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Nonequilibrium Ecosystem Dynamics: Management Implications for Oregon

Institute for Natural Resources, October 13, 2008

Cover photos:
Top: Lookout Creek in the H.J. Andrews Experimental Forest in the Central Cascade Adaptive Management Area.
Bottom: The Warner Creek burn on the Willamette National Forest (in 2000).

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Executive Summary

Change is a fact of life for Oregon ecosystems, but the fact of change is not necessarily well accounted for by current management frameworks. In the most general possible sense, ecosystems are dynamic but management frameworks are static. This paper is the first step in a multi-part project that the Institute for Natural Resources (INR) is conducting for the Oregon Department of Forestry and the Department of Environmental Quality to explain this problem and examine solutions.

The project focuses on nonequilibrium ecosystem dynamics, a body of scientific research that characterizes and interprets ecosystem change. INR summarizes knowledge from this field, describes ways in which the current management framework may be inconsistent with scientific findings, and helps identify options for future management. This paper is designed to be a starting place for a dialog between policy makers, scientists, managers and others that will lead to improved policies and practices.

Nonequilibrium ecosystem dynamics understands ecosystem change to be driven by geography and climate interacting with disturbance processes including wildfires, floods, and management activities such as timber harvest and roadbuilding. Disturbances and changing environmental conditions can maintain a particular pattern of vegetation and nutrient and energy cycling or they can disrupt these patterns and establish new patterns with quite different characteristics.

Management that takes nonequilibrium ecosystem dynamics into account is focused on maintaining desired and appropriate processes at various temporal and spatial scales. Determining what is desired and appropriate depends on social values and a broad understanding of past, present and future conditions. Maintaining appropriate processes is a new approach that we call "ecosystem dynamics management." It will be a particularly useful paradigm when attempting to integrate multiple management objectives.

"Resiliency" is a central concept in the study of nonequilibrium ecosystem dynamics. Resiliency does not mean ecosystems never change. Instead, resiliency in the ecological context means that systems experience the disturbance processes that maintain desired functions and services. It is useful when implementing ecosystem dynamics management to consider the range of disturbances that historically maintained different

systems. However, contemporary land use patterns, the spread of invasive species and climate change, among other factors, mean that the past will not predict the future in many areas.

Global climate change is a critical variable to consider when planning future management. Changes to vegetation communities and ecological process in response to warming will be unpredictable. Water delivery and vegetation dynamics in Western Oregon are likely to be somewhat insulated from the impacts of climate change relative to other parts of the country. As a result, Oregon may experience as many environmental impacts from an increasing population drawn to our state's resources as we will from warming itself.

There has been little field experimentation that puts nonequilibrium ecosystem concepts into practice. This paper presents nine different case studies that may serve as models for future ecosystem dynamics management. Some of these case studies discuss actual management activities that have been implemented. For example, there has been extensive study of historical fire patterns in the Cascades, and two case studies describe efforts to emulate these disturbance patterns with timber harvest.

Other case studies discuss theoretical discussions of potential management based on the latest scientific research. One describes recent research indicating that high-quality salmon habitat is found at heterogeneous temporal and spatial scales as a function of broad-scale disturbance, i.e., large stand-replacing wildfires. Another case study describes models that have been developed to plan fuel-reduction treatments that create more resilient habitat conditions. These theoretical case studies are essentially calls to action: Future management may benefit from testing these models and methodologies in experimental management projects.

Below are brief sketches of some implications and recommendations drawn from the case studies:

- In the Oregon Coast Range, research distinguishes between "pulse" disturbances that contribute large quantities of sediment, wood and other material into streams in a relatively short period of time after a disturbance event, and "press" disturbances characterized by the chronic delivery of sediment, often from an anthropogenic source like a road system. Future management that minimizes press disturbance and emphasizes pulses of material may better provide the building blocks for future high-quality salmon habitat. As an example, timber harvest might make use of temporary roads that can be hydrologically stabilized after use, avoiding a large permanent road system that chronically contributes sediment to streams. This type of management may be particularly relevant in the context of global climate change, which will likely result in more extreme storm events and associated impacts to roads. Transportation infrastructure, i.e., culverts and bridges, should be designed to accommodate the transport of materials like woody debris.

- In the Oregon Coast Range, larger timber harvest units concentrated in one watershed rather than smaller units distributed across a number of watersheds may limit press disturbance and better emulate both pulse disturbance and historical disturbance patterns, i.e., large stand-replacing wildfire. In the course of timber management, key material delivery sites in watersheds might be "loaded" with woody debris that would subsequently be released to streams.
- Research indicates that some of the most important disturbance events, including floods and fires, occur at broad geographic and temporal scales. To account for this fact, managers might develop a system of land exchanges that helps consolidate ownership into larger blocks to facilitate ecosystem dynamics management. Diverse ownerships, however, may allow for more innovation and may be more economically sustainable, in which case policy makers and managers might develop market mechanisms (i.e., an ecosystem services market) that will facilitate better coordination of management of diverse ownerships.
- Meaningful stand-level fuel treatments as well as strategic landscape-level fuel treatments across ownerships would help create more resilient forest conditions in fire-prone forests. Fuel treatments should be integrated with the expanded use of prescribed fire and wildland fire use. Policy changes that should be considered include liability limits and smoke variances for prescribed fire and fire use.
- Changes to the Oregon Forest Practices Act, including variances for larger harvest units, and requirements for lower density plantings in fire-prone forest types, may

help managers better emulate historical disturbance and maintain more resilient forests.

- Creating economic incentives for private landowner conservation measures is an important strategy for restoring ecological processes. An integrated ecosystem services market, including a robust regional market for carbon storage and other ecosystem services, would provide more options for accomplishing the objectives of ecosystem dynamics management.

A variety of different strategies for moving forward in an ecosystem dynamics framework are analyzed, including:

- Launching a long-term conservation planning effort for Oregon.
- Creating an integrated ecosystem services market in Oregon.
- Experimenting with “regime standards” that encompass the desired characteristics of variable natural regimes in stream systems in place of static Clean Water Act standards.

Ecosystem dynamics management offers promise to better integrate environmental, social and economic objectives. Implementation of this paradigm will be challenging, though, because:

- We may lack complete information about historical ecological processes.
- The ecological processes that operate in the future may not be analogous to historical processes due to changing ecological or social conditions (i.e., global climate change and/or demographic and land use changes).
- Legal frameworks and social expectations may not allow for maintenance and/or restoration of key ecological processes (i.e., wildfire near rural residential developments).
- Key processes may operate at a large geographic scale (i.e. a river basin) managed under a variety of different ownerships with very different goals (e.g., federal forest reserves and industrial forestland).

- Key processes may operate at broad temporal scales (i.e., a 100-year flood event) that occur beyond the horizon of a typical manager's realistic planning horizon (or lifetime).
- Existing management frameworks may emphasize maintenance of point-in-time indices of ecosystem function, instead of maintenance of landscape scale, long-term processes.

Ecosystem dynamics management as described in this paper is a challenging new perspective offered in a polarized political and social context. To accomplish needed policy change, this paper suggests that scientists may help facilitate a learning environment in which science findings are integrated into policy frameworks. The following principles would guide the development of this learning environment:

- Broad participation should be solicited, including participation by businesses, private landowners, non-governmental organizations, land managers and researchers.
- We should begin with questions. A learning environment must ascertain the limits of our scientific knowledge and the social expectations of different stakeholders and frame research questions to be responsive to those variables.
- The results of research and the policy changes that follow should be a collaborative process with input from different stakeholders.

The next steps in INR's ecosystem dynamics project will be guided by these principles. We look forward to this exciting process.

Introduction

Ecosystems are dynamic. The range of influences on ecosystem change is vast and includes climate, geology, topography, plant succession, species extinction and species evolution. Disturbance—including fires, floods, insect outbreaks, windstorms, earthquakes, volcanism and the ecosystem modification that results from resource extraction—are also key influences on ecosystem change. Land management policies do not always take the dynamic nature of ecosystems into account both because we do not completely understand the influence of all of these forces, and because we do not always have good frameworks for understanding the way these influences interact over space and time.

Although we will never be able to characterize all of the challenges that will confront land managers with precision, emerging scientific knowledge of nonequilibrium ecosystem dynamics can be organized into a framework for understanding past and future variability and managing change. This paper synthesizes current knowledge of these dynamics and offers a starting point for the development of such a framework. This paper describes an "ecosystem dynamics management" paradigm that integrates other management paradigms and new science findings. This new paradigm will improve managers' ability to make decisions that positively influence ecological outcomes and sustain ecological services.

Part I of this paper introduces the fundamentals of nonequilibrium ecosystem dynamics. It introduces key themes necessary to interpret the case studies, research questions and management implications that follow. It also places ecosystem dynamics management in the context of other management worldviews. Finally, it briefly sketches features of the existing policy framework, including agencies, laws and policies. Management recommendations in Part III will refer to these features.

Part II explores nine case studies of management for nonequilibrium ecosystem dynamics. Since little or no field experimentation has been done to test many key nonequilibrium ecosystem concepts, some case studies are artificially constructed from scientific studies to illustrate key themes. In other case studies presented, the results of scientific study have been integrated into project design. Other case studies describe management activities that have been implemented, and some describe management activities where implementation has been followed by monitoring and evaluation. Each case study is accompanied by a matrix that summarizes the case study with respect to its completeness, as well as a brief discussion of barriers that may have impeded implementation of the concepts, completion of the project, or may impede future attempts at implementation of concepts. Each case study concludes with a series of questions for future research.

Part III interprets management implications of the case studies and presents preliminary and general management recommendations under four different topic areas (aquatic systems, fire and fuels management, climate change and adaptation, and system function and resilience). This section also suggests what ecosystem dynamics management might look like in the future.

Part IV reflects on potential drivers of policy change, presents seven different potential strategies for policy change, offers conclusions about the future of ecosystem dynamics management, and discusses the role of scientists in policy change.

Appendix I reviews and interprets existing literature about nonequilibrium ecosystem dynamics.

Appendix II places the implementation of the ecosystem dynamics paradigm in a social and political context, describing public opinion trends and the role of scientists in policy change.

This paper is the first step of a two-year project by the Institute for Natural Resources for the Oregon Department of Forestry (ODF) and Department of Environmental Quality (DEQ). The next phase will involve a seminar series followed by workshops that consider management implications of science findings. The final phase will be a policy workshop convening managers, scientists and others to consider how policy frameworks might be adjusted to reflect scientific knowledge of nonequilibrium ecosystem dynamics. This paper is far from a definitive study of the management implications of nonequilibrium ecosystem dynamics. Instead, it is meant to begin a dialog between policy makers, researchers, managers and others that will lead to new real world management policies and practices.

Throughout the paper, text boxes set aside from the main narrative provide vignettes to give context for the larger discussion of nonequilibrium ecosystem dynamics, expand on the concepts presented in the main text, or introduce tangential implications of nonequilibrium dynamics research. They do not necessarily need to be read as an integral part of the main text; in some cases the boxes simply hint at the broad range of possibilities offered by the field which are not addressed directly in this paper.

ECOSYSTEMS, POLICY CHANGE AND MONITORING

"The Northwest Forest Plan for federal forests made ecosystem management the foundation of forest management and reduced timber sales there by over 90% compared to the 1980s. The new forest plans for the state forests of Oregon significantly refocused management toward a greater recognition of biodiversity values. Changes to riparian policies for private lands were also made during this period via the Oregon Forest Practices Act. Although these policies were all based to a significant degree on the most current scientific information, no follow-up research was done to determine how well they might meet their individual goals in the future. It was even less clear whether or how any ecological or economic interactions among ownerships in this policy-diverse region would come into play. Until recently, our conceptual and quantitative scientific models have been inadequate to distinguish among different policy approaches in a rigorous way."

—Spies and Johnson (2007)

I. Overview of key concepts

What are nonequilibrium ecosystem dynamics?

Nonequilibrium ecosystem dynamics describe ecosystem change. Scientists and managers have interpreted ecosystem change differently at different times. An older scientific narrative about change in a forest ecosystem described the establishment of early-seral species and their replacement over time by late-seral species, culminating in a climax state that was assumed to be static and unchanging until a major disturbance event. The progression to a climax state was assumed to be predictable, and the attainment of a climax state was often an explicit management goal. Disturbances in this narrative, including fire, insects, and diseases were viewed as "un-natural" and undesirable events that disrupted the system's progression towards a climax state. This view is consistent with an older "scientific" view of management (see "Different paradigms for land management" below), in which managers attempted to optimize commodity production.

DISTURBANCE

"Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment"

—White and Pickett (1985)

This older narrative of forest change is consistent with a successional model first developed by Clements (1936), who described succession as "a predictable, directional, and stepwise progression of plant assemblages that culminates with climax."

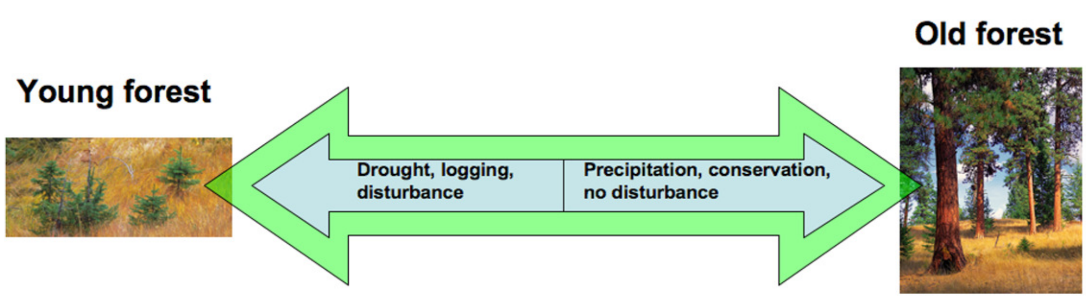

Figure 1. An older Clementsian conceptualization of vegetation succession, featuring a linear progression from young forest to old forest depending on different natural and anthropogenic pressures.

A narrative about nonequilibrium dynamics considers disturbance and disturbance variability as intrinsic properties of ecosystems. In this conception, forest communities may be relatively unchanging, or may be constantly in flux, but are rarely progressing from one condition to another in a linear and predictable fashion (Wallington *et al.* 2005). For instance, although steady tree growth and competition-induced mortality over time in a coastal Douglas fir/western hemlock forest may appear to be propelling the stand towards an eventual stable climax community, this impression is the result of limited observation. In reality, small gap disturbance, fire, insects, climate change, wind throw and other disturbance significantly alters the composition of this "climax" forest over time.

In another example, disturbances may maintain a relatively stable early or intermediate-stage of forest development, as in the high-frequency, low-severity fire regime of some ponderosa pine forests. Disequilibria may also trigger a complete shift from one type of ecosystem to another, as in the case of woody species like juniper encroaching into grassland/shrub steppes.

The study of nonequilibrium ecosystem dynamics concerns itself with the interaction between environmental variables and disturbance events and the ecological outcomes that result. These dynamics and outcomes occur at a variety of spatial and temporal scales.

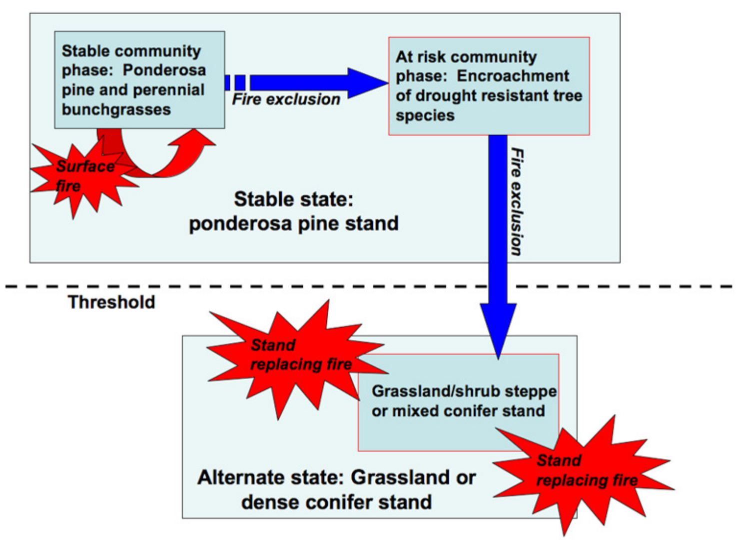

Figure 2 (previous page). A "state and transition model" that illustrates dynamic nonequilibrium ecosystem change. In this model, the stable "community phase" of a ponderosa pine and perennial bunchgrass "state" in Eastern Oregon is maintained by frequent low severity surface fire. Fire exclusion leads to the buildup of drought tolerant species (like white fir) in an "at- risk community phase." The encroachment of white fir carries fire into the forest canopy, and the ponderosa pine state crosses a threshold and transitions to a new state with high severity fire (Savage and Mast 2005; Carr 2007).

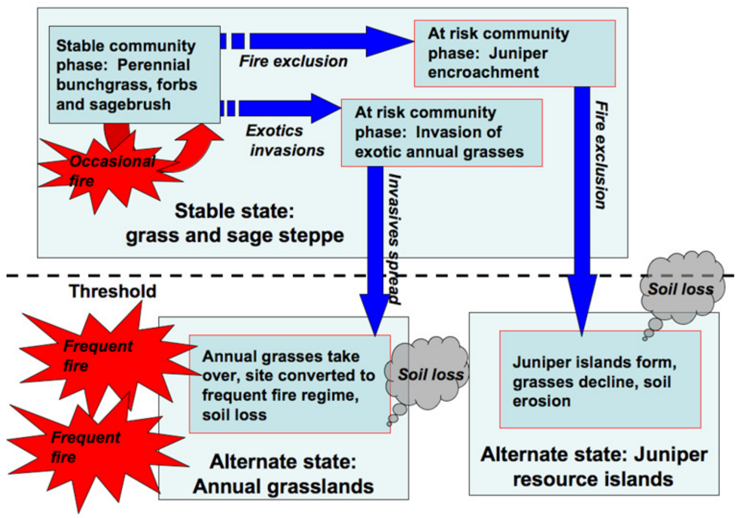

Figure 3. A state and transition model that illustrates theoretical changes to an Eastern Oregon grass/shrub land. In the stable "community phase," grass and shrub cover is maintained by periodic fire. Fire exclusion and/or grazing pressures and/or drought lead to encroachment of juniper trees. When enough trees reach a certain height, the state crosses a threshold where junipers absorb enough water and nutrients from their deep root system to "form resource islands," which deny water and nutrients to grasses and shrubs between juniper trees, leading to erosion, soil loss and site degradation in an alternate juniper resource island "state." In an alternate theoretical pathway, exotic winter annual grasses (i.e., cheatgrass or medusahead) invade the site, crossing a threshold where more frequent fire converts the site to an annual grassland "state," with significantly diminished site productivity and soil loss.

Managing from the perspective of nonequilibrium ecosystem dynamics—ecosystem dynamics management—has a number of implications:

The importance of disturbance: Management requires an understanding of the range of disturbance events possible within a particular system and within a specific geographic area and temporal scale. More importantly, it requires an understanding of how disturbance interacts with current conditions, with anthropogenic disturbance like land use patterns, with exogenous factors like climate, and with other disturbance events. Finally, management must acknowledge that some future changes are unknowable.

The importance of process: This paper explores the tension between ecosystem dynamics and current land-management policy. In many cases, this tension is a result of the fact that much land management policy focuses on achieving discrete and particularized objectives, such as maintaining water temperature suitable for salmon spawning. Nonequilibrium dynamics focus instead on maintaining a range of processes—including vegetation dynamics, climate dynamics and disturbance dynamics—that produce salmon habitat.

THE CUMULATIVE ECOLOGICAL CONSEQUENCES OF DISTURBANCE

"For saproxylic beetle assemblages, the combination of wildfire and forest harvesting (postfire salvage logging) reduced species richness and altered species composition to a greater extent than either disturbance alone. Postfire salvage logging also altered the trophic structure of the saproxylic beetle assemblage and was particularly detrimental for wood- and bark- boring species. Through a series of experiments, the abundance of one such species, *Monochamus scutellatus scutellatus*, was linked to decomposition processes in burned forests. Together, the results of these studies suggest that disturbance combinations should be avoided whenever possible because they may impact not only beetle diversity, but also decomposition processes in forests recovering from wildfire."

—Cobb (2007)

The importance of scale: Nonequilibrium dynamics requires an evaluation of variation in systems at different temporal and spatial scales. The results of observations and interpretations from study will vary depending on the scale of study and the windows of observation utilized (Wallington *et al.* 2005).

It's about relationships: Managing for nonequilibrium ecosystem dynamics requires an awareness of inter-relationships, and an integrated understanding of how various influences drive ecosystem function. One example is the relationship between climate, disturbance, forest fuels, and water delivery. These factors are dots that must be analyzed, monitored and connected with other dots as well as with other relevant features of multiple systems, such as human land use, to create integrated solutions to complex problems (see Figure 4).

Integrate multiple frameworks: Management in a nonequilibrium ecosystem dynamics paradigm requires a thoughtful integration of ecological realities, social expectations and policy frameworks. There are significant problems inherent in synchronizing policy frameworks with the dynamic functioning of natural systems. There are also difficulties integrating the work of different scientific disciplines into a coherent holistic model of ecosystem change. Figure 4 is a snapshot of a subset of ecological dynamics, management decisions and expected outcomes.

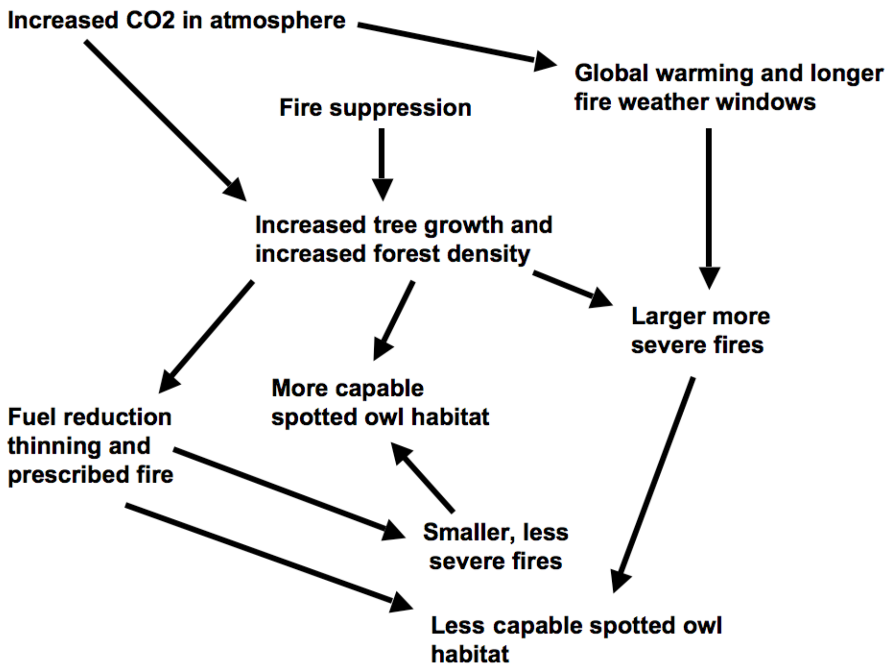

Figure 4. Postulated dynamic interaction of global warming, fuels, fire, management action and spotted owl habitat on the east slope of the Cascades.

A NONEQUILIBRIUM ECOSYSTEM DYNAMICS VIEW OF OLD-GROWTH FORESTS

Our emerging knowledge of nonequilibrium ecosystem dynamics may help inform and clarify (or further confuse!) problems of definition, for instance, how to define old growth forests. The Oregon Department of Forestry's Federal Forest Advisory Committee is developing a definition of old growth (see FFAC Potential Solutions Older Forests v. 4.0, 4/1/2008) that describes old growth as a climax community. However, we are coming to understand that many, if not most, "old growth" stands in Oregon, including many Douglas fir/western hemlock stands, are not true climax communities (although they may be quite old). Indeed, the dominant overstory trees in most old growth ponderosa pine and Douglas fir stands are ponderosa pine and Douglas fir respectively, both of which are not climax tree species (climax species for these forest types would be white fir and western hemlock respectively). In ponderosa pine stands, old growth is a sub-climax community maintained by a frequent negative feedback in the form of fire. Oregon State University (OSU) research has found that even moist Douglas fir forests in the Cascades may experience non-standing replacing fire relatively frequently, which creates a younger, understory age cohort that contributes to the unique structural complexity of this forest type (Tepley 2008).

The range of variability

Since species assemblages and ecological processes are assumed to be adapted to the disturbance regimes typical of their geographic ranges, an important strategy for managing change in an ecosystem dynamics paradigm is to attempt to maintain or restore a landscape so that it experiences the range of disturbance that was historically present on that site (Swanson 2008). This approach—relating current landscape conditions to the variety of known past conditions—involves characterizing the "historical range of variability (HRV)." Both the Oregon Department of Forestry and the US Forest Service have used the HRV concept in developing landscape management plans (ODF 2001; FEMAT 1993). Swanson (2008) offers a comprehensive review of the history and uses of HRV. His key conclusions are summarized below:

Disturbance processes are key: Disturbance such as wildfire and sediment delivery from floods or landslides may strongly influence the species that are present on a site. Different species assemblages, in turn, can have an important role in influencing ecological processes including nutrient cycling. These relationships can be thought of as "keystone" ecological processes.

Use as a planning tool: The historical range of variability may provide a framework for land management planning, as when timber harvest plans are designed to maintain different age classes or distribution of habitat blocks in proportion to the historical conditions present on that site.

Terminology problems exist: A variety of different terminologies are used to describe past conditions. These terms, including, "natural range of variability," "reference period," "reference conditions," "reference variation," etc., may not be strictly synonymous with "historical range of variability." Historical range of variability is necessarily limited to the historical period managers have accurate information about, and may vary from site to site.

Some disturbances are overlooked: HRV analysis may focus on relatively well-understood disturbances, like wildfire, and may neglect important but less well understood ecological processes like insect outbreaks and wind and ice storms (Haeussler 2003). These different disturbance processes have different responses to management practices and, therefore, different implications for future management that retains their role in ecosystem dynamics at desirable levels.

Limited knowledge may constrain management: Restoration of the historical range of variability may be constrained by an incomplete record of the historical conditions of multiple systems, and also by the different spatial and temporal scales considered. The area being managed might be smaller than the size of historical disturbance like wildfire (for instance, because of mixed ownership patterns). Or the area being managed might be larger than the area for which managers have reliable information about past conditions. Historical conditions considered at long, millennial scales might be quite complex and variable, or uncertain.

Need wide range of management options to account for variation: As we learn more about historical conditions and ecological processes, disturbance histories invariably become more complex. Management for historical range of variability, then, should include a wide range of management options to account for variation that may not be understood through contemporary perspectives on historical disturbance.

Use of HRV varies in practice: A number of international and federal land management policies make use of HRV concepts to various degrees, including the Healthy Forest Restoration Act, draft revisions to the National Forest Management Act, the US Forest Service Manual, various Canadian statutes and the Montreal Process of the UN Conference on Environment and Development. Older federal land management statutes, including the Organic Act and the Oregon and California Railroad Act, and many State of Oregon policies, such as some policies required by the Oregon Constitution, fail to incorporate HRV concepts.

HRV is inappropriate in many cases: Use of the historical range of variability to plan future management may be inappropriate in cases where reintroducing historical disturbance may create different outcomes because of alterations to landscapes from climate change, land use, or other factors. The only historical record that is available may not accurately predict future trends (Millar and Woolfenden 1999). Some researchers question whether the historical range of variability should serve as an environmental baseline given the extent of nonnative species invasion, climate change, air pollution and other environmental changes (Kimmins 2004).

Monitoring and analysis of HRV management is essential: Tracking the multiple systems in which disturbance operates over time can help build a record of the range of variability on different sites. Quantitative comparisons of these monitored inputs can be used to reduce uncertainty in our understanding of ecosystem dynamics and the historic range of variability. Collecting data over long periods of time will continue to reduce uncertainty because this temporal grain encompasses a greater range of variability.

