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Compiler

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Volume IV: Restoration of Stressed Sites, and Processes

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Eastside Forest Ecosystem Health Assessment

Richard L. Everett, Assessment Team Leader

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ABSTRACT

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Portions of forest ecosystems in eastern Oregon and Washington are in poor health, are not meeting societies expectations, and have elevated hazard for fire, insects, and disease. Diversity in stream habitats and associated fisheries has declined over the last several decades in several drainage basins, requiring conservation and restoration efforts in key watersheds. Required first steps in restoring forest and aquatic ecosystems are the immediate reduction in hazard for catastrophic loss of biodiversity, site quality, resource commodities, and improved conditions for public health. To prevent loss of future options we need to simultaneously re-establish ecosystem processes and disturbance effects that create and maintain desired sustainable ecosystems, while conserving genetic, species, community, and landscape diversity and long-term site productivity. Restoration of stressed sites is site specific, but the context for the action should be defined by the desired condition(s) of the next higher landscape scale and achieve desired positive cumulative effects over time. Restoration actions should be consistent with the desired level of disturbance effects required to maintain sustainable ecosystems, and standards and guides should reflect the inherent variability associated with dynamic systems. Costs associated with restoration activities should be weighed against the foregone benefits if no action is taken. The restoration of the biological components of ecosystems should provide increased opportunities for the restoration of human cultural, social, and economic ecosystem components and increase options for resource-dependent communities.

Keywords: Restoration; forest health; ecosystem processes; disturbance effects; ecosystem management; insects, disease, and fire hazard.

This volume is in response to the Foley and Hatfield request for recommendations to restore stressed ecosystems in eastern Oregon and Washington. Ecological concerns include insect outbreak hazard, catastrophic fire hazard, decline in sensitive salmon stocks, and sustainable flows of renewable resources (U.S. Department of Agriculture 1991). The science panel requested the assistance of scientists working on these and other similar issues (for example, riparian restoration and rangeland restoration) to provide descriptions of specific stress conditions or altered processes, and make recommendations for their rehabilitation. The science panel appreciates the rapid response and input of these authors.

Contents

INTRODUCTION

Eastside forest ecosystems that are either not meeting society's expectations or are functioning below their biological potential are in need of restoration. The current assessment of eastside terrestrial and aquatic ecosystems suggests that several watersheds have elevated insect, disease, and fire hazards; lowered soil productivity; unstable stream and riparian conditions; and low populations of sensitive species (Harvey and others 1993, Hessburg and others 1993b, Lehmkuhl and others 1993, Marcot and others 1993, McIntosh and others 1993, Wissmar and others 1993).

The causes of ecosystem damage can be traced in part to overuse of renewable resources by early European settlers (Irwin and others 1993, Wissmar and others 1993), past management practices (Oliver and others 1993), and limited funding support for nontimber resource management (Kennedy and Quigley 1993). The recent adoption of ecosystem management principles by the USDA Forest Service and other government agencies provides for greater equity in emphasis among resources. Under ecosystem management goals of conserving biodiversity, long-term site productivity, and sustained resource flows, there is greater impetus to maintain and restore ecosystems (Overbay 1992).

Humans are an integral part of ecosystems and closely tied to the other biological components. "*The disintegration of the social fabric in timber-dependent, rural communities has its counterpart in many of the regions's forest ecological communities*" (Clark and others, Chapter VII in Thomas and Raphael 1993). The same fire, insect, and disease hazards that threaten wildland habitats also threaten the long-term economic stability of the resource base and air and water quality. Resource-dependent jobs are only as stable as the resources they depend upon; loss of jobs erodes individual self esteem, disrupts social structure of small resource-dependent communities, and impacts the ability of local governments to provide for public transportation and education (McKetta 1994, Thomas and Raphael 1993). Human economic and social components of ecosystems in eastern Washington and Oregon are in need of restoration.

Describing restoration of economic and social components of ecosystems is beyond the scope of the Eastside Assessment, although we realize this is a significant component to achieving sustainable ecosystems. The reader is referred to the excellent discussion on social-biological interactions in timberdependent communities of the Pacific Northwest by Clark and others, Chapter VII in Forest Ecosystem Management: An Ecological, Economic, and Social Assessment (Thomas and Raphael 1993). Restoring the ability of rural communities to respond to changes in resource availability and to maintain a work force of resource professionals is required if ecosystem management is to become a reality.

There is an urgency in initiating restoration activities because of hazards from fire, insects, and disease; potential loss of aquatic and terrestrial species or their habitats; and adverse economic and social impacts to resource-dependent communities. Preventing catastrophic loss of species or other resource values seems paramount, reducing current or future hazards secondary, and restoring ecosystem processes and stressed sites a required but less urgent task.

Public Evolvement in Restoring Ecosystems

People in eastern Oregon and Washington are concerned about forest health and are seeking ways to create sustainable forests (Hessburg and others 1993b). The Blue Mountains Natural Resources Institute conducted a forest health workshop for about 150 concerned citizens in Pendleton, Oregon (U.S. Department of Agriculture 1991). The group shared information and discussed strategies for restoring healthy ecosystems, preventing catastrophic fires, minimizing insect and disease damage, increasing economic stability, and ensuring production of forest products. Similarly, the Colville National Forest invited public participation in finding solutions to forest health problems by creating a forest health stakeholder group. Their strategies focused on goals to restore and maintain healthy ecosystems and to ensure and maintain an appropriate level of sustained goods and services (U.S. Department of Agriculture 1993).

The public suggested a path that would explore ecosystem management on a landscape scale; a path that would require a database of resources and hazards. Special attention was to be given to maintaining biodiversity, including sensitive species, fisheries, big game, and fragile habitats (riparian and old-growth). Further, they suggested that management should mimic natural processes, including reintroducing fire and using historical landscapes as management reference points. The Blue Mountain and Colville groups see rangeland condition as part of the sustainable forest ecosystem issue and conserving long-term soil productivity as a desirable goal. Both groups were interested in maintaining commodity flow from the forest, emphasizing diversity in forest values, and developing technology and means to capture the economic benefits of those diverse values.

The panel on restoring ecosystems in the Blue Mountains (Caraher and others 1992) interviewed public stakeholders and found them most concerned about fuel reduction and fire management, water quality, fisheries and riparian areas, and timber management. *The primary needs are to prevent catastrophic fires, provide high-quality water, and maintain sustainable forests resistant to insects and disease*. Information and recommendations provided here on reducing potential catastrophic loss, conserving biodiversity and longterm site potential, and restoring stressed sites and processes address these stated public concerns and can be used in the restoration of forests in eastern Oregon and Washington.

Approach to Restoration

Forest Service emphasis on ecosystem management has been described in five levels of increasing investment for eastern Oregon and Washington (Hessburg and others 1993a). The priorities are to prevent catastrophic losses of species or productivity, stabilize current systems to avoid further degradation, and restore severely stressed sites and processes. Resources are managed for society, not for the resources themselves (Gates 1972); thus, society ultimately makes the choices among different levels of ecosystem management. Society should be informed of the costs and benefits of different levels of investment in ecosystem management (Hessburg and others 1993a). Also, the public needs to know the costs associated with restoration and the benefits foregone if restoration does not occur (Weigand 1993).

An immediate need in eastside ecosystems is the prevention of catastrophic loss in biodiversity and longterm site productivity from severe fire events, widespread insect outbreaks, or the cumulative effects of management practices on unique habitats or sensitive species. Of special concern are overused riparian zones and loss of sensitive fish stocks. Restoration of ecosystem processes, fire, insects and disease, and hydrology are prerequisites to the restoration of stressed sites. If we have not restored the processes that maintain ecosystems, then the restoration of specific sites is in vain. Specific sites identified as needing restoration include riparian zones, overly grazed rangelands, stream systems, and densely treed forest stands (Elmore and others 1993, Everett and Hardesty 1993, Irwin and others 1993, Lambert 1993).

Restoration practices should be applied at the appropriate scale and the context for the restoration.project derived from the next higher scale (Urban and others 1987). The context will provide the reasoning for restoration projects and their integration. Until recently, restoration has been implemented at the stand or stream-reach level, although the desired outcome in process or structure was best evaluated at larger scales. Caraher and others (1992) recommend restoration of forest ecosystems in the Blue Mountains of Oregon and Washington where landscape attributes are outside the range of natural variability. An example of landscape restoration is provided by Shlisky (1993). She uses landscape analysis and design processes to determine historical landscape patterns and to set objectives for future landscape characteristics and restoration priorities.

What follows is a series of invited papers by scientists on specific restoration topics. The series is not intended to be an exhaustive treatment of restoration ecology, but to focus on critical issues identified by the public forums. General guidelines are provided on:

- approaches to prevent catastrophic losses from wildfire, insect epidemics, and degraded stream systems;
- conservation of biodiversity and long-term site quality;
- restoration of critical ecosystem processes; and
- restoration of stressed sites.

These guidelines are intended to be used by restoration practitioners as they develop landscape restoration plans.

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ECONOMIC ISSUES IN ECOSYSTEM RESTORATION

by **James F. Weigand**

Natural restoration of ecosystems is a function of the biophysical capacity of an ecosystem to maintain or recover its original elements, structures, processes, and interactions after disturbance. Restoration is precluded, however, where disturbance to an ecosystem is so profound that the ecosystem has lost its capacity to maintain or recover previous ecosystem features. Restoration is one of several strategies to regain the productivity desired by society.

Restoration is distinguished from other human efforts of reclamation and mitigation. Reclamation of an ecosystem recreates biophysical capacity and results in an engineered ecosystem that differs from the previous one. A notable example of reclamation has been the 1000-year process of diking and draining submerged land in the Netherlands for agriculture and settlement (Wolff 1992), whereby new terrestrial ecosystems replaced marine ecosystems. Compensatory ecosystem mitigation, in contrast, attempts to balance the loss of biophysical capacity at one site by recreating capacity at another site. An example of mitigation is creating salt marshes and wetlands where they previously did not exist as replacements for marsh habitat lost in development projects.

Objectives for Restoration

Society possesses the science and technology to speed the pace of natural ecosystem restoration. Land managers mimic and manipulate forest ecosystem processes to create desired ecosystem states more rapidly than what would occur naturally. Management of forest stands with appropriate tree thinnings, for example, can create stand structures with suitable large live trees, snags, and down wood for various old-growth forest types at a faster rate than does natural stand development after reforestation.

Although science and technology are indispensable to restoration, they do not suffice. A restoration project becomes a reality only with the support and participation of people whose demands are best met by an accelerated process of human-aided ecosystem restoration (Cowell 1993). Project implementation is predicated on societal affirmation that restoration provides greater utility to society than would other management alternatives such as rehabilitation, mitigation, or inaction. If society demands restoration, society must also agree on which previous ecosystem states are desirable for restoration. In some cases, society's best interests are served when natural restoration processes of an ecosystem are allowed to proceed unsupplemented by human inputs because costs of human inputs are too high and the perceived value of restoration benefits is too low.

Economic Implications of Restoration

Human efforts to increase the rate of ecosystem restoration require labor and capital expenditures to augment the energy and biomass budgets of ecosystems. Society has resources that it may choose to allocate to restoration projects. Programs for ecosystem restoration will have to compete with other beneficial social projects for scarce private and, more importantly, public funds. Ecosystems and their lands are themselves scarce resources. A comparative accounting of potential returns and trade-offs between restoration projects and other projects in a complete, impartial, and scientifically valid manner is difficult, if not impossible. Forecasting the stream of goods and services and deciding who pays and who benefits are tasks without ready answers. The type, timing, and quantity of returns on investment to society may be highly uncertain. Unintended benefits may result, and many of the presumed beneficiaries are future rather than present generations.

In a broad policy sense, policymakers will not implement restoration projects if society perceives costs and does not perceive net benefits from restoration efforts. Also, people may advocate an incomplete level of ecosystem restoration whenever the next increment of restoration costs more than the benefit it produces (fig. 1). A fully restored ecosystem, with society footing the bill, may not be acceptable to society because the cost is too high.

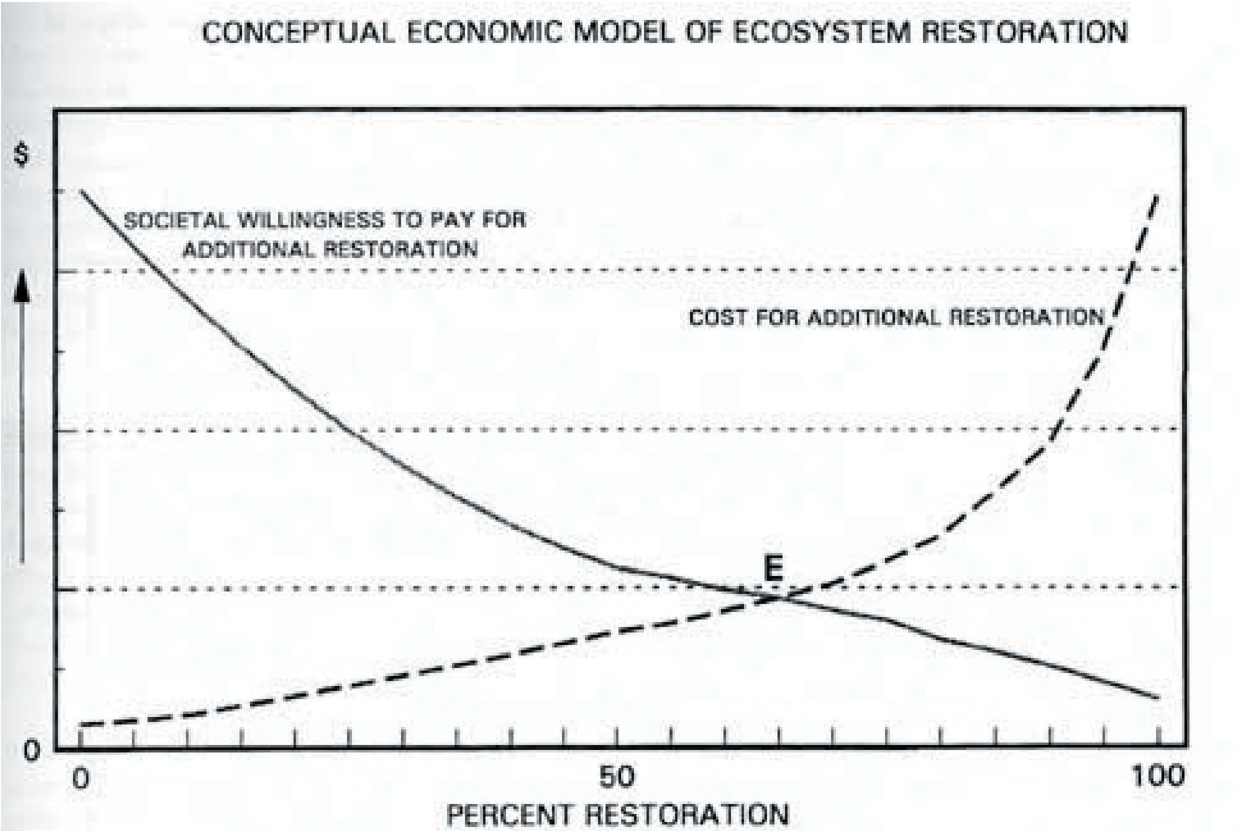

Figure 1. Amount of ecosystem restoration to accomplish is a function of the cost of adding another increment of restoration as societal demand for restoration declines with increasing availability of restored ecosystems. "E" denotes the equilibrium between society's willingness to pay and cost.

Restoration projects are investments with risk. Policymakers have often dismissed the value of ecosystem restoration because restoration projects have been perceived to have high start-up costs and uncertain benefits. Return on investment is ambiguous because investments in ecological infrastructure offset depreciation of ecosystem function brought on by unsustainable resource extraction and by themselves do not increase the gross domestic production (Jacobs 1991). The projects attempt to restore capacity and future options for production and not the production itself. Restoration projects are, in effect, reinvestments in ecosystem infrastructure (Schmidt and others 1993). However, American society traditionally has undervalued sustaining the productivity of land because society perceived that enough extra land was always available as a low-cost substitute for lost productivity of degraded land. A new management philosophy like ecosystem management may affect how society perceives and estimates benefits. Society may wish to recognize as legitimate the benefits of expanded and flexible options from ecosystem production now and in the future.

The quality of restoration projects will assure both the probability and degree of success. Government policies to award contracts on the basis of least (initial) cost may undermine achieving the quality in ecosystem restoration that society demands and is willing to pay for (see Deming 1982). When government is sensitive to the cost of implementing projects but not sensitive to project quality and total net benefit to society, the likelihood is greater that the government will not select the best restoration proposal. Analyses of costs for project implementation are easier to estimate than net benefits to society or costs of societal inaction. King (1991) has shown that parsimony of initial investment brings with it an enduring opportunity cost to society in terms of foregone sustainable ecosystem production as compared to a policy that allocates a larger initial investment (fig. 2).

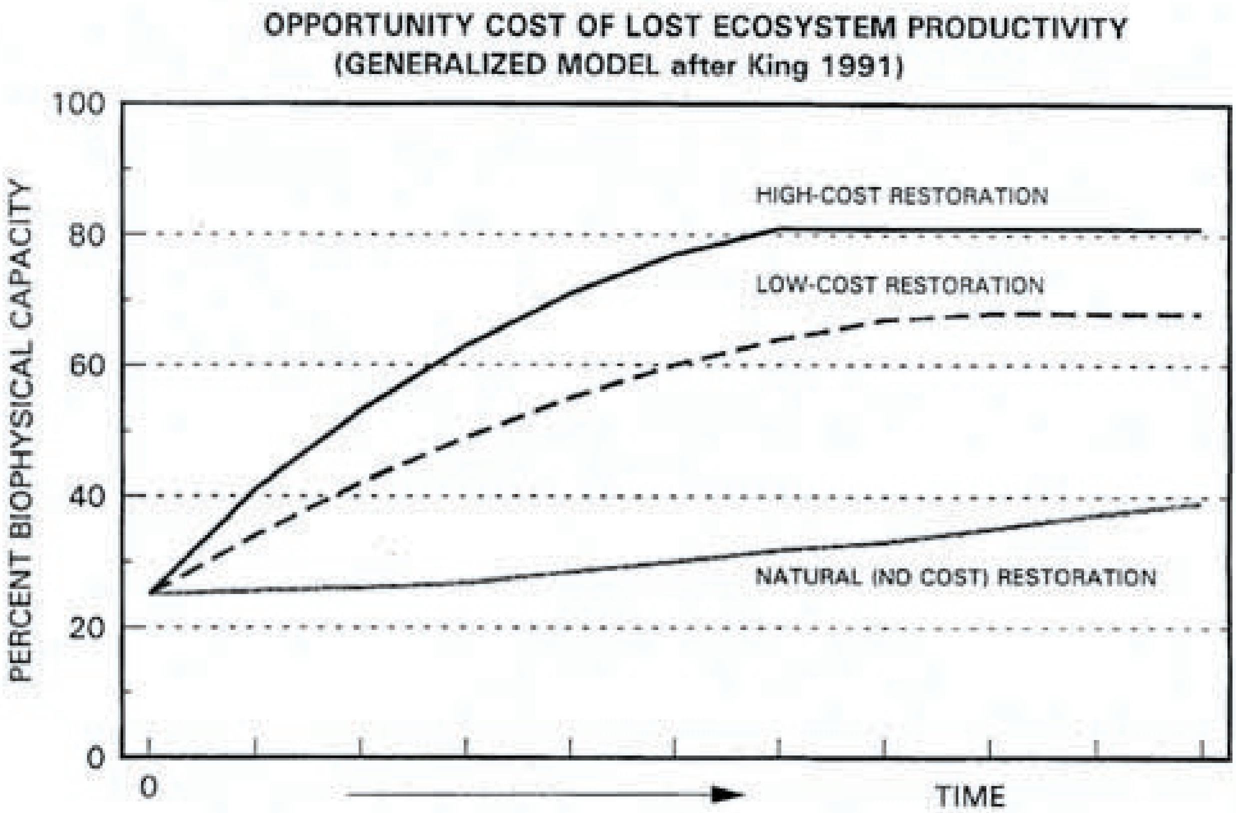

Figure 2. At point 0, the ecosystem's biophysical capacity amounts to 25% of the baseline condition. Loss of ecosystem production from loss of biophysical capacity has a enduring cost to society over time. The area above any one of the three lines represents the opportunity cost of lost ecosystem productivity for that restoration scenario.

In terms of secondary effects, restoration projects offer attractive prospects of employment, particularly when rural economies are depressed. Restoration employment is one of several transitional means to recover ecosystem productivity. The enduring goal is sustainable rural economic development in an undiminished ecosystem producing goods, services, and ecosystem states that respond to constantly changing societal demands.

Performance of restoration efforts is crucial. Measuring the success of restoration projects by monitoring is inherent in the fundamentally experimental nature of restoration and subsequent management for ecosystem sustainability. Protocols to measure performance criteria of ecosystem restoration projects must be developed. Thus far, methodologies have been advanced for monitoring the performance standards (Westman 1991) by using statistical indices of similarity to compare present ecosystem states with desired past ecosystem states. Almost no literature exists at present that treats appropriate economic monitoring for ecosystem restoration projects.

Another implication is that an appropriate social discount rate must be incorporated into analyses that evaluate net benefit to present and future generations gained from restoration projects. This begs the question: what is the appropriate discount rate for restoration projects? Very low (or even negative) discount rates have been proposed for use if concern for future generations is equally important or more important in management objectives. Using a positive, comparatively high discount rate (such as the 4 percent real rate used conventionally by the USDA Forest Service) may be inconsistent with restoration projects that are a prelude to resource sustainability in the future. Assumptions in methodology of economic analyses must not prejudice outcomes. Projects are best examined with a sensitivity analysis involving multiple projects under multiple discount rates. Analyses for present net value and soil expectation value are appropriate tests for project efficiency.

Analysts should consider external economic effects from restoration in one ecosystem on adjacent ecosystems for a complete accounting of net societal benefit (Bradshaw and Chadwick 1980). Economic analyses are most helpful when policymakers conduct them at multiple spatial scales; for example, budget analyses done ecosystem-wide, locally, regionally, and nationally provide a complete understanding of the complex effects of restoration projects. Often, economic benefits that are difficult to quantify, such as so-called "second dividends" of ecosystem services and environmental quality, draw new businesses to the Pacific Northwest (Whitelaw and Niemi 1989, Yang 1992). Perceptions of environmental quality have been conducive to economic development in future-oriented, high-tech industries.

If the condition of ecological and economic sustainability is reached (fig. 3), management will still incur costs of monitoring as part of an ongoing system that alerts managers and policymakers to any potential malfunction in ecosystem sustainability. Without maintenance expenditures for ecosystem monitoring, positive effects of previous capital investment and the ability to make corrective adjustments to current investment or management might be undone. Bureaucratic unfamiliarity with the need to monitor outcomes together with ineptness in monitoring represent an uneconomical loss of information on appropriateness and effectiveness in mitigation efforts upon which to base future endeavors (Holland and Kentula 1992). A better understanding of costeffectiveness in monitoring is needed, particularly on the part of policymakers and regulatory agencies, whether for efforts in mitigation, rehabilitation, or restortion.

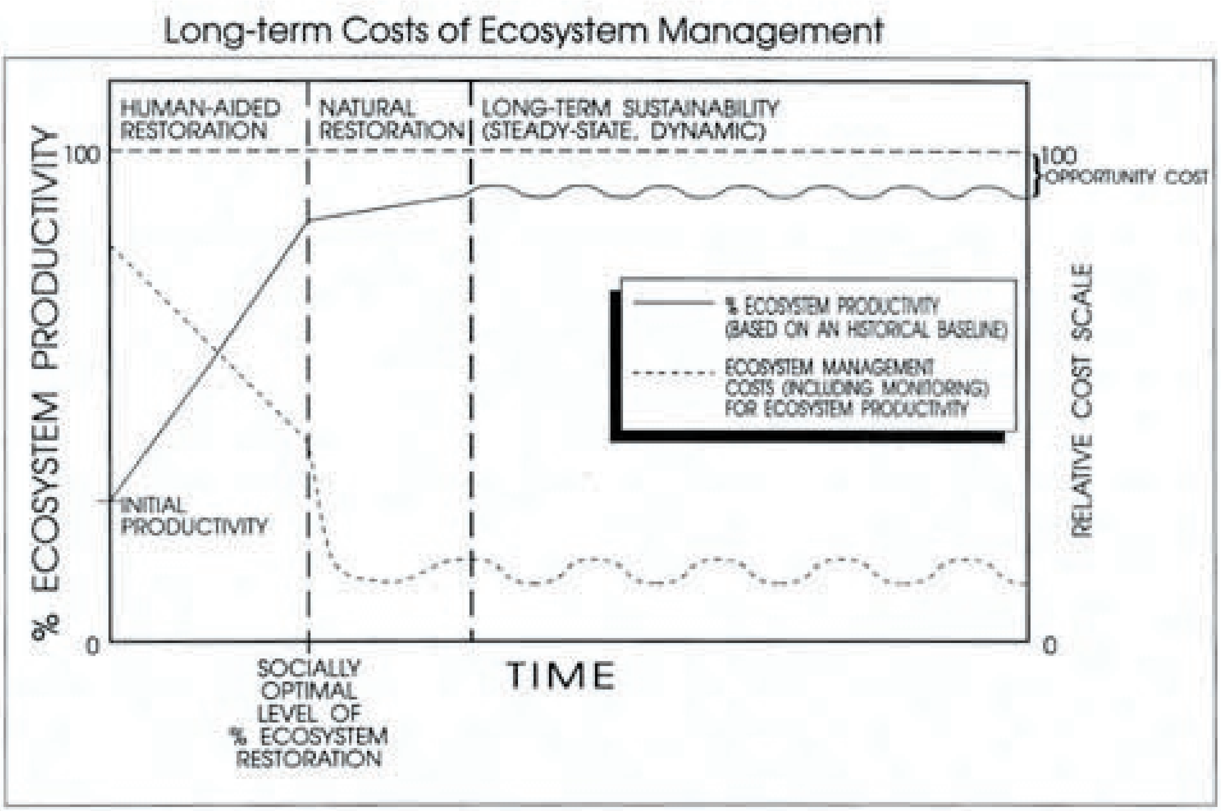

Figure 3. The percentage of ecosystem restoration is the difference between final sustainability productivity and initial productivity.

Institutional Responses for Ecosystem Restoration

Magnitude of restoration efforts creates technical concerns as well. Large-scale restoration efforts, such as those proposed in eastside Oregon and Washington, entail cooperative and coordinated participation of diverse communities as well as regulatory and administrative bureaucracies at multiple geographic scales (local, regional, and national) to achieve success. Administrative and regulatory conflict will only add to costs of restoration projects and reduce future net benefits to society. Technical failure may also result from inadequately coordinated science and technology and from inadequate policies to support restoration targets.

