COOPERATIVE MONITORING, EVALUATION AND REASEACH 02-205

A Review and Synthesis of Available Information on Riparian Disturbance Regimes in Eastern Washington

DOCUMENT PACKAGE

JUNE 2002

SUBMITTED BY

CONCURRENT TECHNOLOGIES CORPORAITON
PSC #02-127

Table of Contents

Section 1 - Context and History of Project

A Review and Synthesis of Available Information on Riparian Disturbance Regimes in Eastern Washington was conducted to analyze the state of knowledge relative to disturbance in eastside riparian vegetation and to produce a thorough, annotated literature review and summary of the best available information. A list of questions was provided for the contractor to address by drawing upon the available information for answers. The contractor was also requested to identify data gaps and develop recommendations for future studies.

Background Information:

New forest practice rules have been established based on the Forests and Fish Report dated April 29, 1999 (available on the WDNR website). The goals established for permanent rules on state and private lands are to protect aquatic and riparian dependent species, meet Clean Water Act requirements, restore and maintain riparian habitat to support a harvestable supply of fish, and maintain an economically viable timber industry (WSR 2001). The new rules are subject to monitoring to determine effectiveness. Additionally, several questions were raised during the process of developing the new rules that need to be addressed. This report contributes to answering one of those questions and will aid in the development of an appropriate monitoring and research programs.

The new forest practice rules use elevation “bands” to group responses to disturbance and dictate appropriate management. Lacking is the baseline data collection and research that links management strategies to riparian responses and to disturbance vectors in Eastern Washington. Within each elevation band the new rules delineate riparian forests into specific zones (the core, inner, and outer zones) and specify objectives and permissible activities for each. Different forest practices are permitted in the core, inner and outer zones. No timber harvest is allowed in the core zone. Timber harvest in the inner and outer zones is permitted if stand requirements are met. Under these rules, RMZ and individual zone widths vary by site-specific conditions. Inner and outer zone widths vary by site class and stream width.

Forest and Fish Report (FFR) reflects the current state of knowledge that forest productivity varies with site condition and habitat type. The resulting rules incorporated disturbance regimes as one of the underlying tenets for management of sustainable riparian zones in eastern Washington. This conceptual model of riparian function incorporates observed relationships between forest productivity and the disturbances caused by insects, disease, and fire. Eastern Washington disturbance ecology is highly varied as shown by differences in communities, topography, precipitation, and soils resulting in a complex landscape. While gradients across upland communities can be steep, gradients between riparian communities and their associated uplands may be even more pronounced.

The awareness of disturbance as a dominant force in forest ecology has been accepted and incorporated into forest management in recent years; however, little attention has been focused on the effect of disturbance on riparian communities. Little is known about the response of riparian communities to disturbance and most of what we find in the FFR is conceptually based on disturbance patterns documented in upland habitats. What is needed is an evaluation of the state of knowledge regarding disturbance in riparian communities.

The adaptive management and monitoring process developed under FFR is charged with determining the effectiveness of the new rules. Through the adaptive management and monitoring process, the underlying assumptions in the FFR rules will also be tested.

For the purposes of this project, SAGE was particularly interested in knowing what information is available to evaluate the appropriateness of the elevation bands, the habitat types defined in FFR, and the basal areas required within the various regulatory riparian management zones as they relate to disturbance regimes.

We recognize that there is and historically were a great deal of natural variability across the landscape. The rules represent an attempt to "bin" the range of conditions into a small number of situations and to develop regulations for these situations that will result in healthy ecosystems. The project objective, therefore, is to analyze the state of knowledge relative to disturbance in eastside riparian vegetation and produce a thorough, annotated literature synthesis and summary of the best information available.

Context:

The CMER- SAGE literature review project titled *A Review and Synthesis of Available Information on Riparian Disturbance Regimes in Eastern Washington* was completed for the State of Washington Department of Natural Resources (DNR) in June 2002, under a personal services contract (Contract No. PSC 2-127) by Concurrent Technologies Corporation, (CTC, Bremerton, Washington). The project ended after a draft was submitted to the DNR and SAGE for review. All allocated funds ($80,000) were paid out at this point with DNR, SAGE project manager and CTC agreeing.

The technical lead contributors from CTC were Richard L. Everett, Concurrent Technologies Corporation, and James P. Dobrowolski, Washington State University. The SAGE Project Manager for the CTC literature review was Domoni Glass.

Seventeen questions were posed to the contractor focusing on several topics:

- Fire, insect, pathogen, and drought disturbance.
- Vegetation response to disturbance by forest type in upland and riparian communities.
- Forest type distribution by elevation zone.
- Influence of elevation on disturbance regimes.
- Historical versus current forest conditions and disturbance regimes.

- Thinning of thick stands as it relates to drought, forest pests, and other disturbances.
- Applicability of current FFR riparian basal area standards using historical or current disturbance regimes and current reference stand conditions.

Several of these topics occur in any one question and multiple questions shared many of the same topics.

The contract directed CTC to specifically consider information available on these topics from investigations conducted in eastern Washington. When little information could be gleaned from eastern Washington, CTC used published information from throughout the Cascade and Rocky Mountain Eco-region Provinces (Bailey 1995) that contained the eastern Washington forest types. When this situation occurred, the amount of scientific material increased significantly and the literature review became representative rather than specific to eastern Washington.

As a disclaimer common to many literature review projects, Concurrent Technologies Corporation explicitly stated that the work product (June 2002 document) does not represent a scientific summary of all the literature available on each of the topics raised in the seventeen questions.

Section 2 - Project Report

A REVIEW AND SYNTHESIS OF AVAILABLE INFORMATION ON RIPARIAN DISTURBANCE REGIMES IN EASTERN WASHINGTON

Submitted to:

STATE OF WASHINGTON

DEPARTMENT OF NATURAL RESOURCES

June 2002

PSC 02-127

Prepared by:

CTC Concurrent Technologies Corporation

5780 West Werner Road
Bremerton, WA 98312

With Edits by the Scientific Advisory Group - Eastside
A Subcommittee of the Cooperation Evaluation
Monitoring and Research Committee

LIMITATIONS

This document is a deliverable to the State of Washington Department of Natural Resources required under Personal Services Contract (No. PSC 02-127) ***"A Review and Synthesis of Available Information on Riparian Disturbance Regimes in Eastern Washington."***

This deliverable represents Concurrent Technology Corporation's (*CTC*'s) best effort within the available resources and is prepared using the standards of practice for professional services and in accordance with the standards of the technical professions represented. This document is intended for the use of *CTC* and its client.

ACKNOWLEDGEMENTS

The following people are gratefully acknowledged for their invaluable contributions to this report.

Technical Leads

Richard L. Everett, Concurrent Technologies Corporation
James P. Dobrowolski, Washington State University

Literature and Information Contributions

James Agee, University of Washington
John Beebe, Tufts University
Susan Bolton, University of Washington
Sondra Collins, Upper Columbia United Tribes
Wallace Covington, Northern Arizona University
Carl Davis, Wenatchee National Forest
Fred Ebil, Society of American Foresters
Greg Filip, Oregon State University
Paul Flanagan, U.S. Department of Agriculture Forest Service
Domoni Glass, CMER SAGE Co-Chair
Jan Hemstrom, U.S. Department of Agriculture Forest Service
Jan Henderson, U.S. Department of Agriculture Forest Service
Larry Irwin, National Council for Air and Stream Improvement, Incorporated
Bud Kovalchik, U.S. Department of Agriculture Forest Service (retired)
Jeff Light, Plum Creek Timber
Terry Lillybridge, U.S. Department of Agriculture Forest Service
Geoffrey McNaughton, Washington State Department of Natural Resources
Shari Miller, U.S. Department of Agriculture Forest Service
Ron Neilson, Oregon State University
Pete Ohlson, U.S. Department of Agriculture Forest Service
Wayne Padgett, U.S. Department of Agriculture Forest Service
Blake Rowe, Longview Fibre
Brion Salter, U.S. Department of Agriculture Forest Service
Craig Schmitt, U.S. Department of Agriculture Forest Service
Don Scott, U.S. Department of Agriculture Forest Service
Duane Vaagen, Vaagen Brothers Lumber Incorporated
Maurice Williams, CMER SAGE Co-Chair
Andy Youngblood, U.S. Department of Agriculture Forest Service
Darlene Zabowskii, University of Washington

EXECUTIVE SUMMARY

Scientific information was evaluated to assess the current level of knowledge about historical and current disturbance regimes and forest responses in riparian and adjacent upslope forests in Eastern Washington. This information was used to address seventeen questions posed by the Cooperative Monitoring, Evaluation, and Research Committee (CMER) Scientific Advisory Group Eastside (SAGE) concerning the ecology and management of riparian forests. Information gaps that prevented or limited the response to the questions are identified, with recommendations for future research. This scoping document represents a summary of scientific literature characteristic of the total available information on each topic discussed.

In addition to addressing the questions posed by CMER SAGE, this report contains an annotated bibliography and a brief summary of two Forest Dynamics Workshops sponsored by the Eastside Riparian Scientific Advisory Group (ERSAG) (now CMER SAGE). The annotated bibliography provides citation information and annotations for the literature assembled to address the questions.

Despite a very large information base on historical and current disturbance regimes within Eastern Washington forests, differences in riparian and upslope forest disturbance regimes and post-disturbance responses are not well known. Both historically and currently, there is limited regional-scale information on what portions of the landscape are most affected by disturbance. Much of the scientific literature describing Eastern Washington disturbance regimes and forest responses is at the forest series or plant association group level and does not distinguish between riparian and upslope communities. Available information has frequently been extrapolated from point observations and limited-spatial area studies or inferred from available information on historical stand characteristics. The differences between current and historical disturbance regimes for fire are better defined than for insects, pathogens, and other disturbance types.

No clear consensus exists on whether there is a difference between disturbance regimes and forest responses of riparian and upslope areas. In fact, available information on riparian ecosystem disturbance regimes and responses was often contradictory. Riparian ecosystems are recognized as corridors of disturbance and are considered both sensitive to and products of drastic disturbance. The effects of disturbance may be of sufficient magnitude to redirect successional paths.

The likelihood of duplicating historical disturbance regimes, to reestablish historical forest conditions, is low given current forest stand conditions and global climate change. Knowledge of disturbance regimes and forest responses supports prediction of post-disturbance response and allows for the revision of forest practices under an adaptive management strategy. Available information indicates that a dynamic approach to management – one that constantly monitors changes in resource conditions – is required. Recently developed models (e.g., FIRESUM) and geographic information system (GIS) tools may be used to assess and integrate information and data. Additional research aimed at regional-scale forest stand disturbance processes is recommended to supplement existing data and better define the role of disturbance in riparian and upslope forest habitats.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ACRONYMS

ABAM	Pacific Silver Fir Series
ABGR	Grand Fir Series
ABLA2	Subalpine Fir Series
ACCI-WEN	Vine Maple - Wenatchee
ACTR	Deerfoot Vanilla leaf Series
ACTR-WEN	Deerfoot Vanilla leaf Series - Wenatchee
ARNU (ARNU3)	Wild Sarsaparilla Series
ATFI	Lady-Fern Series
BP	Before present
CASCP2	Saw-Leaved Sedge Series
CD-ROM	Compact disc-read only memory
Cm	Centimeter(s)
CMER	Cooperative Monitoring, Evaluation, and Research Committee
COCA	Bunchberry Dogwood Series
COD	Coarse organic debris
CLUN	Queencup Beadlily Series
CRBSUM	Columbia River Basin Succession Model
CTC	Concurrent Technologies Corporation
Dbh	Diameter breast height
DNR	Department of Natural Resources
EQUIS	Horsetail Series
ERSAG	Eastside Riparian Scientific Advisory Group
ERU	Ecological reporting unit
F&FR	Forests and Fish Regulations
FEMAT	Forest Ecosystem Management Assessment Team
FFI	Fire frequency interval
FFP	Fire free period
GCM	General circulation model
GIS	Geographic information system
GYDR	Oak-Fern Series
HRV	Historical range of variability
ICBEMP	Interior Columbia Basin Ecosystem Management Project
LALY	Subalpine Larch Series
LOD	Large organic debris
LWD	Large woody debris
Np	Not present
ODF	Oregon Department of Forestry
OPHO	Devil's Club Series
PAG	Plant association group

PICO	Lodgepole Pine Series
PIEN	Engelmann Spruce Series
PIPO	Ponderosa Pine Series
POTR	Quaking Aspen Series
POTR2	Black Cottonwood Series
PSME	Douglas-Fir Series
RHAL	Cascade Azalea Series
RMZ	Riparian management zone
RSAG	Riparian Scientific Advisory Group
SAGE	Scientific Advisory Group Eastside
SDI	Stand density index
SMZ	Streamside management zone
Spp.	Species
SPZ	Stream protection zone
SSR	Seasonal severity rating
SYAL	Common Snowberry Series
TELSA	Tool for Exploratory Landscape Scenario Analyses
THPL	Western Red Cedar Series
TRLA4	Globeflower Series
TSHE	Western Hemlock Series
TSME	Mountain Hemlock Series
UCUT	Upper Columbia United Tribes
USFS	United States Forest Service
VAME	Big Huckleberry Series
WMPIs	Weibull median probability fire return intervals

PART

1

SUMMARY REPORT

Section

1.0

Introduction

Background

This document considered scientific information available on forest disturbance regimes and vegetation responses in riparian and adjacent upslope forests of Eastern Washington. Available information was used to address seventeen questions posed by the Cooperative Monitoring, Evaluation, and Research Committee (CMER) Scientific Advisory Group Eastside (SAGE) on the ecology and management of riparian forests. The questions are a subset of the CMER L-1 list of questions (see *Forests and Fish Report*) designed to evaluate the scientific merits of existing Forests and Fish Regulations (F&FR). There are two major themes addressed in the questions:

1) The validation of Eastern Washington forest habitat types and their associated elevation zones to ensure that appropriate riparian management objectives are applied to the appropriate landscape locations.

2) The validation of the use of inherent disturbance regimes and resultant patch dynamics as the appropriate reference for managing dynamic riparian and adjacent upslope forest systems.

The validation of one of these themes might, in fact, prove the fallacy of the other. Do the F&FR zonal elevation bands define the occurrence of forest types? Or, are forest types found where their growth patterns and regeneration cycles are compatible with the inherent disturbance regime of the area (Oliver and Larson, 1990, Grime, 1977)? Can both be true?

The validation of Eastern Washington forest habitat types presumes that elevation acts as a valid surrogate for the moisture and temperature effects that define the distribution of forest series and their major disturbances. Also, Eastern Washington forest habitat types must have sufficient resolution such that forest series present on the landscape readily group into ponderosa pine forest (0-2500 feet), mixed conifer (2500-5000 feet), and high elevation (greater than 5000 feet) habitat types. The habitat types would require a high degree of homogeneity such that management objectives and forestry prescriptions for the habitat type could be applied throughout the State.

The goal of the Eastern Washington riparian F&FR prescription package is to promote dynamic forest stand conditions that vary over time as would emulate the result of natural disturbance regimes. The validation of the use of disturbance and patch dynamics rather than a fixed resource condition approach (set asides) will test the basic premise whether to manage for or against disturbance in the disturbance-driven Eastern Washington forest system (Forest Ecosystem Management Assessment Team – FEMAT, 1993). By documenting disturbance regimes and stand development and successional processes for the major forest series and associated riparian conditions, it is possible to assess whether forest management can control forest disturbances or whether forest management, for the most part, must respond to these natural processes. If disturbance can be controlled, then spatially explicit resource conditions could be fostered through management. If no control were possible, forest management would shift focus to manage for the occurrence of disturbance and work with the patch dynamics that result.

Diversity of Information Requested

The validation of F&FR use of forest habitat types, elevation zones, and disturbance management (i.e., managing for disturbance and patch dynamics) is a complex issue. The seventeen questions posed by CMER and supporting materials contain topics on:

Fire, insect, pathogen, and drought disturbance.

Vegetation response to disturbance by forest type in upland and riparian communities.

Forest type distribution by elevation zone.

Influence of elevation on disturbance regimes.

Historical versus current forest conditions and disturbance regimes.

Thinning of thick stands as it relates to drought, forest pests, and other disturbances.

Applicability of current F&FR riparian basal area standards using historical or current disturbance regimes and current reference stand conditions.

Several of these topics occur in any one question and multiple questions share many of the same topics.

As per follow-up direction from CMER SAGE, this report is specific to information available on these topics from research and administrative studies conducted in Eastern Washington. When there was a dearth of information, the Concurrent Technologies Corporation (*CTC*) project team used published information from throughout the Cascade and Rocky Mountain Ecoregion Provinces (Bailey 1995) that contain the Eastern Washington forest types. With the need to expand the geographic base to address some questions, the amount of scientific material increased significantly and the literature review, of necessity, became representative rather than all-inclusive. This document is not represented as a scientific summary of all the literature available on each of the topics raised in the seventeen questions.

Linking Questions, Annotated Bibliography, and This Report

The *CTC* project team queried literature databases, conducted literature searches at the University of Washington and Washington State University, and contacted scientists and resource specialists for scientific information on the subject of each of the questions (see Appendix A). An annotated bibliography of the scientific materials used in addressing the questions is provided.

This report addresses each of the seventeen questions and provides a summary of disturbance regimes and riparian forest response in Eastern Washington forest types. Information gaps that prevented or limited the response to the questions and fruitful areas of research are identified.

Ecoregions of Eastern Washington

Eastern Washington forests primarily occur in three ecoregion provinces as defined by Bailey (1995) (Cascade Province to the west, Northern Rocky Mountain Forest Province to the north and the Middle Rocky Mountain Province to the south). The ecoregions are defined by climatic patterns, topography, landforms, soil, and vegetation.

The Cascade Province of Washington is steep and highly dissected with narrow valley bottoms except where glaciated. The province has a maritime climate with annual precipitation declining rapidly from 380 centimeters (cm) at the crest to 51 cm at the eastern slope foothills. The forest transitions from mountain hemlock, western hemlock, pacific silver fir, whitebark pine, subalpine larch, subalpine fir, Engelmann spruce, noble fir, grand-fir, Douglas fir, western larch, and ponderosa pine from the crest to lower eastside elevations. Soils include erosive, unconsolidated volcanic ash.

Steep mountains characterize the Northern Rocky Mountain Forest Province with a broad valley between. The climate is a mix of maritime and continental with annual precipitation ranging from 51 cm to 102 cm. Douglas fir, western hemlock, western red cedar, western larch, grand fir, and ponderosa pine dominate forests. The historical presence of western white pine is missing because of mortality from white pine blister rust. Soils in the mountains are cool and moist and are skeletal in nature.

The Blue Mountains of Eastern Washington fall within the Middle Rocky Mountain Province. These uplifted basalts have a maritime climate with significant continental influence and approximately 77 cm of annual precipitation. This province includes Douglas-fir dominant forests. Grand fir, lodgepole pine, and ponderosa pine are also present.

Non-forested areas of Eastern Washington are within the Intermountain Semi desert Province. In Eastern Washington, the Columbia Plateau represents this province. The dry climate of this province supports sagebrush and dry grassland vegetation.

To be consistent with the most recent ecological assessment of these Eastern Washington forests (Interior Columbia Basin Ecosystem Management Project – ICBEMP, 1999), the three forest provinces are further defined as the Northern Cascades Ecological Reporting Unit (ERU), the Northern Glaciated Mountains ERU, and the Blue Mountains ERU (see Figure 1).

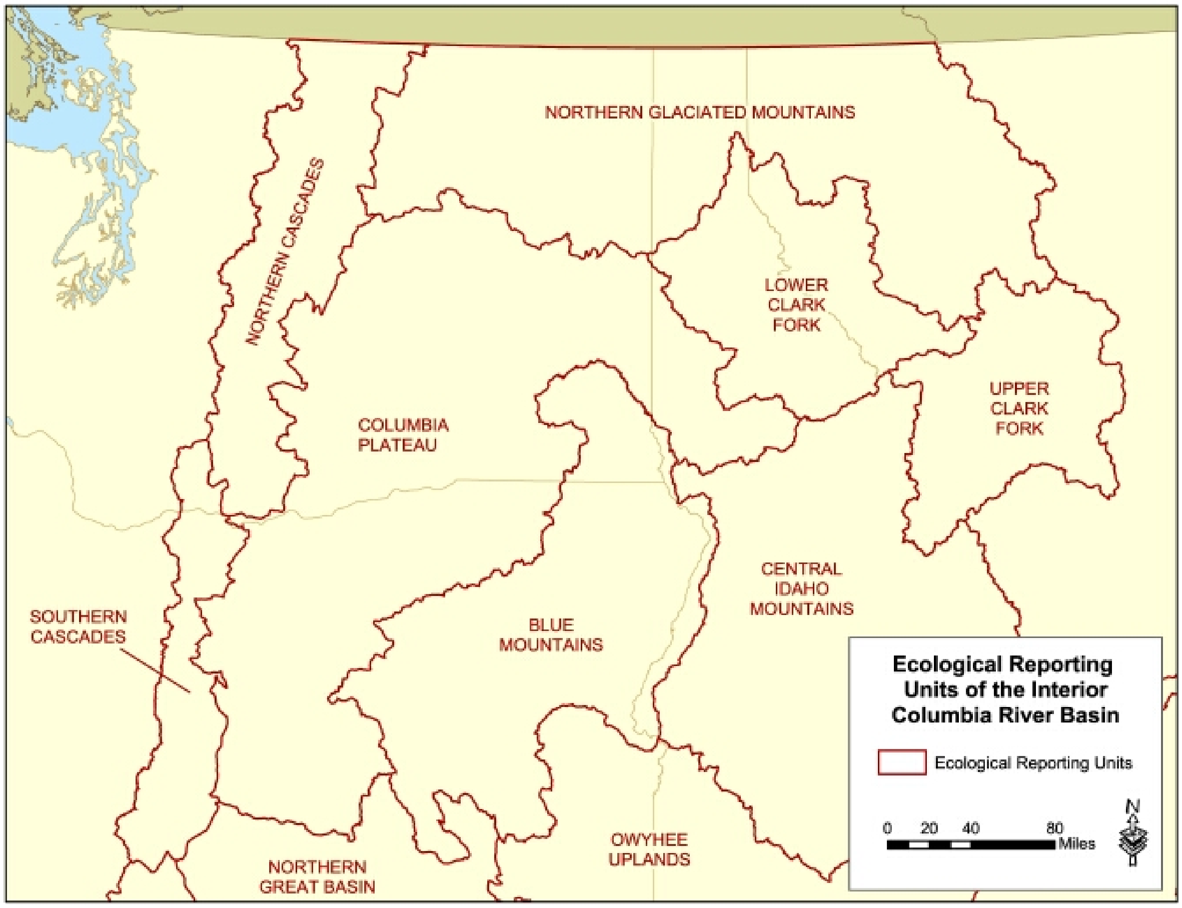

Figure 1. Northern Cascades, Northern Glaciated Mountains, and Blue Mountain ERUs that Comprise the Forests of Eastern Washington (adapted from Hessburg *et al.* 1999)

Ecoregion Variability

An example of the diverse geology, climate, and vegetation on the Wenatchee National Forest (the southern portion of the Northern Cascades Province) illuminates potential variability within an ecoregion (Lillybridge *et al.* 1995). The Wenatchee National Forest is divided into three ecological regions based on geology and climate patterns. One ecological region is known as the "Chelan Terrain." It extends from the Entiat Fault to the Methow Valley. The mountains in this region are relatively higher, steeper, more rugged, and wider than the other two ecological regions. The region is affected by a strong rain shadow from the Cascade Mountains with extended dry periods during summers. Xeric and cold forest types predominate. Douglas fir, subalpine fir, and ponderosa pine are the climax species with subalpine larch and whitebark pine near the timberline. Silver fir and mountain hemlock are present in narrow maritime zones extending only a few miles eastward along major east-west ridges and drainages. Lodgepole pine and Engelmann spruce are present in significant numbers, but more mesic species such as western hemlock, western red cedar, western larch, and grand fir are less common and may be absent.

South of the Entiat Fault to approximately the Yakima River and Ellensburg is the second ecological region within the Wenatchee National Forest. The geology of this region is highly diverse, with most of the region lying outside the area affected by the continental ice sheet. Slopes are steep and long. Elevation in this region is low with relatively narrow mountain ranges. As a result, the rain shadow effect from the Cascades is lessened, allowing more mesic forests of Pacific silver fir, western hemlock, or grand fir to exist than in forests to the north. Species present in this region include ponderosa pine, Douglas-fir, grand fir, and subalpine fir on the relatively drier east side of this region with Pacific silver fir, mountain hemlock, western hemlock, and western red cedar in the maritime areas to the west. As in the region described above, subalpine larch and whitebark pine form forests near the timberline. Other prominent species include lodgepole pine, western larch, and Engelmann spruce.

The third ecological region in the Wenatchee National Forest extends from Ellensburg to the Yakima Indian Reservation. Although no continental glaciation occurred in this region, mountain glaciation is widespread, and volcanic deposits are present. Elevations are relatively low with the exception of the areas near volcanoes. This region has a broad range of climatic conditions, with more mesic forests present than in either of the previously described regions. Major forest zones include ponderosa pine, Douglas- fir, grand fir, and subalpine fir to the more xeric east with Pacific silver fir, mountain hemlock, Alaska yellow cedar, western hemlock, and western red cedar in the more mesic, maritime west. Unlike the other regions, near timberline forests do not contain subalpine larch; whitebark pine is present near the timberline. Lodgepole pine and Engelmann spruce are present.

Section
3.0

The Questions and Explanatory Remarks

Addressing the Questions

Responses to each of the seventeen questions posed by CMER contribute to the validation process of the F&FR use of forest habitat types, elevation zones, and disturbance management. To establish a baseline understanding of terms used in the seventeen questions, this section presents discussions on several topics, including:

Regulatory riparian zones and ecological riparian communities.

Elevation as a surrogate for moisture and temperature in defining vegetation distribution.

Forest zones and elevation contour lines.

Riparian forest series and F&FR forest habitat types.

Forest series heterogeneity.

Climatic climax descriptors of F&FR forest habitat types.

Historical reference conditions.

Regulatory Riparian Zones Versus Ecological Riparian Communities

Disturbance and vegetation response differences that could be anticipated at the ecotone between ecological riparian and upslope forest zones would be missing from regulatory defined riparian buffers that may contain both (Belt *et al.* 1982, Morse, 1999). Conversely, a regulatory riparian buffer, may, by necessity, greatly exceed the ecological riparian boundary to protect aquatic systems from vegetation management activities. Thus, clear definitions for ecological and regulatory riparian buffers and their differences are needed to fully address the questions. Streams and rivers are the riparian systems considered in this discussion since they represent the majority of the land/water interface found on forested lands in the Pacific Northwest (Oakley *et al.* 1985).

Ecological Riparian Communities

Riparian communities are functionally wetland communities and have been defined as the point where shrubby vegetation no longer interacts with the stream (Campbell and Franklin 1979). Species composition, moisture availability, physiognomy, and disturbance regime distinguish riparian communities from adjacent uplands (Brinson 1990, Naiman *et al.* 1992). In riparian forests, the soil is usually mesic or wet, and a fluvial floodplain is formed by coarse textured debris with or without organic soil while the upland has deep organic soils that are slightly dry to moderately moist.

The terrestrial system may influence the aquatic by dictating the stream channel form, controlling material passing through the system, and providing a primary source of energy and nutrient inputs to the channel (Bilby 1988). The mosaic of riparian vegetation reflects a complex interaction among geomorphic processes, vegetation, and time (Johnson *et al.* 2000). Recent studies of the effects of edges along riparian areas on microclimate conditions into the adjoining forest (Chen *et al.* 1995, Brosofske *et al.* 1997, Dong *et al.* 1998) found changes in microclimates extending well beyond the width of the riparian areas (Hibbs and Bower 2001).

In the mid-1980s, Oregon's Riparian Task Force established a more structured definition of riparian ecosystems with three distinct zones. An "aquatic zone" is the wetted area of streams, lakes, and wetlands up to the average high water mark. The "riparian zone" includes terrestrial areas where the vegetation and microclimate are affected by water either intermittently or continually and are typically associated with high water tables and hydric soils. A "riparian zone of influence" is transitional between the riparian zone and the upland vegetation. Trees and shrubs form the outer edge of the riparian ecosystem in this zone, characterized by a change in plant composition, relative plant abundance, and the end of high soil moisture (Raedeke 1988). This zone contains woody vegetation that provides shade, organic material (fine or coarse), and terrestrial insects (Carleson and Wilson 1985).

Riparian systems are products of several types of disturbances interacting at variable frequencies and magnitudes within a varying but generally moist zone, producing plant communities that have generally higher species richness and a more diverse structure than uplands (Agee 1988). Riparian ecosystems generally serve to dissipate water and wind energy that can damage lowlands, often acting as natural windbreaks in moisture-limited systems (Hansen *et al.* 1995).

Regulatory Defined Riparian Areas

Jurisdictional wetlands are those wet areas that are protected by law under the Clean Water Act Section 404 and the swamp-buster provision of the Food Security Act. The determination of jurisdictional wetlands involves the evaluation of three wetland parameters: 1) hydric soils, 2) hydrophilic vegetation, and 3) wetland hydrology. Of the three technical criteria, wetland hydrology is often the most difficult to quantify in the field due largely to annual, seasonal, and daily fluctuations. Except for certain situations defined with the 1987 Corps of Engineers' Wetlands Delineation Manual (Environmental Laboratory 1987), evidence of a minimum of one positive wetland indicator from each wetland parameter must be found to make a positive jurisdictional determination. Jurisdictional problem areas are sites where wetland indicators of one or more parameters may be periodically lacking due to normal seasonal or annual variations in environmental conditions that result from causes other than management activities or catastrophic natural events. The term "non-jurisdictional wetlands" refers to those sites that do not meet the jurisdictional wetland criteria described in the manual.

Riparian zones are often defined in a regulatory sense as the area within some arbitrary distance from the channel edge and may include forest or shrub communities as well as the distinct riparian community. To protect aquatic and riparian resources, riparian buffers are established in the riparian zone directly beside a stream and may extend to the adjacent uplands. A riparian buffer is often applied to a variety of regulatory designated protection zones managed by state and federal agencies, including Idaho's Stream Protection Zone (SPZ), Washington's Riparian Management Zone (RMZ), and the U.S. Forest Service's Streamside Management Zone (SMZ). These regulatory defined terms all describe riparian zones where forest practices are restricted by regulatory or legislative requirements (Belt *et al.* 1992). These buffers are installed to contribute significantly to the maintenance of aquatic and riparian habitat and pollution control. Riparian buffers fulfill three basic roles:

1) Help maintain the hydrologic, hydraulic, and ecological integrity of the stream channel by imparting stream bank stability and contributing coarse organic debris (COD) providing hydraulic structure to the stream channel.

2) Protect aquatic and riparian plants and animals from upland sources of pollution.

3) Supply food, cover, thermal protection, and unique habitat (Belt *et al.* 1992).

These riparian zones, although regulatory assigned, are still dynamic resources changing in time and space with the dynamics of stream hydraulics and flow that eventually sculpt the structure and composition of the vegetation, soil, and channel profile (Pedersen 1988).

Pacific Northwest states have attempted to establish multiple riparian buffer criteria that are simply stated as separate requirements, such as width and number of leave trees. Implementation and interpretation of riparian buffer requirements are left to field staff. Other approaches to defining and implementing buffers included a cartographic approach (Dick

1991), which combined a spatial model with geographic information system (GIS) using a single criterion such as temperature moderation. A second, maximum protection approach would evaluate each of several criteria in terms of buffer width and then adopt the greatest width in order to accommodate all of the criteria. A third more regional method to establish buffer strip widths was based on a regional analysis of selected stream reaches within the region. In a region where fisheries were a major concern, shade and large organic debris (LOD) recruitment might be used as criteria for buffer width determination (Belt *et al.* 1992).

The State of Washington Department of Natural Resources has designed regulatory riparian zones since 1967 as leave strips 10-300 feet wide (Calhoun 1988). The Yakima Tribe has established regulatory riparian buffers on every stream with widths (66 to 330 feet) that often extend beyond the limits of the riparian vegetation (Bradley 1988).

Elevation as a Surrogate for Moisture and Temperature in Defining Vegetation Distribution

Topographic features that interact to influence species composition and structure of plant communities are elevation, aspect, and slope steepness (Perry 1995). Elevation zones used to define F&FR forest habitat types can be useful tools to integrate abiotic attributes that impact vegetation distribution, but the relationship of elevation to temperature, moisture, and solar radiation is confounded by changes in aspect, slope, and weather patterns (Perry 1995). At a given elevation, there can be significant climatic variability over time in Eastern Washington (Ferguson 2001). The relationship between climate and elevation are inconsistent. The relationship of elevation to vegetation is confounded by the aforementioned attributes as well as landforms (Swanson 1978), soils (Daubenmire 1968), and past disturbance history (Agee 1993). Daubenmire (1968) thought that plant communities were fundamentally the products of the interaction between the environmental tolerances of the various plant taxa present and the heterogeneity of the environment. Romme and Knight (1981) provide a graphical demonstration of plant community heterogeneity at a common elevation based on topographic position.

The concept of vegetation type changing with elevation as a result of increasing precipitation and decreasing temperature is valid at a specific location. The concept has been integrated with fire (Agee, 1993), insect (Amman *et al.* 1977), and pathogen (Beard *et al.* 1983) disturbance. An elevation band can have a different temperature and moisture regime based on its location. The precipitation and temperature regime of an elevation zone in the Cascades Province is not the same north to south, nor is it the same in the Northern or Southern Rocky Mountain Provinces.

Forest Zones and Elevation Contour Lines

F&FR utilize forest habitat types that are based on elevation contour lines (0-2500 feet - ponderosa pine, 2500-5000 feet - mixed conifer, and greater than 5000 feet high elevation). These forest habitat types are the basis for Eastern Washington forest management prescriptions. The use of habitat types and elevation bands results in a "vegetation zone" approach to management. Both vegetation zones and habitat types are spatially explicit land areas that support a particular set of plant associations (Lillybridge *et al.* 1995). The F&FR forest habitat types are based on Franklin and Dyrness' (1973) zonal forest approach using climatic climax tree species. Forest types, "arrayed elevationally as zones are the consequence of differing responses of tree species to temperature and moisture gradients interacting with differing degrees of tolerance" (Franklin and Dyrness 1973:160). However, elevation bands for a specific "forest zone" moves up and down slope with changes in topography and zones often inter-finger with each other (Agee 1994). Adams (1994:428) provides an example of the spruce-fir forests growing in "protected valleys and ravines below the spruce-fir zone." With the F&FR elevation zone approach, a mid-elevation contour band will capture a range of forests zones that includes forest zones typical of that contour band as well as forest zones that typically occur at both higher and lower elevations (Agee 1994).

Just as vegetation zones move up and down slope relative to topography, vegetation zones move up and down in elevation moving north or south along the Cascade Range. As an example, the grand fir series is found as low as 1800 feet mid-way up the Northern Cascade Province (northern half of the Wenatchee National Forest), but its lower elevation limit shifts to 2500 feet on the southern part of the Northern Cascade Province (Lillybridge *et al.* 1995). Thus in the mid-portion of the Northern Cascade Province, grand fir is a part of the F&FR ponderosa pine habitat type, but in the south it is restricted to the F&FR mixed conifer habitat type. The forest series represented on the elevation gradient vary among the three ERUs (Northern Cascades, Glaciated Mountains, and Blue Mountains) in Eastern Washington.

Using the Wenatchee National Forest as an example, the F&FR dry ponderosa pine and high elevation forest habitat types fall within their designated elevation zones (0-2500 feet and > 5000 feet, respectively) to a much better degree than the mixed conifer habitat type (2500-5000 feet) (Figure 2). The mixed conifer habitat type is comprised of greater portions of forest series characteristic of the ponderosa pine and high elevation forest habitat types than "mixed" moist forest type (Figure 3, Table 1). Management units comprised of diverse components will respond differently to applied management practices. For example, the Eastern Oregon and Eastern Washington mixed pine-fir type "encompasses primarily the *Pseudotsuga menziesii* and *Abies grandis* zones," where the principal species are "both shade-intolerant (i.e., ponderosa pine, western larch, and lodgepole pine) and relatively shade tolerant (i.e., interior Douglas fir and grand fir)" (Tesch 1994:540). The ambiguity in forest series composition of the mixed conifer habitat type is compounded by the extent of this habitat type within the Wenatchee National Forest. The mixed conifer habitat type comprises over 60 percent (%) of the forested area on the Wenatchee National Forest (Table 2).

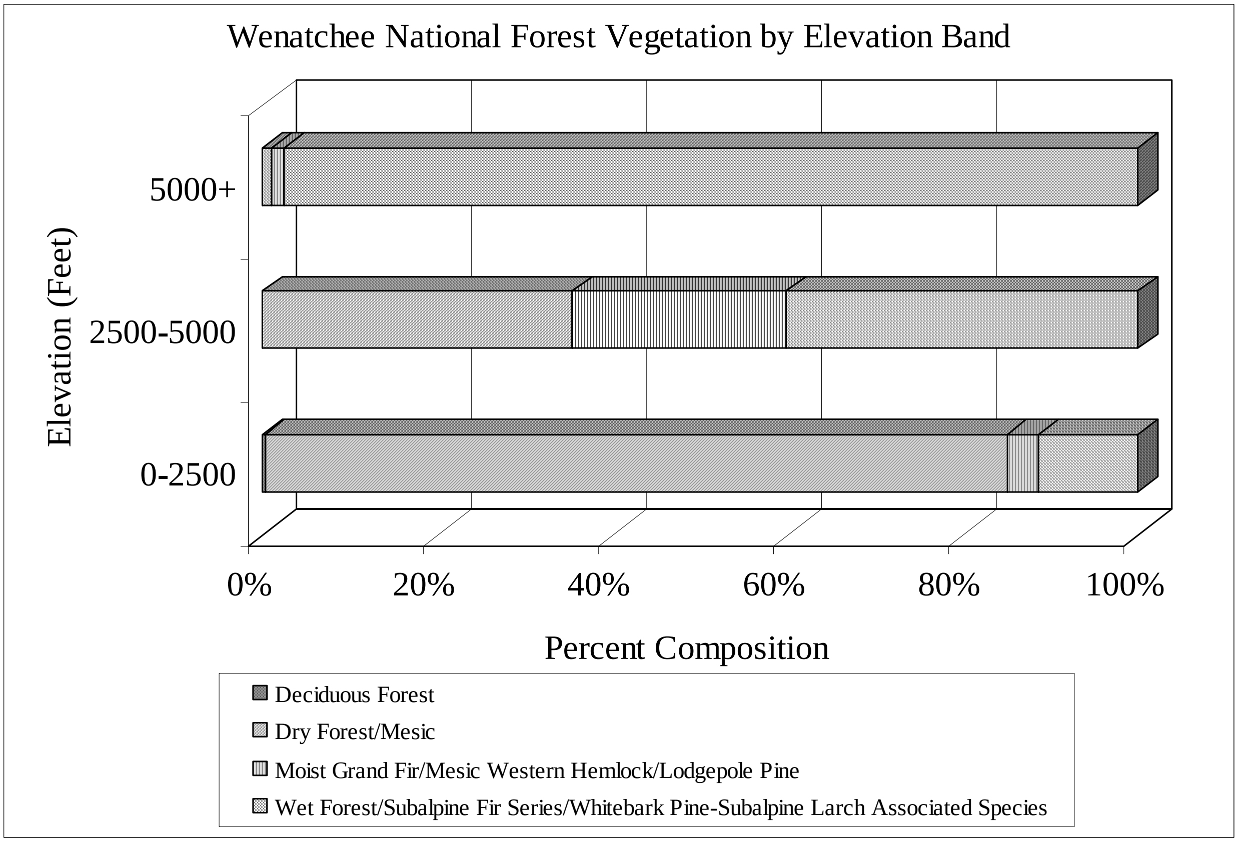

Figure 2. Forest Type Composition of the F&FR Forest Habitat Types by Elevation Zones

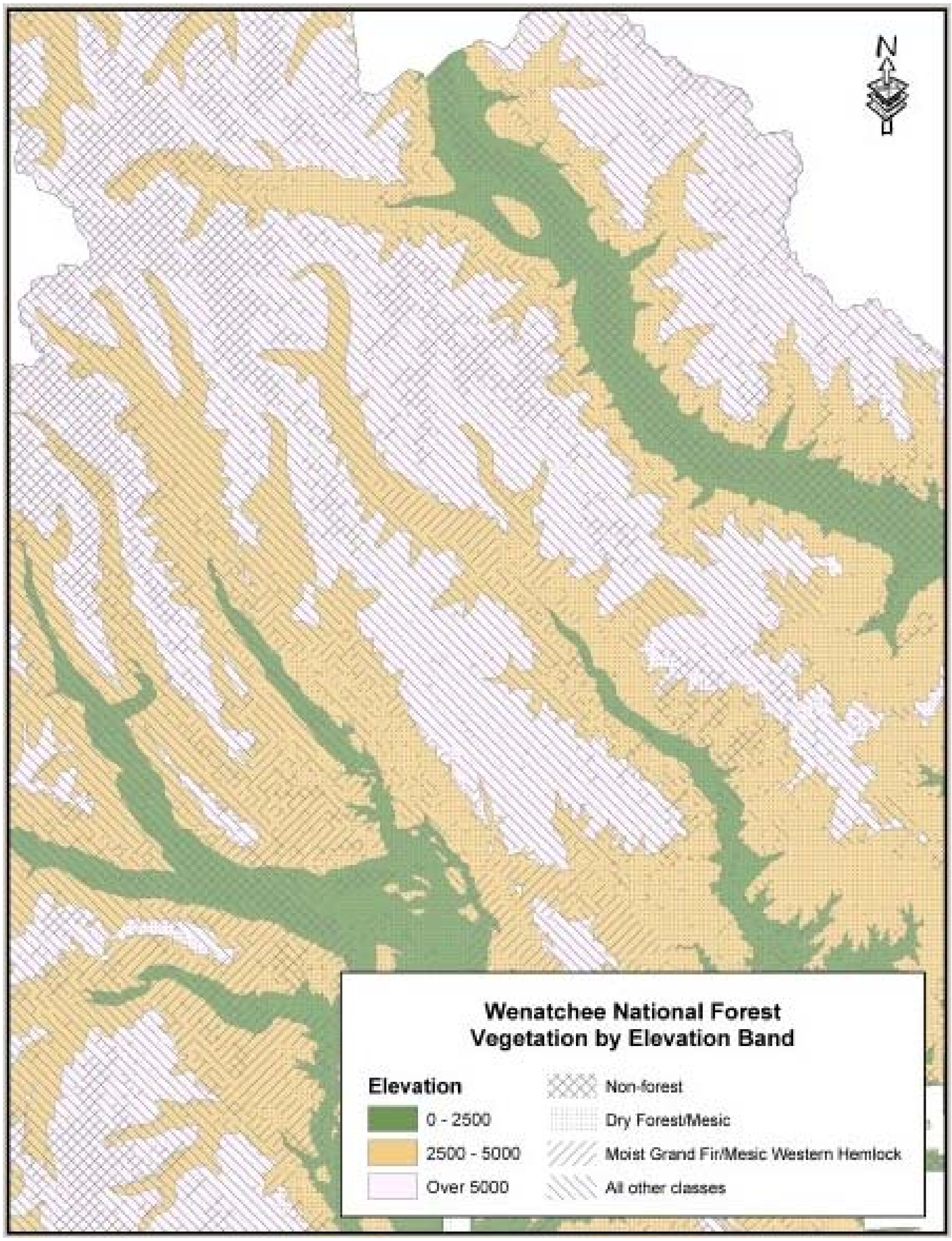

Figure 3. Vegetation by Elevation Band in the Wenatchee National Forest

Table 1. Wenatchee National Forest Land Area and Percent of Area by Forest

Vegetation Type	0 - 2500 Feet		2500 - 5000 Feet		5000+ Feet	
	Acreage	Percent	Acreage	Percent	Acreage	Percent
Deciduous Forest	451	0.26%	704	0.06%	48	0.01%
Dry Forest/Mesic	144,866	84.78%	446,987	35.37%	6,530	1.11%
Moist Grand Fir/Mesic Western Hemlock/Lodgepole Pine	6,125	3.58%	307,947	24.37%	7,940	1.35%
Wet Forest/Subalpine Fir Series/Whitebark Pine-Subalpine Larch Associated Species	19,441	11.38%	508,049	40.20%	572,234	97.53%

Series

Note: Moist and wet forests approximate the F&FR mixed conifer and high elevation forest habitat types, respectively.

Table 2. Proportion of F&FR Forest Habitat Types on the Wenatchee National Forest

Elevation Band	Area (km^2)	Area ($miles^2$)	Area (acres)	Percent of Total Area	Dominant Vegetation Type	Vegetal Variation
0 - 2500 feet	978	377	170,883	8%	Dry Forest/Mesic	8
2500 - 5000 feet	5,890	2,274	1,263,687	63%	Wet Forest/Subalpine Fir Series / Whitebark Pine-Subalpine Larch Associated Species	10
Over 5000 feet	3,397	1,311	586,752	29%	Wet Forest/Subalpine Fir Series / Whitebark Pine-Subalpine Larch Associated Species	9
Total	10,265	3,963	2,021,322			

Riparian Forest Series and F&FR Forest Habitat Types

With the exception of subalpine larch, the lower and upper elevation limits for riparian forest plant associations of Eastern Washington are not contained within the F&FR elevation bands and forest habitat types (Table 3, Kovalchik in press). The lower elevation limit for a riparian forest series was most often found in one F&FR elevation band and the upper limit in the next higher elevation band. Riparian forest series in Eastern Washington straddle the F&FR elevation bands and several riparian series are found in all three F&FR forest habitat types and elevation zones (Table 4, Kovalchik in press). The lack of separation of series among the elevation bands is understandable given topographic and rain shadow effects. Riparian series occur at higher elevations moving from the Wenatchee National Forest in the Northern Cascades to the Colville National Forest in the Northern Glaciated Province to the east (Kovalchik in press).