It is important during this discussion of the historical range of variability to note a potential trade-off between ecosystem dynamics management using the historical range of variability concept and species conservation management. Although management for the historical range of variability may restore the landscape patterns that support species biodiversity and ecological processes, natural and expected fluxes may disrupt habitat. Species conservation measures like the Endangered Species Act attempt to maintain high quality endangered species habitat in a static condition, or even to manage sites so that they deviate from the historical range of variability to ameliorate point-in-time risks to species. This trade-off illustrates a central problem with contemporary natural resource management: *Current land use has disrupted landscape patterns that support landscape-level processes*. This problem weighs against total reliance on the historical range of variability in many if not most situations.

Problems with use of HRV to plan management may be at least partially remedied by adoption of recommendations by Johnson and Duncan (2008), who suggest that social

HISTORICAL RANGE OF VARIABILITY

"The estimated range of some ecological condition or process that occurred in the past. This is often expressed as a probability distribution of likely states. Historically, this range of variability denotes a dynamic set of boundaries between which most native biodiversity variables have persisted – with fluctuations – through time and across space."

FUTURE RANGE OF VARIABILITY

"The estimated range of some ecological condition or process that may occur in the future---a dynamic set of boundaries on some condition or process that may occur in the future. In the work of Duncan, *et al.* (2007), the FRV is expressed as a probability distribution of likely states."

SOCIAL RANGE OF VARIABILITY

"The range of an ecological condition that society finds acceptable at a given time. In the work of Duncan, *et al.* (2007), the SRV is expressed as a distribution of public acceptance."

—Johnson and Duncan (2008)

expectations can be extrapolated to a "social range of variability," and recommend development of a "future range of variability" to account for climate change, habitat fragmentation, invasive species and insect dynamics.[1] In using the future range of variability approach managers would establish what portion of the historical record is available and relevant and essentially strike a compromise between the existing historical record, uncertainties about the historical record, and desired future conditions.

Resilience

"Resilience" is one goal for Oregon's ecosystems that is suggested by our knowledge of nonequilibrium ecosystem dynamics. Resilience implies the "persistence of relationships within a system and is a measure of the ability of these systems to absorb change… and still persist" (Holling 1973). Peterson *et al.* (1998) suggest measuring resilience in terms of the change or disruption that is required to transform an ecological state from one that is maintained by mutually reinforcing processes to another state maintained by different processes (see Figures 3 and 4). Holling and Meffe (1996) propose a management Golden Rule: "Strive to retain critical types and ranges of natural variation in resource systems in order to maintain their resiliency." Utilizing this rule, if a particular ecological state, i.e., an open conifer stand with a well-established grass understory as shown in Figure 3, is desired then the ecological processes that perpetuate this structure, notably frequent fire, should be maintained by managers.

It is important to note that creating resiliency does not necessarily mean limiting large or severe disturbance events, but rather managing for a scale and intensity of disturbance to which different systems are adapted. Cool, moist high elevation true fir and spruce associations in Eastern Oregon are likely adapted to large, severe fires. This forest type is still resilient despite severe disturbance because overtime a similar forest structure and composition, as well as similar ecological processes, emerges. Other forest types in Eastern Oregon, such as lower elevation ponderosa pine, are likely not as well

[1] Shindler *et al.* 2002 examine the "social acceptability" concept, identifying ten key problem areas for forest management and practices on federal lands, and offer five basic strategies to help managers implement solutions. Social acceptability in natural resources decision-making is discussed comprehensively in Appendix 2.

adapted to large, severe fires and this forest type should not be considered resilient if readily susceptible to this type of disturbance.

A coastal Oregon stream may be adapted to a large storm event that inundates the system with sediment and debris and should be considered resilient to the extent that such a storm event is an integral part of long-term, large scale processes that create desired stream conditions. A similar stream system in which ecological function and processes have already been compromised by chronic sedimentation, extensive upland forest conversion, and a hydrologically unstable road system may suffer compounding cumulative ecological impacts as a result of a large storm event and should not necessarily be considered resilient.

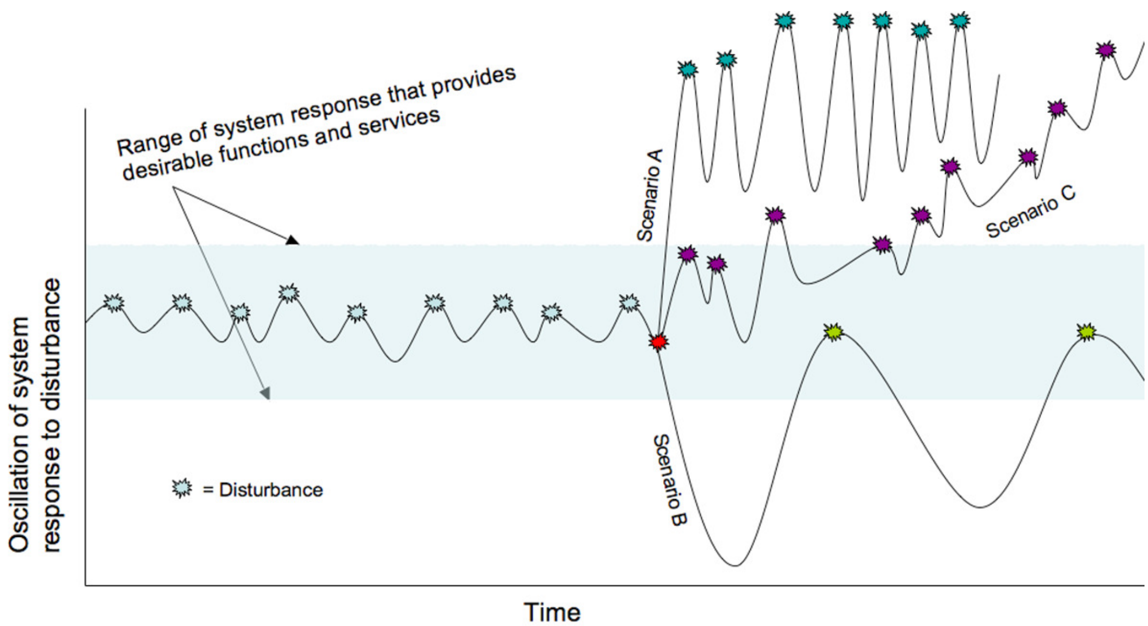

Figure 5. Hypothetical representation of changes to system resilience in response to disturbance over time. A resilient system experiences disturbances at various points in time that drive oscillations in system response that are always within a range that provides desirable functions and services. At a certain point, the system experiences a disturbance event that is unusual in severity, extent, timing or duration and new potential patterns of system response are possible. In Scenario A, disturbance becomes frequent and regular with greater amplitude in system response. Although this new pattern appears to be predictable and resilient, system response is always outside the desired range. In Scenario B, disturbance becomes less frequent. This new pattern also appears to be predictable and resilient within the timeframe considered, with system response sometimes within the desired range. In Scenario C, system response is within the desired range for a period of time, but the pattern of disturbance and system response appears unstable and not resilient into the future.

Management goals for the built environment

Most of Oregon is not managed exclusively to maintain ecological processes—economic objectives drive management of many landscapes. An increasingly significant portion of Oregon's forested landscape can be characterized as a rural-residential environment, where forestland is intermixed with low-density urban or rural residential areas. The conversion of industrial forestlands to low-density urban and rural housing is likely to increase. Currently more than half of Oregon's family forestland owners are over the age of 65, and much of their land is likely to change hands and be developed for other purposes (ODF 2007).

Photo 1. An aerial view of the built environment: A typical mix of farmland, family forestland, rural housing and industrial forestland in the Coast Range foothills west of Salem.

Continued development of these forestlands has a number of environmental and social consequences, including habitat fragmentation, degradation of water quality and increased risk of fire ignition. For instance, the continued residential development of forestland has the potential to significantly increase fire risk and suppression costs. Currently, costs to suppress fires in areas with housing developments are 50 percent greater than in wildlands or industrial forestland (ODF 2007).

The discussion in the previous section placed resiliency in an ecological context—maintaining and restoring ecosystems so that they experience disturbance patterns characteristic of that system. This may not be a realistic goal in the rural-residential built environment that increasingly characterizes Oregon's forestland. Instead, managers should emphasize ecological outcomes that are compatible with social realities, for instance by accommodating housing and associated infrastructure while maintaining water quality, reducing fire risk to structures, and maintaining biodiversity by connecting habitat, reducing the spread of invasive species and protecting critical refugia.

Part IV describes the "policy tool ladder," which distinguishes between incentive-based and regulatory policy tools. The built environment is most often private land, and incentive-based tools to promote resiliency in social contexts may be most appropriate. Wildlands are often state or federally owned land where management plans may be adapted to promote ecological resiliency.

Different paradigms for land management

How would ecosystem dynamics management—a management framework that incorporates knowledge of nonequilibrium ecosystem dynamics—fit into other paradigms for forest management? Johnson (2007) describes the rise of four forest management paradigms over time: the scientific, economic, ecological and social forestry paradigms. Examining these paradigms serves to illustrate what influences contribute to different laws and policies, and how these influences may shift, leading to adoption of a new paradigm.

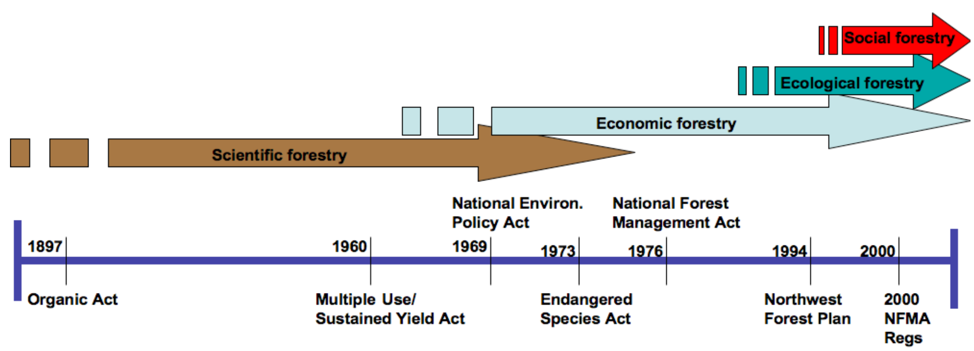

Figure 6. Timeline for the use of different forest management paradigms on federal lands.

The "scientific forestry" paradigm emphasizes the use of classical scientific tools such as economics and silviculture to achieve a sustained yield of timber that does not permanently impair other values of the forest.[2] This paradigm is also known as the "agronomic" model of forestry, because it tends to view forests as a crop, designed to produce a sustainable commodity, but not necessarily to maintain species diversity or ecological processes besides those necessary to perpetuate a working forest. Accurate

[2] In its time (1900s), "scientific" forestry concepts were developed at professional forestry schools associated with universities in the United States and Europe. These concepts made use of the "science" of their day, not the range of scientific disciplines brought to bear on contemporary management problems. In today's terminology might better be described as "sustained yield forestry."

estimates of forest productivity is the primary information base based needed to implement this model. This view of forestry dates back to the end of the 19th Century, and it is the model under which all of Oregon's forests were managed until the 1960s. This management paradigm persists on most private industrial lands (Johnson 2007). Key objectives and values of scientific forestry include: "Sustained yield," "economic development," and "forest productivity."

The rise of economic forestry can be traced to controversy over the sustained yield principle on federal forests. This model emphasizes the maximization of net benefits to society from forest management. The economic forestry paradigm relies on calculations of costs and benefits. Different management alternatives responsive to different costs and opportunities are typically developed to delineate tradeoffs. To implement this model, foresters began to rely on sophisticated planning tools, such as FORPLAN, a "linear programming model that enabled quantitative analysis of the consequences of various planning assumptions" (Johnson 2007). This model is related to the scientific forestry model, but it differs in that it recognizes other goals and provides analytic tools that allow comparison of different management regimes. Forest management under this paradigm is often explicitly linked to overarching state, regional, or national management mandates. One example of this paradigm is management of State Common School Lands, which, under the Oregon Constitution are to "obtain the greatest benefit for the people of this state, consistent with the conservation of this resource under sound techniques of land management." Key values of economic forestry include: "Efficiency," "planning," "maximizing net benefits," and "economic analysis."

The National Forest Management Act, passed by the US Congress in 1976, epitomized the economic forestry model. Although designed primarily to codify economic planning on national forests, the Act's provisions also require the maintenance of viable populations of species. This "viability" requirement ultimately led to legal injunctions against logging habitat for different species—most famously the northern spotted owl. Accommodating pressures to protect non-economic forest values led to the rise of "ecological forestry," which emphasizes scientifically credible forest management plans that make species protection a primary goal. The Northwest Forest Plan, implemented in 1994, is one of the most visible examples of this model of forest management. Key values of ecological forestry include: “the precautionary principle,” “species conservation,” and “habitat protection.”

Scientific, economic and ecological forestry all rest on the premise that management decisions should be, and are, made rationally and informed by technical expertise. Theorists and practitioners have questioned this view, suggesting instead that modern management decisions are and should be informed by a social context, and that local communities should be important actors in management. One example of this “social forestry” concept in practice is the work of the “Quincy Library Group,” a collaboration of diverse forest stakeholders in Northern California that crafted a compromise forest management plan for northern Sierra Nevada National Forests in 1993. Key values of social forestry include: “Community involvement,” “collaboration, “accountability,” and “social acceptability.”

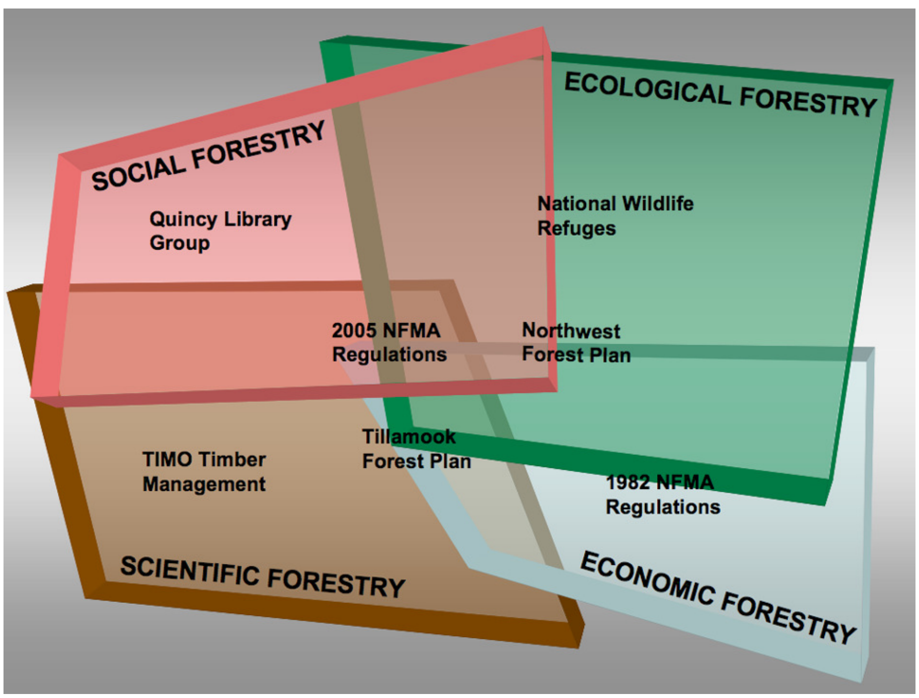

Figure 7. Postulated distribution of various land management strategies among Johnson forestry typologies.

An ecosystem dynamics management paradigm has some elements of ecological forestry in that it relies heavily on the ecological sciences. It differs from this paradigm in that it does not necessarily emphasize the perpetuation of a particular type of forest structure in a static state within particular geographic boundaries over time (i.e., a

Northwest Forest Plan Late Successional Reserve), but emphasizes maintaining the ecological processes that underlie the development and perpetuation of that structure. A reality of management, as noted above, is the built environment, and ecosystem dynamics forestry should place management in the context of the needs and expectations of society, as social forestry does. Key values of ecosystem dynamics forestry include: "Processes," "interactions," "disturbance," "range of variability," and "appropriateness."

Global climate change and Oregon

Any discussion of ecosystem dynamics management must be placed within the context of global climate change. Oregon's climate has undergone dramatic changes during the Holocene (the past 10,000 years), and it is possible if not likely that current climate trends will equal or exceed the most dramatic fluctuations experienced during this period. If dramatic changes do occur, then many key engineering and planning assumptions may be invalid. For instance, many management efforts are planned to accommodate a 100-year disturbance event (i.e., a flood). Dramatic climate change may produce events of even greater magnitude within a shorter time frame. Many planning assumptions may have to be revised accordingly.

In the most basic sense, the implication of climate change is that managers may not be able to depend on what they previously believed to be predictable environmental variance. The growth yields of forests may be greater because of increased CO^2 in the atmosphere, or they may be much less because of more frequent and severe disturbance (or both at different spatial and temporal scales). Changing ocean conditions may have dramatic impacts on salmon runs, which historically played an important role in nutrient cycling in Oregon forests. These are just a few examples of the fundamental uncertainty as to how climate change will affect the interaction of environmental variables.

There has been extensive literature published about some of the likely effects of global climate change on ecosystems. The best single reference about climate change as it relates to Oregon forests is "Forests, Carbon and Climate Change: A Synthesis of Science Findings" (Oregon Forests Resources Institute 2006). Several important points should be made here about climate change to frame the discussions that follow.

First, changes in vegetation communities from climate change will be difficult to predict accurately. Vegetation communities may not simply shift intact to northern latitudes or higher elevations in response to increasing temperatures or altered precipitation patterns. Instead, communities are likely to disaggregate and reassemble into different species assemblages at highly variable temporal and spatial scales. This has critical significance for, among other things, development of reserve strategies for sensitive or endangered species. Habitat for different species might not simply shift; it may be fundamentally reconstituted, with certain species that previously did not co-exist forced into the same habitat, and other species that previously existed together living in different areas. New keystone ecological processes may emerge and others may disappear. This is due in part to multiple changes (i.e., disturbance and land use change) that can be expected to occur concurrently with climate change, and in part to different responses by various species to changes in climate. Detailed mapping and modeling will be necessary to plan for, mitigate, and monitor these changes.

Second, parts of Oregon may be relatively insulated or buffered from changes wrought by global climate change compared to other parts of the country. The climactic and hydrologic influence of the Pacific Ocean, as well as the unique water holding and delivery characteristics of the Cascade Range will tend to moderate the effects of climate change in Western and Central Oregon (Jefferson *et al.,* in press). Long-term observations of climate and ecological processes at the H.J. Andrews Experimental Forest in the middle Cascades currently show few measurable effects from climate change.

Third, changes to vegetation structure, composition and function that occur in the future may be abrupt rather than gradual, and will likely be brought about by disturbance, such as more severe wildfire that results from longer fire weather windows, insect infestation caused by warmer winters, or by the spread of warm-weather invasive species.

Fourth, the fact that parts of Oregon may experience less severe impacts from climate change than other parts of the country means that pressure on resources from dramatically increasing populations may actually outstrip the impacts on water, timber, and wildlife by changing climate. Dramatic demographic changes ("climate refugees") may be the major challenge posed by climate change in Oregon.

Protecting species and habitat

The field of non-equilibrium ecosystem dynamics holds important implications for biodiversity management. The habitat characteristics of distinct geographic areas set aside as reserves to conserve a particular species or assemblage of species cannot be expected to remain static over time. As forests grow and disturbances occur, different successional stages will replace the habitat type currently occupying a particular site (Hobbs 2004 and Wallington 2005). Attempting to maintain forests in a static condition in many cases implies excluding the disturbance processes that are needed to sustain desired conditions. There may be a range of unintended consequences resulting from excluding disturbance. The most obvious examples of unintended consequences from excluding disturbance in Oregon are changes in fuel structure and uncharacteristically severe wildfires.

Many forested systems historically experienced large oscillations in age structure and mortality. Managers may seek an "optimal" landscape pattern or structure (e.g., an "old-growth" condition), but a single landscape pattern or structure may not be ideal for all of the species that we associate with that forest type (Haeussler and Kneeshaw 2003). Furthermore, as noted above, vegetation communities and species assemblages can be expected to disaggregate and reassemble at highly variable temporal and spatial scales in response to climate change. The particular habitat type being managed for—and the species and ecological processes associated with that habitat—may not persist over time.

Two alternate strategies to replace the static reserve strategy are suggested: First, manage static reserves that are adequately large and connected to maintain suitable habitat irrespective of foreseeable future habitat shifts. This is unlikely to be feasible for all species of concern to managers. Second, manage reserves that shift over the landscape over time in response to environmental change. The second strategy may require close integration of the goals and practices of private and public land managers. The second strategy is also likely to require a far more sophisticated and robust adaptive management approach than has ever been practiced (for a discussion of an integrated approach to inventory, monitoring, research, and adaptive management see Halvorson 2004).

The policy environment

Planning objectives must conform to overlapping jurisdictional prerogatives of numerous land management agencies. The table below summarizes some of the important state natural resource agencies in Oregon and their roles.

Agency	Role
Department of Environmental Quality	Administers requirements of federal Clean Air Act, Clean Water Act, and Resource Conservation and Recovery Act; regulates air quality, water quality, and hazardous and solid waste
Dept. of Human Services	Regulates drinking water
Dept. of Water Resources	Regulates water rights and quantity
Dept. of State Lands	Regulates the removal or fill of material into waters of the state, including wetlands. Manages state lands.
Dept. of Agriculture	Regulates agricultural water quality; regulates pesticides under FIFRA
Dept. of Land Conservation and Development	Creates and implements comprehensive land planning; administers Coastal Zone Management Act
Dept. of Forestry	Regulates Forest Practices and manages state forests
Dept. of Fish and Wildlife	Manages fish and wildlife, including endangered species; regulates fish and wildlife harvest; conserves habitat.
Watershed Enhancement Board	Allocates grants for watershed restoration
Lane County Regional Air Protection Agency	Regulates Lane County air quality
County and municipal governments	Promulgate regulations and ordinances, including planning and zoning ordinances, that encourage or prohibit certain types of land management

The next table summarizes important federal agencies that manage or regulate Oregon lands:

Agency	Role
USDA Forest Service	Manages national forests and administers grants to state and private foresters
Bureau of Land Management	Manages public lands, including O&C Lands
US Fish and Wildlife Service	Manages wildlife refuges, administers the Endangered Species Act for terrestrial species and inland fish species
National Oceanic and Atmospheric Administration	Administers the Endangered Species Act for anadromous fish species
Bureau of Indian Affairs	Manages Indian reservations in conjunction with Tribes.
Environmental Protection Agency	Administers federal pollution control laws settings standards for a variety of environmental programs, enforcing federal environmental protection statutes, and administers grants to states, counties and cities.
US Army Corps of Engineers	Maintains and manages structures such as flood control facilities and permits wetland fill under the Clean Water Act.

Some major state and federal statutes that affect state agency land management in Oregon include:[3]

[3] There is an extensive suite of laws and regulations that govern management of federal lands in Oregon, which are not enumerated here in the interests of brevity. Some of the most relevant laws (or at least those most frequently invoked in environmental litigation) include: The National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the National Forest Management Act (NFMA), the Federal Land Management Planning Act (FLMPA), the Clean Water Act (CWA), the Clean Air Act (CCA) the Administrative Procedures Act (APA), the Appeals Reform Act (ARA), the Wilderness Act, and the Wild and Scenic Rivers Act (WSRA).

Statute	Requirements
Oregon Forest Practices Act	Requires reforestation, protection of sensitive and endangered species and scenic resources; regulates road and chemical use
Endangered Species Act	Conserves and recovers listed species
Clean Water Act	Establishes and enforces water quality standards; creates Total Maximum Daily Load Plans to restore degraded waterways; prohibits un-permitted discharges of pollutants in waterways.
Land Conservation and Development Act of 1973	Requires cities and counties to prepare comprehensive land use plans consistent with statewide goals.
Chapter 468B – Water Quality	Oregon Revised Statute that regulates waters of the state (surface and groundwater).

This last table summarizes interests groups that, in addition to state, federal and local agencies, are frequently engaged in natural resource management issues.

Interest group	Position
Industry and property-rights groups (e.g., Farm Bureau, American Forest Resources Council)	Favor maintaining or increasing development of natural resources; emphasize private property rights
Conservation groups (e.g., Oregon Wild and the Sierra Club)	Favor maintaining or increasing environmental protections
Local governments (e.g., county commissions, school boards, municipalities)	Advocate for stable funding from federal and state forest lands to fund local government services
Indian tribes	Advocate for access to natural resources guaranteed by treaty

Proposals to change natural resource management are the purview of combinations of these agencies—subsystems of the larger system of governance. These subsystems are frequently somewhat insulated from that larger system. The concept of subsystems will be returned to in the discussion of policy change in Part IV.

To illustrate the interactions of different policy actors, the policy subsystem that makes decisions about how Forest Service timber sales comport with Endangered Species Act requirements is shown in Figure 8.

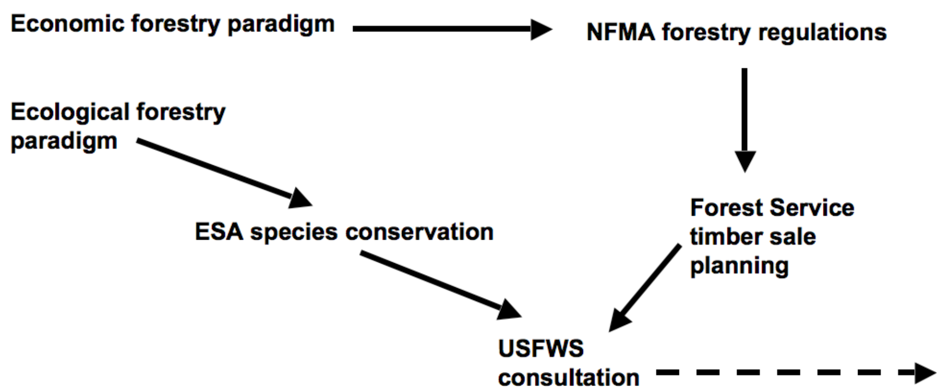

Figure 8. A postulated Endangered Species Act (ESA) consultation policy subsystem. The dotted line below and to the right represents a potential decision. It may be helpful for the reader to imagine this arrow pointing towards the "fuel reduction thinning and prescribed fire" caption in Figure 4 to help conceptualize the relationship between the policy realm and ecosystem dynamics. What ecological outcomes could potentially flow from the economic forestry paradigm? What outcomes flow from the ecological forestry paradigm? How might an ecosystem dynamics paradigm lead to a different result than either of the above?

II. Case studies and management questions

The following selection of case studies describes actual or potential implementation of ecosystem dynamics research. Some of them—such as the first case study of management of aquatic systems—are nothing more than a synthesis and interpretation of important research about ecosystem dynamics management that should inform future management. Other case studies, such as the Blue River Landscape Plan and Study, the Dinner timber sale, and the Five Rivers project provide a summary of actual land management practices based on ecosystem dynamics principles. They also describe the usefulness of these practices for planning future management.

Other case studies, such as the discussions of Oregon's response to climate change, fire management strategies, and distribution of salmon habitat are meant to describe how ecosystem dynamics research is relevant to important contemporary management issues. And finally, the discussions of CLAMS and fuel management in southern Oregon are meant to emphasize technologies that can be brought to bear on future ecosystems dynamics management.

All of these case studies emphasize both the importance of restoring disturbance dynamics to which different systems are adapted, and the necessity of broad-scale spatial and temporal analysis when planning management.

Case study #1: Management of aquatic systems

This case study relies solely on scientific concepts and research, and presents key findings about aquatic processes that should be tested with field experimentation.

The health of our waterways is of immense ecological and emotional significance to Oregonians. To observe a once cold and clear salmon-spawning stream running chocolate brown with sediment from a landslide or slope failure offends our sense of what watershed health and productivity should look like. The legal and policy framework for managing Oregon's waterways reflects this value judgment. The suite of laws and regulations governing water management generally focus on protecting uplands and preventing waterways from exceeding thresholds for sediment, turbidity, temperature and other static indices that define “good” water quality. However, our emerging understanding of nonequilibrium stream dynamics may make these assumptions inaccurate, or at least incomplete.