Funding allocated in small amounts over many years may be less effective than a single large pulse of funding over a shorter period. If society and government decide that restoration is an effective use of public resources, policy instruments—in particular, budgets and legislation—must act in concert with singleness of purpose to achieve stated goals for ecosystem restoration. High goals combined with inadequate funding in (both in amount and timing) frustrate ecosystem managers and the general public.

Restoration projects alone may not achieve societal objectives for ecosystem management. Other options, including ecosystem rehabilitation and mitigation, may prove useful tools for ecosystem management in addition to strategies for restoration. Likewise, policymakers must rely on advice from scientists and public opinion to determine how to connect regional restoration projects effectively with other regional programs for rural economic development and with national policies for protecting ecosystems and ecosystem productivity.

Conclusion

Restoration provides a sense of satisfaction to people that their society is thinking about and providing for the future. Ecologically based, rather than politically motivated, ecosystem restoration projects require not only a sense of altruism but also coordination and common purpose. Restoration, like other infrastructure improvements, is distinct from "production" investments. This distinction obligates policymakers to plan for restoration using economic analyses that are not biased against the societal time preferences and future concerns. Political will and commitment are indispensable to realistic formulation and implementation of restoration efforts. Restoration costs money but its return on investment may be considerable.

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REDUCING HAZARD OF CATASTROPHIC LOSS

REDUCING HAZARD OF CATASTROPHIC LOSS

Catastrophic loss of forest habitats and associated species were primary forest health concerns cited in public forums held in eastern Oregon and Washington (U.S. Department of Agriculture 1991). Fire and insect epidemics were identifed as the most threatening (Caraher and others 1992). Forest health has declined to the crisis stage on some forested landscapes of eastern Oregon and Washington. Over 50 percent of the forest acres in the Blue Mountains had visible insect-caused defoliation and mortality in 1990 (Gast and others 1991). Lehmkuhl and others (1993) report similar insect problems in some watersheds in Oregon and Washington.

The public is concerned about the implications of declining forest health and lost forest resources on employment and sustainability of commodity outputs, the quality of their air and water, and forest aesthetics (U.S. Department of Agriculture 1993). Rural communities are concerned about the increasingly frayed link between availability of renewable resources and the resource-dependent work force (McKetta 1994). The loss of resource-dependent jobs can certainly be catastrophic to the impacted families, and effects on resources may be long lasting and catastrophic if skilled workers are permanently lost and the future ability to conduct ecosystem management reduced.

Catastrophic loss is difficult to define but is characterized by significant adverse impacts on forest function, species viability, or commodity production. Recovery can require a single rotation age for timber, several hundred years for old-growth, several centuries for soil genesis, or may be impossible in species extinction. Current elevated hazard of fire and insect epidemics could have catastrophic effects on sustainable timber supplies. Increased intensity of fires and subsequent removal of protective litter layers across larger burn areas increases the potential for soil erosion and long-term loss of site potential (Grier 1975). Significant reductions in old-growth representation in eastern Oregon and Washington (Lehmkuhl and others 1993) may set the stage for catastrophic loss of terrestrial and aquatic species if additional oldgrowth forests are lost (Scientific Society Panel 1993, Thomas and Raphael 1993).

Listing of sensitive species is increasing at an exponential rate within the United States (U.S. Department of Agriculture 1990), indicating an urgency in restoration of species and required habitats. Numerous plant and animal species are listed or candidates for Federal listing as threatened, endangered, or sensitive in the Pacific Northwest (U.S. Government Printing Office 1991). Restoration strategies have been developed for the northern spotted owl in the ISC (Thomas and others 1990) and for associated oldgrowth species in the SAT (Thomas and others 1993). Strategies for the conservation of sensitive salmon stocks in western Washington and Oregon were addressed in part in FEMAT (Thomas and Raphael 1993), SAT, and in the yet-to-be-released PACFISH report. Salmon runs in streams in eastern Oregon and the Yakima Basin in eastern Washington are significantly reduced from historical levels (McIntosh and others 1993). The loss of salmon stocks would be catastrophic for the species and have significant socioeconomic and cultural consequences (Anderson 1992).

Time is critical; prevention of catastrophic threats to biodiversity, long-term site productivity, renewable resources, and public safety is the highest priority in restoration activities (Hessburg and others 1993). The following papers address the issues of preventing catastrophic loss of forest habitats from fire and insects and disease, and the loss of sensitive salmon stocks. The reader is referred to the ISC (1990), FEMAT (1993), and SAT (1993) reports for restoration activites directed at maintaining viable populations of sensitive terrestrial species.

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REDUCING HAZARD FOR CATASTROPHIC FIRE

by **Stephen F. Arno** and **Roger D. Ottmar**

For thousands of years, fire shaped the composition and structure of forests east of the Cascade crest. This region, with its abundant vegetation, frequent lightning storms, and long, dry summers, had the necessary components for fires to spread across vast areas of the landscape (Agee 1990, Pyne 1982). As a result of frequent fires, most eastside forests have been dominated by the more fire-resistant or fire-adapted seral species such as ponderosa pine,[1] lodgepole pine, western larch, and western white pine. Fire-sensitive, shade-tolerant species, such as grand fir and western hemlock, were minor components of most eastside stands. Forests at lower elevations and on south- and west-facing slopes were generally open and parklike as a result of frequent underburns. Forests on moist sites and at higher elevations were often a patchwork of different structures, including many young communities, as a result of numerous stand replacement or mixed mortality fires.

By the early 1900s, a drastic change in the ecology of eastside forest ecosystems had begun with the attempt to exclude fire (Agee 1990, Kauffman 1990). The complex ecological role of fire was not recognized, and many educated people considered fire to be a scourge introduced by human negligence. At the same time, grazing was removing fine fuels that would have allowed surface fires to spread. By the mid-1900s all fires of low and moderate intensity could be extinguished (Agee 1990). By the late 1900s, in the absence of fire and often aided by the partial cutting of large overstory trees, succession had transformed these forests into dense thickets of shade-tolerant tree species. On moist and upper elevation sites, forests had become older across most of the landscape. Some of these conditions had existed in the past in some stands, but never before had most of the landscape been dominated by dense stands or understories of shade-tolerant species.

These dense stands of small trees are highly susceptible to drought stress, insect and disease epidemics, and severe wildfires. Without the intervention of active management, these ecologically unbalanced forests will continue to diverge from pre-1900 composition and structure. Fire exclusion in frequent-fire forest types such as ponderosa pine is an ecological anomaly, and no one knows what the long-term effects will be, but it appears that insect and disease epidemics and severe wildfires are increasing in importance. Since the late 1970s, an abundance of large, severe wildfires in eastside forests suggests that attempts to eliminate fire have simply led to a different fire regime, disastrous fires burning in heavy fuels in ecosystems formerly supporting light to moderate fires at short intervals (Arno and Brown 1991).

Concomitant with this trend, there has been a great expansion of residential development in the eastside forests. The ability of fire suppression to control large fires is now severely restricted by the necessity of protecting large numbers of residences in forest areas. Fires in the Spokane area in October 1991 destroyed more than 100 homes during an off-season fire bust.

Ironically, protection of fire-dependent forests has made it almost certain that they will be severely disrupted as a scenic resource and as a habitat for some cover-dependent wildlife species. The extensive forest mortality sweeping through the Blue Mountains of eastern Oregon is symptomatic of the fragility of an unbalanced hredependent ecosystem (hutch and others 1993). Today's changing susceptibility to wildfire damage is exemplified by the numerous wildfires in modern stands which have killed ancient ponderosa pine or larch trees, that had withstood many natural underburns during previous centuries. In contrast, there have been numerous documented incidents where stand-replacing wildfires burning through ponderosa pine forests encountered stands that had been managed with prescribed fire or other fuel reduction treatments. In all these cases, the wildfires became less intense underbums and were controllable by firefighters.

[1] Scientific names for all taxa mentioned are given in Appendix A.

Stand-replacement fires occur because of the simultaneous occurrence of ignition, high fuel continuity, excessive fuel loading, and hot, dry environmental conditions. Stand-replacement fires are the normal fire regime for some of the wetter, high-elevation conifer series (subalpine forests) that burn intensely but with low rates of fire return (Agee 1993). The public's concern is with low-elevation ponderosa pine, Douglas-fir/ grand fir climax zone where the fire regime has changed from low-severity, high-frequency surface fires to low-frequency, high-severity crown fires. Now we have landscapes rather than stands with high-severity fire hazard.

The potential number of lightning strikes is expected to remain at historical levels, and weather conditions will probably allow large-scale fires to develop regularly each summer. Reducing fuel continuity and lowering fuel loads are our main approaches to reducing hazard of catastrophic fire. These intensive management activities are practiced at the stand level but are directed at protecting the associated landscape. Reducing fuel levels is an activity in prevention, reducing the rate of spread, and promoting surface rather than crown fires. Reducing fuel continuity is an activity of containment and control directed at the landscape level. The short-term solution to reducing hazard should be compatible with long-term goals of ecosystem sustainability, thus traditional straight-line fire breaks are not the solution. Rather, we need an interconnected network of natural fire barriers and treated stands as zones of opportunity for controlling wildfires. Once such a network is created, the potential for prescribed burn projects to restore natural fire regimes would be less risky. Such a network could limit fire extent, and provide landscape heterogeneity.

The major problem with this approach is the economic removal or prescribed burning of small-diameter trees that provide excessive fuel loading, increased continuity among stands, and fuel ladders to overstory. Lambert (1993) discusses the need for developing technology for this activity.

Within landscapes, we do not know which stands to select for treatment that will provide the greatest reduction in landscape hazard; however, the selection of those stands that add to natural firebreaks would be desirable. Fire behavior models are being developed that should assist in the selection of stands to reduce hazard of catastrophic fire, but those models are not available at this time. Procedures for reintroducing fire into landscapes once catastrophic fire hazard has been reduced are provided later in this report (see Arno and Ottmar).

PROCEDURES TO REDUCE LANDSCAPE HAZARD FROM INSECT OUTBREAKS

by **Richard R. Mason** and **Boyd E. Wickman**

Landscapes are defined as broad landforms with their included vegetation,and habitats. Because they can affect ecological processes over large areas, the patterns of vegetation within landscapes are believed to have an important influence on the dynamics of insect pests. Landscapes influence insect populations primarily by affecting both the distribution of the insect's food and the habitat of their natural enemies (Perry 1988, Schowalter 1988).

In general, survival and spread of insect pests in landscapes are constrained more by heterogeneous than by homogeneous conditions. Defoliators and bark beetles, for example, are usually at more risk in locating and exploiting favored hosts in an environment with a mosaic of forest types than in a single contiguous type (Schowalter and others 1986). Such spatial patterns sometimes affect similar species in different ways, however (Turner 1989). Species capable of dispersing long distances before laying their eggs, such as moths of the western spruce budworm, may be more adversely affected by large, patchy landscapes than are insects whose females do not fly at all, such as the Douglas-fir tussock moth. Landscapes with a variety of tree species and habitats also tend to support a diverse fauna of natural predators and insect parasites, which are critical to limiting generation survival and stabilizing population numbers.

The above logic is the basis of a venerable, ecological axiom that "diversity promotes stability" (Elton 1958, Graham 1952). The principle today, however, is controversial and has been challenged by many population ecologists on both theoretical and empirical grounds (May 1973, Pimm 1984, Stark 1973). The conventional wisdom that a return to the more diverse landscape patterns of presettlement times will reduce the risk of insect outbreaks is, nonetheless, still a popular notion in many quarters (Gast and others 1991). Skepticism is not directed at the desirability of increasing the mosaic of forest patches to improve landscape and species diversity, which will certainly lower vulnerability to pest damage, but at the concept that these practices will necessarily reduce the frequency of insect outbreaks.

The patterns of forested landscapes that exist today are basically the product of long-term interactions of soil, climate, and biota, modified frequently by disturbances like wildfires and recent human activities. Defoliators and bark beetles, today's major insect pests, played significant roles in shaping those landscapes, having coevolved over time with the forests and having served as important agents of change (Wickman 1992; Wickman and others, in press). Outbreaks of these insects were commonly part of the natural process by which many of the existing mosaics of eastside stands were formed (Anderson and others 1987, Swetnam and Lynch 1989, Weaver 1961). In some ways, the diverse landscapes that are the vision of tomorrow might be better achieved by permitting frequent, short-term outbreaks of some of these "pests," particularly in forests where natural processes like fire have been limited (see Daterman 1993). Also, the population fluctuations of defoliators, and to some degree bark beetles, often are driven by dynamic processes that are part of a large population system sometimes operating at a regional scale; such as does the Douglas-fir tussock moth (Berryman and others 1987, Mason 1978, Shepherd and others 1988). These processes are unlikely to be altered meaningfully by changing landscape patterns. The degree to which insect outbreaks can be reduced in the interior Pacific Northwest by modifying these patterns in landscapes is untested, for the most part, and therefore remains somewhat speculative.

Once an outbreak erupts, its severity and duration frequently are related to the abundance and susceptibility of host species types. These conditions can be controlled on stressed sites by selected management practices. The best opportunity for reducing unwanted outbreaks is to implement the procedures already recommended for the silvicultural control of insects at the stand scale and extend them to entire landscapes (Baumgartner and Mitchell 1984). The need for carrying out such practices will depend ultimately on management objectives for the sites in question and whether or not insect outbreaks actually are obstacles to these objectives.

Silvicultural control refers to the manipulation of stands in ways that hold effects of insect pests to a minimum (Graham 1952). In modern pest management, intensive management practices control species composition and stand characteristics, such as tree density, age, growth, and structure, in a way that reduces both susceptibility and vulnerability to significant infestations (Baumgartner and Mitchell 1984, Heddon and others 1981). These manipulations can be accomplished by any number or combination of routine forestry practices like cutting, planting, prescribed burning, or mechanical and chemical treatments. Recommended prescriptions applied on a large landscape scale should be particularly effective in reducing hazard because the possible contagious effects of nearby untreated stands also are minimized. Such preventive management strategies used at the landscape scale will improve general forest health.

Specific recommendations for individual pest problems have been covered elsewhere in this assessment by Mitchell and others, but will be reviewed briefly here. A common theme running through all analyses is that two phenomena are overwhelmingly responsible for the increased stress conditions found on many eastside sites. These are the dramatic shift from forest types once dominated by seral stands of pine to climax stands of fir and the overstocking of millions of acres with more trees than the sites can support (Wickman 1992).

Sixty years ago, 74 percent of the commercial forest land east of the Cascade Range in Oregon and Washington was classified as ponderosa pine type, mostly old-growth (Cowlin and others 1942). Through natural succession aided by fire exclusion and the selective cutting of pine, a significant portion of this type has been replaced by mixed-conifer stands, frequently with an overabundance of fir. These stands today have become prime targets for catastrophic outbreaks of western spruce budworm and Douglas-fir tussock moth (Anderson and others 1987, Williams and others 1980). Other portions of the former oldgrowth pine type are now occupied by overstocked stands of second-growth pine that are periodically ravaged by the mountain pine beetle (Gast and others 1991).

Clearly, a partial solution to reducing the hazards to these insects is to reverse succession by reintroducing fire into the systems, especially on the warm, dry sites once dominated by ponderosa pine and known to be at high risk to infestation. Prescription burning will not only reduce the number of susceptible fir trees, but also will favor the re-establishment and maintenance of species like pine and larch that are resistant to periodic outbreaks of the main defoliators. Controlling the density of pine on stressed sites by precommercial thinning that decreases stocking to efficient basal areas will maintain tree vigor and reduce risk from bark beetle outbreaks (Barrett 1979, Mitchell and others 1983). Such preventive practices of conversion to nonhost species and general stand improvement will reduce vulnerability to a variety of insect outbreaks and restore forest health to the whole landscape.

As already emphasized, insect outbreaks are natural phenomena in eastside forests and will continue to be problems wherever favored tree hosts are growing in abundance, especially in those environments conducive to rapid population buildup (Mason and Wickman 1988). The degree of concern with which outbreaks are viewed will depend ultimately on the principal uses designated for the forest. Where timber production is a primary objective, damaging outbreaks may be unacceptable and integrated pest management strategies, sometimes requiring direct control, will need to be implemented. The tracking of populations of the major pests is a necessary first line of defense in any integrated pest management program (Ruesink and Kogan 1982). Mixed-conifer types, which have always comprised a significant portion of the natural landscape at mid-elevations, will continue to be at risk to tussock moth and budworm outbreaks. These types should be monitored annually to evaluate the status of populations and predict trends. This monitoring will not only give an early alert of impending outbreaks, but also will help gauge the effectiveness of silvicultural and restoration projects in stabilizing populations of the major pests (Spellerberg 1991). Efficient procedures are available for monitoring populations of the Douglas-fir tussock moth and western spruce budworm at the landscape scale (Mason and others 1989, Shepherd and Otvos 1986). Their use should be encouraged for building databases of insect abundance to document long-term behavior of populations over different landscape conditions.

REDUCING HAZARD FOR ENDANGERED SALMON STOCKS

by **Gordon H. Reeves** and **Fred H. Everest**

A suite of factors have contributed to the decline of anadromous salmonids in the upper Columbia River. These factors include over-exploitation in sport and commercial fisheries, upstream and downstream passage problems at hydroelectric dams, and habitat loss and degradation. For the anadromous salmonids that go to the rivers in the upper Columbia River basin, the greatest losses occur at the eight dams downstream. Because of the magnitude of these losses, spawning and rearing habitats acquire additional importance for the survival of these fish, especially in the near term (that is, next 20 to 30 years).

Fish habitat in the upper Columbia River basin has been degraded by recent and past land management activities. Habitat simplification has resulted in a decrease in the diversity of habitat types, reduced levels of large woody debris, and declining water quality (McIntosh and others 1993, Wissmar 1993). These changes have been most pronounced in the areas of low gradient and wide flood plains, which are the more productive parts of the watershed (McIntosh and others 1993).

The status of fish stocks seems to be related to the condition of freshwater habitat. McIntosh and others (1993) found habitat was in better condition (that is, closer to pristine conditions and Forest Service standards) in the Wenatchee and Methow River basins compared to other systems in eastern Oregon and Washington. The Wenatchee and Methow River basins contain large tracts of wilderness and roadless areas. Fish populations in these systems are also in better condition than are populations in systems that have more degraded habitats.

Conservation and restoration of aquatic resources should be focused at the watershed scale. McIntosh and others (1993) and Johnson and others (1991) suggest that "key watersheds" could provide the nuclei of a broad-scale restoration effort for sensitive fish species and salmon stocks. Key watersheds are described as those having at-risk fish species and stocks and high-quality water and fish habitat. Even if a habitat was in a degraded state in a key watershed, it had a good potential of being restored. Key watersheds in eastern Oregon and Washington were identified as a foundation for the protection and restoration effort of at-risk fish species and stocks (McIntosh 1993-see table 22, figs. 1 and 21). Another strategy for the protection and restoration of anadromous and resident fish populations and their habitat is being developed by the Forest Service (U.S. Department of Agriculture 1992). Their report includes key watersheds and other components similar to those proposed by Johnson (1991).

Recommendations have been made recently for maintaining and restoring habitat of potentially threatened and endangered fish species and stocks on Federal lands: Johnson (1991) provide a "watershed and fish habitat emphasis option" for the management of late successional forests. This option focuses on restoring ecological functions and processes in streams, protecting existing good habitat of sensitive fish species and salmon stocks, and restoring habitat in watersheds having the greatest probability of success. They recommend establishing wider riparian corridors, eliminating timber harvest in all riparian areas, reductions in road mileage, not building roads in roadless areas, improved road drainage, and extended rotations in key watersheds. Anderson and others (1992) developed a restoration program for the Grande Ronde River and recommend a horizontal no-cut buffer equal to 75 feet times the stream order plus the width of the flood plain. This width is recognized as conservative but was based on the current status of endangered fish species and their habitat. Recommendations are made to increase pool frequency and depth, and large, woody debris levels. The standard for substrate conditions in spawning habitat was an area-weighted average of fines (less than 1.00 mm) of less than 15 percent. Maximum water temperature of subwatersheds up to the sixth order should not exceed 61° F on any one day, the 7-day average maximum should not exceed 58° F, and the minimum of perennial streams should be above 32° F.

Programs designed to restore fish habitat should be coordinated with restoration of terrestrial systems. A major factor responsible for the degradation of fish habitat has been the loss of large wood in the channel.

Removal of trees from riparian zones may delay the recovery of fish habitat. At a minimum, the largest trees (that is, those > 12 inches in diameter at breast height) should be left in riparian areas for future sources of in-stream wood. This would apply to all streams, as recommended by Anderson and others (1992). Smaller trees could be removed as part of a program for riparian vegetation restoration. Additionally, measures should be taken to reduce possible effects resulting from salvage activities in riparian as well as upslope areas on sediment loads and water temperature.

Anderson (1992) suggests other practices that are necessary for restoring fish habitat. These include improved livestock management in riparian zones, obliteration and upgrading of existing drawbottom roads, reduced road density, rehabilitation of water quality problem areas, and relocation of recreation sites that are in conflict with desired future conditions. Successful restoration of fish habitat in the upper Columbia River basin will require an integrative approach involving in-channel and riparian areas as well as terrestrial areas.

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CONSERVING BIODIVERSITY AND LONG-TERM SITE PRODUCTIVITY

CONSERVING BIODIVERSITY AND LONG-TERM SITE PRODUCTIVITY

Once the hazard of catastrophic loss of biodiversity, site productivity, resource commodities, and human health have been reduced, restoration efforts can focus on practices that provide for their long-term conservation. Re-establishing ecological processes and disturbance effects that create and maintain desired sustainable ecosystems provides a coarse-scale, long-term approach to conserving biodiversity and site productivity. However, specific genetic, species, community, and landscape diversity elements may be lost if not addressed at the same time. As an example, sensitive old-forest species such as the northern spotted owl may currently depend upon anomalous forest conditions with higher insect and fire hazard than historical old forest stands (Thomas and others 1993). Attempts to reduce hazard levels should consider potential adverse impacts to the owl or other old forest-dependent species that currently have fewer traditional old-growth stands available to them. We need to make progress in improving forest health and ecosystem sustainability while we conserve ecosystem species, components, and processes.

Conservation is preferable to restoration as it is much easier to maintain than to restore species populations or terrestrial and aquatic structures and processes. Biological conservation should maintain genetic, species, community, and landscape diversity. In this section, we address conservation and restoration of the forest gene pool, wildlife species, unique habitats, indigenous plant species, and soil productivity.

Conservation of genetic biodiversity is a concern because repeated selective harvest treatments could remove the most robust genotypes (Daniels 1993). Under altered eastside ecosystems, the potential also exists to have genotype-environmental mismatching where current genotypes are ill-adapted to altered site conditions. Gene resource management, including restoration, depends on an understanding of genotypeenvironment mismatching and managing for desired phenotypic response of entire systems rather than individual species.

Conservation of wildlife depends on knowing which sensitive species are at risk and where the remnant populations occur. “Gap analysis” (Scott and others 1993) provides a way to identify areas of high biodiversity that remain unprotected by State or Federal jurisdiction or are currently at hazard from fire or insects. Gap analysis could prove a useful tool in identifying key restoration activities (Martin 1993). Wildlife habitat restoration should be a prime consideration in current salvage logging operations so that stand and landscape legacies are left for wildlife species (Bull 1993).

Unique habitats such as old-growth or riparian areas are susceptible to insect attack in eastside forests, and their rarity suggests that steps should be taken for their protection (Daterman 1993). New pheromone techniques are suggested to cause insects to avoid unique sites, and microbial insecticides are suggested when epidemic levels of defoliators occur.

Noxious weeds have increased substantially in density and extent in forested lands of eastern Oregon and Washington (Harrod 1993). The replacement of indigenous species by noxious weeds is a serious threat to biological diversity. Because of insect outbreaks and increased potential for fire, the spread of noxious weeds into new areas is likely in the future. Prevention of infestation is the first step, followed by control, and then replacement with desirable indigenous species (Harrod 1993).

Conservation of long-term site productivity is key to conserving future management and societal options. Alteration of soil properties by harvesting or grazing activities or by erosion after severe fire has adversely impacted soil productivity (Meurisse and Geist 1993). Standards have been established that limit soil disturbance to less than 80 percent of the activity area. Other techniques, such as helicopter logging or harvesting on frozen ground, can be used to conserve the soil resource.

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CONSERVING BIODIVERSITY: FOREST GENETICS PERSPECTIVE

by **Jess D. Daniels**

The issue of forest ecosystem health is obviously complex. A host of underlying interactions—some quite evident, and others hardly discernible-must be understood if we hope to eventually restore and enhance the health of eastside forests. From a genetics perspective, forest health problems can be viewed simply as a consequences of the mismatching of genotypes (that is, individual organisms with specific genetic constitutions) and environments (the complex of biotic and abiotic factors influencing the expression of an individual's genetic potential). Regardless of the causative factors involved, the phenotypic effect (observable result) of mismatching is that individuals and populations lack adequate adaptedness (genetic capability) to endure environmental stresses without suffering the irreversible strains associated with cell death (Rehfeldt 1991). Mismatching of genotypes and environments can occur as the result of natural processes and human activities that directly affect either the genetic or the environmental components of an ecosystem. From a theoretical ecosystem perspective, we expect that whatever affects one component will indirectly influence other components, because the ecosystem is conceived as an integrated, interactive complex.

To properly assess genotype-environment mismatching, we must try to view it from two different perspectives—the genetics of forest populations and the environments that they inhabit. This will lead to a better understanding of the resultant problems and the prospects for remediation. Such a two-pronged approach admits two distinct possibilities:

- Mismatching resulting from changes in the genetic constitution of a given population that negatively affects its adaptedness to the environmental conditions peculiar to its site. (For convenience, this can be called genetic maladaptation.)
- Mismatching resulting from changes in the environmental conditions of a given site that negatively affects the adaptedness of the resident population(s). (This can be called environmental maladaptation.)

The first possibility (so-called genetic maladaptation) results from what geneticists call the dysgenic effects of events adversely affecting the genetic constitution of populations (in contrast to eugenic effects that are deemed to be beneficial to the health and productivity of the population). Such adversely affected populations might be called genetically inferior, if they are the result of natural processes; if they result from human actions, they might better be called genetically degraded populations. Environmental maladaptation permits a similar distinction to be drawn among sites that are naturally adverse (harsh sites) and those that have been adversely modified by human activity (degraded sites). Of course, there is the possibility of site degradation resulting from presumably natural events (for example, wildfire followed by erosion of denuded land). In such cases, the agent of environmental change is not as important as the relative rapidity of that change. This is the essential distinction to be made relative to the effects of global climate change on forest populations and ecosystems. From the perspective of the populations involved, these postulated large-scale environmental changes constitute wholesale environmental maladaptation radically affecting long-term productivity of forest populations and entire ecosystems.