Table 3. F&FR Elevation Zones and Forest Habitat Types in Relation to Distribution Limits of Riparian Forest Series in Eastern Washington (Adapted from Kovalchik in Press)

Np = not present

Series	Forests and Fish Report Elevation Bands					
	Ponderosa Pine Habitat Type		Mixed Conifer Habitat Type		Upper Elevation Habitat Type	
	0-2500 ft		2500-5000		>5000 ft	
	Lower Limit	**Upper Limit**	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**
PSME (Douglas-Fir Series)						
Colville	rare					
Okanogan	1320			2550		
Wenatchee	1320			2550		
POTR2 (Black Cottonwood Series)						
Colville	1900			4020		
Okanogan	2150			3500		
Wenatchee	1700			3680		
THPL (Western Red Cedar						
Colville	2200			4650		
Okanogan	1850			4360		
Wenatchee	1760			4120		
PIEN (Engelmann Spruce Series)						
Colville	2210					6250
Okanogan	2170					7200
Wenatchee	2380					5920
TSHE (Western Hemlock Series)						
Colville	np					
Okanogan	2270					5200
Wenatchee	2080			4720		
POTR (Quaking Aspen Series)						
Colville	2420			4000		
Okanogan	2400			4520		
Wenatchee	1980			4210		
ABGR (Grand Fir Series)						
Colville	np			np		
Okanogan	np			np		
Wenatchee	2160			4100		
ABLA2 (Subalpine Fir Series)						
Colville			3000			6250
Okanogan			2875			6900
Wenatchee			2550			6620
TSME (Mountain Hemlock Series)						
Colville	np					
Okanogan			5075			5890
Wenatchee			3100			5520
ABAM (Pacific Silver Fir Series)						
Colville	np					
Okanogan			3190	4900		
Wenatchee	2380					5520
LALY (Subalpine Larch Series)						
Colville	np					
Okanogan					6860	7320

Table 4. Riparian Forest Series Present in F&FR Designated Elevation Zones and Forest Habitat Types (Adapted from Kovalchik in press).

0-2500	2500-5000	>5000 ft
Ponderosa Pine Forest Habitat Type	**Mixed Conifer Forest Habitat Type**	**High Elevation Forest Habitat Type**
PSME	PSME	PIEN
POTR2	POTR2	
THPL	THPL	
PIEN	PIEN	
TSHE	TSHE	TSHE
POTR	POTR	
ABGR	ABGR	
	ABLA2	ABLA2
	TSME	TSME
	ABAM	ABAM
		LALY

Forest Series Heterogeneity

F&FR forest habitat types are comprised of different forest series. Forest series represented in each habitat type change within and among ecoregion provinces. This complexity is confounded by the heterogeneity within the forest series. A forest series is defined as all the plant associations capable of supporting a given climax tree species (Daubenmire 1968, Lillybridge *et al.* 1995). An early seral plant community where the climax tree is a minor understory component is included with the old growth stand where the climax tree is dominant. In the Wenatchee National Forest, the grand fir series most often has an over story of Douglas fir or ponderosa pine or both (Lillybridge *et al.* 1995). Grand fir may be a co-dominate species and western larch, lodgepole pine, and Engelmann spruce may be present. A landscape comprised of a single forest series could be diverse in species composition and forest structure.

Fidelity of a species to a specific forest series is rare. "Ponderosa pine is a major seral species in the Douglas fir and grand fir series," and is found with Oregon white oak and, on warmer-drier sites, in the western hemlock and subalpine fir series (Lillybridge *et al.* 1995: 38). "Douglas fir is often the dominant or co-dominant species within stands of the Western Hemlock, Pacific Silver fir, and Grand fir Series"(Lillybridge *et al.* 1995:51).

Climatic Climax Descriptors of F&FR Forest Habitat Types

Vegetation classification protocols for Eastern Washington forests use the climatic climax dominant tree species (Franklin and Dyrness 1973, Lillybridge *et al.* 1995, Kovalchik in press). Daubenmire (1968:32) suggested that, "all the stands in one landscape mosaic are usually found to be components of a few successional sequences leading to still fewer climax types." In recent years, the use of climatic climax dominate tree species in classification work is not so much a statement about successional end points (Clements 1924, monoclimax theory) as it is a tool to group diverse plant associations. The climatic climax species serves as a mapping unit descriptor that will remain valid as current vegetation moves through development and succession stages. This use avoids the illogic use of a climatic climax approach in disturbance driven Eastern Washington forest ecosystems (FEMAT 1993). Disturbance rarely allows forest development and successional processes to proceed to climatic climax in these systems. Camp *et al.* (1996) found approximately 12% of the landscape of the Swauk drainage on the east slope of the Cascades was in old growth refugia. When forest management has prevented disturbance and driven Eastern Washington forests towards climatic climax, catastrophic fires have occurred as fire re-enters the system (Everett *et al.* 1996).

A polyclimax approach (Tansley 1924) recognizes that fire, edaphic, biotic, or other factors create a mosaic of different climax conditions on the landscape and may more closely represent Eastern Washington forest systems. Franklin and Dyrness (1973) describe Douglas fir as the climax tree species in moist habitats in the *Pinus* ponderosa zone and as the climax species on dry ridges in the *Abies grandis* zone.

Overlay the mosaic of different vegetation endpoints with multiple developmental-successional pathways (Keane *et al.* 1996) and a "naturally complex" vegetation mosaic of Eastern Washington forests emerges.

Douglas-fir is both a climax and a seral species-replacing ponderosa and lodgepole pines and western larch, but being replaced in turn on suitable sites by cedar-hemlock, spruce-fir, and grand fir. Douglas fir would replace larch in the absence of fire, but with burning or logging disturbances that leave a bare-soil seedbed, western larch will reproduce readily and outgrow Douglas fir. (Adam 1994).

By virtue of a vegetation classification system, a diverse landscape can be categorized. But categories (e.g., forest series and vegetation zones) are relatively general. The plant associations within each forest series allow greater resolution of current forest conditions, future stand development and successional stages, productivity, and response to management (Lillybridge *et al.* 1995). However, plant associations are climax abstractions and not continuous map themes of what is actually on the ground. A potentially more appropriate tool is a natural vegetation map currently under development for the forests of Washington (J. Hemstrom personal communication). This map will incorporate information on the climatic envelope of the major forest tree species and the disturbance regimes that affect stand development and successional stages. Perhaps, with GIS technology and improved information on vegetation plant associations (Williams and Lillybridge 1983, Johnson and

Clausnitzer 1991, Lillybridge *et al.* 1995, Kovalchik in press) and disturbance regimes, it may be possible to describe “prevailing climax” conditions for Eastern Washington forests (Whittaker 1960 In Agee 1993). With continuous map themes of current forest conditions and knowledge of the stand development and succession pathways of their respective forest series and plant associations, realistic resource goals and management practices may be derived. The information needed to achieve the stated goal of the Eastern Washington riparian prescription package, “to promote dynamic forest stand conditions that vary over time as would emulate the result of natural disturbance regimes,” may soon be available.

In summary, the literature indicates forest vegetation zones are comprised of a mix of different forest series. This is especially true for the mixed conifer habitat type in the 2500 to 5000 feet elevation zone. Forest management practices based on elevation zones and the three forest habitat types (ponderosa pine, mixed conifer, and high elevation forests) may lack the resolution needed to lead to sustainable forest systems.

Historical Reference Conditions

"A science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as a organism" - Aldo Leopold, 1941 (In Swetnam *et al.* 1999). Current forest conditions are not suitable as a reference for sustainable forest management because of significant changes in disturbance regimes and forest structure and composition that have created forests with significant "health" problems (Sampson *et al.* 1994, Covington *et al.* 1994). Opinions differ as to the relative threat of changes in inland forests this century, but there is general agreement that changes have occurred (Baker 1988, Brown 1983). In dry forests, Douglas fir and "closed" pine stands have generally taken the place of more "open" ponderosa pine stands. In moist forests, the shift has generally been toward grand fir-western hemlock-western red cedar stands and away from western white pine-western larch stands (Harvey *et al.* 1994, Mutch *et al.* 1993). Shifts toward late-successional species occurred relatively rapidly, compressing successional processes. The successional process for Douglas fir in the dry forest of Southern Idaho normally requires 300-400 years with historically frequent fire regimes. Data indicate that this successional process has been compressed into only 40 years as a result of fire suppression (Harvey *et al.* 1994). Similar compressed successional process have been observed in the Coeur d'Alene Mountains in Northern Idaho where western white pine-dominated ecosystems have been succeeded by late seral species in less than 50 years rather than the 200 to 300 years expected under historic disturbance regimes (Moeur 1992 from Graham *et al.* 1995).

Characterizing Natural Ecosystem Variability

Dramatic changes in Eastern Washington and Oregon forests caused significant concern to the public and led to the demand for a scientifically based approach to forest management practices (Everett *et al.* 1994). This landscape ecology approach to ecosystem management (Jensen *et al.* 1996) depends heavily upon Hunters' (1991) coarse filter approach to conserving biodiversity and resource productivity. Under the coarse filter approach, known and unknown biodiversity components are conserved by maintaining historical disturbance effects and resulting patch dynamics.

The concept or historical range of variability in ecosystem structure or process is valuable in understanding and illustrating the dynamic nature of ecosystems; the processes that sustain and change ecosystems, especially disturbances; and the current state of the system in relationship to the past. (Morgan *et al.* 1994:105)

Swetnam *et al.* (1999) considered the use of historical context as a tool for evaluating forest conditions to be especially important because of concerns related to human-caused environmental changes.

Historical reference points, and specifically, historical range of variability (HRV), have become a common standard to evaluate current resource conditions and disturbance regimes (Caraher *et al.* 1992, Swanson *et al.* 1994, Lehmkuhl *et al* 1993, Hessburg *et al.* 1999). Morgan *et al.* (1994:101-102) suggested that HRV provides an indication of the "range of desired future conditions," and "acceptable bounds for ecosystem change." Swanson *et al.*

(1994) used historical range in variability of both natural states and disturbance regimes to characterize natural ecosystem variability.

Limitations of HRV

Many of the seventeen questions posed by CMER seek information on historical conditions and disturbance regimes. The text above adds credence to those requests. However, there are potential negative aspects to the HRV approach. A major limitation on the use of HRV has been determining the timeframe to use in establishing the historical period. Timeframes of 100 to 400 years before present (BP) have been suggested (Hann *et al.* 1993, Steele 1994). Often the limiting factor is a diminishing record back in time. Successfully describing HRV is also dependent upon selecting the appropriate spatial scale to capture the dynamics of the condition or process (Morgan *et al.* 1994). Too fine a scale and the noise level hides information. Too large a scale and information is lost in the summation process.

Although very defensible historical data for fire (Agee 1993) and insect disturbances (Swetnam *et al.* 1995) on a stand or forest type basis is available, there is a lack of continuous map themes over large areas. Both the Eastside Forest Health Assessment and the larger Columbia River Basin Assessment utilized sub-sampling (less than 15% of the assessment area) to derive estimates of historical change (Lehmkuhl *et al.* 1994, Hessburg *et al.* 1999). Therefore, estimated historical disturbance and resulting vegetation change for a majority of the landscape must be extrapolated.

These recent assessments have relied on historical aerial photographs to define historical conditions and disturbance regimes. Unfortunately, the limited time span from when aerial photographs became available in the late 1930s to the present may lead to an underestimation of the real changes since European settlement (Lehmkuhl *et al.* 1993). This concern was substantiated in stand reconstruction of Eastern Washington forests that showed significant changes in species composition and tree density between European settlement (1860) and the 1940s (Everett *et al.* 1997, Everett *et al.* 2000).

However, the above concerns are minor compared with other potential problems in the use of HRV, such as:

The assumption that historical conditions were sustainable may not be valid.

Historical fire effects (regimes) may not be re-established because of the absence of indigenous burning and current societal constraints.

Future global climate change may no longer support historical forest composition structure and inherent disturbance regimes.

HRV may be too restrictive under an expanding human population.

Implicit in the use of historical reference points is the assumption that historical conditions prior to European settlement were sustainable (i.e., they conserved biodiversity and site nutrient capital). This assumption has yet to be tested. As an example, the disturbance return interval: recovery period ratio needs to be 1 for a sustainable system to exist (Turner *et al.*

1993). In other words, a system must have time to reach its pre-disturbance state before the next disturbance or site degradation can occur. Too extensive a period without disturbance allows a buildup of biomass and more severe disturbance events are possible. When the established fire frequency interval (FFI, or disturbance return interval) was graphed against the current fire free period (FFP, or recovery period) for mixed conifer forests in Eastern Washington, the ratio was rarely equal to 1 for the period from 1796 to 1916 (Everett *et al.* in press). Eastern Washington forest sites showed cycles of both too frequent (FFP < FFI) and too infrequent burning (FFP > FFI) to have "sustainability" and the patch mosaic was not in a dynamic steady-state.

Indigenous burning played a significant role in defining the forest composition and structure of dry Douglas fir and ponderosa pine forest east of the Cascades (Barrett and Arno 1982, Agee 1993). If HRV conditions are derived from indigenous burning, it may not be possible to re-establish pre-European settlement forests.

Historical and current disturbance regimes and forest conditions may be irrelevant, given the projected changes in global climate on Eastern Washington. "Over the next century, radical changes in climate are expected to have a marked and lasting impact on forests of the Inland West" (Covington *et al.* 1994:44). Climate change is predicted to affect future forest conditions by altering forest processes, disturbance regimes, and biodiversity (Dale *et al.* 2000). The mean seasonal severity rating (SSR) is estimated to increase by 10 to 30% by 2060 for Eastern Washington using the Canadian general circulation model (GCM) and Hadley GCM fire models (Dale *et al.* 2001). SSR is a measure of fire weather severity and potential area burned. Elevated carbon dioxide and climate could significantly alter insect and pathogen disturbances (Ayres and Lombardero 2000).

Historical conditions or disturbances were the part of the larger disturbance potential that was realized. Other historical scenarios were possible given the ignition sources, fuels, insects, pathogens, and storm events. These unrealized scenarios of disturbance and vegetation condition may be more conservative of biodiversity or site nutrient capital, but did not occur because of chance. Limiting forest conditions to historical ranges may not provide the required flexibility to meet future public demands for resource conditions and disturbance regimes.

In summary, historical reference conditions provide valuable tools in the development of knowledge for evaluating sustainability of forest systems. They can be used to estimate how far out of phase current disturbance regimes have become and the resultant changes in forest vegetation composition and structure. However, historical conditions may not have been sustainable, and climatic change may make historical conditions irrelevant. In the future, the knowledge base, rather than the historical condition, will be needed to develop resource objectives and to develop forest management practices. Responses to the seventeen questions posed by CMER will add to the knowledge base necessary to promote dynamic forest stand conditions that vary over time as would emulate the result of natural disturbance regimes.

Questions

Question 1

For each type of disturbance, what is the current and what were the historical (e.g., 200 years ago) frequency, magnitude (e.g., size of disturbance patches in forest and whether single tree, small gap, or large gap), and intensity (e.g., heat and duration of fire) of disturbance? Currently and historically, is there a difference in the periodicity, magnitude, and intensity of fire in upland and riparian areas?

Response

Current and Historical Disturbance Characteristics

There is a very large information base on historical and current disturbance regimes within Eastern Washington forests. Information is available on the inherent fire, insects, and pathogen disturbance regimes for every forest series present. The differences between current and historical disturbance regimes for fire are better defined than for insects and pathogens because of the permanent fire scar record.

Characterizing disturbance effects on forest types is a complex undertaking that is difficult to summarize according to broad forest categories or general disturbance types (e.g., Kovalchik's eight forest series types or F&FR elevation bands). The interaction of several disturbance types or re-occurrences of the same disturbance types requires understanding of the synergistic effects of disturbances, or the development of "composite" disturbance regimes (currently underway). Use of such broad forest classifications masks other characteristics that play a significant role in the severity, extent, and frequency of disturbances, such as the presence and type of under story shrubs and stage of stand succession.

Alteration in Disturbance Regimes

Prior to the arrival of indigenous peoples to Eastern Washington, the disturbance regimes of the forest were defined by the vegetation composition and structure, landform, soils, climate, and the disturbance agents (fire, insects, pathogens, and severe weather). This "inherent" disturbance regime (Everett *et al.* 2000) was altered by the burning activities of the indigenous people. Indigenous peoples increased fire frequency, and may have reduced insect and pathogen effects in the process. With the removal of the indigenous peoples burning effects from around 1890 (M. Ubelecker personal communication), Eastern Washington forests were on a trajectory back to the "inherent" disturbance regimes. However, this transition was truncated by fire suppression activity initiated around 1910.

Summary Information By Disturbance Type

Fire

The natural patterns of fire frequency, extent, and distribution in Eastern Washington were significantly altered beginning in the early 1900s, when land managers began fire suppression practices.

In general, fire frequency decreases along the ecological gradient from warm/dry ponderosa pines to cool/moist subalpine firs.

Fire severity is usually inversely related to fire frequency (Perry 1995).

Both fire spread and severity are linked to the amounts and moisture content of fine surface fuels, fuel ladders to the crown, height to the base of the crown, crown cover, and crown density (Agee 1993).

Kovalchik's (in press) description of fire history for Eastern Washington forest plant associations suggests that, historically, those plant associations in moist environments avoided or had less severe fire events than more xeric plant associations within the same forest series. Whether this phenomenon can be extrapolated to differences between adjacent riparian and upslope plant associations remains undetermined.

In more xeric upland forests, there are increased fire hazards to the riparian plant associations (Kovalchik, in press).

Riparian forests have somewhat longer fire free intervals than upslope forests regardless of slope aspect (Everett *et al.*, in press).

Traditionally "umbrella" type fire regime descriptions – where general descriptors of fire severity, frequency, and extent are assigned to each forest series – are used (see Table 5). However, this approach masks significant variability in fire regime among plant associations within the forest series.

Table 5. Fire Regimes for Eastside Forest Series (Adapted from Agee 1993; Agee 1994; Everett *et al.* 2000; Schellhaas *et al.* 2000)

Forest Series	Fire Severity	Fire Frequency	Fire Extent
Ponderosa Pine	Low with small patch replacement	Frequent (3- 40 years)	Large under burn, clumped pattern (less than 1 hectare per patch)
Douglas-Fir White Fir Grand Fir	Low in warm/dry areas increasing to moderate in cool/moist areas	Frequent in warm/dry areas, Reduced frequency in cool/moist areas	Large under burn, clumped pattern with large stand replacement fires (500-1000 hectares)
Lodgepole Pine	Moderate, includes low severity "cigarette burns" to high severity stand replacement events	Moderate (40-80 years)	From individual log to corridors (less than 30 meters to 1/3 of stand)
Western Hemlock Western Red cedar	Low to moderately high	Moderate (50-100 years) Long (150-500 years)	Large, topographic barriers define burn size (10,000 to 20,000 hectares)
Subalpine Fir Mountain Hemlock	High	Long (more than 100 years)	Small fires (146 hectares) dominate over large fires

Insects and pathogens

There is a significant gap in knowledge about historical insect and pathogen disturbance regimes in Eastern Washington forest types. A notable exception is the history of spruce budworm outbreaks in the Blue Mountains as interpreted from tree ring analyses (Swetnam *et al.* 1995). What little information is available indicates that insect and pathogen outbreaks have become more frequent, of longer duration, and more severe in recent times.

The current insect and pathogen disturbance regimes have been well summarized as part of the Eastside Forest Health Assessment, the Columbia River Basin Assessment, and other work (e.g., Lillybridge *et al.* 1995).

Vulnerability of forest series to insect and pathogen hazard varies among and within ERUs depending upon past management actions.

The threat of defoliation to subalpine fir, Pacific silver fir, western hemlock, western red cedar, and mountain hemlock has increased through larger and more contiguous bands of host communities (Hessburg *et al.* 1994).

Conditions for optimal spread of root diseases and dwarf mistletoes exists in many parts of the lodgepole pine, ponderosa pine, Douglas fir, and grand fir climax series (Hessburg *et al.* 1994).

Some general trends by forest series type are evident:

- There are relatively few serious insect or pathogen pests in the subalpine forest series.
- In the western hemlock and western red cedar forest series, insect pests remain few, but pathogen effects have significantly increased.
- In lodgepole pine forest series, mountain pine beetle and dwarf mistletoe increase fire hazard.
- In the Douglas fir and grand fir forest series, pathogen impacts have declined, but insect effects are not potentially serious.
- In the ponderosa pine forest series, insects remain serious pests, but with fire continually sanitizing the landscape, insect impacts may have been lessened.

Other disturbance types

A review of the literature revealed no information on the current and historical patterns of other disturbance types (e.g., ice storms and debris torrents).

Differences Between Riparian and Upland Areas

Sufficient information is available on vegetation response to disturbance at the individual tree, stand, and landscape level to predict with some confidence forest response to applied disturbances. Predicting vegetation response is dependent upon the knowledge of the disturbance magnitude and the development stage of the plant association group (PAG) or forest series. However, information on differences in riparian and upslope forest disturbance regimes and post-disturbance response is not well known.

Fire suppression techniques have reduced the periodicity of fire in both upland and riparian forest types. Current attempts to buffer forest systems from these fire, insect, and pathogen disturbances have resulted in forest structure and composition that no longer reflects the inherent disturbance regime. When fires do occur today they are large in extent and can be stand replacement events.

Disturbance relationships between upslope and riparian forest fire regimes are being defined. There does not appear to be a consensus as to whether there is a distinct difference between fire effects in riparian versus upslope areas. Fire severity, extent, and patterns are a function of more than just forest type – moisture levels, aspect, slope, season, under story shrubs, valley type, and adjacent community types all have been shown to play a role. There is an information gap in insect and pathogen relationships at this ecotone.

Question 2

Does elevation correlate with historical fire frequency? If so, how? Did this differ between upland and ecological riparian communities? Are there other parameters that were used in the scientific studies to define areas of differing historical disturbance patterns and historical stand conditions?

Response

Correlation of Elevation with Historical Fire Frequency

Elevation is related both directly and indirectly to fire frequency (as well as extent and severity) in several ways. Lightning strikes are more common on the upper one-third of slopes, which increases the probability of fire ignition at higher elevation. Landform influences the spread of fire by channeling winds and the potential for producing a chimney result that increases fire spread and intensity (Agee 1988). Elevation affects the climate and species composition of a site, thereby indirectly influencing fire behavior (Williamson 1999).

The literature suggests that these topographic influences on fire effects do vary between riparian and upland communities. In general, riparian vegetation is often assumed to burn less frequently than upland vegetation (Hinselman 1973, Romme and Knight 1981, Agee 1994) and in some cases these systems form a firebreak. The increased amount of available moisture reduces the chance of carrying a low-severity fire.

However, under certain weather conditions, the complex, multi-layered structure of riparian systems, combined with fire-sensitive species, can make such systems particularly susceptible to intense fires (Williamson 1999). Under these circumstances, the riparian system could burn with greater intensity than surrounding uplands (Agee, 1994, Agee 1998, Williamson 1999) and produce a higher crown fire hazard than surrounding uplands.

With increasing elevation, riparian systems exhibit less frequent but more severe fires than similar lower elevation areas. In lower elevation areas, dry riparian systems have charred live trees, charred stubs, and rings of charred tissue around the base of live trees – suggesting low-severity fires in the past (Agee 1998). Riparian trees with fire scar are common (Heyerdahl and Agee 1996). At higher elevations, riparian areas perhaps burn less frequently, but occasionally more intensely (Agee 1994). Agee (1998) applies a 250-1000 year return interval for fire in “hydric” or riparian forests in mid- and high-elevation zones.

When fires do burn riparian areas, the effects can be more severe than in associated upland areas. Crowe and Clausnitzer (1997) found that riparian areas extend what are generally higher elevation plant series into lower elevation drainages. Riparian areas act as conduits for water, as cold air drainages at night, and receive less insulation during the day (Olson 2000). Higher moisture inputs and lower evaporation produce a riparian forest that is cooler, moister, and more complex than associated uplands (Brosofske *et al.* 1997, Naiman *et al.* 1998, Williamson 1999, Olson 2000). Species with higher moisture requirements generally have a lower resistance to fire. This lower resistance combined with vegetation complexity results in severe fire effects and increased mortality.

Additional information concerning the historical fire patterns and the linkages between elevation and fire disturbance is available from the Wenatchee National Forest.

Influence of Other Parameters on Disturbance Patterns and Stand Conditions

Many studies stress that the elevation-fire relationship is not the sole determinant of fire frequency and severity. In many cases, related variables such as slope, aspect, and forest stand composition play equally important roles. For example, Heyerdahl (1997) and then Olson (2000) found that fire frequency in the Blue Mountains did not vary in terms of fire recurrence due to aspect or elevation. The exceptions were cases where the terrain became more dissected as elevation increased, in which case fire return intervals increased. With increased elevation, forest composition changes in response to topography and temperature. Agee (1994) stated that because changes in vegetation correspond with changes in elevation, the plant series is useful to describe fuel profile. However, Agee, in the same manner as Kovalchik, felt that, "the location and extent of a plant series [and therefore the use of elevation] often required local interpretation" (Agee 1994:6).

The relationship between elevation and forest stand type appears to play a particularly important role in insect and pathogen disturbances and how such disturbances ultimately affect the landscape. For example, in situations where trees are defoliated by western spruce budworm (Stoszek 1988), there is a change in host tree disposition associated with elevation gradients, a synchronization of bud burst with larval emergence from hibernation at higher elevations with shorter growing seasons, and reduced budworm survival at high elevations. At higher elevations, a dynamic tension exists between Douglas-fir/true firs and ponderosa pine (McCullough *et al.* 1998). With historical and regular fire, sites were likely occupied by ponderosa pine. After fire control was initiated, seral pine stands shifted to late-successional stands of shade-tolerant Douglas fir and true firs, the favored host of tussock moth (Wickman 1978, Wickman 1990).

The density of forest types also plays a role in disturbance magnitude and stand condition. Current, late-successional forests with higher densities (as a result of fire suppression) in eastern Oregon and Washington have the same insect and pathogen compliments as the traditional old forests, but the increased continuity of hosts across the landscape leads to an intensification of the magnitude, severity, and duration of outbreaks (Everett *et al.* 1994, Hessburg *et al.* 1993).

Elevation, climate, geology, and vegetation condition are key determinants of disturbance. For example, landslides are produced from overloading already unstable slopes with additional sources of water from intense precipitation events, interception and redirection of groundwater flow paths due to roads, forest cutting that reduces rooting strength and increases soil water volumes from decreased evapotranspiration. These slides can be delivered to the heads or sideslopes of incipient drainages to produce a disturbance cascade (Miles *et al.* 1984, Nakamura *et al.* 2000). Debris slide initiation is more likely to have higher severity of disturbance in the upper elevation zones, but affect a small percentage of lower order/lower elevation channels in any one storm (Swanson *et al.* 1998). Swanson (1981) found that the magnitude and scale of fire effects are, in addition to the size and severity of the fire, related to the geology, topography, and size of stream system, as well as the amount, magnitude, and timing of post-fire precipitation events in the area.

Question 3

What was the persistence and resilience of various stand types to disturbance? What was the typical pattern of recovery in terms of time and species composition following disturbance? Are some communities dependent upon fire to promote reproduction or other ecological processes? Do the answers to these questions differ between ecological riparian communities and upland areas? What are the expected future stand succession and disturbance patterns in the presence of fire suppression? Does this vary by stand type or other parameters?

Response

Persistence and Resilience of Various Stand Types

Persistence, or the more widely used term "resistance," refers to the ability of a forest stand to withstand disturbance without significant structural change (i.e., changes beyond the natural range of variation). Resilience describes the extent to which, following disturbance, a forest stand becomes re-established in its pre-disturbance condition (Agee 1993, Obedzinski *et al.* 2001). For example, low growing and flexible woody species found in riparian avalanche zones are capable of withstanding the force of sliding snow (thereby demonstrating resistance). These plant communities survive avalanche by rapid growth habits and vegetative reproduction (thereby demonstrating resilience) (Cushman 1981, Naiman *et al.* 1992).

Individual tree species have quite different resistance and resilience characteristics that have been summarized by Starker (1934), Agee (1994), Hessburg *et al.* (1994), Lillybridge *et al.* (1995), and Kovalchik (in press). Forest stands will demonstrate the summation of the resistant and resilient attributes of individual tree species, as influenced by stand development stage. For example, a forest stand with flammable foliage (e.g., subalpine fir) will be less resistant to fire disturbance when it has a well-developed crown versus an earlier, more open, developmental stage.

Based upon review of several studies (Miller and Kean 1960, Arno and Davis 1980, Cooper and Pfister 1984, Peterson and Ryan 1986, Mitchel 1987, Stoszek 1988, Biswell 1989, Oliver and Larson 1990, Camp *et al.* 1996, Payne *et al.* 1996, Graham *et al.* 1999), it appears that, in general, heterogeneous landscapes with discontinuous fuels, a range of insect and pathogen hosts, and a mix of successional stages are most resistant to disturbance effects. High stand resilience seems closely tied to high levels of biological diversity and nutrient availability (Brown and DeByle 1989, Meffe and Carrol 1997). However, much of the current information about forest stand persistence and resilience comes from post-fire suppression studies. There appears to be little quantitative data about historical responses of entire stand types to disturbance.

Typical Pattern of Recovery

Little is known about historical successional pathways following disturbance. However, current studies indicate that potential successional development pathways following forest stand disturbance are highly site and disturbance-specific (Arno *et al.* 1985, Everett *et al.* 2000). Approaches that seek to incorporate site-specific vegetation, climate, and disturbance parameters (e.g., Columbia River Basin Succession Model (CRBSUM), by Keane *et al.* [1996] and the Ecosystem Diversity Matrix by Haufler [1996]) may more accurately predict future forest conditions than any single historical model.

Fire-Dependent Communities

The standard example of a fire dependent forest type is lodgepole pine and its serotinous cones that disperse seed following a crown fire event (Wheeler and Critchfield 1985, Kauffman 1988). Aspen stands are another example. They need fire to renew clones and protect young trees from encroachment by firs (Bartos *et al.* 1983, Brown and DeByle 1989). Ponderosa pine stands are also dependent upon fire to reduce the under story of shade tolerant Douglas fir and true firs (Mutch 1970).

These examples illustrate the general principle that all forest series (and, by extension, their surrounding communities) are dependent upon some sort of disturbance to maintain diversity of stand conditions. Heterogeneous landscapes break up continuity in insect and pathogen hosts and fuels (Lehmkuhl *et al.* 1994, Hessburg *et al.* 1994) and thus reduce the probability for catastrophic disturbance events (Everett *et al.* 1996). Insects, pathogens, and fire all play roles in nutrient cycling, habitat creation, and normal successional processes (Haack and Byler 1993, Hessburg and Everett 1993).

Riparian Versus Upland Communities

Current studies (Morse 1999, Everett *et al.* in press) indicate that burn severity is much less in moist riparian areas versus upslope forest areas in Eastern Washington. However, current research is based on forest conditions with significant increases in upslope forest cover. It is unknown whether, under more natural fire regimes with reduced upslope forest densities, this was a trend in historical times as well.

Obedzinski *et al.* (2001) present a simple model of resistance and resiliency for riparian systems in which systems that resist disturbance or are highly resilient continue on their projected development. Systems where disturbance exceeds recovery potential enter a degradation cycle. Another theory might suggest that because riparian and upslope forests share a majority of the same plant associations (Kovalchik in press) more similarities than differences in individual and stand resistance and resilience could be anticipated.

The *CTC* project team's search revealed no available information on the differences between resistance and resilience to insect disturbances between riparian and upslope forest.

Expected Future Succession Patterns

All biomass is cycled. If it is not cycled by fire, then it will be increasingly cycled by insects and pathogens (Hessburg and Everett 1993). With increases in fire suppression in recent years, an increased duration of insect outbreaks has already been observed (Flanagan personal communication). Stand succession without fire will move forests towards climatic climax and catastrophic fire disturbance events when they occur (Ottmar and Sandberg 2001, Everett *et al.* 1996).

With regular fires, shade intolerant early or mid-seral species historically dominated the landscape (Mutch 1970). Without fire, shade tolerant late seral to climatic climax species will continue to have the competitive edge (Kauffman 1988). Forest series with the longest fire return intervals, such as western hemlock or subalpine fir (greater than 300 years, Covington *et al.* 1996), may be the least affected internally by continued fire suppression. Variability among stands within these forest series will likely decline as at least a portion of the type may burn each year.

Question 4

What portion of the landscape was likely to be affected by disturbance historically? How does that differ from the current situation?

Response

Fires

Historically

The geographic extent of historical fires is not well known. Cross dating of fire scars has been used to some extent, largely to develop maps of fire distribution in ecosystems where low-intensity fires were frequent (Agee 1994). Areas that experienced high-intensity burns would have distributions that are observable for a century or more from the mosaic pattern of different-aged stands. Much of the Cascades burned over in a massive forest fire during the 14^{th} century, and many smaller fires have burned since then (Perry 1988).

Current Situation

Currently, fires are often extinguished quickly, with the result that forests burn less frequently (Baker 1992). Fires that do burn are more severe, because of accumulated fuels, and result in loss of vegetation and organic matter storage (Harvey *et al*. 1993). Fire-adapted species are reduced and non-fire-adapted species are increasing where they were historically excluded by frequent fire (Harvey 1994). At the landscape level, there has been a shift in fire regime (Pickett *et al*. 1989). This shift is sufficient to alter the stability of forest ecosystems.

Both historically and currently, there is limited regional-scale information on what portions of the landscape are most affected by fire disturbance. The spatial scale of studies assessing effects of fire has been restricted to point observations and stream transects, and attempts to generalize effects to aquatic systems at the landscape or regional scale have been rare (Gresswell 1999).

Pests and Disease

Historically

In the interior forests east of the Cascades, periodic insect outbreaks appear to be a part of the normal historic pattern (Perry 1988). When a disease, parasite, or herbivore attacked a forest stand, the pattern of damage was often irregular and patchy in distribution. There is evidence that this distribution was often the result of a combination of localized distribution of the attacking species and the apparent preference or avoidance of certain tree phenotypes (Linhart 1988).

In the Blue Mountains, large expanses of open ponderosa pine forests were likely regulated by bark beetles in old-age forests, or fire in immature forests. This resulted in a patchwork of age classes (Wickman *et al.* 1994). Based on historic descriptions and inventory records, the stands were mostly old age, open grown, and dominated by pine. Remaining old-growth mixed-conifer forests at higher elevation and more mesic sites left tree-ring histories that showed about 7-10 budworm or tussock moth outbreaks over the last two centuries (Wickman *et al.* 1994). According to tree-ring analyses, these outbreaks apparently caused heavy defoliation and were often synchronous across the Blue Mountains.

Current Situation

Several characteristics of the landscape have changed over the last century. More uniformity in species distribution allows pests to multiply and disperse much more effectively across a landscape. Defoliating insects and bark beetles (e.g., western spruce budworm and tussock moth) are the most serious pests of interior forests. Wind currents disperse the larvae of these outbreak defoliators. Their survival and the rate of spread depend on the distribution of host and non-host plant species across the landscape. Landscape patterns also influence the habitat for birds, mammals, and spiders that prey on defoliators and bark beetles. Logging roads and increased traffic have facilitated the spread of at least five pest species (gypsy moth, cedar root rot, black stain root disease, tansy ragwort, and spotted knapweed) in the Pacific Northwest.

In white and sugar pine country, the introduction of white pine blister rust early in the century is reducing these species in many areas to less than half of what they were just 40 years ago (Monnig and Byler 1992, O'Laughlin 1994). Ponderosa pine, western larch, and white and sugar pine are broadly adapted and relatively tolerant of many native diseases and insects, but populations have been strongly reduced in the absence of fire. Other native conifers are narrowly adapted and poorly tolerant of changes in their environment or with associated native insects and diseases (Harvey 1994).

The current forests of the Blue Mountains have been so altered that shade tolerant fir now grows on many pine sites historically maintained in a seral state by fire. These stands are 90-140 years old and appear to be regulated by forest insects (budworm and tussock moth) and diseases (Wickman 1994). Tussock moth studies over 20 years showed a pattern of periodic increases and declines caused by density-dependent factors, while the latest budworm outbreak has killed most of the host trees in both fir-invaded pine and historically mixed-conifer. The level of insect populations and resulting host damage indicated in 1994 was considered highly unstable and likely new to the ecological history of the Blue Mountains (Wickman 1994).

Fire-Insect Relationships

Historically

Historically, both low intensity defoliator outbreaks and surface fires probably kept fuel accumulations low and prevented and/or delayed catastrophic stand replacing fires or insect outbreaks. It is unlikely that tree mortality rates similar to the 80% recorded in the most recent budworm outbreak could have been sustained historically (Swetnam *et al.* 1995).

Current Situation

Although major disturbances such as fire or insect outbreaks appear to be independent events, causality exists (McCullough *et al.* 1998). The spatial and temporal patterns that result from disturbance often reflect a synergism among disturbance agents acting within the physical limits of the landscape and ecological processes (Hadley 1994). One disruption to an ecosystem often sets the stage for others (i.e., if the potential exists for wind throw due to a clear cut edge, downed trees from the wind throw may provide a large food base for some species of bark beetles).

Episodic outbreaks of the major defoliators have served a complementary role to that of surface fire by directing succession (Wickman 1978). For example, budworm and tussock moth fed on late-successional Douglas fir and true firs, but left seral pines.

Fire also alters the abundance and spatial-temporal continuity of preferred host species and nutrient cycling and availability, which in turn, determines the quality of trees as hosts (Attiwell 1994). In pine forest of the interior Northwest, extensive, even-aged stands of lodgepole pine, usually established by fire, can promote bark beetle outbreaks. This is a self-maintaining pattern--beetle infestations create large amounts of fuel thereby increasing the potential for wildfire, and fire, in turn, initiates development of new even-aged lodgepole pine stands (Amman and Schmitz 1989, Stuart *et al.* 1989). When no fire occurs after outbreak, lodgepole may be replaced by ponderosa pine at low elevations or by Douglas fir at higher elevations (Mitchell 1990). Fire can predispose surviving trees to attack by insects by scorching or wounding, particularly phloem-boring bark beetle and/or wood borers (McCullough 1998).

Landslides and Debris Torrents

Historically

In areas with steep slopes, landslides were the dominant erosional mechanism (Robison *et al.* 1999). Ketcheson and Froelich (1978) and Ice (1985) found that even in areas with high landslide densities, landslides directly affected less than 2% of the land surface. Impacts of landslides on small streams (1^{st} to 3^{rd} order) can be severe and extensive (Swanson *et al.* 1981b, Robison *et al.* 1999). While landslide features may constitute less than 1% of the total land surface in Pacific Northwest mountainous terrain, they can scour and affect over 10% of the channel network (Swanson *et al.* 1987).

Current Situation

It has been postulated that present-day increases in logging and road building have contributed to increased landslide frequency and severity. However, several studies that have examined differences in landslide patterns between relatively pristine or mature forests and more intensively managed sites have shown only mixed support for this theory. A variety of factors including precipitation patterns, slope, soil type, management, and forest type all play a role. In some cases, the complexity of the interactions makes it difficult to discern management-related effects from natural variability (Ice 1985, Sidle *et al.* 1985, Meehan *et al.* 1991, Robison *et al.* 1999).

Robison *et al.* (1999) found landslide density to vary from 0.4 to 24.4 landslides per square mile out of 45.8 square miles where landslides entered stream channels. The majority of the landslides were not associated with roads. The highest risk for shallow rapid landslide was found on slopes over 70-80%, depending on landform and geology. A moderate landslide risk existed on slopes between 50-70%. Landslides that entered stream channels during the storms of 1996 occurred in very steep landscapes or adjacent to stream channels. At least 78% of the up-slope (versus channel initiation sites) landslides occurred on high-risk sites (i.e., "red zones" with steep slopes and the potential for water accumulation). Earlier studies have speculated that the greatest increase in landslides occurred after roots had decayed and before new roots could take hold, typically a few years after timber harvest.

Swanson *et al.* (1987) found that erosion rates were 1.2 to 1.3 times greater (up to four times greater on the most landslide-prone sites) than unmanaged mature forests for most landscape types in 1,300 acres on the Mapleton Ranger District of the Siuslaw National Forest in Oregon. This study compared an aerial photograph-based clear cut sample to a ground-based forest sample, likely underestimating erosion rate ratios. However, Martin (1997) found no significant differences in landslide occurrence between mature forests, clear cuts, and leave areas.

Robison *et al.* (1999) found no significant differences in landslide density and erosion for their four "red zone" study areas between four age classes (0-9 years – recent clear cut/very young forest, 10-30 years – young forest, 31-100 years – forest, and older than 100 years – mature forest). The lack of differences as explained by Robison was in part due to great differences in landslide characteristics between the study areas. In three out of four study areas in very steep terrain, however, both landslide density and erosion volumes were greater in the 0-9-age class. Stands within the age classes of 10-100 years had lower incidences of landslide than the mature forest.

Forest practices may alter both physical and biological (vegetation) properties related to slope stability. Physical changes that can occur include slope steepening, the addition of soil moisture, and alterations in shear strength. Some of the most important slope stability changes are caused by haul roads and skid trails (Sidle *et al.* 1985). Almost all major road-related landslides that delivered sediment to streams investigated by Oregon Department of Forestry (ODF) prior to the 1996 storms were related to road fills or road side cast (Mills 1991). Toth (1991) found that roads in Washington that were constructed in the last 15 years survived a landslide-inducing storm with minimal damage, while roads constructed earlier had very high damage rates. ODF found that road drainage caused about one-third of the investigated landslides (Mills 1991). Culverts were associated with 29% of damaged sites in the Deschutes River Watershed in Washington (Toth 1991).

Most landslide studies are based on aerial photograph interpretation, a technique that has come under some criticism (Pyles and Froehlich 1987) for its inability to detect landslides due to photograph angles and the obscuring effect of tall trees. Prior to the study by Robison *et al.* (1999), a systematic ground-based sample of landslide occurrence was conducted in only two other forest landslide studies. Hughes and Edwards (1978) investigated a study area of about 0.3 square miles. Ketcheson and Froelich (1978) field-investigated 100 acre or smaller watersheds in the Mapleton, Oregon area that were not influenced by forest roads.

The inability to accurately determine the proportion of the landscape that is or was likely to be affected by disturbance, without field verification, leaves a critical data gap.

A variety of geomorphological processes may be linked sequentially, producing what Nakamura *et al.* (2000) termed “disturbance cascades.” These cascades can propagate down gravitational flow paths from hill slopes through stream networks, particularly through geologically unstable mountainous areas like the Pacific Northwest. In steep terrain, small shallow landslides often transform into debris flows – a semi-fluid, viscous mass scouring soils from slopes along its path. Once the debris flow enters a channel network it becomes a debris torrent. In some cases, a landslide that begins with 10 cubic yards of material or less may become a debris torrent, moving thousands of yards of material and depositing it where the channel gradient declines (Benda and Cundy 1990). On larger streams (4^{th} or 5^{th} order), debris torrents may be immediately entrained in rafts that become jams at a confluence with larger channels. Congested log transport from debris torrents has been known to remove large riparian trees (e.g., 30-year-old alders in recent floods in the Pacific Northwest) (Swanson *et al.* 1998, Wondzell and Swanson 1999). Larger channels will have a more dispersed disturbance with areas of removed, toppled, and standing trees. Thus, there is a gradient of decreased overall disturbance severity and increased variability in that severity as the cascade is propagated downstream (Nakamura *et al.* 2000).

Question 5

How did historical disturbance patterns affect vegetation condition by stand type? Historically, what portion of the upland and ecological riparian forests (by stand type) were likely in a climax and early successional conditions?

Response

Effect of Historical Disturbance Patterns

Prior to European settlement and active disturbance management practices (approximately 1910), disturbances in the form of fire were larger in extent, more frequent, and generally accepted to be of lower intensity than present-day fires. Frequent low-intensity fires at average intervals of between 5 and 30 years favored retention of long-lived, fire-dependent, and fire-resistant species, such as ponderosa pine and western larch (Arno 1988, Arno *et al.* 1997, Camp *et al.* 1996).

Frequent, low intensity fires also resulted in more continuous "cropping" of developing trees and resulted in more open, park-like conditions (Everett *et al.* 2000). Burning in a patchwork pattern, most of the soils and vegetation experienced light disturbance retaining relatively open stands of very large ponderosa pine and western larch. Under stories consisted of a diverse assemblage of fruit bearing shrubs, hardwood trees, grasses, and forbs (McCune 1983, Arno and Peterson 1983). Historical fires were frequent enough to keep fuel loadings light and reduce the hazard of stand-replacing fires across all stand types. Seral stands of large old ponderosa pine and western larch dominated nearly 25 million acres between central Montana and the Cascades of Washington and Oregon (Losensky 1995).

Historical fire patterns showed high temporal and spatial variability in both patterns of occurrence as well as their affect upon the landscape. Klenner *et al.* (2000) modeled forest community dynamics using the Tool for Exploratory Landscape Scenario Analyses (TELSA). They found that natural disturbances, in this case wildfire, created high levels of spatial and temporal variability with stands having different species compositions and age structures. In their simulations, which were based on old-growth stands in south-central British Columbia, historic levels of wildfire affected an average 525 hectares per year with a high annual variability.

While there is little available information regarding historical effects of other types of disturbances, it is likely that they too exhibited a similar pattern. Fires also affected disease and insect occurrences. Frequent historical fires prior to 1900 may also have reduced insect and pathogen effects (Morgan *et al.* 1994). "Recent" historical disturbance patterns (35-50 years ago) are summarized by Lehmkuhl *et al.* (1994) and Hessburg *et al.* (1999).

Portion of Riparian Ecosystems in Climax and Early Successional Conditions

Under historical conditions with more frequent and less severe disturbance patterns, there would have been a greater proportion of early successional stages and greater landscape heterogeneity (Lehmkuhl *et al.* 1994). However, Camp (1996) and Camp *et al.* (1996) found that not all areas within a heterogeneous landscape have the same potential to reach late successional compositions and structures. Individual sites or patches can have specialized topography and moisture conditions that may lengthen fire return intervals, creating fire refugia. In a study at the Swauk Late Successional Reserve in Eastern Washington, such fire refugia were likely to occur on north facing aspects above 4,000 feet elevation and at the confluence of two perennial streams, within a valley bottom, on a flat bench, or within a drainage highwall (Camp 1996).

Historical landscapes were not likely in "equilibrium" conditions. Whenever a single disturbance event can affect a relatively large proportion of the landscape, achievement of an equilibrium state is not likely. There will be wide swings from one decade or century to the next in the proportion of the landscape in different developmental stages (Sprugel 1991). Historically, low-elevation forests of the Pacific Northwest fit this model, where in pre-settlement times individual fires may have covered hundred of thousands of acres (Franklin and Hemstrom 1981).

While there is little specific information about historical successional patterns following disturbances, some current research may provide insights into how such systems might have responded. In the case of fluvial disturbances, the effects are greatest in the central core of the riparian ecosystem and diminish outward to the uplands. If this event scours the stream to bedrock, the rate of recovery depends upon the rate of COD replenishment (rapid with large riparian trees and bank instability) that influences channel morphology and the routing of sediment and water (Franklin *et al.* 1981). The riparian area may then work as a "refuge" for certain types of species (e.g., shade intolerant, Naiman *et al.* 1993).