The work of Gordie Reeves and others describes the dynamic role that disturbance plays in stream function by influencing sediment regimes, wood contribution, channel morphology, and pool and channel ratios. Disturbance may act at highly variable temporal and spatial scales, especially in steep, forested landscapes with erodible soils that experience periodic, large-scale, severe wildfire (such as Coast Range forests). Periods of relative stability in stream function and upland vegetation structure may be punctuated by large pulses of sediment and woody debris after disturbance events like stand-replacing fire that are followed by large winter or spring storms. On a broad, landscape-level scale, disturbance creates a mosaic of different stream conditions over a long period (Poff *et al.* 1997 and Benda *et al.* 2004).

Although mental images of pristine streams providing cool, clean water and good salmon habitat define the ideal for most Oregonians, in reality these conditions are not persistent or unchanging. Reeves *et al.* (1995) describe how episodic disturbance creates differential habitat for salmon. One of his unpublished studies estimates that historically 30-60 percent of 7th field watersheds in the central Oregon Coast Range may have provided good salmon habitat. His modeling indicates that intermediate-aged forests (120-160 years old), not very old or very young forests, may provide the most productive and diverse fish habitat.

Our emerging understanding of the variability inherent in healthy stream systems may be conceptually inconsistent with management for static forest structure. There are several specific examples of the latter paradigm:

- The Northwest Forest Plan is built around a static system of reserves, with a desired future condition for riparian areas dominated by late-successional forests.
- The Oregon Forest Practices Act promotes mature tree cover on fish-bearing streams through time.
- The Oregon Watershed Enhancement Board’s Watershed Assessment Manual, which watershed councils use to assess restoration needs, tends to enforce static conceptions of aquatic conditions (Reeves and Duncan 2008).

- The Clean Water Act requires waterways to meet a given standard for sediment, turbidity and temperature at all points in time. This does not capture the range of aquatic conditions that occurred historically, or which will occur in the future (Reeves and Duncan 2008).

NONEQUILIBRIUM ECOYSTEM DYNAMICS LESSONS NOT APPLIED TO AQUATIC SYSTEMS

"We've tried to apply lessons in the terrestrial ecosystems, but we haven't been able to draw firm conclusions. On the aquatic front, the ball never really got into play. The concept was out there, but there was no implementation."

—Gordie Reeves (on the Northwest Forest Plan)

An important concept that will be returned to later in this paper is the difference between a "press" and a "pulse" disturbance. A "pulse" disturbance dynamic describes a stochastic event, for instance, a large pulse of sediment into a stream system after large stand-replacing wildfire. A "press" disturbance dynamic describes constant, often low-level disturbance, for instance, the constant contribution of sediment to a stream system from a road crossing. These different dynamics have very different effects on aquatic systems. Aquatic organisms and processes may be well adapted to the former type of dynamic, but not the latter (Reeves *et al.* 1995).

All case studies in this paper are characterized with respect to the development of theoretical concepts that could guide future implementation, whether land management projects have been designed, whether projects have been implemented, the extent to which monitoring and evaluation of project activities have taken place, and whether there is an active research-management partnership in place to accomplish adaptive management objectives. This investigation of the management of aquatic systems under a dynamics based management paradigm is theoretical at present.

In all case studies analyzed, the lack of funding for monitoring to support the adaptive management process is a major institutional barrier.

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓				

Barriers to further development/application of concepts:

- There has been little effort to integrate principles of nonequilibrium dynamics at a landscape level in field experimentation or management of stream systems. With the exception of a few projects, like the Five Rivers Project discussed below, there appears to be little coordination between land managers and researchers to test or implement key concepts, and little funding for this type of work.
- The Endangered Species Act, Clean Water Act, Oregon Forest Practices Act, and other laws, policies and regulations may all be obstacles to dynamic rather than static thresholds for stream quality. Departing from static threshold measurements for stream quality, such as sediment and turbidity limits, may be controversial. It may also be undesirable to the extent that excess turbidity could impact municipal water treatment plants and disrupt the availability of drinking water.

Strengths of existing research:

- Scientific research provides an intellectually and practically challenging perspective!

Information needs and hypotheses to be tested with further research:

- The appropriate temporal and spatial scale of riparian reserves and upland reserves needs to be established for different watersheds. The feasibility of a shifting mosaic of reserves that change location in response to the ability of specific watersheds to provide suitable habitat for endangered fish and other species over the long term should be evaluated. What size, distribution and configuration of high quality aquatic habitat capable of supporting landscape-level disturbance are needed?

- Alternative timber harvest models that distribute harvest to account for the historical tendency of some stream systems (i.e., coastal Oregon streams) to experience large stand-replacing disturbance should be developed.
- The different mechanisms for recruiting large wood, gravel, sediment and other inputs should be modeled and analyzed. This case study indicates that many stream systems may be better adapted to large "pulses" of material rather than piecemeal large wood placement. Should we re-evaluate instream restoration strategies accordingly? How can we manage for large-scale disturbance that recruits larger amounts of material over larger areas in relatively short periods of time? Could green tree and coarse woody debris retention in regeneration harvest be used to emulate woody biomass that is left behind by wildfires (as in the Blue River adaptive management described in case study #4)? What fire and post-fire management can promote the type of recruitment to which different stream environments are adapted?
- Different road system design and utilization should be analyzed. For instance, the efficacy of emphasizing temporary roads that may create a "pulse" of sediment during harvest operations over permanent roads that create a "press" of sediment input over long periods could be studied.[4]

Case study #2: Fuel reduction in Southern Oregon

Fire is a key disturbance process, and this case study describes management tools that have been developed to optimize fuel-reduction thinning, a management activity that can potentially restore historical fire patterns.

Fire management is one of the most controversial and important topics in forestry. There is broad appreciation in the scientific community that fire plays a key role in mediating forest ecosystem processes and functions, and that a decades-long history of fire-suppression has disrupted many of these processes and functions. One manifestation of fire-suppression is thought to be increased tree density and biomass accumulation in

[4] Luce and Black (1999) reported that vegetated inboard drainage ditches and cut slopes reduced sediment production by about 7 times compared with cut slopes and ditches cleared of vegetation by road maintenance in the Oregon Coast Range.

some forest types, as well as increasing prevalence of shade-tolerant conifer species in the understory of early-seral stands (i.e., white fir in pure ponderosa and mixed conifer stands). In low-and mixed-severity fire regimes, fire-suppression is thought to have led to increasingly large and severe fires throughout the American West in recent decades.

THE BISCUIT FIRE

The Biscuit fire in the Siskiyou National Forest in Southern Oregon burned within a 499,000-acre fire perimeter and cost approximately $150 million in suppression efforts (GAO 2004), making it one of the largest and easily the costliest fire in the state's history. Bernard Bormann and a team of investigators working for the National Commission on Science for Sustainable Forestry conducted a sophisticated remote sensing study of Biscuit fire patterns and reached interesting and sometimes surprising conclusions, including: 1) Thinning alone may not reduce fire damage to mature trees and that thinning and underburning are both required to adequately reduce fuels; 2) unmanaged stands subject to fire-suppression in the Klamath-Siskiyou region may not necessarily burn severely; 3) intense fires driven by finer material, and large amounts of downed woody debris are not necessarily a predictor of fire severity; and, 4) hardwoods may actually help reduce fire damage to conifers (Bormann *et al*. 2006).

Some question remains as to whether fuel structure or climate play a decisive role in large fire events (Westerling et al. 2006), but it is probably safe to say that both play an important and inter-related role. (There is important geographic variation in terms of warming influence on the extent and duration of large fire events across the West—Westerling shows that climate warming influence on fire behavior in the Pacific Northwest is weak relative to some other parts of the West.) Treatments to remove fuels both mechanically and with prescribed fire are frequently cited as necessary to restore resilient forest conditions (Agee and Skinner 2005; Omi and Martinson 2004). This case study examines management tools that can help account for the nonequilibrium nature of wildfire disturbance and plan management under an ecosystem dynamics management framework (see Figure 4). Unlike the aquatic management case study, the theoretical concepts introduced here are ripe for broad implementation.

Clearly there is a need to proactively treat accumulated fuels to allow the reintroduction of fire in Oregon's forest landscape (Bormann *et al*. 2006). This need may conflict with other management mandates, for instance, the need to maintain relatively dense, closed-canopy old stands for the benefit of endangered and sensitive species such as the northern spotted owl. Roloff *et al*. (2005) used FlamMap and other methods to estimate fire behavior under management that emphasized maintenance of owl foraging habitat in the Elk Creek watershed, a large forested watershed managed by the Forest Service, BLM and private industrial landowners in Southern Oregon.[5] Their simulations predicted a five-fold increase in the risk of uncharacteristic crown fire for the area, suggesting that a more aggressive fuel management strategy, while potentially at odds with current endangered species management plans, may better sustain forest structure and composition, as well as owl populations.

The emerging understanding of the need for fuel-reduction treatments may or may not be conceptually or practically inconsistent with current agency policies. For instance, the Northwest Forest Plan makes fuel-reduction an explicit goal for spotted owl reserves in fire-prone areas in Southern Oregon. Implementation of aggressive fuel management in these reserves may be hindered more by lack of funds or aversion to public controversy than by inflexible policy. Treatments must be considered at two spatial scales: 1) the stand level, where treatments are developed to provide adequate tree and stand resilience during typical fire seasons; and 2) the landscape level, where treatments must aggregate into patterns that meet overarching management objectives. It is only at the second scale that managers can reconcile the disparate objectives identified above.

This case study is a good place to make an observation about species management. The current management framework, particularly on federal lands, places great emphasis on maintaining viable populations of species. Much current management attempts to optimize the habitat needs of a variety of species. There is evidence that some systems experience highly variable disturbance regimes over time, with large oscillations in the distribution of different habitat types. In some systems, there may not be an optimal distribution of species possible at any given point in time (Haeussler 2003).

[5] FlamMap was developed by USDA Forest Service's Missoula, Montana, Fire Science Laboratory and can display potential fire behavior characteristics (e.g., flame lengths, crown fire activity) for snapshots in time given different fuel characteristics and ignition points.

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓	✓			

Barriers to further development/application of concepts:

- Funding for mechanical fuel-reduction and prescribed fire may be lacking.
- Agencies may lack the capacity for widespread fuel-reduction treatments.
- Liability and smoke control issues may limit manager's ability to use prescribed fire.
- Effective fuel-reduction requires coordination among multiple agencies and private landowners that is currently lacking.
- A perceived decrease in protections for endangered species habitat may be controversial. The Endangered Species Act and National Forest Management Act, among other statutes, may prohibit thinning that removes habitat components needed by endangered species.

Strengths of existing research:

- Data-intensive and rigorous models that are suitable for planning fuel-reduction treatments and relate them to alternative management approaches have been tested.
- Adequate models for gauging the relative impacts of fuel-reduction vs. no-action on endangered species habitat and on other ecosystem services have been developed.

Information needs and hypotheses to be tested with further research:

- Pre-fire fuel modeling has been done at a stand level and works well at a stand level. Experimentation and development needs to be done to increase models' usefulness for landscape-level planning and for achieving multiple objectives.

- Endangered species conservation design needs to be tested. For instance, the efficacy of 300-acre buffers around owl nests, protected by fuel treatments in the surrounding area, should be evaluated.

Case study #3: Fire management strategies

This case study draws on scientific research to evaluate the impact of different fire and fuel management strategies on broad scale disturbance processes in Oregon.

Managing wildfire disturbance will be a crucial component of an ecosystem dynamics management approach in Oregon, particularly as the climate changes and there are increasing human population pressures on Oregon's ecosystems. The Oregon Department of Forestry is responsible for wildfire-suppression on 16 million acres of private, county and state forestland, as well as forested Bureau of Land Management districts. The US Forest Service is responsible for wildfire-suppression on an additional 20 million acres of national forest land. ODF fire-suppression costs have risen as the size and severity of fires has increased over the last two decades. On several occasions in recent years, the expenses of large fires have exceeded the capacity of the Oregon Forests Land Protection Fund, which funds "extra" suppression activities across the state. At the same time, federal interagency fire-fighting costs in Oregon have skyrocketed, with large fire complexes like the 92,000-acre B&B fire on the Deschutes National Forest and the 499,000-acre Biscuit Fire on the Siskiyou National Forest costing $40 million and $150 million respectively.

Fire-suppression costs for state and federal agencies in Oregon can be expected to continue to rise dramatically for at least two reasons: First, increasing residential density in forested areas makes for more expensive fire-suppression efforts; and, second, global climate change may lengthen the annual fire season in which most large, severe fires occur (Westerling *et al.* 2006). One report estimates that annual acreage burned in Oregon could increase by 50 percent by the 2020s, and by 100 percent by the 2040s, increasing ODF fire control costs to $60-96 million by the 2020s and to $80-128 million by the 2040s (Oregon Department of Energy 2008). Moreover, increasing fuel costs and other fiscal pressures related to the economic downturn have the potential to significantly increase the cost of fire control above and beyond these estimates.

In addition to the fiscal consequences from fire-fighting costs, increasing spending on wildfire may have Sisyphean ecological consequences. All forests in Oregon are adapted to fire to some degree, and it is widely recognized that fire is integral to a wide variety of beneficial forest function. Suppressing fire in many forest types leads to continued fuel buildup that, along with hotter and drier summer conditions, leads to larger, more severe fires. Suppressing manageable fires only delays the inevitable when the fire cannot be suppressed due to fuel or weather conditions. Increasing agency wildfire budgets when non-discretionary domestic state and federal spending is contracting will have the indirect effect of taking money away from needed preventative forest management to reduce fuel loading in Oregon's forests. This is reflected in Forest Service budgets, where funds for the national forest system have declined by 40 percent while the fire-suppression budget has increased 270 percent in real dollars over the last fifteen years (Johnston 2003).

Figure 9. Current and desired fire management trajectories. (Left photo: Fire fighters on the Kelsey Fire, Umpqua National Forest. Right photo: Completed Camp Sherman hazardous fuel-reduction *treatment, Deschutes National Forest.)*

One recent study provides an explicit warning of the outcome graphically illustrated above. Researchers have developed a state-and-transition model-based methodology to predict outcomes of three different management scenarios—background natural disturbance, fire-suppression only and active fuel management—and found that the fire-suppression only scenario creates the least probability of maintaining resilient old forest structures in the interior Pacific Northwest (Barbour *et al.* 2007). These findings about the ecological consequences of aggressive fire-suppression are inconsistent with current agency policies. Both federal and state agencies as well as private landowners currently insist on fire-suppression in almost every case, while most scientists agree that many more fuel-reduction treatments must be accomplished in fire-prone forests than are currently underway.

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓	✓			

Barriers to further development/application of concepts:

- There may be a lack of funding for preventative fuel-reduction thinning, especially in forest types with little commercial value.
- There is a shortage of personnel trained in fire use and prescribed fire relative to the likely need.
- Fire use and prescribed fire may face considerable opposition from the public because of real or perceived risk from escaped fire and smoke.
- The ESA, Clean Air Act and other statutes may be a barrier to prescribed fire, fire use or widespread mechanical thinning.
- There is a lack of education about "firewise" community protection practices.

Strengths of existing research:

- Models are available for predicting outcomes under different management scenarios.

- Good firewise community models exist (see hypothetical policy change strategy #2 in Part IV).

Information needs and hypotheses to be tested with further research:

- Research should be conducted to determine what type of educational efforts (and policy changes) would lead to broader acceptance of prescribed fire.[6]
- Appropriate funding levels for needed fuel-reduction should be determined. How might markets be developed for currently unmerchantable or submerchantable material (see hypothetical policy change strategy #3 in Part IV)?
- How can stewardship contracting or other innovative contracting mechanisms be designed to enable more cost-effective fuel-reduction?
- Fire use plans that allow wildfires to burn in remote areas as part of a strategy to reduce fire risk in the wildland urban interface, municipal watersheds, endangered species habitat, etc. should be considered.[7]

Case study #4: Fire history and landscape level timber management in the Western Oregon Cascades—The Blue River Landscape Plan and Study

This case study describes a concrete example of ecosystem dynamics management—the design of harvest treatments in the Oregon Cascades that emulate historical fire patterns.

One of the longest-lived and institutionally best-supported examples of ecosystem dynamics management has taken place over the last 12 years in the Central Cascade Adaptive Management Area (CCAMA) on the Willamette National Forest east of Eugene (Cissel *et al*. 1999). The CCAMA was established by the Northwest Forest Plan and tasked with developing "approaches for integrating forest and stream management objectives and on implications of natural disturbance regimes" (USDA and USDI 1994).

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[6] Shindler (2006) notes growing opposition to prescribed burning in Oregon's Blue Mountains.

[7] Collins and Stephens (2007) investigated the efficacy of wildland fire use in large wilderness areas in the Sierra Nevadas. The two largest forest fires in Oregon in the last decade burned almost entirely within the third and fourth largest contiguous roadless areas, respectively, in Oregon. A radical solution to reducing costs of large incidents might be to deliberately set fires in large wildland areas during weather windows where fire behavior can expected to be moderate and personnel can be deployed to contain these prescribed fires at less cost.

The CCAMA used historical range of variability concepts to try and achieve the species conservation goals of the Northwest Forest Plan (NWFP). The tension between the historical range of variability approach and the species conservation goals of the NWFP was evident during implementation of management activities.

The first step in development of the Blue River Landscape Plan and Study (BRLPS) was a detailed reconstruction of fire history over the past 800 years from analysis of fire scars and tree establishment dates. Fire frequency was found to range from 50-500 years, with severities ranging from a light ground fire to stand replacement fire. With these data, land managers worked closely with the research community to develop a landscape management plan that programmed harvest rotations of 100, 180 and 260 years with live tree retention of 50 percent, 30 percent and 15 percent canopy cover, respectively, to emulate historical fire patterns. Other features of the management plan were: 1) treatments designed to minimize habitat fragmentation created by earlier patch clearcutting; 2) different tree retention prescriptions along streamsides to test the efficacy of variable width riparian reserves to meet Aquatic Conservation Strategy objectives (NWFP); 3) prescribed fire to create snags and maintain fire in the ecosystem as a key ecological process; and, 4) areas designated for no-entry over a 40-year period, allowing deactivation of part of the road system (Swanson *et al.* 2008).

The second piece represents one of the only attempts to create variable reserves that shift in position over the landscape over time in response to disturbance dynamics. This feature of the project was controversial both inside and outside the agency, with some agency personnel and advocates resistant to what they perceived to be a decline in protection for aquatic areas and associated sensitive species.

Three timber sales were designed to implement a first phase of the landscape plan and study. All of the sales were delayed by environmental litigation (which affected other timber sales in the region and were not directed specifically at the experimental nature of the BRLPS or implementation of HRV concepts). All three sales were modified slightly in response to pressures both within and outside the Forest Service; modifications included dropping logging units with old-growth trees and increasing the width of no-cut riparian buffers (Swanson *et al.* 2008).[8]

An important feature of all actions undertaken in the CCAMA is a plan-act-monitor-adjust adaptive management process. The Forest Service is currently in the process of revisiting the monitoring plan for the project to improve efficiency and to assure that the most significant site factors are characterized (Swanson *et al.* 2008).

Johnson *et al.* (2003) point out that emulating historical fire disturbance *patterns* with timber harvest does not necessarily emulate the specific ecological outcomes from fire. They recommend a process-oriented approach to forest restoration that considers effects from fire such as age mortality selection, soil smoldering, etc.

CLIMATE CHANGE AND THE BLUE RIVER LANSCAPE PLAN AND STUDY

"Conservation biology and HRV-based landscape management approaches may have to give way gradually to environmental-change management approaches in a manner scheduled out over coming decades. Some would argue that history is dead—and historical ecology with it. We feel that history of the land and our knowledge of it will remain important, but we need to adjust use of that knowledge in the context of changing environmental and social circumstances. Will our ecosystem exhibit threshold responses to climate change? Some higher-latitude systems in the west appear to be profoundly affected by climate change, but the Oregon Cascade forests do not—yet. Will they? By insects? Fire? Physiological collapse due to moisture stress? Andrews Forest LTER science, including long-term environmental and ecological measurement programs, may provide insights to these questions."

—Fred Swanson

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓	✓	✓	✓	✓

[8] Mallon 2006 examines public attitudes towards CCAMA management strategies.

Barriers to further development/application of concepts:

- Turnover in staff introduced different philosophies about project implementation that was a challenge for creating continuity in experiment design and implementation.
- Environmental advocates criticized logging of older trees and adjustments to riparian buffers.
- Regional injunctions against Forest Service timber sales slowed implementation.

Strengths of existing research:

- Management demonstrates the use of fire histories for management.
- Completed projects can be monitored and results applied to future planning.

Information needs and hypotheses to be tested with further research:

- The appropriateness of implementing BRLPS experimental treatments, such as riparian areas with variable width buffers, in other Northwest Forest Plan land management allocations such as matrix lands, late successional reserves or riparian reserves should be evaluated. Could this type of experimental harvest design be adapted for use on state lands?
- Research should be conducted to determine how forest management based on fire history can be integrated with aquatic ecosystem dynamics management (see Case Study #1).
- The implications of climate change for continued use of the historical disturbance regime to guide future management should be evaluated. What practices used at what pace should be employed to guide forests toward resilience or transformation in a changing climate?

Case study #5: Fire history and landscape-level timber management in the Western Oregon Cascades—The Dinner Timber Sale

This case study describes another example of where the historical range of variability was used to design harvest treatments.

The Umpqua National Forest is making use of disturbance history and the corresponding distribution of forest structure in timber harvest planning. The Umpqua National Forest has been divided into different land units (of approximately 25,000 acres each) characterized by different vegetation, disturbance regimes and land use goals. Much of this work was accomplished through use of watershed analyses of fifth-field watersheds required by the Northwest Forest Plan. This knowledge base is being used to plan timber harvest and other land management activities. One example is the Dinner Timber Sale in the Layng Creek Watershed east of Cottage Grove. Updated watershed analysis indicated that late-successional forest habitat was well below historical levels, and that existing habitat was significantly fragmented—distributed in smaller blocks more widely separated than the historical range of variability. Thinning in young planted stands is planned to accelerate development of late-successional forest habitat that, when aggregated with existing late-successional habitat over time, will form large blocks of older interior forest required for spotted owls and other old-growth dependent species.

The project has currently been split into two different commercial timber sales. Roadwork on the sales has been completed as of this writing, with timber harvest scheduled for the summer of 2008 and 2009. According to Forest Service planners, this project has been strongly supported by the local public and by conservation groups, and has not been the subject of appeals or litigation (Anderson 2008).

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓	✓	✓		

Barriers to further development/application of concepts:

- None known.

Strengths of existing research:

- Similar to Blue River Landscape Management Plan and Study.

Information needs and hypotheses to be tested with further research:

- Similar to Blue River Landscape Management Plan and Study. Most of all, this project would benefit from a strong monitoring component in order to extrapolate lessons learned to other areas.

Case study #6: Incorporating forestry and land use into Oregon global climate change action

This case study reviews the use of different management tools that can aid in planning Oregon's response to climate change, which may have significant impacts on ecological processes.

Managing for global climate change is a critical element of ecosystem dynamic management. The climate change dynamic is potentially a two-way street: On one hand, global climate change will affect vegetation, and on the other hand there is growing political momentum to consider the impact vegetation management can have on climate change.

Integrating global climate models and goals into land management plans is necessary for at least three reasons: 1) Changes to vegetation and disturbance patterns caused by climate change may undermine the use of the historical range of variability to craft future management plans and methods; 2) changes to vegetation and disturbance patterns caused by climate change may initiate positive feedback loops in ecosystems that dramatically alter composition, structure and function of systems, and, by extension, the goals and methods of management plans; and, 3) climate change may, by influencing human land use, demographics and consumption patterns, place new demands on resources that alter the assumptions of management plans.

FORESTRY AND WARMING

Historically, deforestation has accounted for greenhouse gas emissions equivalent to approximately 56% of fossil fuel emissions, and as much as 25% of future greenhouse gas emissions may come from deforestation (Salwasser 2006).

VINCERA (Vulnerability and Impacts of North American Forests to Climate Change: Ecosystem Responses and Adaptation) is a modeling project that simulates changes in vegetation distribution, carbon balances, and patterns of fire and drought. In drier systems in interior Eastern Oregon, most computer-generated simulations show extensive expansion of woodlands into grass and shrub steppes. Maritime forests in Oregon's coastal zone are less impacted, although in some models they may be displaced in areas by a "warm temperate-subtropical mixed forest or by mixed conifer types more generally associated with interior Oregon." There is an overall increase in broadleaf vegetation, including alder, maple, oak and madrone (Millar 2006).

In 2004 the Governor of Oregon convened a Governor's Advisory Group on Global Warming, which was tasked with setting goals and future policy for greenhouse gas emissions reductions in Oregon. The Advisory Group proposed the following goals:

- By 2010, arrest the growth of Oregon's greenhouse gas emissions, and begin making measurable progress toward reducing them to 1990 levels.
- By 2020, achieve a 10 percent reduction below 1990 greenhouse gas levels.
- By 2050, achieve a "climate stabilization" emissions level at least 75 percent below 1990 levels (Oregon Department of Energy 2004).

These goals will be achieved through the following broad strategies:

- Invest in energy, land use and materials efficiency.
- Replace greenhouse gas-emitting energy resources with cleaner technologies.
- Increase biological sequestration (farm and forest carbon capture and storage).
- Promote and support education, research and technology development.

To increase biological sequestration, the Advisory Group proposed six strategies:

- Reduce wildfire risk by creating a market for woody biomass from forests.
- Consider greenhouse gas effects in farm and forestland operations.
- Increase forestation of under-producing lands.
- Expand the application of water-erosion reducing practices for cereal production.
- Leverage the Conservation Reserve Program to expand reserved acreage.
- Establish a municipal street tree restoration program.

None of these measures to mitigate global warming comprehensively addresses the role that forests play in carbon cycling. A report from the Governor's Climate Change Integration Group (a successor to the Advisory Group on Global Warming) notes the importance of land use and forestry in developing emissions models, but states that Oregon is "not yet ready" to quantify or qualify the relationship between forest practices and carbon cycling because of "substantial issues with forestry and land use data" (Oregon Department of Energy 2008).

These gaps in Oregon's framework for responding to global warming are unfortunate because Oregon is uniquely positioned to play a lead role in mitigating climate change through biological sequestration and other changes in forest practices. Oregon forests have some of the best carbon sequestration potential of any terrestrial ecosystem, with some coastal forests capable of storing 600 tons of carbon per acre or more (140 tons per acre more than coastal stands in Washington State). Forests in Oregon currently store far less carbon than they are capable of. According to one study, Pacific Northwest forest stands are capable of storing, on average, approximately 160 tons of carbon per acre more than they do now (Smithwick *et al.* 2002).

TIMBER HARVEST, FOREST FIRES AND GREENHOUSE GAS EMISSIONS

One recent study found that timber harvest in Oregon accounts for an annual contribution of 10 Tg of carbon to the atmosphere. Fossil fuel consumption also contributes approximately 10 Tg of carbon annually to the atmosphere. The Biscuit fire, which burned in 2002, may have contributed as much as 4 Tg of carbon to the atmosphere (Campbell *et al.* 2007).

Researchers have developed robust tools that can serve as a starting point for integrating forest management into climate change models and developing local solutions to help mitigate climate change. STANDCARB, for instance, is a simulation model that calculates carbon fluxes in forests based on regeneration, growth, mortality, decomposition and forest disturbance like wildfire (Harmon and Marks 2002). Among the many uses of this model is comparing different types of land uses. For instance, simulations reveal that Douglas fir/western hemlock stands typical of Western Oregon store the most carbon of Oregon ecosystems (93 percent of the maximum), while agricultural fields store the least (15 percent of the maximum). The model can quantify the net carbon decrease from regeneration of older forest stands due to fire or logging, or the net increase from conversion of farmland to forests (Krankina and Harmon 2006). Finally, simulations with STANDCARB have demonstrated that partial harvest of forest stands along with minimal fire use may produce the same volume of forest products as traditional clearcut and partial harvest while maintaining higher carbon storage on site, a finding with significant management implications for Oregon (Harmon and Marks 2002).