The purpose of this report is to clarify the genetic dimensions of eastside forest health problems relative to the various possibilities for genotype-environment mismatching described above, all of which can have adverse effects on ecosystem function, productivity, and sustainability. This "genetic perspective" on forest ecosystem health is not easily attained. Even though the basic genetic principles and concepts are generally well understood, the genetic phenomena and their specific effects are neither readily discerned in nature nor directly observed through experimentation. The difficulty is compounded by our essential ignorance of the genetics of ecosystem biota—the innumerable species and intraspecific populations that comprise the “gene pools” of eastern Oregon and Washington forests. “Genecology” is the study of the genetical basis of ecological differentiation within populations of species (Davis and Heywood 1963). Genecology affords an integrated view from both the genetic and environmental perspectives.

Characterization of Stress Sites and Processes

The problems associated with forest ecosystem health, productivity, and sustainability in eastern Oregon and Washington can be assessed in terms of the two types of maladaptedness (genetic maladaptation and environmental maladaptation) resulting from genotype-environment mismatching. Because scientific data are generally lacking, we must rely on an understanding of the genetic principles, forces, and phenomena that shape forest populations. Both natural forces and human influences are implicated, and we will attempt to clarify their respective genetic effects on eastside forests.

Natural Forces, Genetic Principles, and Phenomena

Powerful natural forces shape the genetic characteristics of forest populations that make them more or less fit to inhabit their respective environments. In a recent paper, Howe (1989) briefly reviews the four major evolutionary forces (mutation, migration, genetic drift, and natural selection) and underlying genetic principles and phenomena (heritability, selection differential, genetic gain, asymmetrical response to selection). The operation of these principles over evolutionary time scales has produced a natural system of genetic variability that differs for every species. This system comprises the sum of the genetic variability existing among individuals within a population and among populations of a species. Populations of a species tend to be locally adapted (that is, physiologically attuned) to certain portions of the environmental gradient occupied by the species as a whole. Rehfeldt (in press) emphasizes the profound significance of all this when he says “The system of genetic variability controls the physiological ecology and phytosociology of species. Ecological distributions, responses to environmental stress, host-pest interactions and, therefore, silvical characteristics are all determined by the system of genetic variability.”

Rehfeldt (1991) has studied these genetic systems in various western conifer species and described a number of different evolutionary modes and adaptive strategies characteristic of certain of these species. He has found that some species (for example, interior Douglas-fir and lodgepole pine) are specialists; they are genetically differentiated across their respective ranges into identifiable populations that have adapted to different environmental niches or segments of clines. Other species (such as western white pine and western larch) are generalists that exhibit relatively little, if any, genetic differentiation throughout their respective ranges. Still other species (such as ponderosa pine) exhibit genetic variation patterns that are intermediate between those of specialists and generalists.

Extant populations are well adapted to their respective environments. As adaptedness of naturally occurring local populations approaches the optimum, then theoretically, the long-term productivity of these local populations will approach the optimum. Presently, however, this is unverifiable because current testing programs do not intensively sample the total range of environmental variation across a species range. Rehfeldt (1991) acknowledges a number of reasons to question this basic assumption, including contrary evidence (Raymond and Lindgren 1989, Roberds and Namkoong 1989), possible effects of changing climate (Stettler 1990), and the probability that adaptedness of all populations has not yet achieved the optimum.

Rehfeldt’s models describe genetic variation patterns resulting from natural selection, but other forces also have played a part in molding the genetic character of eastside forests. Unfortunately, scientific data required to identify and clarify the effects of such forces and phenomena are virtually nonexistent, leaving us to hypothesize about them on the basis of theoretical possibilities. Howe (1976) briefly discussed the evolutionary possibilities associated with wildfires as a natural part of northern Rocky Mountain terrestrial ecosystems. The possibilities for random genetic drift are most apparent, given that major wildfires can leave islands of live trees partially or wholly isolated from external pollen sources. In Howe’s opinion, “These may be ideal situations for major changes in gene frequencies by chance alone. If so we would expect to find many currently non-adaptive traits ...more and different genetic variation than would be created by the normal sexual process in large breeding populations." Thus, it is possible that random genetic drift resulting from wildfire has produced local populations not particularly well adapted to their specific sites; genetic drift could have distinctly dysgenic effects on populations inhabiting naturally regenerated burned-over areas.

Howe (1976) mentions a second evolutionary possibility associated with wildfire that has even more direct forest health implications. Noting that fire may function as a selection agent, he postulates the "possible suppression of the development of genetic resistance in tree species to some indigenous pests." The selection pressure of the pest is periodically relieved by recurrent wildfire with the result "...that insufficient generations of the host are exposed to build genetic resistance." Roth (1953, 1966) suggests this possibility in the case of ponderosa pine and dwarf mistletoe. Presumably, fire suppression could have long-term beneficial effects by allowing natural selection for pest resistance to progress without interruption in local populations. This likely would entail greater losses in the short term due to increased depredations (of, for example, spruce budworm), as suggested by Heinselman (1971).

Human Influences and Management Practices

Certainly, human activity (planned and unplanned) has had some dysgenic effects on eastside forests, resulting in conditions characterized above as poor genotypes on poor sites and poor genotypes on good sites. These can be considered from two perspectives: activities affecting naturally regenerated forests and activities associated with artificially regenerated forests.

Influences on Natural Regeneration

Howe (1989) succinctly summarizes the potential genetic effects of various forest management practices, with emphasis on the dysgenic consequences on naturally regenerated forests. In a very real sense, the silviculturist is a practicing geneticist; all silvicultural operations entailing phenotypic selection of some trees or stands for removal or retention potentially can affect the genetic characteristics of trees and stands produced by the residual trees. A serious concern is high-grading of stands associated with "diameter-limit cutting" for timber harvest. Removing only the best (most commercially valuable) phenotypes will result in serious degradation of the residual forest itself and even more serious genetic losses in subsequent generations produced by inferior genotypes left to naturally regenerate the site. Howe emphasizes the serious genetic risks associated with the use of diameter-limit cutting in uneven-aged silvicultural systems. This constitutes dysgenic selection, because younger, fast-growing trees are removed along with older trees of the same size class. Over time, the best growing genotypes are systematically removed from the population, thereby resulting in a steady decline in genetic growth potential and probably a concomitant increase in pest susceptibility. Summing up, Howe (1989) warns against "...all cutting practices which leave the site occupied predominantly by poor phenotypes which contribute substantially to the regeneration." In his estimation, such practices are "... genetically dangerous, almost always leading to dysgenic consequences either from asymmetry of response to selection or from the leaving of trees carrying genes for increased susceptibility to insects or disease."

Bassman and Fins (1988) considered the genetic implications of cultural treatments in immature stands (thinning, timber stand improvement, fertilization). They pointed out the potential dysgenic effects of high-grading associated with crown thinning and selection thinning of young stands. Selection thinning and timber stand improvement may be expected to have positive effects on quality characteristics, but there is a real danger of genetic degradation due to negative selection with regard to size and vigor.

Influence of Artificial Regeneration

With artificial regeneration systems, the most serious risk is associated with the selection and use of seed sources not well adapted to the particular planting site environments—so called off-site plantations. Foresters generally are well aware of this risk. Current reforestation programs operate acconjing to a regional system of localized seed zones and conservative seed transfer guidelines which were designed to reduce the likelihood of mismatching seed sources to planting sites. The main thrust of the aforementioned genecological research in the region has been directed toward scientific refinement and redefinition of seed zones and seed transfer guidelines for commercially valuable conifer species. These and other research results (such as electrophoretic analysis of isoenzyme variation patterns) also are used for refinement and redefinition of breeding zones for current tree improvement programs throughout the region. Breeding zones are analogous to seed zones; the former pertain to orchard (genetically improved) seedlots and the latter to woods-run (essentially wild) seed collections.

In general, current zone delineation has erred on the conservative side, with more than enough zones to prevent serious maladaptation problems. Where current seed collection and transfer guidelines have been carefully followed, there is no reason to expect that the adaptedness of forest plantations has been negatively affected. Given the operational difficulty of strictly adhering to conventional reforestation specifications, however, there are bound to be some plantations not conforming to set standards. Some could be so poorly mismatched that they should be considered at risk populations that may need remediation. These situations can be identified only by a careful audit of reforestation records at the local level. Knowledgeable experts can then assess the risks associated with specific off-site plantations and recommend appropriate action.

Genetic Improvement

Applied genetics, (tree improvement) has had a limited effect on eastside forests. For the most part, tree improvement programs in eastern Oregon and Washington have not yet begun to produce operational quantities of seed for reforestation. Pacific Northwest Region (U.S. Department of Agriculture, Forest Service) seed orchards are in the establishment stage and still many years away from operational production status (Theisen 1990; S. Martinson, telephone communication). Weyerhaeuser Company has older seed orchards now producing operational quantities of ponderosa pine and lodgepole pine seed for company lands in south-central Oregon. This seed is certified by the State seed-certifying agency in expectation of eventually marketing some of it for use by other landowners in appropriate seed zones (Cress and Daniels 1990).

Some disease-resistant seed currently is being used by the Forest Service. The Pacific Northwest Region is using western white pine seed collected from parent trees that have been screened for blister rust resistance. This is an interim seed source that eventually will be replaced with seed produced in seed orchards now in developmental stages. Western white pine is known to be an extreme generalist; there is no apparent need for localized zones throughout its range in Oregon and Washington. This opens the possibility of using rust-resistant seed from older orchards in other regions for reforestation programs in eastern Oregon and Washington. The most likely prospect for this would be to transfer seed from the program in the Northern Region to the Colville National Forest in Region 6 (S. Martinson, personal communication). Unfortunately, there is not yet a surplus of Northern Region seed for use by the Pacific Northwest Region. Nevertheless, applied genetics is now making a valuable contribution to the improved health and productivity of eastside stands and ecosystems ravaged by this introduced disease. The genetic impact will be much greater in the future when current orchard programs come to fruition.

Philosophy of Restoration Activity

Genecology is the touchstone for understanding the genetic dimensions of the forest ecosystem health issue. It is the philosophical and scientific underpinning for all gene resource management, including activities directed at restoring or improving the genetic components essential to forest health and productivity. Rehfeldt (1991) puts it in these words: “Gene resource management thus begins with an understanding of the system of genetic variability. The genetic resource cannot be preserved, conserved, controlled, manipulated, or reconstituted without an understanding of the manner by which species have achieved adaptedness to heterogeneous environments. This is particularly true when dealing with environmental change, regardless of whether the change is stimulated by management, mismanagement, or nature. Until the system of genetic variability is understood, comprehensive programs of gene resource management cannot be implemented."

If the objective is to effectively manage entire ecosystems toward some desired future goal of optimal productivity and long-term sustainability, this gene resource management philosophy would dictate that we will never be able to do it properly without clearly understanding the genetic systems of the floral and faunal components of the ecosystems involved. As Rehfeldt (1991) puts it, "A plight sorely in need of alleviation is the lack of understanding of genetic variation for all but a few of the economically important species." He is optimistic, however, in his appraisal of this situation and concludes that much of the needed information could be acquired via "...a five-year testing program that incorporates modern laboratory procedures with common garden studies." To this writer, the challenge seems much more formidable than that, given that these investigations should encompass a host of organisms (plants, animals, microorganisms) about which we know virtually nothing of their genetic systems. This is not to deny that a more comprehensive genecological research program could produce very significant and useful results in a relatively short timeframe. But ultimately the scope must be broadened to include many more organisms perceived to be an integral part of the interactive complex constituting an ecosystem.

It is the complexity of interactive relations among all these biological components that poses the biggest challenge for effective ecosystem management and the scientific research that must support it. For any one species (one managed for commodity production), all other associated species (and populations) constitute the biotic elements of a complex, heterogeneous, dynamic environment to which that particular "target" species must be adequately adapted if it is to remain a viable and productive part of the functioning ecosystem. If the goal of management is optimal ecosystem functioning that presumably ensures sustainable ecosystem productivity, then we must learn much more about these very complex genotype-environment interactions than we presently understand. This will require more complicated experimentation than we have been accustomed to in conventional silvicultural and forest genetics research. The focus must shift from the phenotypic response or status of a single species to the phenotypic response or status of the entire system. This means that we must be able to measure and model the interactive responses of all the ecosystem biota. It becomes incredibly more difficult, if we must be able to characterize and quantify the response of all the various individual biotic components (for example, species or populations), rather than simply treating them as intercorrelated environmental variables collectively influencing a particular target species or population. It is imperative that managers and researchers have a clear and common understanding of the objectives of ecosystem management as they pertain to remediation of current problems and to avoidance of future problems associated with both types of genotype-environment mismatching (genetic maladaptation and environmental maladaptation).

Genecological research must be directed toward clarifying these complex relations within existing ecosystems to provide a sound basis for modeling effects of actual and proposed changes in both biotic and abiotic components of eastside ecosystems. This work must be augmented with research aimed at providing data on genetic effects of current silvicultural practices and alternative methods. A case in point is the current shift in forest management philosophy toward natural regeneration and uneven-age management. Genetic theory tells us that there are genetic risks associated with such methods (dysgenic selection and increased inbreeding) that should be carefully assessed before these practices are mandated on a regional scale. Unfortunately, very little scientific data are available for such assessments; this is but one example of the many management scenarios that should be critically evaluated from the genetics perspective. This is a high priority research area that must be included in a comprehensive research and development program for the east side.

Another area that must be included in a comprehensive eastside research and development program is environmental monitoring, characterization, and mapping (EMCAM). There is a woeful lack of quantitative data pertaining to the environmental conditions that actually prevail throughout the vast expanses of eastern Oregon and Washington. Only a limited few authors have used specific physical environmental variables (for example, edaphic characteristics; Monserud and Rehfeldt 1990) and more precise ecological classification (for example, habitat types; Campbell and Franklin 1981) to improve genecological models. It is evident, however, that there is room for improvement of current genecological models, as they account for only a portion (and in some cases only a small fraction) of the phenotypic variation within the experimental datasets. More precise environmental characterization could be essential to future modeling efforts with organisms other than forest tree species. Regardless, precise environmental monitoring, characterization, and mapping would provide a common scientific basis for evaluating and comparing the efficacy of various other environmental classification and stratification systems in use or proposed for specific research and management applications (for example, habitat types, seed zones). This environmental data base would prove invaluable in the development and verification of many different kinds of models pertaining to eastside forest ecosystem function and productivity. Ultimately EMCAM would prove invaluable for monitoring and predicting local effects of global climate change. This level of precision would greatly improve the effectiveness of planning and implementing remediation programs throughout the region.

Recommendations

The following actions and considerations are recommended:

- Strengthen and expand genecological research to encompass a much broader array of eastside species. This should include testing the current methodology on species other than forest trees, evaluating efficacy of such methods, and clarifying methodological modifications that might be needed. Incorporate research results into operational guidelines and specifications for operational collection and use of woods-run seed and ensure operational compliance. Where necessary, modify breeding zones and tree improvement strategies in accordance with research findings for various species.

- Continue operation and development of tree improvement programs for commercially important forest tree species to assure successful regeneration of eastside forests with appropriate levels of adaptedness, genetic diversity, and productive potential. Initiate and develop similar programs for other plant species (for example, forbs, shrubs) that could be used to advantage in wildlife habitat management or remediation of harsh and degraded sites. Take full advantage of opportunities for cooperative programs to include government, industrial, and nonindustrial lands in the region.

- Initiate a multidisciplinary research project (silviculture, genetics and tree improvement, ecology, wildlife biology) aimed at early assessment and long-term verification of the genetic effects of various forest management practices on certain target species (for example, commercial tree species, wildlife species) and on ecosystem function, productivity, and sustainability.

- Assemble an interagency team (geneticists, silviculturists, ecologists, pathologists, entomologists) with responsibility for assessment of possibilities and strategies for avoidance or remediation of risks and problems associated with genotype-environment mismatching in eastern Oregon and Washington forests. The team should consider the relative, long-term genetic risks associated with conventional and alternative silvicultural approaches and forest management systems (for example, uneven-aged management) and develop strategies and operational guidelines for selecting appropriate methods and minimizing risks.

- Organize an interdisciplinary team of scientists (geneticists, ecologists, physiologists, meteorologists, climatologists, remote-sensing specialists, and so forth) to seriously consider the design and specifications for a region-wide environmental monitoring, characterization, and mapping (EMCAM) project to provide a database that could be integrated with other databases pertaining to various aspects of ecosystem function and productivity. This should specifically include integration with global climate change research.

CONSERVING WILDLIFE HABITAT

by **Evelyn L. Bull**

This paper presents options for forest management direction, with wildlife as the key emphasis, for northeastern Oregon forests affected by the western spruce budworm. Eastside, mixed coniferous stands are experiencing outbreaks of western spruce budworm, which have resulted in extensive defoliation and death in many stands. Insect pests are always present in forest ecosystems, and insect outbreaks, which have occurred at regular intervals, are a natural part of ecological processes.

The current insect outbreak is of greater intensity than any experienced in the past 50 years in northeastern Oregon. In the previous 40 years, northeastern Oregon forests have experienced three major insect outbreaks: western spruce budworm in the 1950s, Douglas-fir tussock moth in the early 1970s, and mountain pine beetle in the mid-1970s. Many theories have been proposed on the cause of the current budworm outbreak, but the outbreak was probably caused by a combination of factors including drought, preferential harvest of seral tree species (ponderosa pine, Douglas-fir, and larch), fire suppression, and succession to grand fir dominance.

Wildlife-related factors contributing to the budworm outbreak include removal of old-growth stands that support the highest densities of birds and arthropods that prey on insect pests, and reduction in densities of snags and logs that also support birds and ants that prey on insect pests. Little management attention has been given to the role played by natural predators (ants, predatory insects, birds) in maintaining sparse insect populations and reducing the frequency and severity of outbreaks.

The objective for ecosystem management should be a diversified ecosystem that maximizes natural insect predators so the system remains in dynamic equilibrium with less dramatic extremes to minimize tree loss. More specifically, desired conditions for wildlife enhancement of forest stands depend on the specific objective. Assume, for example, that the objective is to maintain maximum densities of cavity nesters in a stand. For white-headed woodpeckers, this objective would mean retaining old-growth ponderosa pine with a high density of snags and favoring regeneration of ponderosa pine. For pileated woodpeckers, the objective would include maintaining three to four snags and 40 logs per acre in forested stands, favoring regeneration of ponderosa pine and western larch for future nest trees, favoring regeneration of grand fir stands for roost trees and nesting and foraging sites, retaining snags greater than 20 inches in diameter at breast height (d.b.h), and maintaining adequate cover (live trees if present and dead trees if live ones are not present) to prevent predation on the birds (Bull and Holthausen 1993). For three-toed woodpeckers, this objective would mean encouraging regeneration of spruce, lodgepole pine, and subalpine fir while maintaining a stand with a high enough density of snags for nesting and foraging and enough live trees for foraging and cover. If the objective were to provide nest habitat for long-eared owls, dense thickets of Douglas-fir should be retained and mistletoe brooms encouraged. The mistletoe brooms provide nest sites, and the thickets provide cover that protects the owl from avian predators (Bull and others 1989).

Because Forest Plans provide protection for only a limited amount of old-growth in discrete and isolated blocks, fewer options will be available to provide for wildlife species dependent on old-growth on a landscape scale. If other live, old-growth stands are not available to substitute for dying stands, little can be done to salvage of old-growth stands without violating Forest Plan requirements. Large-diameter, dead trees are far better for the birds than no big trees at all.

Experiments are underway to determine the effect of single-tree selection in old-growth to encourage regeneration, and, at the same time, retain the characteristics of old-growth so that those wildlife species associated primarily with it will continue to use the stand. In the long term, additional stands should be targeted to become old-growth, and a mix of tree species should be planted because some wildlife species depend on ponderosa pine for nesting or foraging, some depend on grand fir for roost sites, and some depend on mistletoe brooms in Douglas-fir for nest platforms.

Measures can be taken to promote the appropriate herbaceous forage species if the objective is to enhance elk foraging habitat. Prescribed burning has been used to improve winter range of elk in some areas; however, burning should be used only when the specific objective warrants it.

Prescribed burning is sometimes also recommended to reduce fuel-loading or eliminate encroachment of Douglas-fir and grand fir in a stand. Burning can reduce the amount of downed, woody material but also may eliminate foraging strata for pileated woodpeckers, cover for small mammals and herptiles, and substrate used by ant colonies for nesting. Elimination of these structures will, in turn, affect insect pest densities because pileated woodpeckers and ants prey on these pests. Broadcast prescribed burning can cause large losses of nutrients from the forest floor and surface soil. Many of the eastside forests are limited in key nutrients, such as nitrogen and sulfur, that are readily lost by burning (Tiedemann and Klemmedson 1992). In addition, broadcast burning may cause unacceptable smoke pollution. Alternatives to burning to reduce fuel-loading and encroachment of undesirable tree species should be examined.

The management direction would be different if the objective were to salvage stands, yet retain as much wildlife value as possible for each watershed. Given this objective in a salvage operation, leaving live trees that provide forage for many birds and mammals, nest sites for raptors, replacements for snags, and cover and shelter for most forest birds is critical. Large-diameter snags (> 20 inches d.b.h.) should be left because these trees are in short supply, are least likely to be replaced, and are preferred for woodpecker nest sites. At least 40 logs per acre should be left, preferably > 15 inches d.b.h. These logs provide foraging habitat for woodpeckers, cover for mammals, and nest sites for ants. Hollow, standing cull trees should be left because species like the Vaux's swift, bats, woodpeckers, and mammals depend on them. Their value can be demonstrated by the fact that a pair of Vaux's swifts every day feed their nestlings 4000 to 7000 insects, including western spruce budworm (Bull and Beckwith, in press). These recommendations suggest that salvage operations should concentrate on removing the smaller dead trees, smaller logs, and fine fuels other than those on the forest floor. The remaining live trees and large snags and logs will pose much less fire hazard than if the reverse is done.

For desired future conditions within a watershed, a diversity of seral stages and a diversity of tree species should be maintained. Planting must suit the site and include a variety of species because insect pests specialize on each tree species; diversity is the best defense. Old-growth, relict stands are perhaps the most important to retain because they are in the shortest supply, are keys to genetic sources, and contain the highest density of predators of insect pests. This recommended emphasis for diversity within watersheds will provide a more balanced ecosystem and habitat for a greater variety of wildlife species, but it has its costs. This management direction allows more biomass to be recycled on site and less to be removed for saw logs.

PRIORITY WILDLIFE HABITATS AND RESTORATION MANAGEMENT

by **Sandra K. Martin**

Wildlife deserves consideration in the implementation of restoration projects. Animal species contribute to biodiversity, and they are integral components and purveyors of processes within the ecological webs found in all forest systems. Many wildlife species also require special legal and administrative attention in management decisions made on Federal lands. Finally, wildlife and issues surrounding these species' wellbeing are of tremendous import to many interest groups and the general public. Wildlife issues are often ,he primary, relevant, emotional conduit for many citizens, focusing any interest they may have in wildlands and natural resource management. For these ecological, legal, and sociological reasons, wildlife should be incorporated into the decision process for setting priorities for forest health restoration projects. A key element for wildlife interests is defining the geographic location of sensitive wildlife species and associated hazard from current declines in forest health and planned restoration activities.

The desire to maximize beneficial effects of habitat management and the requirements of law have been influential in the development of data bases and geographical information systems (GIS) in recent years to assist managers and biologists in decision processes. These tools will also be useful in providing information about wildlife when priorities are set for restoring sites where forest health is declining.

Information on the location of wildlife or important habitats on National Forest lands has primarily been collected by the USDA Forest Service Districts in response to specific project needs. Information exists in various formats with little current standardization among National Forests, except for some threatened and endangered species such as the northern spotted owl. In response to frequent requests for information on some of these species, data have not only been compiled for the entire National Forest but are available in computerized data bases and sometimes as GIS-based map layers. Some National Forests have compiled wildlife observations and information from surveys into data bases in the Supervisor's Office, but much information remains scattered among files and reports in District offices throughout the region.

At present, corporate data bases of wildlife species and habitat occurrence information for National Forests are rudimentary for the Region as a whole. Information on the northern spotted owl represents the most detailed and complete regional data base in the Pacific Northwest Region (Region 6) of the Forest Service. This tabular data base includes specific occurrence information by year and by legal location with detail to the quarter-section.

Wildlife habitat relationship models were compiled and summarized for the Blue Mountains by Thomas and his colleagues (1979) and for western Oregon and Washington by Brown (1985). Extensive tabular data from these volumes are available in computerized form in several software formats. Wildlife habitat relation models will predict species presence or absence for an area, given that habitat information is available. These models, with varying degrees of reliability, are generated from the scientific literature, which differs markedly in depth from species to species.

Plans are underway to improve the accessibility of information on all wildlife species on National Forest lands in the Pacific Northwest Region with priority given to threatened, endangered, and sensitive wildlife. Regional staffs are exploring use of a tabular, computerized, wildlife occurrence data base and could shift to GIS data bases in the next several years.

The Washington Department of Wildlife has developed a computerized, point-occurrence data base, available in digital format, for 150 nongame species. The greatest detail and abundance of data are for threatened, endangered, and sensitive species (for example, the northern spotted owl) that require administrative response by government agencies and private citizens engaged in natural resource management in the State. The most complete information in this data base is for State and private lands in Washington. The Department has had intermittent time and resources available for interfacing with Forest Service units, with the result that wildlife occurrence on National Forest lands within the State is sporadically documented.

In the past 4 years, the Washington Department of Wildlife has been developing the Priority Habitats and Species Program. A GIS-based data base is being produced for this program, and includes game species and nongame wildlife. Priority species are defined as those of concern because of their population status, recreational importance, or sensitivity to habitat alterations (Washington Department of Wildlife 1992). Priority habitats are defined as having one or more of the following attributes: high species densities, high species richness, significant breeding habitat, significant seasonal range, significant movement corridors, limited availability, or high vulnerability. GIS-based maps are maintained in an ARC INFO system, with accompanying tabular data available in computerized data bases. Not all areas within the State have been incorporated into this project. Currently, State and private forested lands are included, as are urban growth areas and the shrub-steppe zone of eastern Washington. The inclusion of Federal lands is a goal, and development of a data base for the Wenatchee National Forest was the pilot for this aspect of the program. This information may be available by mid-1993, but few other National Forest data have yet been incorporated.

The Oregon Department of Fish and Wildlife has developed a computerized data base titled the Oregon Species Information System with information on 670 fish and wildlife species. Data for each species include, at the least, distribution by ecoregion and by county within the State, with augmentation from a list of casual observations provided by State biologists.