After a stand replacing debris torrent, the riparian successional sequence is analogous to under story development in upland old-growth Douglas-fir forest: early species richness and structure, mid-successional decline in under story production and richness, and late-successional increases in multi-layered structure (Huff 1984). [Other disturbances complicate the prediction of forest community response to flooding disturbances in riparian areas. Fires and wind affect uplands primarily, but tend to enter the riparian system depending on the disturbance magnitude or width of the riparian area.]

Russell and McBride (2001) studied what physical factors, both static and dynamic, influenced the balance between conifer and hardwood dominance in mixed conifer riparian systems and found proximity to the stream channel to be the most important factor. To a lesser extent, the time since the last fire was also shown to exert an influence on many of the same aspects of stand composition. High soil moisture favored hardwoods and potentially suffocated the roots of intolerant species. Recurrent flooding, and associated COD, damaged standing and susceptible trees.

Question 6

Historically, what was the distribution of stand characteristics (basal area, height, density, age, species diversity, canopy closure) by stand type in upland and ecological riparian communities?

Response

Available Scientific Information

Scientific information on historical stand structure (greater than 100 years BP) in Eastern Washington is scarce, but indicates that tree densities, basal area, and representation of shade tolerant species were significantly less in historical Douglas-fir, ponderosa pine, and grand fir forest series. Currently the greatest information gap is on historic stand characteristics within high elevation forest types (e.g., subalpine fir and Engelmann spruce).

There are two types of information available on historical stand structure in Eastern Washington: 1) recent historical information (1940s) from aerial photograph analysis and 2) pre-European settlement historical information from stand reconstruction and age class studies (Everett *et al.* 1997; Harrod *et al.* 1999; Camp 1999). These information sources are supported by stand information used by Lillybridge *et al.* (1995) and Kovalchik (in press) in their vegetation classifications of pristine, undisturbed upslope, and riparian forests. Stand structure information may be a surrogate for historical conditions, especially in those forest series with long-duration fire return intervals (e.g., subalpine fir and hemlock-red cedar).

Recent large-scale resource assessments (Eastside Forest Health and the Columbia River Basin) used aerial photography to define historical conditions (Lehmkuhl *et al.* 1994 Hessburg *et al.* 1999). The use of "recent historical" (1940 aerial photographs) provides a glimpse of stand and landscape structure already significantly altered from pre-European settlement conditions; these altered 1940s conditions may not be supported by inherent disturbance regimes.

Scientific studies have described a "limited sample" of historic stand structures for several forest series in Eastern Washington. It may be possible to use "reference stands" from vegetation classification work to get an improved idea of the array of "pristine' conditions that were present prior to European settlement.

Historical Stand Characteristics

In general, the data indicate that significant changes in forest stand and landscape structure have occurred from the 1940s to the present and from pre-1900 to the present. Data indicate that forest stand conditions during early European settlement were less dense (fewer trees and less undergrowth) with larger, more shade-intolerant trees than at present. Some notable stand characteristic data are presented below.

Basal Area

Basal area in Douglas-fir/ponderosa pine series on the East slope of the Cascades has continued a steady increase through 1999 (Ohlson *et al.* 2001 unpublished research).

No historical research information on basal area for mixed conifer or high elevation forest types was found.

Density

Tree densities increased from historical (100 years BP) for most size classes in both wet and dry sites on the east slope of the Washington Cascades while differences in tree densities between wet and dry forest settings declined from historical to the present (landscape homogenization), (Everett *et al.* 1997).

Dry ponderosa pine stand reconstruction studies show a significant increase in stand density from historic conditions (Covington and Moore 1994 Covington and Moore 1992 Arno 1988 Harvey *et al.* 1994). Other data indicate that following increases in stand density prior to 1950, tree densities started to decline in numerous PAGs in Douglas-fir/ponderosa pine series on the east slope of the Cascades after the 1950s (Ohlson *et al.* 2001 unpublished research).

Harrod *et al.* (1997) estimated historical (140 years BP) Douglas-fir tree density at 27 to 68 trees per acre and basal area at 10.3 to 22.3 $feet^2$/acre among PAGs in dry ponderosa pine and Douglas-fir series on the Eastern Cascades of Washington.

No historical research information on stand density for high elevation forest types, such as subalpine fir or Engelmann spruce, was found.

Species Diversity

Recent historical information on stand structure suggests that some watersheds had significantly less shade-tolerant under stories in grand fir, Douglas-fir, lodgepole pine, and ponderosa pine forest series (Lehmkuhl *et al.* 1994, Hessburg *et al.* 1994, Hessburg *et al.* 1999). Selective harvesting of shade-intolerant species in some areas (e.g., the Swauk Late Successional Reserve) has further exacerbated this shift in forest species composition (Camp 1999).

Some shade tolerant species (e.g., true firs and Douglas-fir) have increased in number at a greater rate than other species (e.g., ponderosa pine, western larch, and lodgepole pine).

White pine blister rust has significantly reduced white pine representation and added to the dead wood component in inland forests (Harvey *et al.* 1994). Douglas fir, grand fir, white fir, and western hemlock now occupy stands once dominated by white pine.

Other Stand Characteristics

In dry ponderosa pine forests in Eastern Washington, tree diameter distribution has shifted to smaller trees in current stands (Harrod *et al.* 1999).

Root rot pockets were more isolated historically; therefore, smaller patches of dead and down trees may have been present.

With reduced duration of insect outbreaks, fewer standing dead trees would have been evident in historic stands.

Under historic fire regimes, there would have been a greater proportion of early successional stages and greater landscape heterogeneity (Lehmkuhl *et al.* 1994).

Variability in fire return intervals indicate that there were patches with over story and dense under story, but their proportion of the landscape was much reduced compared to present conditions (Everett *et al.* 1996).

A significant increase in dead wood occurred from 1710 to 1993 (Harvey *et al.* 1994).

No information was evident in the literature for historic height, age, or canopy closure.

Question 7

How did the disturbance patterns in ecological riparian and upland communities differ? Did this vary by stand type, channel morphology, or stream size?

Response

Disturbance Patterns in Riparian Communities

Forest riparian ecosystems are corridors of disturbance that maintain a reservoir of disturbance-oriented plant species within a matrix of less frequently disturbed upland forest. Riparian areas are considered both sensitive to and products of drastic disturbance (Thomas 1979). The combination of disturbance type, frequency, and magnitude produces either a relatively stable distribution of riparian plant communities over time or creates periods when early or late successional species dominate (Agee 1988). Edges of the riparian system are often buffered from upland disturbances such as fire or wind and to some extent from fluvial processes. Thus, a typical forested riparian system will experience fewer disturbances by upland mechanisms and increasing disturbances from fluvial processes. These relationships result in a riparian ecosystem with diverse species composition and structure.

Riparian areas have historically been subject to fire as an important element of their natural ecology (Arno *et al.* 1995). The magnitude and scale of effects are related to the size and severity of the fire, geology, topography, size of stream system, and the amount, magnitude, and timing of post-fire precipitation events (Swanson 1981, Meyer *et al.* 1992, Meyer *et al.* 1995). Areas where a large proportion of the watershed is burned in a single event are most susceptible to erosional processes with major channel alterations occurring in the first ten years after fire (Swanson 1981, McNabb and Swanson 1990, Minshall *et al.* 1997). These intensive fires can result in scouring of stream channels, destruction of riparian vegetation essential for providing stream shade, COD, and wildlife habitat (McGreer 1996). In some instances where COD was burned, severe increases in stream sediment transport and degradation have been documented in the absence of overland flow or debris torrents (Troendel and Bevenger 1993). A significant literature is building with accounts of wildfires that resulted in nearly total destruction of riparian vegetation and desirable stream features (Kaczynski 1994, Helvey 1980). Examples of wildfires that have significantly affected riparian systems are:

The Boise River wildfire complex produced bank scour, release of destabilized channel-stored sediments, and debris torrents that discharged an estimated 750,000 tons of sediment to the North Fork of the Boise River during the first summer rains after the fire. On an annual basis, this represented a sediment delivery of 2,600 tons per square mile, 104 times the long-term pre-fire rate (McGreer 1996). All living riparian vegetation adjacent to hundreds of miles of Boise River tributaries was killed.

In ponderosa pine near Yellowstone National Park, a 450% increase was observed in sediment from alluvial storage and stream banks four years after burning the complete wilderness watershed. Riparian root systems and COD were damaged and near-stream vegetation was removed.

Anderson (1968), studying the Sundance Fire in Idaho, found that the fire destroyed extensive acreage of riparian vegetation next to the Pack River. Apparently, firestorms toppled trees into the river and burned hot enough to remove limbs to the water line (McGreer 1996).

Other types of disturbance, such as wind, are far more difficult to characterize as disturbance aspects in riparian systems. Wind throw potential is dependent upon local topography and forest structures. It is more important on poorly drained soils, wide valleys, and where riparian areas are oriented to the prevailing winds (Agee 1988). Tree tolerance to wind is site specific. Western hemlock is generally prone to wind throw. Western red cedar and Sitka spruce are at times wind-firm, while Douglas-fir is often described as both wind tolerant and wind sensitive. Stand dominants are often more wind-firm than intermediate crown-class trees (Gordon 1973).

Disturbance Patterns in Upland Communities

Differences in moisture condition, topographic position, and plant community type were assumed to increase fire frequency and reduce fire severity in upland versus riparian systems (Heinselman 1973, Agee 1994, Camp *et al.* 1997). For example, a high intensity, stand-replacing fire burned the Little French Creek in the Payette National Forest in Idaho while the lodgepole pine covered upland was unburned except for some downed logs (Williamson 1999). The Entiat Fire of 1970 near Wenatchee, Washington burned the riparian system along the Entiat River completely, leaving scattered western red cedar. Agee (1994) found even-aged lodgepole pine in Eastern Washington riparian areas indicating a stand replacement fire in or near the riparian area while upland Douglas fir and ponderosa pine showed evidence of only frequent, low-intensity burning. In dry forests of the Blue Mountains, frequent fires burned consistently across the landscape through the riparian areas with a low severity fire regime due to gentle topography (Olson 2000). Skinner (1997) suggested that fire return intervals were twice as long in riparian reserves than uplands.

In summer, upland areas will not retain moisture as long as nearby riparian areas, thereby increasing flammability and chances of ignition in upland areas (Olson 2000). The 1994 Tyee fire near Wenatchee, Washington burned greater proportions of crowns in upland areas than in riparian areas (Morse 1999). By contrast, channeling of the wind along headwater riparian areas can produce a chimney effect and intensify fire within the riparian corridor (e.g., 1988 Dinkelman Fire near Wenatchee, Agee 1994).

Some pests seem to prefer upland to riparian areas. Pandora moth has a patchy distribution that may depend on soil conditions; larvae appear to prefer loose upland soils developed from weathered granite or pumice where they can burrow to pupate (Furniss and Corolin 1977). Subsequent invasion of weakened trees from bark beetles sometimes leads to extensive tree mortality (Speer *et al.* 2001).

Variation by Stand Type, Channel Morphology, and Stream Size

Olson (2000) concluded that fire intervals were affected more by forest composition and overall climate than whether the fire occurred in riparian or upland forests. Agee *et al.* (1990) found fire intervals in POME/ABGR communities in low elevation riparian areas to be greater (93 years) than in PIPO/POME and PICO/POME upland communities (52 and 76 years, respectively). Fire was less frequent in lower elevations, bottomlands, and riparian areas (mean return interval greater than150 years compared to 114 years for the rest of the study). Heyerdahl (1997) and then Olson (2000) found that dry forests in the Blue Mountains did not vary in terms of fire recurrence due to aspect or elevation unless the terrain became more dissected as elevation increased, then fire return intervals began to lengthen. With increased elevation, forest composition changed in response to topography and elevation changes in temperature, and insulation was less as riparian valleys became deeper. Olson's (2000) study showed that more mesic conditions result in longer fire return intervals.

The nature and magnitude of disturbance effects can be related to stream order (Agee 1988). In small streams (i.e., 1st order streams), the center of the stream channel zone has a high probability of disturbance by fluvial processes, either directly as the result of a precipitation event or indirectly from upland disturbance that results in sediment input upstream. The channel might be scoured by debris torrents and trees may be buried or undercut. First order streams have relatively small topographic depressions that often provide little additional protection from wind, and the microclimate modification is not much of a buffer against fire. The total probability of disturbance is greater in the riparian system than on either side (Agee 1988). This results in the upland forest dominating the riparian system, with enough core disturbances to maintain small populations of invader-type species such as red alder. After a landscape-level fire that might burn across the riparian system, red alder may persist for several decades until upland Douglas-fir, better adapted to burned sites that do not flood, overtops and eventually shades out the red alder. After crown closure, the vegetation structure may be similar between uplands and the riparian area.

In 3rd to 4th order streams, the probability of fluvial disturbance is high near the core zone and decreases outward. Deeper valley settings are likely to reduce the potential for wind throw, with the exception of the stream edge where undercutting of tree roots may increase wind throw potential. Fire potential decreases significantly closer to the stream channel. A disturbance gradient exists with a definite trough at the edge of the riparian system. Lower disturbance probability, or lower intensity disturbance if one occurs, is associated with dominance by later successional species such as western hemlock (depending on soil moisture) and western red cedar. Structurally, the riparian system may have large standing trees that are wind-firm and when undercut and toppled provide a continuing source of COD. Uplands are unlikely to have trees of the size of the riparian systems unless protected by disturbance for centuries. The riparian core is wide enough and disturbed by fluvial disturbance often enough that invader-type species dominate along the channel.

Riparian systems of large streams are just as subject to disturbance as small streams, however, in large streams a dynamic equilibrium of erosion-deposition may be established that maintains a stable distribution of forest age classes (Agee 1988). However, Olson (2000) found an increase in fire return interval for small streams when compared with associated uplands. Large valley floors are corridors for wind, making wind throw important across the floodplain. Species that are shallow rooted may experience blow down in winter on saturated floodplain soils. Typically, fire is not a significant factor across large floodplains. Fluvial processes dominate the disturbance pattern and invader-type species, favored by disturbance, dominate the riparian plant community. On larger streams, fluvial disturbances are concentrated near the channel. Deep alluvial depositions in floodplains can alter the available water on a site. Rapid accumulations of organic materials can occur on wet meadows and overflow channels, altering the water holding capacity and nutrient availability of soil (Hansen *et al.* 1995).

Question 8

What is the typical width of the area containing ecological riparian communities? Does this vary by channel morphology, stream size, valley characteristics, climatologically patterns, or other factors?

Response

Width of Ecological Riparian Communities

No typical width of the area containing ecological riparian communities was identified. Pearson and Manuwal (2001) suggest that the minimum riparian width necessary for supporting an undisturbed bird community differs by region, affected by local species composition and ecological conditions.

The degree of riparian community development is related to the size of the associated river or stream system (Brinson *et al.* 1981, Leopold *et al.* 1964, RHTC 1985). Larger streams/rivers typically have well-developed, complex floodplains, with patches of standing open water in cutoff oxbows with a variety of plant communities, and deep, moist soils. Larger streams have less stream gradient, coarse organic debris tends to be more randomly oriented and is less important geomorphically (Swanson *et al.* 1981b), and the riparian zone tends to be much wider (Agee 1988). Generally, "the river dominates the forest rather that the forest dominating the stream" (Agee 1988:35). Large valley systems influence the distribution of stream power into multiple channels in wider stream reaches. These larger valley systems typically have wide, well developed riparian communities (Bendix 1994). Headwater streams have high topographic relief and restrictive substrate conditions. In these streams, riparian vegetation may be absent thus restricting riparian wildlife habitat to the wetted portion of the riparian ecosystem. Even in areas of low relief, small streams will produce smaller riparian communities because smaller streams carry less water resulting in less influence on the area adjacent to the stream (Bilby 1988). Small streams tend to be dominated by the terrestrial system. The influence of the terrestrial system decreases with stream size since progressively larger pieces of wood are needed to form sediment terraces in larger channels (Bilby and Ward 1987). Fewer woody accumulations are found in larger systems and the impact of this material on stream structure is concomitantly lessened (Bilby and Ward 1987).

The disturbance history (type, frequency, and magnitude) and valley geomorphic features supply the energy and material to create riparian landforms (Swanson *et al.* 1988, Wissmar and Swanson 1990) that define the spatial pattern, type, and successional development of riparian ecosystems (Rot 1995). Geomorphically, valley width influences the distribution of stream power and can constrain the width of both channel and riparian community. Riverine riparian ecosystems have evolved in a highly dynamic, unstable environment where devastation and destruction are normal components (Hall 1988). Large organic debris such as tree boles, root wads, and large branches retain sediment and gravels both affecting the shape of the channel and storing up to 49% of total sediment in seven Idaho streams (Megahan 1982). In stream systems bordered by steep terrain, these sediment terraces formed behind woody debris serve to increase the size of the riparian area by forming wide, flat areas near the stream channel (Bilby 1988).

The physical structure of the riparian ecosystem can be dramatically influenced by infrequent catastrophic events. High discharge accompanied by the battering action of floating debris or chunks of ice can alter the size of the riparian system by damaging or uprooting vegetation. Stream bank erosion can undermine vegetation at the edge of the channel and cause it to collapse into the stream. The severity of these effects depends on riparian area topography, channel morphology, and the flood magnitude. Hydrologic regime alterations of large river systems (e.g., dams, irrigation diversions, dikes, and flow augmentation) have the potential to alter the size and characteristics of riparian communities. The release of large volumes of water at times of low flow can alter the composition of riparian communities. By contrast, flow control can eliminate or reduce inundation, with the result that soil conditions and water availability are altered and vegetation may become more like adjacent uplands (Ohmart *et al.* 1977). Soil fertility might be reduced by the elimination of periodic flooding with the associated deposition of fresh sediment (Bilby 1988).

Question 9

What are the succession variables and timeframes for large tree regeneration following stand replacement fires (by stand type)?

Response

Large Tree Regeneration

Information on tree species growth rates relative to site quality is well established in the literature (Site Index Curves). Also, information is available on relative growth rates of different species on the same site. Combining this information with a knowledge of inherent disturbance regimes (Question 1) and species avoidance, resistance, and resilience (Question 3) provides an estimate of the potential for large trees, the required timeframes, and the species that will be producing large trees most rapidly within a PAG. Silva cultural and prescribed fire treatments are available to maintain thrifty stands and sufficient growing space for rapid large tree regeneration.

Succession Variables

Data indicate that both fire and insect infestation can redirect succession following stand replacement fires. Reoccurring fire can restart large tree regeneration or redirect succession to grass or shrub types of communities for extended periods. Stand development and successional models for forest series in Eastern Washington indicate the multiple fire opportunities that revert developing stands back to a shrub/forb/grass stage (Wischofske and Anderson 1983). Insects that prefer young seedlings or saplings as hosts (e.g., fir engraver, Douglas-fir engraver, and pine engraver) (Hessburg *et al.* 1994), could also affect the regeneration process. Mountain pine beetle attacking stressed lodgepole pine stands, when stem diameter exceeds 8 inches would affect the capability of this species to develop a large tree component.

Timeframe Required for Large Tree Regeneration

For those areas where stand replacement has been complete, the regeneration of large trees is dependent upon the time required for species to re-establish at the site and the time required for the species to grow to a large size. The tree specie that establishes rapidly following fire, has the fastest growing rate, occurs on the most productive sites, and for which development is not redirected by disturbance should provide large trees in the shortest period of time.

Some tree species are able to establish more rapidly than others following a stand replacement fire. The serotinous cones of lodgepole pine provide a ready post-fire seed source. Other species may have to depend upon seed immigration from adjacent unburned areas to re-establish. The re-establishment of aspen by suckering would hasten the process of achieving large trees of this species.

Site quality also plays a significant role in the time required to generate large trees. Site index values use tree heights achieved at specific timeframes, usually 50 and 100 years for conifer species, to estimate site productivity (Cochran 1979). Those sites with the greatest productivity will produce large trees faster than low productivity sites. A comparison of site index curves among various conifer species for an area would give an estimate of which species grow faster than others. For each forest series and PAG, one species may have a better growth rate than another. Lillybridge *et al.* (1995) developed site index values for the tree species growing together within the various plant associations on the Wenatchee National Forest.

Everett *et al.* 1999 presented an example of regeneration of large trees following wildfires for a chronosequence of burns in Eastern Washington. Although lodgepole pine had the fastest establishment rate (10 years), its slower growth rate and poor site quality meant that it did not produce a tree 23-41 cm diameter breast height (dbh) for 54 years, and it did not produce trees greater than 41 cm dbh on these sites. Douglas-fir took longer to become established on the sites following fire, but produced large trees in a shorter timeframe than ponderosa pine.

Excessive regeneration and the absence of disturbance during stand initiation and stem exclusion phases may actually limit the rate of large tree regeneration. Stand stagnation because of limited growing space lengthens the time required to produce large trees. Thinning by fire, insects, pathogens or mechanical means frees up site resources for additional tree growth (Question 11). Stands that are maintained below the maximum stand density index (SDI) (Cochran *et al.* 1995) will have the greatest growth potential for large trees.

Question 10

What is the typical tree survival rate following a stand replacing fire or under story burn? How much standing wood (live and dead) remains after fires of varying intensity? How much wood typically remains on the ground?

Response

Tree Survival Rates

No document that defines the typical survival rate following a stand replacement or under story fire was identified. Tree mortality is a species, stand, and landscape specific phenomenon that changes with amplitude of fire disturbance applied. Rather than searching for a mean mortality estimate with limited applicability, a more fruitful approach would be to use current predictive models, e, g, FIRESUM, validated on forest stands similar to those of interest to this study (Tholen 1999).

There is no "typical' amount of burned and unburned; post-fire landscape is unique to each site. Tree survival following fire is dependent upon the magnitude of the disturbance (fire intensity), tree resistance, avoidance, and post-fire insect mortality. Question 3 addressed tree resistance and avoidance in detail. In summary, those tree species that grow on "safe" sites that do not burn readily (e.g., talus slopes and headwalls) (Camp 1996), avoid fire effects. Species growing where fuel loading is light or moist (e.g., western red cedar) have reduced fire intensity applied. The fire connectivity between upslope and riparian forests is such that riparian areas have the same heterogeneity in burn conditions as upslope forests (Scher 1991).

Surface Fire Mortality

Tree mortality is a function of several factors: percent of live crown scorched or killed, cambial damage in stems and roots, duration of lethal heat, and critical time for crown kill (Peterson and Ryan 1986). The relationship between fire damage and tree mortality has been described for ponderosa pine (Dieterich 1979) and Douglas-fir (Bevins 1980).

Swezy and Agee (1991) used a model developed by Peterson and Ryan (1986) to estimate the sensitivity of different tree species to scorch height and fuel bed properties, and then to estimate probable mortality rates for each species in a Douglas-fir stand. Mortality was estimated at 100% for subalpine fir, grand fir, Engelmann spruce, and lodgepole pine. No mortality was estimated for ponderosa pine or western larch. Young ponderosa pine may survive up to 75% crown scorch with only 25% mortality, but old trees may show poor survival (Swezy and Agee 1991). The predictions from the model are in general agreement with estimates of individual tree fire resistance.

Stand Replacement Fires

By definition, a stand replacement event reduces the basal area of the site by 70% or more (Agee 1994). The percent mortality in stand replacement events varies based on the heterogeneity of the forest landscape and the burning conditions (Agee 1993). Although differences in stand structure and topography create heterogeneous post-fire landscapes (Tholen 1999, Scher 1991), severe firestorms may ignore vegetation and topographic differences with more uniform mortality over extended areas (Swanson 1988).

Quantity of Standing Wood Following a Fire

The quantity of standing wood following a fire is dependent upon fire severity, quantity of biomass present at the time of the fire, site potential (stand and topographic characteristics), and species resistance to fire. For example, it is estimated that little standing dead wood is likely to exist after a low severity fire in dry ponderosa pine/Douglas-fir forests (Mutch 1970), while low severity fires in stands of white fir, hemlock, or red cedar that are sensitive to root charring (Starker 1934) may create a significant standing dead wood component.

Low intensity fires are increasingly rare because of excessive fuel loads (increased tree density and mortality) in all forest types. The probability of high intensity fires has increased for areas that have inherent low severity or mixed fire severity regimes. Therefore, the proportion of dead to live tree biomass following fire should be increasing. The proportion of dead wood to live wood increases with fire severity.

Quantity of On-Ground Wood Following a Fire

Snag fall down rates are species, diameter, and site specific (Dahms 1949, Raphael and Morrison 1987). Ohlson (personal communication) found that snag fall down rates (percent down per unit time) for Douglas-fir decrease with tree diameter. For large ponderosa pine and Douglas-fir snags, the tops fall as well (Everett *et al.*1999). Data indicate that small diameter Douglas-fir and ponderosa pine fall more readily than those of subalpine fir, lodgepole pine, or Engelmann spruce (Everett *et al.*1999). Therefore, post fire-log fuel loadings should increase rapidly where these species predominate (Everett *et al.*1999).

Question 11

What are the disease and drought (climatic variables) influences in thinning thick stands?

Response

Thinning in Riparian Forests

The *CTC* project team found no literature specific to the influences of drought and pest thinning in dense riparian forest stands in Eastern Washington. Since riparian and uplands share a majority of the same plant associations, extrapolation of upslope research into riparian areas may be valid, with some caveats. Soil moisture stress would likely be less within riparian areas. However, with the potential for increased biomass (untested assumption) and less drought tolerant species, drought effects may be equal to those upslope. If the riparian areas have the capacity to grow forests faster because of elevated water availability, then critical SDI values (upper stocking density) may be reached faster and require stocking control sooner than in adjacent upslope stands

Following is a discussion of natural and silvacultural thinning of thick stands and observed insect, disease, and other disturbance effects and risks associated with thinning of thick stands.

Natural Thinning of Thick Stands

Thick stands develop because natural regeneration and reforestation practices generally provide more seedlings per area than can be supported as trees grow and completely occupy the site. Thick stands progress through a number of developmental stages. Stem exclusion is the developmental stage where competition among existing trees prevents the establishment of more seedlings (Oliver and Larson, 1990). Seedlings and saplings usually die first and can succumb under moderate drought conditions (Joyce *et al.* 2001). As stress increases, the less vigorous trees may die and remaining trees compete for their vacated growing space. This self-thinning process results in a reduced number of larger trees with increased vigor to resist drought and ward off insect and pathogen attack occupying the site. This natural thinning process can be repeated if shade tolerant under story eventually overtops shade intolerant species (stem re-initiation phase, Oliver and Larson, 1990).

The timing for the stem exclusion phase and subsequent self-thinning varies by forest type, stocking levels, site quality, and environmental conditions (Oliver and Larson 1990). The stem exclusion phase is a time of stand stress, where weak trees are susceptible to insect and pathogen attack. Fir engraver attack on grand fir is prolonged on sites subject to extended drought (Adams 1994). Douglas-fir may be predisposed to root rots and bark beetle infestations because of reduced vigor due to competition for light (Adams 1994).

Silvacultural Thinning Techniques

Foresters have developed thinning techniques. Five general thinning methods are recognized to redistribute growth potential and restructure stands (Graham *et al.* 1999):

Low, or thinning from below: removal of suppressed and intermediate trees. Thinning from below most closely mimics tree mortality from surface fires or inter-tree competition during stem exclusion.

Crown, or thinning from above: removal of dominates and co-dominates to favor selected species (Nyland 1996 in Graham *et al.* 1995). Crown thinning maintains vertical structure and can increase growth of remaining dominants for wood production or wildlife habitat.

Selection, or diameter-limit thinning: removal of dominates to favor smaller diameter trees. Selection thinning removes dominant trees and perpetuates insect or pathogen problems associated with the under story species.

Mechanical thinning: removal of trees based on spatial location. Mechanical thinning is applicable in plantations where desired tree spacing is maintained for maximum growth during stand development.

Free thinning: selection of specific trees for retention regardless of position in stand structure. Free thinning is designed to release specific trees within a stand and provides maximum flexibility in designing future stand structure.

Silvacultural Thinning of Thick Stands

Thinning is a process to reduce the stocking level of forest stands, with the goal of creating fewer, more vigorous trees that grow faster and are more resistant to insects, pathogens, and drought. Eastern Washington forest stands are thinned to:

Maintain desired species
Better growth of remaining tress by freeing up resources
Increase resistance to insects and pathogens
Reduce continuity in host species for pathogens
Reduce fire hazard

Thinning and resultant tree vigor and growth may reduce the hazard to drought, insect attack, pathogen infestation, and reduce fire hazard by removing ladder fuels and elevating the crown.

In almost every case, reducing stand density, especially if the host conifers are discriminated against mitigates insect and pathogen infestations. With defoliating insects, it's important to reduce both horizontal and vertical stand density. With bark beetles, basal area is the key to hazard reduction and with dwarf mistletoe host-specific thinning should be used to reduce the stand dwarf mistletoe rating. (P. Flanagan personal communication.

Some observed benefits of thinning to specific tree species include:

Both ponderosa and lodgepole pine stands avoid mortality from bark beetle attacks (Cole and McGregoor 1988).

Western larch stands are able to have sufficient height growth to exceed the upward advance of dwarf mistletoe (Wicker and Hawksworth 1991).

Western larch stands benefit from reduced budworm damage because larger diameter shoots are severed less often and vigorous trees are better able to recuperate rapidly (Schmidt and Fellin 1973, Schmidt *et al.* 1976).

Cochran *et al.* (1994) and Schmitt (1999 unpublished) provide information on desired stocking levels and the benefits associated with those stocking levels in reducing forest health problems.

Application of Thinning Techniques in Thick Stands

Stocking guides use basal area to evaluate growing space, however basal area may not be the most useful measure for this purpose. Cochran *et al.* (1994) suggested stocking levels for forest stands in Eastern Washington and Oregon using a SDI that is independent of site quality and stand age. The goal is to define an upper density limit at which a suppressed class of tree begins to develop and manage the stand so that this density does not occur (approximately 75% of SDI). The SDI threshold for mountain pine beetle mortality of lodgepole pine appears to be around 165-170 (Peterson and Hibbs 1989, Mitchell *et al.* 1983). SDI values as presented by Cochran *et al.* (1994) are for specific plant associations. SDI values vary by plant association. An alternate approach developed by Perry (1995), called the "self-thinning rule," uses average plant size density and maximum size density to guide thinning.

Classification schemes developed by entomologists and pathologists may be useful in identifying forest problem areas and setting priorities for preventive activities such as thinning to reduce drought, insect, and pathogen hazard. Entomologists and pathologists have developed various hazard and risk rating systems in an attempt to evaluate and possibly control insect outbreaks and pathogen epidemics (Jurgensen *et al.* 1994). For example, Amman *et al.* (1977), Mahoney, (1977), and Schenk *et al.* (1980) developed various classifications based on different aspects of beetle-host-site interactions. Variables used include elevation, latitude, average stand age, average dbh, resistance to infestation, and pathogen infection.

Effectiveness of Silvacultural Thinning of Thick Stands

Thinning stands may or may not alleviate drought stress and subsequent insect, pathogen, or fire hazard. For thinning to be effective it must remove or ameliorate the stand structural component and or species associated with the hazard. Is the hazard associated with the under story trees? These are suppressed trees with crowns below the dominant tree crown or intermediate trees with crowns into but shaded by the dominant/co-dominate trees (Oliver and Larson 1990). For example, with an under story of Douglas-fir and grand fir and ponderosa pine dominants, the fir confer a higher pathogen and fire hazard to the stand. Thinning from below (removal of the under story) is appropriate, as it would reduce drought stress, ladder fuels, and continuity in host species for pathogens and insects of the fir species. Alternatively, is the hazard associated with the co-dominate and dominate trees in the over story, as could occur with mistletoe infestation? Thinning from below in stands where the over story has a high level of mistletoe infestation would only pass the mistletoe infestation to the post-thinned under story component (Hessburg *et al.* 1994). Thinning within the mixed conifer type requires careful planning. Thinning from above in dense stands of Douglas-fir and grand fir only perpetuates the shade tolerant fir and host continuity for pathogens and insects with elevated fire hazard from low crown base height and high crown bulk densities (Brown 1978). Graham *et al.* (1995:22) concluded that "thinning from below and possibly free thinning can most effectively alter fire behavior by reducing crown bulk density, increasing crown base height, and changing species compositions to lighter crowned and fire-adapted species." Stocking control can prevent suppression-related mortality, reduce the severity of dwarf mistletoe infections, and lower mortality caused by mountain pine beetles (Cochran *et al.* 1994).

Thinning is not without risks. Fuels increase, wind speed increases, and fuels dry out more rapidly from canopy openings (Rothermel 1983). Thinning may increase blow down problems in those stands with species susceptible to windfall, such as lodgepole pine (Adam 1994). Stumps left following thinning may also increase disease infestations if not managed carefully (P. Flanagan personal communication). Thinning in riparian forests may pose additional risks. "Thinning in moist forests should be approached carefully. Any approach to reduce crown fire potential and improve health should be tied to the active restoration of early seral species" (Graham *et al.* 1999:20).

Question 12

Are there other ecological features, such as exotic plants and predation, which may direct an upland or riparian community into a new path of succession?

Response

Redirection of Riparian and Upland Communities by Ecological Features

Animals and exotic plants through predation, competition for resources, and alteration of habitat affect riparian and upland communities. These affects may be of sufficient magnitude to redirect successional paths.

Influence of Animals on Forest Community Succession

Animals can redirect forest succession through predation and alteration of habitat. Predation, in the form of herbivory, directly influences mortality and recruitment in forest communities. If herbivory is excessive, vegetation can be degraded, altered, or eliminated (Oakley et al 1985). Herbivory also has indirect effects (e.g., increases in temperature and available light at the forest floor by defoliation that promotes under story growth, seedlings, and herbaceous plants). Site productivity, slope, elevation, burning, and herbicide treatments (Boyd 1985) all have the potential to affect the intensity and frequency of predation. Both wild and domestic animals alter forest habitat. A significant literature has built up surrounding animal damage research in the Pacific Northwest (*sensu* Crouch 1987). Data indicate that ungulates, beavers, and other mammals can have significant affects on forest communities.

Ungulates

Impacts by large ungulates can be categorized into five areas: 1) soil compaction that might increase overland flow and decrease water availability to plants, 2) plant removal that lowers plant vigor and changes competitive interactions among other plant species, 3) physical damage to vegetation by rubbing, trampling, and browsing, 4) changes in fluvial processes produced by herbage removal, and 5) physical stream bank changes which may lower water tables and/or cause a decline in invasion sites for riparian plant establishment (Kauffman 1988). Excessive browsing of young trees by ungulates reduces the reproduction of riparian trees (Glinski 1977, Kauffman *et al.* 1983). Without recruitment of young trees into the population, unstable age structures might result and these populations may eventually be eliminated. Moderate, prolonged grazing or browsing pressures will shift the normal primary succession sequence of hardwood-conifer back to a disturbance-caused cottonwood condition. Severe, prolonged grazing and browsing pressures may eliminate all conifer and deciduous seedlings and may eliminate under story shrubs as well (Hansen *et al.* 1995). In this situation, the over story cottonwood continues to mature and the site becomes open with an herbaceous under story. Eventually the stand becomes decadent with widely spaced, dying cottonwoods. The site then becomes so open and dry that it is subject to invasion by nearby upland plant species. Coarse organic debris inputs will be reduced with a concomitant alteration of hydrologic properties. In turn, this hydrologic change will further influence successional processes, changing the composition and structure of riparian vegetation.

Beavers

Beavers are obligate riparian residents that can change site characteristics by building dams and alter species composition (and thereby succession) by over-utilizing food supplies. Mass starvation may result from a decline of staple food supplies, leading to a new successional trajectory away from woody vegetation such as alder and willow and creating a sedge-grass meadow (Hall 1988). Beaver dams, in series, can significantly slow water flow and raise stream base levels, leading to higher water tables. These high water tables might influence the survivability of water-tolerant but not obligate plants. These plants could die and/or fail to reproduce, eventually being eliminated from the riparian community. For example, a conifer stand growing on a first terrace would be killed by anoxia or disease and be replaced by sedges due to beaver dam flooding. A change in the base level of a stream can alter the competitive ability of plants, resulting in major shifts of species dominance and composition. Long-term persistence of these dams creates new substrates that restart or redirect successional trajectories.

Other Mammals

Wild and domestic mammals adversely affect ponderosa pine by feeding on and injuring and killing seedlings saplings, and small trees. Injury from rubbing, trampling, and burrowing adds to the damage problem. Animal damage has the greatest impact on regeneration, particularly on sites where habitat favors high animal populations or high use by wildlife (Evans). At the patch scale, pocket gophers (northern and Mozama) can limit successful regeneration of ponderosa pine by clipping and killing seedlings as well as trees 15 to 20 years old. The magnitude and duration of this interaction is a function of both disturbance history and plant community succession. In severe disturbances (Green *et al.* 1987), pocket gopher density can reach more than 6000 mounds per acre.

Influence of Exotic Plants on Forest Community Succession

Ecologically, a weed is defined as an exotic colonizer or a pioneer species of open or disturbed habitats, frequently from anthropogenic activities (Taylor 1990). Weeds are often tenacious and can displace native flora and fauna. Much effort has gone into managing competitive vegetation in managed forests (Baumgartner *et al.* 1986). A characteristic feature of open and disturbed lands is the invasion and establishment of early successional or seral plant species. Many of these early seral species are weeds, particularly in human disturbed areas such as roads and areas where logging, livestock grazing, and recreation are present. Weeds are successful because of a combination of adaptive morphological and physiological characteristics (Harrod *et al.* 1993). During the 1970's when timber management in Eastern Washington shifted to intensive, even-aged management, more roads and large openings were created that provided light and delivery systems for weeds. These changes also resulted in more foraging and/or loitering sites for large herbivores.

Neuenschwander *et al.* (1986) developed a conceptual model of early succession after disturbance that incorporated the critical influences affecting the successional response for "key" competitor species that may be adaptable to invasion and redirection of succession by an exotic colonizer. Environmental conditions, existing vegetation, life history, and ecology of the species available for colonization, kind and severity of the disturbance, and chance were identified as the major influences on successional patterns following disturbance. Critical successional processes were the determination of the initial flora, establishment, growth, and biotic interactions.

Effect of Exotic Plants in Riparian Communities

Streams often provide a vehicle for dissemination of both terrestrial and riparian plant seeds, further influencing the composition and distribution of streamside vegetation (Daubenmire 1968). Although noxious weeds such as knapweed (*Centaurea spp.)* and leafy spurge *(Euphorbia spp.)* along a stream bank might help to trap and provide deep soil-binding properties necessary for maintaining the stream banks, their presence would be a management concern and indicate poor health (Hansen *et al.* 1995). Riparian communities are vulnerable to invasion by exotic weeds. Regular floods decrease the strength of competitive interactions and periodically return parts of riparian systems to early successional stages, providing a diversity of microhabitats on a shifting mosaic of landforms (Pollock *et al.* 1998, Gregory *et al.* 1991, Wissmar and Swanson 1990). These factors promote high plant species richness but may also increase susceptibility to invasion by weeds (Pysek and Prach 1994). Anthropogenic disturbance frequently introduces weeds to riparian communities and natural disturbances can facilitate their spread throughout the stream network. The availability of water and the potential for weed dispersal throughout the network may work synergistically to promote weed invasion (Hood and Naiman 2000). Provided that riparian communities have the expectation of weed invasion and the dramatic influences of exotic species on ecosystem processes (Ramakrishnan and Vitousek 1989), there is cause for concern about the extent and effects of weed invasions on riparian systems.

Hood and Naiman (2000) have assigned the potential for weed invasion to two separate riparian landforms: the macro-channel floor, frequently disturbed by seasonal flooding, alluvial sediment redistribution, and browsing by animals, and the macro-channel bank, with steeper slopes, rarely disturbed by floods, containing no alluvium, and browsed by animals. Plant species on the macro-channel floor and low on the bank are exclusively riparian, whereas upland species are included high on the bank. In a comparison of two Pacific Northwest rivers, one South African river, and one French river, Hood and Naiman found exotic species to range from 5-11% on the macro-channel banks and 20-30% on the macro-channel floors. This suggests that frequently flooded active channel floors are more vulnerable to weed invasion than the more stable and steeper banks and that on the average, the macro-channel floor is three times more invasive than the macro-channel bank.

That riparian systems are the principal mechanism by which exotic plants can invade sites with little anthropogenic disturbance has been shown in arid and semiarid game preserves of South Africa, national parks in Utah, and in Mediterranean climates of France and California. The vulnerability of riparian systems to invasion by weeds is similar in a wide variety of rivers (Hood and Naiman 2000). Mechanisms that promote weed invasion in riparian systems have associated steps in the invasion process: 1) the availability of stream water for the transport of propagules that promotes dispersal to a site appropriate for germination, 2) the frequency and intensity of flooding that provides for germination and establishment with reduced competition, and 3) water availability from the water table that insures rapid growth and reproduction success. Disturbance, flooding in particular, has been correlated with successful weed invasion. Successionally, young areas that experience frequent flooding have a higher percentage (Planty-Tabacchi *et al.* 1996) or number (DeFerrari and Naiman 1994) of weeds.

Notable Exotic Plant Species in Eastern Washington

Knapweeds are one of the most important forest weeds in Eastern Washington. Twelve out of fourteen introduced species of the genus *Centaurea* have demonstrated adaptability to habitats in Washington (Roche and Talbot 1986). Diffuse and spotted knapweeds are the most serious infestations on Eastern Washington forestlands, with diffuse knapweed demonstrating the greater ecological amplitude. Roche (1988:123) stated, "those Eastern Washington forestlands that are not farmed or managed are likely to be diffuse knapweed dominated during some part of their early- to mid-seral stages."

Russian olive (*Elaeagnus angustifolia),* a tree native to southern Europe and western Asia, was introduced into North America during colonial times (Elias 1980). Russian olive was planted in shelterbelts due to its dense growth form, hardiness, and adaptability to a wide range of soil and moisture conditions (Olson and Knopf 1986) and its use for ornamental and wildlife plantings, erosion control, and highway beautification. Russian olive is naturalized throughout the 17 western states. A review of the literature indicates that the naturalization process is rapidly increasing with substantial impacts to floodplain forests (Hansen *et al.* 1995). It has the potential to redirect succession by complete replacement of native riparian plants. This replacement of native species by dense thickets of Russian olive can result in a 30% reduction of breeding bird species (Knopf 1991). These dense stands and low palatability limit access by browsing animals, reducing most forms of predation. Russian olive, spread by birds and small mammals, favors establishment on soils with spring moisture and slight alkalinity. Once established, it is difficult to control and nearly impossible to eradicate. It has become a management concern for many riparian areas throughout the Pacific Northwest (e.g., Barker Ranch, Wetland Enhancement Program, and Yakima River, Washington).

Question 13

Some portion of the areas affected by stand replacing fires will reburn before the forest is re-established. What portions of those areas are expected to be affected by the reburn? What is the effect of the reburn on forest recovery? How much wood typically remains standing or on the ground following the reburn? Does this vary between upland and ecological riparian communities?

Response

Forest Reburn Events

Reburn events following stand replacement fires are surface fires by definition as tree crowns are no longer present. For a reburn to occur, there must be sufficient fuels to carry the fire. Since the first fire (prior to the reburn) removed the tree crowns, surface fuels such as deadwood, understory biomass, and tree seedling/juvenile biomass are required for a reburn to occur. Therefore, the second fire or "reburn" will be a surface fire and its extent will be defined by continuity in surface fuels, topographic effects, and climatic conditions. Reburns should emulate historic surface fires in extent, and perhaps frequency, for forest types in the mixed and low severity fire regimes, with the caveat that the additional dead and down materials in the form of fallen snags from the first burn may increase the rate of fire spread during the reburn. Following a reburn, a forest is considered re-established when the tree component of the forest is dominant and is suppressing understory shrubs and grasses.

Occurrence of Reburn

Numerous authors have assessed the reoccurrence of fires over time for dry grand fir, Douglas-fir, and ponderosa pine forest types in Eastern Washington and Oregon (Wright 1996, Ohlson 2000, Everett *et al.* 2000). This data indicates that fires sequentially reburn portions of previous fires and sometimes reburn the entire area affected by the first fire prior to re-establishment of the forest (Schellhaas *et al.* 2000). The frequency of these fires and their extent suggest that there is a high potential for consecutive reburns. The frequency, extent, and severity of reburns should be dependent upon the characteristics of surface fuels and the fire regime of the area.

No specific information on the proportion of a stand replacement fire that reburned prior to tree establishment was identified. Stand replacing fires would likely remove much of the fire scar record and trees that would be capable of recording the reburn fire date. Given the extended fire return intervals (greater than 100 years) for some forests types (e.g., subalpine fir, Pacific silver fir, mountain hemlock, western hemlock, and western red cedar) reburns prior to forest re-establishment are not likely to be a significant issue in these forest types. Reburns are more likely to occur prior to stand establishment in those forest types where the fire return interval is shorter (e.g., dry grand fir, lodgepole pine, Douglas-fir, and ponderosa pine). However, no literature was identified that estimated the proportion of stand replacement fire areas that reburn prior to tree establishment for any forest series.

Effect of Reburn Events

Only one study was identified that was conducted specifically to define the effects of reburn on forest structure. That research was conducted at the Wenatchee Forestry Sciences Laboratory and remains unpublished. The *CTC* project team was not able to obtain a copy of that research for this report, but in summary: reburns following a stand replacement fire: 1) reduce the amounts of dead and down materials created by the previous fire event, 2) reduce the post-fire understory response, and 3) result in an increase in weedy (or invasive) species (J. Landsburg personal communication).

Other references indicate that reburns have additional effects on forest stands. Agee (1993) reported the loss of understory species following two fires in rapid succession. He suggested that the loss of species resulted from depletion of remnant plants and soil seed reserves. For example, in the grand fir series, if a stand of lodgepole pine, Douglas-fir, and grand fir has a second fire within 20 years of a stand replacement event the stand will lose its pine component through mortality of the pine and the loss of the lodgepole pine seed source (Cattelino *et al.* 1979).