Land use laws in Oregon have an important bearing on fire protection, carbon sequestration potential, water use and a host of other issues. One study estimates that as many as two million acres of forestland in the Pacific Northwest could be lost to development (Alig and Plantinga 2004). There is considerable uncertainty with regards to the future of land use as a result of the passage of Measure 37 in 2004 (the impacts of Measure 37 may be considerably mitigated by the passage of Measure 49 in 2007).

There are at least three reasons to integrate forestry and land use into frameworks for managing global warming: 1) Mitigating the effects of global warming will be critical to maintaining ecosystem resiliency in Oregon; 2) the carbon cycle is an excellent conceptual model for analysis and management of ecosystem dynamics, for instance the interaction of fire, fuels, large scale disturbance, stream dynamics, and changes in land use patterns; and, 3) forest practices that help reduce atmospheric greenhouse gas levels, such as incentives for carbon sequestration in forests, will help leverage other ecosystem dynamic management goals, such as reducing fuel loads in forests and protecting forestland from conversion to urban development.

An understanding of the role that forests can play in mitigating global warming has not found expression in policy. Strategy G of the Oregon Forestry Program recognizes this deficiency and has made promotion of carbon sequestration in forests a goal of the Oregon Department of Forestry.

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓				

Barriers to further development/application of concepts:

- There is a lack of a formalized market for carbon sequestration in forests.
- There has been little effort to educate landowners about the potential economic benefits from carbon sequestration in forests.

Strengths of existing research:

- Robust models for carbon storage potential and predictive models for optimizing carbon sequestration relative to likely disturbance patterns and different management scenarios have been developed.
- Tools for modeling expected vegetation change in response to warming have been developed.

Information needs and hypotheses to be tested with further research:

- A carbon sequestration policy framework that addresses leakage, substitution, etc. and is appropriate for Oregon's forests should be developed.
- The impact of changes in Oregon's land use planning on management of forests to mitigate climate change should be evaluated.
- A comprehensive and integrated vegetation monitoring program that integrates botanical information for different forested ecosystems in Oregon needs to be developed. This monitoring data can be used to test hypothesized shifts in the geographic distributions of plant species independent of their associations as atmospheric CO_2 and temperatures increase. This information will also be critical for developing adaptation and mitigation policies and for testing the validity of simulations.

Case study #7: The CLAMS project and age class and structural patterns of forest cover in the Oregon Coast Range.

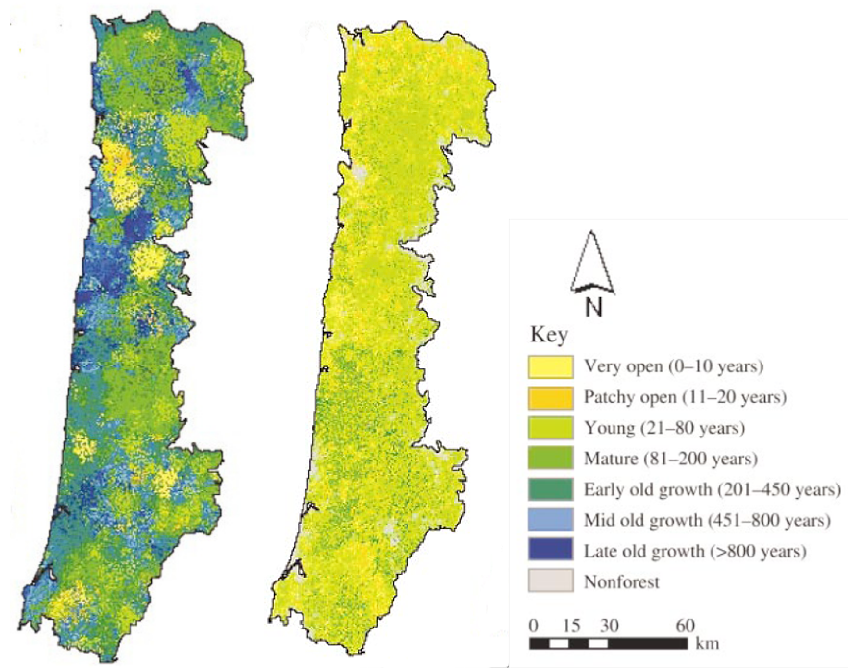

Figure 10. Hypothetical historical age structure distribution with large patches of old forest (right) and current age structure distribution dominated by young forest (left) (from Wimberly).

This case study evaluates a broad scale, multi-ownership, multi-disciplinary planning effort that analyzes restoration of Oregon Coast Range landscape patterns and processes.

The Coastal Landscape Analysis and Modeling Study (CLAMS) is a multi-disciplinary, multi-agency effort to analyze and synthesize the ecological, economic, and social consequences of land management in the Oregon Coast Range. It is a good example of ecosystem dynamics management in part because it develops management scenarios informed by knowledge of vegetation change over a relatively large area over a relatively long period of time. This research found profound changes to the pattern of forest structure and age class in the Coast Range as a result of land management, a finding particularly relevant if managers attempted to use the historical range of variability to guide future management.

Research sponsored by CLAMS conducted by Etsuko Nonaka, Tom Spies and others characterized the historical range of variability of vegetation dynamics in terms of the amount of major forest types and the spatial pattern of the forest mosaic. This analysis can serve as a coarse model for future management strategies. Modeling established that old forest was the dominant historical forest type, that the average size of old forest patches had decreased, the area of young forests had increased dramatically, and that distances between young forest patches had significantly decreased while distances between old forest patches had significantly increased (Nonaka and Spies 2005).

Thompson *et al.* (2005) used a landscape simulation model to compare the economic and ecological consequences across different land ownerships of current management practices versus management that studied past disturbance patterns to move the landscape towards the historical range of variability. Within a hundred years, historical disturbance-based policies were found to re-establish the historical proportion of younger forests, while the proportion of older forests moved closer to, but remained below historical levels. The study showed a 20-60 percent decline in harvest volume under the disturbance-based policies relative to current management, and noted that public lands would be relied upon heavily to provide large patches of older forest in order to approximate historic conditions.

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓				

Barriers to further development/application of concepts:

- At present, there appears to be little demand from policy-makers for the type of cross-ownership analysis that CLAMS can provide.

Strengths of existing research:

- CLAMS offers robust modeling of expected outcomes under different management scenarios, as well as coarse-scale information about historical vegetation dynamics in the Coast Range.

Information needs and hypotheses to be tested with further research:

- Plans for better coordination in fuel-reduction strategies between federal, state and private ownerships should be developed.

Case Study #8: The Five Rivers Landscape Management Project and restoring old forest structure in the Oregon Coast Range

This case study describes experimental efforts to restore broad scale ecological patterns and processes in the Oregon Coast Range.

A primary management goal of the Siuslaw National Forest (which makes up 10 percent of the Coast Range physiographic province) following implementation of the Northwest Forest Plan in 1994 has been restoring large blocks of contiguous older forest habitat to better approximate the historical range of variability. One of the first, and still the largest, efforts at implementing this direction was the Five Rivers Landscape Management Project, which, like the Blue River Landscape Plan and Study, attempts to use different harvest retention levels to test different means to restore historic conditions.

The Five Rivers project is located in the Alsea River basin, 34 miles southwest of Corvallis, and covers about 37,000 acres (about 13 percent of which is privately owned). Before the 1800s, most of the Five Rivers landscape was an old-growth forest of Douglas fir, western hemlock, and western red cedar, growing in large stands of more than 100,000 acres. The existing landscape age structure of 150+ year older forest mixed with <50 year old young stands is the result of the Yaquina Fire of 1849, subsequent smaller fires, and extensive clearcut timber harvesting. Existing un-logged conifer habitat is fragmented relative to historical conditions, with an average patch size of 2,000 acres (USDA Forest Service 2001).

The Five Rivers Landscape Management Project involved a package of terrestrial and watershed restoration projects, including commercial thinning to accelerate development of late-successional characteristics and enhance species and structural diversity of Douglas fir plantations between 25-and 50-years old, precommercially thinning plantations between 5-and 15-years old, closing and decommissioning roads, placing large conifer trees in streams as habitat structures, and planting conifers and hardwoods in riparian areas (USDA Forest Service 2003).

Photo 2. Typical young forest structure in the Oregon Coast Range

An integral part of this project was a management study that compared three different management approaches to enhancing late-successional characteristics and species and structural diversity: 1) no thinning; 2) light thinning; 3) heavy thinning and road removal. Federal regulatory agencies were concerned about the impact the third treatment would have on endangered species. Interestingly, this project was initially enjoined as part of a regional legal injunction against the Forest Service's implementation of the Northwest Forest Plan's Aquatic Conservation Project.[9] Because of the project's conservation focus, however, conservation groups subsequently agreed to release this project from that injunction (Bormann 2008).

All of the commercial thinning associated with this project has been completed. Critically, at present, very little monitoring of the project has been done. Research needs include testing the efficacy of road closures and the degree to which wind throw affected thinning treatments (Bormann 2008).

Like the Blue River Landscape Plan and Study, the Five Rivers Project was meant to test adaptive management strategies (the Five Rivers Project was the subject of an unpublished Council on Environmental Quality report on adaptive management). Three

[9] Pacific Coast Federation of Fishermen's Ass'n, Inc. v. Nat'l Marine Fisheries Serv., 265 F.3d 1028, 1034 (9th Cir. 2001).

major observations can be made about adaptive management in the Five Rivers project that also hold true for many other similar federal land management projects: 1) It was implemented via a landscape-scale, integrated, long-horizon Environmental Impact Statement (EIS) rather than a piecemeal series of smaller Environmental Assessments (EAs); 2) it was not true adaptive management in the sense that treatments were adjusted during implementation, rather the lessons learned from this project are intended to be applied to future decisions; and, 3) the lack of funding for meaningful monitoring was a was a significant challenge.[10]

Thinning projects that restore historical vegetation patterns are conceptually consistent with federal forest management that has as its goal the restoration and perpetuation of older forests. These projects are conceptually inconsistent with the goals of most, if not all, industrial forestland and some state forestlands. In general, the goals of these lands are maximizing economic value, which most often involves short-rotation harvest and dense replanting.

<u>Case study development to date</u>:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓	✓	✓		

<u>Barriers to further development/application of concepts</u>:

- Initially, this project was the collateral victim of environmental litigation but seems to have enjoyed broad support among conservation groups and the general public.
- Initially, this project faced opposition from regulatory agencies but ended up being well supported.

[10] Environmental documentation for the Five Rivers project was remarkably concise. The EIS was 84 pages of text describing 3,200 acres of commercial thinning and associated activities within a 32,000-acre planning area. This compares favorably (or unfavorably, if the goal is an agonizing level of detail) with typical Forest Service EISs for similarly sized, though frequently more controversial, land management projects.

- Post-implementation monitoring has been less than expected and has, so far, yielded little information.

Strengths of existing research:

- Similar to the Blue River Landscape Plan and Study and the Dinner Timber Sale.

Information needs and hypotheses to be tested with further research:

- Information about the effects of the various thinning regimes needs to be collected, analyzed and applied to future land management actions.

Case study #9: Distribution and management of salmon habitat in the Oregon Coast Range

This case study describes research into the effect that land ownership patterns have on endangered species management.

Recovering endangered salmon runs is an important goal of land managers in Oregon. Management across land ownership patterns will be critical to successful ecosystem dynamics management. One study sponsored by CLAMS indicates that the pattern of land ownership in coastal Oregon streams may pose a challenge to restoration efforts. Most of the stream reaches with the potential to be high quality salmon habitat were found adjacent to non-industrial private ownership, agriculture and developed uses. These results suggest that widespread recovery of Coho salmon will be difficult unless there is a strong focus on private lands (Burnett *et al.* 2007).

Case study development to date:

Development of theoretical concepts	Project design	Project implementation	Project monitoring and evaluation	Active research-management partnership
✓				

Barriers to further development/application of concepts:

- Ownership patterns may impede restoration work.

Strengths of existing research:

- Robust mapping of high potential salmon habitat has been completed.

Information needs and hypotheses to be tested with further research:

- Incentives (i.e., ecosystem services payments) that could encourage landowners to take actions that create or restore salmon habitat on private land should be evaluated.
- Planning for better integration of management strategies among federal, state and private managers should be undertaken.

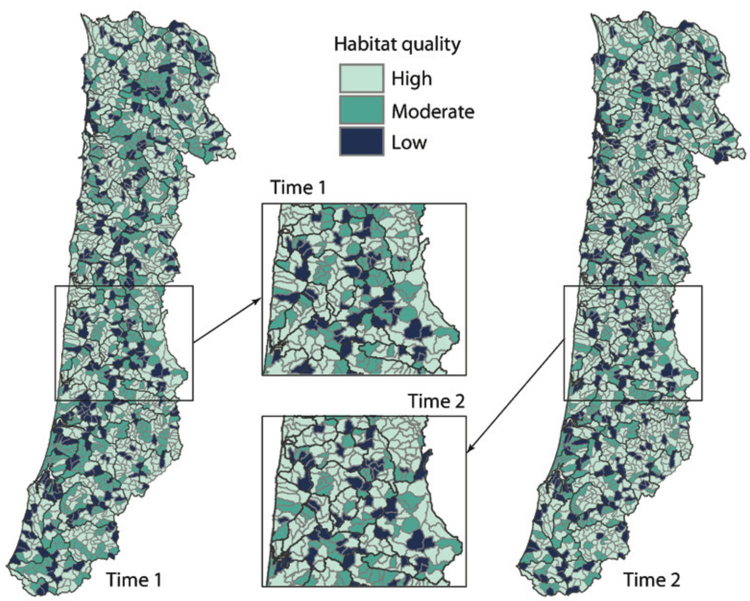

Figure 11. Hypothetical distribution of coastal salmon habitat over time from Reeves and Duncan 2008 (figure by Kathryn Ronnenberg, US Forest Service, PNW Research Station).

III. Summary and synthesis of management implications and recommendations from case studies

Making recommendations for management in an ecosystem dynamics framework is somewhat problematic for several reasons. First, our knowledge is incomplete, and alternatives to current management strategies should be developed and adapted only in recognition that management may need to shift significantly in the future. Second, some recommendations may not initially be feasible, such as those aimed at integrating management strategies across large geographic areas and ownerships. Finally, there is danger in selectively implementing recommendations. For example, if managers simply embrace more flexible implementation of existing regulatory frameworks like the Clean Water Act without simultaneously implementing holistic process-oriented restorative actions then significant environmental degradation may result.

Preliminary and general recommendations for ecosystem dynamics management are summarized under four categories below. Agencies, statutes, regulations and policies that may need to be re-examined in implementing these recommendations are also identified. Consistent themes in the recommendations include an emphasis on ecological processes, a shift in the scale of analysis and implementation of land management actions, and integration of geography and management frameworks.

Photo 3. Closed road in the Steamboat Creek drainage, Umpqua National Forest

Aquatic systems

→ Where appropriate, manage streams to account for pulses of material that create diverse stream conditions over space and time. Limit chronic “press” disturbance to stream systems. One potential mechanism for creating flexibility is through development of a water quality trading system that would maintain high quality water in some areas and allow for disturbance caused fluctuations in certain water quality indices (in particular, sediment, turbidity and temperature) in other areas. Water quality trading should encourage an overall regional upward trend in water quality and habitat. Another mechanism for creating pulse disturbance and limiting press disturbance would be concentrating rather than dispersing management activities (see "Creating the case study of the future" below).

→ Where appropriate, identify and restore (or emulate) the disturbance processes that produce aquatic habitat components. For example, manage and plan for large stochastic events, such as stand-replacing wildfire, that may contribute large quantities of material (soil, gravel and wood) to streams. In some stream systems, strategic areas might be "loaded" with material such as woody debris that will be delivered to streams in the future to provide for aquatic habitat recruitment.

→ Develop new road management strategies that encourage use of temporary systems and removal of road components like culverts post harvest, especially where management objectives provide for long intervals between harvests.[11]

→ Many planning assumptions, such as the design of transportation infrastructure to account for "100-year" flood events, should be reconsidered in light of climate change models that predict more frequent and severe storm events. Where possible, future infrastructure development should be designed to allow for passage of material such as large woody debris that contribute to the development of desired aquatic habitat.

→ Promote better coordination between landowners and agencies on stream management by integrating watershed assessment protocols and formats. For instance, promote coordination between Forest Service watershed analysis (usually upper-watershed), BLM watershed analysis, and OWEB watershed council watershed assessments (usually lower watershed). Rework watershed assessment tools to reflect the importance of stream disturbance events.

→ Encourage the Forest Service and BLM to use the Northwest Forest Plan's watershed analysis to adjust riparian reserves to account for the disturbance regimes of different watersheds.

→ Work with private owners, state agencies, and non-governmental partners to conserve instream flows to promote resiliency of aquatic habitat.

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[11] If environmental plaintiffs prevail in their appeal of NEDC v. Brown (U.S. Court of Appeals, Ninth Circuit, No. 07-35266), the Oregon Department of Forestry may have to consider a new planning framework for the road system in light of new Clean Water Act requirements.

→ Establish a watershed-scale experiment in dynamic aquatic processes management (see “Creating the case study of the future” below). This experiment should be as large as possible and embrace as many jurisdictions as possible (i.e., federal, tribal, state and private). The experiment should introduce large-scale disturbance, such as fire or timber harvest. Different reserve designs should be tested. Different mechanisms for material input (large wood, gravel, etc.) should be modeled and tested. Regime standards that reflect anticipated broad scale watershed scale processes should be developed and tested (see hypothetical policy change strategy #6 in Part IV).

→ Efforts should be made to manage over broad landscapes. Strategic land exchanges may facilitate more effective management of key resources.[12] Models for basin-scale collaboration among different ownerships should also be developed.

Laws, regulations or policies to study for changes	Oregon Plan for Salmon, Clean Water Act, Northwest Forest Plan, Oregon Forest Practices Act
Agencies and/or interest groups to study	Private owners, USFS, ODF, DEQ, OWEB, BLM, USFWS, NOAA, Dept. of Human Services, Dept. of Water Resources, tribal governments

Fire and fuels management

→ Promote a diversity of vegetation treatments consistent with other land management objectives for different agencies that reduce tree density and total standing biomass and restore and maintain appropriate fuel levels in canopies and on the forest floor surface.

→ Prioritize strategic, landscape-level treatments that create a pattern of resilient forest conditions.

→ Integrate fuels treatments more closely with suppression strategies; do not default to total suppression in low to moderate fire weather conditions. Rethink initial attack strategies and prepare comprehensive plans for wildland fire use.

[12] See http://oregonstate.edu/dept/iifet/2000/papers/sessions.pdf for a discussion of the Umpqua Land Exchange Project.

→ Promote increased use of prescribed fire. Treating surface fuels is a key to forest restoration in many forest types, and burning is preferred to mechanical treatments based on cost, residual site damage and the unique ecosystem responses to fire.

→ Create finer scale information about forest and fuel distribution with modeling tools, which will promote better and faster fire decisions.[13]

→ Integrate other disturbance vectors, like insect infestations, into analysis of fire risk and manage accordingly.

→ Create legal variances for smoke production during wildfire use or prescribed fire.

→ Create liability limits and insurance programs for escaped prescribed fire and wildland use fire.

→ Amend the Oregon Forest Practices Act to require lower tree density and spatial heterogeneity in planted forested stands on private lands in fire-prone areas.

Laws, regulations or policies to study for changes	Healthy Forest Restoration Act, Northwest Forest Plan, Oregon Forest Practices Act, ESA, Clean Air Act
Agencies and/or interest groups to study	Private owners, USFS, ODF, USFWS, NOAA, EPA, LRAPA

Climate change and adaptation

→ Conduct research to establish what threshold changes can be expected in Oregon, and what indicators predict threshold changes. Build a regional climate model to help managers plan for change.

→ Develop models that predict changes to vegetation communities in response to climate change, disturbance and invasive species.

→ Conduct research on the effects of climate change on insect dynamics.

[13] The Healthy Forests Restoration Act of 2003 (HFRA) authorizes expedited thinning on forestlands identified as at risk of catastrophic fire. The HFRA calls for expedited thinning in forests categorized in certain "condition classes." These condition classes are coarse-scale models that overlay huge geographic areas without regard to the different forest types within those areas, all of which respond to fire (and fuel treatments) very differently. The condition class maps included as part of HFRA mislabel the condition class of many moist forests in western Washington and northwestern Oregon.

→ Require better weatherized roads, including more emphasis on temporary roads (used for dry season operation and hydrologically recovered for wet season). Prepare road system for increasingly severe storm events.

→ Develop a regional (multi-state) carbon sequestration market, possibly as an incentive-based alternative to land use planning invalidated by Measures 37/49. Integrate this market with other ecosystem services markets (see hypothetical policy change #5 in Part IV).

Laws, regulations or policies to study for changes	Oregon Forest Practices Act, Land Conservation and Development Act
Agencies and/or interest groups to study	Private owners, USFS, ODF, Dept. of State Lands, Dept. of Land Conservation and Development.

System function and resilience

→ Design flexible reserves systems that span environmental gradients so that species can move across the landscape in response to pressures from disturbance and climate change.

→ Promote active management of reserves to increase system resiliency.

→ Manage for ecological processes instead of single-species conservation.

→ Improve coordination between federal, state, local and private conservation efforts.[14]

Laws, regulations or policies to study for changes	Northwest Forest Plan, Oregon Forest Practices Act, ESA
Agencies and/or interest groups to study	Private owners, USFS, ODF, USFWS

Lessons learned: Creating the case studies of the future

As noted in the introduction, the case studies in Part II are imperfect examples of ecosystem dynamics management in practice. Below are general principles for a hypothetical implementation of the concepts this paper introduces:

[14] See Wimberly (2004)

- Implementation should occur on a large geographic scale, optimally involving multiple ownerships.
- An accurate and comprehensive range of historic variability should be developed for the landscape, as well as a future range of variability that takes into account climate change, land use and social expectations.
- Broad-scale ecological processes should be restored. For instance fire use plans should accommodate natural or prescribed fire. Where feasible, management that approximates historic disturbance, i.e., timber harvest, should be scheduled. Care should be taken when emulating the *pattern* that results from historical disturbance that the disturbance *processes* are taken into consideration (Haeussler 2003 and Johnson 2003).
- Monitoring and adaptive management should be prominent features of implementation.

The basic contours of a Coast Range implementation of ecosystem dynamics management might involve:

- Including multiple fifth-field watersheds that encompass multiple ownerships. Managing to recover old forest structure by thinning in younger stands (see CLAMS case study). Concentrate regeneration harvest (or use fire) to create pulses of material into streams. Alternate concentrated timber harvest between different watersheds over many decades. Experiment with different retention levels.
- Hydrologically recover the road system in “resting” watersheds. Design a temporary road system for “working” watersheds that can be hydrologically recovered following timber harvest.
- Use land exchanges and/or incentive programs to connect and restore high value salmon habitat in conjunction with other management operations.
- Integrate management with a water quality-trading scheme, leveraging variances for “working” watersheds.

- Integrate management with new forest practices standards to allow large harvest units with more residual material (snags and coarse woody debris) strategically placed in transport zones.

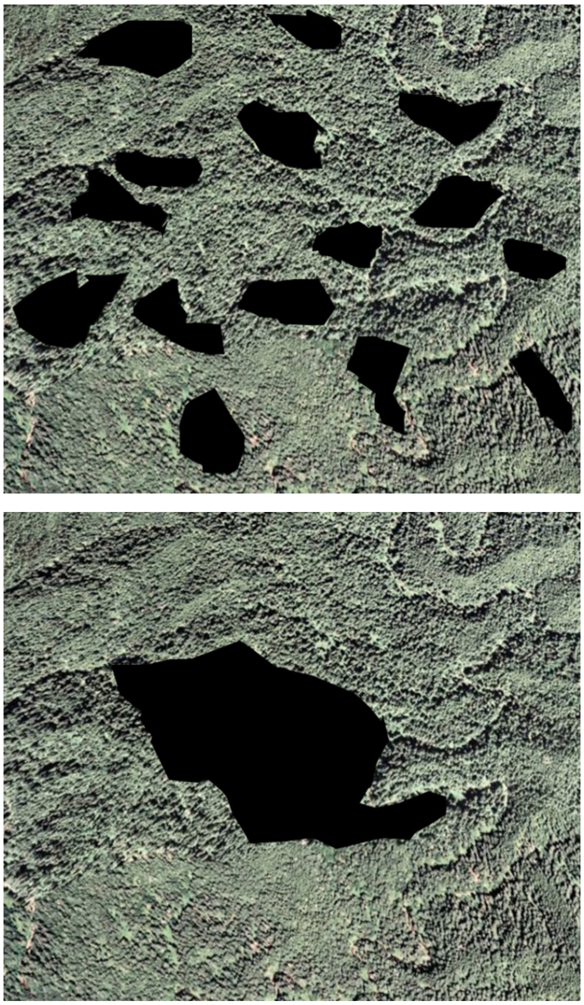

Figure 12. Hypothetical dispersed timber harvest (above) vs. concentrated timber harvest (below).

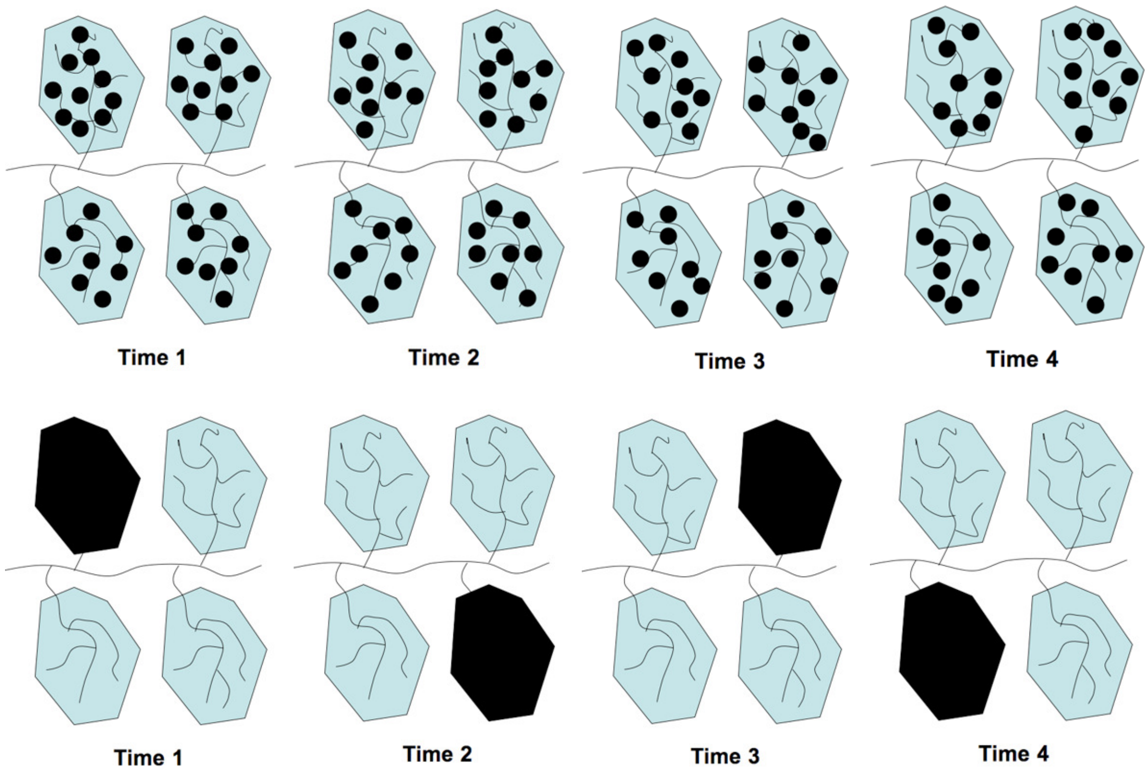

Figure 13. Hypothetical dispersed management regime in four watersheds. In this extremely simplified representation, each of the four watersheds would be harvested in sequence, instead of a quarter of each simultaneously. In addition to the potential ecological benefit of emulating pulse vs. press disturbance, there are potential economic benefits to this approach in terms of the energy required to remove a fixed volume of trees from one localized watershed for an extended period rather than several smaller areas dispersed over several watershed. From Reeves et al. *(1995).*

The basic contours of a fire-prone forest implementation of ecosystem dynamics management might include:

- Collaborate with private and public owners over a large geographic area in a fire-prone forest in Eastern or Southern Oregon to reduce fire risk through comprehensive thinning and prescribed fire.
- Encourage desired forest density on private lands by amending replanting standards.
- Encourage older, widely spaced trees on private lands with incentives for carbon sequestration and/or ecosystem services.