Habitat associations in Oregon Species Information System are generated for each species from the scientific literature. This data base can be queried for species found in a specific county and a specific habitat type. The data base can be used as a data source for ARC INFO; so that map displays of data queries can be generated. The Nature Conservancy has been active in developing Natural Heritage data bases across the country for fish, wildlife, and plants. In Washington, The Nature Conservancy's efforts provided the seed for the growth of the Nongame Data base Program in the Washington Department of Wildlife. In Oregon, The Nature Conservancy continues to maintain and update a Natural Heritage data base in a computerized format. This private group conducts data sharing with Forest Service units, though botanical data from National Forests are much more complete than are wildlife data.

In recent years, the concept of biodiversity has spawned an interest in mapping species richness and vegetation types as surrogates for diversity or unique assemblages of species. These GIS-based analyses, first generated in Idaho in the 1980s by the State Fish and Game Department, are currently underway in most States, including Oregon and Washington, under the auspices of the U.S. Fish and Wildlife Service. The methodology and analyses are referred to as "gap analysis" because one initial goal of such projects was to identify gaps in networks of existing reserves where biodiversity could be preserved and protected (Groves 1992).

In gap analysis, several types of GIS data layers are generated for a given area, such as a State--vegetation, distributions of animal species, and locations of parks, reserves, or other management designations of interest (Scott and others 1993). The integration of data layers on animal distributions can disclose patterns of species richness, and correlation with vegetation information can provide wildlife habitat relationship models (or be used to test models already in existence). The resulting maps, reports, and data bases from gap analysis can provide powerful landscape- and regional-scale tools for tracking species' occurrence, identifying gaps in preserve networks, and predicting effects of proposed habitat alteration.

Gap analysis for Oregon, initiated in 1989, will be completed in 1993. The digital vegetation map for Oregon's gap analysis is in ARC INFO format and is housed at the Oregon Department of Fish and Wildlife in Portland. Potential ranges for wildlife species were generated by linking wildlife habitat relation models from Oregon Species Information System with the vegetation map. The resulting species distribution maps are under review by State wildlife experts.

In Washington, gap analysis is in similar stages of process, with completion anticipated by late 1994. The products from this analysis eventually will be housed at the Washington Department of Wildlife in Olympia, but work on the project is currently underway at various of sites across the State, including the University of Washington and Washington State University.

The Washington analysis group is using a national standard of 100 hectares as the minimum mapping unit for the vegetation layer. Animal occurrence information is being generated by searching for information in museums across the State. Tabular data bases, which document habitat requirements for all species, are also being generated for all species from various sources, including the scientific literature and the personal knowledge of experts. The resulting digital data bases will be in ARC INFO and ERDASS formats.

In a process of setting priorities for restoration management of National Forest lands, a valuable way to interface information on distributions of endangered, threatened, or rare wildlife or unique and important wildlife habitats would be to use map-based data as an overlay in a graphic display system. This type of data storage and analysis capability is a current goal for fish and wildlife staffs in several government agencies in the Pacific Northwest, but so far, little such information exists for Federal lands in the region.

In summary, the Washington Department of Wildlife soon will have a GIS-based map of priority habitats available for the Wenatchee National Forest and for some National Forest acreage found in areas of checkerboard ownership with State and private forested lands in the State. The Oregon Department of Fish and Wildlife can feed information from a relational data base into a GIS and produce maps at a resolution of county units. This data base is for the entire State of Oregon, including National Forests. Additionally, each National Forest in Region 6 has varying amounts of wildlife data entered into local GIS systems, although much of this information is concerned with a few species, such as the northern spotted owl.

Changes in wildlife habitat occur over time in any ecosystem. But changes associated with declining forest health in western North America may be significantly more dramatic than gradual successional changes in both geographic scope and the suddenness of the habitat alteration. Many affected forests in the Pacific Northwest are mature or old-growth and provide dense, structurally complex habitat to wildlife species dependent on these habitat features. As forest health declines precipitously, vast acreages are undergoing extensive defoliation, which may be followed by massive tree mortality.

Extensive defoliation of the forest canopy has the potential to place habitat quality for forest interior wildlife species in steep decline in the short term. Recent work on many wildlife species in mature and old-growth forests has concluded repeatedly that high levels of canopy cover, or related parameters, contribute to habitat quality. If substantial tree mortality is a permanent effect of infestations by defoliators or other insects and diseases, the reduction in habitat quality for wildlife species associated with mature forests will be intense and long term. Scenarios involving catastrophic fire, salvage logging, or even unprecedented densities of dead, standing trees would all result in shifts in successional stage of forest wildlife habitat from late to early seral stages.

The integrated wildlife data base generated by gap analysis could be used to identify areas with maximum biodiversity or sites with selected wildlife, such as threatened, endangered or sensitive species. The definition of priority wildlife habitats in any restoration management plan will no doubt include an emphasis on biodiversity at several appropriate scales and the protection of critical habitat for key species. Gap analysis should be available for Oregon near the end of 1993 and for Washington in late 1994.

Every source of GIS-based information mentioned above has shortcomings related to the task of setting priorities for restoration of areas on National Forest lands. Some sources do not yet cover much National Forest acreage (Washington Department of Wildlife Priority Habitats Program). Those data sets that do include National Forests have low resolution in GIS format (Oregon Department of Fish and Wildlife). Gap analysis conducted by the U.S. Fish and Wildlife Service and State governments in Oregon and Washington are not yet complete, but when they are, resolution also may be too coarse for site-specific queries below the subdrainage scale.

Now, and for the next few years, sites proposed for restoration management must be reviewed for wildlife priorities by querying existing knowledge sources site by site for information on species presence. In general, the lowest resolution possible is township, range, and section; (640 acres). Several knowledge sources should be investigated for each site, including State data bases and sources available from the relevant National Forest. Data base format differs among National Forests, though for most endangered, threatened, or sensitive species information is available in hard copy report or tabular format in Supervisors' offices. Summing and cross-checking information from these various sources will be a required step in generating a priority list of sites that is based on presence of rare and unique wildlife or critical habitats. This work will require the expertise of wildlife biologists with technical knowledge in a variety of subdisciplines that reflects the biodiversity of the National Forests.

The arduous labor of such a process will decrease as more and more data bases come on-line in GIS-based formats. Reliability of the analyses also will increase as on-going research, surveys, and monitoring update these corporate data bases.

The utility of regional wildlife information will become starkly apparent when restoration management gets underway. This program may provide a catalyst for intensified development of corporate regional wildlife data bases focused on National Forest lands. In Oregon and Washington, State governments and the U.S. Fish and Wildlife Service will soon have several products that could serve as admirable beginning points for reliable, adequately detailed wildlife-distribution data bases. Such tools will be essential to successfully implement landscape-scale management with a variety of goals, including restoring forest health in the inland Pacific Northwest.

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PROTECTING UNIQUE HABITATS AND RIPARIAN AREAS FROM INSECT ATTACK

by **Gary E. Daterman**

The unique habitats referred to here are mainly old-growth areas, many of which include riparian zones. Outbreak populations of western spruce budworm, a major defoliator, and the Douglas-fir beetle and other bark beetle species are currently running rampant in eastside forests of Oregon and Washington.

As a result of outbreaks of populations of bark beetles and other insects, old-growth areas, riparian zones, and other high-value timbered sites (such as campgrounds) are being severely affected. This condition is not surprising for old-growth sites where large, often overmature, trees are purposely retained for their contribution to the desired old-growth character of the site. Many of these overmature trees will be highly susceptible to attack by bark beetles. Thus, because of high beetle populations and large numbers of susceptible trees, heavy tree mortality can be expected to occur in such areas. Drought conditions coupled with defoliation by western spruce budworm further weaken tree resistance, thus making them even more susceptible to bark beetle attack and further accelerating the degradation of the habitat condition.

An added consideration here is that once outbreak populations of bark beetles are present in an area, the will have dramatic effects on the structure and composition of these unique stands, regardless of the health and resistance of their host trees. Such outbreak populations of a bark beetle species like spruce beetle or Douglas-fir beetle can successfully attack and kill even the more healthy and resistant trees.

To greater or lesser degree, old-growth and riparian areas contain trees highly susceptible to insect attack throughout the eastside forests of Oregon and Washington. If outbreak populations of insects exist near these unique habitats, the habitats are in jeopardy. Further, because the insects are mobile, all of these areas will eventually be pressured by insect attack. Because these unique habitat areas are already relatively scarce and in various states of degradation, steps must be taken for their protection. If not protected, they will be further reduced in quantity and quality. The consequences mean reduced ecosystem health in terms of reduced richness in biological diversity (both in abundance of species and their numbers), degraded water quality and fish habitat, and reduced social and economic values dependent upon the habitats (game and nongame fish and wildlife, mushrooms, recreational values, scenic beauty). Furthermore, due to the unprecedented high levels of tree mortality and related fuel loads occurring in many of these areas, there is a high probability of stand replacement fires affecting their integrity.

Philosophy for Protection and Restoration

The key to restoration of existing unique habitats, and improving them in abundance and quality for the future, calls for short-term protection measures and a long-term strategy to reduce the effect of disturbance agents on stand structure and composition to the extent possible through cultural and management practices. The long-term approaches are covered elsewhere in this document. This particular section addresses the need for protecting remaining old-growth and other unique habitats from insect attack in the short term to prevent further degradation and loss.

The unique habitats discussed here are integral components of eastside forest ecosystems. Forest ecosystem health depends on restoring and conserving old-growth and other unique habitats to maintain and enhance biological diversity. Several threatened, endangered, and sensitive species depend on these unique habitats, as do many other species that compose the biological richness of eastside forests. More specific information about the particular species that occupy these habitats and their requirements may be found in other sections of this document.

Urgently needed are measures to prevent further bark beetle-caused mortality of the larger trees in old-growth and riparian areas. True firs, Douglas-fir, Engelmann spruce, lodgepole pine, and ponderosa pine are at particularly high risk of being killed by bark beetles, and the true firs and Douglas-fir are also at risk of being weakened by western spruce budworm and Douglas-fir tussock moth. Past and most current efforts to reduce bark beetle mortality have been aimed mainly at removing infested trees and logs to reduce continued buildup of beetle populations. Recently, supplementary efforts have used pheromone lures to make this salvage process more effective, and additional new pheromone technology could soon become available, leading to more effective beetle management and habitat protection.

Alternative Actions for Protecting and Restoring Unique Habitats

Bark beetles—The standard practice for managing bark beetle infestations is the timely removal of infested stems to prevent further buildup of beetle populations in the general area. Often, this tactic is only marginally successful because not all infested trees are found or because colonized stems are removed after the beetles have emerged in the spring and already attacked and colonized new hosts.

A recent improvement on the standard approach has been the intensive use of winter logging for more timely removal of the infested material. In addition, some land managers have placed synthetic aggregation pheromone dispensers in strategic locations to induce bark beetle attack in stands scheduled for harvest, or in stands of lesser value than the unique habitat areas or other highly valued locations. This action is then conscientiously followed up by timely removal of the infested trees, usually by winter harvest with helicopters.

Additional, very promising pheromone technologies are currently being field tested. When operational and registered for commercial sales, these new methods are expected to greatly enhance the capability for protecting high-value stands from bark beetle attack. The first of these methods uses a synthetic antiaggregation pheromone, which induces an aversion or repellent response in flying beetles, to cause host-seeking beetles to fly elsewhere for a potential host tree. These materials are chemically identified and available in synthetic form and in commercial dispensers for either ground or aerial application. Effective antiaggregation pheromone blends are known for Douglas-fir beetle, spruce beetle, and the mountain pine beetle (Amman and others 1989, 1991; Furniss and others 1976; McGregor and others 1984; Shea and others 1992. These repellent materials are scattered in a prescribed way on the site to be protected, thereby causing host-seeking beetles to fly elsewhere. This method is very near operational for Douglas-fir beetle, requiring only registration by the Environmental Protection Agency and some additional field testing. The method may be available for use by land managers by 1994. For spruce beetle, mountain pine beetle, and possibly other species, operational use is less imminent, but land managers may have it in hand by 1995 or 1996.

A second method is to employ high-strength aggregation pheromone lures in a trapping device to reduce populations of bark beetles. This approach is somewhat like the current method that depends on lures placed on trees in stands of lower value or those scheduled for harvest. An important difference is that the trap captures plus the "spillover" attacks in nearby trees absorb more beetles than will the "tree baits" alone. This effect occurs because the traps remove a large number of beetles from the population and remain attractive throughout the flight season, thereby causing repeated spillover attacks, that absorb more of the beetle population. In contrast, the baited trees lose their attractiveness once they are fully colonized by attacking beetles. Again, if the traps are placed where spillover will not create a higher risk to unique habitat areas or other high-value stands and trap placement can be accommodated and integrated into an annual harvest or salvage plan, the spillover aspect should not be a problem. Additional field research must be completed, however, before this particular approach can be recommended for operational use. The integrated application of antiaggregation and aggregation pheromone strategies across the landscape should result in the most effective approach for bark beetle management.

Defoliators—Defoliators, particularly the Douglas-fir tussock moth and the western spruce budworm, also can be hazardous to the continued health and existence of unique habitats. The tussock moth can severely defoliate trees in a relatively short time and even cause tree mortality. Budworm defoliation is usually less severe, extends over several seasons, and only rarely is the direct cause of tree mortality. In both cases, however, the defoliation can weaken trees and cause increased susceptibility to mortality caused by bark beetles.

Outbreaks of western forest defoliators are generally treated with the microbial insecticide B.t. (*Bacillus thuringiensis*) (Beckwith and Stelzer 1987; Beckwith and Daterman, in press). This biological insecticide is specific for lepidopteran insects and is efficacious for tussock moth and spruce budworm, but it also may cause mortality of other Lepidoptera if they happen to be present in a vulnerable life stage at the time of spray application. These nontarget Lepidoptera represent a significant concern because they may have important roles in ecosystem processes. As an example, bird and mammal species, possibly even threatened, endangered and sensitive species, may depend on these insects for food. This possibility is sometimes justification for opposition to the use of insecticide sprays, even microbial insecticides like B.t., in forest ecosystems. Usually, however, a more realistic concern is for the health and well-being of the habitat itself. Clearly, if lack of treatments for the defoliators would lead to greater tree mortality by bark beetles or by the defoliators themselves, habitat degradation could be expected. Such habitat degradation could prove much more devastating to the nontarget Lepidoptera and other species inhabiting the ecosystem than the potential side effects of the microbial insecticide sprays, particularly in the long term.

Recommendations for Protecting and Restoring Unique Habitats

Because of the abundance of trees susceptible to insect attack within unique habitats, and the high value of the habitats as integral and necessary components of eastside forest ecosystems, major efforts must be made to protect and maintain these areas. As practiced in the past, and to this day in many locations, salvage removal of infested stems has not been timely or adequate for managing tree-killing bark beetle species. Additionally, beetle management activities sometimes are restricted to the stand scale.

Where substantial tree killing by bark beetles is occurring near unique habitat sites (within several miles), a bark beetle management plan for the ecosystem should be implemented on a landscape scale. The philosophy of this approach will be to identify and remove all infested host material from the ecosystem before beetles can emerge and increase their populations by infesting additional trees. The management plan must be landscape in scale because of the strong flight capability of the beetles and related capacity to move long distances into new hosts. Managers should also use commercial tree baits to manipulate beetle populations into trees and stands targeted for removal, in contrast to high-value areas for retention, such as old-growth areas and other unique habitats.

As new pheromone-based methods are perfected, they should be used to supplement these management recommendations. Specifically, when repellent pheromone methods are available commercially, they should be used to prevent bark beetle attacks in unique habitats. This method should be available very soon for large-scale use to prevent Douglas-fir beetle attack and in the near future for spruce beetle and mountain pine beetle.

A further recommendation is to treat unique habitat areas with microbial insecticides when they are threatened by outbreak populations of defoliators such as western spruce budworm or Douglas-fir tussock moth. Although such sprays also could kill some nontarget species of Lepidoptera, the benefit of protecting the health of old-growth or riparian areas would be preferred for purposes of achieving the long-term desired condition for the forest ecosystem.

Other Considerations and Recommended References

The long-term objective for eastside forest ecosystems is to restore them to a condition that is resistant to undue harm from disturbances caused by pests and other natural agents. Increased resistance from insect attack and damage is certainly possible for individual trees, stands, and landscapes. That insects are impressively resourceful in locating suitable host material must also be considered. For bark beetles, such hosts can be windfalls, lightning-killed trees, disease-weakened trees, fire-damaged trees, and the like. If left to their natural tendencies, bark beetles can proliferate into outbreak populations by beginning their colonizations on such weakened or storm-killed hosts. Once their populations reach epidemic proportions, these beetles can once again become tree-killing threats to unique habitats and other high-value ecosystem resources.

Therefore, maintaining vigilance and an active pest management policy for protecting old-growth and other unique habitats from undue insect damage is essential. Such management policies should be developed on a landscape in scale for area-wide management of potential insect problem populations and, as outlined above, take full advantage of pheromone technologies and microbial insecticides to prevent or reduce insect-caused damage. For additional references on use of pheromones to manage forest insect pests, see Borden (1990) and Daterman (1990).

PRACTICES TO REDUCE AND CONTROL NOXIOUS WEED INVASION

by **Richy J. Harrod**

Ecologically, weeds are considered colonizers or pioneering species of open or disturbed habitats and largely result from human activity (Baker 1965, 1986; Taylor 1990). Socially, weeds may be considered those plants growing where they are not wanted (Ashton and Monaco 1991). Perhaps the most applicable definition of a weed is an "exotic" plant that colonizes disturbed habitats or invades undisturbed native plant communities and may have deleterious effects on native plants, wildlife, crops, or livestock (Harrod and others, in press). The term "noxious weed" is a legal designation and does not necessarily have biological meaning. For example, Washington State (RCW 17.10.010) uses the term noxious weed to mean "...any plant which when established is highly destructive, competitive, or difficult to control by cultural or chemical practices."

Undisturbed native forest and range plant communities are fairly resistant to invasion by weeds. Many weeds introduced from foreign lands during the last century, however, can compete successfully with native plants. Overgrazed grasslands, waterways, roadsides, and other disturbed or open habitats are particularly susceptible. As a result, the "natural" successional character of eastside forest and range ecosystems has been altered.

Alien plants can alter ecosystems by negatively affecting native plants and animals and the communities they comprise (Hobbs and Huenneke 1992, Tyser and Worley 1992, Vitousek 1986). Purple loosestrife, a European weed, invades wetland ecosystems, displacing native plant species and forming monospecific stands (Thompson and others 1987). This change in plant species composition may have secondary effects on waterfowl, fish, and aquatic insects. Other changes are more subtle. Goodwin (1992) reports that nonmycorrhizal weeds cause fungal populations to decline in steppe communities that are dominated by mycorrhizal, native bunchgrasses. The actual extent of the potential threat weeds pose to native ecosystem composition, function, and process is yet to be determined.

From a social perspective, changes in native plant communities mean loss of recreational opportunities, loss of forage production for livestock, or both. Weeds account for a third of all crop losses in the world (Strobel 1991). Knapweeds alone have been estimated to cost $900,000 annually in forage reduction in British Columbia (Strang and others 1979), and Bucher (1984) estimates annual forage loss in Montana to be $4.5 million. Agriculturists in eastern Oregon and Washington often are forced to abandon fields because of severely reduced yields and the high cost of control. The need for managing and controlling weeds that are apparently altering natural resources is obvious.

Philosophy of Restoration Activity

The desired future conditions of native forest and range ecosystems is to maintain compositional, structural and functional components, and successional processes that reflect the range of natural variability for a given ecosystem. Managing and controlling noxious weeds on forests and range lands are of paramount importance in preventing detrimental effects to native plant and animal communities.

A successful weed management program must integrate weed management tactics into long-term strategies for dealing with weeds (Ashton and Monaco 1991). Prevention should be an integral part of any weed management program, in both the short and long terms. Existing weed problems must first be identified and then a strategy developed that takes into account short- and long-term effects on the weed population. Noxious weeds and their distribution should be inventoried before control is implemented. A major goal of weed control is to restore or maintain ecosystem components and processes. Weed control methods should therefore be selected after careful consideration of environmental, cultural, economic, and management factors (Harrod and others, in press).

Restoration Actions

Six methods of weed of control—biological, prescribed burning, manual, mechanical, herbicidal, and cultural—are described below. The most effective results are achieved when they are used in combination.

Biological control—Noxious weeds were usually introduced without the natural predators and competitors that coevolved with them in their native lands. These plants, therefore, often have an inherent advantage over the native species they are competing with. The concept of biological control is to introduce one or more of the weeds' natural enemies, including host-specific fungal pathogens, herbivores, or parasites. Biological controls also may include competitive plants, such as many grass species, which crowd out noxious weeds (Larson and McInnis 1989).

Biological controls are currently only a limited alternative to other types of control (Ashton and Monaco 1991). Results often are slow to occur or are ineffective, and not every noxious weed has an effective biological control agent. Complete control of noxious weeds through the use of natural predators can never be achieved (Harrod and others, in press); however, biological controls are cost effective, and sometimes—such as control of tansy ragwort by the cinnabar moth—can significantly reduce the rate of spread (Dan Sharatt, personal communication).

Prescribed burning—Although not fully tested, prescribed fire may remove or at least inhibit competitive noxious weeds so that native species can reclaim sites. For example, preliminary results (Harrod and Everett, unpublished study) suggest that fire may reduce the ability of a population of diffuse knapweed to produce seed in the current year. Some bolting stems appear to be returned to rosette stage, which may allow grasses (that appear to be stimulated by fire) to gain a competitive advantage.

Manual control—Manual control methods include such procedures as handpulling or clipping. These methods are the most selective and specific means of removing noxious weeds. Newly established weed populations are most effectively controlled by handpulling, particularly if the use of chemicals or other methods cannot be used (along streams, for example). At the same time, manual methods are time consuming, expensive and impractical for large-scale weed control. Some weeds may not be controlled by manual methods because of their life histories or morphological characteristics. For example, dalmatian toadflax is a rhizomatous weed that has been shown to be enhanced by pulling (Harrod 1989). Repeated and regular pulling would be needed before root reserves could be depleted. Obviously, before manual methods are chosen and implemented, the biology of the target weed should be known.

Mechanical control—Machines can be used to remove or reduce cover of unwanted vegetation. Mechanical control saves time and money because large areas can be treated by one person in a short time. Mowing is the most common mechanical method used along roadsides, drainage ditches, or fields. Timing mechanical treatment is important as it is with other means of control. For example, diffuse knapweed is an obligate outcrosser (Harrod 1991), so mowing before flowering may greatly reduce seed production. Repeated mowing may be necessary to control some species, but other species may not be greatly affected at all. Yellow starthistle has been observed to bloom and set seed at mowing height (Dan Sharatt, personal communication). Again, knowing the biology of the target weed will greatly increase the likelihood of selecting an effective control method.

Herbicidal control—Chemicals can be used to control noxious weeds rapidly and efficiently. Herbicides may be applied in several ways including by aircraft, spraying implements, or backpack sprayers. Timing of application is very important and depends on the type of chemical used. Herbicides are grouped into categories based on chemical similarity, mode of action, movement within plants, selectivity, and application and use patterns (Ashton and Monaco 1991). It is important that applicators be properly trained before handling and using herbicides. Environmental consequences must be analyzed and considered before herbicides are applied.

Cultural control—Cultural practices are those human activities affecting weed management. Seeding with competitive grasses in newly disturbed areas such as roads is an example of a cultural practice. The emphasis is on prevention. Projects should be carried out with the idea that weed invasion or establishment will be minimized. Control of weeds is more likely if only small populations become established.

New methods for evaluation and testing—The chemical industry has responded to the need for weed control by producing herbicides, but herbicides can pose serious environmental and human health problems, particularly if misused (Strobel 1991). Biological controls have become popular alternatives to other means of control because of their specificity and neutral effects on the environment. Generally, organisms such as insects or fungal pathogens are released to attack and damage weed species. Concerns exist about the possibility that these biological agents may become problems themselves. Strobel (1991) has been studying a biological approach that bypasses the need to release whole organisms and the potential for native species to become pathogenic hosts. He and his colleagues have isolated a species-specific phytotoxin called maculosin, produced by a fungal pathogen, that causes necrosis and chlorosis when, applied to spotted knapweed leaves.

It is apparent that more research in biological control should be carried out. Naturally occurring phytotoxins could be produced and extracted naturally or even synthesized. The biologic, economic, and social benefits derived of such materials may extend far beyond our current situation.

Recommendations for Restoring Infested Areas

The most important aspect of noxious weed management is prevention. Human-caused disturbances of ground and plant communities should be carried out in ways that keep weeds from becoming established which requires a change in management emphasis and increased awareness. Prevention must occur simultaneously with restoration activities in areas already infested. Restoration activities include not only control of weeds, but also re-establishment of native plants and animals along with ecosystem structure and function.

Restoration actions recommended include:

- Ensure that noninfested disturbed and undisturbed areas are protected from invasion by weeds through revegetation or other preventive means.
- Identify management practices that cause or enhance the spread of weeds, and immediately modify those practices.
- Assess new restoration methods for reclaiming invaded sites with native species that are genetically adapted and local to the site.
- Determine which weeds are causing the most serious stresses outside the range of natural variability of ecosystem processes.

CONSERVING SOIL RESOURCES

by **Robert T. Meurisse** and **J. Michael Geist**

Soils are an integral part of terrestrial, aquatic, and riparian ecosystems. Therefore, understanding the role of soils is crucial to understanding stress processes within ecosystems. Due to their composition; soils have defined sets of inherent properties and potentials; however, activities imposed on them can alter, and indeed have altered, the soil system to varying degrees. Some alterations can be beneficial such as manipulating soil moisture and nutrients to improve the status of some chosen vegetation. But some manipulations of soils can be detrimental and increase stresses by reducing the soils' ability to supply nutrients, water, and other soil properties and processes. A common example of such alteration of physical soil properties is the excessive use of heavy equipment for timber harvest. Historical excesses in animal use of riparian areas and road construction also have changed physical and chemical soil properties, and have also increased stressed conditions. Other ecosystem stresses have occurred from episodic wildfires of high intensity and duration that resulted in severe soil erosion. These stresses affected not only vegetation on site from loss of topsoil, but also off-site aquatic systems from excess sediment.

Soil is formed from the interaction of parent material, climate, biota, and topography acting through time. Each resultant soil has certain capabilities and limitations. Some of the limitations can be augmented by applying specific management practices; however, soil limitations can be exacerbated if practices are improperly applied. Thus, knowledge of the soil properties and processes, including their variability, is fundamental to restoring and sustaining healthy and diverse ecosystems.