Remaining On-Ground Wood Following a Reburn

The *CTC* project team found no literature specific to snag- or log-loading following re-burn of sites with a previous stand replacement fire. Extrapolating from existing literature, log biomass may be estimated or modeled for stands following reburn. Given that reburns are surface fires, these events are unlikely to cause significant damage to standing snags. Therefore, only the consumption of log biomass by the reburn need be considered. Of primary concern are the small diameter logs currently on the ground and the small diameter snags that will become logs prior to the reburn event. Conversion of small snags to logs is anticipated to be more dependent upon decay than reburn effects. Large logs are anticipated to be more resistant to surface fires than small diameter logs during the interval between the first fire and the reburn. Information is available on snag fall down rates by species and stem size (Morrison and Raphael 1993, Everett *et al.* 1999, Harrod *et al.* 2000). The number or volume of small diameter (less than 23 cm dbh) snags that will fall within the median fire frequency interval for the site can be estimated. Adding current small logs to small diameter snags that will become logs prior to fire provides an estimate of potential reburn effects on the dead and down component of the stand.

If reburns are surface fires and fuel moisture is higher in riparian areas than upslope, discontinuous fires within the riparian areas are anticipated. Based on this assumption, it is feasible that riparian areas could support more logs than in more xeric upland forest sites. However, no information was available to confirm this assumption.

Question 14

How are disease and insect infestations affected by stand density (by stand type)? How do current disease and insect infestation rates compare with historical rates? Did this vary between upland and ecological riparian communities?

Response

Availability of Information

A wealth of information is available on the inherent insect and disease disturbance regimes associated with each Eastern Washington forest series. In some cases, information is specific to stand development stages for PAGs. Little information is available on historical disease and infestation rates in Eastern Washington forests. Estimated rates are largely inferred from information on historic stand characteristics. There appears to be very little information on the differences between pathogen and insect disturbance regimes between riparian and upland forests. Contacts with professions in the field did not reveal additional published information on this subject (C. Schmitt personal communication, D. Scott, personal communication).

Effect of Stand Density on Disease and Insect Infestations

Question 11 includes a discussion of the probability for increased disease, insect, and drought disturbances with increasing stand density. Disease and insect infestations are related to stand density, but species resistance increases with improved site quality. Successional stages in stand development may increase the abundance and continuity of host species and create favorable insect habitat (Hessburg *et al.* 1999). Associated with this increased opportunity for insect outbreak is the associated decline in individual tree and forest stand capability to resist attack because of tree density induced water or nutrient stress (Stoszek 1988).

Joyce *et al.* (2001) stated that, "Forests tend to grow to maximum leaf area that uses nearly all available growing-season soil water." Heavily stocked stands where all growing space is occupied have less buffering capacity to withstand drought impacts than more open stands where all resources are not being currently utilized. Consequently, a low precipitation year can create stress within forest stands. Low precipitation years have been associated with insect outbreaks (Thompson and Shrimpton 1983) and may increase the risk of insect, pathogen, and fire disturbance in stands (McCullough *et al.* 1998). It may be inferred that competition for water within dense stands, even under more moderate precipitation conditions, may simulate drought stress thus increasing the risk of pathogen and insect infestation.

Today, the ten-fold increase in basal area of the Douglas-fir understory produces an evident stress on ponderosa pine, western larch, and Douglas-fir. Foliage of both ponderosa pine and western larch crowns are noticeably thin and sparse. The Douglas-fir understory is heavily infected with dwarf mistletoe and radial growth is very slow. Some post 1919 understory Douglas fir and western larch have advanced bole rot. Average radial growth in the last 20 years on ponderosa pine averaged 0.4 inches. All of these symptoms indicate severe growth stress related to overstocking (Arno 1997).

General trends have been for increased impacts from insects and pathogens as the amount of biomass cycled by fires has declined through fire suppression (Hessburg *et al.* 1994, Hessburg *et al.*1999). Landscape level assessments (Eastside Forest Health Assessment, Lehmkuhl *et al.* 1994) and the Columbia River Basin Assessment (Hessburg *et al* 1999) have shown that differences in historical and current insect and pathogen levels are sub-watershed specific. Portions of a watershed or ERU may have elevated insect pests while other portions of the watershed have seen the pest hazard decline. When a portion of a watershed is harvested or burned, one set of insects and pathogens may decline while another set increases. Swetnam *et al.* (1995) demonstrated that spruce budworm outbreaks have been a part of Eastern Washington forest ecology for centuries, but now those outbreaks are more frequent and severe.

Specific insect species that benefit from increasing tree density include:

Western pine-shoot borer

> Infestation rates of western pine-shoot borer in ponderosa pine, and lodgepole pine were found to be positively related to stand density (basal area) and growth increments, but negatively related to elevation (Stoszek, 1988). Low soil moisture holding capacity and low nutrient availability is associated with increased infestation levels.

Douglas fir tussock moth

> Outbreaks of Douglas-fir tussock moth in Douglas-fir and true firs are associated with drought conditions (Brookes *et al.* 1978 in Stoszek 1988). In the Clearwater National Forest in Idaho, defoliation from Douglas-fir tussock moth increased with elevation, stand age, and stocking levels within a site productivity class. Defoliation increased as the proportion of grand fir in the stand increased and the soil moisture holding capacity of the soil declined.

Western spruce budworm

> Defoliation of western spruce budworm on Douglas-fir, Engelmann spruce and western larch was heaviest in fast-growing (pole-size) stands in early successional development and declined with increasing stand age (Stoszek, 1988). Infestation rates increased with stand density.

Disease and Insect Infestations Relative to Stand Type

High elevation forests comprised of subalpine fir or Engelmann spruce have fewer pathogen or insect pests than other forest series, except for dwarf mistletoe western larch is probably the most pathogen and insect pest free tree species. Western hemlock and red cedar are impacted by pathogens. Lodgepole pine has moderate hazard to both pathogens and insects and grand fir, Douglas-fir, and ponderosa pine forests have major insect pests. Tree ring data suggests that insect outbreaks were present in historical forests, but they were less frequent and of less severity.

Severe insect outbreaks have occurred in riparian stands (e.g., spruce beetle on the northern portion of the Wallowa-Whitman National Forest and Douglas-fir beetle in old-growth riparian stands following the western spruce budworm outbreak in Northeast Oregon from 1980-1993), (D. Scott, personal communication). Available data did not indicate whether these outbreaks in riparian areas are significantly more severe or occur more frequently than in upslope areas.

Question 15

Do climax forests have catastrophic collapse when left undisturbed? Does this vary between upland and ecological riparian communities?

Response

Stand Succession

White (1987) defined a feedback loop between the successional stage of the plant community and its susceptibility to disturbance as a specific period that varies with forest series (U.S. Department of Agriculture Forest Service 1992). All forest stands pass through these stages of initiation, development, and eventual collapse or destruction. In the progression from initiation of a stand to old growth status, the stand passes through several varied disturbance events that can partially or completely reinitiate stand development (Everett and Baumgartner 1997). Studying the eastside of the Cascades in Eastern Washington, Camp *et al.* (1996) found that only 10-16% of forest stands in pristine forests of the Swauk Late Successional Reserve were actually late successional old growth. Approximately 88% of the landscape had been subjected to at least partial stand disturbance. Natural disturbances rarely kill all structural elements from the preceding stands (Franklin *et al.* 2002). Even when multiple or extreme disturbances occur, some organisms often survive, including sexually mature trees (Franklin *et al.* 1995). Trees are sometimes killed by natural disturbances, but most disturbances remove or consume only a part of the killed trees and, in the case of windstorm, little of the organic matter (Franklin *et al.* 2002).

Upland Forests

Everett *et al.* (1994) compiled distributions of late-successional forests throughout Eastern Washington. During maturation, mortality shifts from competitive to non-competitive. In later stages of maturity, insects, disease, and wind become more important causes of mortality (Franklin *et al.* 2002). Falling trees or snags do important mechanical work by often killing other trees or other organisms. Greater than 15% of tree death in mature and old-growth Douglas-fir stands in the Pacific Northwest consists of trees felled, broken, or crushed by falling trees (Franklin *et al.* 1987).

Although the death of mature trees may sometimes be abrupt, mortality is more often a complex and gradual process with multiple contributing agents. The exception is volcanism, an abiotic, allogenic, and extrinsic disturbance that is too random in its timing and impact to have much of an evolutionary effect, but produces a catastrophic collapse. Franklin *et al.* (1985) studied plant community dynamics at Mount Saint Helens and showed that the survival of organisms and the rate and composition of post-eruptive forest recovery were season-dependent. Franklin (1988, 1993) pointed out that in the case of Mount Saint Helens, the catastrophic disturbance to the uplands lead to creation of significant biological legacies in associated riparian and aquatic systems. Specifically, streams received major inputs of COD within areas of blown-down forest.

Diseases may also kill trees quickly or predispose them to mechanical failure. A large percentage of old-growth Douglas-fir felled by windthrow contains significant butt rot. Both insects and disease may be the final, “proximate” cause of death in trees already weakened by other factors. Another exception to the gradual mortality rule might be global climate change. Under global warming scenarios, as temperatures increase, the fertilizing effect of increased carbon dioxide concentrations is overwhelmed by exponential increases in evapotranspiration, reductions in precipitation, or potentially both. Reduced precipitation could set up a threshold response that shifts the processes from increased productivity to a rapid, drought-induced mortality (Aber *et al.* 2001). These changes could induce catastrophic and more frequent fires (Dale *et al.* 2000).

Inherent declines in vigor and growth reduce the ability of a tree to resist agents of mortality, and these patterns can be quite species-specific. Tree genera vary with respect to lifespan – some survive for millennia (e.g., *Cupressaceae* and *Taxodiaceae*). Some live longer when site conditions are harsh (e.g., bristlecone pine in the White Mountains of California live in excess of 3,000 years). Manion (1981) produced a mortality spiral for Douglas-fir where healthy tree are suppressed by larger trees. The tree is predisposed to attack by defoliators, weakened, and then becomes attractive to bark beetles. Bark beetles then infect the tree with blue stain fungus that blocks the transpiration stream causing desiccation of the leaves.

The timing of tree death is variable and unpredictable, and depends upon cohort age, succession, and chance. Competition among trees becomes important when canopies close, initiating thinning mortality, an ecological process that may dominate in Douglas-fir for up to 150 years. During this process, wind and pathogens are the immediate causes of death, with environmental stresses, senescence, and competition contributing to tree death. Mortality rates generally decline and become more complex as a forest stand approaches a stable plant assemblage.

Much of tree death is considered episodic and erratic. Catastrophic destruction of stands represents the extreme form of episodic mortality where rates are greater than background for a cohort of trees. Episodic mortality rates vary with successional stage, tree species, and forest type, with some episodes occurring predictably, while others (e.g., volcanism and unusual climatic events) occurring by chance. Some of these episodes are related to successional stage (e.g., bark beetle attacks). Forest stands may develop beyond the long-term carrying capacity of the site during favorable periods, and have to respond to stress during unfavorable climatic periods (Franklin *et al.* 1987). These stress periods such as extensive windthrow in Douglas-fir, create conditions for bark beetle outbreak and consequent additional tree mortality. In the Pacific Northwest, mortality rates in mature and old-growth stands are not evenly distributed spatially. Generally, mortality is greater in habitats of high productivity than low productivity. A regional gradient exists where Sitka spruce-western hemlock is more susceptible than Douglas-fir, which, in turn, has greater productivity that ponderosa pine. Mortality from windthrow, wildfire, and fluvial patterns has strong spatial patterns.

As previously stated (Question 2), current late-successional forests with higher densities in Eastern Oregon and Washington have the same insect and pathogen compliments as the traditional old forests, with increased magnitude, severity, and duration of outbreaks (Everett *et al.* 1994, Hessburg *et al.* 1993). A mosaic of younger forest types with a greater potential for wildfire surrounds old forest remnants (Agee 1993, Everett *et al.* 1994). Lynch and Swetnam (1992) found that western spruce budworm did not directly threaten old growth stands *per se*, but contributed greatly to fuel loading and to fire risk and hazard. If budworm outbreaks are more severe in the surrounding matrix due to fire exclusion and subsequent dominance by multi-storied stands of shade tolerant species, then old growth is threatened by proximity alone.

Old-growth conifer forests frequently are considered vulnerable to catastrophic fire, due to the large amounts of surface fuel and abundant ladder fuels (Heinselman 1981). Older forests in the northern Rockies, particularly those in transition from lodgepole pine to spruce and fir, are the most susceptible to wildfire (Perry 1988). In contrast, Western Washington old-growth areas appear to be less vulnerable than younger forests due to the horizontal discontinuity of fuels produced by patchiness in the crown layer. Rust (1990) discovered that susceptibility to windfall is enhanced by root rot disease in old-growth grand fir and Douglas-fir. Mortality in grand fir can also be the result of insect or fungal attack after wounding by fire.

Riparian Forests

Without disturbance, and in the absence of a nearby seed source for shade-tolerant trees, the riparian plant community might disappear over time. Hibbs and Bower (2001) and Nierenberg and Hibbs (2000) studied 150-year-old unlogged, unmanaged streams in Oregon’s Coast Range and found that, when the current stand was alder or Douglas-fir, the long-term future of many of these riparian areas is a relatively treeless condition. This is perhaps not catastrophic, but is a major shift in the overstory dominants nonetheless.

Flooding and its associated events such as sedimentation, bank scour, landslides, and debris torrents dominate riparian disturbances. These processes are intimately linked to the formation and maintenance of riparian systems. Channel formation begins with water accumulation, overland flow due to localized saturated areas, and a break in slope (Montgomery and Dietrich 1994). These processes do not disappear when late-successional plant communities dominate the riparian system. Water continues to flow downhill with the ability to do work on the landscape. Even in bedrock controlled systems, clear water is sediment hungry and has the capacity or competence to move a certain amount of bedload. Given a heavy snow year, warm rain on a wet snowpack, the appropriate geology, and overloading of a steep slope with moisture, conditions exist for a debris slide that turns into a debris torrent upon entering the stream channel (Dale *et al.* 2000, Johnson *et al.* 2000). A debris torrent has the potential to eliminate late-successional riparian vegetation with a single event (Johnson *et al.* 2000, Nakamura *et al.* 2000).

Are climax forests possible in riparian ecosystems? The argument is that plant communities progress along successional pathways, but are continually adapting to changes in climate and natural disturbance, and, therefore, never truly reach an end point in succession. This argument has particular relevance to highly dynamic environments of the riparian ecosystem where hydrologic and geomorphic influences provide for an ever-changing environment.

Question 16

Where does the basal area as required in the new forest practices rules fall within the range of natural variability for historic stands (both upland and ecological riparian communities)?

Response

Availability of Scientific Information

The absence of a significant information base on historical basal area and tree density by plant association limited the *CTC* project team's ability to address this question. Additional information on historical basal area and tree density is needed before this question can be answered with confidence. Using information that was available, the following conclusions were drawn.

Basal Area Requirements Relative to Natural Variability in Stands

The F&FR minimum basal area requirement of 60 feet^2 per acre is high compared to historical values (10.3 to 22.3 feet^2 per acre basal area) for dry Eastern Washington Douglas-fir/ponderosa pine stands (Harrod *et al.* 1999). The high basal area group requirement of 50 trees per acre appears to be in the high range of the historical tree data (Harrod *et al.* 1999). There does not appear to be any corroborating information for the tree density standard for the low basal area/high tree density group.

In the mixed conifer forest habitat type, the minimum basal area requirements for low, medium, and high productivity sites fall within the range of historical (1899) basal area values for Douglas-fir on the east slope of the Cascades (Ohlson *et al.* 2001 unpublished research). It appears that the 120 tree per acre target for the riparian management zone (RMZ) inner zone of low basal area/high density stands may be too high in some plant associations. Historical (100 years BP) tree density estimates for dry grand fir/Douglas-fir indicate that there may not have been 50 trees with greater than13 cm dbh on many of these sites (Everett *et al.* 1996).

Historical estimates of basal area in riparian forests for western hemlock, mountain hemlock, western red cedar, grand fir and Douglas-fir would appear to exceed the minimum F&FR basal area requirements for the highest site potential stands. Lodgepole pine basal area would exceed the requirements for low and medium site index sites. However, the minimum F&FR basal area requirements for high elevation forests of 285 feet^2 per acre exceed the values found by Kovalchik (in press). The F&FR guides may not be in the range of historic conditions if the sites used in Kovalchik's classification serve as valid surrogates for historical conditions.

Question 17

Where do the current timber habitat types defined in F&FR lie within the current and historical spatial and temporal variability of riparian communities of Eastern Washington?

Response

Spatial Distribution of Riparian Communities

Kovalchik (in press) provides an assessment of the riparian plant communities. Using the community compositions provided by Kovalchik, the F&FR elevation zones, and forest habitat types (ponderosa pine, 0-2500 feet; mixed conifer, 2501-5000 feet; and high elevation, greater than 5000 feet), a list of current riparian associations in each of the categories is presented.

THPL

Two western red cedar associations (*Thuja plicata/Oplopanax* and *Thuja plicata/Athyrium filix-femina*) are common, distinctive meso-riparian types occurring at moderately low to moderate elevations (plot ranges for all associations 2400-4250 feet elevation) within mesic valleys. Most are located on the Colville and Kettle Districts on the central and eastern parts of the Colville National Forest where they are at least of minor occurrence. These associations occur in V-shaped and U-shaped valleys, on wet streambanks, floodplains, and terraces. These two associations fall into the mixed conifer/2500-5000 feet type. Two other western red cedar associations (*Thuja plicata/Aralia nudiculis* and *Thuja plicata/Clintonia uniflora*) reflect the drier sites and lower elevation zones of the western red cedar series. Elevations range from 2200-4000 feet with THPL/ARNU found in wide U-shaped valleys and THPL/CLUN found in narrow, V-shaped valleys. Both associations occur on stream terraces and the margins of basins and represent xero-riparian conditions. These two associations also fit into the mixed conifer/2500-5000 type with some overlap into the ponderosa pine/0-2500 feet type.

PIEN

This series contains four associations that are quite different. The *Picea engelmanii/Carex scopularum* v. prionophylla is abundant at moderate to subalpine elevations on the Okanogan and Colville National Forests. Plot elevations range from 4400-7200 feet in the Cascades. This association is prominent along the margins of large flat basins and narrow stringers of steep, subalpine streams. Valleys are both U- and V-shaped. This association would fit primarily into the upper elevation/greater than 5000 feet type with some overlap into the mixed conifer/2500-5000 feet type. The other three associations (PIEN/*equisetum* spp., PIEN/*Gymnocarpum dryopteris*, and PIEN/*Cornus canadensis*) fit the mixed conifer/2500-5000 type. These sites vary from the margins of wet basins, on the tops of banks or on moist floodplains and terraces, or adjacent to stream on dry floodplains, respectively. PIEN/GYDR and PIEN/COCA represent xero-riparian conditions and PIEN/EQUIS is meso-riparian.

ABLA2

All but two of the associations in the ABLA2 series are riparian areas in the subalpine zone (*Abies lasiocarpa/Rhododenron albiflorum*, ABLA2/*Gymnocarpum dryopteris*, ABLA2/*Cornus canadensis* and ABLA/*Trautvetteria carolinensis*). These associations occur on both the Colville and Okanogan National Forests. They represent cold, moist bottoms in both U-and V-shaped valleys. Sites are on streambanks, floodplains, and terraces where they represent xero-riparian conditions. The other two associations (ABLA2/*Arthirium filix-femina* and ABLA2/*Streptopus amplexifolus*) are at more moderate elevations with plots elevations ranging from 3160-5300 feet. These two would conform to F&FR mixed conifer/2500-5000 feet types with some overlap into the high elevation/greater than 5000 feet type. These latter two associations represent cold, moist valley bottoms and sub-irrigated side slopes representing meso-riparian conditions.

POTR

One association (*Populus tremuloides/Cornus stolonifera*) is a minor type at moderate elevations in the Colville, Republic, and Tonasket districts of the Colville and Okanogan National Forests. This riparian association is found in low gradient basins in trough-shaped valleys. The association is seasonally flooded, but represent xero-riparian conditions.

POTR2

Two associations of the black cottonwood series (*Populus trichocarpa/Alnus incana*, POTR2/*Cornus stolonifera*) exist in low to moderately low elevations through Colville and Okanogan National Forests. Both are found in wide, U-shaped valleys on terraces of major streams and rivers and the margins of lakes and basins. Sites are often seasonally flooded, but represent xero-riparian conditions.

The other series represented by riparian plant associations in Eastern Washington are shrub and herbaceous, such as tall and short willow, Sitka/alder, other shrubs (e.g., red-osier dogwood), sedge, and herbaceous non-sedge, are not included because timber types represent less than 15% of these associations.

Temporal Distribution of Riparian Communities

A mid-scale, Interior Columbia Basin-wide analysis of changes in riparian vegetation from pre-settlement showed a general decline in shrublands in the riparian areas in more than half of the ERUs (Quigley and Arbelbide 1997). Shrublands shifted to forests and herbaceous communities through succession or disturbance. Forests (that include riparian species such as cottonwood, aspen, and willow), woodlands, and herbaceous riparian communities remained approximately the same. However, other, more widespread forest types mask cover types dominated by riparian trees. Riparian forest types declined in six of thirteen ERUs. Important decreases occurred in the headwaters of the Snake River and the Columbia Plateau. Riparian area integrity and extent along watercourses has been altered and fragmented throughout the Columbia Basin in response to forest conversion and streamside disturbance (Quigley and Arbelbide 1997). Unfortunately, broad-scale changes in vegetation patterns were not assessed for riparian terrestrial vegetation types. Because these types generally occurred in scattered, relatively small-to medium-sized patches, they tended to be underestimated as mapping resolution increased. Since the historical vegetation layer was developed at a coarser resolution than the current period vegetation layer, bias in the two mapping efforts might be different. Thus, changes in riparian vegetation types between historical and current period were not assessed completely (Quigley and Arbelbide 1997).

On the broad scale, riparian woodland did not decline substantially between historical and current periods. Fine- or mid-scale analysis, however, suggested that this woodland type declined substantially. This decline is attributed to agricultural development, urbanization, and invasion by exotic plant species. The elevational distribution did not change substantially. Since the historical period, the structure and composition of riparian woodlands have changed due to disturbance by livestock grazing, invasion of exotic plants, agriculture, and urban development. Solid comparisons between historical and current periods may exist for certain habitat types (e.g., ponderosa pine, Arno 1993); however, a comprehensive evaluation was not found. Indirectly, this information could be inferred from fire history and frequency studies, but until 1998, few researchers specifically focused on successional dynamics in riparian areas (rather than aquatic habitats).

Identified Data Gaps and Recommendations

In the process of addressing the project questions, the following data gaps and associated recommendations were identified.

General Data Gap

The scientific basis for future forest management may need to incorporate a finer scale than forest habitat type (e.g., disturbance and patch dynamics). The scientific literature describing Eastern Washington disturbance regimes and forest vegetation is at the forest series or PAG level.

Question 1

Data Gap: Relatively few studies have examined the differences in fire, insect or pathogen disturbances between riparian and upslope forests. There are no studies on differences in pathogen or insect disturbance regimes for riparian and adjacent upslope forests. The inherent disturbance regime for insects and pathogens is less well defined because of the absence of a permanent historical marker for pathogen disturbance.

Recommendation: Conduct focused research projects that develop information on insect and pathogen disturbance regimes and vegetation response between adjacent riparian and upslope forests.

Question 2

No data gap identified.

Question 3

Data Gap: Avoidance, resistance, and resilience concepts need to be defined at the finer scale of stand development stages and at the coarser scale of landscapes. Disturbance hazard is often related to stand structure and the significance of that hazard is evaluated at the landscape scale.

Recommendation: Conduct focused research projects that develop information on a finer scale of stand development stages and at a coarser scale of landscapes.

Question 4

Data Gap: There is an inability to accurately determine the proportion of the landscape that is or was likely to be affected by landslide disturbance without field verification. A bias towards detecting a greater percentage of landslides and erosion volume in younger versus older forests using air photographs significantly influences landslide density and erosion calculations

Recommendation: Conduct focused field research projects that develop information on landslide disturbance in younger versus older forests.

Question 5

No data gap identified.

Questions 6

Data Gap: Scientific information on historical stand structure (greater than 100 years BP) in Eastern Washington is scarce. The greatest information gap is on historical stand characteristics within high elevation forest types (e.g., subalpine fir and Engelmann spruce). The use of "recent historical" (1940 aerial photographs) provides a glimpse of stand and landscape structure already significantly altered from pre-European settlement conditions. These altered 1940s conditions may not be supported by inherent disturbance regimes.

Recommendation: Consider the use of "reference stands" from vegetation classification work to get an improved idea of the array of "pristine" conditions that were present prior to European settlement. Historical stand characteristics should be defined for all stand development stages to provide for a more "complete" view of stand structures and, collectively, "historical landscapes" supported by inherent disturbance regimes. Also, needed is landscape-level historical information on the proportion of different stand structures that populated the landscape.

Question 7

No data gap identified.

Question 8

No data gap identified.

Question 9

Data Gap: There is little stand-level information on large tree regeneration following stand replacement fires.

Recommendation: Use information on stand successional processes and individual tree re-establishment rates to help identify the stand types (plant associations and associated tree species) that would produce large trees when disturbances are applied.

Question 10

Data Gap: There is no information on "typical" survival rates following a stand replacement or understory fire.

Recommendation: The current mortality prediction models (e.g., FIRESUM) appear to accurately estimate mortality for specific areas and burn conditions. Managers should use such models to estimate stand response to different fire intensities.

Question 11

Data Gap: There is no literature specific to the influences of drought and pest thinning in dense riparian forest stands in Eastern Washington.

Recommendation: In the absence of such information, data on silvacultural thinning practices and their effects may be used to develop an active management approach that reduces riparian forest health issues prior to the occurrence of catastrophic fire events.

Question 12

No data gap identified.

Question 13

Data Gaps: Three data gaps related to reburn following stand replacing fires were identified. No or limited data exists on the following:

Across all series, the proportion of stand replacement fire areas that reburn prior to tree establishment.

The snag or log loading following a reburn of sites with a previous stand replacement fire.

A comparison of reburns upslope and adjacent to riparian forests.

Recommendation: Conduct research on the proportion of stand replacement fire areas that reburn and how such reburns affect riparian and upslope areas. Such information is needed if managers choose to re-introduce fires into Eastern Washington.

Question 14

No data gap identified.

Question 15

No data gap identified.

Questions 16

See question 6.

Question 17

Data Gap: There is a lack of solid, comprehensive comparisons between historical and current forest structure, composition, and distribution (for all forest stand types).

Recommendation: Use fire history and frequency studies to develop a more comprehensive comparison of historic versus current forest stand distributions in Eastern Washington.

PART

2

ANNOTATED BIBLIOGRAPHY

Section

1.0

Scope of Work Task A

Background

This portion of this report presents information requested in the Scope of Work Task A: "Annotated Bibliography." An annotated bibliography related to the topics described in Task B: "Summarize Available Information," was assembled from literature searches and submittals obtained from scientists and resource specialists (see Appendix A). Best efforts were made to identify pertinent reference materials for this annotated bibliography. Task A also involved gathering, summarizing, and documenting two Forest Dynamics Workshops sponsored by Eastside Riparian Scientific Advisory Group (ERSAG) (now CMER SAGE).

To identify appropriate references, the *CTC* project team developed an assessment methodology to screen references. To complete this task, the *CTC* project team identified topic areas within the project questions, determined relationships between topic areas, and selected keywords to facilitate literature searches. The *CTC* project team screened references by geographic location, relevance to topic areas, and type of document (either summary document or single study). Categorized references are presented in Part 2, Section 3.0 in the following order:

Highly Relevant Summary Documents
Highly Relevant Studies
Other Highly Relevant References
Relevant Summary Documents
Relevant Studies
Supporting Documents
Supporting Studies
General References
Other Works Cited

No attempt to categorize references by disturbance type, duration, or other metric was made. Upon review of the materials, the extent of cross-over between documents made classification by these categories impractical. The *CTC* project team focused the available project resources on summarizing the identified information.

Section

2.0

Eastside Forest Dynamic Workshops

The CMER and the ERSAG sponsored two Eastside Forest Dynamic Workshops during the spring of 2001. One workshop was held in Spokane, Washington on February 22, 2001, and the other in Ellensburg, Washington on May 22, 2001. The purpose of the workshops was to provide ERSAG with information to support their efforts related to Forests and Fish Report adaptive management issues, which include providing direction to CMER, developing research, and forming effectiveness-monitoring programs.

A brief summary of the workshops is presented here. This summary is based on workshop materials and a video provided to the *CTC* project team by Pete Peterson, Upper Columbia United Tribes (UCUT), via Domoni Glass, and electronic files provided by Domoni Glass and Sondra Collins, UCUT.

The *CTC* project team attempted to contact the four speakers from the Ellensburg workshop. The *CTC* project team was successful in contacting Jim Agee, Gardner Johnston, and Diana Olson to request additional materials for their presentations; no additional materials were made available. No contact information was provided for Jeanette Smith and subsequent attempts to obtain contact information for her were unsuccessful.

The *CTC* project team was not provided with sufficient suitable material to compile graphs and tables from each presenter, as requested by DNR.

Forest Dynamic Workshop in Spokane, February 22, 2001

Summary

The Spokane workshop was held on February 22, 2001, between 9 a.m. and 4 p.m. at the Gonzaga University Foley Teleconference Center. Presentations made at the workshop are as follows:

Fire Frequency in Riparian Areas
Presenters: Richard Schelhaas and Don Spubeck.

Eastern Washington Riparian/Wetland Classification
Presenter: Bud Kovalchik

Computer Programs to Simulate Forest Processes
Presenters: Chad Oliver

Small Woody Debris
Presenter: Charles Chesney

Transcribed Text from Spokane Workshop, February 22, 2001

The ERSAG Forest Dynamic Workshop held in Spokane was transcribed. The transcribed text was provided to the *CTC* project team electronically in four Microsoft® Word files. The contents of those files are provided in Appendix B.

Summary of Presentations Delivered at the Dynamic Forest Workshop in Spokane, February 22, 2001

"Fire Frequency in Riparian Areas"
Presenters: Richard Schelhaas and Don Spubeck

Topics of the presentation included landscape and historic fire regimes in ponderosa pine and Douglas-fir forest series and historic fire regimes in riparian areas in Douglas-fir, ponderosa pine, and red fir series. The presenters defined historic conditions as those that existed prior to 1900.

Information presented was based on historic forest regime projects conducted in Eastern Washington during the last ten years. Study sites were located in the Okanogan and Wenatchee National Forests and range from 10,000 to 40,000 acres in size. Study activities included dendrochronology techniques and were designed to identify the frequency, severity, and size of historic fires.

Study data were used to identify fire characteristics. Data indicated that historically, fires were frequent and of low intensity. Under current conditions, fires are infrequent, due to fire suppression, and of high intensity. Data also indicated that the behavior of historic fires was not affected by landscape aspect (e.g., fires burned across ridge tops and riparian areas and there was no significant difference between north and south aspects). Forest conditions have been significantly altered during this century leading to increased understory growth, presence of shade tolerant Douglas-fir, stand density, and insect infestations, notably spruce budworm. Data indicated that riparian zone fires tended to be more severe than upslope areas due to increased accumulation of fuel in gullies.

The presenters asserted that, "Continuity in disturbance between riparian and sideslope forest and the continuity in disturbance between opposing slope forests suggest that management should consider landscape units in their entirety rather than as riparian and sideslope isolates when implementing ecosystem and disturbance management."

"Eastern Washington Riparian/Wetland Classification"
Presenter: Bud Kovalchik

The presentation focused on how a riparian or wetland classification may – through a hierarchical, geomorphic view of riparian and wetland zones – help managers better understand riparian and wetland zone functions and processes, estimate their status and potential, prescribe proper management direction, and focus salmon recovery efforts.

After briefing the audience on his background and publications, the presenter provided information on riparian and wetland classifications. The presenter discussed his methodology of classifying areas that includes examining the geomorphology, physiography (geology and climate), hydrology, and potential natural plant community or climax conditions of a location. Broad-scale classifications have an accuracy of approximately 2/3 (i.e., 30% error). The presenter discussed several specific locations and their classifications. Additional discussion topics included riparian buffers, large woody debris, channel morphology, timber harvesting, and stream functions and processes.

The presenter asserted that Eastern Washington timber habitat types should not be based on coarse-scale concepts such as broad elevation bands and timber habitat types. A geomorphic-based/vegetation classification may be used at different scales to stratify the landscape to develop effective, reality-based management strategies for salmon habitat restoration in riparian/wetland zones.

"Computer Programs to Simulate Forest Processes"
Presenters: Chad Oliver and Jason Cross

This presentation focused on how information and knowledge can be integrated using science and technology to address forest management issues. Science-based concepts include forest dynamics, forest use, and demand for forest products. Forest management can focus at several levels (e.g. individual trees, stands, landscapes, and regions). These levels result in a hierarchy. The systems approach requires an understanding of the behavior of the hierarchy system. This approach relies on using best available science and completing sensitivity analyses and monitoring (i.e., continuous quality improvement).

Until recently, the predominant ecological paradigm was that the forest existed in a steady state, climax condition that could be managed through selective cutting and preservation of large tracts to retain native species. It is now accepted that forests are very dynamic because of vegetation growth and disturbances. Additionally, present-day forests have multiple uses that require different ecological conditions. To attain these conditions, integrated management is needed. Computers may be used to evaluate forest growth, silvicultural operations, timber inventory, geography (GIS), financial analyses, habitat suitability indices, and riparian relationships. Changing forest structures and values can be projected and modeled over time.

The remainder of the presentation focused on how computer simulations may be used to facilitate integrated forest management. A brief demonstration of a computer model, called *Landscape Management System*, was presented. Simulations can be used to estimate the effect of stand management activities on forest and riparian functions and conditions, including habitat conditions needed to maintain water quality and fish habitat and slope stability. Simulation models have the potential to be very complex depending on what inputs and outputs are desired.

"Small Woody Debris"
Presenter: Charles Chesney

A long-term monitoring project is being conducted with the goal of improving forest management activities. The project includes monitoring activities at 18 sites both managed and unmanaged. Data are collected at 5-year intervals or on event-triggered basis to determine how much riparian vegetation is needed for adequate wood input to the channel, how much functional in-channel wood is needed to retain sediment, and to develop recommendations for creating conditions for a self-sustaining wood supply. Small woody debris is defined as a range of woody debris with a minimum size of 1-foot in length and 1-inch mid-point diameter and a maximum size of 6-feet in length and 4-inch mid-point diameter. The presenter asserted that small woody debris plays just as significant a role in stream habitats as large woody debris.

Dynamic Forest Workshop in Ellensburg, May 22, 2001

Summary

The Ellensburg workshop was held on May 22, 2001, between 9:00 a.m. and 4:15 p.m. at Holmes Hall at the Holmes Community Center. Presentations made at the workshop are as follows:

Historical Riparian Conditions – What Do We Know, What Don't We Know
Presenter: Jim Agee

Historical Riparian Characteristics in the Blue Mountains
Presenter: Diana Olson

Historical Shade Conditions in Eastern Washington
Presenter: Gardner Johnston

Historical Wood Loads in North Eastern Cascade Streams
Presenter: Jeanette Smith

Summary of Presentations Delivered at the Dynamic Forest Workshop in Ellensburg, May 22, 2001

Historical Riparian Conditions – What Do We Know, What Don't We Know Presenter: Jim Agee

No record of Dr. Agee's presentation was made available to the *CTC* project team. When contacted by email, Dr. Agee responded that no concurrent paper was prepared or requested for the meeting. No documentation for this presentation was made available.

Historical Riparian Characteristics in the Blue Mountains Presenter: Diana Olson

No record of Diana Olson's presentation was made available to the *CTC* project team. Subsequent efforts to contact her were unsuccessful. Since the title of her presentation matches the title of her Master of Science thesis, the abstract of the thesis is presented here:

Despite the ecological importance of fire in Pacific Northwest forests, its role in riparian forests is not well documented. This study reconstructed the historical occurrence of fire within riparian forests along different stream sizes within three different national forests in Oregon. Two study areas were located in mostly dry, low-severity fire regime forests in the Blue Mountains of northeastern Oregon (Dougout and Baker) and the third study area was located in more mesic, moderate-severity fire regime forests on the western slopes of the southern Oregon Cascades (Steamboat). Fire scar dates and tree establishment dates were determined from a total of 424 fire scarred tree wedges and 81 increment cores taken from 67 riparian and upslope plots. Based on the data from this study, fire was common historically in the riparian zones of all three study areas. Weibull median probability fire return intervals (WMPIs) for riparian forests in Dugout ranged between 13 and 14 years, and were only slightly longer than those for upslope forests (averaging one year longer). In Baker, differences between riparian and upslope forest WMPIs were greater, ranging between 13 and 36 years for riparian WMPIs, compared to 10 to 20 years for upslope WMPIs. However, further analyses suggested that forest type and slope aspect play a larger role than proximity to a stream when it came to differentiating fire regimes in this study area. For both Dugout and Baker it appeared that stream channels did not necessarily act as fire barriers during the more extensive years. Steamboat riparian WMPIs were somewhat longer (ranging from 35-39 years) than upslope WMPIs (ranging from 27-36), but these differences were not significant. Fires were probably more moderate in severity and likely patchy, considering the incidence of fires occurring only at a riparian plot or an upslope plot within a pair, but not at both. It is possible that fire return interval lengths were associated with aspect, but more sampling would need to be done to show this. Based on the results from this study, it is evident that: 1) restoring fire, or at least conducting fuel reduction treatments, will be necessary to protect riparian forests in comparable forest ecosystems, 2) forests should be managed according to forest type, not just by proximity to a stream, and 3) historical recruitment of large woody debris was likely small but continuous for low-severity fire regime riparian forests, with a relatively short residence time, and patchy and more pulsed for the more moderate-severity fire regime forests. (See annotated bibliography for citation information).

Historical Shade Conditions in Eastern Washington
Presenter: Gardner Johnston

No record of Gardner Johnston's presentation was made available to the *CTC* project team. When contacted, Gardner Johnston directed the *CTC* project team to his recently completed thesis at the University of Washington. Attempts to obtain the thesis were unsuccessful. Communications with Gardner Johnston indicate that he is traveling and will not return until June 10, 2002. The *CTC* project team will attempt to contact him at that time to obtain additional information for inclusion in the final draft of this report.

Historical Wood Loads in North Eastern Cascade Streams
Presenter: Jeanette Smith

This presentation focused on large woody debris (LWD). Interior Columbia Basin Ecosystem Management Project (ICBEMP) and U.S. Forest Service (USFS) standards for LWD vary. The ICBEMP standard is 20 pieces per mile. The USFS standard for the Okanogan National Forest is 100 pieces per mile. Both systems define LWD as woody debris that is greater than 35 feet in length and greater than 20 inches in diameter. Neither standard is considered representative of reference conditions in the Northeastern Cascades.

Information was presented on a study conducted for the Chewuch River. Aerial photograph analysis shows that over time LWD accumulated at the same sites, indicating that channel and valley geomorphology may be influencing factors. Data indicated that LWD jams recovered over time. Patterns of LWD distribution indicated that LWD appears in accumulations that, without further disturbance, continue to accumulate material and individual pieces at greater frequencies.

Differences in forest type may be as important as channel and valley geomorphology, large river processes, disturbance regimes, and management, when evaluating reference conditions. Dry ponderosa pine had lower recruitment rates, increased root strength, slower growth to maturity, and longer recovery time than higher elevation, wetter spruce/lodgepole pine. Study results suggest that sub-regions that reflect differences in LWD recruitment and depositional processes and channel geomorphologic parameters such as gradient and confinement should stratify LWD parameters.

Section

3.0

Bibliography

Organization of References

References below have been sorted into seven categories ranging from highly relevant to less relevant:

Highly Relevant Summary Documents: Includes summary documents (i.e., references that refer to more than a single study) that were deemed by the *CTC* project team to be highly relevant to this project because of topic areas covered and geographic location of studies included in the document. References included in this category addressed at least one project topic area directly and were geographically focused on Eastern Washington or other, very similar landscape, such as Eastern Oregon.

Highly Relevant Studies: Includes single study reports that were deemed by the *CTC* project team to be highly relevant to this project because of topic areas covered and geographic location of the study. Studies included in this category addressed at least one project topic area directly and were geographically focused on Eastern Washington or other, very similar landscape, such as Eastern Oregon.

Other Highly Relevant Reference: Includes references that were deemed by the *CTC* project team to be highly relevant to this project because of topic areas covered and geographic focus of the study. No abstracts or summaries were available.

Relevant Summary Documents: Includes summary documents that were deemed by the *CTC* project team to be relevant to this project because of topic areas covered or geographic focus of studies included in the document. References included in this category addressed at least one project topic area, directly or indirectly, or were geographically focused on Eastern Washington or other, very similar landscape, such as Eastern Oregon.

Relevant Studies: Includes single study reports that were deemed by the *CTC* project team to be relevant to this project because of topic areas covered or geographic focus of the study. Studies included in this category addressed at least one project topic area, directly or indirectly, or were geographically focused on Eastern Washington or other, very similar landscape, such as Eastern Oregon.

Supporting Summary Documents: Includes summary documents that were deemed by the *CTC* project team to be supportive to this project because of topic areas covered or geographic focus of studies included in the document. References included in this category addressed at least one project topic area to a limited extent, but may not be related geographically to the project area.

Supporting Studies: Includes single study reports that were deemed by the *CTC* project team to be supportive to this project because of topic areas covered or geographic focus of studies included in the document. References included in this category addressed at least one project topic area to a limited extent, but may not be related geographically to the project area.

General References: Includes documents that were deemed by the *CTC* project team to be general references for this project because of topic areas covered or geographic focus of studies included in the document. References included in this category may not address any of the project topic areas directly, but do provide useful background information.

Other Works Cited: Includes a list of other references cited. Complete citations were unavailable.

For each citation (except where noted), there is an annotation. There are two types of annotations: abstracts and summaries. An abstract is a direct quote from the cited reference. An abstract may be the actual abstract presented by the author(s) or may be an excerpt from the text of the document that summarizes the citation. A summary is not a direct quote from the citation. Each summary was written by a member of the *CTC* project team and briefly outlines the topics and conclusions of the citations.

1. Aber, J., R. P. Neilson, Steve McNulty, J. M. Lenihan, D. Bachelet, and R. J. Drapek. 2001. Forest processes and global environmental change: predicting the effects of individual and multiple stressors. *BioScience* 51, no. 9:735-751.
   Notes: Relevant Summary Documents
   Abstract: An article reviewing the state of prediction of forest ecosystem response to envisioned changes in the physical and chemical climate. These results are offered as one part of the forest sector analysis of the National Assessment of the Potential Consequences of Climate Variability and Change. The article includes three sections: (1) a brief review of the literature on the effects of environmental factors on forest ecosystem function; (2) a summary of the results from the Vegetation/Ecosystem Modeling and Analysis Project (VEMAP); and (3) a brief review of other regional modeling efforts that have addressed climate change or have looked at the possible effects of other components of global change, using tropospheric ozone and nitrogen deposition as examples.

2. Adams. 1994.
   Notes: Other Works Cited

3. Agee, J. K. 1996. Achieving conservation biology objectives with fire in the Pacific Northwest. *Weed Technology* 10:417-421.
   Notes: Relevant Summary Documents
   Abstract: Fire has been a part of natural ecosystems for many millennia. The species of those ecosystems have evolved through a series of "coarse filters," one of which is resistance or resilience to disturbance by fire. Plant adaptations to fire include the ability to sprout, seed bank adaptations in the soil or canopy, high dispersal ability for seeds, and thick bark. These adaptations are often to a particular fire regime, or combination of fire frequency, intensity, extent, and season. Fire can be used by managers to achieve species to ecosystem-level conservation biology objectives. Examples using prescribed fire include the grasslands of the Puget Trough of Washington State, maintenance of oak woodlands, and perpetuation of

ponderosa pine/mixed-conifer forests.

4. Agee, J. K. 1994. *Fire and weather disturbances in terrestrial ecosystems of the Eastern Cascades*. Portland, Oregon: U. S. Forest Service, PNW-GTR-320.
Notes: Highly Relevant Summary Documents
Abstract: Fire has been an important ecological process in eastside Cascade ecosystems for millennia. Fire regimes ranged from low severity to high severity, and historic fire return intervals ranged from less than a decade to greater than 300 years. Fire history and effects are described for grassland and shrubland ecosystems, and the range of forested communities by plant series: ponderosa pine, douglas fir/white fir/grand fir, lodgepole pine, western hemlock/western redcedar, and subalpine fir/mountain hemlock. The riparian zones within these communities may be more or less impacted by fire. The effects of extreme weather events, including unusual temperature, wind, or moisture have generally had less significant impact than fire. Management practices, including fire suppression, timber harvesting, and livestock grazing, have altered historical fire regimes, in some cases irreversibly. The management issues for the 1990s include both management and research issues, at a grand scale with which we have little experience. Ecosystem and adaptive management principles will have to be applied.

5. Agee, J. K. 1993. *Fire ecology of Pacific Northwest forests*. Washington, D. C.: Island Press.
Notes: Highly Relevant Summary Documents
Abstract: This book began as a source book for natural area managers interested in restoring or maintaining fire in the natural areas of the Pacific Northwest. It grew to encompass a broader charge: to provide a natural baseline that wildland managers, or those interested in wildland management, could use in understanding the effects of natural or altered fire regimes in the western United States. This ecological perspective about fire is not a prescriptive guide, since prescriptions must include management objectives. The management emphasis is on the role of fire in natural areas, but such information is also useful in fire applications for other management purposes.

The structure of most virgin forests in the American West today reflects a past disturbance history that includes fire. Although media reports of the 1988 Yellowstone fires treated the scene as an ecological catastrophe, these forests were born of fire in the 1700s and are now being reborn in the 1990s. Knowledge of the natural and often inevitable disturbances likely to affect forests, including fire, is essential to any forest management plan, whether the objective is timber production, wildlife conservation, or wilderness management. Creating desirable forest stand structures in the future for these objectives may not require simulation of past fire activity. Such effort, however, will be successful only if we understand the processes responsible for desirable structures we see today before undertaking future stand manipulation.

The geographic coverage of this volume is applicable too much of the western United States, although the focus is on forest types found in Oregon, northern California, and Washington. Where those types occur in adjacent regions, information on them has been included. I chose to exclude those forest types endemic only to other areas of the West, such as giant sequoia forests. Non-forest vegetation is included where it is transitional to forest, as in oak and juniper woodlands or subalpine environments.

