous production. Perhaps most devastating has been the irruption of increasingly large and devastating crownfires, which were not part of the evolutionary experience of most of these ecological systems. When you think about it, it would be very difficult to design a more devastating assault on the biodiversity of ponderosa pine/bunchgrass ecosystems. Imagine the outcome of an environmental assessment of fire exclusion conducted in the 1870's if they knew then what we know now.

Conclusion

Although at differing stages, these transformations are ubiquitous throughout the range of ponderosa pine from Canada to Mexico (Covington et al. 1994). In addition to areas in the Southwest, I have visited sites from through out this range from Kamloops, British Columbia, the Black Hills (South Dakota), Colville Indian Reservation in Eastern Washington, the Sierra Nevada of California, the Sierra Madre Occidental of Mexico. In Mexico, some still burn on a 3-10 year interval (Fulé and Covington 1994, Fulé and Covington, this volume).

Setting these ecosystems on a more sustainable path is straightforward. What is needed are interagency cooperators of practitioners and researchers from throughout this range who are interested in implementing ecosystem restoration in an adaptive ecosystem management context (Williams et al. 1993). A team of scientists at NAU is working on one such project with the Arizona Strip District of the Bureau of Land Management (Taylor, this volume). In that project we are initiating cooperative ecosystem management work to answer questions regarding whether existing disturbances can restore ecosystem structure and function, to test hypotheses regarding ecosystem restoration treatments, and to establish demonstration areas to serve as public information and education areas.

In conclusion, it seems clear that ecological restoration of western long-needled pine ecosystems offers unparalleled opportunities for implementing ecosystem management with a win/win outcome. We could restore ecological integrity and improve resource values, paid for at least in part by removal of postsettlement trees. The risks of inaction far outweigh the risks of implementing ecosystem restoration.

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