Soils are critical ecosystem components, acting as both "factories" and "regulators" of system processes, as well as being ecosystems in themselves. As components, they make up the principal environment for the primary producers, the plants. Soils behave as "factories" because they manufacture new components from more elemental materials. For example, humus is produced from raw organic material. Soils modify precipitation and air temperature so that soil climate is different from the general climate. Thus the amount of moisture and status of heat in soils regulate basic ecosystem functions such as nutrient cycling, carbon cycling, energy flows (reception, storage, transformation, and transmission), and hydrologic function. As ecosystems, soils harbor millions of bacteria, fungi, insects, earthworms, and related organisms in very small volumes of material. Some of these organisms can be pathogens which negatively stress the environment, while others can be a positive influence. Additionally, numerous vertebrate fauna, such as gophers, inhabit the soil. Through burrowing processes, these inhabitants incorporate significant quantities of organic material and "till" the soil-thus altering soil structure and porosity. Soil organisms, both large and small, function in myriad ways to make nutrients and water available to higher plants.

The Multiple Use Sustained Yield Act (1960) and the National Forest Management Act (1976) require that we manage "without impairment of the productivity of the land." Productivity can be defined in a variety of ways. In general, it is the rate of dry matter production over a specified period A general functional model illustrates the role of soil properties and processes in regulating productivity. This model, in terms of "state" variables, is: $P = f(SM, SN, SA, L, H, V)$ where productivity (P) is a function of available soil moisture (SW available nutrients (SN); aeration (SA); light (L) (quantity and quality); heat (H); and vegetation (genotype and phenotype) (Meurisse 1988). Of these variables, moisture, nutrients, aeration, and heat are a direct function of soil properties and conditions interacting with the vegetation. Whether inherent in the specific soil type or altered as a result of management practices, moisture, nutrients, and aeration relate directly to "stress" conditions. Heat fluxes can also be altered to either increase or decrease stress.

Management practices may increase or decrease stress. By having an understanding of specific soil properties and conditions, and applying that understanding through specific management decisions, stresses can be minimized. Soil degradation can be prevented and proper management can be prescribed to make optimal use of the soil resources, such as water and nutrient supplies. Stresses can also be alleviated by restoration of previously degraded soils. There are many examples of management successes.

A general overview of soils and associated vegetation in the interior northwest and western montane areas are described by Harvey and others (1989), Meurisse and others (1991), Geist and Cochran (1991) and Harvey and others (1993). These sources describe the great diversity and capabilities of soils in the region. They also emphasize the need for making decisions based on site-specific knowledge and knowledge of landscape heterogeneity and pattern of soil/vegetation conditions.

Philosophy of Restoration Activity

The goal of soil restoration is to manage complex soil resources in such a way as to optimize their basic capabilities and suitabilities, and to maintain or enhance their properties and qualities. Management practices should provide for adequate aeration of soils, moderate heat fluxes, and minimize stress conditions related to the supply of moisture and nutrients. Although desired future societal values are difficult to predict, appropriate management should maintain flexibility in providing for future options. First priority must be given to preventing influences on soil properties that impair soil capabilities or functional processes. Where damage has occurred from past practices or events, including catastrophic fires, restoration of soil conditions must proceed in concert with other ecosystem restoration practices for the reduction of stress.

One means of expressing desired soil conditions is to establish quality standards that can be measured and evaluated (Geist and others 1991). Regional soil quality standards have been in place in the Pacific Northwest Region since 1976 (Meurisse 1988). The standards are established for specific soil conditions and define detrimental conditions. Briefly, the standards state that a minimum of 80 percent of a management activity area, including permanent roads, will be left with an acceptable productivity potential for trees and other managed vegetation. About 5 percent is in permanent transportation system. So, 85 percent of the actual activity area must be in an acceptable condition to meet soil quality objectives for maintaining productivity and hydrologic function.

Specific detrimental conditions are as follows:

- Soil compaction—volcanic ash/pumice soils: an increase in soil bulk density of 20 percent or more over the undisturbed level;
- Other soils: an increase in soil bulk density of 15 percent or more over the undisturbed level or a macro pore space reduction of 50 percent or more;
- Puddling: depth of rutting of 6 inches or more;
- Soil displacement: removal of 50 percent or more of the topsoil or humus-enriched Al, AC horizon, or both from an area 100 square feet or more which is at least 5 feet in width;
- Severely burned: the top layer of mineral soil has been significantly changed in color, usually to red, and the next half-inch blackened from organic matter charring.
- Surface erosion: erosion standards are in terms of providing minimum effective ground cover for each of four erosion hazard classes. Standards are intended as “point-in-time”working guides that will be adjusted as new science dictates.

There are not specific Regional standards for amount of organic matter to leave on the surface. However, National Forest land management plans have included standards for amounts in various size classes for large woody materials. Refinements of these standards are in progress.

Another means of expressing desired condition is to have an adequate understanding of soil capabilities, and develop and apply management prescriptions compatible with those capabilities. For example, many forest stands have developed with stocking levels in excess of the ability of the soils to supply adequate moisture and nutrients to maintain vigor (Agee 1993, Harvey and others 1993). Stocking level control is critical for maintaining health and vigorous plant growth. This can be accomplished by either appropriate use of fire or by mechanical treatment. However, there is some evidence that growth reductions can occur under certain conditions with fire.

Alternative Restoration Actions

Prevention methods using logging and site preparation methods: Prevention of detrimental soil conditions can be achieved in a variety of ways. Some of the more common means are designated skid trails, specification of soil conditions when ground equipment is permitted based on such things as moisture content, frozen ground, or snow depth; and use of logging systems such as helicopter and cable yarding (Froehlich and others 1981). Treatment of residues by broadcast burns within prescription, or crushing, may be acceptable for specific soil/site conditions. Tractor piling of residues covers extensive areas and can cause excessive soil compaction and displacement. Also, harvest practices with equipment such as feller bunchers that go to each tree also can cause extensive soil compaction or puddling.

Harvest equipment technology is changing rapidly. New developments lead to new questions about effects on the soil resource. More effort is needed to understand the effects from various equipment and to seek ways to use it without causing excessive soil damage. Often, careful planning of the entire operation from harvest to reforestation can be accomplished without excessive damage if expertise is available to assist with the plans.

Silvicultural systems that minimize number of entries, such as even-aged management, offer advantages for preventing soil damage. Where uneven-aged silviculture is desired, methods that limit the amount of ground covered or that occur with prescribed cushions from residues, frozen ground, or adequate snow depths may meet the soil quality standards.

Implementing Practices To Restore Productivity

Restoration of soil physical properties can be accomplished with properly prescribed and implemented soil tillage techniques. There is extensive use of this practice, especially subsoiling. However, it has not always been applied with appropriate equipment or prescriptions; thus, the results have often fallen short of optimum. Questions remain about the degree of restoration by such methods. Also, questions remain about the effect subsoiling has on soil-borne root diseases such as *Armillaria*. New guidelines are being developed as new information is obtained.

An alternative approach for restoring physical properties is the use of specific vegetation adapted to sitespecific conditions (Everett and others 1991). Though this method is a much longer process, it has the advantage of a more aesthetically pleasing appearance. Use of species that can fix nitrogen has the potential to improve nitrogen availability over time.

Where nutrients are severely limiting, leading to stressed conditions, fertilizers can be a means of quickly reducing nutrient stress. Such practices are costly but can increase productivity and wood recovery value (by altering taper) and enhance nutrient cycling in some cases. There can also be some complicated and confounding interactions, such as with insects, that are not completely understood.

Where surface organic matter has been reduced by harvest removals or repeated fires, additions of organic matter may be enhanced by leaving appropriate amounts of logging residues and crushing it for greater soil contact. In some cases, nutrient cycles can be accelerated to release nutrients by use of prescribed fire. In some places, usually on the colder sites, with little or no management, surface organic layers have accumulated to considerable depths. In such cases nutrients may be tightly bound and only slowly available for tree growth. Prescribed fire may be an effective tool for short-term nutrient enhancement.

Recommendations for Restoration

Restoration of soil-ecosystem processes must be multifaceted. First, it is critical to have an adequate understanding of the soil resources, their properties, variability, and their processes at multiple scales. These scales must be from site-specific to landscape or watershed levels. There also is a need to have a measurement of the extent of current soil conditions and damage from prior activities in order to determine specific soil treatment needs. Additionally, there is need for an integrated inventory, monitoring, analysis, and planning process that effectively assesses soil-ecosystem potentials and opportunities at multiple scales. Restoration should be a total effort so that whole watersheds are treated as a unit rather than treating a stand without considering the adjacent riparian areas. Thus, salvage and reforestation must include treatment of the basic ecosystem, including soils.

A broad spectrum of restoration needs must be addressed in choosing restoration treatments. Treatments must be integrated and include restoring and maintaining riparian conditions, reducing soil compaction in uplands, and minimizing any further degradation of soil conditions and processes.

There is need for an effective, integrated, ecosystem monitoring system to monitor ecosystem composition, structure and function. Field guides are needed for managers and practitioners to evaluate stress conditions and opportunities for treatment. Additional research is needed to evaluate effects of mechanized equipment on soil properties and to evaluate restoration methods. Pioneering efforts toward accomplishing these three objectives are being conducted by the "Stressed Sites RD&A Project" in La Grande, Oregon. Expansion of this project would help accomplish these much needed products in a shorter time period.

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RESTORATION OF ECOSYSTEM PROCESSES AND DISTURBANCE EFFECTS

RESTORATION OF ECOSYSTEM PROCESSES AND DISTURBANCE EFFECTS

We must address restoration of ecosystem processes and disturbance effects that create sustainable forests before we can speak to the restoration of stressed sites; otherwise, we will forever treat the symptom and not the problem. Eastern Oregon and Washington forest ecosystems are dynamic and constantly shift in character and composition because of successional processes and disturbance events (Johnson and others 1993). One of the most significant management impacts on the sustainability of forest ecosystems has been the disruption of ecosystem processes through actions such as fire suppression (Mutch and others 1993), dewatering of streams for irrigation (Wissmar and others 1993), truncation of stand succession by timber harvest (Walstad 1988), and maintaining numbers of desired wildlife species such as elk in excess of historical levels (Irwin and others 1993). Several ecosystem processes are in an altered state because we have interrupted the cycling of biomass through fire suppression or have created different cycling processes through resource extraction (timber harvest, grazing, fish harvest).

Management actions such as flood control, fire prevention, and insect spray programs that reduce disturbance levels have many short-term benefits to society but may increase fire and insect hazard conditions in future forests and prevent long-term benefits of flooding to aquatic and riparian systems. Fire suppression has interrupted the rapid but moderate biomass cycling process in high-frequency, low-severity fire regime zones (Agee 1993). The longer this process is postponed, the more severe the adjustment (greater fire intensity and extent) and the longer the postfire recovery period. Severity and extent of wildfires have increased in recent years in eastside forests (Mutch and others 1993).

Fire suppression has accelerated tree biomass conversion by insects and disease through increased amounts and continuity of host plant species (Lehmkuhl and others 1993). Insect outbreaks are not occurring more often than in historical times, but they are of greater intensity and duration (Hessburg and others 1993). Insects and disease play a required role in the development of landscape heterogeneity and associated wildlife habitats; our goal is not to exclude these natural processes but to reduce their intensity and extent through landscape and stand manipulations (Hessburg and Everett, in press; Mason and Wickman 1993; Torgersen 1993).

Hydrologic stability has been impacted by timber harvest, road building, and livestock grazing (Wissmar and others 1993). High streamflow events are more common and severe in intensively managed watersheds than those under custodial management (McIntosh and others 1993, Wissmar and others 1993). Loss of riparian vegetation, increased stream temperatures, and increased sedimentation are adversely impacting fisheries (Anderson 1992). Robison and Bennett (1993) suggest that restoration must consider hillslope, riparian, and stream channel processes to be effective.

Public forums on forest health have requested management practices that reintroduce fire into eastside ecosystems, reduce density and continuity of host species creating the current insect outbreaks, and restore hydrologic stability and fisheries to disturbed streams (U.S. Department of Agriculture 1991, 1993). These practices may be used to mimic ecosystem processes and disturbance effects that created historical habitat conditions for species, resources, and aesthetics, or society may prefer alternative sustainable systems and rates of change.

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REINTRODUCTION OF FIRE INTO FORESTS OF EASTERN OREGON AND WASHINGTON

by **Stephen F. Arno** and **Roger D. Ottmar**

As long as eastside forests remain wildlands—are not converted to agricultural fields, industrial compounds, commercial or residential sites—they are subject to burning. Management or protection strategies can, however, greatly influence how they will burn. Allowing forest fuels to accumulate due to fire suppression will lead to severe, uncontrollable fires that threaten watershed, wildlife habitat, and scenic resources along with forest residential areas. These severe fires can also produce immense smoke episodes that may require evacuation of sizable areas, as was demonstrated during the 1987 fire season in northern California and southwestern Oregon.

Some people have suggested that natural fire should be reintroduced only by allowing lightning fires to burn or by using prescribed fires without cutting trees. This is possible in some forest types and large wilderness areas, such as the 1.3-million-acre Selway-Bitterroot Wilderness. However, most of the drier, eastside forest types have undergone dramatic structural changes in the absence of fire during several natural fire cycles. Dense understones and thickets of drought-stressed trees now characterize many of these stands, making it virtually impossible to return them to their pre-1900 ecological conditions using fire alone.

In the dry eastside forests, open stands of ponderosa pine and other seral species characterized much of the pre-1900 landscape. These forest conditions would be more suitable to sustain wildlife habitat, scenery, and other resource values than are modern, dense stands, given the continual threat of wildfire. In some of the higher elevation types, notably lodgepole pine, pre-1900 conditions were characterized by a landscape mosaic containing many young stands, which are less combustible. Coincidentally, these open and young pine stands (and other stands dominated by seral tree species) are more resistant to large epidemics of forest insects and diseases. Maintaining a semblance of the pre-1900 forest structures shaped by fire also perpetuates important wildlife forage species such as willow, Rocky Mountain maple, bitterbrush, and serviceberry, as well as large snags of ponderosa pine and larch, which are important for cavity nesting birds and mammals. All the aforementioned species are fire dependent and decline with forest fire suppression.

It may be possible in some cases to design silvicultural treatments without fire that help maintain some long-term wildland forest resource values. These approaches, however, are fraught with difficulties. For instance, widespread applications of herbicides and scarification by bulldozer are the usual substitutes, and both of these are subject to numerous environmental problems such as pollution, soil compaction, erosion, and the invasion of introduced weeds. Moreover, the heat-killing and nutrient-converting attributes of fire are not duplicated by substitute treatments. An example of the unique attributes of an underburn is its ability to kill most of the small shade-tolerant trees, many of which survive all but the most severe dozer scarification.

In most cases in the dry, eastside forest types, a carefully selected combination of silvicultural improvement cutting coupled with prescribed fire treatments is effective for restoring and maintaining forest cover that is resistant to severe insect, disease, and wildfire damage. In higher elevation and moist forests, patch and irregularly shaped block cuttings combined with broadcast burning also may be quite appropriate, leaving some standing dead trees in the units.

Alternatives for reintroducing fire in eastside forests differ with the pre-1900 fire regime type (examples follow) and with the level of roading and development appropriate for the area. In low-severity, high-frequency fire regimes (for example, forests that once supported ponderosa pine), understory reduction cutting or improvement cutting is often necessary in conjunction with a sequence of two prescribed burns to reduce fuel loadings to within the normal range before 1900. Planting may be necessary to re-establish young ponderosa pine and larch. After this "restoration forestry" treatment, it may be possible to maintain pre-1900 stand structures with periodic prescribed burning alone. The addition of silvicultural maintenance cuttings in combination with prescribed fire will aid long-term stand maintenance because favorable burning periods are limited by weather and availability of personnel and silvicultural cuttings can aid the use of fire.

Reintroducing natural fire in high-intensity, low-frequency fire regimes is possible in large natural areas such as the Selway-Bitterroot Wilderness. In smaller areas, manager-ignited prescribed fires can sometimes be used, as has been done in lodgepole pine stands in the Uncompahgre, Gunnison, and Grand Mesa National Forests of Colorado. Such applications in eastside Pacific Northwest forests are generally complicated by the interspersion of private lands, communities, resorts, and other developments across most of the forest landscape. One alternative for dealing with this situation is to develop large swaths of forested firebreaks between wildlands and private lands and developments (areas at risk from an escaped fire). This would have the additional advantage of providing protection from wildfire damage. Another alternative for restoring high-intensity fire regimes is to cut or harvest irregular blocks in the shape of desired units and then burn them by using slash as the fuel at a time when there is little danger of fire spreading into the adjacent green stands. It is often desirable to leave individuals or groups of trees in such units to provide seed sources, snags, shade shadows for regeneration, or other features similar to those of a natural burn.

Many people believe prescribed fire in combination with mechanical treatment or other management alternatives is necessary to restore fire-adapted ecosystems to a more healthy state. Although in many situations fire may produce positive effects that cannot be accomplished by mechanical or chemical means, it has the potential to degrade visibility, violate current air quality standards, and impact human health (Peterson, in press). If fire is to be reintroduced into the ecosystem, society has the right to know the tradeoffs of prescribed fire and the potential for wildfire and air quality effects so they can make creditable, informed decisions about the appropriate role of prescribed fire in restoring forest health. Managers must plan for and apply smoke mitigation techniques to reduce air quality effects.

Reintroduction of fire into the ecosystem will require a landscape-level effort. A new or adapted fire management strategy should be designed by a select team of prescribed fire and scientific experts. The team could assess the transitional problems, integrate fire effects and fire ecology research into proposed solutions, identify and demonstrate new and innovative prescribed fire techniques, and address regulations and environmental concerns, including the production and dispersal of smoke.

Fires frequented the landscapes of eastern Oregon and Washington before fire suppression activity, and because fire produces smoke, the area was often hazy during the dry season. Historians note that vast areas of the landscape were shrouded in smoke during the summer months because of the numerous fires dotting the landscape. As fire suppression forces became more efficient and mechanized after 1930, acreages burned by wildfire were reduced and smoke occurrence lessened. However, as natural fire was eliminated from the landscape, fuels built up to alarming levels. Currently, acreages burned by wildfire are on the increase along with smoke production (Ottmar, in press).

Is it correct to say that the earlier forest ecosystem structures (dependent upon fire) were healthier and more desirable than present structures? If so, what are the tradeoffs in air quality with a prescribed fire program versus inevitable severe wildfires? Because managed fires are planned in advance, mitigation techniques are available to reduce air quality effects. Uncontrollable wildfires are not planned, therefore, there is no opportunity to employ mitigation. Severe wildfire does have one advantage over prescribed fire: it may not occur for a long time in a given area. Will the public be willing to accept smoke from prescribed fires spread over a period of years, or is it preferable to gamble that a catastrophic wildfire, which sends out large amounts and greater concentrations of smoke perhaps lasting several weeks, will not occur for many years?

For example, the amount of smoke produced by reintroducing prescribed fire into the Blue Mountains of eastern Oregon for forest health concerns is estimated at about 37,500 tons of particulate matter 2.5 microns or less in diameter (PM2.5) per year (Ottmar, in press). This rate would represent an increase of 7500 tons of

PM2.5 per year over current prescribed fire levels. A portion of the PM2.5 production could be reduced and the effect lessened by burning when fuel moisture contents are high and less fuels consume, by removing or mechanically treating fuels so that burning is not needed, and by burning when dispersion conditions and wind directions are favorable.

In comparison, a 250,000-acre wildfire would produce over 50,000 tons of PM2.5 over a relatively short time, and these emissions would be at the mercy of current wind dispersion conditions. The potential to severely effect a sensitive airshed would be much greater. The potential for this severe wildfire to damage watershed values, fish habitat, and scenic resources is also great.

The public has previously chosen to bear the costs associated with clean air. Will the public rate short term air quality values higher than forest health values by choosing to accept wildfire in place of prescribed fire? Probably the answer is yes, unless a strategic plan is developed to address all regulatory requirements such as Prevent Significant Deterioration guidelines, visibility, emissions reduction, and health risks associated with prescribed fire; an education program is initiated to inform public of tradeoffs; the public regulatory agencies are involved with fire-management planning; and a strong research program is provided.

Fire is not a tool to use on all sites or in all situations. It is, however, a tool that should be available and understood when designing a management strategy for our natural resources. Proper application of fire, in harmony with other management techniques, often may be the best option for meeting specific objectives while creating the least amount of adverse environmental damage. The National Forest Management Act, the Endangered Species Act, and other legislation serves as guides for management of public wildlands aimed at maintaining more or less natural ecosystems. Attempts at fire exclusion greatly threaten this goal in the drier forest types.

MAINTENANCE AND RESTORATION OF ECOLOGICAL PROCESSES REGULATING FOREST-DEFOLIATING INSECTS

by **Torolf R. Torgersen**

Natural ecosystems contain a multitude of functional processes that provide stability. Even healthy systems with well-developed regulatory processes will go through cyclic or sporadic fluctuations. The pattern that seems to be emerging is one of sporadic outbreaks of defoliating insects (Wickman 1992, Wickman and others 1993) that cause declining tree vigor, reduced growth, top-kill, and eventually some mortality-largely of trees poorly adapted to the site. Weakened trees may be invaded by bark beetles that hasten tree death. These dead trees remain a part of the ecosystem in the form of structural components for nesting or colonization, foraging, and protection of forest-dwelling animals, and ultimately, in nutrient cycling.

Insects are always present in the forest, but we tend to pay attention to them only when they disrupt our management expectations for timber or nontimber resources. For example, we tend to notice insects like the western spruce budworm, Douglas-fir tussock moth, mountain pine beetle, and Douglas-fir beetles only during outbreak periods when we see defoliation or re-topped and dying trees. From a management standpoint, what is more significant and often ignored are those long periods of time between outbreaks when the insects seen to have disappeared.

Studies of the population dynamics of important forest insects such as the budworm and tussock moth have shown that natural enemies are an important component in the complex processes that keep these pests in check. Some of the fundamental knowledge of the major natural enemies of these insects was developed through studies done in eastside forests. But similar studies of natural mortality processes have been done throughout the montane West—in east-central Washington, south-central and northeastern Oregon, north-central Idaho, northern California, and western Montana (Brookes and others 1978, 1987; Campbell and others 1984; Mason 1992; Mason and others 1983; Mason and Wickman 1988; Torgersen and others 1990). These studies not only identified the presence of a large assemblage of natural enemies, but also quantified some of their effects on budworm and tussock moth populations.

We know that Western mixed-conifer forests have experienced sporadic outbreaks of defoliating insects for hundreds of years (Swetnam and Lynch 1989, Wickman and others 1993). Severe defoliation of grand and Douglas-fir has caused, and continues to cause, death and varying amounts of top-kill of these tree species. The concern is that current outbreaks appear to be more severe and involve larger areas than those in the past. If this is true, it means that we may have destabilized eastside ecosystems which could have dramatic consequences in terms of long-term ecosystem sustainability. Given enough time, the system may establish a sort of dynamic equilibrium, but in the interim there could be unacceptable consequences in terms of societal expectations for timber supplies and green forests.

Philosophy of Maintenance and Restoration of Regulatory Processes

The objective of ecosystem management should be to maintain or restore forest structural components that promote the proper functioning of important ecological processes. For example, in terms of regulating forest insect pests, such as the budworm, tussock moth, and larch casebearer, the processes of parasitization and predation have been identified and largely quantified (Mason and Torgersen 1983, Mason and Wickman 1988, Ryan 1986). Thus, there is compelling evidence to manage for ecosystem components that conserve and encourage the functioning of these processes.

There is a broad diversity of organisms involved in these mortality processes. At least 110 species of parasitic wasps and flies attack the budworm and tussock moth. Nearly all occur on the east side and throughout the range of the pests (Carolin and Coulter 1959, Torgersen 1981). Parasitization by this array of species can be substantial. More than half of all tussock moth eggs in a site may be destroyed by a single species of parasitic wasp (Torgersen and Mason 1985). Other studies suggest that parasitization together with other mortality processes can affect the population behavior of the budworm (Torgersen and others 1984). Parasitoids are also dominant factors in the dynamics of tussock moth and larch casebearer populations and contribute to maintaining these insects at nondamaging levels (Mason and others 1983, Ryan and others 1987).

Research on predators and predation processes has contributed to our knowledge of how defoliator populations are regulated. The earliest research on insectivorous birds and ants as predators of tussock moth and budworm was done in eastside ecosystems. Studies in southern Oregon showed that the tussock moth is preyed upon by birds (Torgersen and others 1984). Other eastside studies on the budworm showed that trees where birds and ants are excluded have 10 times as many budworms as trees with the predators (Campbell and others 1983, Campbell 1987). Subsequent observations have documented that there are at least 32 species of birds that feed on the budworm and tussock moth; 20 of these are neotropical migratory species (Sharp 1992). The mountain chickadee and red-breasted nuthatch dominated both observations of actual predation on the budworm and tussock moth and density of individual species (Langelier and Garton 1986, Torgersen and others 1984, 1990). Korol (1985) indicated that 19 species of birds prey on the mountain pine beetle; woodpeckers are the primary avian predators of bark beetle larvae and adults (Dahlsten 1982). Birds also function in spreading diseases of insects, dispersing seeds of some forest trees and shrubs, and contributing to nutrient cycling by spreading wood-rotting fungi (Otvos 1979).

Arthropod predators of defoliators and bark beetles include spiders, ants, true bugs, nerve-winged insects, beetles, flies, and wasps. Over a dozen species of forest-dwelling ants prey on budworm and tussock moth (Bain 1974; Markin 1975, 1979; Torgersen and others 1990; Youngs and Campbell 1984). Among these, carpenter ants and thatch mound-building ants live underground or in association with stumps, logs, and snags, but ants forage in the crowns of living trees where they tend aphids or hunt for prey on the foliage. In one study, 85 percent of the budworm pupae artificially stocked on experimental branches were killed by ants within 3 days of stocking (Campbell and Torgersen 1982). Ants significantly reduce budworm populations on conifer seedlings in sites regenerated by seed-tree cuts (Campbell and others 1984). Ants are also a primary dietary component for pileated woodpecker. (Beckwith and Bull 1985), a bird designated as a Management Indicator Species by the USDA Forest Service (Irwin 1987). Thus, management actions that favor populations of forest-dwelling ants are important both for regulation of pest insects and for providing a prey base for an Indicator Species.

Predation of defoliating insects by spiders is less well known than that of birds and ants but it is recognized as an important predatory component in forest ecosystems. This group comprises a major portion of the foliagedwelling arthropod fauna in mixed-conifer forests in the montane West (Mason 1992, Moldenke and others 1987). Documentation of spider predation and its effects on population dynamics of tussock moth and budworm has been reported by Torgersen and Dahlsten (1978), Mason and Torgersen (1983), Fellin (1985) and Mason and Paul (1988). Nothing is known of potential effects of silvicultural practices on spiders.