6. Agee, J. K. 1991. Fire history of douglas fir forests in the Pacific Northwest. In *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests*, edited by Ruggiero, L. F., K. B. Aubry , A. B. Carey, and M. H. Huff (Portland, Oregon: U. S. Forest Service, PNW-GTR-285).
Notes: Highly Relevant Summary Documents
Abstract: The fire history of Pacific Northwest douglas fir forests is varied and complex because douglas fir exists in a variety of forest types over a wide range of environments. Douglas-fir has been dominant over this region because of disturbance by fire and the species' adaptations to fire. Human-caused fires have been locally important, but lightning appears to be most significant in explaining fire history. A lightning fire model based on climate suggests a strong north-south gradient in lightning ignitions. The western Olympic Mountains have a very low

probability of ignition by lightning; the southern Washington Cascades have twice as much; the western Oregon Cascades have another 60 percent more; and the Siskiyou Mountains have twice, again as much. Our knowledge of fire return intervals based on forest age-class data shows a parallel history, ranging from fire return intervals over several centuries in the Olympics to several decades in the Siskiyous. Most Olympic forests have developed as first-generation stands after historic fires; Siskiyou forests are usually multi-aged stands that have experienced several fires. Almost all of the old-growth douglas fir resource is a product of fire: it not only has created and maintained such stands but has destroyed them as well. In the short term, management strategies to perpetuate old growth can focus on protection against fire. In the long term, we will be forced to recognize a more dynamic management strategy, sensitive not only to historic fire regimes, but also to those expected with future climatic change.

7. Agee, J. K. 1998. *Historic vegetation in the Central Eastern Cascades of Washington*. Seattle, Washington: Unpublished manuscript, University of Washington, College of Forest Resources.
Notes: Relevant Studies
Abstract: This report is divided into two independent chapters. This first chapter deals with the concept of the historical range of variability of the major forest types in the central eastern Cascades of Washington. It summarizes concepts of ranges of variability, briefly summarizes the major forest types, develops equilibrium age structures, and applies these to develop historic ranges of forest structures across the landscape. The second chapter focuses on reconstructing the species composition and structure of the lower Teanaway River drainage lands currently owned and managed by the Boise Cascade Corporation. This reconstruction used early survey records from the General Land Office that were obtained from the Bureau of Land Management, and provides a snapshot of the late nineteenth century vegetation in the Teanaway.

8. Agee, J. K. 1988. Successional dynamics in forest riparian zones. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington: University of Washington, Institute of Forest Resources, Contribution #59).
Notes: Other Highly Relevant References

9. Agee, J. K., M. Finney, and R. deGouvenain. 1990. Forest fire history of Desolation Peak, Washington. *Canadian Journal of Forest Research* 20:350-356.
Notes: Other Highly Relevant References
Abstract: Seven forest community types were defined, and a 400-yr fire history was developed for this 3500 ha area. Average natural fire rotation was 100 yr; this varied by a factor of 2 by century and by topographic aspect. Forest types typical of coastal regions had mean fire return intervals (108-137 yr) much lower than in other W. Washington areas. The most interior forest type had a higher mean fire return interval (52 yr) than reported for similar forest types E. of the Cascades.

10. Agee, J. K. and K. R. Maruoka. 1994. *Historical fire regimes of the Blue Mountains*. La Grande, Oregon: Blue Mountains Natural Resources Institute, Technical Notes #1.
Notes: Highly Relevant Studies
Abstract: The authors discuss fire as a natural disturbance process in the Blue Mountains. The role of fire is described using the concept of the fire regime. Fire regimes are described for several vegetation types, as are adaptations of vegetation to fire.

11. Agee, J. K., C. S. Wright, N. M. Williamson, and M. H. Huff. 2002. Foliar moisture content of Pacific Northwest vegetation and its relation to wildland fire behavior. *Forest Ecology and Management* 167, no. 1/3:57-66.
Notes: Highly Relevant Studies
Abstract: Foliar moisture was monitored for five conifers and associated understory vegetation in Pacific Northwest forests. Declines in foliar moisture of new foliage occurred over the dry season, while less variation was evident in older foliage. Late season foliar moisture ranged from 130-170%. In riparian-upland comparisons, largest differences were found for understory vegetation, with less variation evident for overstory trees. Minimum foliar moisture values of

100-120% are appropriate to use in crown fire risk assessment for the Pacific Northwest.

12. Aho, P. E. 1974. *Defect estimation for grand fir in the Blue Mountains of Oregon and Washington*. Portland, Oregon: U. S. Forest Service, PNW-RP-175.
Notes: Supporting Studies
Abstract: Management of grand fir is difficult because of excessive defect, mainly decay. Two methods had been used to estimate the extend of defect. However, after these methods were developed, cull rules for true firs changed, requiring a revision in present board-foot, defect-indicator percentages. This paper reports on the revised grand fir defect indicator percentages, with the aim of making indicator length deduction factors more readily available.

13. Alexander, R. R. 1987. *Ecology, silviculture, and management of the engelmann spruce - subalpine fir type in the Central and Southern Rocky Mountains*. Washington, D. C.: U. S. Forest Service, Agriculture Handbook #659.
Notes: Supporting Summary Documents
Abstract: Summarizes and consolidates ecological and silvicultural knowledge of spruce-fir forests. Describes the biological and environmental values, stand regeneration, stand management, and growth and yield.

14. Amman, G. D. , Mark D. McGregor, D. B. Cahill, and W. H. Klein. 1977. *Guidelines for reducing losses of lodgepole pine to the mountain pine beetle in unmanaged stands in the Rocky Mountains*. Ogden, Utah: U. S. Forest Service, INT-GTR-36.
Notes: Other Works Cited

15. Amman, G. D. and Schmitz. 1989.
Notes: Other Works Cited

16. Anderson, L. , C. E. Carlson, and R. H. Wakimoto. 1987. Forest fire frequency and western spruce budworm outbreaks in Western Montana. *Forest Ecology and Management* 22:251-260.
Notes: Relevant Studies
Abstract: Duration and intensity of western spruce budworm (*Christoneura occidentalis* Freeman) outbreaks have increased with the decrease in forest fire frequency in western Montana since 1910. Frequency of budworm outbreaks, however, was not affected. Feeding activity and fire occurrence were measured in 20 mixed douglas fir (*Psuedotsuga menziesii* var. glauca Beissn Franco)-ponderosa pine (*Pinus ponderosa* var. ponderosa dougl. ex laws.) stands representing dry douglas fir habitat types. Outbreak frequency, duration and intensity were inferred from analyses of radial increment cores and fire history from basal fire scars on old-growth pines and firs. Data were compared between the pre-fire suppression period (1814-1910) and the fire suppression period (1911-1983). Since 1910, douglas fir, a shade-tolerant conifer and host for budworm has invaded and dominated sites previously occupied by non-host ponderosa pine. This increase in the abundance of host is a response to decreased wildfire frequency and has resulted in stand conditions favorable for budworm populations, an important factor contributing to current widespread and damaging populations of western spruce budworm.

Judicious use of ground-fire, thinning, and other silvicultural treatments that favor seral non-host conifers, reduce stand density, and minimize the number of canopy layers in managed stands would reduce the amount and quality of budworm habitat and significantly reduce the risk of damaging outbreaks.

17. Anderson, R. S. 1996. Postglacial biogeography of sierra lodgepole pine (*Pinus contorta* var. murrayana) in California. *Ecoscience* 3, no. 2:343-351.
Notes: Relevant Studies
Abstract: Plant macrofossils and pollen from 13 sites are used to reconstruct the biogeography of Sierra lodgepole pine (*Pinus contorta* Dougl. ex. Loud. var. murrayana), and its relationship to climate change, within the Sierra Nevada. During late-Wisconsin deglaciation, lodgepole

pine grew at least 500 m lower in elevation than today. Lodgepole pine was widely established within its modern elevational range between 10, 500 and 9,000 years BP. During the early Holocene, lodgepole pine remained an integral member on montane forest assemblages below its present elevational range. Macrofossil evidence suggests successive disappearance from most lower elevation sites between 9,000 and 6,750 years BP. A likely explanation suggests progressive climatic warming and drying of soils during the dry Holocene, causing local extermination at the lower elevation sites. Within its present elevational range, a lack of macrofossils and a decline in diploxylon pollen suggests possible absence of lodgepole pine near several sites during the middle Holocene, with the tree continuing a retreat to higher, cooler elevations during this time. A return to lower elevation sites after ca 700 years BP probably resulted from cumulative cooling during the Neoglacial. The postglacial migration pattern for Sierra lodgepole pine differs somewhat from that of the more widely distributed Rocky Mountain subspecies (*P. contorta* var. latifolia). While the pattern for the Rocky Mountain lodgepole was both latitudinal and elevational (only now reaching its northernmost extent in Canada [Cwynar & McDonald, 1987]), Sierra lodgepole's migration was largely elevational with little migrational lag. Additional paleo-sites south of the present distribution of ssp. murrayana will help to clarify any latitudinal movements during the late Wisconsin.

18. Arno, S. F. and others. 1993.
Notes: Other Works Cited

19. Arno, S. F. and others. 1995.
Notes: Other Works Cited

20. Arno, S. F. 1988. Fire ecology and its management implications in ponderosa pine forests. In *Ponderosa Pine: The Species and its Management*, edited by Baumgartner, David M. and J. E. Lotan (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

21. Arno, S. F. and D. H. Davis. 1980. Fire history of western red cedar/hemlock forests in Northern Idaho. In *Proceedings of the Fire History Workshop*, edited by Stokes, M. A. and J. H. Dieterich (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-81).
Notes: Other Highly Relevant References

22. Arno, S. F. and T. D. Petersen. 1983. *Variation in estimates of fire intervals: a closer look at fire history on the Bitterroot National Forest*. Ogden, Utah: U. S. Forest Service, INT-GTR-301.
Notes: Other Highly Relevant References

23. Arno, S. F., D. G. Simmerman, and R. E. Keane. 1985. *Forest succession on four habitat types in Western Montana*. Ogden, Utah: U. S. Forest Service, INT-GTR-177.
Notes: Other Highly Relevant References

24. Arno, S. F., H. Y. Smith, and M. A. Krebs. 1997. *Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fires and fire exclusion*. Ogden, Utah: U. S. Forest Service, INT-RP-495.
Notes: Relevant Studies
Abstract: Presents detailed age structure for two western larch stands that historically experienced frequent fires. Compares age structures of eleven ponderosa pine and western larch stands representing a broad range of sites that had frequent fires. Interprets causal factors possibly linked to variations in stand age structures.

25. Attiwill. 1994.
Notes: Other Works Cited

26. Ayres, M. P. and Lombardero. 2000.
Notes: Other Works Cited

27. Bachelet, D. , J. M. Lenihan, and C. Daly. 2001. *MC1: a dynamic vegetation model for estimating the distribution of vegetation and associated ecosystem fluxes of carbon, nutrients, and water: technical documentation, version 1.0*. Portland, Oregon: U. S. Forest Service, PNW-GTR-508.
Notes: Supporting Summary Documents
Abstract: Assessments of vegetation response to climate change have generally been made only by equilibrium vegetation models that predict vegetation composition under steady-state conditions. These models do not simulate either ecosystem biogeochemical processes or changes in ecosystem structure that may, in turn, act as feedbacks in determining the dynamics of vegetation change. MC1 is a new dynamic global vegetation model created to assess potential impacts of global climate change on ecosystem structure and function at a wide range of spatial scales from landscape to global. This new tool allows us to incorporate transient dynamics and make real time predications about the patterns of ecological change. MC1 was created by combining physiologically based biogeographic rules defined in the MAPSS model with a modified version of the biogeochemical model, CENTURY. MC1 also includes a fire module, MCFIRE that mechanistically simulates the occurrence and impacts of fire events.

28. Bachelet, D. and R. P. Neilson. 2000. Biome redistribution under climate change. In *The Impact of Climate Change on American's Forests*, edited by Joyce, L. A. and R. Birdsey (Fort Collins, Colorado: U. S. Forest Service, RMRS-GTR-59).
Notes: Supporting Summary Documents
Abstract: This chapter addresses the following question: To what geographic extent will potential ecosystem types change or move across the United States, as measured in composition and boundary changes? To do so, the authors used results from three different studies and three different models (DOLY, MAPSS, and BIOME3) at two different spatial resolutions. Results include a discussion of North American, continental U.S., and regional impacts and implications. Results also include a discussion of model limitations, one of which is their ability to accurately predict the impact of disturbance (fire, drought, flooding, hail, hurricanes, and tornadoes).

29. Bailey, R. G. 1995. *Description of the ecoregions of the United States, 2nd Edition*. Washington, D. C.: U. S. Forest Service, Miscellaneous Publication #1391 (revised).
Notes: Highly Relevant Studies
Abstract: This publication describes and illustrates a map showing the ecosystems of regional extent, or ecoregions, differentiated according to a hierarchical scheme modified from Crowley (1967), using climate and vegetation as indicators of the extent of each unit.

30. Baker. 1988.
Notes: Other Works Cited

31. Baker, W. L. 1992. Effects of settlement and fire suppression on landscape structure. *Ecology* 73, no. 5:1879-1887.
Notes: Other Highly Relevant References

32. Barrett, J. W. and L. F. Roth. 1985. *Response of dwarf mistletoe-infested ponderosa pine to thinning: 1. sapling growth*. Portland, Oregon: U. S. Forest Service, PNW-RP-330.
Notes: Supporting Studies
Abstract: Observations of thinned ponderosa pine infested with dwarf mistletoe over a 17-year period suggests that on average or better sites most infested stands can be managed to produce usable wood products in reasonable time, if trends found in juvenile stands continue.

33. Barrett, S. W. and S. F. Arno. 1982. Indian fires as an ecological influence in the Northern Rockies. *Journal of Forestry* 80:647-651.
Notes: Other Highly Relevant References

34. Barrett, S. W., S. F. Arno, and J. P. Menakis. 1997. *Fire episodes in the Inland Northwest (1540-1940) based on fire history data*. Ogden, Utah: U. S. Forest Service, INT-GTR-370.

Notes: Highly Relevant Studies
Abstract: Information from fire history studies in the Northwestern United States was used to identify and map "fire episodes" (5 year periods) when fire records were most abundant. Episodes of widespread landscape-scale fires occurred at average intervals of 12 years. Mean annual acreage burned was calculated based on estimated areas of historical vegetation types with their associated fire intervals from the fire history studies. An average of about 6 million acres of forest and grass and shrubland burned annually with the 200 million acre Columbia River Basin study region, and especially active fire years probably burned twice this much area. For comparison, the largest known fire years since 1900 have each burned 2 million to 3 million acres in this region. We also compare the occurrence of regional fire episodes to drought cycles defined by tree-ring studies.

35. Bartos, D. L., F. R. Ward, and G. S. Innis. 1983. *Aspen succession in the intermountain west, a deterministic model*. Ogden, Utah: U. S. Forest Service, INT-GTR-153.
Notes: Other Works Cited

36. Baumgartner, David M., R. J. Boyd, D. W. Breuer, and D. L. Miller. 1986. *Weed control for forest productivity in the interior West.* Pullman, Washington: Washington State University, Cooperative Extension Unit.
Notes: Other Highly Relevant References

37. Beard, T. H. , N. E. Martin, and D. L Adams. 1983. Effects of habitat type and elevation on occurrence of *Stalactiform* blister rust in stands of lodgepole pine. *Plant Disease* 67:648-651.
Notes: Relevant Studies
Abstract: Stalactiform blister rust, caused by *Cronartium coleosporioides*, occurs on hard pines throughout the northern United States and Canada. Locations of lodgepole pine reported in disease surveys of Idaho forests, 1968-1980, showed stalactiform blister rust occurring at elevations between 1,500 and 2,477m. *Abies lasiocarpa*/*Xerophyllum tenax* and *A. lasiocarpa*/*Vaccinium scoparium* were the most common habitat types supporting lodgepole pine and stalactiform blister rust.

38. Belt, G. H., J. O'Laughlin, and T. Merrill. 1992. *Design of forest riparian buffer strips for the protection of water quality: analysis of scientific literature*. Moscow, Idaho: University of Idaho, Idaho Forest, Wildlife and Range Policy Analysis Group, Report #8.
Notes: Highly Relevant Summary Documents
Abstract: The primary purpose of this report is to identify, evaluate, and synthesize research-based information relating riparian buffer strips to forest practices, water quality, and fish habitat. Objectives for this report are stated as five focus questions around which the report is organized: [1] What is a buffer strip? [2] How do forest practices within buffer strips affect water quality and fish habitat? [3] How effective are buffer strips in reducing impacts of forest practices? [4] What are the issues in buffer strip design? [5] What models are available for use in buffer strip design?

39. Benda, L. E. and T. W. Cundy. 1990. Predicting deposition of debris flows in mountain channels. *Canadian Geotechnical Journal* 27:409-417.
Notes: Other Highly Relevant References
Abstract: An empirical model for predicting deposition of coarse-textured debris flows in confined mountain channels is developed based on field measurements of 14 debris flows in the Pacific Northwest, USA. The model uses two criteria for deposition: channel slope (less than 3.5°;) and tributary junction angle (greater than 70°;). The model is tested by predicting travel distances of 15 debris flows in the Oregon Coast Range and six debris flows in the Washington Cascades, USA. The model is further tested on 44 debris flows in two lithological types in the Oregon Coast Range using aerial photos and topographic maps; on these flows only the approximate travel distance is known.

40. Benda, L. E. and J. C. Sias. 1998. *Landscape controls on wood abundance in streams*. Seattle,

Washington: Unpublished manuscript, Earth Systems Institute.
Notes: Relevant Studies
Abstract: Storage of large woody debris in streams is variable in time and space because wood recruitment and transport are driven by episodic disturbances that occur over cycles of decades to centuries. Collecting information on woody debris by strictly empirical means is hindered by time limitations of field studies and complexities of natural environments. As a consequence, the range and magnitude of variability of wood in streams are not well constrained to circumvent those limitations, long-term patterns of wood recruitment, transport, and storage are evaluated by employing simplified expressions to represent climatic, biotic, and geomorphic processes. Five universal landscape processes that govern wood storage are considered: (1) Frequency of stand-resetting disturbances and subsequent trajectories of forest biomass accumulation and stand mortality; (2) intensity of bank erosion and its spatial variance in a network; (3) temporal and spatial frequency of mass wasting; (4) fluvial transport controlled by number of upstream contributing segments and wood loss through export or valley floor storage; and (5) rates of wood decay. The structure of variability in wood abundance, in the form of frequency distributions, is predictably constrained by the general magnitude of landscape process rates and vegetative characteristics of streamside forests. Variations in these attributes within individual watersheds and across different regions alter patterns of wood abundance. Relationships among landscape process rates, their spatial variance in a basin or landscape, and the resulting shapes of frequency distributions of wood recruitment and storage constitute a set of general theoretical principles which have practical applications, including: (I) Providing a framework for constructing wood budgets, including estimating the range and magnitude of variability in wood abundance; (II) generating testable hypotheses on current wood loading and future trends; and (III) setting realistic targets for future wood recruitment and storage.

41. Bendix. 1994.
Notes: Other Works Cited

42. Bethlahmy, N. 1974. More streamflow after a bark beetle epidemic. *Journal of Hydrology* 23:185-189.
Notes: Relevant Studies
Abstract: A beetle epidemic near the Continental Divide in Colorado destroyed the timber in two large drainages but bypassed a third drainage. Long-term streamflow records were available for the three drainages for the periods before and after the onset of the epidemic. Analysis of these records reveals that a major increase in streamflow occurred after the epidemic.

43. Beukema, S. J., J. A. Greenough, D. C. E. Robinson, W. A. Kurz, E. D. Reinhardt, N. L. Crookston, J. K. Brown, C. C. Hardy, and A. R. Stage. 1997. An introduction to the fire and fuels extension to FVS. In *Proceedings: Forest Vegetation Simulator Conference*, edited by Tech, R. M., Melinda Moeur, and J. Adams (Ogden, Utah: U. S. Forest Service, INT-GTR-373).
Notes: Supporting Summary Documents
Abstract: The fire Effects Model Extension is a new extension to FVS and PPE that allows users to simulate the effects of fire on a number of indicators, including stand structure and composition, fuel loading, and size and density of snags. In the absence of fire, the model can be used to simulate snag and fuel dynamics resulting from tree growth and mortality and stand management. While the model produces indicators of stand risk to fire (in terms of potential flame length), the model cannot be used to simulate fire spread or the probability of a fire. A brief description of the model is given here, with some sample results showing some of the new indicators at the stand and landscape level.

44. Bevins, C. D. 1980.
Notes: Other Works Cited

45. Bilby, Robert E. 1988. Interactions between aquatic and terrestrial systems. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington: University of Washington, Institute of Forest Resources Contribution #59).

Notes: Other Highly Relevant References

46. Bilby, Robert E. and J. W. Ward. 1987. *Changes in large organic debris characteristics and function with increasing stream size in Western Washington*. Weyerhauser Company, Technical Report.
Notes: Other Highly Relevant References

47. Bilby, Robert E. and L. J. Wasserman. 1989. Forest practices and riparian management in Washington State: data based regulation development. In *Practical Approaches to Riparian Management*, edited by Gresswell, Robert E., B. A. Barton, and J. L. Kershner (Billings, Montana: Bureau of Land Management, BLM-MT-PT-89-001).
Notes: Highly Relevant Summary Documents
Abstract: In the past, forest practice regulations for riparian zones in Washington have been based primarily on political, rather than scientific, considerations. In 1986 a new process, called Timber, Fish and Wildlife, attempted to formulate regulations based on technical data. Separate regulations were devised for eastern and western Washington due to the difference between the two regions in vegetation, climate, and timber management strategies. In western Washington, where clear-cutting is the predominant harvest method, regulations were based on existing data on large organic debris (LOD) loading in channels coupled with simulation models of stand dynamics. The regulations were designed to provide for the maintenance of LOD at the levels observed in streams in old-growth timber. Data for Eastern Washington riparian zones were collected specifically for the purpose of designing new regulations. Uneven-aged management is the most common silvicultural technique practiced in this area. Information was collected on riparian stand characteristics and LOD size and frequency in streams. Regulations were designed to maintain LOD levels observed in unmanaged stands and were based on relationships between stand density and LOD frequency. Wildlife needs were addressed by providing sufficient numbers of larger trees to generate snags, provide desired levels of canopy cover and maintain a multi-storied canopy.

48. Binkley, D. and T. C. Brown. 1993. *Management impacts on water quality of forests and rangelands*. Fort Collins, Colorado: U. S. Forest Service, RM-GTR-239.
Notes: General References
Abstract: Following an overview of water quality concerns in Chapter 1 and a description of basic forest and rangeland hydrology and water quality process in Chapter 2, we summarize what has been learned about the effects of land management practices on nonpoint source pollution at generally small experimental forest and rangeland sites in the United States and Canada. The final chapter describes laws affecting forest and rangeland water quality and the use of best management practices to protect water quality. The quality of water from forested watersheds is typically very good, even on disturbed and managed sites. At most sites, forest practices lead to minimal impacts on water quality and do not seriously impair fish habitat or water supplies. However, at more sensitive sites, special care is required. Existing best management practices, if followed, adequately protect forest water quality. Most states have active programs to promote the use of such practices. Unlike forest practices, impacts of grazing on water quality have received little careful study, and few states have specified best management practices to control grazing impacts. Future study is needed to improve the specification of best management practices for site specific forest situations. A sufficient base of information is also needed to design efficient best management practices for rangelands.

49. Biswell, H. H. 1989. *Prescribed burning in California wildlands vegetation management*. Berkeley, California: University of California Press.
Notes: Other Highly Relevant References

50. Bork, J. L. 1984. *Fire history in three vegetation types on the Eastern Side of the Oregon Cascades*. Corvallis, Oregon: Doctoral Dissertation, Oregon State University.
Notes: Supporting Studies
Abstract: Historic fire return intervals in three different vegetation types dominated by ponderosa pine (*Pinus ponderosa* Laws.) were determined using fire scarred trees.

Dendrochronological techniques were used to achieve accuracy in dating fire scars on samples colleted from six 40 acre plots established in each site. Mean fire return intervals (MFRI) differed for site and plots within each site; Pringle Butte site showed the shortest MFRI of 4 years with an average of 11 years for individual plots, Cabin Lake site had a 7 year MFRI and a 24 year MFRI for plots, while Lookout Mountain site had a MFRI of 8 years and 16 years for plots. The overall average for plots incorporates all of the data for the site but uses a 40 acre plot mean to determine length of time required for fire to return to the same location, giving a more accurate indication of MFRI in a given stand. The plot mean may be the most useful way of expressing the data. Basal area and understory vegetation were found to be useful for predicting MFRI. Tree-ring chronologies from the three sites were examined to determine their suitability for climatic interpretation. Statistics show low mean sensitivities, high serial correlations and low variance for all trees and cores, suggesting that chronologies are of limited use for climatic analysis. However, climatic information was found. Growth patterns in sites show similar years for drought and high precipitation. Long-term trends were not evident at Cabin Lake or Lookout Mountain. Pringle Butte provided the chronology most useful for estimating climatic history, with 3 long periods of slow growth, 1900-1980, 1710-1790, and 1590-1640.

51. Boyd, R. J. 1986. Caution-silvicultural weed control may not improve tree performance. In *Weed Control for Forest Productivity in the Interior West*, edited by Baumgartner, David M., R. J. Boyd, D. W. Breuer, and Miller D. L. (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

52. Bradley, W. P. 1988. Riparian management practices on Indian lands. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington: University of Washington, Institute of Forest Resources, Contribution #59).
Notes: Other Works Cited

53. Bragg, D. C. 1997. Simulating catastrophic disturbance effects on coarse woody debris production and delivery. In *Proceedings: Forest Vegetation Simulator Conference*, edited by Tech, R. M., Melinda Moeur, and J. Adams (Ogden, Utah: U. S. Forest Service, INT-GTR-373).
Notes: Relevant Studies
Abstract: For decades, coarse woody debris (CWD) recruitment has remained a largely unknown component of riparian zone management. The integration of the Forest Vegetation Simulator (FVS) and a mechanistic CWD recruitment post-processor (CWD) provided insights into some of the factors involved in CWD delivery though the comparison of two simulated catastrophic disturbances (a spruce beetle outbreak and a clearcut) and an unmanipulated old-growth control. Compared to the old-growth control, spruce beetle-impacted riparian forest varied the timing and increased the overall delivery of CWD, while to clearcut reduced delivery and in-stream loads for many years. This exercise also suggested that natural catastrophic disturbance in riparian forest may bolster CWD recruitment, a process that could prove beneficial in the recovery of CWD-depauperate streams.

54. Bren, L. J. 1995. Aspects of the geometry of riparian buffer strips and its significance to forestry operations. *Forest Ecology and Management* 75, no. 1:1-10.
Notes: Supporting Studies
Abstract: A stream buffer strip is an area within a defined distance from a stream in which land use activities are restricted for stream protection purposes. This study used a sophisticated Geographic Information System to examine the extent, distribution, and boundary properties of land defined by buffer strips of differing widths. The prototype catchment studied was the mountainous $65 km^2$ Tarago River catchment in eastern Victoria. The West Tarago River is a fourth-order stream network. This was accurately delineated using the topographic map supplemented by high quality aerial color transparencies. This showed that the map had inadequate detail of smaller streams. The streams had a branching network with an overall fractal dimension (measure of complexity) of 1.75, although the fractal dimension of the

individual stream reaches was only slightly greater than one. The area of land occupied by buffers increased substantially with increasing width of buffers, with 95% of the catchment occupied by buffers of 300m width. As buffer width increased to 100m, many areas became entrapped by buffers and hence became effectively inaccessible. Individual boundaries reached their greatest complexity at 10m buffer width, but the buffer/non-buffer network achieved greatest complexity at 100 m buffer width. Small buffers had a very high perimeter/area ratio. As buffer width increased the perimeter/area ratio of non-buffer areas slowly increased, reflecting that non-buffer areas were becoming smaller and more fragmented.

55. Brinson, M. M., B. L. Swift, R. C. Plantico, and J. S. Barclay. 1981. *Riparian ecosystems: their ecology and status*. Kearneysville, West Virginia: U. S. Fish and Wildlife Service, FWS-OBS-81/17.
Notes: Other Highly Relevant References

56. Britton, D. L. 1991. Fire and the chemistry of a South African mountain stream. *Hydrobiologia* 218:177-192.
Notes: Relevant Studies
Abstract: The effects of a late-summer prescribed burn on the chemistry of a second-order mountain stream in the south-western Cape, South Africa were investigated. Nitrate concentrations in stream water were significantly higher during the winter of the post-burn year. Increased concentrations of chloride, bicarbonate, polyphenols and potassium and decreased sodium concentrations were also recorded. The burn did not significantly affect concentrations of ammonium, phosphate, calcium, magnesium, total dissolved solids and hydrogen's ions. Ionic export form the catchment was generally greater in the post-burn year. Apart from nitrate, however, values probably lie within the natural range of year-to-year variation. It is predicted that enhanced losses of nitrate will decrease progressively with the recovery of the vegetation and the re-establishment of soil/plant nutrient cycles. Atmospheric losses of nutrients in smoke were unquantified, but may be of more significance to site productivity than losses though surface runoff, which, in the case of nitrogen, appear to be compensated by precipitation inputs.

57. Britton, D. L. 1990. Fire and the dynamics of allochthonous detritus in a South African mountain stream. *Freshwater Biology* 24:347-360.
Notes: Relevant Studies
Abstract: (1) Input of allochthonous material, standing stocks of benthic organic matter (BOM) and suspended particulate organic matter (POM) were measured in a south-western Cape mountain stream from March 1986 to February 1988. The surrounding fynbos-dominated catchment was subjected to a prescribed burn in March 1987. (2) Litter-fall in the pre-burn year exhibited a distinct seasonal pattern, with peak falls during the early summer. Although the fire did not directly affect the riparian canopy, in that it did not burn, a heavy seasonal leaf-fall occurred shortly afterwards. The following summer, litter-fall was less than half that of the pre-burn summer. (3) Standing stocks of BOM were significantly higher in autumn than in winter in the pre-burn year and were inversely related to discharge. Despite the heavy post-burn leaf-fall and low litter-fall during the post-burn summer, there was no significant difference between pre and post-burn BOM standing stocks. (4) Proportions and quantities of fine benthic organic matter (FBOM) in the soft BOM fraction were significantly higher in the post-burn spring, and monthly accumulation of ultra-fine benthic organic matter (UBOM) was also significantly higher in the post-burn spring and summer. These results may reflect accelerated decay rates of BOM in response to enhanced post-burn nitrate concentrations in stream water. (5) Export of CPOM was low in comparison to FPOM and particularly to UPOM, and the stream appears to be highly retentive of CPOM. (6) The natural resilience of the riparian vegetation minimizes the potentially disturbing effects of fire on the stream environment. As a result, the prescribed burn had a less than expected effect on both standing stocks of BOM and the stream environment in general.

58. Brookes, M. H., R. W. Stark, and Robert W. Campbell. 1978. *Douglas-fir tussock moth: a synthesis*. Washington, D. C.: U. S. Department of Agriculture, Technical Bulletin #1585.
Notes: Other Works Cited

59. Brosofske, K. D., J. Chen, Robert J. Naiman, and Jerry F. Franklin. 1997. Harvesting effects on microclimate gradients from small streams to uplands in Western Washington. *Ecological Applications* 7, no. 4:1188-1200.
Notes: Other Highly Relevant References

60. Brown. 1978.
Notes: Other Works Cited

61. Brown. 1983.
Notes: Other Works Cited

62. Brown, J. K. 1985. Fire effects and application of prescribed fire in aspen. In *Rangeland Fire Effects: A Symposium*, edited by Sanders, K. and J. Durham (Boise, Idaho: Bureau of Land Management, Idaho State Office).
Notes: Relevant Studies
Abstract: The influence of low- and high-intensity fire on successional patterns of climax and seral aspen (*Populus tremuloides*) is discussed. Mechanisms of aspen regeneration and how fire affects these mechanisms are reviewed. Sucker densities following fire and the influence of fire severity and intensity on sucker response are discussed. Understory response to fire and grazing is summarized from the literature. Appropriate land management and fire objectives are suggested for maintaining the aspen forest. A vegetation-fuel classification is described that recognizes three classes where aspen dominates: aspen-shrub, aspen-tall forb, and aspen-low forb. Two classes are recognized in mixed conifer-aspen forests: mixed-shrub and mixed-forb. Fuel loadings, fire intensities, and probabilities of successful prescribed fire are described. The aspen-shrub class is the most flammable and aspen-low forb and mixed-forb classes are the least flammable. Flammability is altered by slope, grazing intensity, curing of herbaceous vegetation, quantities of downed wood material, crown closure, and pocket gopher activity. Methods of predicting and estimating live fuel moisture contents are described.

63. Brown, J. K. and N. V. DeByle. 1989. *Effects of prescribed fire on biomass and plant succession in western aspen*. Ogden, Utah: U. S. Forest Service, INT-RP-412.
Notes: Relevant Studies
Abstract: Plant succession and production of biomass were determined for three prescribed fires in aspen (*Populus tremuloides*) and aspen-conifer forests. Forbs and shrubs dominated the understories. Preburn fuel loadings ranged from 19,200 to 56,400 kg/ha. Fires ranged from low to high severity and overstory mortality from 20 to 100 percent. Total fuel consumption alone was poorly related to fire severity. Over 4 postburn years, production of grasses and forbs averaged 1.5 to 3.3 times that of the controls. Maximum production was 2,240 kg/ha, five times that of the associated control. High-severity fire favored forbs over grasses. After 5 years, shrub biomass was 21 to 100 percent of preburn biomass. The proportion of shrub biomass less than 0.5cm diameter peaked after 2 years. Species responses were varied. Aspen sucker densities peaked during the first 2 postburn years and ranged from one-half to five fold their preburn densities. Suckering was most prolific following fire of moderate to high severity. The varied patterns of seral vegetation and their management implications are discussed.

64. Brown, T. C. and D. Binkley. 1994. *Effect of management on water quality in North American forests.* Fort Collins, Colorado: U. S. Forest Service, RM-GTR-248.
Notes: Relevant Studies
Abstract: Although the quality of water draining forested watersheds is typically the best in the Nation, some forest management practices can seriously impair streamwater quality. Sediment is the main concern. High suspended sediment levels, and adverse changes in stream channels, are potential problems in several regions, especially after road construction, and some harvesting and grazing practices. Impacts are most serious where fish reproduction is affected. Nitrate and water temperature are less serious problems. Harvesting can increase nitrate levels markedly, in some locations; and removal of overstory from along streambanks can raise water temperatures enough to impair fish survival. Best management practices (BMPs) can avoid

most of these harmful effects. Additional work is needed, in some locations, to encourage BMP use and to tailor BMP specifications to site-specific conditions.

65. Bull, E. L, K. B. Aubry, and B. C. Wales. 2001. Effects of disturbance on forest carnivores of conservation concern. *Northwest Science* 75:180-184.
Notes: Highly Relevant Summary Documents
Abstract: The effects on forest carnivores of forest insects, tree diseases, wildfire, and management strategies designed to improve forest health (e.g., thinning, salvage operations, prescribed burns, and road removal) are discussed. Forest carnivores of conservation concerns in eastern Oregon and Washington include the Canada Lynx (*Lynx canadensis*), wolverine (*Gulo gulo*) and fisher (*Martes pennanti*). All three species depend to some degree on forest structures, stands, and landscapes created by insects, disease, and fire. Wildfire and insect outbreaks maintain a mosaic of structural stages across the landscape that is used by lynx. Thinning of dense lodgepole pine (*Pinus contorta*) stands that result largely from wildfire and insect outbreaks is detrimental to snowshoe hares (*Lepus americanus*), which are the primary prey of lynx. Fishers use large stands of mature forest and snags, hollow live trees, logs, stumps, witches-brooms, and other structures for rest and den sites Salvage harvesting, thinning, and conversion from predominantly fir stands to ponderosa pine (*Pinus ponderosa*) may adversely affect habitat conditions for fishers. Use of roads is perhaps most detrimental to wolverines because they are easily trapped and avoid humans.

66. Burton, T. A., D. M. Dether, J. R. Erickson, J. P. Frost, L. Z. Morelan, L. F. Neuenschwander, W. R. Rush, J. L. Thorton, and C. A. Weiland. 1999. A fire-based hazard/risk assessment. *Fire Management Notes* 59, no. 2:31-36.
Notes: Relevant Studies
Abstract: In the Boise National Forest, wildfires in ponderosa pine forest have been increasingly large and severe since 1986. To respond to the threat to the forest's ponderosa pine ecosystem, a forest interdisciplinary team, working in partnership with the University of Idaho, developed a hazard/risk assessment using a geographic information system (GIS). This paper provides a description of the assessment, the methodology used to develop it, and the results of the analysis.

67. Busch, D. E. 1993. Fire in southwestern riparian habitats: functional and community responses. In *Sustainable Ecological Systems: Implementing an Ecological Approach to Land Management*, edited by Covington, W. W. and L. F. DeBano (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-247).
Notes: Relevant Studies
Abstract: A study of how fire affected riparian ecosystem processes in the lower Colorado and Bill Williams River floodplains. The study reports on both the functional responses (e.g., soil properties, leaf nitrogen concentrations) and community responses (e.g., relative cover and frequency of various species) of over 11,000 hectares of riparian vegetation subject to 166 fires between 1981 and 1992.

68. Busch, D. E. and S. D. Smith. 1993. Effects of fire on water and salinity relations of riparian woody taxa. *Oecologia* 94:186-194.
Notes: Relevant Studies
Abstract: Water and salinity relations were evaluated in recovering burned individuals of the dominant woody taxa from low-elevation riparian plant communities of the southwestern U. S. Soil elemental analyses indicated that concentrations of most nutrients increased following fire, contributing to a potential nutrient abundance but also elevated alluvium salinity. Boron, to which naturalized *Tamarix ramosissima* is tolerant, was also elevated in soils following fire. Lower moisture in the upper 30cm of burned site soil profiles was attributed to shifts in evapotranspiration following fire. Higher leaf stomatal conductance occurred in all taxa on burned sites. This is apparently due to higher photosynthetic photon flux density at the midcanopy level and may be partially mitigated by reduced unit growth in resprouting burned individuals. Predawn water potentials varied little among sites, as was expected for plants

exhibiting largely phreatophytic water uptake. Midday water potentials in recovering *Salix gooddingii* growing in the Colorado River floodplain reached levels that are considered stressful. Decreased hydraulic efficiency was also indicated for this species by examining transpiration water potential regressions. Recovering burned *Tamarix* and *Tessaria* sericea had enriched leaf tissue S13C relative to unburned controls. Higher water used efficiency following fire in these taxa may be attributed to halophytic adaptations, and to elevated foliar nitrogen in *Tessaria*. Consequently, mechanisms are proposed which would facilitate increased community dominance of *Tamarix* and *Tessaria* in association with fire. The theory that invading species alters whole ecosystem processes may thus be extended to include those processes related to disturbance.

69. Calhoun, J. M. 1988. Riparian management practices of the Department of Natural Resources. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington: University of Washington, Institute of Forest Resources, Contribution #59).
Notes: Other Works Cited

70. Camp, A. E. 1996.
Notes: Other Works Cited

71. Camp, A. E. 1999. Age structure and species composition changes resulting from altered disturbance regimes on the eastern slopes of the Cascade Range, Washington. *Journal of Sustainable Forestry* 9, no. 3/4:39-67.
Notes: Highly Relevant Studies
Abstract: Age and diameter distributions are powerful tools for assessing changes in forest structure and composition over time. This study analyzed the age distribution of 2,345 trees from 487 plots in the Eastern Washington Cascades to document increases in per-hectare tree densities and shifts in species composition since Euro-American settlement. Diameter distributions of these trees plus an additional 814 snags, stumps, and logs were analyzed to determine the extent and pattern of structural and compositional change resulting from post-settlement fire exclusion and preferential harvest of large ponderosa pine (*Pinus ponderosa* v. Dougl. Ex Laws.) and western larch (*Larix occidentalis* v. Nutt.). Per-hectare densities of most species increased following settlement, with shade-tolerant/fire-intolerant species showing the biggest gain. A comparison of diameter distributions for live and dead trees indicates existing stands may not provide snags and logs of adequate dimensions for future habitat needs. Changes in forest structure and composition over the past century increase risk for insect outbreaks, diseases, and catastrophic wildfires.

72. Camp, A. E., P. F. Hessburg, and Richard L. Everett. 1996. Dynamically incorporating late-successional forest in sustainable landscapes. In *The Use of Fire in Forest Restoration*, edited by Hardy, C. C. and S. F. Arno (Ogden, Utah: U. S. Forest Service, INT-GTR-341).
Notes: Other Highly Relevant References

73. Camp, A. E., C. D. Oliver, P. F. Hessburg, and Richard L. Everett. 1997. Predicting late-successional fire refugia pre-dating European settlement in the Wenatchee Mountains. *Forest Ecology and Management* 95:63-77.
Notes: Relevant Studies
Abstract: Fires occur frequently in dry forests of the Inland West. Fire effects vary across the landscape, reflecting topography, elevation, aspect, slope, soils, and vegetation attributes. Patches minimally affected by successive fires may be thought of as 'refugia', islands of older forest in a younger forest matrix. Refugia support species absent within the landscape matrix. Our goal was to predict the occurrence of pre-settlement refugia using physiographic and topographic variables.

We evaluated 487 plots across a 47,000ha landscape using three criteria to identify historical fire refugia: different structure from surrounding matrix; different fire regime from surrounding matrix; presence of old individuals of fire-intolerant tree species. Several combinations of aspect, elevation, and topography best predicted refugial presence.

Less than 20% of the pre-settlement landscape was identified as historical fire refugia. Refugia were not connected except by younger stands within the matrix. Current management goals of increasing amounts and connectivity of old, refugia-like and catastrophic wildfires.

74. Campbell, Alsie G. and Jerry F. Franklin. 1979. *Riparian vegetation in Oregon's western Cascade Mountains: composition, biomass and autumn phenology*. Seattle, Washington: University of Washington, Coniferous Forest Biome, Bulletin #14.
Notes: Other Works Cited

75. Campbell, Alsie G., P. M. Wohlgemuth, and W. G. Wells. 1987. Post-fire response of a boulder-bed channel. In *Erosion and Sedimentation in the Pacific Rim: Proceedings at the Corvallis Symposium Held at Oregon State University*, edited by Beschta, R. L., T. Blinn, G. E. Grant, F. J. Swanson, and G. G. Ice (Wallingford, Oxfordshire, England: International Association of Hydrological Sciences, Publication #165).
Notes: Relevant Studies
Abstract: This study investigated the post-fire response of a boulder-bed channel in a 4 km^2 portion of the Santa Ynez River drainage basin (34 29' N, 119 26' W) that burned in the Wheeler Fire of July 1985. Four representative channel reaches were selected for surveys during October 1985 and March 1986. The study found that while the general pattern of channel response was aggradation followed by degradation, the response at individual cross sections varied. The responses of the channel may have been related to changing erodibility of slopes that were actively recovering, variations in precipitation, and the distribution of boulders along the stream channel.

76. Campbell, I. C. and T. J. Doeg. 1989. Impact of timber harvesting and production on streams: a review. *Australian Journal of Marine and Freshwater Research* 40:519-539.
Notes: Supporting Summary Documents
Abstract: Timber harvesting operations have significant effects on both water quantity and water quality. The effects on water quantity have been well documented both in Australia and elsewhere. The effects on water quality are less widely appreciated, and include elevated concentrations of dissolved salts, suspended solids and nutrients, especially during peak flow periods. Several Australian studies have failed to measure peak flow transport of suspended solids, or have measured it inadequately, thus severely underestimating transport.

The major short-term effects of timber harvesting on the aquatic biota result from increased sediment input into streams or increased light through damage to, or removal of, the riparian vegetation. Sediment that settles on, or penetrates into, the streambed is of more concern than suspended sediment, and can lead to long-term deleterious changes to fish and invertebrate populations. Increased light causes an increase in stream primary production that may increase invertebrate densities, and alter community composition. These biological consequences have not yet been adequately investigated in Australia. Longer-term effects, as yet not investigated in Australia, include changes to stream structure as the re-growth forest has fewer large logs to fall into the stream. These large logs play a major role as habitat and retention structures in streams.

There has been no attempt to evaluate the effects of timber production activities, including pesticide use and fuel reduction burning on the Australian stream biota. Likewise, although buffer zones are widely advocated as a protection measure for streams in Australia, there have been no studies to evaluate their effectiveness.

77. Campbell, S. and L. Liegel. 1996. *Disturbance and forest health in Oregon and Washington*. Portland, Oregon: U. S. Forest Service, PNW-GTR-381.
Notes: Highly Relevant Summary Documents
Abstract: The scope and intensity of disturbance by such agents as fire, insects, diseases, air

pollution, and weather in Pacific Northwest forests suggests that the forest health has declined in recent years in many areas. The most significant disturbances and causes of tree mortality or decline in Oregon and Washington are presented and illustrated. We discuss the interrelations of disturbance with forest management actives and the effect on native trees and suggest some solutions for reducing the severity of disturbance. One chapter reports on a forest health monitoring pilot project.

78. Campbell, S. , K. Ripley, and K. Snell. 1996. An overview of disturbance and forest health in Oregon and Washington. In *Disturbance and Forest Health in Oregon and Washington*, edited by Campbell, S. and L. Liegel (Portland, Oregon: U. S. Forest Service, PNW-GTR-381).
Notes: Highly Relevant Summary Documents
Abstract: This report was written to help people understand the disturbances at work in the forests of Oregon and Washington, their significance, the underlying causes, and possible actions to improve forest health. Chapter 1 is devoted to some forest health topics that people in both states are concerned about: vegetation change, mortality, weather trends, exotic pests, and air pollution. We also include a section on forest health monitoring methods.

79. Caprio, A. C. and T. W. Swetnam. 1995. Historic fire regimes along an elevational gradient on the West Slope of the Sierra Nevada, California. In *Proceedings: Symposium on Fire in Wilderness and Park Management*, edited by Brown, J. K., R. W. Mutch, C. W. Spoon, and R. H. Wakimoto (Ogden, Utah: U. S. Forest Service, INT-GTR-320).
Notes: Relevant Studies
Abstract: A study documenting fire occurrence patterns in the montane forest stands on the east slope of the Sierra Nevada for the last 300 to 400 years using dendrochronological analysis of tree-ring samples. This work is part of a larger research effort to understand and predict climate-related changes in ecosystems of the Sierra Nevada. Includes an analysis of the spatial and temporal fire patterns since 1700.