An overarching consideration when implementing these recommendations must be the always-evolving social values of the public. At a minimum, a thoughtful public information strategy should precede all the policy changes contemplated above.

IV. Creating policy change

The pace of change in natural resource management

Incorporating scientific knowledge of ecosystem dynamics into natural resource management policy may be difficult, because while our knowledge may indicate that significant shifts in policy are appropriate, the pace of change in the policy arena is generally slow and incremental.

True *et al.* (1999) describe a "punctuated equilibrium" theory of policy change in which institutions are stable and policy change is incremental until dramatic shifts occur. Normally, a wide variety of issues—from higher education to logging practices—are "parallel processed" by independent sub-systems of the larger political system. These sub-systems typically consist of relatively small groups of agencies and a narrow set of interest groups. Change ("disequilibrium") occurs when a policy subsystem can no longer effectively process a policy problem, often because of a crisis, and the issue moves out of that subsystem to be considered "serially" in a larger political venue (True *et al.* 1999 and Baumgartner and Jones 1991).

As an example, thinning in federal forests was historically designed to increase tree growth and vigor and maximize the economic value of stands managed for timber. Decisions about thinning were made by a subsystem consisting of the Forest Service and a limited number of other federal agencies influenced by a limited number of actors—primarily the timber industry and environmental groups—with little scrutiny or involvement by other constituencies. Widespread and unusually severe wildfires highlighted the need to thin forests not necessarily to maximize economic value, but to reduce hazardous fuels. The inability of traditional actors like the Forest Service, the timber industry and environmental groups to come to agreement about this policy shift independently resulted in the issue being taken out of the hands of the subsystem and considered in a higher order political venue. In this case, the US Congress ultimately took legislative action to mandate fuel-reduction thinning.[15]

[15] See PL 108-148, the "Healthy Forest Restoration Act of 2003."

Managing policy change

According to True *et al.* (1999), when an issue is brought to the forefront of a large political venue, either because of a crisis or an unusual social or political mobilization, dramatic shifts in policy may occur quickly. These shifts occur because of a plethora of potentially overlapping jurisdictions in the modern political system. When a macro forum considers an issue, new institutions scrutinize a previously isolated subsystem. These new jurisdictions often have an explicit interest in change, for instance, local governments that had previously been uninvolved in logging practices may want to increase logging to augment their tax base, or an Indian Tribe that had not previously been involved in sediment regulation might insist on stricter standards to protect critically endangered fish runs protected by treaty.

The policy changes that are needed to account for non-equilibrium ecosystem dynamics may be controversial and face resistance from some groups or interests. There may be a tendency, when trying to implement change, to marginalize these forces. A wiser course of action may be to expand the constituencies that care about and are engaged in the policy to be changed. For instance, Steel argues that scientists should assume a larger role in shaping policies to conserve wild salmon runs in order to shift momentum from symbolic to substantive political action (Steel 2006).

The State of Oregon has in the past made efforts to expand the constituency of thorny management issues. In 1999, for instance, Gov. Kitzhaber and Forest Service Chief Dombeck launched the Blue Mountain Demonstration Project (BMDA) with much fanfare. The impetus for the BMDA was Kitzhaber's sense that the Forest Service was not vigorously implementing the recommendations put forward by a State of Oregon citizen forestry advisory panel. His solution was a state-federal partnership to promote needed thinning and restoration work in a three million acre demonstration area in the Blue Mountains. Although extensive on-the-ground management activities were accomplished, political momentum for the project declined amid discordant stakeholder expectations. These and other policy initiatives should be analyzed for lessons that can be applied to future efforts.

The Pew Center on Global Climate Change has developed a "Policy Tool Ladder" that conceptualizes different mechanisms for effecting policy change, encompassing

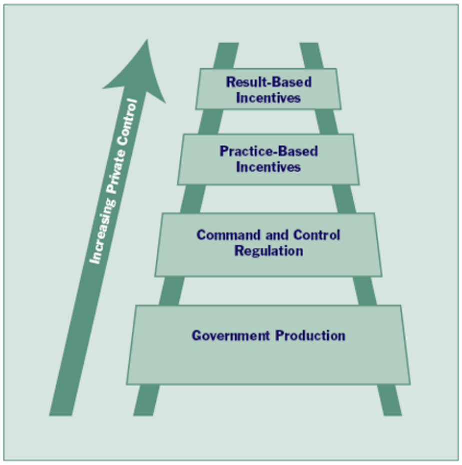

Figure 14. The Policy Tool Ladder (from Pew Charitable Trust)

practices ranging from government production to regulation to incentive based programs. One way to change policy is to use one or more of these tools to involve additional constituencies in needed policy change. For instance, an agency like the Oregon Watershed Enhancement Board could be given a greater purview, providing funding to landowners for providing an array of ecosystem services, including connecting salmon habitat (see aquatic system policy recommendations in Part III).

Appendix II describes key changes in demographics, values and socioeconomics in the Pacific Northwest. We can conclude from trends in public opinion that controversy over older management paradigms is likely. New policy tools should be developed in anticipation of the need for dramatic shifts in policy.

Hypothetical policy change strategy #1: Incentive-based Willamette Valley oak conservation

Oregon white oak woodlands and savannahs—once widespread in the Willamette Valley—are among the most biologically diverse ecosystems in Oregon, providing important habitat for a variety of declining species (Coblentz 1980). White oak woodlands and savannahs were maintained by frequent fire, and this forest type has declined dramatic due to fire suppression and changes in land use (Agee 1995; Vesely and Tucker 2004). In addition to serving as an example of how changes to disturbance patterns and land use disrupt ecosystem function and processes, research into white oak conservation in the relatively densely populated and largely privately owned Willamette Valley may demonstrate how incentive-based policies can promote conservation of rare habitat, protect water quality, or reduce fire risk in rural residential areas.

Research by Fischer (2007) documents private landowner attitudes towards oak conservation and suggests strategies for working with owners to conserve oaks. Not surprisingly, she found that private landowners place great value on autonomy and self-determination in managing their lands, and concludes that incentive-based programs offer the best chance of successfully promoting oak conservation. Her research indicates that there is often a lack of knowledge of the importance and value of oak conservation, and that incentives such as tax credits, cost-sharing, regulatory relief, conservation rent and/or market creation may be most effective when preceded by educational and networking efforts. The threat of regulation, especially regulation of oak obligates like the Fenders blue butterfly under the Endangered Species Act, may discourage landowner participation in collaborative programs and from making use of technical assistance from agencies. Fischer's research also points to the need for multiple, negotiated conservation strategies at different scales to accommodate land owners' diverse motivations, capacity levels, and desire for self-determination.

Fischer's doctoral dissertation (based on qualitative interviews with Willamette Valley land owners) presents two figures that are helpful in understanding how different policy tools can work to change private landowner behavior. In the first figure, she maps different landowner motivations and the appropriate corresponding policy tool.

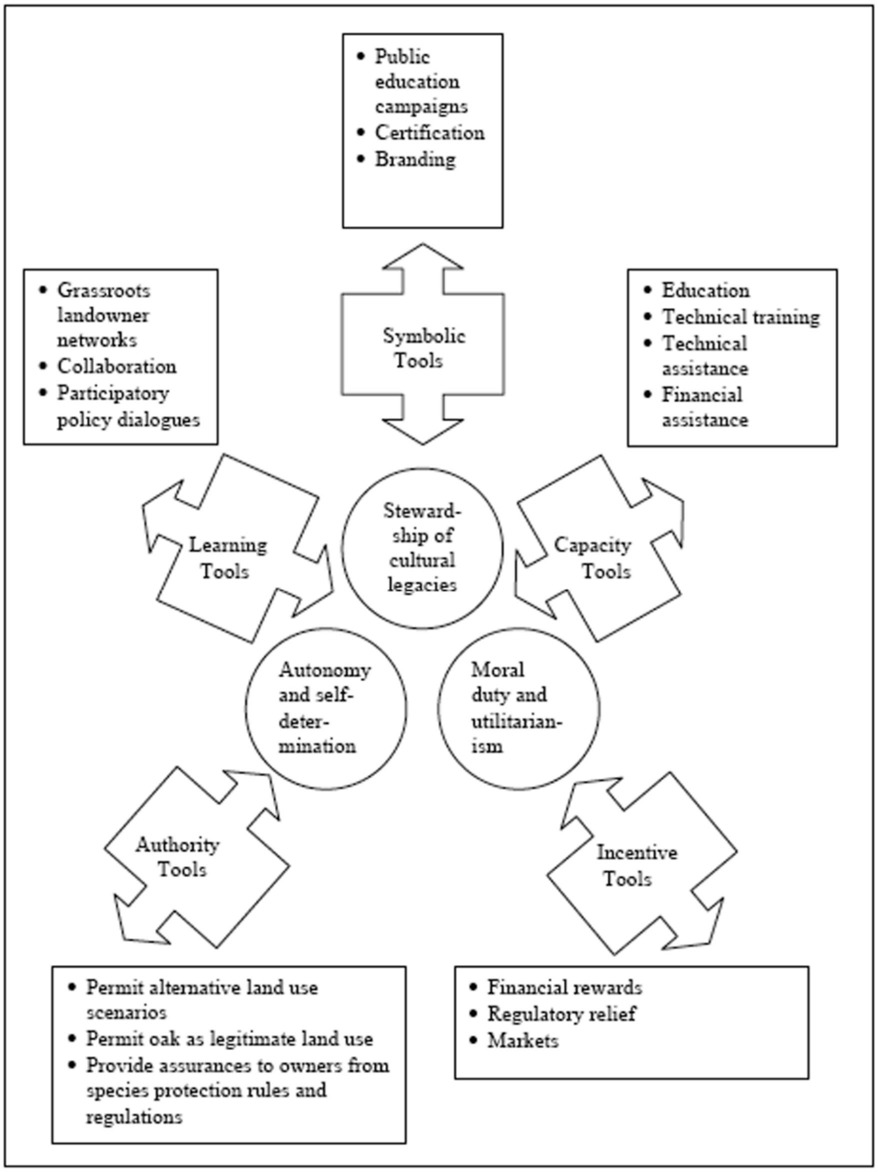

Figure 15. Landowner attitudes and corresponding policy tools for encouraging oak conservation (from Fischer 2007).

The second figure is a conceptual model of different social, economic, legal and policy forces that benefit or detract from oak conservation.

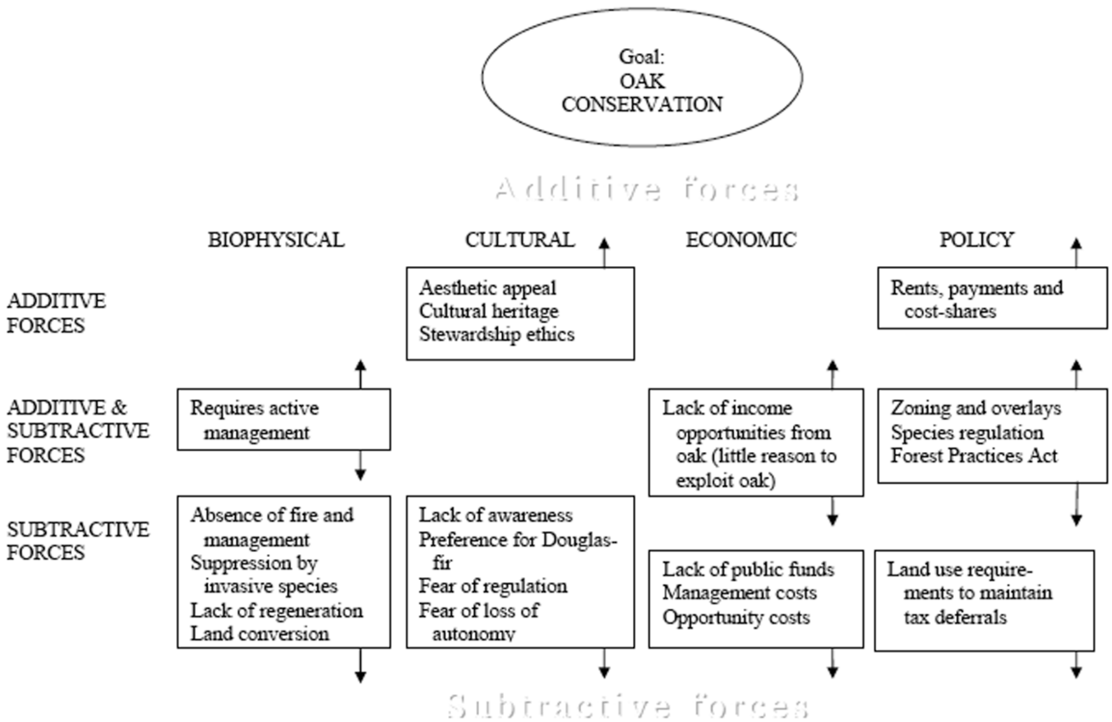

Figure 16. Forces that add to or subtract from oak conservation efforts (from Fischer 2007).

Hypothetical policy change strategy #2: Regulation-based community fire protection

Sunriver, a central Oregon community of 3,374 acres and up to 12,000 residents, provides an example of effective regulatory action to reduce fire risk in the wildland-urban interface. The Sunriver Owner's Association and the Sunriver Fire Department created the *Sunriver Community Wildfire Protection Plan: A Handbook for Wildland-Urban Interface Communities* in response to several nearby wildfires in the 1990's. Like many planned communities, Sunriver initially prohibited tree and brush removal and required wood shake roofs. By 1996 the community had rescinded these policies. Today, a staff provides education, property inspections, and manages fuel-reduction thinning on common grounds. Other priority strategies of the Plan include controlling bitterbrush, increasing spacing between trees and ladder fuel removal.

Under the Plan, homeowners must meet a variety of compliance measures. New roofs and remodels must be constructed to meet a Class "A" fire rating. All chimneys must maintain spark arresters, landscaping plans must meet stringent standards, and outdoor burning is prohibited. The homeowner's association has the authority to increase precaution levels to include prohibiting use of chainsaws and outdoor grills during periods of high fire risk weather (Sunriver Owners Association and Sunriver Fire Department 2005).

Hypothetical policy change strategy #3: Planning for biomass utilization in Eastern Oregon

Researchers and policy-makers have focused considerable attention on reducing fuels in the fire-prone forest types that typify Eastern Oregon. It is generally accepted that removal of fine fuels—including litter, brush, and small-diameter trees—is important to moderate severe fire behavior (Agee and Skinner 2005). While some thinning projects that remove commercially merchantable small diameter trees may pay for themselves, there is a recognized need to develop markets for currently unmerchantable material to leverage needed work in a time of constricted land management budgets and declining timber markets. One solution is to burn fine material to produce power or convert it to fuels like ethanol.

One biomass utilization and technology assessment for Baker, Union and Wallowa counties found that there was significant biomass available for power or fuel production from agricultural and forestry practices in these counties. Siting biomass utilization facilities in close proximity to fuel sources, and matching the capacity of these facilities with available supplies was found to be important for successful development of a biomass market. A barrier to private sector investment in facilities was a lack of information about long-term supply, delivery costs, costs of biomass and suitable location (Oregon Department of Energy 2003).

Hypothetical policy change strategy #4: Long-term land use and land acquisition planning

Part I briefly discussed the potentially huge impact that increasing population pressures may have on natural resources in Western Oregon, particularly within the context of global climate change. It should be clear by now that ecosystem dynamics management involves managing human behavior and expectations as much as the behavior of natural systems.

A very troubling picture emerges if we assume that 1) there will be substantial increases in Oregon's population, especially in proximity to Western Oregon ecosystems that are relatively buffered from the effects of climate change; 2) there will be a corresponding increase in demand on natural resources, including demands on water and developable land; and, 3) because of recent political decisions, there will be less not more capacity for planning and regulating growth. If we make all these assumptions, a logical solution is to embark on a comprehensive, long term planning effort for development of Western Oregon's lands and resources over a very long-term (50+ year) horizon. A recent long-term conservation strategy for the Puget Sound area may be a useful example. The Cascade Agenda: A 100 Year Vision for Pierce, King, Kittitas and Snohomish Counties was the result of the "Cascades Dialogues" between stakeholders in the Puget Sound area convened by the "Cascades Dialogues Steering Committee," composed of local conservation organizations and elected governments. The final report identifies 1.26 million acres in rural and wildland settings that are targeted for conservation acquisition and proposes urban and rural design measures that will take population pressure off of rural areas.[16]

Hypothetical policy change strategy #5: Creating an ecosystem services market for Oregon

The Institute for Natural Resources recently completed a report, "Policy Cornerstones and Action Strategies for an Integrated Ecosystem Market in Oregon," that has important implications for ecosystem dynamics management. Many of the policy changes recommended in this paper contemplate incentives to landowners to change their

[16] The complete Cascade Agenda report can be downloaded at www.cascadeagenda.org.

management practices to comport with the natural range of variability and/or to support desired future ecological processes. Currently, existing markets that provide fiscal or other types of incentives to landowners include carbon, wetlands, habitat, open space and hazard reduction markets. INR's report contains recommendations for a more efficient and integrated ecosystem services market (Institute for Natural Resources 2008) that can better provide incentives to landowners involved in strategic conservation practices.[17]

Hypothetical policy change strategy #6: Alternative Clean Water Act implementation (a "hard" framework)

The federal Clean Water Act of 1972 is a lengthy and complex statute that employs two basic approaches to cleaning up waterways. The first approach is the use of technology-based effluent standards and a system of permitting (the National Pollution Discharge Elimination System or NPDES) to control discharges from "point" sources. NPDES permits required use of the "best practicable technology available" during the 1970's and 80's. This approach is widely credited with substantially reducing pollution into the nation's rivers, streams and lakes over the last thirty years.

The current approach to Clean Water Act administration is based on water quality. In addition to the use of NPDES permits, the water quality approach addresses pollution in the form of elevated nutrients, sediment, temperature and toxics from diffuse "non-point" sources, which monitoring has established to be the principal threat to water quality in most of the nation's waterways. This approach entails establishment of ambient water quality standards, designation of streams that don't meet these standards, and development and implementation of plans—called Total Maximum Daily Load (TMDL) plans—that establish load limits for nutrients, sediment, temperature, and toxics (National Research Council 2001).

Regulation of chemical pollution into waterways with technology standards is straightforward and appropriate in almost every case because managers can be confident that exceeding chemical pollution standards is due to human activity. The other water quality variables regulated as pollutants, including elevated sediment, nutrient and temperature levels, in contrast, do not necessarily lend themselves to regulation by static

[17] See http://inr.oregonstate.edu/download/ES_Cornerstones_July2008.pdf.

standards because this type of pollution is naturally highly variable. Nonetheless, designing thresholds that distinguish between natural dynamics and unacceptable human impacts can be difficult. A threshold that is within the range of natural variability may actually be harmful to aquatic life. Managing for thresholds may also tend to homogenize systems that are historically quite variable (Poole *et al.* 2004).

As an alternate management strategy, Poole *et al.* (2004) suggest development of "regime standards," that encompass the desired characteristics of variable natural regimes. Regime standards would "describe a desirable distribution of conditions for water quality over space and time, rather than rely on a single threshold value." These regime standards would be applied at broad geographic and temporal scales and would describe desirable conditions distributed at different places and at different points in time. As an example, in managing temperature suitable for salmonid recovery in Oregon coastal streams, a regime standard would describe thermal conditions in streams contiguous enough to support life cycles of local populations. Accomplishing this result would require management of many streams as a single unit. The broader unit, not individual streams (which may be in a disturbed condition), would be analyzed for compliance or non-compliance with the regime standard (Poole *et al.* 2004).

To regulate non-point pollution the Clean Water Act requires individual states to establish ambient standards, list streams that don't meet these standards pursuant to §303(d) of the Act, and develop TMDLs. The Oregon State legislature has delegated non-point source regulation for forestry to the ODF. The Oregon Forest Practices Act inserts economic criteria into silviculture non-point source regulation.

Moving to a regime standard model for Clean Water Act enforcement might involve developing ambient water quality standards that are tailored to reflect the natural range of variability in stream systems and other waters of the state and writing TMDLs that allow for large pulses of sediment and material (e.g. large woody debris) that are within the natural range of variability. This would require close coordination between land management plans and TMDLs to ensure recovery of degraded stream systems.

One possible example of this approach is the Umatilla River TMDL, where analysis and load allocation was done at a 5th field watershed scale.[18] The DEQ's temperature standard also incorporates natural variability. The standard includes maps, a table of natural maxima and a provision for natural thermal potential in different stream systems (i.e., if a stream's natural temperature is higher than the standard, the natural temperature becomes the new standard for that stream).[19]

The language of the Clean Water Act and the voluminous case law that interprets the Act creates a strong mandate for use of the best available science in developing water quality standards and TMDLs. The heart of a TMDL is typically a detailed scientific model of water quality variability for a particular stream system. Although the Environmental Protection Agency (EPA) delegates considerable authority to states to craft appropriate water quality standards and TMDLs, critically, the EPA must approve all TMDLs promulgated by the states. Section 505 of the Act provides for citizen suits to enforce the Act's mandate to use robust scientific models in developing water quality standards and TMDLs.

The Clean Water Act is not the purview of a smaller policy subsystem; it is a federal statute and only the United States Congress, a high order political system, can make substantive changes to the law, possibly in response to a crisis in governance such as that described above.[20] Because only major federal action can change the requirements of the Act, and because environmental litigation can be expected to curtail innovations to the Act that don't meet a high standard of scientific integrity, the Clean Water Act can be characterized as a "hard" framework resistant to change.

What would constitute a defensible scientific rationale for alternative water quality standards or TMDLs that account for the full range of natural variability in stream systems? What do land managers need to do to show that practices benefit the watershed? First, vigorous models of stream variability would need to be developed. Second, future variations in stream sedimentation, temperature, large wood, etc. would have to be

[18] See http://www.deq.state.or.us/wq/TMDLs/umatilla.htm.
[19] See http://www.deq.state.or.us/wq/pubs/imds/Temperature.pdf.
[20] The last major amendments to the Clean Water Act were in 1990. Several attempts to make the law more flexible have failed, including HR 961, which passed the US House of Representatives but stalled in the Senate.

designed to reflect the spatial and temporal patterns to which the stream is adapted. As noted in case study #1, many stream systems in Western Oregon typically experience stochastic wildfire/storm events that create large pulses of material within a relatively short time span. This contrasts with typical forest management practices, which often contribute chronic low-level sediment on a continuous basis. The key to allowing large pulses of material within the context of a scientifically defensible TMDL may be ensuring that the pulses are temporally distinct, rather than ongoing.

Expanding the geographic scope of management has been a consistent theme in this paper's discussion of an ecosystem dynamics management approach. Expanding the typical geographic reach of a TMDL may be a scientifically defensible approach to managing for highly variable stream dynamics. The expanded authority of a point source permit in Washington County provides an example. In 2004, Clean Water Services (CWS), the water resources management agency for Washington County, received the first fully integrated municipal NPDES permit, which covers the operation of four wastewater treatment facilities and one urban stormwater system. Five separate permits had previously covered these operations. The new integrated permit allows trading of water quality credits to achieve overarching water quality goals. To meet temperature goals, for example, CWS may compensate for heat released from the treatment facility with cooling mitigation measures such as shade-providing tree plantings on other facilities operated under the integrated permit.

Similarly, a number of TMDLs for different stream systems or basins might be combined into one TMDL, with a water quality trading system that allows for large pulses of sediment in one stream system to be compensated for by mitigation measures in the other stream systems. The development of a market for ecosystem services discussed above might aid in this approach.

Hypothetical policy change strategy #7: New Oregon Forest Practices Act regulations (a "soft" framework)

Because it is the purview of a smaller policy subsystem (a state vs. a federal legislature and interest groups), and because many requirements are derived from administrative regulations developed at the discretion of agencies, private forest management under the Oregon Forest Practices Act is likely to be a more flexible policy framework than water quality protection under the Clean Water Act. The Forest Practices Act is thus a "soft framework" relative to the Clean Water Act.

As noted above, the Clean Water Act delegates considerable authority to state agencies. The Oregon legislature has made the ODF the "Designated Management Agency" for regulation of water quality on nonfederal forestlands. Oregon statute (ORS 527.765) requires the Board of Forestry, in consultation with the Environmental Quality Commission (EQC), to establish best management practices for forestry activities that are designed to limit non-point sources of pollution to achieve water quality standards established by the EQC.

Oregon statute grants the Oregon Board of Forestry broad discretion to promulgate best management practices. Pursuant to ORS 527.765, factors that inform development of best management practices include "Natural variations in geomorphology and hydrology"—presumably including the aquatic ecosystem dynamics described in this paper.

The Forest Practices Act's emphasis on maintaining mature forest conditions in riparian areas is derived from administrative regulations developed at the discretion of the ODF. OAR 629-640-0000(2) states that: "The desired future condition for streamside areas along fish use streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands." Changes to clearcut limitations and reforestation requirements are found both in the Oregon Forest Practices Act (ORS 527.745) and in administrative regulations (OAR 610). Changing these requirements would require action by the legislature and the ODF.

Summary and conclusions about ecosystem dynamics management policy change

Ecosystem dynamics management should focus on the maintenance and restoration of ecological processes that perpetuate resilient systems within the context of social expectations. Maintaining and/or restoring ecological processes that perpetuate resilient systems will be challenging because:

- We may lack complete information about historic ecological processes.

- The future ecological processes in an area may not match closely in type and rate with those operating in the past.
- Legal frameworks and social expectations may not allow for maintenance and/or restoration of key ecological processes (i.e., wildfire near rural residential developments).
- Key processes may be operating at a large geographic scale such as a river basin, managed under a variety of ownerships with very different goals (e.g., federal forest reserves and industrial forestland).
- Key processes, such as hundred-year flood events, may be operating at long temporal scales that occur beyond the horizon of a typical manager's realistic planning horizon (or lifetime).
- Existing management frameworks may emphasize maintenance of point-in-time indices of ecosystem function, instead of maintenance of landscape scale, long-term processes.

The solution to these problems is straightforward but difficult to implement:

- Comprehensive research that reconstructs historical ecological processes.
- A scientific and social consensus about desirable and realistic future ecological processes.
- Changes to the regulatory framework that emphasize maintenance and restoration of key ecological processes.
- Creation of durable management frameworks that cover broad temporal and spatial scales.

Imperfect responses to these challenges are the most realistic outcome given these constraints. This paper offers ideas about policy change to stimulate future discussion. These ideas include:

- To the extent feasible, consolidate ownerships in large geographic blocks and/or develop voluntary market mechanisms to encourage cross-ownership coordination of management practices.

- Develop a broad suite of policy instruments to provide incentives to private landowners to implement management that maintains and restores key ecological processes, for example, a robust and integrated ecosystem services market and a program of land exchanges.
- To the extent feasible, rework the management framework of small political subsystems to reflect ecosystem dynamics management considerations.

This paper describes the general contours of an ecosystem dynamic management paradigm and makes preliminary observations about specific policy changes that might reflect this new paradigm. However, the paper leaves unanswered the most basic question about how to gain public acceptance for new policies and achieve policy change. Appendix II, a paper by Steel *et al.* (2008) serves as a starting point for answering this question.

The first section of Appendix II paints a complex view of the public's views and values when in comes to natural resource management. Two very general themes emerge. There is an unmistakable trend in modern post-industrial society towards conservation and environmental consciousness that reflects the trend toward a more urbanized society. And there is also a trend towards polarization in natural resource management values.

The second section of Appendix II examines a potential new role for scientists in policy making, suggesting that scientists move beyond their traditional role interpreting the results of research for managers and help facilitate the integration of research findings into policy. There is strong support for the latter "post-normal" or "civic science" role, suggesting a broader role for scientists in the policy-making arena, for instance, by promoting incremental policy change through use of adaptive management mechanisms (Swanson 2004 and Lach 2003).

