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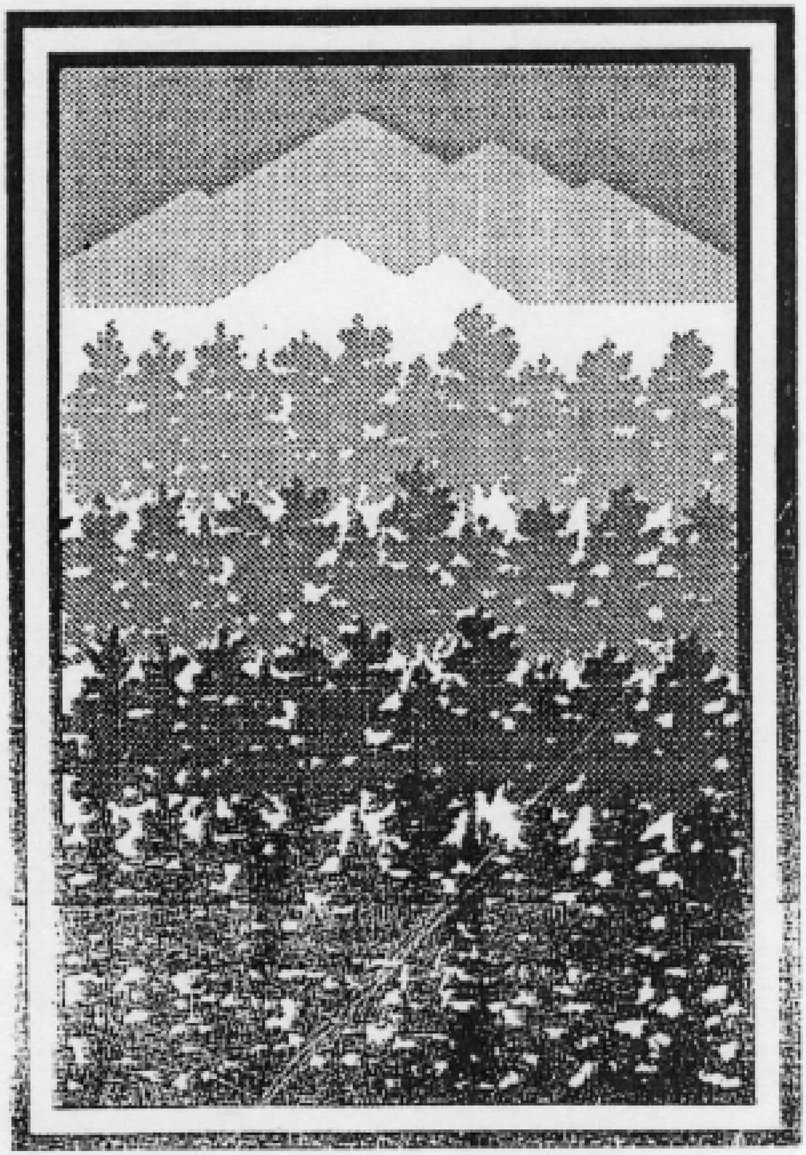

Implications for Ponderosa Pine/Bunchgrass Ecological Systems

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Astract — When viewed from a conservation biology perspective, postsettlement outbursts of ponderosa pine trees in ponderosa pine/bunchgrass ecosystems not only reduce biological diversity but also lead to nonadaptive catastrophic processes. These changes, in conjunction with parallel decreases in natural resource conditions, are compelling reasons for beginning ecological restoration treatments designed to establish landscape conditions which more closely approximate the conditions which these ecosystems have experienced over evolutionary time.

"Between the two extremes of passively following Nature on the one hand, and open revolt against her on the other, is a wide area for applying the basic philosophy of working in harmony with natural tendencies" (H. J. Lutz 1959).