Mortality processes are interrelated in various ways, but one of the structural features they have in common is dead wood—both standing snags and downed, woody material. Therefore, restoration activities should include dead wood components. Data are now being analyzed that will clarify the question of how much dead wood, in what size classes, and of what species and decay classes is appropriate in the ecological management of eastside mixed-conifer stands (Torgersen and Bull, in preparation).

Recommendations for Restoration

An appropriate philosophy to adopt in restoration planning is to recognize that we are working with an incomplete ecological picture; major functional systems may yet be discovered. Continuing research is needed to discover and elucidate interrelations that will help managers to conduct ecologically sound management.

To prevent possible further destabilization of eastside forest ecosystems, given our current limited knowledge of ecosystem function, we should maintain old, relict stands. Precisely because these stands have survived a long time suggests that they may contain key elements necessary for the pursuit of sustainable ecosystem management. Loss of old-growth will result in loss or depletion of species that are narrowly adapted to such stands and the standing and downed, dead wood components associated with them (Thomas and others 1975). As Leopold (1953) cautioned, "To keep every cog and wheel is the first precaution of intelligent tinkering."

Salvage of insect-killed trees is currently being used to prevent further buildup of woody fuels, to capture merchantable volume before it deteriorates, and to improve conditions for stand replacement by shadeintolerant early successional species. In sales involving removal of standing, insect-killed trees, current Forest Service standards and guidelines for residual dead woody debris are being used. Recent research may yield information useful for updating standards and guidelines governing amounts of woody debris to be left as substrate for predators and other dead-wood-dependent species (Bull and Holthausen 1993, Maser and Trappe 1984, Torgersen and Bull, in preparation).

Prescribed burning is emerging as a preferred method for reducing fuel levels and for stand conversion. Fellin (1980) determined that burning of logging residue could adversely affect some forest floor arthropods, particularly ants, beetles, and spiders. Research is needed on the effects of fire on key soil arthropods, on mid-successional nitrogen-fixing shrubs, on the amount and condition of large woody debris, nutrient losses, and air and stream pollution (Tiedemann 1981, Tiedemann and Klemmedson 1992). Site- and landscape-sensitive alternatives for integrated use of fire and mechanical methods of debris management need to be investigated before large-scale prescribed burns are done.

Various studies on the effects of thinning, selection cuts, clearcutting, and prescribed fire on forest-dwelling birds have shown that certain species of birds increased and other species decreased as a result of various silvicultural prescriptions or harvest regimes (Austin and Perry 1979, Franzreb 1977, Szaro and Balda 1979, Tobalske and others 1991). The array of effects of forest management prescriptions on birds alone, much less other vertebrates, attests to the variety of habitat needs of forest-dwelling animals and the complexity of management alternatives that affect stand structure (Hunter 1990). Thomas and others (1975) and Meslow (1978) reviewed the literature and pointed out that the species composition of birds changes with forest successional stages under natural or human-influenced conditions. They indicated their concern that as forest management for timber values becomes more intense, forest structure will become more homogeneous and the attendant fauna will become less diverse. In particular, they suggest that truncated succession of grass, forbs, and shrub stages may result in a loss of avian species needing these early successional stages. Prescribed fire may increase the length of time in these early successional stages and favor some of the birds associated with them (Thomas and others 1975). The admonition here as elsewhere is to proceed with caution based on current knowledge and develop new information as avenues of investigation become apparent.

The use of chemical insecticides for suppressing forest-defoliating insect populations has been a common practice since the 1940s. Carbaryl is the primary insecticide registered for suppression of budworm. Studies have established that effects of treatment on selected parasite species in their budworm hosts were negligible, and that parasitization recovered in about 2 years (Schmid 1981; Torgersen and others, in review). Based on the work of Roush and Akre (1978) and Murphy and Croft (1990), carbaryl was found to have short-term effects on foraging ants in areas treated with this insecticide for suppression of tussock moth and budworm. Definitive studies are still needed to determine the effect of this chemical on other forest-dwelling solitary and social wasps and bees, parasitic flies and wasps, and predaceous arthropods in general. Use of the bacterial insecticide *Bacillus thuringiensis* (B.t.) against defoliators is much preferred, but like carbaryl, its effects on budworm populations last only two or three seasons (Torgersen, in press). The disadvantage of using B.t. is that it does not discriminate between the target pest and larvae of other moths and butterflies, some of which may be pollinators or prey for threatened, endangered, or sensitive species of plants or animals.

It is important for managers to recognize that no matter what is done, there always will be outbreaks of insect pests. Without careful attention to the values of diversity in forest structure and species, we may further destabilize eastside ecosystems. Destabilization will translate into more severe outbreaks or ones that occur more regularly, or both. Given that pest insects and pathogens will always get their "cut" of forest productivity, and that the dead trees thus created are a vital part of the system, research should be supported that will quantify what that "cut" is in terms of the harvestable resource.

RESTORATION OF HYDROLOGIC PROCESSES

by **Tom Robison** and **Mel Bennett**

A watershed is the total area of land above a given stream location that contributes water to the stream at that point (Schwarz and others 1976). A watershed has three main parts: the stream channel, the riparian zone adjacent to the stream, and the surrounding hillslopes. Hydrologic processes, that is, infiltration, percolation, surface and subsurface water flow, are the various pathways of water moving through the watershed that link the three components into one system.

Stream channels and landscapes have evolved into a state of dynamic or quasiequilibrium over time, given the unique combination of geology, geomorphology, climate, and vegetation in the watershed. Healthy ecosystems have an inherent resiliency to quickly adjust to extreme events without degradation to the system (Heede 1980). In a healthy ecosystem, the stream moves laterally across the flood plain by increasing point bars and widening outer curves but is stable in a vertical dimension. It neither aggrades (builds up) nor degrades (cuts down) the base level. The amount of sediment supplied to the channel system is moved through the system by the available water. The stream has a predictable shape and form (Leopold and Maddock 1953).

The riparian zone is the land bordering the stream that acts as a buffer between hillslope processes and the stream channel. The riparian zone shades the stream, stabilizes streambanks, and adds vegetative material to the channel. It slowly releases a base flow of water to the stream channel during low flow periods of the year. It functions as a floodplain by dissipating the energy of flood flows, reducing the velocity of streamflow, and trapping sediment.

The hillslopes of the watershed are the surfaces that intercept water and route it to the channel. Their health is directly related to the condition of vegetation and the soil that affects how the hillslopes handle water.

An assessment of the health of hydrologic processes for a watershed should involve an assessment of all three components of the watershed system: the stream channel, the riparian zone, and the hillslopes. Rarely has such a comprehensive assessment been completed for a broad geographic area. More typical is a functional assessment that looks at one component of the watershed for a smaller geographic area.

Streams surveyed in the 1930s and 1940s were recently resurveyed and analyses were made of change over time (McIntosh and others 1993, Wissmar 1993). Because the stream channel is an indicator of the health of all the hydrologic processes within the watershed, surveys of change-in-condition over time suggest change in the overall health of watersheds and their hydrologic processes.

Five large watersheds were selected for a detailed assessment: the Methow and Wenatchee River basins of north-central Washington, the Little Naches River of the Yakima system in central Washington, the John Day River of north-central Oregon, and the Grande Ronde basin of eastern Oregon. Comparisons between stream surveys taken in 1935-36 and 1990 for the Little Naches River indicated significant changes in various stream channel characteristics over that time. The average size of stream bottom substrate material is much larger. There is a greater percentage of exposed bedrock in the stream bottom. Spawning gravels have been flushed out of the system. The stream bed seems to be scouring, downcutting, or degrading over a long period of time. The change in stream channel morphology appears to be the result of confinement of the main channel. The input of fine sediment has increased. Off-channel fish habitat, channel complexity, riparian cover, edge area, and quantity of spawning gravels have decreased over time.

Four streams were surveyed in the Wenatchee River watershed, three in areas of low-intensity land management, one in a high-intensity managed area. Over time, pool habitat has increased in all streams, however, the rate of increase was twice as great for streams within the low-intensity managed areas. A major difference between the two areas is the fully functioning flood plains of the low-intensity managed area. Streams have nearly three times the large woody debris and a much more complex stream habitat than that in the high-intensity managed area.

The riverine system of the John Day watershed has dramatically changed. Base streamflow volume has increased in all intensively managed areas of the watershed but has remained the same in the wilderness area. High streamflow events are more common and severe in intensively managed areas. Changes to riparian vegetation have been drastic. Stream shading has decreased with the result that stream temperature, both summer and winter, is a critical limiting factor for salmonids.

Comparison of current and historical stream surveys for three major drainages of the Methow River watershed indicated that pool frequencies have doubled in high-intensity managed areas and more than tripled in low-intensity managed areas. The area with the most intense land use over the past 50 years shows the lowest level of improvement in pool habitat.

There has been a 60-percent loss in pool habitat for the Grande Ronde River since 1941. The percentage of fine sediments in spawning habitat has increased. Riparian habitat has degraded. Water temperatures on both winter and summer have increased. Analysis of long-term streamflow and climatic records indicates that since 1904 summer low flows have increased but annual and winter precipitation has decreased. The timing of peak flow is one month earlier.

For each watershed, the nature of historical land use varies but involves a combination of mining, grazing, water impoundments and irrigation diversions, timber harvest, roads, and fires during the last 100 or more years. Typically, the dominant disturbance has changed over that time from one activity to another. Intensively managed watersheds usually need less sediment, more shade, more large woody debris, and increased habitat complexity to restore fish habitat to a level that will support self-sustaining fish populations. The frequency of large pools has decreased 28 percent over the past 50 years, however, it has increased 77 percent for low-intensity managed watersheds, and the trend for these basins is toward improved habitat.

What are the consequences of land use patterns on these river basins? In the Little Naches River, 90 percent of the annual run of salmon and steelhead trout is now eliminated. The impact on survival of smolts in the Grande Ronde basin could be immense from the increased water temperatures alone. The Methow River populations of wild anadromous fish have declined. Whatever the specific cause and effect, the conclusion is that the ability of these systems to sustain continued production of a variety of quality watershed, water, and water habitat beneficial uses is in jeopardy. The potential continues for accelerated flood damage and destruction from watersheds that cannot handle extreme climatic events.

There are obstacles to changing this situation, finding solutions, preventing further effects, and initiating recovery. The nature of cumulative effects is a major obstacle in itself. Cumulative effects are by definition not limited to the site boundary of a land use activity but are additive with those effects from all disturbing activities within the entire watershed. The effects transcend property and political boundaries, and the effects continue for many years. Resolution requires coordinated land use by all landowners within the watershed.

Another obstacle is the perpetuation of a system of resource planning and budgeting that puts emphasis on products instead of ecosystem processes and on individual resources instead of integrated management. The approach to management of watershed ecosystems should be to understand and manage them to perpetuate their health and diversity. Benefits, uses, and products should be secondary, not the primary factor driving management decisions.

Additional obstacles are the cost of rehabilitation efforts, existing commitments to historical patterns of land use, historical use of riparian corridors for transportation and increasing urbanization of riparian zones, inability of surface water to meet consumptive water demand, and historical water uses.

Restoration Philosophy

Entire watersheds including side slopes, riparian zones, and stream channels should be maintained in a state of dynamic equilibrium, such that they are resilient to a range of natural events from average to extreme and hydrologic processes are maintained in good health. Watershed hillslopes should be vegetated to handle water at the potential infiltration and percolation rates. Off-site erosion should be contained within a pre-disturbance range of landform development processes. Riparian zones should function as flood plains by dissipating energy, trapping sediment, buffering hillslope processes, providing shade, contributing vegetative material to the channel, and yielding slow-release streamflow. Stream channels should move laterally across the riparian zone without aggrading or degrading the overall longitudinal profile. Stream channels should exhibit a shape and form typical for the physical and climatic characteristics of the basin.

The above is a statement of a desired future condition, an objective to move toward. It should be specific to a given watershed and related to the inherent uniqueness of geology, geomorphology, climate, and vegetation that make up that particular system. It should be specific and measurable so that progress toward attainment can be monitored. It should be based on an understanding of the natural range in variability of system components, that is, stream channel morphology, water temperature, riparian vegetation composition and structure, and hillslope water movement. It should be a guide in development and design of site-specific, project-level management activities.

At the project level of planning, a number of concepts should be used to ensure maintenance of watershed system health. These include use of ecosystem management planning techniques that assess cumulative effects and recognizes the linkages among hillslope processes, riparian areas, and stream channel systems. Each of these different components of the landform should have a unique and site-specific management strategy (Chaney 1990; Platts 1979, 1980).

Planning should consider road density, area of vegetative management disturbance, inherent hydrologic recovery rates, water temperature levels, stream sediment levels, condition of the hillslopes, riparian area, and the stream channel in determining risk of cumulative watershed effects (U.S. Department of Agriculture 1993). Watershed planning should be coordinated both spatially and temporally with all landowners within a river basin.

Roads deserve special attention. Transportation planning should be considered on an integrated, area-wide basis to minimize total number of road miles and road density within any watershed, select the best locations for road construction, and meet the needs of all road users. Roads should be located on suitable sites that do not constrain riparian zones or stream channels. Roads should have sediment filters at stream crossings, drainage features, and rolling grades to minimize cuts and fills. Roads should avoid unstable areas. Roads should be designed with a primary objective of protecting the ecosystem. Unsurfaced roads should be seasonally closed during adverse weather conditions. Roads should be relocated away from stream channels and, if possible, away from riparian zones. When it is not possible to relocate the road, the level of maintenance should be increased, surfacing improved, and seasonal road closures used to minimize movement of sediment from the road to the stream channel. Old road surfaces should be outsloped and revegetated. Culverts should be removed, and over-steepened fillslopes cut back.

Range ecosystems should have adequate vegetative cover to ensure proper soil stability essential to maintaining satisfactory range condition (Blaisdell and others 1982). Prescribed fire management and other fuel reduction methods should be used to lessen the risk of catastrophic wildfire that destroys soil organic material and removes all vegetative cover thereby predisposing the soil to erosion from rainstorms. Prevention rather than corrective measures should be used to control all types of erosion.

Attainment of desired future condition should be monitored as an integral part of ecosystem management. Objectives are set on a watershed basis but can only be attained incrementally through projects on a site-level basis. Monitoring should be continuous to measure movement toward the desired future condition for the entire watershed.

Restoration Work

Restoration work where needed should be related to the larger goals. Watershed restoration work often has been accomplished as individual projects based on site-specific needs without consideration of activities in the larger system. Restoration work should be coordinated to meet needs of all processes, be they hillslope, riparian or stream channel. Most important, restoration work should be initiated only when the cause of the problem is understood and corrective action has been taken. Often this involves a change in land use pattern. Restoration work by itself without change in land use will be temporary and will not result in long-term improvement (Chaney and others 1990, Elmore and Beschta 1987).

Project-level restoration work should start with a watershed assessment that shows how the components of the watershed system interact and identifies the weak links. The assessment should identify the current condition, the potential, and the steps needed to get there. It should state a desired future condition as the ultimate goal of all management within the watershed. Monitoring efforts can then focus on whether conditions are moving toward that goal. When a watershed assessment has been completed, project restoration work becomes integrated with management of the watershed, becomes more efficient and effective, and has a better chance of resulting in lasting improvement.

Restoration work in a degraded stream channel should begin from a stable point and work upstream. Channel downcutting progresses in an upstream direction with every upstream channel reach in jeopardy of being lowered. Beginning from a stable point and working upstream increases the chances that improvement work will be lasting and effective. Where the incised channel has resulted in a lowered water table in the riparian zone, it is necessary to raise the water table back to the point where riparian vegetative species can be maintained. Vegetation restoration projects, on the other hand, should begin from the top of the watershed and work toward the outlet.

Summary

This report is not a hydrologic assessment of eastside Washington and Oregon watersheds, but rather an attempt to survey available information from which inferences could be made about the health of hydrologic processes. Information on historical and current land use compared with stream survey data from two points in time was used as a basis for making intuitive comments about watershed health. The conclusion is that cumulative effects from land uses have had and continue to have an effect on how water and sediment move through eastern Washington and Oregon watersheds. As a result, the dynamic equilibrium and health of these hydrologic systems, and the quality of the beneficial uses these watersheds produce, are at risk.

Hydrologic health assessments on a watershed basis should be made for the entire study area. These assessments should start with an analysis of the condition of the processes now occurring in relation to the potential condition of the processes for watersheds with specific geology, geomorphology, climate and vegetation characteristics. Second, a desired future condition of these processes should be selected and a strategy chosen for achieving that condition. Third, individual projects as they are completed within the watershed boundary should be monitored to measure progress toward attaining the overall watershed desired future condition.

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RESTORATION OF STRESSED SITES

RESTORATION OF STRESSED SITES

Philosophy of Restoration

Change in forest and aquatic systems does not in itself denote degradation and the need for restoration. Disturbance and subsequent response are required to create and maintain heterogeneous landscapes and stream reaches characteristic of sustainable ecosystems (Everett and others 1993). Degradation may occur if change is more rapid or of greater extent, intensity, or frequency than historical or desired levels. When return frequency of disturbance exceeds the recovery time for restoration, a downward spiral of site potential can occur (Turner and others 1993). True site degradation occurs with the permanent loss of future options.

Restoration is a subset of reclamation: the restoration of biophysical capacity with the additional caveat of returning sites to previous, desired conditions (Weigand 1993). Society may desire new and novel conditions that better meet their expectations, but sustainability of these new conditions and the ability to provide for species and long-term site productivity are unknown. At a minimum, we need the reclamation of stressed sites to conserve future biological options. Additional restoration actions to achieve previous conditions are desirable to support biological conservation until we understand the tradeoffs associated with alternative ecosystem states.

To restore stressed sites, managers need to define the role of the site in the landscape, define the characteristics of the site that will support the landscape objectives, and identify the attributes of the site that must be managed to accomplish those objectives. This strategy follows the hierarchical landscape ecology principles of Urban and others (1987). One focus of restoration is creating the desired landscape configuration whether that landscape configuration is a historical one or a modified alternative preferred by society (Everett and others 1994). Restoration of landscapes should be closely integrated with restoration actions for unique habitats (Daterman 1993) and sensitive species (Thomas and Raphael 1993). Restoration activities resulting in conflicts between individual species and landscapes need to be identified and resolved.

In a hierarchical landscape approach, we must look at the landscape as well as the individual sites to determine the context and significance of individual site stress. Disturbed sites need not be restored if they reflect a historical or acceptable level of disturbance needed to maintain the desired landscape characteristics. Restoration of all sites, in all time frames and to constant standards and guides, ignores the requirement for disturbance to create and maintain sustainable ecosystems.

Broad View Of Stressed Sites

The public forums on forest health (U.S. Department of Agriculture 1991, 1993) provided insight to the public's broad view of what constitutes a stressed site. Stressed sites include overgrazed rangelands, degraded riparian areas, areas with excessive roading, degraded wildlife and fisheries habitat, and insectdamaged forests. Five kinds of stressed sites are mentioned specifically in Volume III, Assessment: riparian areas, rangelands, overstocked forestlands, excessively roaded areas, and unstable stream systems (Irwin and others 1993, McIntosh and others 1993, Oliver and others 1993, Wissmar and others 1993). The restoration of streams in eastern Oregon and Washington has been addressed previously (Anderson 1992, Reeves and Everest 1993, Thomas and Raphael 1993) and will not be discussed here.

Riparian areas have been overused by livestock, wildlife, and recreationists and degraded by timber harvesting activities (Elmore and others 1993). We need to restore riparian systems to their productive potential to maintain their integrity and provide sustainable flows of resources. Restoration activities range from simple species seedings to the complete rebuilding of entire stream reaches (Elmore and others 1993). Roads have been linked to loss in wildlife habitat effectiveness and a decline in water quality and fisheries (Megahan and others 1993). The most effective way to reduce the impacts of roads is to reduce their numbers.

Eastern Oregon and Washington forests have tree densities, especially Douglas-fir and grand fir understory species, in excess of historical levels (Caraher and others 1992, Lehmkuhl and others 1993). Excessive tree densities produce tree stress and act as a precursor to insect attack and fire. The reintroduction of fire to east-side ecosystems is restricted by air quality standards (Arno and Ottmar 1993); thus other means of restoring desirable stand structure are needed. New harvesting techniques are needed that remove small-diameter logs from overly dense stands, reduce fire hazard, and provide a flow of resources (Lambert 1993).

Rangelands are not meeting the multiple demands of diverse publics. Over 47 percent of riparian areas in Forest Service grazing allotments nationwide are not meeting management objectives (U.S. Department of Agriculture 1992). Conflicts are occurring over proper use by wildlife and livestock. Expectations for restoration of rangelands should be based on the current site potential and not on a historical potential that no longer exists.

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RESTORATION OF RIPARIAN ECOSYSTEMS

by **D. Wayne Elmore, Bernard L. Kovalchik,** and **Louis D. Jurs**

The degradation of riparian and stream ecosystems is well documented in the literature (Elmore and Beschta 1987, Kovalchik and Elmore 1991, Platts 1984). Effects include loss of riparian vegetation (thereby changing the composition and quantity of streamside vegetation) and altering channel morphology by widening and deepening streams (thereby lowering ground water tables, and decreasing summer stream flows, and increasing summer water temperatures and winter icing) (Armour and others 1991). Adverse changes in streams and riparian vegetation can result from many causes: changing climatic and precipitation patterns, more frequent flooding, altered beaver populations, heavy streamside grazing, improper use of upland watersheds or adjacent slopes, road construction, timber harvest and others (Elmore and Beschta 1987). Collectively, the result is deteriorated conditions for stream riparian function, wildlife habitat, and aquatic organisms (Chaney and others 1990).

The general assessment for the lands managed by the Forest Service (U.S. General Accounting Office 1988) was that most are in need of restoration. Recreational demands are especially high for riparian and stream zones, yet 70 to 90 percent of all natural riparian areas in the United States have possibly been altered (Hirsch and Segelquist 1978). The public has become increasingly aware of the enormous potential of western riparian areas, not only from a wildlife habitat perspective, but also from the perspective of stream riparian function. Riparian areas in good condition buffer flood flows and increase ground water recharge. The riparian vegetation filters sediment which helps to improve water quality. It also builds flood plains and increases areas for ground water storage which help hold streambanks and reduce erosion.

Current Forest Service policy calls for undertaking a national riparian strategy designed to improve markedly riparian conditions along lakes and streams by the year 2000. Therefore, the continued classification of riparian plant associations by the Forest Service is timely and desirable.

Philosophy of Restoration Activities

The desired future condition of riparian ecosystems must be based on management strategies that will allow our streams and riparian systems to approach their productive potential (Elmore and Beschta 1987). Potential desired outputs from riparian ecosystems include wildlife and fisheries habitat, water quality and quantity, livestock forage, recreation, and long-term maintenance of endemic plant and animal species.

To accomplish this, it must be recognized that each stream has unique combinations of channel morphology, streamside vegetation, hydrology, geology, and soils (Elmore and Beschta 1987). Management must be tailored to allow the basic riparian functions of sediment filtering, bank stability, aquifer recharge, and water storage to occur in each stream.

We also must remember that all riparian areas cannot be changed immediately to improve the functioning condition. Elmore and Beschta (1987) list some questions that may help assess priorities:

- Which riparian areas have the greatest potential for vegetative response?
- In which areas will vegetation succession occur quickly, and what pathways will this succession take? Classification, will help answer this.
- Which streams appear to have the greatest potential for storing subsurface water?
- Which streams have the greatest potential for filtering and storing sediment and improving water quality?

- Which riparian areas have the greatest potential for increased Animal Unit Months and how can the preferred timing and intensity of use be determined?
- To what extent will habitat for fisheries and wildlife improve?

It should be acknowledged that there are gaps in our knowledge base that preclude fully answering these questions. However, addressing these questions offers tremendous opportunity for innovative management as we advance the understanding of riparian areas and the wide array of benefits they provide.

Restoration of Stressed Sites—Stress Agents

Managed stress: These are unnatural system stresses caused by land use activities including overgrazing, agriculture, forestry, roads, watershed manipulation, and recreation. Some of the stresses that occur are manifested through noticeable effects such as accelerated erosion, dewatering of wetlands, bank cover reduction, siltation, increased stream temperatures, reduced habitat diversity, structural and functional simplification, and others. Some effects, especially those that may interrupt natural function or system processes, are less apparent.

Natural stress: Natural stress agents are mainly those dictated by climate or weather events. These include flooding, drought, and windstorms. Other natural stresses can include insect infestation, wildlife effects, ice damage, volcanism, earthquakes, fire, and similar phenomena often grouped together as "acts of God." The effects from natural stress agents can be similar to those experienced in managed stress situations but tend to be of a localized nature. The ability of streams and their associated riparian areas to handle natural stresses is heavily influenced by the management prescriptions applied in the watershed.

Some natural systems will function normally at a level close to the threshold of system failure, thereby making them highly susceptible to added stress levels from either a managed or natural source. Ecosystems on highly erodible soils or those dependent on limited nutrient supplies or close-tolerance chemical balances are good examples. Managed riparian areas often can be placed in a precarious stress balance due to implementation of management objectives that attempt to force a particular system to function at or near the threshold of system component failure. Land use management objectives that feature the maximization of a single value or that encourage the maintenance of certain seral stages to favor a particular species are common examples.

The difficulty faced by the land manager considering site restoration options is how to balance the complex issues of natural resource commodity production with the sustainability of ecosystem function so that natural systems and processes will not fail.

Before we can begin to restore degraded riparian areas, we must be able to characterize the resource through some form of classification. Many synecologists are developing vegetation-based site classifications for uplands in the Western United States. The majority of these classifications either do not include the riparian zone or treat it broadly. With increased interest in riparian management, several comprehensive riparian classifications have been developed for portions of the National Forest System (Cowardin and others 1979, Kovalchik 1987, Youngblood and others 1985a, 1985b). Because Kovalchik (1987) uses geomorphology and is specific to eastern Oregon, we will use this riparian classification as an example in the rest of this paper.

The recurrence of similar plant associations across the riparian zone can be used to stratify the landscape (Daubenmire 1976). The vegetation, soils, water, and physical characteristics can be used to predict plant responses to management, productivity potential, and future species composition. However, not all questions about a piece of land can be answered by a plant association classification. Therefore, geomorphic classification must be considered to effectively describe and manage riparian ecosystems.

The objectives of classification are to:

- Describe the general geographic, topographic, edaphic, functional, and floristic features of riparian ecosystems.
- Describe successional trends and predict vegetative potential on disturbed riparian ecosystems.
- Present information on resource values and management opportunities.

Classification allows us to stratify sites for identification and to compare them to reference sites with respect to composition, structure, and function. Restoration information can be readily transferred among similar sites for greater efficiency.

Objectives for Restoration

The goal is restoring riparian ecosystems, not a single structure, function, or species. Before we can begin to restore a riparian system to meet land use objectives, we must know the present condition, potential of the site, and functions of the system. We also need a vision of where we want to go that is shared and designed by an interdisciplinary group. Some characteristics of a good objective are:

- The expected results must be measurable.
- The expected result(s) or intent are clearly written or stated.
- They are realistic and challenging but attainable.
- They contain specific timeframes within the constraints of the system.
- They are compatible with the overall mission or vision.
- They are worth achieving.