Ecosystem dynamics management as described in this paper is a challenging new perspective offered in a polarized political and social context. Adoption of the ecosystem dynamics paradigm must involve an innovative new approach, the creation of a learning policy environment with broad participation by diverse stakeholders. The following principles should guide the development of this learning environment:

- Invite broad participation, including businesses, private landowners, non-governmental organizations, land managers and researchers.
- Begin with questions. A learning environment must ascertain the limits of our scientific knowledge and the social expectations of different stakeholders and frame research questions to be responsive to those variables.
- The interpretation of research results and the policy changes that follow should be a collaborative process with input from different stakeholders.

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Reeves GH, Duncan S. 2008. Illusions of failure in managing aquatic ecosystems: Ecological history versus social expectations. Submitted: Ecology and Society.

Reeves GH, Benda LE, Burnett KM, Bisson PA, Sedell JR. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitat of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334-349.

Rieman BE, Dunham JB, Clayton JL. 2006. Emerging concepts for management of river ecosystems and challenges to applied integration of physical and biological sciences in the Pacific Northwest, USA International journal of river basin management. 4(2):85-97.

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Appendix I
Ecosystem dynamics literature review

Barbour RJ, Hemstrom MA, Hayes JL. 2007. The Interior Northwest Landscape Analysis System: A step toward understanding integrated landscape analysis. Landscape and Urban Planning 80(3):333-344.

This paper, summarized in case study #3, describes the Interior Northwest Landscape Analysis System (INLAS), a method for integrated landscape analysis of watersheds in the interior Columbia Basin. This method relies on state and transition models of vegetation change and probability estimates of transitions. Among the variables considered is wildlife habitat quantity, insect activity, grazing by ungulates, timber management, and wood utilization potential. Interpretation of these variables allows prediction of vegetation succession and disturbance under different management scenarios. Preliminary modeling with this methodology yields a number of important conclusions for ecosystem dynamics management, including: 1) maintenance of older multistoried structure in the interior Northwest will be difficult; 2) both active fuel treatments and passive management is likely to increase the proportion of older single storied forests; and, 3) fire-suppression alone is the least effective of the management scenarios considered in producing and maintaining large old trees in either dry or moist forest types.

Topic area	Fuel reduction, disturbance
Case studies or examples presented?	Yes, interior Columbia Basin modeled
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Benda L, Poff L, Miller D, Dunne T, Reeves G, Pess G, Pollock M. 2004. Network Disturbance Theory: Landscape and River Organization Environmental Variance. Bioscience 54:413-427.

This paper describes network disturbance theory, a unified framework for understanding geomorphic processes and their role in producing patchy mosaics of different habitat in streams. This theoretical framework can predict biological outcomes, including biodiversity in aquatic systems. Among the paper's conclusions is that "increased habitat heterogeneity can directly promote greater aquatic and riparian diversity and indirectly promote biological productivity by increasing retention of nutrients and organic matter."

Topic area	Riverine ecology
Case studies or examples presented?	No
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Benda L, Miller D, Sias J, Martin D, Bilby R, Veldhuisen C, Dunne T. 2003. Wood Budgeting: Quantitative Theory, Field Practice and Modeling. In: Gregory SV, Boyer KL, Gurnell AM, editors. The Ecology and Management of Wood in World Rivers American Fisheries Society, Symposium 37, Bethesda, Maryland.

This paper presents a model for "wood budgets" in river system that takes into account punctuated forest mortality from fire, chronic mortality, bank erosion, mass wasting, decay, and stream transport. These wood budgets can be used to describe the relative importance of different landscape scale processes. Critically, for the purposes of ecosystem dynamics management, these models can be used to describe the range of variability of wood budgets and to predict variations in wood budgets due to changes in climate and land management.

Topic area	Riverine ecology
Case studies or examples presented?	Yes, references to studies in the Pacific Northwest
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Both
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Benda L, Poff NL, Tague C, Palmer MA, Pizzuto J, Cooper S, Stanley E, Moglen G. 2002. How to Avoid Train Wrecks When Using Science in Environmental Problem Solving. BioScience 52(12):1127-36.

This paper discusses some common pitfalls in interdisciplinary scientific collaboration, and suggests a formal methodology for structuring interdisciplinary efforts. This methodology involves structuring knowledge into five categories: (1) disciplinary history and attendant forms of available scientific knowledge; (2) spatial and temporal scales at which that knowledge applies; (3) precision (i.e., qualitative versus quantitative nature of understanding across different scales); (4) accuracy of predictions; and (5) availability of data to construct, calibrate, and test predictive models. This structure can be used to identify gaps in knowledge and solve problems. The methodology is illustrated by examining the general topic of land use impacts on riverine ecosystems, a management topic that involves hydrology, fluvial geomorphology, and riverine ecology, among other disciplines.

Topic area	Ecosystem dynamics problem solving; management methodology
Case studies or examples presented?	Yes, hypothetical example of problem solving for riverine ecosystems.
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Relatively practical theoretical model for decision making
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Burnet, KM, Reeves GH, Miller DJ, Clarke S, Vance-Borland K, Christiansen K. 2007. Distribution of Salmon-Habitat Potential Relative to Landscape Characteristics and Implications for Conservation. Ecological Applications 17(1):66-80.

As described in case study #11, this paper describes how high potential salmon habitat is distributed relative to different ownership and land use patterns. Much high quality salmon habitat in the Oregon Coast Range is found on private lands, suggesting that private lands should be the focus of efforts to connect habitat.

Topic area	Salmon recovery
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	Data set of high potential salmon habitat relative to ownership and land use patterns.
Management tools that can be immediately	Yes

adapted for use managing Oregon ecosystems?

Canadian Forest Board. 2007. The Effect of Mountain Pine Beetle Attack and Salvage Harvesting On Streamflows—Special Investigation. FPB/SIR/16.

This paper examines pre-disturbance conditions in a watershed currently infested with mountain pine beetle in interior British Columbia, and the effects of streamflow from conventional harvest, mountain pine beetle attacks, and salvage operations typical of mountain pine beetle infected forests. The study found an increase in peak flows in mountain pine beetle infested watersheds relative to pre-infestation baselines, and an accelerated increase following salvage logging. These findings suggest the need to develop plans to protect water quality and fish stocks. This paper is of interest to ecosystem dynamics in Oregon first because, like the Cobb piece described below, it characterizes the cumulative effect of disturbance, and because it provides direction in case of insect infestation in our region.

Topic area	Insect dynamics
Case studies or examples presented?	Yes, interior BC watershed studied
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Cobb TP. 2007. Boreal Mixed-wood Beetles and the Cumulative Ecological Consequences of Disturbance. Doctoral dissertation, Univ. of Alberta.

This dissertation investigates the cumulative effect of wildfire and postfire salvage logging on species composition and richness in a central Alberta post fire environment. It finds that postfire logging negatively altered the trophic structure of beetle assemblages, suggesting that cumulative disturbance should be avoided because, among other things, it disrupts decomposition processes.

Topic area	Post-fire management
Case studies or examples presented?	Yes, study of fire area in Alberta
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Duncan S, McComb B, Johnson KN, 2008. In review. Integrating Ecological and Social Ranges of Variability in Conservation of Biodiversity: Past, Present, and Future. Ecology and Society online, special issue.

This paper integrates the concepts of historical and future ranges of variability. Oak Savannah and coast range seral communities are used as examples (the former was historically maintained by extensive human management, the latter much less so). This paper has a very cogent discussion of changes in disturbance patterns relative to social expectations.

Topic area	Historical range of variability, disturbance
Case studies or examples presented?	Yes
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No

Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Haeussler S, Kneeshaw D. 2003. Comparing forest management to natural processes. In: Burton PJ, Messier C, Smith DW, Adamowicz WL (eds.). 2003. Towards sustainable management of the boreal forest. National Research Council of Canada. NRC Press.

This chapter provides an important reassessment of mechanical silviculture that mimics natural disturbance. This analysis deals with Canadian boreal forests, but is applicable to other forest types. Most operational silvicultural models are based on stand replacing wildfire, but the role of this type of fire may have been over-emphasized. Environmental change from insects, pathogens, large animals, wind, snow, and ice damage may be more prevalent and important influences on ecological process than wildfire. Other discrepancies between natural disturbance phenomenon and silvicultural practices, such as the existence of a road network, may also be a challenge in duplicating historical conditions.

The range of variability in Canadian boreal systems is unclear. Historically, there may have been large oscillations in tree mortality. Managers often seek an "optimal" historical wildfire-based landscape age structure, but there may not be a single landscape pattern that is ideal for all species (or forest uses) associated with boreal forests.

This study found that silviculture in boreal forest types generally did not reduce species diversity or ecosystem productivity, but also found significant shifts in species composition (i.e., more deciduous and fir species) that affects broad scale diversity and ecological processes. As currently practiced, silviculture is expected to cause progressive change to boreal systems. The study's basic recommendation is to adopt a variety of different forest practice. Creating complex spatial mosaics may not truly emulate historical conditions, but might achieve socially desirable goals compatible with maintaining biodiversity and ecosystem function.

Topic area	Historical range of variability, disturbance

Case studies or examples presented?	No
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Harmon ME, Marks B. 2002. Effects of silvicultural treatments on carbon stores in forest stands. Canadian Journal of Forest Research 32:863-877.

Among other methodologies and models, this paper introduces the reader to "STANDCARB," a computer model that can be used to simulate changes to carbon pools under different harvest scenarios. These simulations indicate that partial harvest and minimal fire may provide similar wood products outputs as traditional clearcut and slash burn methods while storing more carbon. This model could y be useful in calculating carbon storage if carbon markets were developed to encourage conservation practices by private landowners.

Topic area	Carbon storage
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Johnson EA, Morin H, Miyanishi K, Gagnon R, Greene DF. 2003. A process approach to understanding disturbance and forest dynamics for sustainable forestry. Chapter 8. Pages 261-306. in: Burton PJ, Messier C, Smith DW, Adamowicz WL (eds.). 2003. Towards sustainable management of the boreal forest. National Research Council of Canada. NRC Press.

Although specific to management of boreal forests, this study provides a variety of important insights into forest management generally. Among other things, it may be read as critique of the "disturbance regime" approach to management, which seeks to recreate with management activities the landscape patterns that result from historical disturbance variability. The disturbance regime approach may not fully acknowledge disturbance processes and their results. To illustrate this point, this study considers two disturbance processes: wildfire and eastern spruce budworm. Both wildfire and spruce budworm result in specific soil smoldering effects, age specific tree mortality, and seedbed dynamics, all of which result in different cohort age structure. Better understanding of these effects is necessary to design successful management based on historical disturbance.

Topic area	Historical range of variability, disturbance
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Johnson KN, Duncan S. 2007. The Future Range of Variability: Project Summary. National Commission on Science for Sustainable Forestry.

This paper, discussed in Part I, describes how the “future range of variability” can supplement the historical range of variability concept.

Topic area	Historical range of variability, disturbance
Case studies or examples presented?	Yes, five case studies, one in Oregon
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Kittredge DB, Finley AO, Foster DR. 2003. Timber harvesting as an ongoing disturbance in a landscape of diverse ownership. Forest Ecology and Management 180:425-442.

In this study of forestry practices in New England, selective logging by non-industrial forest owners in an area with complex ownership was found to have a significant influence on forest pattern. This study indicates that small forestland owners, potentially including small forestland owners in Oregon, may exert an important but largely unstudied influence on habitat, ecological processes and forest dynamics.

Topic area	Forest dynamics, ownership patterns
Case studies or examples presented?	No
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes

Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Landres PB, Morgan P, Swanson FJ. 1999. Overview of the use of natural variability concepts in managing ecological systems. Ecological Applications 9:1179-1188.

This article demonstrates that the range of natural variability is an important tool for managers. Absent systematic knowledge of ecosystems, knowledge of past conditions is the best way to predict impacts to systems today. The article highlights some common pitfalls in the use of the natural range of variability to design management. Specific goals, site specific field data, inferences from data collected elsewhere, modeling, and value judgment should inform selection of a particular time period that defines the range of variability.

Topic area	Forest dynamics, ownership patterns
Case studies or examples presented?	No
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Mallon AL. 2006. Public acceptance of disturbance-based forest management: a study of the attentive public in the Central Cascades Adaptive Management Area. Corvallis, OR: Oregon State University, M.S. Thesis.

There is currently little information about public attitudes about disturbance history-based management. This study examines public perceptions of disturbance-based management practiced at the Central Cascades Adaptive Management Area (CCAMA), which is the subject of case study #4. Respondents to a survey nearby residents found they had a good deal of knowledge about general ecosystem management concepts, but knowledge of disturbance-based management techniques was low. An analysis of responses indicates that the public would support disturbance-based management if based on sound science and a transparent and inclusive decision making process. The study recommends acknowledging the role of the public, including them early in planning processes, and explaining and clarifying the management approaches adopted, including a thorough disclosure of risks and uncertainty.

Topic area	Social acceptability of management practices
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

McComb B, Duncan S. 2008. In review. Biodiversity Conservation in Contemporary Landscapes, Stressors, and Ranges of Variability: Scientific and Social Views. Ecology and Society online, special issue.

This paper evaluates the usefulness of the future range of variability concept (see Part I) for five different sites in the United States, including one in Oregon.

Topic area	Historical range of variability, disturbance
Case studies or examples presented?	Yes, five case studies, one in Oregon
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of	Synthesis

existing knowledge?	
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Morgan P, Aplet GG, Haufler JB, Humprhries HC, Moore MM, Wilson WD. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. J. Sustainable Forestry 2:87-111.

This is another study that reviews the usefulness of designing management around the historical range of variability. In particular, this study finds that the historical range of variability is useful in determining the limits of desirable ecosystem change. The authors note that ecosystems are structured hierarchically, and so the historical range of variability must be characterized at multiple temporal and spatial scales.

Topic area	Historical range of variability
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Nonaka E, Spies TA. 2005. Historical range of variability in landscape structure: a simulation study in Oregon, USA. Ecological Applications. 15(5):1727-1749.

As discussed in Case Study #7, this study examines the historical range of variability in the Oregon Coast Range physiographic province. This study is an excellent example of research that establishes past forest structure and models future management to recreate that structure. This study found that current landscape patterns in the Coast Range are far outside the historical range of variability and examined several alternate management scenarios that could recreate historical conditions. Current ownership patterns were found to be a major barrier in using the historical range of variability to recreate historical patterns at broad geographic scales.

Topic area	Historical range of variability, disturbance, regulatory regimes
Case studies or examples presented?	Yes
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Perera AH, Buse LJ, Weber MG. 2004. Emulating Natural Forest Landscape Disturbances. New York: Columbia University Press.

As suggested by the title, this book provides a comprehensive overview of management that emulates natural disturbance. The editors and contributors provide a cogent narrative about use of the term "natural" to describe disturbance patterns, what emulating natural disturbance involves, and rationale for use of natural disturbance patterns in designing contemporary management. The book can be read as an analysis and critique of the use of the historical range of variability. The book includes a variety of case studies from across the United States and Canada (including one in the Oregon Coast Range).

Topic area	Historical range of variability, disturbance

Case studies or examples presented?	Yes
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Poole GC, Dunham JB, Keenan DM, Souter ST, McCullough DA, Mebane C, Lockwood JD, Essig DA, Hicks MP, Sturdevant DJ, Materna EJ, Spalding SA, Risley J, Deppman M. 2004. The Case for Regime-based Water Quality Standards. Bioscience 54:155-161

As described in Part IV, this article proposes to replace point-in-time water quality standards with "regime standards" that account for disturbance variability in stream systems.

Topic area	Clean Water Act, stream system dynamics
Case studies or examples presented?	No
Integrates other research on the topic?	No
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Reeves GH, Duncan S. 2008. Illusions of failure in managing aquatic ecosystems: Ecological history versus social expectations. Submitted: Ecology and Society.

This is an important paper for its critique of current regulatory regimes. It discusses problems with the uniform application of measurement-based regulations like the Clean Water Act relative to natural fluctuations in dynamic stream systems. The authors find a "fundamental incongruity between regulations and on-the-ground reality." They suggest flexibility in regulation that allows "for changes through time and across different scales, from stream reaches to large landscapes."

Topic area	Historical range of variability, disturbance, regulatory regimes
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Reeves GH, Benda LE, Burnett KM, Bisson PA, Sedell JR. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitat of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334-349.

This paper offers hypotheses about how salmonids respond to change in habitat patterns over large landscapes, a subject that is currently poorly understood. The Coast Range of Oregon is used to test these hypotheses. Field observations and a simulation model developed by Benda demonstrate that episodic disturbance events (including storms and large stand-replacing fires) create highly variable habitat over large landscapes. In the Coast Range, "intermediate" succession forest stands (120-150 years old) stream were found to provide the best salmonid habitat. The authors recommend managing for "pulse" rather than "press" style disturbances, and recommend a "shifting mosaic of reserves that change location in response to the ability of specific watersheds to provide suitable habitat conditions." In this conceptualization, some salmon habitat will "wink out" in response to anthropogenic or natural disturbance while other sites "wink on."

Topic area	Historical range of variability, disturbance, regulatory regimes
Case studies or examples presented?	Yes, Oregon Coast Range analyzed
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Rieman BE, Dunham JB, Clayton JL. 2006. Emerging concepts for management of river ecosystems and challenges to applied integration of physical and biological sciences in the Pacific Northwest, USA. International Journal of River Basin Management 4(2):85-97.

Like the Reeves *et al.* paper above, this study questions the notion that there are stable or ideal riverine conditions. Instead, it demonstrates that stream habitat conditions shift over time in response to dynamic disturbance processes. One problem identified is that of scale: Although riverine processes like sedimentation may be well understood on small scales, they are rarely placed in larger contexts. A principle management recommendation has to do with the design and location of reserves: "Protection and restoration of key areas or 'reserves' where management is essentially excluded has been argued as the only way to assure the maintenance of ecological diversity (Frissell and Bayles, 1996; Noss and Cooperider, 1994), at least in the short term. Such reserves might be viewed as a safety net bridging the gap until more enlightened management can actually be implemented (Reeves *et al.*, 1995), or conserving the last remnants of diversity if it is not."

Topic area	Historical range of variability, disturbance, regulatory regimes
Case studies or examples presented?	Yes, Oregon Coast Range analyzed
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Roloff GJ, Mealey SP, Clay C, Barry J, Yanish C, Neuenschwander L. 2005. A process for modeling short- and long-term risk in the Southern Oregon Cascades. Forest Ecology and Management 211:166–190.

This paper, summarized in case study #2, describes a robust modeling capability for simulating impacts to spotted owl habitat and fire behavior from different treatment regimes in a Southern Oregon watershed. This study has an equally robust management implication: Aggressive hazardous fuel-reduction may yield better outcomes for spotted owl conservation.

Topic area	Fuel reduction, endangered species conservation
Case studies or examples presented?	Yes, Southern Oregon watershed modeled
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both

Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Shindler BA, Brunson M, Stankey GH. 2002. Social acceptability of forest conditions and management practices: a problem analysis. PNW-GTR-537. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

This paper points out that the social acceptability of management actions depends on a wide variety of factors and identifies ten different key problems faced by land managers, for example: "Confusing the provision of information with increased public understanding, and ultimately with public acceptance, is a mistake. Information alone is rarely sufficient to produce change. Public understanding is based on various factors wrapped in the context of personal experience." Social acceptance is never final or absolute, and is always situational. The authors explain five basic strategies to help guide managers efforts to gain social acceptability, i.e. "Focus on the contextual conditions of forest landscapes and communities."

Topic area	Social acceptability of management practices
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Swanson FJ. 2004. Roles of Scientists in Forestry Policy and Management: Views from the Pacific Northwest. In: Arabas K, Bowersox J (eds.). Forest Futures: Science, Politics, and Policy for the Next Century. Oxford, UK. Rowan & Littlfield Publishers, Inc.

This book chapter uses natural resource conflict in the Pacific Northwest as a backdrop for examining the role of scientists in formulating forest policy. Swanson notes research by Steel *et al.* (see Appendix II) that found support among researchers, managers and others for an augmented role for scientists in policy making. He suggests that in the future researchers should critically examine various land management paradigms and integrate these frameworks to meet local management objectives. Blending scientific worldviews will assist scientists in playing an "integrative" role in policy making (see Part IV). Better institutional support of adaptive management programs, for instance the Northwest Forest Plan's adaptive management areas, is an important investment needed for this process to succeed.

Topic area	The role of science in policy change
Case studies or examples presented?	Yes
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Szaro RC, Johnson NC, Sexton WT, Malk AJ (eds.). 1999. Ecological stewardship: a common reference for ecosystem management. Oxford, UK. Elsevier Science, Ltd.

This book summarizes the results of a two-week workshop organized by the US Forest Service, five Department of the Interior agencies, and private foundations to implement an "ecological stewardship" approach to natural resource management within the context of the ecosystem management paradigm, a holistic approach to natural resource management that has quickly replaced the sustained yield/multiple use approach to land management.

The ecosystem management approach is characterized by the integration of social, ecological and economic objectives to make decisions at multiple geographic scales. Management under this paradigm requires the best available scientific and technical information. This approach is relatively new, making it difficult to quantify or qualify successes. The state of scientific knowledge has generally outpaced efforts to develop practical applications that managers can use. The contributing authors develop a number of key themes, including: 1) Key parties must be "kept in the loop" while implementing the ecosystem management approach; 2) sharing information among researchers and managers is a key to success; 3) successful implementation requires developing a culture of ecological stewardship; and, 4) interagency collaboration is critical.

Topic area	Ecosystem management
Case studies or examples presented?	Yes
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Thompson RT, Johnson KN, Lennette M, Spies TA, Bettinger P. 2006. Historical disturbance regimes as a reference for forest policy in a multiowner province: A simulation experiment. Canadian Journal of Forest Resources 36:401-417.

This paper is part of the CLAMS research discussed in case study #7. This study simulates different management scenarios—both current management and management based on historical disturbance—for the Oregon Coast Range. Modeling demonstrates that historical distribution of younger forests could be re-created within 100 years, but that re-creation of older forests would take longer. Timber harvest would decline between

20-60% under the historical disturbance management (although costs would also decline over time). Public lands under the historical disturbance management regimes would need to provide significant large blocks of older forest habitat.

Topic area	Oregon Coast Range; historic range of variability
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Wales BC, Suring LH, Hemstrom MA. 2007. Modeling potential outcomes of fire and fuel management scenarios on the structure of forested habitats in northeast Oregon, USA. Landscape and Urban Planning 80:223-236.

Like the Barbour and Roloff papers described above, this paper models the use of thinning and prescribed fire to reduce the risk of large, severe wildfires, and the ecological consequences of this thinning. Specifically, this study uses a state and transition-based modeling to gauge the impacts of four different management scenarios on habitat for species that depend on large trees, and on habitat for Canada lynx, in Northeastern Oregon. The findings suggest that forests with large diameter trees are well below the estimated historical range of variability on federal lands in Northeastern Oregon, and that fuel management resulted in a smaller area of closed canopy forest with large and medium diameter trees than passive management.

Topic area	Fuel reduction, disturbance
Case studies or examples presented?	Yes, Northeastern Oregon modeled

Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Empirical research
Practical theoretical models or management tools presented?	Yes
Management tools that can be immediately adapted for use managing Oregon ecosystems?	Yes

Wallington TJ, Hobbs RJ, Moore SA. 2005. Implications of Current Ecological Thinking for Biodiversity Conservation: A Review of the Salient Studies. Ecology and Society 10(1):15

This paper is a comprehensive review of key non-equilibrium ecosystem dynamics concepts. It offers important management recommendations, including: Develop a better understanding of land use and disturbance regimes; rethink some reserve strategies; emphasize monitoring; and, rethink rare species conservation.

Topic area	Non-equilibrium dynamics, historical range of variability, disturbance, regulatory regimes
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Synthesis
Practical theoretical models or management tools presented?	No
Management tools that can be immediately adapted for use managing Oregon ecosystems?	No

Whitlock C, Shafer SL, Marlon J. 2003. The role of climate and vegetation change in shaping past and future fire regimes in the northwest US and it implications for ecosystem management. Forest Ecology and Management 178:5-21.

An analysis of charcoal, pollen and other evidence of past fire indicate that the Pacific Northwest and summer-dry regions of the Rocky Mountains experienced severe drought 11,000-7,000 years ago and approximately 1,000 years ago. Drought conditions are the principal driver of extreme fire behavior. Climate change models indicate that severe fire behavior might become more prevalent in coming years.

Topic area	Climate change and disturbance
Case studies or examples presented?	No
Integrates other research on the topic?	Yes
Empirical research presented or synthesis of existing knowledge?	Both
Practical theoretical models or management tools presented?	Yes

Appendix II
The Social and Policy Context for Ecosystem Dynamics Management

Appendix: The Social and Policy Context for Dynamic Ecosystem Management

In recent years, the use of public lands in the Western United States has become the subject of national as well as regional debate. Public concern for wildlife, fish species, wilderness preservation, recreational access, and other values associated with these lands has increased substantially since the 1960s. These concerns have clashed with the traditional extraction orientated policies that have dominated the use of these lands for over a century, resulting in often acrimonious public controversy and frequent litigation. At the heart of this debate are differing philosophical and normative views about the natural environment and appropriate human relationships to that environment. These views in turn are connected to different conceptions of how the proper management of natural resources ought to be organized and carried out.

To a substantial degree, public values concerning the environment set parameters for public policy, both for policies protecting ecosystems and for programs aimed at maintaining the economic and cultural vitality of natural resource-dependent communities. In many areas sustained public support is essential to the successful implementation of public policies seeking to balance environmental and socioeconomic objectives. Not only do public values about natural environmental systems affect the overall public policy process and the character of management of natural resource systems employed by government, but public values also strongly affect the psychological, sociological, and economic systems of the many traditionally resource dependent communities throughout the American West including Oregon. Therefore, any effort at implementing dynamic ecosystem management of Oregon public forests would necessarily entail a dynamic understanding of the social and policy contexts of natural resource management.

Dynamic ecosystem management will also necessarily involve a new role for science and scientists in the natural resource management and policy process. The traditional role of researchers and scientists—also called "normal" science—has been one of providing relevant expertise about scientific data, theories, and findings that policymakers and managers may or may not use to make decisions. In this management model, scientists are detached form the actual policy and management process. A second, emerging model challenges this first model on the proper roles for research scientists in policy and management by proposing that analysts become more integrated into communities, management and policy processes and directly engage in public policy and management decisions with managers, policy-makers and communities. This emerging "Post-normal," "integrative" or "collaborative" approach to research and science will be essential for implementation of dynamic ecosystem management.

This appendix contains two original papers that focus on the dynamic social context of natural resource management in the American West and Oregon, followed by a second paper that examines new approaches for science and scientists in the management of natural resources. Both papers provide important considerations for not only adopting dynamic ecosystem management, but also the successful implementation of such a new approach. The first paper ("An Introduction to Natural Resource Policy and the Environment: Changing Paradigms and Values") will provide a brief introduction to the changing social context of natural resource management and the various "driving forces" of these changes. The second paper ("Collaborative Community Based Science: Possibilities and Best Practices") will examine support for collaborative science approaches and new forms of science communication, as well as provide some "best practices" where scientists have successfully worked with communities and managers to integrate science at the local level.

An Introduction to Natural Resource Policy and the Environment: Changing Paradigms and Values

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Public lands in the western United States have become the subject of both a national and regional debate concerning the proper use and long-term well-being of forests and rangelands. Timber extraction and grazing historically have been the primary economic products derived from public lands in the region, with mineral extraction and fossil fuel collection taking a position of secondary importance in most (though not all) areas. However, public concern for wildlife habitat, protection of fish species, wilderness preservation, recreational access, and other nonextractive use values associated with these lands has increased substantially since the 1960s, and the primacy of management for timber and grazing has become the subject of increasing controversy and litigation, particularly with regard to public forest lands (Wondolleck, 1988). At the heart of this debate are differing values and interests concerning the natural environment and the proper relationship of humans to their ecological surroundings. These views in turn are connected to different conceptions about how the management of common pool natural resources ought to be provided for in the contemporary setting.