INTRODUCTION

This document presents an overview of some unintended consequences of failure to manage in harmony with natural tendencies in the Southwest. Although the paper focuses on ponderosa pine/bunchgrass ecological systems, parallel changes of ecosystem structure and function have occurred throughout other forest and woodland types in the Southwest.

This discussion will be placed in the context of key concepts of conservation biology and restoration ecology. The paper begins with a quick overview of some consequences of overly simplistic approaches to resource management. This is followed by a brief outline of some central postulates of conservation biology. Next will be a synopsis of changes since settlement in ponderosa pine/bunchgrass ecosystems. This synopsis is followed by a brief outline of ecological restoration concepts as stated in draft policy statements by the Society for Ecological Restoration. Then comes a presentation of some ideas of how we might apply these principles to the restoration of more nearly natural condition in southwestern ponderosa pine/bunchgrass ecosystems. Finally, the paper closes with a challenge for action and an alarm regarding the impending loss of key components of our natural resource management infrastructure.

OVERSIMPLIFICATION IN NATURAL RESOURCE MANAGEMENT

It is interesting to think about ecological management problems in the context of the "exploitation heritage" of contemporary natural resource management. In large part, this notion stems from a reductionist, anthropocentric view of ecological systems, in contrast to a more holistic, ecocentric view (Leopold 1933, 1939, and 1949; Flader 1974; Devall and Sessions 1985). The exploitive view traces its roots to the industrial revolution and specifically to a commodity view of the land, in which the land is viewed merely as a source of resources for the "engine" of economic growth (Flader 1974 and this volume; Callicott, this volume). The cornerstone in such a view is that the role of humans is to exploit natural resources by channelling the "machinery" of natural resource production to support the accumulation of wealth. A consequence of this thinking is the conclusion that the best and highest value of the land will be achieved by killing all of the predators, spraying all of the insects, putting out all of the fires, and replacing all of the slowly growing and "decadent", old-growth trees with rapidly growing and "vigorous", young trees. These management actions are viewed as eliminating the "waste" from, and increasing the "efficiency" of, natural resource production.

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Ironically predator control (extermination) programs, insect spraying programs, fire suppression programs, and old growth liquidation programs all appear to be successful at first and thus become strongly entrenched policies (e.g., see Holling 1981). Nature's backlash occurs fairly rapidly in predator:prey systems. For example, land degradation caused by overpopulation by deer (in turn caused by wolf and lion extirpation programs) was obvious within the first decade of this century (Leopold 1949, Flader 1974). It can take longer in insect spraying programs. C.S. Holling (1981 and elsewhere) has documented the backlash in spruce budworm spraying programs in northern coniferous forests. While successful initially, eventually (within 2 to 4 decades) so much of the forest becomes susceptible to budworm outbreak that spraying could not prevent mortality on an unprecedented scale.

In the case of fire suppression, the lag in Nature's backlash is even longer, perhaps 5-10 decades depending upon the interplay between fuel production and decomposition and between new tree establishment and mortality (Sando 1978, Holling 1981, Kilgore 1981, Covington and Moore 1992). Eventually though, enough fuel accumulates so that no amount of fire suppression effort can contain ensuing wildfires.

Replacement of old-growth trees and stands with younger stands was a very successful strategy while wood fiber production was the dominant goal of public forest management in the U.S. (arguably almost the entire history of public forestry, except the last few decades). Today, naturally functioning old-growth trees and stands are widely viewed as an integral component of forest landscape ecosystems and one which has become exceedingly rare, if not totally absent, in most forest and woodland types (Hoover and Wills 1984, Thomas 1979, Booth 1991, Kaufmann et al. 1992).

SOME POSTULATES OF CONSERVATION BIOLOGY

Michael Soule, in his 1985 paper, presented some postulates of the discipline of conservation biology which are relevant to interpreting the ecological consequences of changes since settlement in ponderosa pine ecosystems. He proposed two sets: a functional, or mechanistic set and an ethical, or normative, set. For this discussion I will focus on the functional postulates. Soule defined the functional postulates as working propositions based partly on evidence, partly on theory, and partly on intuition:

The first, the evolutionary postulate reads: Many of the species that constitute natural communities are the products of coevolutionary processes.