With these characteristics in mind, managers need to ask themselves six questions when designing and writing an objective:

1. What do we want?
2. Where do we want it?
3. Why do we want it?
4. When do we want it?
5. How much or how many do we want?
6. For how long do we want it?

To manage riparian ecosystems effectively, we must determine the needs of the stream and riparian area before we can decide how to partition its use among the wide array of competing natural resource interest groups: The management objectives and restoration plans should be based primarily on the functions of the system and should consider the needs and objectives of the uses of that system.

To successfully manage our riparian areas, from an ecosystem perspective, we must consider the following:

- Full floodplain function—preferably the 100-year flood plain.
- We must manage riparian areas within the context of the environment in which they are located, recognizing their unique value, and remembering that what works for one system may not work for another.
- We must recognize the importance of all stream systems, regardless of size, and view these streams and their associated riparian areas in a landscape perspective.
- Restoration activities within the stream channel and the riparian zone should re-establish natural ecological processes and communities.
- We must manage to maintain connectivity across landscapes. No other landscape feature is as effective as riparian areas in linking ecosystems:

Recommendations for Restoration

Physical manipulation of habitat elements is commonly used to help "fix" natural systems that have been stressed. Existing literature describes many different methods of altering habitat components to reach certain conditions. In riparian zones, one of the most common methods is to attempt replacement of missing vegetative or physical components through reseeding, replanting, or replacing the missing component with structures. In extreme cases, stream reaches have been completely rebuilt with various hydrologic and bioengineering techniques. Many of the manipulation techniques are extremely expensive, and project success over the long term is not well documented. If time is a less important project element, implementing land use management often can result in achieving desired future conditions at a more reasonable cost. For example, grazing systems, timber harvest systems, and even engineering designs for roads and trails have been developed that allow some classes of wetland and riparian sites to restore functional capability naturally, over time.

An example: the restoration of willow-dominated riparian zones—To restore forage and willow production in riparian zones, grazing systems must become oriented to the entire ecosystem, not just to the upland-area (Kaufmann and others 1983, Smith 1981). A combination of both woody-rooted and fibrous species provides physical protection to the hydraulic forces of eroding water and allows forbs, grasses, and sedges to bind the finer particles. In combination, this diversity of plant species is much more effective in promoting bank stability than is any one species by itself. Woody vegetation also is important for wildlife and fisheries habitat by providing food, cover, reproduction areas, and shade for reducing summer stream temperatures (Elmore 1988). Most traditional grazing systems were developed for upland grasses, not riparian species (Platts 1986). Although grazing systems, such as deferred or rotation, have improved the condition of most upland range in the last 50 years, they encourage concentrated livestock use in riparian zones during mid- and late-summer periods and have resulted in minimal improvements in riparian conditions (Platts 1986). Eventually, hydrologic changes reach a threshold, after which the stream proceeds into a cycle of gully development or braiding (fig. 1; Kovalchik and Elmore 1991).

Riparian habitats require site-specific management (Platts 1986). Several stream reaches, each with a different mosaic of plant associations and communities, may occur in a single grazing allotment (Kovalchik 1987). These communities have different tolerances to grazing (Benke and Raleigh 1978). Grazing systems that are compatible with one community may harm another (Kauffman and others 1983). Therefore, to maintain diversity of plant associations along each stream reach, grazing systems must be carefully designed for the communities that are present and desired, or both.

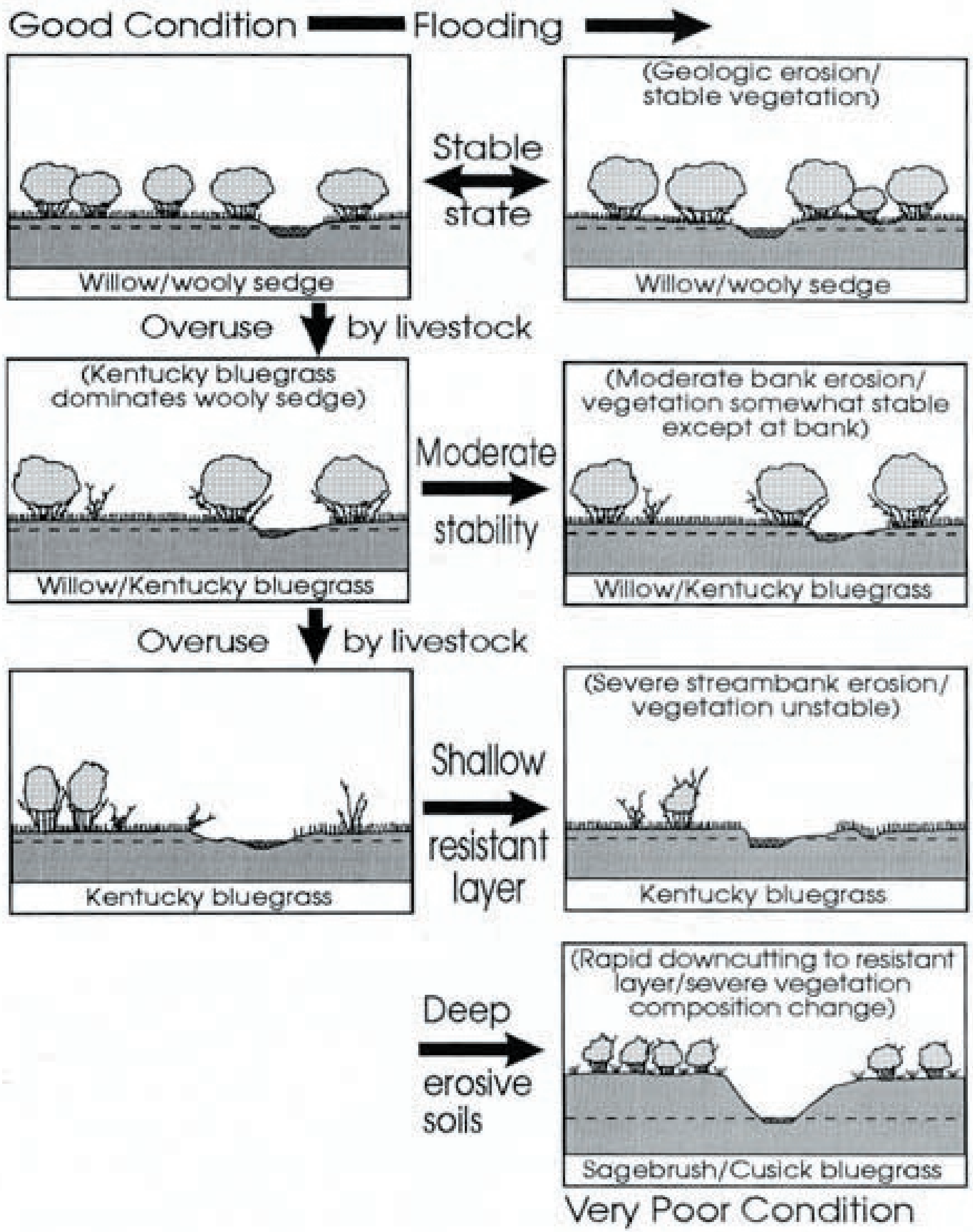

Figure 1. Deterioration of sites supporting the willow/wooly sedge plant association with flooding and improper use by livestock.

The switch from grazing herbaceous plants to browsing shrubs is the single most important factor in the change from willow-dominated plant associations to less stable communities. Unless grazing systems allow for sufficient, herbaceous, vegetative height growth during the mid- to late-summer period, they will generally fail to maintain willow-dominated plant associations. Sufficient forage height acts to prevent excess browsing, provides for regrowth of riparian plants after use, and leaves sufficient vegetation for streambank protection.

The degree to which browsing of willows is compatible with long term stream and plant community maintenance depends on the relative number of willows present. Few willows (where there should be many) should dictate conservative use. Use can be greater where willows are abundant or where management objectives do not call for increased numbers of willows. Figure 2 rates common grazing systems by their effects on willow-dominated plant associations in fair to good condition (Kovalchik and Elmore 1991).

The requirements of riparian vegetation must be evaluated differently than in the past, and changes in management must be instituted to improve the ecological condition of stream and associated riparian systems (Elmore 1992). Furthermore, the watershed, not just the stream system, must be the focal point because the runoff from the uplands has a major effect on what happens in the stream system. If improvements in water quality and hydrologic regime are needed, then alteration of those practices affecting the whole watershed must be a significant component of riparian restoration programs (Elmore 1992).

SYSTEMS HIGHLY COMPATIBLE WITH WILLOW MANAGEMENT

Corridor fencing	Willows ⇑ Sedges ⇑	Riparian pasture	Willows ⇑ Sedges ⇑
Spring grazing	Willows ⇑ Sedges ⇑	Winter grazing	Willows ⇔ to ⇑ Sedges ⇑

SYSTEMS MODERATELY COMPATIBLE WITH WILLOW MANAGEMENT

Two-pasture rotation	Willows ⇔ to ⇑ Sedges ⇑	Three-pasture rotation	Willows ⇔ to ⇓ Sedges ⇑
Three-pasture deferred rotation	Willows ⇔ to ⇓ Sedges ⇔ to ⇑		

SYSTEMS INCOMPATIBLE WITH WILLOW MANAGEMENT

Spring-fall grazing	Willows ⇓ Sedges ⇔ to ⇓	Deferred grazing	Willows ⇔ to ⇓ Sedges ⇔ to ⇓
Late-season grazing	Willows ⇓ Sedges ⇓	Season-long grazing	Willows ⇓ Sedges ⇓

⇑ = highly compatible
⇓ = incompatible
⇔ = no change

Figure 2. Generalized relationships between grazing system and willow and sedge response on willow-dominated plant associations.

ESTABLISH STABLE STAND STRUCTURES AND INCREASE TREE GROWTH: NEW TECHNOLOGIES IN SILVICULTURE

by **Michael B. Lambert**

Exclusion and suppression of fire, market selection and harvesting of single species, and construction of logging roads according to standards and density required to support contemporary harvest and transportation equipment (social direction and management practices) have degraded weakened ecosystems and their ability to withstand cyclic drought and resulting insect cycles (biological/environmental conditions and reactions) (Gast and others 1991).

The stressed site conditions of the eastside ecosystems are the outcomes of interacting forces from at least three sources: biological and environmental conditions and reactions, social direction and management practices, and operational capabilities. Improvements in efficiency and economy of future operational capabilities can help establish stable stand structures through selective thinning. Correct stocking levels can also help increase tree growth and fire/insect/disease resistance of stands. There is an urgent need to develop operational technologies which support economical, sustainable management practices of restoration and prevention.

The formidable task required of this technology to achieve restoration and sustainable forest management includes:

- Thinning of overstocked, low-vigor stands.
- Selection cutting for species adjustments.
- Salvage cutting to recover market value from deteriorating stands.
- Removal of fuel buildup to reduce the risk of stand-replacement fires.
- Removal of dead and dying trees to reduce insect and disease attack.
- Protection of soils from compaction and movement.
- Manipulation of vegetation in and near riparian areas.
- Forest operations requiring fewer, lower cost roads for hydrologic stability.
- Retention and controlled distribution of site nutrients.
- Enhanced structure of forest materials for wildlife habitat improvements.
- Mechanical removal of fuels to reduce effects of fire on air quality.

An approach is presented for forming a cooperative development effort to foster learning and rapid solutions wherein people work toward common goals by communicating with each other, helping each other, relying on each other's strengths, and evaluating progress toward the goals. Rapid progress toward these goals requires continual refinement of objectives along the way.

Logging systems have changed very little and very slowly in the face of changing social, environmental, and ecosystem management requirements. One reason for this is because equipment design and operational practices follow current social direction and management practices. Managers tend to prescribe treatments that they know from experience can be accomplished with available technology. If social direction and management practices do not change, there is no reason to expect operational capabilities to improve. On the other hand, there is no need to sacrifice management objectives for want of technology because technology can be developed faster than new timber stands (Lambert 1990). The problem is how to organize people, funding, and requirements of several disciplines to make progress in the development of technology used in restoration. Equipment suppliers, engineers, operators, and land managers need to understand operational requirements and then work together to upgrade operational approaches that will relieve conditions on stressed sites.

Steps to arrive at the desired future conditions of restored forest structure, value, and productivity often include structural rearrangement of trees and other vegetation. Prescriptions for particular tree or canopy spacing, or thinnings to achieve diverse species or canopy layers are sometime desired. Specifications for the desired structure will come from the collective thinking of many scientists and ecosystem managers. Providing the appropriate equipment and the training in its use are the tasks of engineers, equipment manufacturers, dealers, and operators. There is an irony here. Managers prescribe treatments based on their knowledge of what is achievable on the ground, while equipment specialists provide systems designed to do the work that they expect will be prescribed. This circular approach makes only slow progress over long periods—too late to help sites that are stressed now.

A new philosophy must break the cycle of practices that are constrained by real or imagined limitations in operational capabilities and lack of cooperation among contracting parties. A spirit of togetherness and cooperation that fosters interdependence and trust is needed to break the cycle and lead to progress toward realistic solutions. The evolution of hardware and management prescriptions must progress hand in hand. Old strategies and operational procedures have brought us to the current; stressed conditions. Use of the same approaches will exacerbate the stresses. Future management of the ecosystems will require different approaches. But, when operators and purchasers are financially burdened, there is no incentive to capitalize or develop new operational systems. Existing logging operations have already reached their lower economic limits. With the value of stands declining, the old operational systems are no longer viable, however, the owners of those systems are unable or unwilling to upgrade their capabilities.

Operational economics have squeezed many logging companies out of business. Bankers learn that financing logging equipment is risky. Equipment suppliers are not encouraged to develop new systems because of poor sales prospects. The Forest Service is not chartered to fund or engage in equipment development activities. Forest Service research has some authority to function in research, development, and application, but the magnitude of funding for this effort is dwarfed by the magnitude of true development costs. Funding and long-term (3 to 5 years) contracting authorities exist in the Forest Service, but "development" may not be funded this way legally. With this in mind, how can we improve the operational systems needed to tackle the new, more difficult tasks of stressed site restoration and ecosystem management?

All this must be done within operational costs that are lower than the value of marketable materials produced, unless subsidies or revenues for forest resources other than timber can be found. Currently, forest amenities and social values such as scenic quality, habitat quality, and watershed characteristics do not generate direct cash flow for management on these bases. In the immediate future, the value of products sold therefore must equal or exceed the cost of operations.

Development of technologies to accomplish the restoration tasks listed above will require the combined energy of all affected parties; it is beyond the reach of single interests. One suggestion is to merge missions, expertise, and funding in the Forest Service, research, industry, and public realms to achieve urgently needed progress. If scientists, land managers, operators, and wood product manufacturers join forces, progress can be made through sharing and synergism. A partnership of interested people could embark on a cooperative development and learning exercise that would result in refinement of an integrated harvesting and stand improvement system. The integrated system would have flexible operational capability for restructuring forest vegetation according to prescriptions evolving from current science and past experience. It could also recover marketable resources such as saw logs, chips, and energy wood, important for continuing operations.

A cooperative approach among this group would create opportunities for advances in many areas, including enhanced equipment capabilities; knowledge of how best to apply new technologies; studies of ecosystem responses to particular controlled treatments; recovery of additional smaller stems for market; the economics and social aspects of marketing forest products following processing and sorting in the woods; and studies of effects on employment, forest worker safety, air quality, and so forth.

Together, the group could work toward development of a system with new operational capabilities. An effective, integrated harvesting system for restoration operations could selectively access designated trees and materials. It could accomplish stand structural changes needed for restoration and also provide a flow of commodities. The in-woods processing capabilities of the system would enable it to leave desired trees and parts of other trees on site for nutrient, habitat, or stand-enhancement reasons. Materials to be removed would be efficiently processed into the highest value form for subsequent sale and transportation to market. Marketable forms of wood include saw logs, chip logs (with or without bark), clean chips, and whole tree chips. Appropriate handling and transporting equipment would protect soils and leave trees. The system would operate over long distances without the need for new or reconstructed roads. An important attribute of this system is that it should get the total job done in one continuous process and be self-supporting from the value of products it removes, even in stands in poor health.

A full-scale, outdoor experiment should be undertaken to establish the best operational system for achieving the mechanical treatments needed to accomplish restoration and subsequent productivity of the eastside forests. Outdoor laboratory test sites from among various stressed conditions are needed. The sites should have actual and hypothetical prescriptions that embody the best scientific management philosophy . Equipment that can accomplish the above silvicultural, salvage, restoration, improvement, and ecosystem management tasks should be put into service on the test sites and steadily improved. A monitoring process should be established for progressive evaluation by all parties concerned over a long time to establish design and application criteria for industry and ecosystem managers.

A true research, development, and application study of this trial system could be undertaken with the collective attention and feedback of operators, sale planners, sale administrators, biologists, landscape architects, ecologists, hydrologists, equipment designers, public, product end users, and other interested groups. The magnitude of the required effort is beyond the scope of any individual group, but collectively, a cooperative effort could achieve solutions that would benefit all and lead to restoration and future protection.

A successful cooperative effort could realize the following objectives:

- Accomplish effective treatments on many acres.
- Foster educational opportunities so that sale planners and administrators learn the capabilities and limitations of equipment.
- Identify more effective procedures, more efficient methods, ways to reduce costs, ways to reduce soil disturbance and tree wounding, and other improved operational approaches.
- Explore alternative marketing strategies.
- Transfer knowledge and experience through publications, workshops, demonstrations, and other extension methods to all concerned. This will have a snowball effect on the operational capability to achieve restoration and sustained productivity on currently stressed sites.

Technologies developed to operate successfully on stressed sites will be even more successful when applied to the management of healthy sites. As forest health and productivity are restored, the economics of use of the new technology will improve. Successful development of economical operational capabilities will contribute to a viable timber industry in the area. A stable industry, working in partnership with land managers and the public, is needed to use advanced technology to achieve balance between the ecological possibilities of the land and human needs and wants.

FOREST ROADS AND FOREST HEALTH

by **Walter F. Megahan, Larry L. Irwin**, and **Larry L. LaCabe**

One of the issues in the East Cascades is that of forest roads, including the construction and management of National Forest System roads as well as the disposition of old, usually abandoned, access routes that are not part of the Forest road system. By providing access to National Forest lands, roads provide various benefits. However, roads also can cause adverse environmental effects that are manifested on site, downstream, or both.

Onsite Effects

Potential onsite effects of roads include effects on terrestrial wildlife, the introduction of noxious weeds (Harrod 1993) and reductions in site productivity. One consequence of extensive road building has been changes in abundance and distributions of wildlife in association with human use along roads. Large mammals, such as deer and elk, shy away from areas of human activity; grizzly bears particularly are sensitive to human use along roads (Manley and others 1992).

The relative effects of roads on wildlife depend on the interactions among the topography, frequency of human use, and vegetation conditions (Edge and Marcum 1991, Irwin and Peek 1979). Thus, road placement and configuration are important factors in management planning. For example, straight roads are considered to have higher effects on wildlife than winding roads (Lyon 1975). And, roads near wet meadows where large mammals forage have greater effects than roads in areas that are used less frequently.

Two or three decades ago, wildlife managers frequently requested National Forest managers to develop more roads as a means of managing the size of big game herds through hunting. Now big game managers call for restrictions in road building and for increased road closures because road densities can be too high (Lyon 1983) and because increased hunter densities (Vales and others 1991) have changed big game population structure (Leckenby and others 1991). Thus vulnerability of big game to hunters is a primary concern, and road management, forest stand size, and stand structure have become major topics in forest management planning (Lyon and Canfield 1991).

Construction of timber harvest roads initially removes anywhere from 1 to about 30 percent of the area from tree production, depending on the type of logging system used. Losses in site productivity depend on road longevity, size, location and design, the part of the road in question (cutslope, ditch, tread, or fillslope), and the characteristics of the biogeoclimatic region of concern. In general, net long-term productivity losses tend to be considerably less than the percentage of the area initially involved in road construction except where off-road groundwater or erosion problems exist (Megahan 1988).

Offsite Effects

Potential downstream effects from forest roads include changes in the quality and quantity of streamflow, impaired aquatic habitat, and sedimentation damage to water-related infrastructures such as dams, irrigation works, and bridges. Causal factors include changes in the hydrologic function of the watershed as well as direct channel encroachment (Megahan 1987).

Accelerated sedimentation is by far the most common cause of deteriorated water quality from road construction. Megahan (1981) summarized results from 24 different studies documenting increased erosion and, in many cases, sedimentation from forest roads in the interior West. Additional damages to water quality are possible from introduced chemicals from road surfacing materials and chemical spills (Furniss and others 1991). Increased streamflow quantities following road construction depend on the area of roads and how well the runoff from roads synchronizes with the runoff from the remainder of the watershed (Megahan 1987).

Damage to aquatic habitat is primarily the result of accelerated sedimentation and direct channel encroachment. Furniss and others (1991) reported that changes in sediment loading, channel morphology, riparian conditions, and other road-related effects can adversely affect all freshwater stages of salmonids including migration, spawning, incubation, emergence, and rearing. Platts and others (1989) document changes in salmon spawning and rearing habitat from increased delivery of fine sediment following logging and associated road construction in the South Fork of the Salmon River in Idaho.

Nearly all public recreation on National Forest lands depends on road access. Roads also provide access for management, protection, and use of National Forest resources. Currently there are about 57,000 miles of National Forest System roads in the eastside forests of the Pacific Northwest Region. About 15 percent are maintained and suitable for passenger cars, 62 percent are suitable for high-clearance vehicles, and 23 percent are closed to public use for at least a portion of the use season (U.S. Department of Agriculture, n.d.). Most of these roads have been built under contract by the purchasers of National Forest timber and paid for with offsetting credits for timber. The number and location of these roads (road density) often is determined by the logging system intended to be used for the initial harvest (Kramer and Owen, n.d.).

Philosophy of Restoration Activities

Since the 1950s and 1960s, efforts have increased to identify and mitigate the negative effects of forest roads. Research conducted by the Forest Service and others has led to technologies and methods that have been incorporated into Forest Service handbooks and technical publications. Technology transfer networks are available to disseminate this information. Recently, concern about, the habitat of the northern spotted owl, Native American tribal rights, and the declining salmon runs in the Columbia and Snake Rivers, along with other issues, have focused additional attention in this area. The Forest plans for the individual National Forests in eastern Oregon and Washington contain standards and guidelines for the location, construction, and operation of roads. Additional standards and guidelines are being developed by PACFISH, an interregional Forest Service team formed in 1993 and concerned about anadromous fish habitat, and SAT, scientific analysis team (Thomas and others 1993) established to advise the Federal court during litigation concerning the northern spotted owl.

Recommendations for Restoration

Problems from roads would be reduced by limiting new construction to provide the fewest number of lowest standard roads necessary to manage the ecosystems. These roads should be safe and durable structures built and maintained to standards appropriate to their intended uses, and should be designed and operated to minimize their negative effects on the environment. Reconstruction of the existing system should include identifying and correcting barriers to fish and wildlife. Roads in riparian, wetland, and other sensitive areas should be relocated if practical; or reconstructed to incorporate mitigation features, such as sediment traps and screens, pavements to harden surfaces, and revegetation or other protection of erosive sites.

Perhaps the most effective way to reduce the effect of roads is to obliterate roads no longer needed for ecosystem management. Since fiscal year 1991, Congress has made funds available to the Forest Service for that purpose, and about 1,000 miles of road have been obliterated in eastern Oregon and Washington at a cost of $800,000. In fiscal year 1993, an estimated 80 additional miles will be obliterated at a cost of $93,000. The Forests of the Pacific Northwest Region are currently involved in an Access and Travel Management process that will determine, among other things, a prioritized list of roads to be obliterated. That process will not be complete until near the end of fiscal year 1993, but the Regional Office has estimated that as many as 19,000 miles of road in eastern Oregon and Washington may no longer be needed. Site-specific project planning should determine if road obliteration will involve establishing a traffic barrier, removing the drainage structures and restoring the natural drainage patterns--then allowing the natural processes to reclaim the land; or if it may require scarification, seeding, planting and re-establishing the natural land contours. Road obliteration is a labor-intensive activity requiring the use of road construction equipment.

RESTORATION OF STRESSED, FORESTED RANGELANDS

by **Richard L. Everett** and **Linda H. Hardesty**

Increased emphasis on ecosystem sustainability requires that criteria in addition to forage and timber yield be used to evaluate rangeland ecosystems and to direct their management (Quigley 1989, Quigley and Ashton 1990). Stressed rangelands are characterized by loss of site potential reflected in altered species composition, soil loss, negative cumulative effects on landscape characteristics such as water quality, and reduced ability to provide desired products and services. Degradation of rangelands can occur from improper grazing by liveestock and wildlife, soil compaction and disturbance by logging activities, increased tree competition, catastrophic fire, invasion of noxious weeds (Harrod 1993), and changes in climate (Branson 1985). Excessive livestock and wildlife use of forage resources causes shifts in plant community composition, loss of protective plant cover, and loss in site potential from soil erosion (Irwin 1993). Timber harvesting methods that compact and disturb forest soils also reduce herbaceous plant cover (Harvey 1993). Loss of herbaceous vegetation has been associated with encroachment of western juniper woodlands into adjacent shrub or grassland communities in eastern Oregon (Vaitkus and Eddleman 1991) and with canopy closure during the conversion of open pine stands to overstocked Douglas-fir stands Gohnson 1993).

Degradation alters ecosystem processes and structure on and off site. Grazing has reduced flashy fuels and fire frequency, contributing to the development of currently overstocked stands and associated severe fire regimes (Agee 1993). Grazing pressure by livestock or wildlife, timber harvest, and wildfires all increase opportunities for erosion, affecting downstream water quality and fisheries habitat through elevated temperatures, increased sediment loading, or both (Platts 1981).

Rangelands currently are not meeting the multiple demands of the livestock industry and environmental groups. Loss of riparian vegetation from improper grazing and its attendant effects on fisheries and water quality are serious public concerns (Anderson 1992). Conflict between wildlife and livestock interests over forage allocation is a significant socioeconomic issue in eastern Oregon and Washington. The livestock industry is suffering numerous difficulties but is contributing to the economic health of the region.

Nationally, 70 percent of Forest Service range allotments are not meeting management objectives, and 25 percent are overstocked and on a downward trend (U.S. General Accounting Office 1990). These values are approximations because Forest Service managers were not sure of conditions on 23 percent of the rangelands they manage. About 10 to 20 percent of Forest Service-administered rangelands in Oregon and Washington are in poor condition (Society for Range Management 1989), and the trend is downward on a similar percentage of these lands.