The purpose of this paper is to provide a brief introduction to these differing value orientations toward the environment, and toward the management of public forests. I will begin with a brief literature review concerning changing values toward the environment, and then identify some of the socioeconomic factors that are believed to be responsible for the development of conflicting natural resource management paradigms concerning public lands. Next, I discuss these competing management paradigms and then present some Oregon public opinion data concerning general orientations toward the environment and toward the management of natural resources.

Value Change Concerning the Environment and Natural Resources: A Brief Literature Review

In the decades following World War II a number of fundamental changes transpired in the industrial nations, especially those usually identified as the "Western Democracies" (Dalton and Kuechler, 1990). In contrast to the prewar period, economic growth in the 1950s and 1960s was so rapid that fundamental structures of society were altered, and social commentators began to note a new stage of development. This new stage or phase of socioeconomic development in advanced industrial society has been assigned the label "postindustrial" in the social science literature on modernity and postmodern intellectual thought (Rosenau, 1992).

A substantial number of classic studies are available for review, which examine in considerable depth the social, economic, and political implications of postindustrialism (Bell, 1973; Heisler, 1974; Huntington, 1974). While some definitional disagreement is present among scholars, a few commonly agreed upon central features of this new type of society can be identified. Postindustrial societies are characterized by the following traits: economic dominance of the service sector over those of manufacturing and agriculture; complex nationwide communication networks; a high degree of economic activity based upon an educated workforce employing scientific knowledge and technology in their work; a high level of public mobilization in society (including the rise of new social causes such as the civil rights movement, the antiwar movement, the antinuclear movement, the environmental movement); increasing population growth and employment in urban areas (and subsequent decline in rural areas); and historically unprecedented societal affluence (Bell, 1973; Galston, 1992; Inglehart, 1995 and 1990). It is argued that the advent of postindustrial society has altered individual value structures among citizens (particularly younger persons) such that "higher order" needs (self-actualization) have supplanted more fundamental subsistence needs (basic needs, material acquisition) as motivation for much societal behavior (Abramson and Inglehart, 1995; Inglehart, 1991; Flanagan 1982; Yankelovich, 1994). Value changes entailing greater attention to "postmaterialist" needs are thought to have brought about changes in many types of personal attitudes--including those related to natural resources and the environment (Steger, et al., 1989).

What this means for natural resource policy is that structural change in the economy featuring growth of urban service economies (or "the core") with concomitant decline in natural resource rural economies (or "the periphery") has lead to urban service areas exerting ever more influence over life in rural areas. This influence derives from their greater economic and political power, their superior technical expertise, and their substantial knowledge and information base (i.e., scientific knowledge, policy process knowledge, timely access to information, etc.) and control of mass communications channels, which tend to be increasingly effective measures for the propagation of their values and belief systems (Pierce, et al., 1993). Finally, with the advent of postmaterialist value orientations in these core urban service areas, urban mass publics and elites have come to have belief systems concerning natural resource issues and land use policy in the periphery that are quite different from the economic growth oriented views that used to predominate in the past. Increasingly, then, natural resource-based communities at the periphery become subject to the environment protective rules devised in urban cores (Dietrich, 1992). This state of affairs eventually leads to sharp conflict with the periphery, and ultimately to the urban service core, mandating severe changes in land use practices and policies in the periphery, which come to be seen as challenging the customary and much preferred "way of life" of rural citizens (Carroll, 1995).

Factors Associated with Changing Natural Resource Management Paradigms

Most scholars investigating the topic of postindustrial society tend to agree that a relatively small number of key socioeconomic factors have led to the development of conflicting core versus periphery natural resource management paradigms, resulting in frequent policy conflict and occasional complete stalemate in advanced industrial societies. The thirty-year-long standoff between the national authorities and local farmers backed by environmental activists at Tokyo's Narita airport, the two-decade-long Sagebrush Rebellion in the American West, and the continuing battle over farmland preservation in California are examples of such impasse situations (Dalton and Kuechler, 1990). Among the most salient factors generally thought to be involved are the following:

Population Change: Postindustrial societies experience a shift in population from periphery to urban core areas. For example, the United States has been transformed from a rural nation of 3,929,214 people in 1790 to an urban society of 281,421,906 people in 2000 (U.S. Census

Bureau, 2001). After a relatively slow rate of growth in the eighteenth century, the pace of urbanization was historically unprecedented during the nineteenth and early twentieth centuries. Starting in the twentieth century, the urban population continued to increase and suburban areas started to develop and grow as well. During the 1980s and 1990s a substantial number of rural counties in the United States lost population, while urban and suburban counties grew at a rapid rate. The migration of people from rural to urban/suburban counties was driven by the most highly educated and/or skilled younger cohorts leaving rural areas to seek jobs or further education in urban core areas (Deavers, 1989). These migration patterns have led to the acquisition of increased economic and political power by urban and suburban elites and contributed to the political and economic decline of elites based in the periphery (Beale and Fuguitt, 1990). Certainly this has been the case in Oregon.

According to Kenneth Johnson and Calvin Beale, however, by the 1990s this pattern of rural population decline was somewhat reversed, with a gain of 2.1 million people between the period 1990 and 2000 (2001: 1). In fact, between 1990 and 2000 "nonmetropolitan areas—those without an urban center of 50,000 or more—gained 5.2 millioin additional residents (10.3 percent)…in contrast, such areas grew by only 1.3 million during the 1980s" (Johnson and Beale 2001: 1). Most of this growth has been in rural counties located on the periphery of metropolitan areas—a situation of urban sprawal and suburbanization. Almost "86 percent of these adjacent counties gained population in the 1990s" due to "the proximity of urban jobs and growth on the urban periphery" (Johnson and Beale 2001: 2).

Another characteristic of this growth in some nonmetropolitan counties is the presence of recreational opportunities and other amenities that attract retirement populations (e.g., Deschutes County). Those counties that are "dependent on farming and mining were least likely to grow and what gains they did experience resulted from natural increase" (Johnson and Beale 2001: 2). What this signifies for environmental policy is that the growth of urban and suburban population centers, and the migration of retirees and others seeking recreational amenities to certain rural counties, will lead to urban areas exerting evermore influence over life in rural areas. This influence derives from the former's greater economic and political power, as well as their control of mass communications channels, which tend to be increasingly effective vehicles for the propagation of their values and belief systems (Pierce, Steger, Steel and Lovrich, 1992).

Continuing growth and development of urban and surburban areas in the United States, along with the decline in natural resource and agricultural sectors of the economy, has led to the service sector employment accounting for over 72 percent of the U.S. economy. Employment in the agricultural and natural resource sectors has declined to less than 2 percent of the labor force (OECD, 1999: 323). In addition, unemployment and poverty rates are typically higher and wages lower in the rural periphery when compared to the urban core (Gorham and Harrison, 1990; Johnson and Beale, 1998; Shapiro and Greenstein, 1990). Substantial economic decline in the rural periphery can contribute to a felt imperative among its residents to increase natural resource extraction in order to sustain community viability, while growth in the urban service industry creates a contrary imperative toward nonmaterial uses of natural environments such as recreation and wildlife habitat (Nicholson, 1987; Stern, Young, and Druckman, 1992; Yankelovich, 1990).

Technological Change: The role of technological innovation and change is central to the relationship between core and periphery. The role of science and technological change is particularly important to understanding environmental politics and policy. As Frank Fischer has argued (2000: 89):

> Tensions between science and politics have been intrinsic to environmental struggles from the outset. On the one hand, science and technology have been identified closely with the major causes of environmental degradation; on the other, they have served as the primary methods for both detecting environmental problems and searching for effective solutions.

This situation leads Fischer to conclude that environmental policy making has become a "technocratic" endeavor. While technological innovations have provided Americans with increasing amounts of information about the status of our environment, environmental management issues are so highly complex and technical in nature that political scientist Mathew Cahn makes the following argument regarding citizen engagement in the policy process (1995: 27):

> …environmental improvement is a highly specialized field encompassing physicists, chemists, geologists, engineers, physicians, economists, and other experts. Specific regulatory proposals, consequently, are beyond most people's grasp. This results in two dynamics: most people lose interest in the specifics of the environmental debate; and those who remain interested are often shut out from participation due to a lack of expertise. As a consequence, the public is vulnerable to simplistic answers and symbolic explanations.

Cahn's concern for the technological complexity of environmental issues and the ability of the public to understand these issues has been termed the "democracy and technocracy quandary" (Pierce *et al*., 1992; McAvoy, 1999). As discussed above, the U.S. is a postindustrial society that faces numerous environmental and natural resource problems that are increasingly scientific and technical in nature. At the same time, the U.S. is a democratic system that, over the past several decades, has experienced a highly noteworthy growth in distrust of government and increasing demands among some segments in society for citizen involvement in governance – especially in the environmental policy arena. Environmentalists, for example, argue that there "must be *more* rather than *less* democracy" (emphasis in original; Fischer 2000: 112).

The central issue here is the proper balance between technocratic expertise to solve complex environmental problems, and the ability of citizens to participate in that process. Many fear that these two elements may be mutually exclusive, or at least very difficult to balance. Placing too much emphasis on technical expertise as the primary determinant of environmental policy risks the erosion of democratic institutions (McAvoy, 1999). However, an excess of democratic participation (i.e., direct involvement of citizens in highly scientific and technically complex policymaking and implementation) may relegate technical expertise to a peripheral role and increase the probability that complex problems will not be managed properly. Some observers, such as Gregory McAvoy, argue that citizen participation in the policy process is desirable for two important reasons: (1) it provides "legitimacy to democratic governance;" and (2), it leads to good policymaking because it "requires all participants to justify their technical assumptions and implicit and explicit value judgments" (1990: 141). McAvoy believes that technical experts should not be accorded a dominant role in the policy process. Citizens are very much capable of participating and making environmental policy decisions themselves.

Along this line of reasoning is Kai Lee's work in *Compass and Gyroscope: Integrating Science and Politics for the Environment* (1993). Lee calls for a "civic science" that "should be irreducibly public in the way responsibilities are exercised, intrinsically technical, and open to learning from errors and profiting from successes" (1993: 161). A major component of civic science is the use of "adaptive management," which views environmental policies as practical experiments where scientists, policy makers, and citizens can learn (Lee 1993: 9). However, Lee suggests that if there is a scientific consensus on an environmental problem, then "democratic governments should consider action" (1993: 184). It is in the area of scientific ambiguity and uncertainty where political conflict arises and the need for civic science emerges.

Value Change: It has been argued by many that the advent of postindustrial society has altered individual value structures among citizens (particularly younger cohorts) such that "higher order" needs (e.g., quality of life) have begun to supplant more fundamental subsistence needs (e.g., material acquisition) as the motivation for much societal behavior (Dunlap and Mertig, 1992; Inglehart, 1991; Flanagan, 1982; Yankelovich, 1990). Value changes entailing greater attention to "postmaterialist" needs are thought to have brought about changes in many types of personal attitudes, including those related to natural resources and the environment (Xiao and Dunlap, 2007).

In fact, some observers have suggested that the development of the environmental movement was, in great measure, a product of the vast socioeconomic changes evident in postwar advanced industrial societies (Caldwell, 1992; Milbrath, 1984; Xiao and Dunlap, 2007). The development of environmental consciousness and the advent of the environmental movement in the urban core has resulted in the open questioning of many of the traditional political and economic institutions of modern society (Habermas, 1981; Offe, 1985). These changing value orientations among individuals, groups, and elites in the urban core pose serious consequences for land use in the periphery, and have led in time to the articulation of two conflicting natural resource management paradigms concerning the use of public lands. These conflicting paradigms have been well articulated by Brown and Harris (1992).

The two competing natural resource management paradigms identified by Brown and Harris—derived from the ideas of Gifford Pinchot and Aldo Leopold, respectively—have been labeled the "Dominant Resource Management Paradigm" and the "New Resource Management Paradigm" (see Table 1). The former world view advocates the anthropocentric belief that the management of public forests ought to be directed toward the production of goods and services beneficial to humans. The latter paradigm has emerged more recently and grown rapidly in popularity in postindustrial society. It has a biocentric view toward forest management that emphasizes maintaining intact all the elements of forest ecosystems, and is best summarized in the words of Leopold (1949: 262): "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise."

A passage from William Kittredge's *Who Owns the West?* (1996: 5) is quite descriptive of these conflicting paradigms, and characterizes well the situation in which many western communities now find themselves:

> Again our culture in the West is remixing and reinventing itself. It's a process many locals, descendants of people who came west only a few generations back, have come to hate; some think they own the West because their people suffered for it, and in that way they earned it. They feel that it's being taken away from them, and they're often right; they think they are being crowded out, and they are. They feel that nobody in greater America much cares about their well-being or dreams, and they are right.

The following section provides an Oregon perspective concerning these issues, and generally supports Kittredge's assessment of the national public's sentiments concerning these broad matters of public affairs.

Table 1
Conflicting Natural Resource Management Paradigms

New Resource Management Paradigm [Biocentric]	***Dominant Resource Management Paradigm*** [Anthropocentric]
Nature for its own sake	Nature to produce goods and services
Emphasize environmental protection over commodity outputs	Emphasize commodity outputs over environmental protection
General compassion for future generations (long-term perspective)	General compassion for this generation (short-term perspective)
Less intensive forest management; selective cutting, prescribed fire, watershed protection, etc.	Intensive forest management; clear-cutting, herbicides, slash burning, fire suppression, etc.
Limits to resource use and growth; earth has a limited carrying capacity.	No resource shortages; science and technology will solve production shortages.
New politics, consultative, decentralized and participatory.	Old politics, determination by experts; centralized and hierarchical decision making.

Source: Revised from Brown and Harris, 1992.

NATIONAL ORIENTATIONS TOWARD THE ENVIRONMENT AND NATURAL RESOURCES

In the most thorough and comprehensive review of recent trends in American public opinion toward the environment in the Twentieth century, the widely cited Environmental Sociologist Riley Dunlap concludes the following (1992):

- Public environmental concern developed dramatically in the late 1960s coinciding with other new social movements.
- After a decline in environmental concern in the 1970s there has been a significant and steady increase in both public awareness of environmental problems and support for environmental protection efforts.
- By Earth Day in 1990, public concern for the environment reached unprecedented levels in the United States.

An indication of the strong public support expressed for environmental protection and the environmental movement are results from a 2008 Gallup survey where 70 percent of respondents considered themselves “sympathetic” to the environmental movement (*Gallup Poll*, 2008). In addition, 85 percent of those surveyed indicated that they worry about the loss of natural habitat a “fair amount” to a “great deal” (58% said they worry a “great deal”). Perhaps one of the most important findings of the survey was that around half of the survey respondents reported that they had “contributed money to an environmental, conservation or wildlife preservation group.” Given these findings, it is not surprising to see that declining populations of certain birds and animals have generated much public concern and considerable activism.

In surveys conducted by a multi-disciplinary team of researchers at Washington State University and Oregon State University in 1991 and 2004, Oregonians from randomly selected households were asked to indicate their level of agreement or disagreement with a variety of statements concerning natural resource management and public policies pertaining to the environment and more specifically forests. In Table 2, Oregonians were asked: “*Public forest management may require difficult trade-offs between restoring environmental conditions (e.g., wildlife, old growth forests) and socioeconomic considerations (e.g., employment, tax revenues). Where would you locate yourself on the following scale concerning this issue?”* (see Table 2). In the 1991 survey 72 percent of respondents can be found in the middle of the socioeconomic versus environmental priority scale (3, 4 and 5 responses) compared to 74 percent in the 2004 survey. The perspective of Oregonians on this issue has remained very stable between 1991 and 2004 and is consistent with many of the management goals promulgated by the National Research Council’s 2000 report *Environmental Issues in Pacific Northwest Forest Management*.

Table 2

Oregon Public Preferences Concerning Economic and Environmental Trade-offs—1991 & 2004

Question: *Federal forest management may require difficult trade-offs between restoring environmental conditions (e.g., wildlife, old growth forests) and socioeconomic considerations (e.g., employment, tax revenues). Where would you locate yourself on the following scale concerning this issue?*

	Scale	**1991**	**2004**
The highest priority should be given to Environmental conditions, even if there are negative socioeconomic consequences. →	1	10%	10%
	2	12%	13%
	3	14%	14%
Environmental and socioeconomic factors should be given equal priority. →	4	45%	48%
	5	13%	12%
	6	4%	2%
The highest priority should be given to socioeconomic considerations, even if there are negative environmental consequences. →	7	2%	1%

Sample sizes: 1991=876 respondents; 2004=1,512 respondents

It was suggested earlier that a number of scholars have suggested that there are growing generational differences in value orientations toward the environment and natural resources in postindustrial society (Inglehart, 1995). These differing orientations were argued to be the product of postmaterialist values among younger, post-World War II generational cohorts. The survey findings presented in Table 3 provide some empirical evidence for this hypothesis among Oregonians in 2004. For most of the indicators presented in Table 3, younger cohorts register greater concern for protecting nature than do older cohorts; the most striking finding is for the first indicator, where 81 percent of the 18 to 29 age group disagreed with the statement "plants and animals exist primarily for human use." This finding compares to 33 percent of the 61-plus age group disagreeing with the statement. It seems clear from this survey evidence that Roderick Nash's theme of an emerging "rights of nature" ethic is deeply imbedded in the cognitive maps (the "hearts and minds") of contemporary American youth (Nash, 1989). Similarly, findings from studies of generational patterns of belief and opinion on environmental issues in Canada suggest a similar pattern of pro-environmental orientations among the younger age cohorts (Steel, et al., 2001).

Table 3
Oregon Generational Differences in Environmental Values—2004

	Disagree	Neutral	Agree
Plants and animals exist primarily for human use.			
18 to 29 years	81%	12%	7%
30 to 45 years	63%	10%	27%
46 to 60 years	52%	8%	39%
61-plus years	33%	19%	48%
Humankind was created to rule over the rest of nature.			
18 to 29 years	65%	15%	20%
30 to 45 years	61%	9%	30%
46 to 60 years	43%	10%	47%
61-plus years	36%	15%	49%
Humans have an ethical obligation to protect plant and animal species.			
18 to 29 years	11%	4%	85%
30 to 45 years	3%	4%	93%
46 to 60 years	12%	2%	86%
61-plus years	8%	5%	87%
Wildlife, plants & humans have equal rights to live and develop on the earth.			
18 to 29 years	9%	2%	89%
30 to 45 years	23%	8%	69%
46 to 60 years	25%	10%	66%
61-plus years	21%	7%	72%

The data displayed in Table 4 examine Oregon public support for commodity versus ecosystem based forest management policies in 1991 and 2004. What is interesting is the stability of support during this period of time for most management approaches. In general, people have been and are still concerned about wildlife, wilderness, and old growth forests. In fact, support for the statement "Greater efforts should be made to protect the remaining old growth forests" increased from 51 percent agreeing and strongly agreeing with this statement in 1991 to 59 percent in 2004.

What these data show—including the findings displayed in Table 2—is that the public (at least in Oregon) would like a balanced forest policy that provides for wealth and beauty, but does not sacrifice old growth, wilderness and wildlife protection. There is some of polarization however, with 42 percent of respondents in 2004 agreeing that the "economic vitality" of local communities should be given highest priority compared with 41 percent disagreeing with this statement. However, taken with the results displayed in Table 1, there is concern for timber dependent rural economies IF old growth, wilderness and endangered species are not harmed. Building trust with the public is crucial if a dynamic management approach is to be successful.

Table 4
Oregon Public Support for Federal Forest Management Policies: 1991 and 2004

Please indicate your level of agreement or disagreement with the following statements concerning the management of federal forest lands (i.e., USDA Forest Service and Bureau of Land Management):

	Strongly Agree (%)		Agree (%)		Disagree (%)		Strongly Disagree (%)	
	1991	2004	1991	2004	1991	2004	1991	2004
Commodity-based orientation:								
The economic vitality of local communities should be given the highest priority when making federal forest decisions.	20	18	26	24	27	26	17	15
Some existing wilderness areas should be opened to logging.	11	8	21	16	16	23	35	38
Endangered species laws should be set aside to preserve timber jobs.	13	10	24	21	17	21	31	35
Public forest management should emphasize timber and lumber jobs.	16	14	16	15	21	22	18	19
Ecosystem-based orientation:								
Clear-cutting should be banned on public forest lands.	35	38	22	25	18	15	12	9
More wilderness areas should be established on public forest lands.	25	29	21	22	12	13	18	12
Greater efforts should be made to protect the remaining "Old Growth" forests.	35	41	16	18	17	14	15	12
Greater efforts should be given to wildlife on publc forest lands.	30	33	25	27	16	15	9	9

Sample sizes: 1991=876 respondents; 2004=1,512 respondents. "Uncertain" responses not shown in table.

Conclusion: Finding a Middle Ground That Can Provide for Core Versus Periphery Fairness and Dynamic Management of Public Timber Lands

The foregoing discussion of societal value changes taking place in the setting of postindustrial America involving conflicting views of what public policy ought to be on public lands in the West with respect to urban core and rural periphery populations and with respect to older generations and the younger cohorts provides an appropriate backdrop to the chapters to follow. As economic growth and the increasing application of technology to societal needs have transformed our politics and called into question our previously boundless faith in progress, we have found ourselves questioning our conventional values, discovering ever broader stakeholders in decisions about our natural resources, and needing to work out some difficult trade-offs between deeply felt needs and values. As we become increasingly likely to be the denizens of cities and metropolitan areas, we are inclined to develop sympathy for the Spotted Owl and the Pacific Salmon and other endangered species, and we become desirous of preserving the old growth forests and other national treasures for our children and their offspring to marvel at and derive inspiration from as they come to learn of the spiritual and/or aesthetic value of natural preserves. Too often, however, we forget about the families and communities of the periphery, about the value they attach to the rangeland and forests and fish habitats that have provided for their livelihood. For their part, the residents of the periphery too often refuse to believe that the inexorable forces of societal change will require a fundamental change in how they will have to relate to the public lands and waters around them. Both sides in the core and periphery spheres have much to learn and think through. Similarly, the generations have interests that are not entirely compatible with respect to natural resources and our posterity; there is ample room for better understanding in this relationship as well.

Change has come to the West rapidly, showing little mercy for those caught in its grip. When we think of the state of Nevada just forty years ago being the most rural state in the United States and now being the most highly urbanized, we begin to get a good sense of the scale and scope of change affecting our lives as citizens of the American West. Under the pressure of this type of change, we need case studies of attempts to come to grips with change of the sort included here, and we need to encourage and support efforts to promote public deliberation and dialogue. As Jane Mansbridge (1983) has argued, we need to move "beyond advocacy democracy" to achieve some sort of policy learning (Jenkins-Smith and Sabatier, 1993). While there is no assurance that collaborative processes will lead to consensus (Kelman, 1992), it is also clear that some noteworthy successes at collaborative environmental policy negotiations have occurred (Crowfoot and Wondolleck, 1990; Fiske, 1991). Knowing this, should this approach not be given increased opportunity to succeed? It is also clear that "civic journalism" (Dahlgren and Sparks, 1991; Fouhy, 1994) can do much to promote the type of public discussion and deliberation, which occasions a "coming to public judgment" (Yankelovich, 1991; Gundersen, 1995). Government agencies, such as the Oregon Department of Forestry, managing public forest lands will continue to face challenges to their policies (and even their very authority), and they too will need to promote the goals of collaborative problem solving and support the efforts of responsible journalists seeking to promote public education on environmental issues.

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Collaborative Community Based Science: Possibilities and Best Practices

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In recent years there has been an increasing emphasis among decision makers, interest groups, and citizens about the importance of science-based environmental policy at local, regional, national, and international levels of governance (Johnson et al., 1999; Sarewitz et al., 2000). Many advocates of science have normative expectations that science can improve the quality of complex environmental policy decisions (e.g., Ehrlich and Ehrlich, 1996). The assumption is that scientists can and should facilitate the resolution of public resource decisions by providing objective scientific information to policymakers and the public, and by becoming more directly involved in policy arenas than they have traditionally (Mazur, 1981). This assumption suggests a changing expectation for science and scientists from traditional positivistic roles to a more “post-normal,” “integrative” or “civic science” model of engagement and involvement (Funtowicz and Ravetz, 1992; Lee, 1993).

This study builds on our previous National Science Foundation (NSF) pilot study that examined the role of science and scientists at the H.J. Andrews (HJA) experimental forest, a Long Term Ecological Research (LTER) site in Oregon supported by the NSF since 1980 (Steel et al., 2004). In that study, data were collected from interviews and surveys of four different groups involved in environmental policy and management in the HJA context including ecological scientists at universities and federal agencies; natural resource and environmental managers of state and federal programs; members of interest groups (e.g., environmental groups, industry associations, etc.); and the “attentive public” (i.e., those who have been involved in the environmental policy process). In general, the pilot study found that while there are limits to the roles that ecological scientists can play in environmental policy, there is still broad support for more active involvement by scientists.

As the scientific community has advanced our understanding of environmental issues and problems over the past three decades, it has become an ever more important participant in the policy process. When asked, many observers including scientists themselves, agree with Harmon’s observation that, "We in modern society give tremendous prestige and power to our official, publicly validated knowledge system, namely science. It is unique in this position; none of the coexisting knowledge systems – not any system of philosophy or theology, not philosophy or theology as a whole – is in a comparable position" (Harmon, 1998: 116). The importance of science and scientists is reflected by the National Academy of Sciences, which was established by a Congressional charter in 1863 to “advise the federal government on scientific and technical matters" (National Academy of Sciences Charter). The Academy has been called on in recent years to research and advise the government on environmental issues such as global warming, nuclear waste management and disposal, wildlife and fisheries management issues, and others. Another perspective on science, influenced by postmodernism, suggests that scientists and scientific data are only one source of information and authority among the many sources involved in the policy process. Scientists, policy makers, and those affected by policy typically work together to construct the meaning of the policy and the relevant science, commonly ignoring the boundaries and authority of science assumed by many scientists. From this perspective, the value of scientific information can be considered to be entirely contingent on context, and non-scientific, political, personal, and ideological information can readily override scientific data in policymaking at many points. The emergence of this second understanding of the role of science in the policy process has been described by Shabecoff (2000: 139): "In recent decades, science has begun to slip from its lofty pedestal as it has become apparent that it is not adequate either to meet all the needs of humanity or to protect us from the dangers that science and technology themselves create." This model posits that science and scientists are considered just one of many sources of authority concerning natural resource management issues; that scientific information is biased; and that other types of policy actors, information, and values are important in arriving at sensible public choices (e.g., Collingridge and Reeve, 1986; Ezrahi, 1980; Ravetz, 1990).

What these different orientations toward science reveal is that there are various definitions and attitudes toward science, and these in turn influence orientations toward the role science and scientists should play in the environmental policy process. Indeed, our previous research on this topic reveals significant differences among scientists, natural resource managers, and the public in the Pacific Northwest about what constitutes science and what the most suitable role for ecological science and scientists in the policy process should be (Steel et al., 2004).

The study presented here replicates our Pacific Northwest study at the national level. This is part of a larger project that examines these same issues with other case study sites controlling for rural-urban and regional locations, as well as different types of ecosystems (desert, temperate forest, etc.). Using data and interviews conducted with national samples of ecological scientists, natural resource and environmental managers, natural resource and environmental interest groups, and the general public, we examine the preferred role for scientists in natural resource management and policy, and then we examine the degree to which scientists support and participate in natural resource management and policy processes. We will first review the literature concerning the changing role of science and scientists in the policy process followed by an analysis of survey data collected from the four study groups. Then in the conclusion we will examine some "best practices" of integrating science and scientists in natural resource management developed at several LTER case study sites.

Science and the Roles of Scientists in Natural Resource Management and Policy

While there are many advocates of using science to inform policy, the strongest supporters of the potential of science to accurately and objectively predict various phenomena are adherents to various versions of positivism. Finding it roots in the Enlightenment during the sixteenth and seventeenth centuries, positivism came to be identified with the writings of the philosopher Auguste Comte and Ernst Mach, among others. Typically supporters of this approach believed that the "scientific method and practice distinguished the people of the West from civilizations that the West had conquered" and that science "was a matter of truth" (Pyeson and Pyeson, 1999: 5). The scientific method was considered objective and therefore would bring about a new age of prosperity through the use of quantitative methods to understand both physical and social affairs.