80. Caraher and others. 1979.
Notes: Other Works Cited

81. Carleson and Wilson. 1985.
Notes: Other Works Cited

82. Carlson, C. E. 1989. Influence of habitat types on forest pests of the Northern Rocky Mountains. In *Proceedings - Land Classifications Based on Vegetation: Applications for Resource Management*, edited by Ferguson, D. E., P. Morgan, and F. D. Johnson (Ogden, Utah: U. S. Forest Service, INT-GTR-257).
Notes: Supporting Summary Documents
Abstract: Major pests of Northern Rocky Mountain forests are affected by environmental conditions and vegetation depicted by habitat types (h.t.), but the interactions are weakly understood. Mountain pine beetle activity is limited in high-elevation PICO and ABLA h.t.'s where weather is very cold and moist, but is high in mid-elevation ABLA and PSME types where weather is more moderate. Western spruce budworm is most active on dry, warm PSME and ABGR h.t.'s, and similar to the beetle, is least active in the cold, wet ABLA types. *Armillaria spp.* occur most frequently in the productive ABGR, THPL, and TSHE h.t.'s but cause most damage in the poorer PSME and ABGR types. Susceptibility (probability of occurrence) and vulnerability (probability of damage) to all three pests seem to depend on relative shade tolerance of the host species. In general, when more than one host species is present, the most shade-tolerant ones, or the indicated climax, will be most susceptible and vulnerable to the pest. But when only one host species is present, and it is seral--such as lodgepole pine on ABLA h.t.s'--it may be extensively exploited by the pest. Multiple-use values are usually enhanced when forest management is structured to favor the seral species.

83. Catellino and others. 1979.
Notes: Other Works Cited

84. Chen, J., Jerry F. Franklin, and T. A. Spies. 1990. Microclimatic pattern and basic biological responses at the clearcut edges of old-growth douglas fir stands. *Northwest Environmental Journal* 6, no. 2:424-425.
Notes: Relevant Studies
Abstract: Microclimatic patterns and associated biological features have been under study along edges of mature and old-growth douglas fir (*Pseudotsuga menziesii*) fires in the Pacific Northwest since 1988. Preliminary results are presented here. This study has focused on forest edges adjacent to recent clearcuts. Edge exposure (orientation) is a primary variable. At each edge, portable weather stations and sampling plots are established at seven points along a transect extending from a clearcut to the interior (240m) of the forest during summer and early fall. Temperature and moisture content of air and soil, wind speed, and short-wave radiation are monitored. Tree growth, regeneration, mortality, and stem distribution are measured on sample plots. Twenty different edges were studied during 1988 and 1989, in and around the H. J. Andrews (OR) and Wind River (WA) Experimental Forests.

85. Childs, T. W. 1968. *Elytroderma disease of ponderosa pine in the Pacific Northwest*. Portland, Oregon: U. S. Forest Service, PNW-RP-69.
Notes: Supporting Summary Documents
Abstract: The needle cast of *Pinus ponderosa* caused by *Elytroderma deformans* is a native disease that intermittently causes severe local damage. The fungus is perennial within the host, where it spreads vegetatively from one twig or branch to another. Even in its vegetative stage the fungus appears unusually sensitive to climatic stresses.

Foliage on infected twigs dies early in its second year, and the twigs usually die within a few years. Growth rates are reducing in approximated proportion to extent of crown damage. Uncrowned saplings and poles with healthy leaders can recover eventually from fairly severe infection if they are not attacked by other parasites while weakened. In mature stands, crown damage from extensive killing of twigs and branches is permanent, moderately infected trees become and remain more susceptible to root disease and beetle attack, and heavily infected trees are often killed directly by defoliation.

Despite its alarming appearance in outbreak centers, the disease is just another of the many normal hazards to which forests are subject. It does not threaten to exterminate ponderosa pine as a commercial species even on local areas, and usual good management practices should go far towards reducing its future inroads.

86. Chojnacky, D. C., B. J. Bentz, and J. A. Logan. 2000. *Mountain pine beetle attack in ponderosa pine: comparing methods for rating susceptibility*. Fort Collins, Colorado: U. S. Forest Service, RMRS-RP-26.
Notes: Supporting Studies
Abstract: Two empirical methods for rating susceptibility of mountain pine beetle attack in ponderosa pine were evaluated. The methods were compared to stand data modeled to objectively rate each sampled stand for susceptibly to bark-beetle attack. Data on bark-beetle attacks, from a survey of 45 sites throughout the Colorado Plateau, were modeled using logistic regression to estimate the probability of attack on individual trees from tree and stand variables. The logistic model allowed flexibility to easily scale results up to a stand level for comparison to the empirical methods. The empirical methods, developed by Munson and Anhold, most closely correlated to the logistic regression results. However, the Munson/Anhold method rated all 45 study sites as either moderately or highly susceptible to bark-beetle attack, which raises concern about its lack of sensitivity. Future work on evaluating risk of bark-beetle impact should consider more than stand characteristics.

87. Cochran, P. H. 1979.
Notes: Other Works Cited

88. Cochran, P. H. and others. 1995.

Notes: Other Works Cited

89. Cochran, P. H. and J. W. Barrett. 1999. *Growth of ponderosa pine thinned to different stocking levels in Central Oregon: 30-year results*. Portland, Oregon: U. S. Forest Service, PNW-RP-508.
Notes: Relevant Studies
Abstract: No mortality occurred at the lowest growing stock level (GSL) during any of the six 5-year periods of study. After the first period, plot mortality never exceeded two trees per acre for any 5-year period where stand density index values were below 240 at the start of the period. All mortality was attributed to mountain pine beetles (*Dendroctonus ponderosae* Hopkins). Pandora moth (*Coloradia pandora* Blake) caused partial defoliation during 1992 and 1994, which reduced growth rates in the last period (1991-95). Periodic annual increments for survivor quadratic mean diameters decreased curvilinearly with increasing GSLs, and the survivor height PAI-GSL relation varied with period. Gross volume and basal area PAI increased linearly with increasing GSLs. Gross basal area PAI and 30-year mean annual growth rates increased with increasing GSLs, but a significant curvilinear relation was not detected. Scribner board-foot yields at the stand age of 95 years increased linearly with increasing GSLs, while corresponding cubic-volume yields increased with increasing GSLs only if the initial thinnings were excluded. Mean annual increments (MAIs) for cubic volume increased with increasing stand age for all GSLs only if the initial thinning was excluded. Board-foot MAIs, with and without inclusion of initial thinning, increased with increasing stand age and with increasing GSLs. Mean annual growth of basal area and cubic volume for the 20 trees per acre with the largest diameters at the start of the study decreased curvilinearly with increasing GSLs. Increased periodic thinning levels greatly increased average tree size and reduced basal area and volume growth rates per acre.

90. Cochran, P. H. and J. W. Barrett. 1998. *Thirty-five-year growth of thinned and unthinned ponderosa pine in the Methow Valley of Northern Washington*. Portland, Oregon: U. S. Forest Service, PNW-RP-502.
Notes: Supporting Studies
Abstract: It is commonly expected that self-thinning will maintain small-diameter stands at near-normal densities and allow dominant trees to grow reasonably well. Such self-thinning did not occur in the unthinned plots in a thinning study in the Methow Valley of northern Washington, even though there was some suppression-caused mortality. A shift from suppression-caused mortality to insect-caused mortality took place when quadratic mean diameters (QMDs) reached 7 inches. Thinning to spacing wider that 9.3 feet reduced growth of both basal area and cubic volume per acre but greatly increased growth of board-foot volume per acre, and diameter and height growth. Periodic annual increments of cubic volume and QMD are curvilinearly related to stand density index. Growth of the largest 62 trees per acre was clearly reduced by the presence of smaller trees in the stand. Density management is necessary to produce reasonable growth rates of even the largest trees in the stand and to speed the development of mid-seral conditions.

91. Cochran, P. H. and Walter G. Dahms. 2000. *Growth of lodgepole pine thinned to various densities on two sites with differing productivities in Central Oregon*. Portland, Oregon: U. S. Forest Service, PNW-RP-520.
Notes: Supporting Studies
Abstract: Plots in two natural lodgepole pine (*Pinus contorta* Dougl. Ex Loud.) stands with differing productivities were repeatedly thinned to one of five growing-stock levels (GSLs). Bole area was used to define GSLs. A linear relation between stand density index (SDI) and bole area was found after each thinning on the highly productive site, but the slope of this relation decreased with successive thinning as trees grew larger. On the site with intermediate productivity, the upper limit for bole area was higher and a curvilinear SDI-bole area relation occurred. A constant bole area level probably does not represent the same competition level across a range of tree sizes. Low incidence of mortality caused by mountain pine beetle (*Dendroctonus ponderosae* Hopkins) occurred at SDIs below 170 for both sites. Concave curvilinear decreases in diameter growth occurred with increasing GSLs. Significant decreases in height growth with increasing GSLs were not detected. A convex curvilinear increase in

gross basal-area growth and cubic-volume growth took place with increasing GSLs. Gross total cubic-volume PAIs increased with increasing SDIs for both sites until stand densities reached 95 percent of the normal stand SDI. These cubic-volume PAI-SDI curves then flattened with increasing SDIs. Maximum cumulative net cubic-volume (total and merchantable) and board-foot yields were produced at the intermediate growing-stock level at the high site. Little apparent difference in these yields occurred among the four highest GSLs at the intermediate site. Net total cubic-volume yield was higher for the three highest GSLs than net yields for unmanaged stands from yield tables at comparable sites and ages. These studies have not continued long enough to determine the approximate age of culmination of net mean annual cubic-or board-foot volume increments. Ponderosa pine (*Pinus ponderosa* Dougl. Ex Law.) outgrew lodgepole pine for the range of stand ages on the highly productive site where the growth of both species was examined (33 to 58 years). Ponderosa pine should not be planted on lodgepole pine sites on flats and basins, however, because ponderosa pine is subject to radiation frost damage. Early spacing control coupled with later commercial thinning to keep stand densities between SDI 114 and SDI 170 should reduce mortality considerably, allow most of the wood produced to be captured by merchantable trees, and greatly increase quadratic mean diameters and live crown ratio over unmanaged stands at the same age. These stands would be more pleasing visually, and their rotation ages may be longer.

92. Cochran, P. H. and Walter G. Dahms. 1998. *Lodgepole pine development after early spacing in the Blue Mountains of Oregon*. Portland, Oregon: U. S. Forest Service, PNW-RP-503.
Notes: Supporting Summary Documents
Abstract: Seedlings were thinned to spacing of 6, 9, 12, 15 and 18 feet and measured periodically. Twenty-seven years after treatment, quadratic mean diameters increased curvilinearly ($p < 0.05$) as spacing increased, but total height did not differ significantly ($p<0.05$) with spacing. Corresponding basal areas decreased curvilinearly ($p<0.05$), and cubic volumes decreased linearly ($p<0.05$) as spacing increased. All periodic annual increments differed with period or age. Periodic annual increments for mean diameter and basal area varied curvilinearly ($p<0.05$), whereas volume increments varied linearly ($p<0.05$) with spacing for each period. Height increments were greatest at intermediate spacing during some periods, at wide spacing during other periods, and at the narrowest spacing during one period. Crown widths increased ($p<0.05$) as spacing widened. Fifty percent crown cover was attained at a stand density index of about 80 for all spacing. Simulation to a breast high age of 100 years indicated that the most merchantable cubic volume was produced at the 6-foot spacing but that the 12-, 15-, and 18-foot spacing produced about the same board-foot volume.

93. Cochran, P. H., J. M. Geist, and D. L. Clemens. 1994. *Suggested stocking levels for forest stands in Northeastern Oregon and Southeastern Washington*. Portland, Oregon: U. S. Forest Service, PNW-RN-513.
Notes: Supporting Studies
Abstract: Catastrophes and manipulation of stocking levels are important determinants of stand development and the appearance of future forest landscapes. Managers need stocking level guides, particularly for sites incapable of supporting stocking levels presented in normal yield tables. Growth basal area (GBA) has been used by some managers in attempts to assess inherent differences in site occupancy but rarely has been related to Gingrich-type stocking guides. To take advantage of information currently available, we used some assumptions to relate GBA to stand density index (SDI) and then created stocking level curves for use in northeastern Oregon and southeastern Washington. Use of these curves cannot be expected to eliminate all insect and disease problems. Impacts of diseases, except dwarf mistletoe (*Arceuthobium campylopodum* Engelm.), and of insects, except mountain pine beetle (*Dendroctonus ponderosea* Hopkins) and perhaps western pine beetle (*Dentroctonus brevicomis* LeConte), may be independent of density. Stands with mixed tree species should be managed by using the stocking level curves for the single species prescribing the fewest number of trees per acre.

94. Cochran, P. H. and K. W. Seidel. 1999. *Growth and yield of western larch under controlled levels of stocking in the Blue Mountains of Oregon*. Portland, Oregon: U. S. Forest Service, PNW-RP-

517.
Notes: Supporting Studies
Abstract: Repeated thinning to five growing-stock levels resulted in widely differing tree sizes and volumes per acre after 30 years. Largest trees but the least cubic-volume yield per acre were produced in the heaviest thinning level, whereas highest board-foot yields were found in intermediate thinning levels. Partial defoliation by larch casebearer (*Coleophora laricella* Hubner), drought, and top damage from ice occurred, and site trees grew less in height than expected during the 30-year study. Curvilinear increases in periodical annual increments of both basal area and cubic volume generally occurred with increasing stand density, but increments dropped off at the highest stand densities for some periods. Anticipated patterns for these increments were found after fitting a model that included stand density index, height increments of site trees, and dummy variables for periods as independent variables. Heavy thinning did not increase the age of culmination of cubic-volume mean annual increment as expected. Thinning stands of larch to densities as low as 50 percent of "normal" results in little loss of basal-area growth, a moderate loss in volume production, and a large increase in tree diameter. Thinning is necessary in many larch stands to maintain vigorous, rapidly growing trees. Thinning levels will greatly affect the appearance of future stands.

95. Cole, Dennis M. and Mark D. McGregor. 1988. Stand culture/bark beetle relationships of immature tree stands in the Inland Mountain West. In *Proceedings, Future Forests of the Mountain West: a Stand Culture Symposium*, edited by Schmidt, Wyman C. (Ogden, Utah: U. S. Forest Service, INT-GTR-243).
Notes: Other Works Cited

96. Cole, W. E. and D. B. Cahill. 1976. Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine. *Journal of Forestry* 74, no. 5:294-297.
Notes: Supporting Studies
Abstract: Mountain pine beetle attacks in lodgepole pine stands are generally concentrated on trees of large diameter and thick phloem, and brood production is greatest within such trees. Three lodgepole stands infested at various epidemic levels were sampled in 1971 and pre-epidemic diameter and phloem thickness distributions were estimated. Estimates of residual food supplies for beetles when partial cutting levels were applied to the data show that managing the stands so that trees did not reach 10 inches in dbh would have substantially lowered the probabilities that epidemics would develop.

97. Cooper and R. Pfister. 1984.
Notes: Other Works Cited

98. Cornish, P. M. and D. Binns. 1987. Streamwater quality following logging and wildfire in a dry sclerophyll forest in Southeastern Australia. *Forest Ecology and Management* 22, no. 1:1-28.
Notes: Relevant Studies
Abstract: In an 8-year study in two large adjacent forested river basins located in southeastern Australia, streamwater cationic composition was found to be greatly influenced by the minerology of the major lithology In each basin. While sodium was the dominant streamwater cation in each basin, it was relatively much higher in the Wallagaraugh Basin in which the major bedrock contained considerably greater proportions of potash feldspar than in the Townamba Basin. The chemistry of bulk precipitation, while similar in each basin, may have influenced the ultimate ionic composition of streamwater to a greater degree in the Towamba Basin than in the Wallagaraugh Basin.

Streamwater cationic concentrations in small sub-catchments subjected to logging and/or wildfire initially decreased relative to concentrations in an untreated control catchments in response to relative discharge increases, but became relatively greater than pre-wildfire 3-4 years later. Potassium concentrations in streamwater increased relative to the control in the year of the fire. Changes in the proportions of cations in streamwater in the small catchments during the study suggested that hydrologic changes resulting from a protracted drought, and from the

logging and/or wildfire, might have influenced ionic release and ionic transport processes in these catchments. While these changes were readily detected in small catchments, they seem to have been largely buffered out in the major rivers.

Streamwater turbidity levels were increased in the year of logging by combinations of clearfall logging and wildfire in the small catchment study. Wildfire alone did not increase sampled turbidity levels. All burnt catchments, and especially those logged, experienced a reduction in sampled stream turbidity levels during the post-treatment period such that within 5 years the levels were significantly lower than those in unburnt, unlogged controls. These reductions are attributed to better catchments protection afforded by the dense revegetation of burnt areas that occurred during this period.

Turbidity levels in the logged research catchments were in general similar to those in major streams in the Wallagaraugh Valley whose catchments had also been subject to logging during the study period. Streams sampled in the nearby Towamba Valley, which experienced less logging in the period, had lower turbidity values throughout.

99. Coulson, R. N. 1979. Population dynamics of bark beetles. *Annual Review of Entomology* 24:417-447.
Notes: Supporting Summary Documents
Abstract: A discussion and presentation of a structure for the population system of bark beetles, focusing on the genus *Dendroctonus*. Considers the interaction of bark beetles and their hosts at three levels of organizational complexity: the tree, the stand, and the forest. Specific objectives are to (A) define a temporal-spatial structure as the basic population unit of bark beetles; (B) to investigate the operation of the basic population system at the infestation (stand) level of organization; and (C) to investigate the consequences of the operation of the infestation population system at the forest (ecosystem) level of organization.

100. Covington, W. W. and others. 1996.
Notes: Other Works Cited

101. Covington, W. W., Richard L. Everett, R. Steele, L. L. Irwin, T. A. Daer, and A. N. D. Auclair. 1994. Historical and anticipated changes in forest ecosystems of the inland west of the United States. *Journal of Sustainable Forestry* 2:13-63.
Notes: Highly Relevant Summary Documents
Abstract: Euro-American settlement of the Inland West has altered forest and woodland landscapes, species composition, disturbance regimes, and resource conditions. Public concern over the loss of selected species and unique habitats (e.g., old-growth) has caused us to neglect the more pervasive problem of declining ecosystem health. Population explosion of trees, exotic weed species, insects, diseases, and humans are stressing natural systems. In particular, fire exclusion, grazing, and timber harvest have created anomalous ecosystem structures, landscape patterns, and disturbance regimes that are not consistent with the evolutionary history of the indigenous biota. Continuation of historical trends of climate change, modified atmospheric chemistry, tree density increases, and catastrophic disturbances seems certain. However, ecosystem management strategies including the initiation of management experiments can facilitate the adaptation of both social and ecological systems to these anticipated changes. A fairly narrow window of opportunity perhaps 15-30 years exists for land managers to implement ecological restoration treatments.

102. Covington, W. W. and M. M. Moore. 1992. Postsettlement changes in natural fire regimes: implications for restoration of old-growth ponderosa pine forests. *Journal of Sustainable Forestry* 2:153-181.
Notes: Highly Relevant Studies
Abstract: Heavy livestock grazing and fire suppression associated with Euro-American settlement has brought about substantial changes in forest conditions in western forests. Thus old-growth definitions based on current forest conditions may not be compatible with the natural conditions prevalent throughout the evolutionary history of western forest types. Detailed analysis of data from two study areas in the southwestern ponderosa pine type suggests that

average tree densities have increased from as few as 23 trees per acre in presettlement times to as many as 851 trees per acre today. Associated with these increases in tree density are increases in canopy closure, vertical fuel continuity, and surface fuel loadings resulting in fire hazards over large areas never reached before settlement. In addition, fire exclusion and increased tree density has likely decreased tree vigor (increasing mortality from disease, insect, drought, etc.), decreased herbaceous and shrub production, decreased aesthetic values, decreased water availability and runoff, decreased nutrient availability, changed soil characteristics, and altered wildlife habitat. To remedy these problems and restore these forest ecosystems to more nearly natural conditions, and maintain a viable cohort of old age-class trees, it may well be necessary to thin out most of the postsettlement trees, manually remove heavy fuels from the base of large, old trees, and reintroduce periodic burning.

103. Covington, W. W. and M. M. Moore. 1994. Southwestern ponderosa forest structure. *Journal of Forestry* 92, no. 1:39-47.
Notes: Supporting Summary Documents
Abstract: Southwestern ponderosa pine forests are a classic example of how Euro-American populations changed forest conditions. Before settlement, these forests were much more open and parklike. Postsettlement increases in tree density have contributed to changes not only in ecological patterns and processes but also in timber, forage, water, wildlife, and esthetic conditions. This study quantifies some of the associated shifts in ecosystem structure and resource conditions and predicts changes 40 years into the future. The results from this and subsequent studies on other sites should serve as a reference point or baseline for eventual restoration of more nearly natural patterns and processes.

104. Cowlin, R. W., P. A. Briegleb, and F. L. Moravets. 1942. *Forest resources of the ponderosa pine region*. Washington, D. C.: U. S. Forest Service, Miscellaneous Publication #490.
Notes: Relevant Summary Documents
Abstract: This document is a forest inventory that consists of the following elements: (1) areas of the several forest types, by ownership and class; (2) areas of the even-aged immature conifer types, by age class and degrees of stocking, and uneven-aged immature conifer types, by degrees of stocking of poles and reproduction combined; (3) a classification of forest areas according to site quality; and (4) computation of the volume of the present timber stands, including residual stands on cut-over lands, by species and ownership class.

105. Cramer, W. A., H. H. Shugart, I. R. Noble, F. I. Woodward, H. Bugmann, A. Bondeau, J. A. Foley, R. H. Gardner, W. K. Lauenroth, L. F. Pitelka, and R. W. Sutherst. 1999. Ecosystem composition and structure. In *The Terrestrial Biosphere and Global Change: Implications for Natural and Managed Ecosystems*, edited by Walker, B. (Cambridge, England: Cambridge University Press).
Notes: Supporting Summary Documents
Abstract: The structure of terrestrial ecosystems influences their responsiveness to most drivers of global change: for example, growth responses to enhanced CO_2 are less at higher levels of organization and over longer periods of observation.

The future structure and composition of terrestrial ecosystems will be affected by responses at the patch, landscape and global scales. Direct extrapolation from the patch to the globe is unlikely to yield realistic projections of ecosystem change; landscape-scale processes must be taken into account.

A general finding from patch model studies is that many forests appear to be sensitive to global change on the time scale of centuries. On shorter time scales, e.g. for the next few decades, many forests will show little response due to the lag effects in demographic processes. However, in systems where intense disturbances are more common, or become more common under global change, there will be opportunities for mortality and replacement of existing trees, and changes in forest structure and composition may be more rapid.

The interaction of global change and landscape phenomena can greatly modify both the magnitude and rate of change in community composition and structure. The importance of selforganization in landscape dynamics implies that change will not be incremental and smooth, but instead, punctuated and lumpy.

Migration plays a critical role in the process of ecosystem adaptation to climate change; human modification of landscapes affects the possible velocity of migration. Migration rates through the markedly non-random landscapes created by human activities are usually slower than those based on predictions derived from theoretical studies based on randomly fragmented landscapes. Many species may face a 'double bind' in which they need to migrate in response to climate change, but have few places to go and too much hostile territory to cross.

Assessments of the response of the terrestrial biosphere to global change are moving from an equilibrium towards a dynamic representation, triggered by the recognition that two major problems exist in the equilibrium assessments: By definition, equilibrium models simulate no transient changes in vegetation. Therefore, these simulations may at best be used to indicate the direction of possible change but not the time it might take to reach the new conditions.

Evidence from the past show that biomes are unlikely to be displaced as homogenous entities. Rather, differences in species' fundamental ecological niches, and their widely varying abilities to migrate, will result in quite different assemblages over a long period of time.

106. Cramer, W. A. and W. Steffen. 1997. Forecast changes in the global environment: what they mean in terms of ecosystem responses on different time-scales. In *Past and Future Rapid Environmental Changes: The Spatial and Evolutionary Responses of Terrestrial Biota*, edited by Huntley, B., W. A. Cramer, A. V. Morgan, H. C. Prentice, and J. R. M. Allen (Berlin, Germany: Springer-Verlag, NATO ASI Series Volume 1 No. 47).
Notes: Supporting Summary Documents
Abstract: The authors briefly discuss the following topics: the nature of anticipated global environmental change, rates and patterns of anticipated climate change, impacts on and feedbacks from land surface processes, short and long term dynamics in current terrestrial land surface models, types of ecosystem responses and ways to simulate them on a global scale, and modeling medium-term dynamics.

107. Crouch, G. L. 1987. A bibliography of publications from Forest Service animal damage research in the Pacific Northwest, 1961-1986. In *Animal Damage Management in Pacific Northwest Forests*, edited by Baumgartner, David M., R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

108. Crowe and Clausnitzer. 1997.
Notes: Other Works Cited

109. Cushman, Martha J. 1981. *Influence of recurrent snow avalanches on vegetation patterns in the Washington Cascades*. Seattle, Washington: Doctoral Dissertation, University of Washington.
Notes: Other Works Cited

110. Dahl, D. W. , S. Pyne, E. V. Anderson, and T. Crow. 1981. Fire and public policy. In *Proceedings of the Conference Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-26).
Notes: Supporting Summary Documents
Abstract: The fire management policy of the USDA Forest Service was revised in 1978 to permit cost-effective fire suppression tactics to be employed. Further, fire management activities are directed to meet land management objectives. This paper examines some of the factors involved with changing fire management policy. Emphasis is on the influence of the Industrial Revolution, European culture, and 1910 fires, more of early foresters in America, scientific technology, philosophy, and the post-1910 period including the influence of the

Civilian Conservation Corps. Public policy is presented as a dynamic political manifestation of interactions of these factors.

111. Dahms, Walter G. 1949. *How long does ponderosa pine snags stand?* Portland, Oregon: U. S. Forest Service, PNW-RN-57.
Notes: Other Works Cited

112. Dale, Virginia H. and Jerry F. Franklin. 1989. Potential effects of climate change on stand development in the Pacific Northwest. *Canadian Journal of Forest Research* 19:1581-1590.
Notes: Highly Relevant Studies
Abstract: Long-term climate and stand structure records and projections from a simulation model are used to explore effects of predicated changes in temperature on forest development in the Pacific Northwest. Few climate trends have occurred during the past 92 years, although there have been variations in September temperatures. The lack of climate trends makes it impossible to relate past changes in stand development to climate. Measures of stand development from six long-term forest plots over the past 7 decades are typical of Douglas fir stands; stem density declines, leaf area stabilizes, aboveground biomass increases, and shifts in size distribution occur. These changes are consistent with patterns of natural succession. A computer model projected forest development under two climate scenarios: current temperature conditions and temperature warming (such as that predicted under a doubling of atmosphere CO_2). The model predicted changes in species composition, leaf area, and stem density in response to temperature increases. Total aboveground biomass is not sensitive to the simulated temperature alterations. Predicted biomass stability suggests that the Pacific Northwest forest would continue to store large amounts of carbon in the living trees even with climatic warming. Therefore, the predicted temperature change would not alter the role of the Pacific Northwest forests as a major storage location of terrestrial carbon. Changes in precipitation patterns or in disturbance frequency or intensity that might occur with climatic warming could alter these predications.

113. Dale, Virginia H., L. A. Joyce, and Steve McNulty. 2000. The interplay between climate change, forests, and disturbances. *Science of the Total Environment* 262:201-204.
Notes: Supporting Summary Documents
Abstract: Climate change affects forests both directly and indirectly through disturbances. Disturbances are a natural and integral part of forest ecosystems, and climate change can alter these natural interactions. When disturbances exceed their natural range of variation, the change in forest structure and function may be extreme. Each disturbance affects forests differently. Some disturbances have tight interactions with the species and forest communities that can be disrupted by climate change. Impacts of disturbances and thus of climate change are seen over a broad spectrum of spatial and temporal scales. Future observations, research, and tool development are needed to further understand the interactions between climate change and forest disturbances.

114. Dale, Virginia H., L. A. Joyce, Steve McNulty, R. P. Nielson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, and A. E. Lugo. 2001. Climate change and forest disturbances. *BioScience* 51, no. 9:723-734.
Notes: Relevant Summary Documents
Abstract: Climate change can affect forests by altering the frequency, intensity, duration, and timing of fire, drought, introduced species, insect and pathogen outbreaks, hurricanes, windstorms, ice storms, or landslides.

Over geologic time, changes in disturbance regimes are a natural part of all ecosystems. Even so, as a consequence of climate change, forests may soon face rapid alterations in the timing, intensity, frequency, and extent of disturbances. The number and complexity of climate variables related to forest disturbance make integrated research an awesome challenge. Even if changes cannot always be predicted, it is important to consider ways in which impacts to forest systems can be mitigated under likely changes in disturbance regimes. The task for the next decade is to understand better how climate affects disturbances and how forests respond to them. Improved monitoring programs and analytical tools are needed to develop this understanding. Ultimately, this knowledge should lead to better ways to predict and cope with disturbance-induced changes in forests.

115. Dale, Virginia H., Linda A. Joyce, Steve McNulty, and Ronald P. Neildon. 2000. Interplay between climate change, forests and disturbances. *Science of the Total Environment* 262:201-204.
Notes: Other Works Cited

116. Daubenmire, R. 1956. Climate as a determinant of vegetation distribution in Eastern Washington and Northern Idaho. *Ecological Monographs* 26, no. 2:131-154.
Notes: Relevant Summary Documents
Abstract: A review and study of whether the "universal" climatic classifications can accurately describe and/or predict patterns of vegetation in eastern Washington and northern Idaho. The author tested the classifications of Koppen, Thornthwaite (1931, 1948), and Swain using established weather stations and vegetation maps, and found that the same climatic symbol was often used several different vegetational belts and that even the distinction between grassland and forest climates could not be defined consistently. A different classification approach using mean monthly temperatures plotted against median monthly precipitation was found to be more successful in defining discrete "phytogeograhpic" units.

117. Daubenmire, R. 1968. *Plant communities: a textbook of plant ecology*. New York, New York: Harper and Row.
Notes: Other Highly Relevant References

118. Deferrari, C. M. and Robert J. Naiman. 1994. A multi-scale assessment of the occurrence of exotic plants on the Olympic Peninsula, Washington. *Journal of Vegetation Science* 5:247-258.
Notes: Other Highly Relevant References

119. Dent, L. F. and J. B. S. Walsh. 1997. *Effectiveness of riparian management areas and hardwood conversions in maintaining stream temperature*. Portland, Oregon: Oregon Department of Forestry, Forest Practices Monitoring Program, Forest Practices Technical Report #3.
Notes: Relevant Summary Documents
Abstract: Temperature in forested streams is a critical component of fish habitat. Management alongside forested streams has the potential to significantly affect the amount of solar radiation reaching the stream surface as well as the condition of other environment parameters that are correlated with stream temperature response. In 1995, the Oregon Department of Forestry conducted a monitoring project to evaluate the effectiveness of the forest practice rule in preventing increases in stream temperature associated with forest harvesting. The project set out to answer the questions: Are the best management practices resulting in unacceptable temperature increases at the site and watershed level?

Temperatures recorded continuously on 13 stream reaches and one basin were used to analyze the effects of Riparian Management Areas (RMA's) and Hardwood Conversions (HWC's) on maintaining stream temperature throughout the summer lowflow season. RMA's are unmanaged forest buffers of varying widths depending on stream size and type situated between upslope harvest operations and streams. HWC's are managed riparian buffers that are capable of supporting conifers but which are currently dominated by hardwoods. Active management is not permitted within RMA (OAR 629-635-310) and is permitted within a HWC (OAR 629-640-300). Using various statistical methods, including repeated measures on analysis of variance and distribution tests, stream temperatures recorded immediately below the harvest units were compared to control temperatures recorded above the harvest units and those recorded approximately 500 feet below the harvest units.

Results from this monitoring project are limited by lack of pre-harvest data and variability among the sample sites. Differences in elevation, harvest methodology, and georegion as well as data collection problems, especially with canopy cover, contributed to a highly variable sample population. However, consistent, if not significant, increases in stream temperature below harvested reaches indicated that the forest protection rules may not always provide adequate protection to meet water quality standards.

In general, the 7-day moving average of maximum, minimum and average temperature increased through the harvest units, whether it was a RMA or HWC. Average 7-day maximum increase for RMA's was 2.5^{o}F and 2.5^{o}F for HWC's. However, four out of eight streams experienced stream temperature increases greater that 3^{o}F while only one out of five RMA streams showed increases greater that 3^{o}F. When variance in temperature contributed by distance from divide was theoretically accounted for, temperature increases were not significant. Without accounting for the natural downstream increase in temperature, temperature increases throughout the harvest units were statistically significant. Depending on the position of the harvest units within a watershed, stream temperature did or did not decrease downstream again after returning to an unmanaged canopy. Those reaches that were sampled higher in the basin did show a corresponding decrease in temperature 500ft downstream, while those reaches sampled lower in the basin did not show a decrease in stream temperature 500ft downstream.

The water quality standard for the 7-day moving average of maximum (64^{o}F) was exceeded more often downstream of harvested units that upstream. On all streams the standard was exceeded only 9.4% of the time. However only three of the thirteen streams never exceeded the water quality standard.

Continued monitoring and assessment will be completed to address the limitations of this monitoring project and attempt to better determine where rules can be improved and how forested stream systems respond to management.

120. Dick, Jim. 1991. Region 3 report. In *New Perspectives in Forest Management Planning: Proceedings of the Timber Management Planning and Inventory Workshop*, edited by Lund, H. Gyde (Washington, D. C.: U. S. Forest Service).
Notes: Other Works Cited

121. Dieterich, J. H. 1979. *Recovery potential of fire-damaged Southwestern ponderosa pine*. Fort Collins, Colorado: U. S. Forest Service, RM-RN-379.
Notes: Other Highly Relevant References

122. Dong, J., J. Chen, K. D. Brosofske, and Robert J. Naiman. 1998. Modeling air temperature gradients across managed small streams in western Washington. *Journal of Environmental Management* 53, no. 4:309-321.
Notes: Other Works Cited

123. Ehlert, H. and S. Mader. 2000. *Review of the Scientific Foundations of the Forests and Fish Plan*. Bellevue, Washington: CH2M-Hill.
Notes: Supporting Summary Documents
Abstract: This review identifies the scientific foundations for the recommendations contained in the Forests and Fish Report and assesses the effectiveness of the recommendations in meeting the goals set forth by the Washington Forest Practices Board. The document contains background information on the Forest and Fish Report and its legal and scientific context. It also contains "functional discussions" in seven issue areas: (1) Large Woody Debris; (2) Heat Energy; (3) Coarse Sediment; (4) Fine Sediment; (5) Hydrology; (6) Pesticides; and (7) Litterfall.

124. Elias. 1980.
Notes: Other Works Cited

125. Entry, J. A., R. G. Kelsey, and N. E. Martin. 1991. Response of douglas fir to infection by *Armillaria*

ostoyae after thinning or thinning plus fertilization. *Phytopathology* 81, no. 6:682-689.
Notes: Supporting Studies
Abstract: Second-growth stands of douglas fir (*Pseudotsuga menziesii*) were thinned to a 5 x 5m spacing (TT); additional plots were thinned and fertilized once with 360 kg of N (as urea) per hectare (TF). An unthinned, unfertilized stand (UT) served as a control. Ten years after treatment, trees were inoculated with two isolates of *Armillaria ostoyae*. Trees receiving the TF and TT treatments produced greater diameter growth, leaf area, and wood production per square meter of leaf area per year than did those under the UT treatment. Rates of infection by *A.ostoyae* were highest in trees that received the TF and lowest in trees that received the TT treatment. Concentrations of sugar, starch and cellulose in root bark tissue were highest in trees receiving the TF treatment and lowest in trees receiving the TT treatment. Concentrations of lignin, phenolics and protein-precipitable tannins were highest in root bark from TT trees and lowest in root bark from TF trees. Biochemical parameters of root bark tissue were regressed with incidence of infection; coefficients of determination (r2) ranged from 0.07 (starch) to 0.57 (phenolic compounds). Ratios of the energetic costs of phenolic and of lignin degradation to the energy available from sugars (Epd:Eas and Eld:Eas) were correlated with incidence of infection (r^2=0.77 and 0.70, respectively). Thinning combined with fertilization may predispose *P. menziesii* trees to infection by *A. ostoyae* by lowering concentrations of defensive compounds in root bark and increasing the energy available to the fungus and degrade them.

126. Environmental Laboratory. 1987. *Corps of Engineers wetlands delineation manual*. Vicksburg, Mississippi: U. S. Army Engineer Waterways Experiment Station, Technical Report Y-87-1.
Notes: Other Works Cited

127. Evans.
Notes: Other Works Cited

128. Everett, Richard L. and David M. Baumgartner. 1997. Disturbance management and resource product availability. In *Role of Wood Production in Ecosystem Management: Proceedings of the Sustainable Forestry Working Group*, edited by Barbour, R. J. and K. E. Skog (Pullman, Washington: Washington State University, and U. S. Forest Service, FPL-GTR-100).
Notes: Supporting Summary Documents
Abstract: Disturbance is an integral part of ecosystem process; its conservation is of equal importance as the conservation of species or habitats, and it provides an ecological approach to resource product availability. Disturbance management is a technique that can be used to maintain ecosystem integrity and associated sustainable levels of commodity extraction on public lands. Public expectations for resource conditions and resource extraction need to be grounded in the reality of required disturbance regimes to maintain ecosystem integrity. The mosaic of post-disturbance vegetation patches contributing to biodiversity also represents a portfolio of economic opportunities. Management for disturbances and resulting patch dynamics across large landscapes in "whole-unit management" is suggested as a flexible institutional approach to resource management that incorporates planned and unplanned disturbances into long-term management goals for ecosystem integrity and resource extraction.

129. Everett, Richard L., David M. Baumgartner, V. Demietriev and others. 2002. Russian forests with an intact fire regime provide forest structure reference points for altered Eastern Washington forests. In *Small Diameter Timber-Resource Management, Manufacturing and Markets, Proceedings of a Symposium*, edited by Baumgartner, David M. and others (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Highly Relevant Studies
Abstract: Fire regime, fire history and stand structure were defined for 14 mixed conifer stands on southerly aspects in both Eastern Washington (US) and in Siberia, Russia in 1997. Russian stands shared a common fire regime, but not fire history with US stands. Fire history of current Russian most closely matched that of US forest stands of 1796. Using the fire metric “FFI-out” (disturbance interval/recovery period ratio) we found Russian stands to be sustainable, but current US stands were not. Using the fire metric “FFI-out” we found Russian stands to be in a

dynamic steady-state of post-fire recovery phases, but US forests were not. Using these same fire metrics US stands in 1796 were found to be both sustainable and in a dynamic steady state. If the sustainable US forest stands of 1796 are a desired condition then current Russian stand structure may serve as a reference point. Current Russian stands (and 1796 US stands by inference) had significantly ($p < 0.05$) fewer large and small trees (>, < 9 in. dbh), and small snags and logs than current US stands. Under the intact fire regimes of Russian forests the mean abundance per acre of trees, snags and logs (>16 in. dbh, dia.) was 18.3 [95% CI 26.6 to 9.9], 14.9 [95% CI 21.9 7.8] and 4.3 [95% CI 7.6 to 0.9], respectively.

130. Everett, Richard L., A. E. Camp, and R. Schellhaas. 1995. Building a new forest with fire protection in mind. In *Proceedings of the Society of American Foresters*, (Portland, Maine: Society of American Foresters, SAF-96-01).
Notes: Supporting Studies
Abstract: Dry pine sites of the Inland West are becoming increasingly susceptible to catastrophic fire events as the disparity between historical and current disturbance regimes and associated vegetation conditions increases. Following catastrophic fires on public lands, management should capitalize on forest remnants to provide future forest legacies for logs and snags, but may need to reduce future fire hazard from an excess of dead and down trees or accept the additional fire risk. Examples from the 1994 Tyee Fire and nearby areas on the Wenatchee National Forest demonstrate how creating new forests with reduced hazard for catastrophic fires can be accomplished while simultaneously achieving vegetation characteristics required to meet public expectations on an array of specific land allocations. Vegetation characteristics that support emphasized uses within land allocations need to be evaluated for synchrony with the inherent disturbance regimes of the area. We suggest that recognizing and managing disturbances is key to protecting emphasized uses, integrating adjacent land use allocations, restoring the continuity of inherent disturbance regimes among allocations, and reducing future hazard to catastrophic fire events.

131. Everett, Richard L., P. F. Hessburg, M. E. Jensen, and B. Bormann. 1994. *Eastside Forest Ecosystem Health Assessment: Volume I: executive summary*. Portland, Oregon: U. S. Forest Service, PNW-GTR-317.
Notes: Other Highly Relevant References

132. Everett, Richard L., P. F. Hessburg, J. F. Lehmkuhl, M. E. Jensen, and P. S. Bourgeron. 1994. Old forests in dynamic landscapes. *Journal of Forestry* 92, no. 1:22-25.
Notes: Highly Relevant Summary Documents
Abstract: Old-forest abundances have been significantly reduced in most major conifer series and most geographic areas of eastern Oregon and Washington since presettlement times. Open, parklike, multicohort forests of ponderosa pine (*Pinus ponderosa*) once covered extensive areas prior to 1850 (Cowlin *et al.* 1942). The current late-successional and old ponderosa pine forest covers 2-8 percent of that originally occurring in eastern Oregon national forests (Scientific Society Panel 1993). New, younger, multilayered forests of dense douglas fir and grand fir (*Abies grandis*) have been created as a result of fire suppression and selective harvesting. Although these forests possess some old-forest attributes, they are more vulnerable to insects, pathogens, and strand-replacing fires (Caraher *et al.* 1992, Agee 1993, Hessburg *et al.* 1993, Mason and Wickman 1993).

Current anomalous landscapes and disturbance regimes need to be restored to a more sustainable state if old-forest remnants are to be conserved and old-forest networks created and maintained. Moreover, any plan to sustain old forests must first address the ecological sustainability of the landscapes of which they are a part. This article will describe old forests of eastern Oregon and Washington, contrasting historic (for this article, 1930-50) and current (1980-90) abundance and structure. It will also offer a philosophy for conserving old-forest patches and associated landscapes.

133. Everett, Richard L. and J. F. Lehmkuhl. 1999. Restoring biodiversity in public forest lands through

disturbance and patch management irrespective of land-use allocation. In *Practical Approaches to the Conservation of Biological Diversity*, edited by Baydack, R. K., H. Campa, and J. B. Haufler (Washington, D. C.: Island Press).
Notes: Other Highly Relevant References

134. Everett, Richard L., J. F. Lehmkuhl, M. E. Jensen, P. F. Hessburg, and P. S. Bourgeron. 1995. Application of the Eastside Forest Ecosystem Health Assessment to ecosystem management. In *Proceedings, Forest Health and Fire Danger in Inland Western Forests September 8-9, 1994, Spokane, Washington*, (Washington, D. C.: American Forests).
Notes: Supporting Summary Documents
Abstract: A short overview of the Eastside Forest Ecosystem Health Assessment and its efforts to construct an ecosystem management framework for six river basins in eastern Oregon and Washington. The overview includes a discussion of the project's conceptual framework, a description of the assessment findings and how they should be applied, and three recommendations for Eastside land managers.

135. Everett, Richard L., J. F. Lehmkuhl, R Schellhaas and others. 2002. *Snag dynamics in a chronosequence of 26 wildfires on the East Slope of the Cascade Range in Washington*.: Unpublished manuscript.
Notes: Relevant Studies
Abstract: Snag numbers and decay class were measured on a chronosequence of 26 wildfires (ages 1 to 81 years) on the east slope of the Cascade Range in Washington. Snag longevity and resultant snag densities varied spatially across burns in relation to micro-topographic position. Longevity of snags <4cm dbh was greater for thin-barked engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*) and lodgepole pine (*Pinus contorta*) than thick-barked douglas fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). With larger diameter snags, however, douglas fir persisted longer than englemann spruce. The time period required for recruitment of soft snags >23cm dbh was estimated to exceed snag longevity for ponderosa pine, Englemann spruce, lodgepole pine, and subalpine fir, causing an "on-site gap" in soft snags for these species. Snags of douglas fir >/=41cm dbh stood for a sufficient time (40% standing after 80yr.) to potentially overlap the recruitment of soft snag >/=23cm dbh from the replacement stand. Providing continuity in soft snags following stand-replacement events would require a landscape-scale perspective, incorporating adjacent stands of different ages or disturbance histories. Results suggest that standards and guidelines for snags on public forest lands need to be sufficiently flexible to accommodate both disturbance and stand development phases and differences in snag longevity among species and topographic positions.

136. Everett, Richard L., J. F. Lehmkuhl, R. Schellhaas, P. Ohlason, D. Keenum, H. Riesterer, and D. Spurbeck. 1999. Snag dynamics in a chronosequence of 26 wildfires on the East Slope of the Cascade Range in Washington State, USA. *International Journal of Wildland Fire* 9, no. 4:223-234.
Notes: Other Highly Relevant References

137. Everett, Richard L., D. Schellhaas, D. Spurbeck, P. Ohlson, D. Keenum, and T. D. Anderson. 1997. Structure of northern spotted owl nest stands and their historical conditions on the Eastern Slope of the Pacific Northwest Cascades, USA. *Forest Ecology and Management* 94:1-14.
Notes: Supporting Summary Documents
Abstract: The northern spotted owl (*Strix occidentalis caurina*) uses a wide array of nesting habitat throughout its current range and successfully reproduces in a variety of stand types on the eastern slope of the Pacific Northwest Cascades. The species has the ability to utilize dynamic forest stands that continue to undergo significant changes in tree density, proportion of tree size classes, and tree species composition. Current stand structure and composition reflect the results of timber harvest, reduced fire effects and ongoing successional and stand development processes. In nest stands, multi-layered canopy was more strongly expressed in numbers of both small (<13cm DBH) and large (>14cm DBH) trees than in unoccupied stands of the same type within the owl neighborhoods. Tree density and the proportion of shade-

tolerant tree species have increased significantly in spotted owl nest sites in both dry and wet forests since Eurosettlement. Barring disturbance, further increases in the dominance of shade-tolerant species should occur over time with continual change in nest stand structure and composition. The development of dense forest stands and "old-forest structural attributes" as a result of reduced fire effects could be potential mitigating factors to the loss of old-forest habitat from harvest and should be considered in determining the available owl habitat in the eastern Cascades. However, old-forest structural attributes in dense, overstocked stands are at high fire hazard and should be viewed as transitional until old-forest habitat with improved sustainability becomes available.