The second functional postulate concerns the scale of ecological processes: Many, if not all, ecological processes have thresholds below and above which they become discontinuous, chaotic, or suspended. Two major assumptions, or generalizations, underlie this postulate. First, the temporal continuity of habitats and successional stages depends on size. Second, outbursts reduce diversity.

Finally, genetic and demographic processes have thresholds below which nonadaptive, random forces begin to prevail over adaptive, deterministic forces within populations.

CHANGES IN SOUTHWESTERN PONDEROSA PINE ECOSYSTEMS

The most extensive study of postsettlement changes in southwestern ponderosa pine to date is the monograph by Cooper (1960). In this dissertation work, Cooper used a combination of historical methods and direct observations of stand structure to document changes since settlement in west-central Arizona. He used reports from early travelers to illustrate the changes in appearance of the ponderosa pine forest since settlement. For example, E. F. Beale's 1858 report is quoted by Cooper (1960) as follows:

"We came to a glorious forest of lofty pines, through which we have travelled ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, it was not so in this instance; every foot being covered with the finest grass, and beautiful broad grassy vales extending in every direction. The forest was perfectly open and unencumbered with brush wood, so that the travelling was excellent" (Beale 1858).

Cooper (1960) concluded that, "The overwhelming impression one gets from the older Indians and white pioneers of the Arizona pine forest is that the entire forest was once much more open and park-like than it is today."

Before European settlement of northern Arizona in the 1860's and 70's, periodic natural surface fires occurred in ponderosa pine forests at frequent intervals, every 2-12 years (Weaver 1951, Cooper 1960, Dieterich 1980, Stein 1988, Swetnam 1990). Several factors associated with European settlement caused a reduction in fire frequency and size. Roads and trails broke up fuel continuity. Domestic livestock grazing, especially overgrazing and trampling by cattle and sheep in the 1880's and 1890's, greatly reduced herbaceous fuels. Active fire suppression, as early as 1908 in the Flagstaff area, was a principal duty of early foresters in the Southwest. A direct result of interrupting and suppressing these naturally occurring periodic fires has been the development of overstocked forests.

Changes in the forest structure (e.g., tree density, cover, age distributions) in southwestern ponderosa pine forests since European settlement have been blamed for many ecosystem management problems (Cooper 1960, Biswell 1973, Weaver 1974, Covington and Sackett 1990, Covington and Moore 1992). Problems attributed to fire exclusion and resulting increased tree density in ponderosa pine include:

1. an increase in tree density, especially of small diameter trees — Arnold (1950), Cooper (1960), Biswell (1973), Weaver (1974), Steele et al. (1986), Barrett (1988), Laudenslayer et al. (1989), Savage (1989), Keane et al. (1990), Covington and Moore (1992)
2. a decrease in herbaceous and shrub production — Arnold (1950), Cooper (1960), Biswell (1973), Weaver (1974), Steele et al. (1986)
3. a consequent decrease in the diversity of net primary production and hence food web diversity (i.e., a tendency toward a monotypic photosynthesis concentrated in ponderosa pine trees) — This conclusion comes from the fact that NPP in open park-like stands was spread across 50-200 vascular plants in addition to ponderosa pine, whereas today it is concentrated primarily in ponderosa pine.
4. a shift in wildlife habitat from one favoring species requiring open, park-like stands dominated by large trees to one favoring species which are more successful in dense forests composed of smaller diameter trees (Covington and Moore 1992)
5. accumulation of pine litter on the soil surface as forest floor fuels (pine litter is very high in lignin compared to herbaceous litter; lignin is a broad-based metabolic inhibitor.) — Ponderosa pine litter has one of the lowest decomposition rates ever observed (Olson 1963 and van Wagtendonk 1985)
6. disruption of organic matter processing and nutrient cycling — Covington and Sackett (1984, 1986, 1990)
7. increased crown fuel loading and increased crown closure — see references under item 1 (above) plus Barrows (1978), Sando (1978), and Covington and Moore (1992)
8. increased fuel ladder (vertical fuel continuity) — Barrows (1978), Swetnam and Dieterich (1985), Swetnam (1990), and Covington and Moore (1992)
9. increased patch and landscape crownfire hazard and occurrence — see references in item 7 (above)
10. decreased tree vigor, especially the oldest age classes (300 yrs old) — Avery et al. (1976), Sutherland (1983), Waring (1983), Covington and Moore (1992)
11. increased tree mortality due to insects and diseases which attack trees of low vigor — Sartwell (1971), Sartwell and Stevens (1975)
12. ecosystem simplification at all levels in the biotic and landscape hierarchy (decreased nutrient recycling, forest floor fuels steadily accumulating, simplification of NPP and food webs, decreased species diversity, larger and more homogenous disturbances, decreased landscape diversity) — Mooney (1981), Covington and Moore (1992)