Although in contemporary times there are many doubts about positivism as well as theoretical diversity evident among positivists themselves, there are similarities in the shared belief that science is the best way to get at truth, to understand the world well enough so that we might predict the future, and then possibly control and manipulate physical and social phenomena in specific ways. The underlying assumption is that the world and the universe operate by laws of cause and effect, which can be discovered through the scientific method.

William Bechtel (1988) and others affirm that most contemporary philosophers reject positivism in its various, original formulations, and the idea of positivism has come under critical scrutiny over the past forty years. Few scientists today would completely accept Comte's view of a logically ordered, objective reality that we can understand once and for all, even with the powerful resources of contemporary scientific research**.** As Nobel Prize winner John C. Polanyi states: "Science is done by scientists, and since scientists are people, the progress of science depends more on scientific judgment than on scientific instruments" (1995: 7). Moreover, the rise in importance of the history and sociology of science as academic disciplines has led to a more complex characterization and debate about the nature of science and its relationship to social and personal factors (e.g., Jasanoff, et al., 1995). At the same time, Bechtel (1988: 49) argues, "…the Positivists' picture of science remains the most comprehensive we have," and, in practice, even the reports we provide in our peer-reviewed publications are still framed within the positivistic model. Simplified forms of the traditional model of science have filtered down into both the "culture" of contemporary science as well as popular depictions of science and scientists. According to some, this has created a mythical view of the nature and power of science that has remained prevalent in some quarters (e.g. Kitcher, 1993).

While many contemporary scientists wouldn't agree with all tenets of positivism, they would most likely agree with Levien (1979) that science and scientists can and should play an important and useful role in natural resource management and policy. He argues there are three ways that this can occur. First, science and scientists can provide a clear understanding of the basic dimensions of environmental problems, identifying both what is known and what is uncertain. Second, science and scientists can then describe and identify options for the appropriate solution of those problems, some of which might not be considered by political decision-makers. Finally, science can contribute to the resolution of environmental problems by estimating the economic, social, environmental and political consequences of proposed solutions through time and space, and across population groups (Levien, 1979).

Accordingly, "science and technology play an unusual role in environmental policy…environmental policy rests on a foundation of scientific research without which it would not even exist" (Von Moltke, 1996: 193). Scientists have been called upon by citizens, governments, and NGOs to predict the impact of human caused activities on the world's climate, oceans, air, species, and other environmental components (Hess, 1997: 1-2). Sarewitz and Pielke have described these expectations as “justified in the large part by the belief that scientific predictions are a valuable tool for crafting environmental and related policies" (2000:11). They further argue that scientific prediction is not the same as predicting the outcome of an environmental law or policy, which is necessarily more complicated because of the number of ecological, social, economic and political variables involved (Funtowicz and Ravetz, 1999). This leads Von Moltke to conclude: “This creates a unique and uneasy relationship between scientists and policymakers” (1996: 193). Scientists often engage in basic research, which because of differing time frames, research expectations, etc., makes it difficult to “transfer from one jurisdiction to another” for use by managers (Von Moltke, 1996: 193). Therefore, even scientists who are optimistic about their role to inform the policy process are cautious concerning their efforts to provide correct predictions (e.g., Allen, et al., 2001). At the same time, these same scientists are strong advocates of science and the scientific method and believe that “…science still deserves to be privileged, because it is still the best game in town” (Allen, et al., 2001).

Current perspectives on the proper role for scientists in the environmental policy process are potentially related to how science is defined and understood. As discussed above, the traditional, or what has been called “normal” model of science and scientists is an outgrowth of positivism. The role of scientists in this model is to provide relevant expertise about scientific data, theories, and findings that others in the policy-making process can use to make decisions, not to make the decisions themselves or to be advocates of particular policy positions. Moreover, scientists are not to become biased by involvement in environmental policy or to become policy advocates. In this model, science is revered by resource managers and the public, and has a special authority in environmental management because of its independence and its power to objectively interpret the world. However, scientists can lose their credibility as scientists if they cross the line between science and policy, science and management (Alm 1997-98; Lackey, 2007). This leads to a “separatist” role for scientists; ideally they are removed from management and policy and serve as experts or consultants only; called upon as the need arises and as policy-makers, managers, and the public require.

An alternative emerging model challenges the normal science model, not so much on the authority of scientific information and the acceptability of positivism, but on the exclusion of scientists and the public in natural resource management (Kay, 1998; Lubchenco, 1998). It proposes that scientists should become more integrated into management and policy processes. Research scientists need to come out of their labs and in from their field studies to directly engage in public environmental decisions within natural resource agencies and such venues as courts and public hearings. This has led former president of the American Association for the Advancement of Science Jane Lubchenco to argue for a “new social contract” for scientists with society (1998: 491):

> The new and unmet needs of society include more comprehensive information, understanding, and technologies for society to move toward a more sustainable biosphere—one which is ecologically sound, economically

> feasible, and socially just. New fundamental research, faster and more effective transmission of new and existing knowledge to policy- and decision-makers, and better communication of this knowledge to the public will all be required to meet this challenge.

There is a need for more science in these processes and decisions, the model argues, but this can only be brought about if research scientists themselves become more actively involved. Moreover, this model suggests that scientists should not hesitate to make judgments that favor certain management alternatives, if the preponderance of evidence and their own experience and judgment moves them in certain practical directions (Lubchenco, 1998). They are, after all, in the best position to interpret the scientific data and findings and thus are in a special position to advocate for specific management policies and alternatives.

Lubchenco's new social contract has also been called "integrative" and "post-normal" science and is related to Kai Lee's "civic" science (1993). All of these models call for more personal involvement by individual research scientists in bureaucratic and public decision making, providing expertise and sometimes even promoting specific strategies that they believe are supported by the available scientific knowledge (Ravetz, 1987). Funtowicz and Ravetz, (1999) have articulated this model as follows:

> …there is a new role for natural science. The facts that are taught from textbooks in institutions are still necessary, but are no longer sufficient. For these relate to a standardized version of the natural world, frequently to the artificially pure and stable conditions of a laboratory experiment. The world as we interact with it in working for sustainability is quite different. Those who have become accredited experts through a course of academic study, have much valuable knowledge in relation to these practical problems. But they may also need to recover from the mindset they might absorb unconsciously from their instruction. Contrary to the impression conveyed by textbooks, most problems in practice have more than one plausible answer; and many have no answer at all.

In our pilot study, we investigated orientations toward the proper role of scientists in the policy process. Based on interviews and an exploratory survey of scientists, we developed a list of five potential roles of scientists in the policy process. These ideal types reflect a complex relationship among expectations of science, attitudes about resource management, and decision-making styles. While the categories reflect levels of preference for scientist involvement ranging from minimal to dominant roles, they also distinguish between science as an activity separate from other, non-scientific activities and science as an activity integrated with management and other non-scientific activities.

The first role, reflecting the traditional science model, limits research scientists to reporting results and letting others make resource decisions. As part of an "emerging role," we described two possibilities: for research scientists to interpret scientific results so that others can use them and a more involved role in working closely with managers and others to integrate scientific results directly into resource policies and decisions. Another potential role is for research scientists to actively advocate for specific resource policies or management decisions that they prefer or believe flow from their scientific findings. A final role, reflecting the increasingly technical and complicated decisions facing natural resource managers, is to have such scientists make resource decisions themselves (i.e., "technocracy").

In our Pacific Northwest survey of scientists, managers, interest groups, and members of the attentive public, we asked respondents to tell us how much they agreed with each of these potential roles. The two most popular roles for scientists in the natural resource policy process for all four study groups were working "closely with managers to integrate scientific results" and "interpreting the results of research for others involved in the process" – descriptions of the emerging role. Managers, NGOs and the attentive public most often preferred "helping managers to integrate research results," while scientists themselves preferred the slightly less involved role of only "interpretation of research results." In general, most respondents were least supportive of scientists making decisions themselves; however NGOs and the attentive public also were not enamored with a minimalist role of "just reporting scientific results" and were more likely than scientists and managers to support an advocacy role for scientists. Scientists and managers were unlikely to support an advocacy role for scientists. In summary, both scientists and managers were more likely to agree that integrative roles are more preferable than any of the other roles, including the minimalist traditional role of just reporting results.

Finally, we also discovered that a "culture of science" affects research scientists in a manner that does not so clearly apply to other groups (managers, citizens and interest groups) in the policy process (Steel et al., 2004). Thus, research scientists operate in a communal scientific environment that imposes different demands on their time and energy, and their reputations and identities as scientists depend upon a different system of institutional relationships and rewards. Involvement in resource management and public environmental policy processes requires somewhat different communication and interpersonal skills than those that are effective in the scientific community. It may also elicit normative opinions in the scientific and policy arenas that can undermine scientists' authority and personal decorum. Other scientists sometimes have reservations about researchers who do become involved in policy matters, and may question their standing and credibility as a result. These, and other, factors can mean that scientists will be wary of researchers taking a more active**,** integrative role in policy making. As EPA scientist Robert Lackey has argued (2007: 12):

> I am concerned that we scientists in conservation biology, ecology, natural resources, environmental science, and similar disciplines are collectively slipping into a morass that risks marginalizing the contribution of science to public policy…Scientists are uniquely qualified to participate in public policy deliberations and they should, but advocating for their policy preferences is not appropriate.

Resource managers, on the other hand, work in an environment that is quite different than that of research scientists. For example, because of bureaucratic imperatives they do not always have the time to wait until "all the evidence is in" or the uncertainties are finally removed from the latest scientific findings. Nor do they have to satisfy their curiosities in research or gain the consequent rewards that scientists receive from interactions with other scientists. They may not be involved in the scientific community and thus may not share as deeply the values and norms that define the culture of science. This leads many of them to view the role of scientists in a different way than scientists themselves, accepting their authority as scientists but not as advocates.

While most theorists and participants have normative expectations that including ecological scientists and ecological information will improve complex natural resource decisions, there is increasing experiential evidence that tensions between the distinct institutional needs and cultural values of decision makers and scientists may preclude the effective use of science in many environmental decisions (e.g., Brown and Harris, 1998**;** Collingridge and Reeve, 1986; Meidinger and Antypus, 1996). As Hess commented, "scientists have come to recognize the political nature of the institutions of science, and their research problems have become increasingly tied to public and private agendas outside their disciplines" (1997: 2). This national study can help expand our understanding of the expectations of relevant groups for the use of ecological information in environmental policy making, how science is perceived in terms of objectivity, and the range and acceptability of appropriate roles that scientists can take in policy making and natural resource management.

Research Expectations

Given our literature review and previous findings from the Pacific Northwest pilot study, we expect the following findings:

- The public and interest group leaders will be the most supportive of post-normal/integrative roles for scientists when compared to managers and scientists.

- While many scientists may express support for post-normal/integrative roles for themselves, few have actually participated in such efforts.

- Successful or "best practices" of integrating science and scientists will involve greater efforts by scientists themselves in engaging in community based activities and research.

Methods

In 2006 and early 2007, survey data were collected from national random samples of different groups potentially involved in environmental policy and natural resource management: natural resource and ecological scientists at universities and federal/state agencies who have participated in the National Science Foundation's Long Term Ecological Research program (LTER); managers of state and federal natural resource and environmental agencies (e.g., U.S. Forest

Service, Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, state departments of natural resources, parks, environmental quality, etc.); directors and leaders of natural resource and environmental organizations (e.g., environmental groups, industry associations, recreation groups, etc.); and the general public (random sample of households). The scientist sample was provided by the LTER program, the public sample was provided by a national sampling company, and the manager and interest group samples were compiled by systematic random sampling from association and group directories available in print and on the internet. More detail on the sampling frames can be obtained from the authors.

For all samples, three waves of mail surveys were initially sent along with a fourth telephone reminder (and email if available) if necessary. Sample sizes and response rates are as follows:

Sample:	*Sample Size:*	*Surveys Returned:*	*Response Rate:*
Scientists	424	355	84%
Managers	500	272	54%
Interest Group	500	287	57%
Representatives			
Public	3,147	1,605	51%

The response rate for scientists was very similar to our previous pilot study, with the topic of the survey resonating well due to current political debates regarding climate change, etc., and the perceived threat from the Bush Administration concerning the non-use of science for policy. In addition, the director of the LTER program personally requested participation among LTER scientists. However, while the response rates for managers, interest groups and the public were much lower than in our pilot project, they remain respectable rates for social science research of this nature.

Findings

A major goal of this study was not only to investigate attitudes toward science and the scientific process but to also investigate orientations toward the proper role of scientists in the policy process and then determine what relationship may exist between the two. Based on the interviews and exploratory survey of scientists discussed above in the methods section, we developed a list of five potential roles for scientists in the policy process. These *ideal types* reflect a complex relationship among expectations of science, attitudes about resource management, and decision-making styles (see Table 1).

Table 1

Attitudes Toward Scientist Roles in Natural Resource Management

Roles:		**Scientists** *Mean (s.d.)*	**Manager s** *Mean (s.d.)*	**Interest Groups** *Mean (s.d.)*	**Public** *Mean (s.d.)*
A.	Scientists should only **report** scientific results and leave others to make natural resource management decisions. *F-test* = 22.64***	2.21 (1.24)	3.02 (1.29)	2.27 (1.24)	2.46 (1.31)
B.	Scientists should report scientific results and then **interpret** the results for others involved in natural resource management decisions. *F-test* = 16.48***	4.32 (0.78)	4.02 (1.06)	4.19 (0.87)	3.91 (1.16)
C.	Scientists should work closely with managers and others to **integrate** scientific results in management decisions. *F-test* = 10.33***	4.49 (0.70)	4.57 (0.67)	4.53 (0.80)	4.32 (0.99)
D.	Scientists should actively **advocate** for specific natural resource management policies they prefer. *F-test* = 25.54***	2.95 (1.26)	2.75 (1.25)	3.23 (1.25)	3.37 (!.27)
E.	Scientists should be responsible for **making decisions** about natural resource management. *F-test* = 13.99***	2.55 (1.25)	2.23 (1.14)	2.89 (1.21)	2.64 (1.22)
		n=352	n=262	n=280	n=1,601

[*Scale used:* 1=strongly disagree, 2=disagree, 3=neutral, 4=agree, and 5=strongly agree.]
Significance level: *** $p \leq .001$

The first role limits research scientists to reporting results and letting others make resource decisions. This reflects the “traditional role” for scientists as discussed above. As part of the “emerging role,” we described two possibilities for the scientists. The first is for research scientists to interpret scientific results so that others can use them. This is often expressed as a scientist’s promise to granting organizations that the results will be “translated” for non-scientific users—something that is certainly not uncommon for research scientists today. A more involved role for research scientists is to work closely with managers and others to integrate scientific results directly into resource policies and decisions. Implementation of “adaptive management” experiments in Pacific Northwest forests is an example of this type of scientific integration in resource decision-making. Another potential role is for research scientists to actively advocate for specific resource policies or management decisions that they prefer or believe flow from their scientific findings. A final role, reflecting the increasingly technical and complicated decisions facing natural resource managers, is to have such scientists make resource decisions themselves.

This list is not technically a scale or index, and we asked respondents to tell us how much they agreed with each of these potential roles. The roles are thus not mutually exclusive, although it is unlikely that anyone who favors a minimal role for scientists will also prefer the technocratic role of putting them in charge of resource decisions. We asked respondents to report how much they agreed with each of the roles on a five-point scale from “highly disagree” to “highly agree.” Table 1 presents mean scores for the responses for all four groups included in the study.

The two most popular roles for scientists in the natural resource policy process for all four groups are working "closely with managers to integrate scientific results" and “interpreting the results of research for others involved in the process,” with all four groups ranking “helping managers to integrate research results” highest. In general, most respondents were least supportive of scientists making decisions themselves, however interest group representatives, scientists, and the public also were not enamored with a minimalist scientist role of just reporting scientific results and were more likely to support an advocacy role than a minimal role for scientists. Scientists and managers, on the other hand**,** were less supportive than interest groups and the public of an advocacy role for scientists. In general, then, managers and scientists have very similar preferences for the potential roles of research scientists in natural resource decision-making.

When asked to designate their *preferred* role for scientists in natural resource policy (see Table 2), respondents exhibit a pattern similar to that discussed above. All four groups report preference for a role for science and scientists in the policy arena that reflects the notion of “post-normal science.” The highest preference among all four groups is for an integration of science and scientists in management decisions. However, scientists and managers next most common preference is for scientists to interpret results (20.6% and 35.1% respectively), while interest group representatives and the public tend to identify the advocacy role as the second highest preference (22.0% and 27.9% respectively). Scientists actually reported the lowest rate of preference for the traditional role for science with members of the public reporting the highest (3.4% and 9.5% respectively).

Table 2

Preferred Role for Scientists in Natural Resource Management

Question: *Which is the best single description of your preferred role for scientists in natural resource policy and management (please select only one)?*

Roles:		**Scientists** % *Preferred*	**Managers** % *Preferred*	**Interest Groups** % *Preferred*	**Public** % *Preferred*
A.	Scientists should only **report** scientific results and leave others to make natural resource management decisions.	3.4%	7.6%	7.1%	9.5%
B.	Scientists should report scientific results and then **interpret** the results for others involved in natural resource management decisions.	20.6%	35.1%	18.1%	21.0%
C.	Scientists should work closely with managers and others to **integrate** scientific results in management decisions.	63.4%	46.6%	49.6%	37.3%
D.	Scientists should actively **advocate** for specific natural resource management policies they prefer.	9.4%	9.9%	22.0%	27.9%
E.	Scientists should be responsible for **making decisions** about natural resource management.	3.1%	0.8%	3.2%	4.3%
	Chi Square = 159.41, p =.000	n=350	n=262	n=282	n=1,594

One small difference between the findings presented here and our previous Pacific Northwest study is the preference of managers for more limited roles for scientists. Managers in the Pacific Northwest study were somewhat more open to active roles for scientists, especially in terms of helping to integrate science into management decisions. Our interviews with managers in various geographical locations provide some insight into this finding. Managers in the Pacific Northwest study were disproportionately working with federal forest management issues—more specifically the Northern Spotted Owl and other endangered species on public forest lands. There has been extreme polarization of these issues with many lawsuits, civil disobedience, etc. Therefore managers are looking for some “cover” from scientists when developing management plans. While such issues are not unknown in the rest of the United States, managers in other geographical locations did not express such high levels of frustration and experience with extreme policy polarization.

Given the high level of support for post-normal science in natural resource management and policy among scientists, citizens, interest group representatives and managers evident in this study, to what degree do scientists actually support and participate in specific post-normal, collaborative activities? In the survey of scientists we provided a list of normal and post-normal science activities and asked scientists the importance of each activity and the frequency of personal participation in each activity. The data presented in Table 3 provides mean scores for likert scales measuring the level importance and frequency of participation for each activity. We have rank-ordered the results based on the frequency of participation. We have also provided correlation coefficients for the relationship between activity importance and participation as an indicator of attitude-behaviour consistency.

Table 3

Normal and Post-normal Activities of Scientists

How frequently have you engaged in the following activities on an annual basis? 1 = "Never" to 5 = "Very Frequently"			*How important do you consider these activities?* 1 = "Not Important At All" to 5 = "Very Important"	
Mean		**Activities**	**Mean**	**Tau b**
3.79	**A.**	Present research results at professional meetings.	4.36	.318**
3.66	**B.**	Publish research results in academic journals.	4.65	.290**
2.61	**C.**	Communicate research results directly to non-scientists through field trips or on-site demonstration.	3.60	3.41**
2.56	**D.**	Translate research results into a format that elected officials or staff can readily understand and use.	4.22	.245**
2.34	**E.**	Communicate research results directly to non-scientists through the internet.	3.33	.400**
2.28	**F.**	Translate research results into a format that mass media (newspaper, television, etc.) can readily use.	3.97	.284**
2.22	**G.**	Communicate research results directly to non-scientists through organization/agency publications.	3.58	.250**
2.03	**H.**	Translate research results into a format that natural resource managers can readily understand and use.	3.98	2.41**
1.93	**I.**	Present information at public planning hearings for natural resource agencies.	3.77	.240**
1.24	**J.**	Provide expert scientific testimony on pending legislation in judicial proceedings.	3.64	.088

*** $p \leq .01$

Not surprisingly, scientists were most likely to engage in the normal science activities of "presenting research results at professional meetings" and publishing "research results in academic journals." These two activities were also considered the most important activities. The remaining activities listed include more active efforts consistent with post-normal and collaborative science to disseminate scientific information to the public, elected officials, agencies and managers. The activity that had the third highest mean score was communicating research results to non-scientists through field trips and on-site demonstrations. However, the 2.61 mean score is situated between "infrequently" and "sometimes" engaging in this activity. Similarly, the fourth ranked activity is "translate research results into a format that elected officials or staff can readily understand and use." The remaining activities listed had very low levels of participation by scientists ranging from "communicating research results directly to non-scientists through the internet" (mean=2.34) to the least engaged in activity of "provide expert scientific testimony on pending legislation in judicial proceedings" (mean=1.24). While most of the activities were engaged in infrequently or never by most scientists, how important are they considered by scientists?

The mean scores listed on the right hand side of Table 3 indicate how important scientists consider the activities. We also report correlation coefficients as an indicator of behavior-attitude consistency. Is it the case that scientists feel some activities are important yet do not engage for some particular reason(s) such as time constraints, lack of training, promotion and tenure considerations, etc. Similar to self-reported engagement, the two activities considered most important by scientists were the normal science activities of presenting research at professional meetings and publishing in academic journals. The mean scores for these two activities are situated between "important" and "very important." However, a third activity also received a high level of importance—translating research results for elected officials and their staff (mean=4.22). Translating research results for the mass media and natural resource managers were also considered important (mean scores of 3.97 and 3.98 respectively). All of the remaining activities mean scores are located somewhere between "somewhat important" and "important," indicating that scientists in general consider all of these normal and post-normal activities useful activities. When we examine the correlation coefficients (Tau b) between frequency of activity and importance of activity, we find positive and statistically significant relationships for all activities but providing scientific testimony on pending legislation (this is primarily due to the lack of variation in the number of scientists engaging in this activity). However, the strength of the relationships are relatively weak. Believing that an activity is important doesn't mean scientists will take on that activity.

While the findings presented so far in this paper indicate strong support for collaborative/post-normal approaches to science among the public, resource managers, interest groups and scientists, the level of participation and engagement by scientists themselves has not matched this level of support. However, there are some successful examples of collaborative community based science that can be used as examples for "best practices" (i.e., by successful we mean activities that engage the public, managers and scientists to work together on a common research effort). As part of this research project we conducted case study visits at several LTER sites that have a history of engagement with managers, citizens and the public in order to identify some examples of successful efforts of communicating and integrating science. In the next section of this paper we describe just a few brief examples of these efforts.

Best Practices

Welp et al. (2006: 171-172) and other advocates of the new science paradigm argue that integrative/collaborative research can actually improve the quality and relevance of research for at least four reasons: (1) managers and other stakeholders can "boost the creative process" by helping scientists identify relevant and challenging research questions; (2) collaborators can provide scientists a "reality check" by evaluating research methodologies and research results; (3) much basic science research is often devoid of important ethical or cultural considerations and fraught with scientific jargon and terms that leads to confusion and ambiguity. Collaboration can lead to better understanding among all involved parties and lead to research results that are culturally and ethically sensitive; and (4), collaborative efforts give scientists access to important "data and knowledge that otherwise would remain unknown or at least very difficult to access."

At several LTER sites, including our original case study of the H.J. Andrews LTER site in Oregon, we found strong support for Welp et al.'s arguments. Stankey and Shindler's (2006) work with management plans for rare and little-known species (RLKS; e.g., slugs and fungi) found that limited public awareness and knowledge led to community resistance to management programs and therefore species decline. They found that while there had been much research on the biological and economic aspects of RLKS management, there had been no research whatsoever to "foster cultural adoptability, or as commonly termed, social acceptability" of management plans among the public (2006: 29). In order to enhance public understanding and participation in RLKS management, Stankey and Shindler took a proactive and post-normal approach by having scientists, managers and community members engage in joint-fact finding and collaborative discovery. They argue that the key for social acceptability and participation for successful management requires collaborative approaches that (2006: 28): (1) clarify the rationale and potential impacts of policies on species and communities; (2) outline specific actions that will be taken with the management plan; (3) specify and adapt to the contextual setting of the issue; and (4), identify where and when management plans will be implemented.

Other activities used at several other LTER case study sites such as Coweeta LTER (Southern Appalachian Mountains), Central Arizona-Phoenix LTER (Arizona), Northern Temperate Lakes (Wisconsin), and Sevilleta LTER (New Mexico), include K-12 and university student outreach and field trips to LTER research sites, on-sight demonstrations for the public and managers, and sometimes even collaborative research. An interesting project conducted by Northern Temperate Lakes (NTL) LTER researchers associated with the University of Wisconsin-Madison found that healthy fish populations and biodiversity among Wisconsin's many small lakes were most likely to be evident in lakes where dead trees and branches were found along the shoreline (Bates, 2008). Dead trees and natural debris are extremely important to aquatic food chains. The problem is that many of Wisconsin's smaller lakes are on private lands with many summer cottages and cabins along the shoreline. Many private land owners along lakes were found to be removing woody debris for docks and general aesthetic reasons thus damaging aquatic ecosystems and fish populations. Through the use of demonstration projects on several experimental lakes on state land, and participation of land owners in research by asking them to leave fallen trees and other debris on the shoreline and in the water, NTL researchers are now in the process of changing shoreline owners behaviors for ecologically healthier lakes.

A third and final example of an interesting and successful collaborative science research project has been developed at the Central Arizona-Phoenix (CAP) LTER site. This project looks at vegetation patterns, water-use, biodiversity, and how humans affect urban landscapes (Martin et al., 2008). More specifically, this research examines landscaping alternatives in the Phoenix, Arizona metropolitan area and how landscaping choices affect human behavior and urban ecosystems. Included in the study are various neighbourhoods, plots, and k-12 schools. In total there are 200 sites where differing landscaping practices are being used (e.g., native Sonoran Desert vegetation versus "Wisconsin" style vegetation with lawns, non-indigenous plants, etc.). Students, citizens and scientists then take longitudinal surveys and measurements of plants, trees, lichens, insects, pollutants, animals, water use, and resident attitudes and behaviors, etc., to determine the effect of humans on vegetation and the effect of differing landscapes on water use and biodiversity. This collaborative longitudinal research has engaged an enormous number of non-scientists with scientists into valuable research that has enormous potential to affect policy in years to come.

Summary

The results reported in this study suggest that there is surprisingly strong support for "integrative" or "post-normal" science with scientists directly involving themselves in natural resource and environmental policy and management. This "post-normal" approach to science calls for increasing involvement by researchers in public and bureaucratic decision-making, providing expertise and helping integrate new information into existing decision routines and practices (Ravetz, 1987; Steel and Weber, 2001). Others, such as Kai Lee, have similarly called for something they call a "civic science" that brings scientists and scientific information into active collaboration with others to craft workable solutions to pressing environmental problems (Lee 1993). These approaches do bring scientists out of the laboratory and into the political realm, which may be uncomfortable for scientists who aren't familiar or skilled at working in these arenas. It also raises issues of scientific credibility, which is still tied to the positivistic ideals of objectivity and neutrality. Scientists willing and skilled in walking the tightrope that is policymaking will help to familiarize non-scientists with both the strength and limitations of science. As Larson has argued, if scientists want to contribute to sound policy, "…they cannot simply present the facts, but need to interact with non-scientists both in the design of their research as well as in its application to particular problems" (2007: 953). It will also help scientists understand more clearly the possible roles for science in the "sausage-making" of public policy. Best practices reveal how collaborations between scientists, managers and the public can generate excitement about issues. A greater commitment by all involved can lead to more successful outcomes. This will be especially important for the successful implementation of dynamic ecosystem management.

Notes

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