138. Everett, Richard L., R. Schellhaas, T. D. Anderson, J. F. Lehmkuhl, and A. E. Camp. 1996. Restoration of ecosystem integrity and land use allocation objectives in altered watersheds. In *Watershed Restoration Management: Physical, Chemical, and Biological Considerations (Proceedings, AWRA Annual Symposium)*, edited by McDonnell, J. J., J. B. Stirling, L. R. Neville, and D. J. Leopold (Herndon, Virginia: American Water Resources Association).
Notes: Highly Relevant Summary Documents
Abstract: Overstocked stands, resulting from a century of reduced fire effects and selective tree harvesting, are taxing the biological capacity and increasing the fires and insect hazard of the dry ponderosa pine forests of the Inland West. These dense, multi-canopy forests are not sustainable under the inherent high fire frequency-low severity fire regime characteristic of this forest type. The increasing disparity between current and inherent disturbance regimes and associated vegetation characteristics sets the stage for catastrophic disturbance events that can adversely impact the biological capacity of the ecosystem and our ability to restore vegetation characteristics required for emphasized uses within established land allocations. The restoration of the 1994 Tyee Burn in Eastern Washington is used as an example of how to plan for future forests that maintain biological capacity while meeting public expectations for vegetation characteristics that define a desired level of biological integrity within land use allocations. The restoration approach evaluates stand and landscape attributes required to reduce hazard for post-burn catastrophic events and to achieve emphasized uses for an array of land use allocations, integrates these hazard reduction and emphasized use attributes, and evaluates the composite forest attributes for sustainability under the inherent disturbance regimes for the area.

139. Everett, Richard L., R. Schellhaas, and D. Keenum. 2000. Fire history in the ponderosa pine/douglas fir forests on the East Slope of the Washington Cascades. *Forest Ecology and Management* 129:207-225.
Notes: Highly Relevant Studies
Abstract: We collected 490 and 233 fire scars on two ponderosa pine (*Pinus ponderosa*)/douglas fir (*Pseudotsuga meziesii*) dominated landscapes on the east slope of the Washington Cascades that contained a record of 3901 and 2309 cross-dated fire events. During the pre-settlement period (1700/1750-1860), the Weibuil median fire-free interval (WMFFI) and the mean fire-free interval (MFFI) were 6.6-7 years at both sites. The MFFI during the settlement period (1860-1910) varied within 3 years of the pre-settlement value, but increased to 38 and 43 years for a truncated fire suppression period between 1910 and 1996. Increase variation in MFFI among aspect polygons suggest fire regimes have become more complex since Euro-settlement. In the pre-settlement period, an area equal to approximately 50-60% of the study area burned every 6-7 years, an amount of fire disturbance apparently in balance with landscape and stand vegetation structure. Overlapping fires have created a complex mosaic of different fire histories on these forested landscapes. Mapped fire events from the 1700-1910 showed 134 and 157 separate fire history polygons (FHP) at the two sites. Fire disturbance rates and patterns are suggested as ecologically defensible reference points for landscape heterogeneity to reduce the potential for catastrophic fires and to establish vegetation disturbance management guidelines.

140. Everett, Richard L., R. Schellhaas, P. Ohlson and others. 2002. Continuity in fire disturbance between riparian and adjacent sideslope Douglas-Fir forests. *Forest Ecology and Management*.
Notes: Highly Relevant Studies
Abstract: Fire-scar and stand-cohort records were used to estimate the number and timing of fire disturbance events that impacted riparian and adjacent sideslope douglas fir (*Pseudotsuga*

menziesii Mirbel Franco) forests. Data were gathered from 49 stream segments on 24 separate streams on the east slope of the Washington Cascade Range. Upslope forests had more "traceable" disturbance events than riparian forests in each of the valley types with a mean difference of 8 to 62%. Approximately 55 to 73% of the total traceable fire disturbance for a stream segment occurred on either sideslope or 24 to 27% in the riparian forest. Plant association groups in the riparian forest had 25 to 42% fewer fire disturbance events than the same plant association group upslope. Fewer traceable disturbance events in riparian forests may indicate a reduced disturbance frequency or a more severe disturbance regime or both. The two sideslopes on either side of the riparian forest shared the same fire event in 65 and 54% of the recorded fire events on east/west and north/south sideslopes, respectively. Riparian forests share fire events with adjacent sideslope forests. Fire disturbance regimes of sideslope and riparian forests are quantitatively different, but interconnected through shared fire disturbance events. Disturbance events play a role in maintaining ecosystem integrity and we suggest that disturbance may need to be planned for in administratively defined riparian buffer strips to protect long-term ecological integrity of riparian and adjacent upslope forest.

141. Everett, Richard L., J. Townsley, and David M. Baumgartner. 2000. Mapping wildfire hazards and risks: inherent disturbance regimes: a reference for evaluating the long-term maintenance of ecosystems. *Journal of Sustainable Forestry* 11:265-288.
Notes: Other Highly Relevant References

142. Ferguson, D. E. and D. L. Adams. 1980. Response of advance grand fir regeneration to overstory removal in northern Idaho. *Forest Science* 26, no. 4:537-545.
Notes: Supporting Studies
Abstract: A mathematical model predicting height growth for released grand fir regeneration is presented. Data used to develop the model indicate that response to release depends on tree characteristics and site conditions interacting with physiological shock. Tall trees that are equally or more suppressed by the overstory do not respond as well as short trees. Logging damage decreases response. Recommendations for releasing stands of advance grand fir and guidelines for thinning released stands are provided.

143. Ferguson, S. A. 2001. Climatic variability in Eastern Oregon and Washington. *Northwest Science* 75:62-69.
Notes: Relevant Summary Documents
Abstract: Climate is a driving factor in forest health and productivity that limits species survival and affects disturbance processes. Complex topography and mosaics of land cover compound the variability of climate in eastern Oregon and Washington. The area is a transition zone between marine, arctic, and continental influences with associated extremes in weather. Such extremes affect insect populations, animal migration, streamflow, flooding, and wildfire potential. Additionally, human activities such as deforestation and atmospheric pollution interact with climate, and may cause changes similar in magnitude to the glacial-interglacial epoch in the next 50 to 100 years. Effects of anthropogenic climate changes are ambiguous, however, and could counter-balance each other. For example, tree populations may have more difficulty reestablishing, but growth rates could accelerate. Conversely, management actions can mitigate the effect of climate on fisheries, water resources, wildfire, and floods. Also, management actions can affect climate by modifying carbon exchange and water and energy exchange between land and atmosphere. Models are increasingly able to predict climate variability and trends in climate-related disturbances such as wildfire.

144. Ferguson, S. A. 1995. Potential climate change in northern North America. In *Human Ecology and Climate Change: People and Resources in the Far North*, edited by Peterson, D. L. (New York, New York: Taylor & Francis).
Notes: General References
Abstract: An overview that describes the factors that affect global climate and how a warmer climate might affect the regional climatic patterns of North America. Discusses the environmental controls on high-latitude climate (the greenhouse effect, solar radiation, global

winds, the ocean, and albedo) and regional climatic patterns in northern North America (including the Arctic coast, the Subarctic interior, and the Alpine transition).

145. Filip, G. M. 1995. *Effects of silvicultural techniques on forest insects and disease pathogens in the Blue Mountains*. La Grande, Oregon: Blue Mountains Natural Resources Institute, Technical Notes #7.
Notes: Relevant Summary Documents
Abstract: An overview of how several silvicultural techniques affect forest insect and disease dynamics in the Blue Mountains of Oregon. Eight silvicultural techniques are examined: (1) precommercial thinning; (2) commercial thinning, seed tree and shelterwood harvesting; (3) sanitation-salvage harvesting; (4) clearcutting and regeneration; (5) uneven-age management; (6) prescribed burning; (7) stump treatments for root disease; and (8) fertilizing. It is stressed that the long-term effects of such practices are not well known.

146. Filip, G. M. 1990. Effects of tree harvesting on Armillaria root disease in an old-growth mixed-conifer stand in an old-growth mixed-conifer stand in Northeastern Oregon. *Northwest Environmental Journal* 6, no. 2:412-413.
Notes: Relevant Studies
Abstract: This study tests the hypothesis that root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. The study area is near La Grande, Oregon. The stand is composed of old-growth ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), douglas fir (*Pseudotsuga menziesii* var. glauca), and western larch (*Larix occidentalis*). A portion of the stand is affected by Armillaria root disease (*Armillaria ostoyae*). This study is designed to examine disease spread and tree mortality over several decades.

147. Filip, G. M. 1993. Further studies on the effects of thinning and harvesting of conifers on *Armillaria ostoyae* and *Heterobasidion annosum* in Oregon, USA. In *Proceedings of the Eighth International Conference on Root and Butt Rots*, (Uppsala, Sweden: Swedish University of Agricultural Sciences).
Notes: Supporting Studies
Abstract: Although thinning and partial harvesting have been used in Oregon, USA, for decades, their effects on root pathogen/host interactions are not well known. Precommercial thinning has been shown to have no significant effect on crop-tree mortality caused by *Armillaria ostoyae* in several conifer species in central Oregon. Thinning with nitrogen fertilizing significantly decreased the percentage of stem decay caused by *Heterobasidion annosum* in *Abies grandis* in southern Oregon. Neither season of harvesting nor stump size significantly affected the amount of stump decay caused by *H. annosum* in *A. grandis* stumps of trees cut 5 to 10 years earlier in northeastern Oregon.

148. Filip, G. M. 1989. Incidence and biology of root and stem decay fungi in thinned conifer stands, Oregon and Washington, USA. In *Proceedings of the Seventh International Conference on Root and Butt Rots*, edited by Morrison, D. J. (Uppsala, Sweden: Swedish University of Agricultural Sciences).
Notes: Supporting Studies
Abstract: Stumps resulting from thinning operations serve as infection foci for root pathogens such as *Phellinus weirii*, *Armillaria ostoyae*, *Heterobasidion annosum*, and *Ceratocystis wageneri* in Oregon and Washington. *Heterobasidion annosum* has been reported in thinning stumps of *Tsuga hertophylla*, *Pinus ponderosa*, and *Larix occidentalis* but is probably most abundant in *Abies grandis* and other species of Abies. *Armillaria ostoyae* has been identified as causing severe damage in central Washington and is presumed to be responsible for most damage formerly attributed to *A. mellea* through Oregon and Washington. *Heterobasidion annosum* has been reported in residual trees in thinned stands of *Tsuga heterophylla*, *Abies grandis*, and *A. concolor*. *Armillaria ostoyae* has been reported in residual trees in thinned stands of *Pinus ponderosa*, *Pseudotsuga menziesii*, *Abies procera* and *A. magnifica*. Mortality caused by *Ceratocystis wageneri* is associated primarily with stands of *Psuedotsuga menziesii* that have been thinned or disturbed. Infection of residual trees by root pathogens is mainly via

adjacent infected stumps.

149. Filip, G. M., J. J. Colbert, C. A. Parks, and K. W. Seidel. 1989. Effects of thinning on volume growth of western larch infected with dwarf mistletoe in Northeastern Oregon. *Western Journal of Applied Forestry* 4, no. 4:143-145.
Notes: Relevant Studies
Abstract: Cubic volume growth and tree vigor of 70-year-old western larch (*Larix occidentialis*) with and without dwarf mistletoe (*Arceuthobium laricis*) were measured 15 years after thinning from above or below to residual densities of 50 to 170 ft^2/ac. Vigor was assessed by cambial electrical resistance (CER). Proportional volume growth increased after thinning; was significantly related to the interaction of thinning method and residual density; and decreased with increased dwarf mistletoe severity. Thinning from above was associated with significantly higher proportional volume growth, but led to increased mortality from snow and ice damage to infected trees. CER was significantly related to severity of infection but not to treatment. Thinning is recommended in dwarf mistletoe infested stands of western larch to increase volume growth and reduce new infections in residual trees.

150. Filip, G. M., S. A. Fitzgerald, and L. M. Ganio. 1999. Precommercial thinning in a ponderosa pine stand affected by Armillaria root disease in Central Oregon: 30 years of growth and mortality. *Western Journal of Applied Forestry* 14, no. 3:144-148.
Notes: Supporting Studies
Abstract: A 30-yr old stand of ponderosa pine was precommercially thinned in 1966 to determine the effects of thinning on tree growth and mortality caused by Armillaria root disease in central Oregon. After 30 yr, crop tree mortality was significantly (P=0.03) less in thinned plots than in unthinned plots. Tree diameter growth was not significantly (P=0.17) increased by thinning. Crop-tree basal area/ac growth was significantly (P=0.03) greater in thinned plots. Apparently from a root disease perspective, precommerical thinning of pure ponderosa stands significantly decreases the incidence of crop-tree mortality after 30 yr and significantly increases basal area/ac growth but not individual tree diameter growth. Recommendations for thinning based on stand density index (SDI) are given.

151. Filip, G. M. and D. J. Goheen. 1995. Precommercial thinning in *Pseudotsuga*, *Tsuga*, and *Abies* stands affected by Armillaria root disease: 10-year results. *Canadian Journal of Forest Research* 25:817-823.
Notes: Relevant Studies
Abstract: Four 10-to-20-year-old stands were precommercially thinned to determine the effects of thinning on tree growth and mortality caused by armillaria root disease in the Cascade Range of western Oregon and Washington, U.S.A: one stand of douglas fir (*Pseudotsuga menziesii* Mirb. Franco var. menziesii) and noble fir (*Abies procera* Rehd.). One of douglas-fir and western hemlock (*Tsuga heterophyila* Ref. Sarg.), one of douglas-fir alone, and one of shasta red fir (*Abies magnifica* A. Murr. Var. shastensis Lemm.) and mountain hemlock (*Tsuga meriensiana* bong. Carr.). After 10 years, differences in crop-tree mortality between thinned and unthinned plots were not significant in any of the four stands. Tree radical growth was significantly increased by thinning in 6 of 15 plots. Crop-tree basal area (per hectare) growth was significantly greater in thinned plots. Basal area (per hectare) growth of all trees was significantly greater in unthinned plots. Apparently, from a root-disease perspective, precommerical thinning does not affect the incidence of corp-tree mortality after 10 years, but tree growth increases significantly.

152. Filip, G. M., J. W. Schwandt, and S. K. Hagle. 1990. *Estimating decay in 40- to 90-year-old grand fir stands in the Clearwater Region of Northern Idaho*. Portland, Oregon: U. S. Forest Service, PNW-RP-421.
Notes: Supporting Studies
Abstract: The fir decay equation for Oregon and Washington was used to predict stem decay in 12 grand fir (*Abies grandis* Dougl. Ex D. Don Lindl.) stands in the Clearwater region of northern Idaho. These 12 stands represented a range in geographic and stand characteristic

variation. All 12 observed decay percentages were within their associated 95-percent predication intervals. We therefore concluded that the fir decay equation for Oregon and Washington could be used to estimate stem decay in 40-to-90 year-old grand firs stands in the Clearwater region. Information also is presented on decay biology, hazard-rating techniques, and stand management recommendations.

153. Flanagan, P. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

154. Flanagan, P., P. Morgan, and Richard L. Everett. 2002. *Snag recruitment in subalpine forests of the North Cascades, Washington State*. Berkeley, California: U. S. Forest Service, PSW-GTR-181.
Notes: Highly Relevant Studies
Abstract: We recorded snag species, locations, and casual agents of tree mortality, and estimated fire histories and standing dead and downed fuel abundance in polygons in subalpine forests in the Entiat watershed in Washington State. The overall snag density was 51+/- 5.2 snags per hectare. The density of dominant and codominant snags did not differ by aspect or slope categories ($p=0.74$), but the density of intermediate and suppressed snags was highest on steep south-facing slopes ($p<0.05$). Weather-related effects created more snags than any other disturbance in the period between stand-replacing fires. More weather-caused mortality occurred on northerly aspects than on southerly aspects ($p<0.05$) and on mid-slopes than either upper or lower slopes ($p<0.05$). Standing dead and downed fuel, and tree mortality caused by weather (snow, ice, and wind), root diseases, animals, and bark beetles were related to stand structural stage. We estimate the mean fire interval was 12 years for the 5,685 ha encompassed the study area. The estimated mean size of stand-replacing fires was 146+/- 95 ha.

155. Franklin, Jerry F. 1993. Fundamentals of ecosystem management with applications in the Pacific Northwest. In *Defining Sustainable Forestry*, edited by Aplet, Gregory H. (Washington, D. C.: Island Press).
Notes: Other Works Cited

156. Franklin, Jerry F. and T. Blinn. 1988. *Natural vegetation of Oregon and Washington: commentary and bibliographic supplement*. Corvallis, Oregon: Oregon State University.
Notes: Supporting Summary Documents
Abstract: A supplemental bibliography to the 1973 Pacific Northwest vegetation classification "Natural Vegetation of Oregon and Washington." Contains over 500 publications considered by the authors to be relevant to the areas of: plant community analysis and classification, disturbance ecology, and ecosystem processes.

157. Franklin, Jerry F., K. Comack, W. Denison, A. McKee, C. Maser, J. R. Sedell, F. J. Swanson, and G. Juday. 1981. *Ecological characteristics of old-growth douglas fir forests*. Portland, Oregon: U. S. Forest Service, PNW-GTR-118.
Notes: Other Highly Relevant References

158. Franklin, Jerry F. and C. T. Dyrness. 1988. *Natural vegetation of Oregon and Washington* . Corvallis, Oregon: Oregon State University Press.
Notes: Relevant Summary Documents
Abstract: We present here a generalized account of the major vegetation types within the states of Oregon and Washington, an integration of the scattered information into a regional account. Published articles, theses, and personal data files are the source materials. The purpose is threefold: (1) to outline major phytogeographic units and suggest how they fit together and relate to environmental factors; (2) to direct the interested reader to sources of detailed information on the environment and vegetation of the Pacific Northwest, since such information cannot be provided in an account of this size; and (3) to illustrate the major plant communities with photographs.

159. Franklin, Jerry F., P. M. Frenzen, and F. J. Swanson. 1988. Re-creation of ecosystems at Mount St.

Helens: contrasts in artificial and natural approaches. In *Rehabilitating Damaged Ecosystems*, edited by Carins, J. (Boca Raton, Florida: CRC Press).
Notes: Other Highly Relevant References

160. Franklin, Jerry F. and M. A. Hemstrom. 1981. Aspects of succession in the coniferous forest of the Pacific Northwest. In *Forest Succession: Concepts and Applications*, edited by West, C., H. H. Shugart, and D. Botkin (New York, New York: Springer-Verlag).
Notes: Other Highly Relevant References

161. Franklin, Jerry F., J. A. MacMahon, F. J. Swanson, and J. R. Sedell. 1985. Ecosystems responses to the eruption of Mount St. Helens. *National Geographic Research* 1:198-216.
Notes: Other Highly Relevant References

162. Franklin, Jerry F., H. H. Shugart, and M. E. Harmon. 1987. Tree death as an ecological process. *BioScience* 37, no. 8:550-556.
Notes: Supporting Summary Documents
Abstract: An overview of tree death as a rich ecological process. Included are the causes of tree death, its consequences, its variability, and the importance of species' natural histories. The authors also use tree death to illustrate some general aspects of ecological processes.

163. Franklin, Jerry F., T. A. Spies, R. Van Pelt, A. B. Carey, D. A. Thornburgh, D. R. Berg, D. B. Lindenmayer, M. E. Harmon, W. S. Keeton, D. C. Shaw, K. Bible, and J. Chen. 2002. Disturbances and structural development of Natural Forest ecosystems with silvicultural implications, using douglas fir forests as an example. *Forest Ecology and Management* 155:399-423.
Notes: Highly Relevant Studies
Abstract: Forest managers need a comprehensive scientific understanding of natural stand development processes when designing silvicultural systems that integrate ecological and economic objectives, including a better appreciation of the nature of disturbance regimes and the biological legacies, such as live trees, snags, and logs, that they leave behind. Most conceptual forest development models do not incorporate current knowledge of the; (1) complexity of structures (including spatial patterns) and developmental processes; (2) duration of development in long-lived forests; (3) complex spatial patterns of stands that develop in later stages of seres; and particularly (4) the role of disturbances in creating structural legacies that become key elements of the post-disturbance stands. We elaborate on existing models for stand structural development using natural stand development of the douglas fir--western hemlock were in the Pacific Northwest as our primary example; most of the principles are broadly applicable while some processes (e.g. role of epicormic branches) are related to specific species. We discuss the use of principles from disturbance ecology and natural stand development to create silvicultural approaches that are more aligned with natural processes. Such approaches provide for a greater abundance of standing dead and down wood and large old trees, perhaps reducing short-term commercial productivity but ultimately enhancing wildlife habitat, biodiversity, and ecosystem function, including soil protection and nutrient retention.

164. Franklin, S. E., R. H. Waring, R. W. McCreight, W. B. Cohen, and M. Fiorella. 1995. Aerial and satellite sensor detection and classification of western spruce budworm defoliation in a subalpine forest. *Canadian Journal of Remote Sensing* 21, no. 3:299-308.
Notes: Other Works Cited

165. Furniss, R. L. and V. M. Carolin. 1977. *Western forest insects*. Washington, D. C.: U. S. Forest Service, Miscellaneous Publication #1339.
Notes: Other Highly Relevant References

166. Gast, W. R. , D. W. Scott, C. L. Schmitt, D. L. Clemens, S. Howes, C. G. Johnson, R. R. Mason, F. Mohr, and R. A. Clapp. 1991. *Blue Mountains forest health report: new perspectives in forest health*. Portland, Oregon: U. S. Forest Service, Pacific Northwest Region.

Notes: Highly Relevant Summary Documents
Abstract: A report that provides the Umatilla, Malheur, and Wallowa-Whitman National Forests (Blue Mountain National Forests) with a preliminary framework upon which land managers can build appropriate strategies for restoring and maintaining the health of forest resources in Northeast Oregon and Southeast Washington. The report includes a discussion of the primary issues of forest health, analyses of existing conditions, and recommendations for future management.

167. Glinski, R. L. 1977. Regeneration and distribution of sycamore and cottonwood trees along Sonoita Creek, Santa Cruz, Arizona. In *Importance, Preservation and Management of Riparian Habitat: a Symposium*, edited by Johnson, R. Roy and Dale A. Jones (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-43).
Notes: Other Works Cited

168. Goheen, D. J. and E. M. Hansen. 1978. Black stain root disease in Oregon and Washington . *Plant Disease Reporter* 62, no. 12:1098-1102.
Notes: Supporting Studies
Abstract: Surveys and collected observations indicate that black stain root disease, caused by *Verticicladiella wagenerii*, is fairly common and widely distributed in western Oregon and Washington. Concern about the possible importance of the disease is mounting. Douglas-fir is the major host, but ponderosa pine and mountain hemlock also have been found infected. The disease is usually found in small, fairly discrete infection centers and causes rapid tree decline and death. It frequently predisposes trees to attack by insects and infection by *Armillaria mellea*.

169. Gordon, D. T. 1973. *Damage from wind and other causes in mixed white fir-red fir stand adjacent to clearcuttings*. Berkeley, California: U. S. Forest Service, PSW-RP-90.
Notes: Other Highly Relevant References

170. Graham, R. T. and others. 1995.
Notes: Other Works Cited

171. Graham, R. T., A. E. Harvey, T. B. Jain, and J. R. Tonn. 1999. *Effects of thinning and similar stand treatments on fire behavior in western forests*. Portland, Oregon: U. S. Forest Service, PNW-GTR-463.
Notes: Relevant Summary Documents
Abstract: In the West, thinning and partial cuttings are being considered for treating millions of forested acres that are overstocked and prone to wildfire. The objectives of these treatments include tree growth redistribution, tree species regulation, timber harvest, wildlife habitat improvement, and wildfire-hazard reduction. Depending on the forest type and its structure, thinning has both positive and negative impacts on crown fire potential. Crown bulk density, surface fuel, and crown base height are primary stand characteristics that determine crown fire potential. Thinning from below, free thinning, and reserve tree shelterwoods have the greatest opportunity for reducing the risk of crown fire behavior. Selection thinning and crown thinning that maintain multiple crown layers, along with individual tree selection systems, will not reduce the risk of crown fires except in the driest ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forests. Moreover, unless the surface fuels created by using these treatments are themselves treated, intense surface wildfire may result, likely negating positive effects of reducing crown fire potential. No single thinning approach can be applied to reduce the risk of wildfires in the multiple forest types of the West. The best general approach for managing wildfire damage seems to be managing tree density and species composition with well-designed silvicultural systems at a landscape scale that includes a mix of thinning, surface fuel treatments, and prescribed fire with proactive treatment in areas with high risk to wildfire.

172. Green, P., D. Harper, and M. E. Jensen. 1987. Pocket gopher and successional plant community relationships within the grand fir/wild ginger habitat type of Northern Idaho. In *Animal Damage*

Management in Pacific Northwest Forests, edited by Baumgartner, David M., R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

173. Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. *BioScience* 41:540-551.
Notes: Other Highly Relevant References

174. Gresswell, Robert E. 1998. Fire and aquatic ecosystems in forested biomes of North America. *Transactions of the American Fisheries Society* 128:193-221.
Notes: Supporting Summary Documents
Abstract: Synthesis of the literature suggests that physical, chemical, and biological elements of a watershed interact with long-term climate to influence fire regime, and that these factors, in concordance with the postfire vegetation mosaic, combine with local-scale weather to govern the trajectory and magnitude of change following a fire event. Perturbation associated with hydrological processes is probably the primary factor influencing postfire persistence of fishes, benthic macroinvertebrates, and diatoms in fluvial systems. It is apparent that salmonids have evolved strategies to survive perturbations occurring at the frequency of wildland fires (1 - 100 years), but local populations of a species may be more ephemeral. Habitat alteration probably has the greatest impact on individual organisms and local populations that are the least mobile, and reinvasion will be most rapid by aquatic organisms with high mobility. It is becoming increasingly apparent that during the past century fire suppression has altered fire regimes in some vegetation types, and consequently, the probability of large stand-replacing fires has increased in those areas. Current evidence suggests, however, that even in the case of extensive high-severity fires, local extirpation of fishes is patchy, and recolonization is rapid. Lasting detrimental effects on fish populations have been limited to areas where native populations have declined and become increasingly isolated because of anthropogenic activities. A strategy of protecting robust aquatic communities and restoring aquatic habitat structure and life history complexity in degraded areas may be the most effective means for insuring the persistence of native biota where the probability of large-scale fires has increased.

175. Gresswell, Robert E. 1999. Fire and aquatic ecosystems in forested biomes of North America. *Transactions of the American Fisheries Society* 128:193-221.
Notes: Other Highly Relevant References
Abstract: Synthesis of the literature suggests that physical, chemical, and biological elements of a watershed interact with long-term climate to influence fire regime, and that these factors, in concordance with the postfire vegetation mosaic, combine with local-scale weather to govern the trajectory and magnitude of change following a fire event. Perturbation associated with hydrological processes is probably the primary factor influencing postfire persistence of fishes, benthic macroinvertebrates, and diatoms in fluvial systems. It is apparent that salmonids have evolved strategies to survive perturbations occurring at the frequency of wildland fires (1 - 100 years), but local populations of a species may be more ephemeral. Habitat alteration probably has the greatest impact on individual organisms and local populations that are the least mobile, and reinvasion will be most rapid by aquatic organisms with high mobility. It is becoming increasingly apparent that during the past century fire suppression has altered fire regimes in some vegetation types, and consequently, the probability of large stand-replacing fires has increased in those areas. Current evidence suggests, however, that even in the case of extensive high-severity fires, local extirpation of fishes is patchy, and recolonization is rapid. Lasting detrimental effects on fish populations have been limited to areas where native populations have declined and become increasingly isolated because of anthropogenic activities. A strategy of protecting robust aquatic communities and restoring aquatic habitat structure and life history complexity in degraded areas may be the most effective means for insuring the persistence of native biota where the probability of large-scale fires has increased.

176. Grime, J. P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to

ecological and evolutionary theory. *American Naturalist* 111, no. 982:1169-1194.
Notes: Other Works Cited

177. Grissino-Mayer, H. D. and T. W. Swetnam. 1995. Effects of habitat diversity on fire regimes in El Malpais National Monument, New Mexico. In *Proceedings: Symposium on Fire in Wilderness and Park Management*, edited by Brown, J. K., R. W. Mutch, C. W. Spoon, and R. H. Wakimoto (Ogden, Utah: U. S. Forest Service, INT-GTR-320).
Notes: Relevant Studies
Abstract: The purpose of this research was to: (1) determine the history of fire occurrence over the past 300 to 600 years in various habitat types using dendroecological techniques; (2) investigate spatial differences in fire regimes between sites, and propose possible historical and ecological explanations for these differences; (3) investigate temporal differences in fire occurrence within sites and propose possible explanations for these differences; (4) suggest preliminary recommendations for implementing a fire management policy that considers the complexity of the landscape and the historical perspective of human land-use patterns. Habitat types for this study are based on geologic characteristics, such as those used by Smathers and Mueller-Dombois (1974) for volcanic areas in Hawaii, rather than potential climax associations.

178. Haack, R. A. and J. W. Byler. 1993. Insects and pathogens: regulators of forest ecosystems. *Journal of Forestry* 91, no. 9:32-37.
Notes: Supporting Summary Documents
Abstract: An article that describes how insects and pathogens can be considered beneficial from an ecosystem perspective. Focusing on “forest health” or the ability of a forest to recover from natural or human-cause stressors the authors discuss how insects and pathogens affect forest succession, carbon and nutrient cycling, food sources, the creation of wildlife habitat, and pollination.

179. Hadfield, J. S., D. J. Goheen, and G. M. Filip. 1986. *Root diseases in Oregon and Washington conifers*. Portland, Oregon: U. S. Forest Service, Pacific Northwest Region Forest Pest Management, R6-FPM-250-86.
Notes: Supporting Summary Documents
Abstract: Root diseases are responsible for large losses of timber in Pacific Northwest forests. All conifer species and all forested areas suffer damages from root diseases. This booklet has been prepared for foresters and others concerned with controlling conifer root diseases in Oregon and Washington forests. It describes how to recognize the most important root diseases, how they spread and damage host trees, and how to reduce losses. Controlling root diseases can significantly expand resource productivity of infested sites.

The information presented has been compiled from many sources and represents more than 75 years of research and observations by forest pathologists in the Pacific Northwest.

180. Hadley. 1994.
Notes: Other Works Cited

181. Hagle, S. K., G. I. McDonald, and E. A. Norby. 1989. *White pine blister rust in Northern Idaho and Western Montana: alternatives for integrated management*. Ogden, Utah: U. S. Forest Service, INT-GTR-261 or 419.
Notes: Supporting Summary Documents
Abstract: This report comprises a handbook for managing western white pine in northern Idaho and western Montana, under the threat of white pine blister rust. Various sections cover the history of the disease and efforts to combat it, the ecology of the white pine and Ribes, alternate host of the rust, and techniques for evaluating the rust hazard and attenuating it. The authors advocate an integrated control strategy based on local stand conditions. Options include planning resistant strains of pine, excising cankers, and chemical, mechanical, and silvicultural control of Ribes.

182. Hall. 1988.
Notes: Other Works Cited

183. Hall, F. C. 1988. Characterization of riparian systems. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington : University of Washington, Institute of Forest Resources Contribution #59).
Notes: Other Highly Relevant References

184. Halpern, C. B. 1988. Early successional pathways and the resistance and resilience of forest communities. *Ecology* 69, no. 6:1703-1715.
Notes: Highly Relevant Studies
Abstract: Vegetation changes were studied for 21 yr in two clearcut logged and slash-burned *Pseudotsuga* forests in the western Cascade Range of Oregon. Detrended correspondence analysis (DCA) was used to examine the successional relationships among six understory communities exposed to a gradient of disturbance intensity. Euclidean distances between pre and postdisturbance samples in ordination space were used to compare community resistance to disturbance and long-term recovery, or resilience. Ordination through time for plant communities revealed a common pattern of rapid floristic change away from predisturbance composition, followed by gradual, unidirectional return. Early, but transient, convergence of successional pathways was common among mesic- and dry-site communities, reflecting the broad distributions of colonizers and the floristic similarity of predisturbance understories. District sequences were observed on moist sites, reflecting more unique residual and colonizing floras. Ordinations also revealed increasing compositional change with disturbance intensity. Successional sequences were dominated by residual species on relatively undisturbed sites and by alternate suites of invading species on moderately disturbed and burned sites. Variation in the response gradient between watersheds reflected the modifying influence of local environment, stand history, and chance in succession.

Resistance and resilience varied little among plant communities but were generally lowest for the depauperate *Coptis* community and greatest for the compositionally and structurally diverse *Plystichum* and Rhododendron-Gaultheria types. Both measures were strongly influenced by disturbance intensity. The stability of *Pseudotsuga* understories derives from the moderate tolerance of initial understory dominants to burning and in their ability to subsequently perennate from subterranean structures. Variation in the long-term response of communities reflects complex interactions between species life history, disturbance intensity, and chance, suggesting that both deterministic and stochastic factors must be considered in evaluating community stability and response to disturbance.

185. Halpern, C. B. 1989. Early successional patterns of forest species: interactions of life history traits and disturbance. *Ecology* 70, no. 3:704-720.
Notes: Relevant Studies
Abstract: Patterns of abundance were examined for vascular plant species during 21 yr of succession in two clear-cut and burned *Pseudotsuga* forest in the western Cascade Range of Oregon. A majority of forest understory species persisted through disturbances. Most colonizing species established within 2 yr after burning. Individualistic species responses were described by a series of broadly overlapping, unimodel curves of constancy and canopy cover, differing in time of initiation, duration, and magnitude. Thus, early successional change was characterized by gradual shifts in the abundance of generally persistent species.

Eleven population patterns (species groups) were identified. Interactions of life history traits and disturbance explain the temporal trends of the most common species. Within the groups of invading species, the timing of initial establishment, as well as the timing and magnitude of peak abundance were related to the origin of propagules, phenological traits, potential for vegetative expansion, and temporal and spatial variations in disturbance. Abundance patterns of invading species were also influenced by stochastic and historical factors. Contracting responses of species between sites reflected differences in histories of logging and slash burning. Within the groups of residual species, temporal patterns of abundance reflected initial species distribution, resistance to logging and burning disturbance, mode of reproduction, morphological traits, and spatial variation in disturbance intensity.

These observations suggest that early secondary succession in *Pseudotsuga* forests has a determinstic component, founded in the life history and traits of the available species, and a stochastic component reflecting site history and variation in disturbance.

186. Hann, W. J. and others. 1993.
Notes: Other Works Cited

187. Hansen, P., R. Pfister, K. Boggs and others. 1995. *Classification and management of riparian and wetland sites in Montana*. Missoula, Montana: University of Montana, School of Forestry.
Notes: General References
Abstract: Presents a riparian and wetland vegetation-based ecological site classification for Montana. The classification is designed to provide (1) assistance to resource managers as they identify, describe, communicate about, and manage riparian and wetland areas; (2) describe the general geographic, topographic, pedologic, floristic, and functional features of riparian and wetland ecosystems; (3) describe successional trends and predict vegetative potential on undisturbed riparian and wetland sites; and (4) present type-specific information on resource values and management opportunities.

188. Harrington, T. C., F. W. Cobb, and J. W. Lownsbery. 1985. Activity of *Hylastes nigrinus*, a vector of *Verticicladiella wageneri*, in thinned stands of douglas fir. *Canadian Journal of Forest Research* 15:519-523.
Notes: Supporting Studies
Abstract: Live adults of *Hylastes nigrinus* (Mann.), a root-feeding bark beetle suspected of being a vector of *Verticicladiella wageneri* Kendr. were trapped in infection centers of black stain root disease and allowed to feed on seedlings of douglas fir (*Pseudotsuga menziesii* Mirb. Franco) in the greenhouse. Three of 22 beetles that were artificially contaminated with conidia of *V. wageneri* introduced the pathogen into seedlings. One of 47 seedlings infested with pairs of *H. nigrinus* that were not artificially contaminated became infected with *V. wageneri*. The activity of *H. nigrinus* in thinned plots at three sites near the North Coast of California was monitored with sticky traps. In 1981, 100 adults were trapped in plots mechanically thinned on 13 April 1981. Only two *H. nigrinus* were trapped in unthinned, control plots. Twenty-two adults were trapped in plots chemically thinned by the injection of cacodylic acid. In 1982, as many or more adults were trapped in plots that were thinned after the seasonal peak of *H. nigrinus* in 1981 as in plots that were freshly thinned. Roots of living Douglas-fir trees examined in a mechanically thinned plot had feeding wounds similar to those described as feeding wounds made by *H. nigrinus*. Roots of living Douglas-fir in an unthinned plot had no evidence of insect feeding. Although no black stain was found associated with feeding wounds on living trees, the previously noted association of black stain root disease in thinned stands may still be due to an increased activity of *H. nigrinus*.

189. Harrod, J. C., M. E. Harmon, and P. S. White. 2000. Post-fire succession and 20^{th} century reduction in fire frequency on xeric southern Appalachian sites. *Journal of Vegetation Science* 11, no. 4:465-472.
Notes: Other Works Cited

190. Harrod, Richy J., W. L. Gaines, and W. E. Hartl. 1998. *Estimating historical snag density in dry forests East of the Cascade Range*. Portland, Oregon: U. S. Forest Service, PNW-GTR-428.
Notes: Relevant Studies
Abstract: Estimating snag densities in pre-European settlement landscapes (i.e., historical conditions) provide land managers with baseline information for comparing current snag densities. We propose a method for determining historical snag densities in the dry forest east of the Cascade Range. Basal area increase was calculated from tree ring measurements of old ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) trees. Historical stand structure was

assumed to be open and parklike, with low densities favoring larger diameter trees, and it was considered relatively stable at the landscape level. Snag density (S) was calculated by holding forest stand structure relatively constant (basal area range 13.8 to 18.4 square meters per hectare [60 to 80 ft^2/acre] and diameter size class distributions with q-factors of 1.1 or 1.2), assuming snag recruitment could be no greater than annual basal area increase, and estimating that all snags fail by 45 years; S=(1+Eri), where a is annual recruitment and Eri is a sum of the ratios of snags remaining from previous recruitment years (I). If eight representative snag sizes are selected, snag density in historical landscapes ranged from 14.5 to 34.6 snags per hectare (5.9 to 14.1 snags per acre).

191. Harrod, Richy J., B. H. McRae, and W. E. Hartl. 1999. Historical stand reconstruction in ponderosa pine forests to guide silvicultural prescription. *Forest Ecology and Management* 114:433-446.
Notes: Highly Relevant Studies
Abstract: We reconstructed the historical stand structure and spatial patterning of fire-maintained ponderosa pine forests in the Eastern Cascades of Washington to develop and design silvicultural prescriptions to restore historical structure and composition. The structures of the dominant overstory was inferred from the size and spatial patterning of stumps, logs, snags, and live trees (>140 years of age) within 48 0.5ha plots. Size class distributions, basal area, and spatial distribution of historical trees were compared among plant association groups representing a range of environmental conditions. Using spatial point pattern analysis, we found that significant clumping at fine scales (0-15m) existed historically. Spatial patterning of present day and historical trees of four comparable plots suggest that while strong clumping exists in present day stands, the largest trees today exhibit less clumping than did large historical trees. Historical SDI (260) for dominant overstories was nearly the same as threshold for serious beetle mortality (263) for ponderosa pine. Cut-tree marking was carried out within 15m radius circles, as guided by the spatial patterning analysis, and using a sliding scale of trees per circle by quadratic mean diameter.

192. Harrod, Ricky J., R. J. Taylor, W. L. Gaines and others. 1993. Noxious weeds in the Blue Mountains. In *Search for a Solution: Sustaining the Land, People, and Economy of the Blue Mountains*, edited by Jaindl, R. G. and T. M. Quigley (Washington, D. C.: American Forests).
Notes: Other Highly Relevant References

193. Harrord, Richy J., D. E. Knecht, E. E. Kuhlmann, M. W. Ellis, and R. Davenport. 1998. Effects of the Rat and Hatchery Creek Fires on four rare plant species. In *Fire Effects on Rare and Endangered Species and Habitats Conference*, edited by Greenlee, Jason M. (Fairfield, Washington: International Association of Wildland Fire).
Notes: Other Works Cited

194. Harvey and others. 1994.
Notes: Other Works Cited

195. Harvey, A. E. 1994. Integrated roles for insects, diseases and decomposers in fire dominated forests of the Inland Western United States: past, present and future forest health. *Journal of Sustainable Forestry* 2 , no. 1/2:211-220.
Notes: Relevant Summary Documents
Abstract: Forest ecosystems characterizing much of the Inland Western United States occupy precarious, changing environments that can be moisture, temperature, and/or nutrient limited. Rapid vegetative adaptations to inherent change are critical to both plant community stability and to the survival of individual species. Biological decomposition processes are often constrained and natural wildfires represent an important recycling agent. Recycling of resources is critical. It is proposed that native insect, disease and other decomposer activities, plus natural wildfire, historically provided coordinated biological and physical processes that were integral to carbon, nitrogen, and other nutrient cycling, and to rapid evolution and adjustment of native conifers (and of their ecosystems) in this dynamic environment. Current conditions, as imposed by traditional harvesting and fire control over the last 100 years, plus the introduction of white

pine blister rust in the early 1930s, have changed many native vegetative and microbial systems. Endemic insects and diseases have to respond to these changes by increasing activities. Their effects counter many of the destabilizing actions of site deterioration, fuel accumulation, changes in species and genetic compositions, increased stand densities and impairment of recycling processes. At least in the short term, many ecosystems are now highly vulnerable to potential damage from high fuel wildfire and perhaps to the momentum of alternative biological decomposition processes. Genetic resources and other diversity components may be at especially high risk. Many current trends place future values in increasing danger until the course is changed. Adjusting cycle processes, stand density and species composition will often be more important than controlling individual pests when managing forest health for this region in the future.

196. Harvey, A. E., G. I. McDonald, and M. F. Jurgensen. 1992. Relationships between fire, pathogens, and long-term productivity in Northwestern forests. In *Fires in Pacific Northwest Ecosystems: Exploring Emerging Issues*, (Corvallis, Oregon: Oregon State University).
Notes: Highly Relevant Summary Documents
Abstract: An introduction to the relationship between fire and disease in Northwestern Forests. The authors hypothesize that critical ecosystem functions of native pests likely amount to more than just agents for carbon and nutrient cycling but they include a genetic screening component as well, and that this is an important additional dimension to pest management, particularly in inland forests.

197. Harvey, E. M., G. H. Mohammed, and T. L. Noland. 1993. *Bibliography on competition, tree seedling characteristics and related topics* . Sault Ste. Marie, Ontario, Canada: Ontario Ministry of Natural Resources, Forest Research Institute, Forest Research Information Paper #108.
Notes: Other Works Cited

198. Haufler, J. B., C. A. Mehl, and G. J. Roloff. 1996. Using a coarse-filter approach with species assessment for ecosystem management . *Wildlife Society Bulletin* 24, no. 2:200-208.
Notes: Other Highly Relevant References

199. Hawksworth, F. G. 1977. *The 6-class dwarf mistletoe rating system*. Fort Collins, Colorado: U. S. Forest Service, RM-GTR-48.
Notes: Supporting Summary Documents
Abstract: Several rating systems have been proposed to describe the intensity of dwarf mistletoe infection in individual trees or stands, but the 6-class dwarf mistletoe rating (DMR) system, described in 1956, has been most widely adopted. This system is being used for several dwarf mistletoe host/parasite combinations in western North America. Uses and limitations of the 6-class system are discussed, and several applications of the system are cited.

200. Hawksworth, F. G. and D. W. Johnson. 1989. *Biology and management of dwarf mistletoe in lodgepole pine in the Rocky Mountains*. Fort Collins, Colorado: U. S. Forest Service, RM-GTR-169.
Notes: Relevant Studies
Abstract: This publication synthesizes the vast literature on lodgepole pine dwarf mistletoe (*Arceuthobium americanum*) and adds some new information on biology of the parasite. Although dwarf mistletoe has been recognized as a serious parasite of lodgepole pine for more than 75 years, its routine operational control through forest management has been primarily a development over the past two decades. This report discusses silvicultural control of dwarf mistletoe in various types of stands where fiber production is the primary goal, and also in forests used mainly for recreation.

201. Hawksworth, F. G., D. W. Johnson, and B. W. Geils. 1987. Sanitation thinning in young, dwarf mistletoe-infested lodgepole pine stands. In *Management of Subalpine Forests: Building on 50 Years of Research*, edited by Troendle, C. A., H. R. Kaufman, R. H. Hamre, and R. P. Winokua (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-149).
Notes: Supporting Studies

Abstract: Dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is the most serious tree disease agent of lodgepole pine in the Rocky Mountains. This parasite occurs on more than half of the 2 million acres of commercial lodgepole pine forests in the Central Rocky Mountains, and causes an annual volume loss of more than 15 million cubic feet. Dwarf mistletoes are one of the few forest diseases that can be effectively controlled by silvicultural means (Johnson and Hawksworth 1985). However, some early cultural practices actually intensified the problem. For example, harvest operations that left infected residual trees provided ideal conditions for maximum spread and intensification of the disease into young stands.

Thousands of acres of lodgepole pine in the Rocky Mountain Region were partially logged in the 1950's and 1960's and many mistletoe-infected but non-merchantable trees were left standing. These trees now provide a serious source of infection for the young, naturally regenerated stands that have become established beneath them. Sales contracts now call for removal of all infected trees in cutting areas, but vast problem areas of infected reproduction remain in older sales areas.

202. Heinselman, M. L. 1973. Fire in the virgin forest of the Boundary Waters Canoe Area, Minnesota. *Quarternary Research* 3:329-382.
Notes: Other Highly Relevant References

203. Heinselman, M. L. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. In *Proceedings of the Conference: Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-26).
Notes: Relevant Summary Documents
Abstract: Most presettlement Canadian and Alaskan boreal forests and Rocky Mountain subalpine forests had lightning fire regimes of large-scale crown fires and high-intensity surface fires, causing total stand replacement on fire rotations (or cycles) of 50 to 200 years. Cycles and fire size varied with latitude, elevation, and topographic-climate factors. Some areas had smaller, less-intense surface fires at shorter intervals. The Great Lake-Acadian forests had regimes of short cycle crown fires in near-boreal jack pine and spruce forests, combinations of moderate intensity short-interval surface fires and small-scale crown fires at longer intervals in red-white pine forests, and low intensity long-interval fires in hardwoods. Fire maintained the structure and pattern of the forest mosaic. These regimes still prevail in the far north. Elsewhere regimes and the forest mosaic are greatly modified by logging, man-caused fires, and fire suppression.