Covington and Moore (1992) present quantitative estimates of changes since settlement for two study areas in the Arizona ponderosa pine type. Their estimates of 23-56 trees per acre (with most trees being large, old, "yellow" pine) at the time of settlement in the Flagstaff area and on the Kaibab Plateau are consistent with the results of other studies including those of Woolsey (1911), Rasmussen (1941), Cooper (1960), and White (1985). This open, presettlement forest structure stands in stark contrast to today's dense, postsettlement stands containing 200-1,200 trees per acre with very few remaining old-growth trees. The magnitude of such a population irruption is staggering. For example, a "back of the envelope calculation" would yield an estimate of an excess of over one billion trees in Arizona alone (this estimate is based on a presettlement density of 40 trees per acre, a current density of 350 trees per acre (Fox et al. unpublished), and a total of 3.35 million acres of the ponderosa pine type in Arizona). Such a population irruption dwarfs the irruptions in deer populations estimated by Leopold (cited in Flader 1974).

Covington and Moore went on to estimate changes in resource conditions since settlement. These results indicated, among other things, decreases in water availability and runoff, in aesthetic values, and in forage production. Although their inferences regarding changes in wildlife habitat have been controversial, there can be little doubt that the change from a landscape dominated by prairie vegetation with patches of pine trees to one where pine trees dominated the net primary productivity has wrought substantial changes in both the composition and the population sizes of animal communities.

ECOLOGICAL RESTORATION

Given that many of these changes are deleterious, the question then becomes, "What can we do to remedy these problems?" In a predator:prey system, if predators are suddenly reintroduced into a prey population that is too low in vigor or too few in number, the whole system might well crash. Wholesale cessation of insect spraying programs could result in very large and massive tree mortality requiring many decades for recovery (Holling 1981). Similarly, allowing fires to burn freely in ecosystems which have unnaturally heavy fuel accumulations might cause extensive long term damage to food webs, nutrient cycles, and soil development (via accelerated erosion). In fact, research in giant sequoia/mixed conifer, oak-savannah, and ponderosa pine/bunchgrass indicates that manual removal (thinning) of trees and spot fuel treatment may be necessary prerequisites for restoration of fire as a natural component of ecosystems adapted to a frequent, low intensity fire regime (see Parsons (1981), Bonnicksen and Stone (1985), Parsons et al. (1986) for a lively discussion of policy concerns). The need for manual thinning and spot fuel treatment as components of an ecological restoration program in southwestern ponderosa pine are indicated by the difficulty of thinning postsettlement trees by prescribed burning and the high mortality rate of old-growth trees following prescribed burning of current heavy forest floor loads (Harrington and Sackett 1992).