That Forest Service rangelands are not all properly managed is not surprising given that rangelands constitute over 54 percent of Forest Service-administered lands but they receive less than 1 percent of the budget (U.S. Department of Agriculture 1992,). Each range staffer manages about 298 square miles (U.S. General Accounting Office 1988). Updated grazing allotment plans, which determine the resource base and carrying capacity for livestock and wildlife, have not been completed for 122 of the 637 allotments in eastern Oregon and Washington (unpublished data, U.S. Department of Agriculture 1992b). Only 254 allotments are estimated to be meeting desired forest management objectives.

Given the current funding for rangeland management, the biotic potential of these sites is unlikely to be realized or maintained. Restoration priorities must be established. Focusing on sites currently not meeting management objectives is justified (U.S. General Accounting Office 1988), but even more critical is maintaining the condition of rangelands that are meeting management objectives. Unique habitats and remnants of former communities that may provide information for future generations should be identified and protected before they are inadvertently altered or lost. Priority also should be given to preventing the impending loss of biodiversity and site potential that catastrophic fires, salvage logging, and riparian grazing may be causing in currently stressed ecosystems. The reality is that with current funding prospects, a triage approach must be formulated to attain the best range conditions possible over a wide area, without the hope of achieving the full potential of every site.

A Philosophy for Restoration Activities

The desired future condition of forested rangelands is that they maintain the structural and functional capacity to provide resources and values at the site and landscape scales for current and future generations. Potential outputs include desirable vegetation, wildlife habitat, forage for livestock and wildlife, recreation, sustained populations of plant and animal species, and proper hydrologic function (Quigley and Ashton 1990). Rangeland are associated with other ecosystems; thus, restoring stressed rangelands must consider not only the desired restoration outcome for the specific site, but also the desired restoration outcome for the landscape where the site occurs. Expectations for restoration should be based on the most probable plant community, given the current site potential, rather than on a historical site potential that no longer exists (Society for Range Management 1991).

Reducing the occurrence and intensity of adverse effects is a prerequisite for restoration activities and the maintenance of current and future improvements. The stocking rates for livestock and wildlife must be related to the carrying capacity of the land, and future timber management activities should make site stability a priority. Restored areas should not be viewed as reserves but managed to maintain the ecosystem benefits of restoration.

Economic evaluation of restoration projects should not be constrained to cost-benefit analysis of single-use returns but broadly construed toward maintaining ecosystems. The question is not so much the "before and after" benefits as it is "with and without" (Fulcher 1973) and the alternative costs of ecosystem degradation. Factoring in the "external costs" of degradation will shift the outcome of analyses that historically focused only on economic costs and benefits to the proximate few.

Formulating Restoration Plans

Management tools for improving rangelands include revegetation, control of undesirable vegetation, prescribed burning, grazing management, and combinations of these practices. We need to define the desired trajectory for the stressed range site and design restoration and management practices to complement natural processes to achieve that end. The difficulty and costs associated with trying to maintain plant communities counter to natural successional processes should be considered if rangelands are for dedicated use rather than ecosystem sustainability.

Preventing Loss of Site Potential

Soil erosion is a natural ecosystem process, but accelerated erosion from wildfire, grazing, or timber management activities can significantly reduce site potential (Megahan 1991) and reduce future management options. Maintaining site potential should be a priority to preclude the more difficult and expensive job of restoration. The erosion-productivity problem is difficult to detect initially but can proceed exponentially, rapidly becoming economically impossible to repair (Gifford and Whitehead 1982). In this cycle, loss of plant cover means reduced infiltration which equates to increased erosion, thereby causing lower site productivity and further reduced plant cover (Simanton 1991). A major concern on eastside forests is the potential for large-scale surface and mass-wasting erosion when postwildfire soil surfaces are unprotected and subject to high-intensity thunderstorms (Helvey and others 1985).

New Technologies

Technologies currently under development may assist in preventing or improving degraded transitional range sites. New methods are being developed to harvest small-diameter logs to reduce stress from tree competition (Lambert 1993). Once fuel loadings have been reduced, prescribed fire can be used to reestablish low-severity fire regimes and more open forest communities (Ottmar, in press). Even with appropriate stocking rates, overuse of riparian areas by livestock is a major concern, and fencing is often not a viable alternative. Electric-aversion ear tags are being tested to restrict cattle use of sensitive areas (Tiedemann and Quigley, personal communication). Fertilizer treatment to restore meadows degraded by elk and cattle is being evaluated (Everett, study plan on file, Wenatchee FSL).

Restoring Biodiversity—Species and Processes

Improper grazing, timber harvest, and anomalous tree competition levels can affect plant species competition. Loss of plants often is apparent from mechanical or grazing damage, but loss of soil seed reserves, though less apparent, is just as significant (Koniak and Everett 1983). If desirable native species are not adequately abundant, propagules from off-site or replacement species may need to be introduced (Brooke and Holl 1988).

Concerns exist over use of introduced rather than native species in restoring rangelands. Introduced species may compete with indigenous species and alter plant succession. Introduction must be justified by what the introduced species contributes to important landscape values. For example, potential exists for severe erosion after large-scale wildfires in the mountainous terrains of eastern Oregon and Washington (Helvey 1980). Revegetation must be rapid to conserve the soil resource, but this may affect biodiversity if exotic species are introduced. The decision process must evaluate whether the long-term loss of soil is more significant than successional consequences of species introduction. Some seeded species may persist for decades (Geist 1976) or rapidly lose dominance to native species (Lyon 1976).

Opportunities to restore and enhance degraded transitional rangelands could be unprecedented, given current forest health and the potential for catastrophic fire and salvage logging associated with insect outbreaks in eastern Oregon and Washington. The size and intensity of wildfires is increasing dramatically (Agee 1993), and the potential for salvage logging exists on thousands of acres in the Blue Mountains (U.S. Department of Agriculture 1993). These areas present opportunities to re-establish desirable rangeland plant communities, but are prime for further degradation if adequate restoration is not undertaken. Invasion of disturbed sites by weeds is also a major threat (Harrod 1993). Invasive exotic weeds such as cheatgrass and several species of *Centaurea* (knapweed, star thistle) dominate extensive areas in Oregon and Washington (Allen and Jackson 1992). Choosing between desirable, introduced species or invasion by weeds, requires comparing the longterm potential threats from each source. Plant and animal communities are sufficiently interdependent that many insect, wildlife, and microbial populations depend on specific plant communities. These links must be recognized in decisions about the future diversity of plant communities.

We need to consider the potential of seeding desirable species before timber harvest to ensure desirable species response if remnant plants and soil seed reserves are insufficient to prevent invasion of noxious weeds. We also need to develop means to protect recently logged sites from grazing until herbaceous and shrub species become established, as well as to investigate use of livestock to manipulate understory growth and precondition wildlife browse.

Recommendations for Restoration of Forested Ranges

Restoration of rangeland ecosystems should focus on ecosystem structure and function rather than specific resources or values such as forage production or wildlife habitat. Undisturbed relict areas have been used as reference sites for investigating ecosystem structure and function, and for defining the potential natural plant community associated with a given range setting. The potential natural plant community may not be desirable when other plant communities more closely meet society's needs. However, in the acceptance and management of these other plant communities, the requirement of no loss in future options should be explicit.

Restoration activities should be embedded in a comprehensive .approach to managing rangeland ecosystems and larger landscape units. The decision process should be shared among all (national, regional, and local) social communities interested in this issue (Weigand 1993).

Recommended restoration actions, in order of priority, are:

- Immediately assess. the need for restoring and protecting recently burned areas or insect epidemic areas recently salvage-logged and implement appropriate measures to protect site stability and potential.
- Immediately assess restoration needs associated with the conservation of rangeland riparian areas, water quality, and fisheries and implement appropriate restoration practices.
- Identify sites currently in satisfactory condition, but with a downward trend, and implement management designed to maintain satisfactory.condition.
- Prevent the spread to and increased density of noxious weeds on degraded rangelands (on- and off-site management required).
- Complete or update allotment management plans to define the current resource base, carrying capacity for wildlife and livestock, and the need for restoration actions.
- Develop a strategy to ensure that adequate seed and other planting materials are available for use on catastrophic burn and salvage-logged sites to prevent soil loss and undesirable changes in plant species composition.
- Develop a set of measures to evaluate rangeland resources and their management relative to ecosystem sustainability; reallocate the Forest Service budget to manage for ecosystem goals.

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SUMMARY

The preceding invited papers were directed at specific concerns voiced by the public at forest health forums and working groups held in eastern Oregon and Washington (U.S. Department of Agriculture 1991, 1993). Collectively the papers address the critical issues that were raised by the public, but these issues did not cover all aspects of ecosystem restoration. The reader interested in a broader treatment of principles and applications for restoring disturbed ecosystems is referred to previous published works (Bradshaw and Chadwick 1980, Cairns 1988).

Major forest health concerns in eastern Oregon and Washington were the potential for catastrophic fire, loss in water quality, decline in fisheries, loss of terrestrial and aquatic species, reduced resistance of forests to insects and disease, and loss of commodity production from public lands (U.S. Department of Agriculture 1991). Long-term solution of these concerns requires the adoption of sustainable ecosystem management: (1) conservation of biological diversity, (2) conservation of long-term site productivity, and (3) the sustainable flow of renewable resources (Overbay 1992).

Public investment in restoration projects to hasten the rate of ecosystem recovery is justified by a more rapid and complete achievement of ecosystem production (King 1991). Additional benefits are employment opportunities in economically-depressed rural communities and the ethical reward of conserving forest options for future generations (Weigand 1993).

Philosophical Base for Restoration

The public call for ecosystem restoration focuses beyond simply restoring damaged areas to restoring a balance in how we value and treat forest ecosystems to prevent future damage. This philosophical shift characterizes a maturing society that is abandoning the “frontier ethic” of waging war against nature to extract commodities to one of working with nature to preserve its biological integrity (Cairns 1991). Ecosystems that have a full complement of structure, function, and composition have increased resiliency to disturbance, and from these robust ecosystems, sustainable levels of resources can be provided for the long-term maintenance of the ecosystem’s human component.

Restoration can rely on several philosophical approaches such as hierarchical landscape ecology (Jensen and Bourgeron 1993), watershed analysis, (Thomas and Raphael, FEMAT, 1993), and individual species viability (Thomas and others, ISC 1990, SAT 1993) to provide direction and goals. Different conservation biology approaches, such as the coarse- and fine-filters, can be used to ensure that landscapes, habitats, and species are conserved and restored (Hunter 1991, Marcot and others 1993). Historical variability in vegetation types, amounts, and spatial patterns can be used as reference points, but other alternative states that better meet society’s expectations may be more desirable as restoration goals. Restoration of ecosystems to rigid standards and guides may not be appropriate as this ignores inherent differences in resource values over different kinds of sites. Also, resource values on a site can be expected to change over time because of inherent disturbance events required to maintain these historically dynamic ecosystems.

Restoration at a minimum must restore biological capacity (reclamation) if future resource options are to be maintained. The maintenance of future potential is paramount as public expectations of their forest lands have changed often and dramatically over the last century. Public emphasis has shifted from watershed protection, to livestock grazing, to timber supply, and most recently to ecosystem integrity over the last century (Kennedy and Quigley 1993).

Public Consensus on Goals of Restoration

The resource base is currently inadequate to meet all the diverse needs of the public (Cairns 1991). There are social conflicts and disputes in land allocation among competing values for limited resources (Daniels and others 1993). In restoration efforts, should we emphasize biological reserves or timber harvest, wildlife or livestock, edge-dependent wildlife species such as elk or interior forest-dependent species such as the pileated woodpecker? Before restoration efforts can be successful, consensus is needed on goals and expectations of the desired future condition(s) for public lands. Definitive restoration goals will depend on a collaborative approach to forest policy formation in the implementation of ecosystem management (Daniels and others 1993).

Restoration can alleviate potential resource conflicts by redirecting focus from dividing scarce resources to the restoring biological potential and increasing abundance of resources (Kruger 1992). Kruger used the example of increasing the abundance of resources on two-thirds of the Nation's rangelands currently providing less than half of their perceived potential (Society for Range Management 1989) to reduce resource conflicts among wildlife, watershed, and livestock interests. Similarly, improving forest health in Oregon and Washington should provide increased opportunities for conflict and dispute resolution among logging, wildlife, and fisheries interest groups.

Ecosystem Restoration as an Adaptive Management Experiment

Restoration of ecosystems must be conducted on an experimental basis because we have incomplete information on the character and functioning of forest ecosystems, public expectations of those ecosystems, and ecosystem response to management practices (Everett and others 1993). The formalized process of adaptive management allows restoration activities to be initiated based on current information, but efforts need to be constantly updated and redirected as new information becomes available (Baskerville 1985). Monitoring of restoration efforts is required if we are to improve our understanding of systems, to evaluate if restoration practices are achieving desired goals, and to redirect restoration actions when required by biological or social factors.

Catastrophic Loss

The prevention of catastrophic loss in wildlife habitat, human life, and property from fire and the loss of terrestrial and aquatic species and site potential from management actions are the highest priorities for the restoration of ecosystems in eastern Oregon and Washington (Caraher and others 1992, U.S. Department of Agriculture 1991). In reviewing current scientific literature and personal communications with experts, we have found no defined strategy to protect landscapes, unique habitats, or sensitive species from catastrophic fire. There are innovative approaches using insect pheromone to protect unique habitats from insect damage (Daterman 1993), but strategies should be developed for protecting unique habitats from catastrophic fire.

Mutch and others (1993) and Arno and Ottmar (1993b) provide insight to the problems of restoring historical fire effects in altered ecosystems having high fuel loadings and continuous fuels across the landscape. They recommend a landscape approach using both mechanical and fire reduction of fuel loads. New silviculture practices that extract small-diameter logs are suggested as a means of reducing tree density and fuel loadings so that fire hazard is reduced and a flow of timber resources is obtained (Lambert 1993).

Mutch and others (1993) suggest that a severalfold increase in the annual acreage burned by prescribed fire is needed to reintroduce fire into eastside ecosystems. This must be balanced, however, against adverse effects on air quality and potential fire escape. The amount of smoke produced by prescribed fire is estimated at half that produced by wildfire from the same area (Arno and Ottmar 1993a, Lehmkuhl and others 1993).

Society will make a decision, even if by default from no action, to either experience twice the amount of smoke in episodic occurrences of unplanned fire, or to accept less smoke over a longer time frame from planned burns. The latter can achieve desired ecosystem goals; the former may lead to ecosystem degradation. The Native Americans of the Northwest opted for the planned burn in the creation and maintenance of landscapes that met their cultural needs (Robbins and Wolf 1993).

The loss of forest and human structures by fire is dramatic and readily apparent; the loss of individual species, site potential, or genetic material is much less visible but can have longer lasting effects. Consideration should be given to gene resource management in restoration activities. The goal should be to retain desirable genetic traits of species for their proliferation rather than the proliferation of traits of species left by default through management actions (Daniels 1993).

Species extinction is irreversible and soil genesis on eroded lands is measured in tens of centuries. Although information is not complete on sensitive species viability or rates of soil genesis, “some risks are potentially so serious, and the time for recovery so long, that risk reduction actions should be viewed as a kind of insurance premium and initiated in the face of incomplete and uncertain data” (U.S. Environmental Protection Agency 1990). The ISC (Thomas and others 1990) report on spotted owl viability and regional guides to limit soil disturbance (Meurisse and Geist 1993) are examples of risk reduction procedures. Guidelines for restoration of key watersheds have been developed to protect sensitive salmon and freshwater fisheries of the Pacific Northwest (Reeves and Everest 1993, Thomas and Raphael 1993) .

Restoration Opportunities

After large-scale disturbances, we have an unprecedented opportunity to enhance diversity, site productivity, and ecosystem integrity of future forests. Conversely, adverse impacts to the soil, water, or plant resource base during “restoration activities” could cause long-term loss in site potential. Loss of the soil resource to erosion after sequential fire and storm events is a significant concern in eastside forests (Grier 1975, Meunsse and Geist 1993)

Loss of existing forest stands from insects and fire creates a biological vacuum that will be filled by desirable or undesirable species and processes. Remnant or immigrating species could provide the foundation for desirable future forests or they could be noxious weed species (Harrod 1993). In salvage logging operations, we have the opportunity to leave legacies for future forests and stream ecosystems. Stand legacies could be in the form of snags and leave trees that provide wildlife habitat, including homes for insect predators that maintain insects at endemic levels (Bull 1993, Torgerson 1993). Landscape legacies could be in the form of unharvested stands adjacent to riparian areas that provide for increased terrestrial and aquatic biodiversity.

Restoration of Landscapes

Although we have methods to restore species or structures on stressed sites, we are only now considering how to restore stressed landscapes. The historical focus on individual stand management allowed negative cumulative effects to occur at larger landscape scales. Caraher and others (1992) and Lehmkuhl and others (1993) found several landscape vegetation characteristics outside of the historical range of variability for drainage basins in eastern Oregon and Washington.

In landscape restoration, we wish to generate positive cumulative effects; thus, restoration of stands and stream reaches must be in agreement with the desired condition(s) for the larger landscape in which they reside. Shlisky’s (1993) case study on the restoration of altered forest ecosystems in the Blue Mountains provides an example of designing and implementing landscape restoration projects to restore forest sustainability. The goal is to provide landscape characteristics that meet public expectations, are biologically sustainable, and maintain future biological and social options.

Landscape sustainability can be enhanced by designing heterogeneity into landscapes to reduce continuity in insect host species, thus reducing opportunities for large-scale insect outbreaks (Mason and Wickman 1993). Landscape heterogeneity has a similar role in providing opportunities to control fire spread (Arno and Ottmar 1993b).

Restoration of fisheries, watersheds, and riparian areas focuses on the entire watershed to acquire a dynamic, hydrologic equilibrium between upslope and aquatic systems (Robison and Bennett 1993). The goal is to provide adequate quality and flow of water, protect riparian vegetation, and sustain fisheries. Watershed-specific hydrologic health assessments are recommended for all watersheds to determine current condition and trend.

Larger landscape-scale restoration activities need to address regional biodiversity goals. The use of a "gap analysis" approach to define the location of sensitive species and habitats at risk from insect or fire loss is recommended (Martin 1993).

Recommendations to Restore Sustainable Ecosystems

The Forest Service and society should consider the benefits of ecosystem management in maintaining and restoring ecosystem processes and structures (Weigand 1993). This requires a major funding investment in ecosystem management by the U.S. public (Hessburg and others 1993). Restoration practices recommended here closely follow those of Caraher and others (1992), and both are responsive to previously stated public concerns (U.S. Department of Agriculture 1991). One rule or strategy for restoration cannot be applied in all cases. A broad policy of restoration can be legislated, but the characteristics of its application will differ case by case.

Reduce Catastrophic Loss

- Recommend developing and evaluating landscape level experiments on the appropriate mix of silviculture treatments and prescribed fire to significantly reduce the hazard of catastrophic fire.
- Recommend that salvage logging operations capitalize on opportunities to conserve biodiversity and long-term site quality, and that they leave stand and landscape legacies to hasten recovery of future forests.

Conserve Biodiversity and Long-Term Site Productivity

- Recommend that watershed-specific hydrologic health assessments be conducted to define watershed conditions and provide baseline information on managed and reserved stream systems.
- Recommend research be conducted on defining appropriate width of protected riparian corridors by stream reach and landform position.
- Recommend that salvage logging operations be based on improvement of future forests through the conservation of species, structures, and gene pools.
- Recommend that action be taken to prevent loss of site potential from soil erosion or compaction during salvage logging and that steps be taken to prevent invasion of noxious weeds on disturbed forest sites.
- Recommend adjusting livestock and wildlife grazing in riparian zones to sustainable ecosystem levels such that future management options are conserved.

Restore Disturbance Processes

- Re-establish historical fire effects to reduce fire and insect hazard to forested landscapes while minimizing adverse impacts on air quality.
- Restore endemic populations of insect pests through silviculture, prescribed fire, and other techniques that increase heterogeneity on the landscape and increase habitat for insect predators.

Maintain Sustained Flow of Renewable Resources

- Recommend evaluation of small-diameter timber harvest methods as a way to reduce excessive tree densities and hazard from fire and insects.
- Recommend developing techniques that provide for livestock and wildlife grazing and maintain long-term site productivity and biodiversity of riparian zones and associated aquatic systems and fisheries.

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GLOSSARY

Base flow—Typical flow for a given stream at a particular time of year

Biota—The animal and plant life of a particular region

Biophysics—The physics of biological processes

Broadcast burning—Burning forest fuels as they are; no piling, windrowing.

Compensatory mitigation—To create biophysical capacity of a particular type of ecosystem where the ecosystem did not previously exist as a substitute for biophysical capacity of the ecosystem lost at another site

Defoliator—An insect that feeds on tree foliage

Degradation—Erosional removal of materials from one place to another, which lowers the elevation of streambeds and floodplains

Dividends—Income or rents of ecosystem outputs that result from investments of capital in ecosystem management

Fillslope—That portion of a road that is filled material

Fuel load—The dry weight of combustible materials per unit area; usually expressed as t/ac

Geomorphology—The geological study of land form evolution and configuration

GIS—Geographic Information System; an information processing technology to input, store, manipulate, analyze, and display spatial resource data to support decision making

Hierarchy—Geographic grouping of land units based on how they fit together and interact on the landscape; commonly used for spatial arrangement

High grading—Uneven-aged harvest systems where the most valuable trees and species are removed, and trees of lesser value and quality are left to grow

Management indicator—An attribute of forest landscapes that can be quantified to simplify land management planning; management indicators have been used to determine the success of management planning and implementation according to the apparent prosperity of the management indicator species

Management indicator species—Any of a number of species of fish or wildlife for which a set of management guidelines have been written; species are chosen to simplify land management planning and to aid in determining the effects of management; one type of management indicator species is the ecological indicator species

Monitoring—Actions undertaken to evaluate the efficacy and effects of any management activity on species, processes, habitats, flows, landscape and ecosystem characteristics, and outputs; monitoring provides a feedback loop to ecosystem management experiments that addresses accountability and validity of actions

Montane—Of, growing in, or inhabiting mountain areas

Morphology—The form and structure of organisms

Neotropical migratory species—Species that breed in temperate zones in North America and then migrate to the tropics for winter (between the Tropic of Cancer and the Tropic of Capricorn)

Parsimony—A tendency to be overcareful in spending; unreasonable economy

Reclamation—To recreate biophysical capacity of an ecosystem in such a way that the resulting ecosystem is different from the ecosystem existing before a disturbance

Restoration—To maintain or recover original elements, structures, processes, and interactions of an ecosystem after a disturbance

Rhizomatous—Producing rhizomes, rootlike stems which grow horizontally underground, and give rise to above-ground stems and root systems

Scarification—Physical disturbance of surface soil horizons, usually to improve germination and early survival of natural regeneration

Seral—1. Successional; 2. describing species or a community that will be replaced by another in succession

Seral species—Plant species of early, middle, and late successional plant communities of any plant association; often used in a more limiting sense to speak of the dominant conifer vegetation that follows major disturbance episodes

Seral stage—Any of a predictable sequence of transitional plant communities that leads to the terminal or climax community

Sere—The entire set of all developmental phases of a forest stand; each developmental phase is a seral stage (see seral stage)

Series—An aggregation of taxonomically related associations that takes the name of the climax species that dominates the principal layer; a taxonomic unit in a classification

Social discount rate—The preference or value expressed by society for the timing of production of goods, services, and ecosystem states from an ecosystem; a positive discount rate reduces the value of a product produced in the future by a certain percent annually up to that future time as compared to the unreduced value of the same product produced in the present; a zero social discount rate presumes that society is indifferent to the time when the product is produced, now or in the future

Soil bulk density—The mass of dry soil per unit bulk volume; the bulk volume is determined before drying to constant weight at 105° C; a unit of measure expressed as g per cubic cm or lb per cubic ft

Thinning—The planned removal of trees during the development of a forest, used to regulate characteristics of tree growth through adjustments in tree spacing and density without creating a new age class

Watershed (also catchment area; basin; drainage area)—Total land area draining to any point in a stream, as measured on a map, aerial photo, or other horizontal, two-dimensional projection

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APPENDIX A

List of Common and Scientific Names

Common Name	Scientific Name
Bitterbrush	*Cardamine* spp.
Blister rust	*Cronartium* sp.
Carpenter ants	*Camponotus* spp.
Cheatgrass	*Bromus tectorum*
Dalmatian toadflax	*Linaria dalmatica* (L.) Mill.
Diffuse knapweed	*Centaurea diffusa* Lam.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Douglas-fir tussock moth	*Orgyia pseudotsugata* McDonnough
Douglas-fir beetles	*Dendroctonus pseudotsugae* Hopkins
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
Fungal pathogen	*Alternaria alternata*
Grand fir	*Abies grandis* (Dougl. ex D. Don) Lindl.
Grizzly bears	*Ursus horribilis*
Knapweeds	*Centaurea* spp.
Larch casebearer	*Coleophora laricella* Hubner
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Long-eared owl	*Asio otus*
Mountain chickadee	*Parus gambeli* Ridgway
Mountain pine beetle	*Dendroctonus ponderosae* Hopkins
Northern Spotted Owl	*Strix occidentalis caurina*
Pileated woodpecker	*Dryocopus pileatus*
Ponderosa pine	*Pinus ponderosa* Dougl. ex Laws
Purple loosestrife	*Lythrum salicaria* L.
Red-breasted nuthatch	*Sitta canadensis* L.
Rocky Mountain maple	*Acer glabrum* Torr.
Serviceberry	*Amelanchier alnifolia* Nutt.
Spotted knapweed	*Centaurea maculosa* Lam.
Spruce	*Picea* spp.
Spruce beetle	*Dendroctonus rufipennis* Kirby
Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
Tansy ragwort	*Senecio jacobaea* L.
Three-toed woodpecker	*Picoides tridactylus*
Vaux's swift	*Chaetura vauxi*
Western larch	*Larix occidentalis* Nutt.,
Western hemlock	*Tsuga heterophylla* (Raf). Sarg.
Western spruce budworm	*Choristoneura occidentalis* Freeman
Western white pine	*Pinus monticola* Dougl. ex D. Don.
White-headed woodpeckers	*Picoides albolarvatus*
Willow	*Salix* L.
Yellow starthistle	*Centaurea solstitialis* L.

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Required first steps in restoring forest and aquatic ecosystems are the immediate reduction in hazard for catastrophic loss of biodiversity, site quality, resource commodities, and improved conditions for public health. To prevent loss of future options we need to simultaneously reestablish ecosystem processes and disturbance effects that create and maintain desired sustainable ecosystems, while conserving genetic, species, community, and landscape diversity and long-term site productivity.

Keywords: Restoration, forest health, ecosystem processes, disturbance effects, ecosystem management, insects, disease, and fire hazard.

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