Answering the question, "What can we do to remedy these problems?" is what the field of restoration ecology and management is all about (Jordan et al. 1987, Jackson 1992). It deals specifically with research and management experimentation to determine ways to safely restore degraded ecological systems to more nearly natural conditions. Restoration ecology was founded by Aldo Leopold after he abandoned the sustained yield view of game management, shortly after his arrival in the Southwest. As Leopold said, "The first step is to reconstruct a sample of what we had to begin with." Ironically, one of Leopold's first (1924) professional publications (written while he was a forester with the Southwestern Region of the Forest Service) dealt with the postsettlement decrease in grasses and the increase in shrubs, trees, and fuels in Arizona.

Although some of the principles for ecological restoration are still in the development stage, several have received broad-based support. Various authors in Jordan et al. (1987) provide stimulating discussions of some of these principles. Perhaps the most useful restoration definitions and principles in the context of this paper are those presented in the 1992 draft policy statements of the Society for Ecological Restoration. In that document "ecological restoration" is defined as the process of intentionally altering a site to establish a defined, indigenous, historic ecosystem. The goal of this process is to emulate the structure, function, diversity and dynamics of the specified ecosystem. The policy statement goes on to state that while human use of restored landscapes is not only inevitable but also desirable, these uses should be designed to be compatible with the principle of sustainability.

Regarding the preservation of biodiversity and endangered species, the policy statement recognizes that endangered species cannot be sustained satisfactorily apart from viable ecosystems. This has lead the society to advocate that resource agencies charged with preserving biodiversity and protecting endangered species focus attention on restoring and maintaining the ecosystems upon which endangered species depend.

CONSERVATION AND RESTORATION OF SOUTHWESTERN PONDEROSA PINE ECOSYSTEMS

Given the well documented outburst of ponderosa pine since Euro-American settlement and the consequent declines in both ecological conditions and resource values, it is incumbent upon today's generation of natural resource managers to begin to set things right. Although little practical thought has been put into how exactly to accomplish this on a large scale, such a program would clearly involve site-specific adaptations of the following elements:

1. Preserve all trees which predate grazing and fire exclusion.
2. Thin all postsettlement trees, except for those needed to emulate presettlement densities and diameter distributions.
3. Manually or mechanically remove heavy forest floor material from under presettlement tree canopies.
4. Prescribe burn — Initial cool season prescription (ideally wet soil, cool air temperatures; eventually warm season maintenance burning or burning alternating with livestock grazing to approximate effects of natural fires while minimizing air quality degradation by smoke).
5. Reintroduce indigenous biota (plants and wildlife, in particular) when necessitated by local extinction.

CONCLUSIONS

In summary, owing largely to the lack of an ecological view of the land, the history of Euro-American settlement of the southwestern ponderosa pine/bunchgrass type has been characterized by open revolt against Nature. While there can be little doubt that much remains to be discovered about ponderosa pine ecosystem structure and function, what we do know is that inaction is indefensible, with long-term negative ramifications for ecosystem structure and function. Reliance on piecemeal approaches (one species at a time, one process at a time) is overly simplistic and likely to have undesirable consequences for the land system as a whole. Instead, it is becoming increasingly apparent that large-scale, whole-system, management experiments are necessary for discovering how best to restore the health (inherent ability for self-renewal) and integrity (coevolved biological diversity) of ponderosa pine ecosystems.

Finally, removal of excess trees and prescribed burning possibly in conjunction with carefully controlled livestock grazing are necessary steps not only in restoring but also in maintaining the health and integrity of our southwestern forest ecosystems. A failure to understand conservation biology and restoration ecology by many in the debate over forest management in the Southwest has lead to constraints which may well result in the destruction of much of the "tree removal" and forage (herbaceous fuel) management infrastructure essential for restoring and maintaining ecosystem health and integrity while maintaining a culturally acceptable fire regime. If we allow this to happen, it seems probable that, within the next generation or two, our children and grandchildren will have to invest tax dollars to rebuild that infrastructure — unless insects, disease, and wildfire preempt their options.

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