204. Helvey, J. C. 1980. Effects of a north central Washington wildfire on runoff and sediment production. *Water Resources Bulletin* 16, no. 4:627-634.
Notes: Other Works Cited

205. Hemstrom, J. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

206. Hemstrom, M. A., J. J. Korol, and W. J. Hann. 2001. Trends in terrestrial plant communities and landscape health indicate the effects of alternative management strategies in the Interior Columbia River Basin. *Forest Ecology and Management* 153:105-126.
Notes: Highly Relevant Studies
Abstract: Current and potential future conditions of terrestrial plant communities and landscape health were modeled for three alternative public land management strategies in the interior Columbia River basin. Landscape health was defined as an integration of the degree to which vegetation and disturbance conditions resemble native patterns and support levels of human activity. The range of vegetation and disturbance variability for a period before the middle 19th century was used as a basis for comparison of current and future regimes to the "historical" system. Departure from the "historical" regime in wildland environments was found to be

related to altered disturbance patterns, especially changed fire regimes, forest insect and disease levels and excessive livestock grazing effects. Overall, mid-seral forest are currently more prevalent than they were in the past and old forests, especially single-layer structural types are less abundant. Non-native plant species and altered plant community composition conditions exist across broad areas of rangelands. Landscape health has declined substantially in many areas. Proposed management strategies that emphasize maintenance and restoration activities in a hierarchical landscape approach should generate improved landscape health conditions over the next 100 years. However, the massive scale of changes to disturbance and vegetation patterns from historical to current times and the cost of implementing restoration activities make dramatic improvement unlikely.

207. Hessburg, P. F. and others. 1993.
Notes: Other Works Cited

208. Hessburg, P. F. and Richard L. Everett. 1993.
Notes: Other Works Cited

209. Hessburg, P. F., R. G. Mitchell, and G. M. Filip. 1994. *Historical and current roles of insects and pathogens in Eastern Oregon and Washington forested landscapes*. Portland, Oregon: U. S. Forest Service, PNW-GTR-327.
Notes: Highly Relevant Summary Documents
Abstract: This paper examines by climax conifer series, historical and current roles of many important pathogens and insects of interior Northwest coniferous forests, and their unique response to changing successional conditions resulting from management.

Insects and pathogens of the subalpine fir and mountain hemlock series historically reduced inter-tree competition for site resources, and generated most of the coarse woody debris between fires. Severity of growth and mortality effects was proportional to the abundance of susceptible seral species such as douglas fir, grand-fir, and lodgepole pine within and adjacent to subalpine fir and mountain hemlock forests. Laminated root rot, a mortality factor, influenced successional status, fire intensity, and fire behavior. Insects and disease disturbances in present day western hemlock and western red cedar climax forests are much the same as those occurring historically, but increased scale of fire disturbance resulting from fire exclusion, has increased the scale of insect and pathogen disturbances associated with changing successional conditions.

Spectacular differences are apparent when comparing historical and current roles of pathogens and insects of the douglas fir and grand-fir series. Before the advent of fire control on public lands, late successional and climax forest stands were relatively scarce in comparison with current distribution. A century of fire protection has produced a steady shift away from parklike ponderosa pine and western larch forests toward denser late-successional fir forests. Harvesting of high-value seral overstories accelerated conversion to insect- and pathogen-susceptible late-successional forests. Douglas-fir and grand (white) fir are highly susceptible to root pathogens, bark beetles, defoliators, and dwarf mistletoe. Excluding fire from grand fir and douglas fir forests has perhaps been the single greatest detriment to diversity of eastside forests, and a primary factor in current susceptibility to major pathogens and insects.

Low intensity fires, once common to historical ponderosa pine climax forests, maintained low fuel loads, minimized fuel ladders, and spaced trees struggling to survive under severe moisture-limited growing conditions. The western pine beetle and mountain beetle thinned densely stocked areas missed by fire, and killed trees injured by wind and weather, or weakened by root disease, dwarf mistletoe, pandora moth, or advanced age. With fire control, overstocked conditions became widespread and bark beetles assumed the role of under burning to the elimination of trees in excess of site potential. Regeneration of historical lodgepole pine forests was predicated on mountain pine beetle outbreaks and subsequent stand replacing four events. Today, with fire control, mountain pine beetle outbreaks affect larger areas, for longer periods, often with greater intensity than historical outbreaks.

Specific solution to elevated insect and disease disturbance in current forests is complicated by great variety in environmental and vegetal conditions where rehabilitation might be needed, and change in biological and physical potentials as a direct result of management. Still, much can be done. Stocking can be reduced where long-term carrying capacity is exceeded. Developing a seral-dominated forest matrix can reverse the shift toward late-successional, fire intolerant, pathogen- and insect-susceptible forests. Management activates can promote landscape structure, composition, and pattern, consistent with historical disturbance regimes and land potentials.

Future research on forest pathogens and insects should address three primary subject areas; insect and pathogen population dynamics in managed and unmanaged forests; ecological roles and effects of native and introduced pathogens and insects; and, effects of natural disturbances and management practices on native insects, pathogens, and their natural enemies.

210. Hessburg, P. F., R. B. Salter, B. G. Smith, S. D. Kreiter, C. A. Miller, C. H. McNicoll, and W. J. Hann. 1999. *Historical and current forest and range landscapes in the interior Columbia River Basin and portions of the Klamath and Great Basins: Part 1: linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances*. Portland, Oregon: U. S. Forest Service, PNW-GTR-458.

Notes: Highly Relevant Summary Documents

Abstract: Management activities of the 20th century, especially fire exclusion, timber harvest, and domestic livestock grazing, have significantly modified vegetation spatial patterns of forests and ranges in the interior Columbia basin. Compositional patterns as well as patterns of living and dead structure have changed. Dramatic change in vital ecosystem processes such as fire, insect, and pathogen disturbances, succession, and plant and animal migration is linked to recent change in vegetation patterns. Recent change in vegetation patterns is also a primary reason for current low viability and threatened, endangered, or sensitive status of numerous native plant and animal species. Although well intentioned, 20th-century management practices have not accounted for the larger patterns of living and dead vegetation that enable forest ecosystems to function in perpetuity and maintain their structure and organization through time, or for the disturbances that create and maintain them. Knowledge of change in vegetation patterns enhances resource manager and public awareness of patterns that better correspond with current climate, site conditions, and native disturbance regimes, and improves understanding of conditions to which native terrestrial species have already adapted.

In this study, we characterized recent historical and current vegetation composition and structure of 337 randomly sampled subwatersheds (9,500 ha average size), in 43 of 164 total subbasins (404,000 ha average size), selected by stratified random draw on all ownerships within the interior Columbia River basin and portions of the Klamath and Great Basins (collectively referred to as the basin). We compared landscape patterns, vegetation structure and composition, and landscape vulnerability to 21 major insect and pathogen disturbances of historical and current vegetation coverages. For each selected subwatershed, we constructed historical and current vegetation maps from interpretations of 1932-66 and 1981-93 aerial photos, respectively. Areas with homogeneous vegetation composition and structure were delineated as patches to a minimum size of 4 ha. We then attributed cover types (composition) structural classes (structure), and series-level potential vegetation types (site potential) to individual patches within subwatersheds by modeling procedures. We characterized change in vegetation spatial patterns by using an array of class and landscape pattern metrics and a spatial pattern analysis program. Finally, we translated change in vegetation patterns to change in landscape vulnerability to major forest pathogen and insect disturbances. Change analyses results were reported for province-scale ecological reporting units.

Forest and range ecosystems are significantly altered after their first century of active management, but there is reason for guarded optimism. Large areas remain relatively unchanged and intact, such as can be found on the east side of the Cascade Range in Washington and in the central Idaho mountains, and these areas may provide an essential "nucleus" for conservation strategies and ecosystem restoration. Strategies for improving the health of basin ecosystems can build on existing strengths. Improved understanding of change in vegetation patterns, causative factors, and links with disturbance processes will assist managers and policy makers in making informed decisions about how to address important ecosystem health issues.

211. Hessburg, P. F., B. G. Smith, C. A. Miller, S> D. Kreiter, and R. B. Salter. 1999. *Modeling change in potential landscape vulnerability to forest insect and pathogen disturbances: methods for forested subwatersheds sampled in the midscale Interior Columbia River Basin assessment*. Portland, Oregon: U. S. Forest Service, PNW-GTR-454.
Notes: Highly Relevant Studies
Abstract: In the interior Columbia River basin midscale ecological assessment, including portions of the Klamath and Great Basins, we mapped and characterized historical and current vegetation composition and structure of 337 randomly sampled subwatershed (9500 ha average size) in 43 subbasins (404,000 ha average size). We compared landscape patterns, vegetation structure and composition, and landscape vulnerability to 21 major forest insect and pathogen disturbances of historical and current forest vegetation overages. Forest vegetation composition, structure, and patterns were derived from attributes interpreted and mapped from aerial photographs taken from 1932 to 1966 (historical), and from 1981 to 1993 (current). Areas with homogeneous vegetation composition and structure were delineated as patches to a minimum size of 4 ha. Results of change analyses were reported for province-scale ecological reporting units (ERU's). In this paper, we report on methods used to characterize historical and current patch and subwatershed vulnerability to each of 21 insect and pathogen disturbance agents.

We assessed landscape vulnerability to defoliator, bark beetle, dwarf mistletoe, root disease, blister rust, and stem decay disturbances. We used patch composition, structure, logging disturbance, and physical environmental attributes to compare vegetation vulnerability of historical subwatersheds with that of their current condition. Patch vulnerability factors included items such as site quality, host abundance, canopy layers, host age of host size, patch vigor, patch (stand) density, connectivity of host patches, topographic setting, and presence of visible logging disturbance. Methods reported here can be used in landscape or watershed analysis to evaluate or monitor change in the magnitude and spatial pattern of vegetation vulnerability to insect and pathogen disturbances, and in planning to compare potential disturbance futures associated with alternative vegetation management scenarios.

212. Hessburg, P. F., B. G. Smith, and R. B. Salter. 1999. Detecting change in forest spatial patterns from reference conditions. *Ecological Applications* 9, no. 4:1232-1252.
Notes: Relevant Studies
Abstract: Timber harvest, fire suppression, road construction, and domestic livestock grazing have transformed spatial patterns of Interior Northwest forests. As a consequence, parameters of current disturbance regimes differ radically from historical regimes; present day wildlife habitat distributions differ from historical distributions; and long-term survival of some native terrestrial species is uncertain. Public land managers are under increasing scientific and social pressure to mold existing forest spatial patterns to reflect those resulting from natural disturbance regimes and patterns of biophysical environments. However, knowledge of the characteristics of natural spatial patterns is unavailable.

Using a dichotomized ordination procedure, we grouped 343 forested subwatersheds (mean area, 8,000 ha) on the eastern slope of the Cascade Mountains in Washington State into ecological subregions by similarity of area in potential vegetation and climate attributes. We built spatially continuous "historical" (1938-1956) and "current" (1985-1993) vegetation maps for 48 randomly selected subwatersheds from aerial photo interpretations. From remotely sensed attributes, we classified cover types, structural classes, and potential vegetation types and attributed them to individual patches. We then estimated a reference variation (RV) in spatial patterns of patch types (cover type and structural class), by subwatersheds and five forested ecological subregions, using the 48 historical vegetation maps stratified by subregion and a spatial pattern analysis program. Finally, we compared the current pattern of an example subwatershed (MET_11) with the RV estimates of its corresponding subregion to illustrate how

reference conditions can be used to evaluate the importance of spatial pattern change. By evaluating pattern changes in light of RV estimates (nominally, the sample median 80% range of a metric) and the full range of class and landscape metrics, we could identify both current and historical conditions of MET_11 that fell outside the RV. This approach gives land managers a tool to compare characteristics of present -day managed landscapes with reference conditions to reveal significant pattern departures, as well as to identify specific pattern characteristics that might be modified through management. It also provides a means to identify "outlier" conditions, relative to subregion RV estimates, that may occasionally be the object of pattern restoration activities.

213. Hessburg, P. F., B. G. Smith, and R. B. Salter. 1999. *Using estimates of natural variation to detect ecologically important change in forest spatial patterns: a case study, Cascade Range, Eastern Washington*. Portland, Oregon: U. S. Forest Service, PNW-RP-514.
Notes: Highly Relevant Studies
Abstract: Using hierarchical clustering techniques, we grouped subwatersheds on the eastern slope of the Cascade Range in Washington State into ecological subregions by similarity of area in potential vegetation and climate attributes. We then built spatially continuous historical and current vegetation maps for 48 randomly selected subwatersheds from interpretations of 1938-49 and 1985-93 serial photos, respectively, and attributed cover types, structural classes, and potential vegetation types to individual patches by modeling procedures. We estimated a natural range of variation (NRV) in spatial patterns of patch types by subwatersheds and five forested ecological subregions. We illustrate how NRV information can be used to characterize the direction and magnitude of vegetation change occurring as a consequence of management.

214. Heyerdahl, E. K. 1997.
Notes: Other Works Cited

215. Heyerdahl, E. K. and J. K. Agee. 1996. *Historical fire regimes of four sites in the Blue Mountains, Oregon and Washington -- final report*. Seattle, Washington: University of Washington, College of Forest Resources.
Notes: Other Works Cited

216. Hibbs, Dave E. and A. L. Bower. 2001. Riparian forests in the Oregon Coast Range. *Forest Ecology and Management* 154:201-213.
Notes: Relevant Studies
Abstract: We examined the structure and composition of forested buffer strips in the central and northern Coast Range of Oregon and found little botanical evidence of an effect on plant community composition or dynamics from isolating these forests as buffers. Thus, concerns about microenvironment changes due to extended edge effects appear unfounded in this region for the plant community. Tree stocking was low, especially on terraces; evidence suggests that competition, as well as site conditions, limits the regeneration of trees, including conifers. Understory diversity (richness) was greater under conifer canopy types; understory cover was greater under hardwood canopy types. Tree regeneration, especially on terrace and under hardwoods, was limited although more abundant than in older, unmanaged riparian forest. In the long term, succession models for this region suggest that many of these riparian areas will succeed to a largely treeless community.

217. Hood, W. G. and Robert J. Naiman. 2000. Vulnerability of riparian zones to invasion by exotic vascular plants. *Plant Ecology* 148, no. 1:105-114.
Notes: Highly Relevant Studies
Abstract: We compared the invasibility of riparian plant communities high on river banks with those on floodplain floors for four South African rivers. Analyses of abundant and significant riparian species showed that the floors have 3.1 times more exotic plants than the banks. The percent exotics ranges from 5% to 11% of total species richness for the banks, and from 20% to 30% for the floors. Species richness and percent exotics are negatively correlated for the banks, but not correlated for the floors.

Despite great differences in climate, species richness, and land use history, the percentages of exotic plants in three rivers in the Pacific Northwest of the USA and one river in southwestern France are similar to those in South Africa (24-30% vs. 20-30%, respectively). Furthermore, the high proportions of exotic species in these riparian plant communities are comparable to those reported for vascular plant communities on islands. We conclude that the macro-channel floor regions of the riparian zones of South African rivers are highly vulnerable to invasion by exotic vascular plants.

218. Hopkins, J. C. and B. Callan. 1991. *Atropellis canker*. Victoria, British Columbia, Canada: Forestry Canada, Forest Pest Leaflet #29-6/25.
Notes: Supporting Summary Documents
Abstract: *Atropellis piniphila* (Weir) Lohman and Cash is a fungus that causes perennial stem and branch cankers of lodgepole pine (*Pinus contorta* Dougl.). In locations where this disease is prevalent, most or all host trees may become infected and multiple stem and branch infections are common. The disease reduces the value of trees for lumber, or pulp and many countries prohibit its importation in lumber.

This leaflet describes *A. piniphila*, one of four North American species of the genus, which cause disease in pines. The information provided is probably also applicable to *A. pinicola* Zeller and Goodding. *Atropellis pinicola*, which attacks western white pine (*P. monticola Dougl*.) and, occasionally, lodgepole pine, is the only other species of *Atropellis* found in B. C.

219. Huff, M. H. 1984. *Post-fire succession in the Olympic Mountains, Washington: forest vegetation, fuels, and avifauna*. Seattle, Washington: Doctoral Dissertation, University of Washington.
Notes: Other Highly Relevant References
Abstract: The lower montane zone in Olympic National Park was selected to study fire effects in westslope western hemlock (*Tsuga heterophylla*)/douglas fir (*Pseudotsuga menziesii)* forests. Vegetation, snags, dead and down fuels, and birds were examined along a post-fire chronosequence: years 1-3, 19, 110, 181, and 515. The objectives of this research were to document the successional patterns of a moist temperate coniferous forest following large lightning fires, and to determine the broad ecological effects of fire in these forests. The 1978 Hoh Fire caused extensive overstory tree mortality. On the study plots, only three large douglas firs survived the fire; these trees eventually died. The first year after the fire, numerous seedlings (73606/ha) became established, primarily western hemlock and douglas fir. By year 3 tree establishment ceased. However, regeneration continued at the 19-year-old site. Post-fire tree reestablishment spanned a 30-40 year period at the 110-year-old site. Most regeneration occurred 10-15 years after the fire. A much longer reestablishment period, extending 50-75 years, was observed at the 181-year-old site. Least-squares regression lines of diameter and age were examined at the 110, 181, and 515-year-old sites. Weak or no relationships existed for douglas fir or western hemlock on any sample site. Generally, the amount and size of dead and down fuels were significantly different among the different aged study areas. Each fuel component or particle size showed different maximum and minimum patterns along the successional gradient. Avifauna that commonly breed in disturbance or mature-type forests were present in post-fire years 1-3. In year 1, the breeding density and diversity was similar to the nearby old-growth (pre-burn) forest. Breeding density and diversity decreased in years 2 and 3. The 19-year-old site maintained the highest number of species and second highest density throughout the study areas. Diversity and density was lower at the closed canopy forest, except in the old-growth forest (year 515) where the highest avian density was recorded.

220. Hughes and Edwards. 1978.
Notes: Other Works Cited

221. Hunter. 1991.
Notes: Other Works Cited

222. Ice, G. G. 1985. *Catalog of landslide inventories for the Northwest*. New York, New York: National

Council of the Paper Industry for Air and Stream Improvement, Technical Bulletin #456.
Notes: Other Highly Relevant References

223. Jensen, M. E., P. Bourgeron, Richard L. Everett, and I. Goodman. 1996. Ecosystem management: a landscape ecology perspective. *Journal of the American Water Resources Association* 32, no. 2:203-216.
Notes: Other Highly Relevant References

224. Johnson and Clausnitzer. 1991.
Notes: Other Works Cited

225. Johnson, D. W. 1986. *Comandra blister rust*. Washington, D. C.: U.S. Department of Agriculture, Forest Insect & Disease Leaflet #62.
Notes: Supporting Summary Documents
Abstract: An overview of Comandra Blister Rust, a disease of hard pines that is caused by a fungus growing in the inner bark. Includes a discussion of the following elements: range and hosts, life cycle and spread, damage, symptoms, factors affecting outbreaks, control recommendations, and a description of the future of rust control.

226. Johnson, D. W. and F. G. Hawksworth. 1985. Dwarf mistletoes: candidates for control through cultural management. In *Insect and Disease Conditions in the United States 1979-1983: What Else is Growing in Our Forests?* edited by Loomis, R. C., S. Tucker, and T. H. Hofacker (Washington, D. C.: U. S. Forest Service, WO-GTR-46).
Notes: Supporting Summary Documents
Abstract: The dwarf mistletoes are one of the most widespread and damaging groups of forest diseases in North America. This overview generally describes their evolution, how they have affected timber and recreational forest resources throughout the United States, and how they can be prevented or suppressed in the future.

227. Johnson, S. L., F. J. Swanson, G. E. Grant and others. 2000. Riparian forest disturbances by a mountain flood - the influence of floated wood. *Hydrological Processes* 14:3031-3050.
Notes: Highly Relevant Studies
Abstract: Large floods can have major impacts on riparian forests. Here we examine the variability and spatial distribution of riparian forest responses along eight third-to-fifth-order streams following a large flood (100 year recurrence interval) in the Cascade Mountain Range of Oregon. We categorized disturbance intensity (physical force) exerted or riparian trees during floods into three classes (I) purely fluvial (high water flow only); (II) fluvial supplemented by dispersed pieces of floating wood (uncongested wood transport); (III) fluvial with movement of batches of wood (congested wood transport). These types of material transport and associated classes of disturbance intensity resulted in a gradient of biotic responses of disturbance severity ranging from standing riparian trees inundated by high water, to trees toppled but still partially rooted, to complete removal of trees. High within-stream and among-stream responses were influenced by pre-flood stream and riparian conditions as well as flood dynamics, especially the availability of individual pieces or congested batches of wood.

Fluvial disturbance alone toppled fewer riparian trees than in reaches where floodwaters transported substantial amount of wood. Debris flows delivered additional wood and sediment to parts of reaches of four of these study streams; riparian trees were removed and toppled for up to 1-5 km downstream of the debris flow tributary channel. Congested wood transport resulted in higher frequency of toppled trees and greater deposition of new wood levels along channel margins. The condition of the landscape at the time of a major flood strongly influenced responses of riparian forests. Recent and historic land-use practices, as well as the time since they previous large flood, influenced not only the structure and age of the riparian forests, but also the availability of agents of disturbance, such as large pieces of floating wood, that contribute to disturbance of riparian forests during floods.

228. Joyce, L. A., J. Aber, and Steve McNulty. 2001. *Forest sector, the potential consequences of climate variability and change*. Washington, D. C.: U.S. Department of Agriculture, Global Change Research Program Office.
Notes: Relevant Summary Documents
Abstract: Forests cover nearly one-third of the U.S., providing wildlife habitat, clean air and water, cultural and aesthetic values, carbon storage, recreational opportunities such as hiking, camping, fishing, and autumn leaf tours, and products that can be harvested such as timber, pulpwood, fuelwood, wild game, ferns, mushrooms, and berries. This wealth depends on forest biodiversity-the variety of plants, animals, and microbe species, and forest functioning-water flow, nutrient cycling, and productivity. These aspects of forests are strongly influenced by climate and human land use.

229. Jurgensen, M., P. F. Hessburg, W. F. Megahan, J. Nesser, R. D. Ottmar, and E. D. Reinhardt. 1994. Risk assessment methodologies in the interior west. In *Ecosystem Management: Principles and applications*, edited by Jensen, M. S. and P. J. Bourgeron (Portland, Oregon: U. S. Forest Service, PNW-GTR-318).
Notes: Other Works Cited

230. Kaczynski, V. W. 1994. Wildfire impacts on stream habitats and salmonids. In *Proceedings of the Conference, Forest Health and Fire Danger in Inland Western Forests*, (Spokane, Washington: International Association of Wildland Fire).
Notes: Other Works Cited

231. Kauffman and others. 1983.
Notes: Other Works Cited

232. Kauffman, J. B. 1990. Ecological relationships of vegetation and fire in Pacific Northwest forests. In *Natural and Prescribed Fire in Pacific Northwest Forests*, edited by Walstad, J. D., S. R. Radosevich, and D. V. Sandberg (Corvallis, Oregon: Oregon State University Press).
Notes: Relevant Summary Documents
Abstract: Through the millennia, fire has greatly affected the composition, structure, and numerous ecological processes of forest ecosystems in the Pacific Northwest. All forest organisms of the Pacific Northwest are intimately suited for survival in their environment, and this includes specific adaptations to ensure persistence following fire. Adaptations to fire might be best thought of as adaptations to survive within the given fire regime of an ecosystem. Therefore, species adaptation that facilitates survival in one fire regime may not necessarily ensure the same in another.

In general, adaptations to fire can be broadly generalized to include those traits which facilitate survival of the individual, and those traits which facilitate reproduction and, hence, perpetuation of the species. Examples of fire-survival traits include thick bark to protect living tissues or the capacity to sprout from below-ground organs. Thick bark is an effective insulator that can protect cambial tissues from damage by surface fires. Bark can also protect dormant buds on trunks and main branches in epicormically sprouting species. Among sprouters, plant age, phenology, and vigor can affect a species; capacity to sprout following fire. Fire severity (i.e., the level of fire intensity and/or fuel consumption) will greatly influence plant survival. For example, thick bark is an adaptation for survival in regimes of low-intensity surface fires, but of little value in severe, stand-replacement fires.

Numerous seedlings from species, which require fire for, flower stimulation, seed dispersal, or seed scarification and mineral soil exposure for germinations and establishment will be present following fire. However, low-consumption fires may not scarify dormant seeds in the soil or create bare mineral soil conditions required by some species to establish. Conversely, high-consumption fires may kill large numbers of dormant seeds, resulting in decreased seedling densities. These high-severity fires would, however, result in large are of bare ground, facilitating establishment of windborne seeds with a mineral seedbed requirement.

The functional role of coarse woody debris includes nutrient and carbon storage, sites for plant establishment, the maintenance of soil stability, and the presence of wildlife habitat. In many ecosystems, fire is an important disturbance, which influences both input and disappearance of coarse woody debris. In regimes characterized by stand-replacements fires, huge inputs of coarse woody debris occur following fire. In regimes characterized by frequent surface fires, the input may be relatively continuous, with small quantities added with each fire. Consumption by fire may be the primary means of disappearance of coarse woody debris in regimes with frequent fire return intervals, whereas decay or decomposition is more important in forest with long fire return intervals.

Changes in forest structure caused by land-use activities can greatly alter fire regimes, resulting in changes in species composition, ecosystem functions, and success ional dynamics. Fire suppression and livestock grazing have effectively eliminated the frequent surface fires that characterized the fire regimes of many ponderosa pine and mixed-conifer forests. As a result, fire-intolerant, shade-tolerant conifers have increased, forest insect outbreaks and fuel loads have increased, and habitat diversity and forage production have decreased. Severe stand-replacement fires now occur. On the other hand, in Douglas-fir and Sitka spruce forests of western Oregon and Washington, clear-cut and burn rotations of 60-100 year intervals now occur where the natural fire return intervals were 250-500 years or more. These changes have altered forest structure, ecosystem function, and wildlife habitats.

Prescribed burning can be utilized in a positive manner when resource managers are aware of the historical role and ecological influences of fire in forest ecosystems. Knowledge of the vegetation response and potential effects on forest composition and productivity is necessary in order to improve managerial decisions concerning the use of prescribed fire.

233. Kauffman, J. B. 1988. The status of riparian habitats in Pacific Northwest forests. In *Streamside Management: Riparian Wildlife and Forestry Interactions*, edited by Raedeke, K. J. (Seattle, Washington: University of Washington, Institute of Forest Resources, Contribution #59).
Notes: Other Highly Relevant References

234. Kaye, J. P. and S. C. Hart. 1998. Restoration and canopy-type effects on soil respiration in a ponderosa pine-bunchgrass ecosystem. *Soil Science of America Journal* 62:1062-1072.
Notes: Relevant Studies
Abstract: In ponderosa pine (*Pinus ponderosa* Douglas ex. P. Lawson & Lawson)-bunchgrass ecosystems of the western USA, fire exclusion by Euro-American settlers facilitated pine invasion of grassy openings, increased forest floor detritus, and shifted the disturbance regime toward stand-replacing fires, motivating ecological restoration through thinning and prescribed burning. We used in situ soil respiration over 2-yr period to assess belowground responses to pine invasion and restoration in ponderosa pine-bunchgrass ecosystem near Flagstaff, AZ. Replicated restoration treatments were: (I) partial restoration-- thinning to presettlement conditions; (II) complete restoration--removing trees and forest floor material to presettlement conditions, native grass litter addition, and prescribed burnings; and (III) control. Within treatments, we sampled beneath different canopy types to assess the effects of pine invasion into grassy openings on soil respiration. Growing season soil respiration was greater in the complete restoration (346+24 g CO_2-Cm^2) and control (350+8g CO_2-Cm^2) than the partial restoration (301+5g CO_2-Cm^2) in 1995. In 1996, the complete (364+17g CO_2-Cm^2) and partial (328+7g CO_2-Cm^2) restoration treatments had greater growing season respiration rates than the control (308+13g CO_2-C m$^{2)}$. Results suggest that restoration effects on soil respiration depends on interannual soil water patterns and may not significantly alter regional C cycles. Soil respiration form grassy openings were 15% greeter than form soil beneath presettlement or postsettlement pines in 1995 and 1996. A lack of active management will decrease belowground catabolism if pines continue to expand at the expense of grassy openings.

235. Keane, R. E., D. G. Long, J. P. Menakis, W. J. Hann, and C. D. Bevins. 1996. *Simulating coarse-scale vegetation dynamics using the Columbia River Basin Succession Model - CRBSUM*. Ogden, Utah: U. S. Forest Service, INT-GTR-340.

Notes: Highly Relevant Studies
Abstract: The Columbia River Basin Succession Model (CRBSUM) simulates broad-scale landscape changes as a consequence of various land management policies. CRBSUM is a spatially explicit, deterministic model with stochastic properties that simulates changes in vegetation cover types and structural stages on landscapes over long periods. CRBSUM was used to simulate course-scale landscape changes in the Interior Columbia River Basin as a result of four management scenarios called management futures. CRBSUM results have an inherent 1 to 5 percent variability because of the stochastic structure of the model. Sensitivity analysis results suggest moderate changes in disturbance probabilities (25 percent increase) will only slightly affect simulated results.

236. Ketcheson, G. and H. A. Froehlich. 1978. *Hydrologic factors and environmental impacts of mass soil movements in the Oregon Coast Range*. Corvallis, Oregon: Oregon State University, Water Resources Research Institute, Bulletin #56.
Notes: Other Highly Relevant References

237. Kilgore, B. M. 1981. Fire in ecosystem distribution and structure: western forests and scrublands. In *Proceedings of the Conference: Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-40).
Notes: Relevant Summary Documents
Abstract: Fire plays an important role in determining structure of forests and scrublands throughout the West. Distribution and structure of vegetation depends upon topography, climatic regime, and fire regime. Six fire regimes of defined based on fire frequency and intensity, varying from frequent, low-intensity surface fires to very long return interval, stand replacement fires. In certain western forests and scrublands fire suppression for the past 50 to 100 years has lead to longer intervals between fires, increases in surface and crown fuels, changes in forest structure, and sequential impacts on fire intensity, postfire age structure, species composition, fuel accumulation, and both horizontal and vertical pattern. Better understanding of fire regimes is basic to our management of western ecosystems.

238. Kipfmueller, K. F. and T. W Swetnam. 2000. Fire-climate interactions in the Selway-Bitterroot Wilderness Area. In *Wilderness Ecosystems, Threats, and Management*, edited by Cole, D. N., S. F. McCool, W. T. Borrie, and J. O'Loughlin (Fort Collins, Colorado: U. S. Forest Service, RMRS-P-15).
Notes: Supporting Studies
Abstract: Tree-ring reconstructed summer drought was examined in relation to the occurrence of 15 fires in the Selway-Bitterroot Wilderness Area (SBW). The ten largest fire years between 1880 and 1985 were selected from historical fire atlas data; five additional fire years were selected from a fire history completed in a subalpine forest within the SBW. Results of the analysis indicate summers during the fire year were significantly ($p<0.001$) drier than average conditions. The summer preceding the fire year tended to be drier than average, but results were not statistically significant ($p>0.05$). A significant ($p<0.05$) wet year occurred four years prior to fire occurrence in the SBW. Further research, which examines fire-climate interactions differentiated by forest type, may provide an improved understanding of the dynamics between fire and climate.

239. Kipfmueller, K. F. and T. W. Swetnam. 2001. Using dendrochronology to reconstruct the history of forest and woodland ecosystems. In *The Historical Ecology Handbook: A Restorationist`s Guide to Reference Ecosystems*, edited by Egan, D. and E. A. Howell (Washington, D. C.: Island Press).
Notes: Supporting Summary Documents
Abstract: In this chapter we review the guiding principles of dendrochronology as they relate to reconstruction of the ecological history of forests and woodlands. We also discuss some basic techniques and practices used to cross-date and ensure accurate dating of tree rings. Using "classic" and recent examples, we focus on the use of dendrochronology to understand the

mechanisms of ecological change and variability across time and space, and on applications toward the restoration of ecosystems. Finally, we discuss some important limitations of dendrochronology as a tool for historical ecology.

240. Kirschbaum, M. U. F., A. Fischlin, M. G. R. Cannell, R. V. Cruz, W. Galinski, and W. A. Cramer. 1996. Climate change impacts on forests. In *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*, edited by Watson, R. T., M. C. Zinyowera, and R. H. Moss (Cambridge, England: Cambridge University Press).
Notes: Relevant Summary Documents
Abstract: The authors summarize available information on the sensitivity of forests to climate change. Observations from the past, experimental studies, and simulation models based are used to support the authors' conclusions. Regional assessments for tropical, temperate, and boreal forests are presented. A number of conclusions are presented along with the level of confidence associated with the likelihood of the stated conclusions actually occurring.

241. Klenner, W. , W. A. Kurz, and S. J. Beukema. 2000. Habitat patterns in forested landscapes: management practices and the uncertainty associated with natural disturbances. *Computers and Electronics in Agriculture* 27:243-262.
Notes: Relevant Studies
Abstract: We present the results of a study to examine the effects of management actions and natural disturbances in influencing the evolution of habitat patterns on forested lands. TELSA, a spatially explicit vegetation succession model with the ability to apply user-defined management actions and stochastic wildfires calibrated to local conditions, was used to evaluated changes in several indicators of habitat condition. We assessed seral stage and patch size changes over multiple 200-year simulations under constant rate of harvest within each of these analyses. In the absence of natural disturbances, old growth habitat and large patches of forest of similar age and tree species composition decreased unless special management practices were applied. Old-growth management area reserves and periodic 'aggregated cutblock' harvesting entries helped maintain forest seral stage distribution at the target level, and patch size characteristics similar to the patterns that would have occurred under historic natural disturbances. Adding wildfire to the management scenarios substantially reduced the amount of old growth habitat in designated old-growth management area reserves, compromising the ability to maintain old-growth at target levels. 50% increase in the area designated as old-growth management area reserves would be required to offset the loss of old growth due to wildfire. Although the amount of old-growth habitat was diminished by wildfire, the availability of large habitat patches greater than 250ha increased. We discuss the need to consider the role of management and natural disturbances in landscape planning, and suggest that redundancy is essential to maintain those features vulnerable to stochastic disturbances. Landscape scenario modeling can facilitate the development of risk adverse plans, and encourage the development of innovative approaches to achieving timber and non-timber objectives.

242. Knopf. 1991.
Notes: Other Works Cited

243. Knutson, D. M. and R. O. Tinnin. 1986. Effects of dwarf mistletoe of the response of young douglas fir to thinning. *Canadian Journal of Forest Research* 16:30-35.
Notes: Supporting Studies
Abstract: Four sites from two forests were examined to determine the effect of various levels of infection by *Arceuthobium douglasii* on the growth of *Pseudotsuga menziesii* in precommerically thinned stands. We found less than 1% mortality among the trees that we examined. Changes in level of infection did occur, we estimate that changes to levels of infection sufficient to cause significant reductions in diameter growth occurred among 19% of the infected trees that we studied. Height growth was significantly reduced in both forests, while diameter growth was reduced by infection in one forest. Trees of lower infection rating (dwarf mistletoe rating 0-2) showed a significant increase in radical growth following thinning

in both forests, while more heavily infected trees (dwarf mistletoe rating 5 to 6) did not. Trees that were heavily infected and had spike tops consistently showed significant reductions in diameter growth in both forests.

244. Knutson, K. L. and V. L Naef. 1997. *Management recommendations for Washington's priority habitats: riparian*. Olympia, Washington: Washington Department of Fish and Wildlife.
Notes: Highly Relevant Summary Documents
Abstract: By virtue of its high productivity, diversity, continuity, and critical contributions to both aquatic and upland ecosystems, riparian habitat provides a rich and vital resource to Washington's fish and wildlife. Riparian habitat occurs as an area adjacent to rivers, perennial or intermittent streams, seeps, and springs throughout Washington. Because it is generally a narrow band, riparian habitat covers a relatively small portion of the state. Riparian areas contain elements of both aquatic and terrestrial ecosystems, which mutually influence each other and occur as transitions between aquatic and upland habitats.

The Washington Department of Fish and Wildlife has developed statewide riparian management recommendations based on the best available science. Nearly 1,500 pieces of literature on the importance of riparian areas to fish and wildlife were evaluated, and land use recommendations designed to accommodate riparian-associated fish and wildlife were developed. These recommendations consolidate existing scientific literature and provide information on the relationship of riparian habitat to fish and wildlife and to adjacent aquatic and upland ecosystems. These recommendations have been subject to numerous review processes.

Recommendations on major land use activities commonly conducted within or adjacent to riparian areas are provided, including those relative to agriculture, chemical treatments, grazing, watershed management, roads, stream crossings and utilities, recreational use, forest practices, urbanization, comprehensive planning, restoration, and enhancement. Management recommendations for riparian areas are generalized for predictable application across the Washington landscape.

245. Kovalchik, B. L. in press. *Classification and management of Eastern Washington's aquatic, riparian, and wetland sites Part 1: the series descriptions*. Colville, Washington: U. S. Forest Service, INT-GTR-?
Notes: Highly Relevant Studies
Abstract: The area covered by this classification includes all riparian and wetland sites within the Colville, Okanogan, and Wenatchee National Forests. It covers aquatic, riparian, wetland, and transitional series and plant associations that: (1) occur repeatedly in Eastern Washington; (2) are large enough to be mapped for project-level wildland management; and (3) have distinct management differences. This classification supplements and expands information presented in upland forest plant association classifications in Eastern Washington.

246. Kovalchik, B. L. 2001. The classification of aquatic, riparian and wetland sites on the National Forests of Eastern Washington: (Part 1: the series). In *ERSAG Forest Dynamics Workshop*, (Spokane, Washington: ERSAG).
Notes: Supporting Summary Documents
Abstract: The intent of this presentation is not to lay blame for the trend to oversimplify riparian zones--but to explain how a aquatic/riparian/wetland classification may -- through a hierarchical, geomorphic view of riparian and wetland zones -- help managers:

- better understand functions and processes in these zones
- make reasonable estimates of the status and potential of these zones
- help prescribe proper management direction for riparian and wetland zones

help with salmon recovery efforts by providing site-based stratification of landscapes and data for evaluating desired future conditions (targets).

247. Kovalchik, B. L. 1987. *Riparian zone associations: Deschutes, Ochoco, Fremont, and Winema National Forests*. Portland, Oregon: U. S. Forest Service, R6-ECOL-TP-279-87.

Notes: Relevant Summary Documents
Abstract: The classification covers riparian and transitional associations that: (1) occur repeatedly in Central Oregon; (2) are large enough to be mapped for project level wildland management; and (3) have distinct management differences. This classification supplements and expands the riparian information presented in plant association guides by Hall (1973), Volland (1976), Hopkins (1979) and Hopkins and Kovalchik (1983).

248. Kovalchik, B. L. and L. A. Chitwood. 1990. Use of geomorphology in the classification of riparian plant associations in mountainous landscapes of central Oregon, U.S.A. *Forest Ecology and Management* 33/34:405-418.
Notes: Highly Relevant Summary Documents
Abstract: Resource managers are increasingly interested in the importance, unique values, classification, and management of riparian zones. Understanding the ecology of the riparian zone is complicated by extreme variation in geology, climate, terrain, hydrology, and disturbances by humans. As a result, it is often difficult to determine the vegetation potential of riparian sites and develop management options. A recent riparian classification in central Oregon uses geomorphology in addition to traditional floristic classification to help identify vegetation potential in the riparian zone. A four-level geomorphic/floristic classification is proposed. Geomorphology is especially useful on riparian sites where the natural vegetation composition, soils, and/or water regimes have been altered by past disturbance, either natural or human-induced.

249. Kulman, H. M. 1971. Effects of insect defoliation on growth and mortality of trees. *Annual Review of Entomology* 16:289-324.
Notes: Supporting Summary Documents
Abstract: A review of quantitative studies of tree mortality and increment reduction related to measured amounts of insect and artificial defoliation in which the foliage is removed at the time of treatment. Included are discussions of artificial defoliation as well as defoliation by a range of pests: sawfly, jack pine budworm, spruce budworm, lodgepole needle miner, dendrolimus species, miscellaneous lepidoptera, gypsy moth, forest tent caterpillar.

250. Kurz, W. A. and M. J. Apps. 1999. A 70-year retrospective analysis of carbon fluxes in the Canadian forest sector. *Ecological Applications* 9, no. 2:526-547.
Notes: Relevant Studies
Abstract: The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2) is a framework for the dynamic accounting of carbon pools and fluxes in Canada's forest ecosystems and the forest product sector. The model structure, assumptions, and supporting databases are described. The model has been applied to estimate net ecosystem carbon fluxes for Canada's 404 Mha forest areas for the period of 1920-1989. Changes in disturbance regimes have affected the forest age class structure and increased the average forest age during the period 1920-1979. The resulting changes in dead organic matter and biomass carbon during this period were estimated with the model. In the last decade of the analysis, large increases in disturbances, primarily fire and insect damage have resulted in a reduction in ecosystem carbon storage. The estimates of biomass pool sizes obtained are consistent with those of other studies, while dead organic matter carbon pool estimates remain somewhat uncertain. Sensitivity analysis of several sources of uncertainty indicate that the pattern of net changes in ecosystem carbon pools of the 70-yr. period was hardly affected and that the numerical estimates change by <15%.

251. Landres, P. B., P. Morgan, and F. J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications* 9, no. 4:1179-1188.
Notes: Supporting Summary Documents
Abstract: Natural resource managers have used natural variability concepts since the early 1960s and are increasingly relying on these concepts to maintain biological diversity, to restore ecosystems that have been severely altered, and as benchmarks for assessing anthropogenic change. Management use of natural variability relies on two concepts; that past conditions and

processes provide context and guidance for managing ecological systems today, and that disturbance-driven spatial and temporal variability is a vital attribute of nearly all ecological systems. We review the use of these concepts for managing ecological systems and landscapes.

We conclude that natural variability concepts provide a framework for improved understanding of ecological systems and the changes occurring in these systems, as well as for evaluating the consequences of proposed management actions. Understanding the history of ecological systems (their past composition and structure, their spatial and temporal variability, and the principal processes that influenced them) helps managers set goals that are more likely to maintain and protect ecological systems and meet the social values desired for an area. Until we significantly improve our understanding of ecological systems, this knowledge of past ecosystem functioning is also one of the best means for predicting impacts to ecological systems today.

These concepts can also be misused. No prior time period or spatial extent should be used in defining natural variability. Specific goals, site-specific field data, inferences derived from data collected elsewhere, simulation models, and explicitly stated value judgment all must drive selection of the relevant time period and spatial extent used in defining natural variability. Natural variability concepts offer an opportunity and a challenge for ecologists to provide relevant information and to collaborate with managers to improve the management of ecological systems.

252. Landsburg, J. 2002. *Personal communication with Richard Everett.*
Notes: Other Highly Relevant References

253. Lehmkuhl, J. F., P. F. Hessburg, Richard L. Everett, M. A. Huff, and R. D. Ottmar. 1994. *Historical and current forest landscapes of Eastern Oregon and Washington. Part I: vegetation pattern and insect and disease hazards*. Portland, Oregon: U. S. Forest Service, PNW-GTR-328.
Notes: Relevant Studies
Abstract: We analyzed historical and current vegetation composition and structure in 49 sample watersheds, primarily on National Forests, within six river basins in eastern Oregon and Washington. Vegetation patterns were mapped from aerial photographs taken from 1932 to 1959, and from 1985 to 1992. We described vegetation attributes, landscape patterns, the range of historical variability, scales of change, and disturbance hazards. Forest cover increases eight percent in three river basins, but remained relatively unchanged in the other basins. Forests became denser in vertical and horizontal canopy structure as understory cover increase with regeneration of mostly shade-tolerant species. The distribution of forest age classes and structure has changed, with smaller area in early-seral and old forest stages and greater area in multiple-canopy young and mature stands. The percentage of visible dead trees increased in all river basins. Landscape pattern has become more diverse and fragmented over time in five of the six river basins. Insect and disease hazards changed little, usually <10 percent, at the river basin scale because there was considerable variation at the watershed scale, where large changes in hazards were common.

254. Lenihan, J. M. and R. P. Neilson. 1995. Canadian vegetation sensitivity to projected climatic change at three organizational levels. *Climate Change* 30:57-73.
Notes: Supporting Studies
Abstract: The potential equilibrium response of Canadian vegetation under two double-CO_2 climatic scenarios was investigated at three levels in the vegetation mosaic using the rule-based Canadian Climate-Vegetation Model (CCVM) and climatic response surfaces. The climatic parameters employed as model drivers (i.e. degree-days, minimum temperature, snowpack, actual evapotranspiration, and soil moisture deficit) have a more direct influence on the distribution of vegetation than those commonly used in equilibrium models. Under both scenarios, CCVM predicted reductions in the extent of the tundra and subarctic woodland formations, a northward shift and some expansion in the distributions of boreal and the temperate forest, and an expansion of the dry woodland and prairie formations that was especially pronounced under one of the scenarios. Results of the response surface analysis

suggest the potential for significant changes in the probability of dominance for eight boreal tree species. A dissimilarity coefficient was used to identify forest-types under the future climatic scenarios that were analogous to boreal forest-types derived from cluster analysis of the current probabilities of species dominance. All of the current forest-types persisted under the doubled-CO_2 scenarios, but 'no-analog' areas were also identified within which an empirically derived threshold of the distance coefficient was exceeded. Maps showing the highest level in the vegetation hierarchy where change was predicted suggest the relative impact of the response under the two climatic scenarios.

255. Leopold, L. B., M. G. Wolman, and J. P. Miller. 1964. *Fluvial processes in geomorphology*. San Francisco, California: W. H. Freeman and Company.
Notes: Other Highly Relevant References

256. Lillybridge, T. R., B. L. Kovalchik, C. K. Williams, and B. G. Smith. 1995. *Field guide for forested plant associations of the Wenatchee National Forest*. Portland, Oregon: U. S. Forest Service, PNW-GTR-359.
Notes: Other Highly Relevant References

257. Lindenmayer, D. B. 1995. Forest disturbance, forest wildlife conservation and the conservative basis for forest management in the mountain ash forests of Victoria - comment. *Forest Ecology and Management* 74:223-231.
Notes: Supporting Summary Documents
Abstract: A recent interview by Attiwill outlined a range of aspects of disturbance regimes in forests and attempted to demonstrate their value in developing a basis for the "conservative management" of wood production areas. One of the key themes in these papers-that natural disturbance regimes should be a model for forest management, is a good one. However, there are major difficulties in determining the intensity, frequency and extent of timber harvesting operations that mimic "natural disturbance regimes" and, in turn, form the basis of "conservative management" strategies, which account for the full spectrum of forest values. This paper highlights a few of the many key considerations for truly integrated multiple-use forest management that were overlooked by Attiwill and which are an essential component of ecologically sustainable forest management. These relate to aspects of the conservation of forest wildlife that are sensitive to forest disturbances resulting from timber harvesting operations. Many of the examples of the response of wildlife to forest disturbance outline by Attiwill are from the mountain ash (*Eucalyptus regnans*) forests of Victoria, south-eastern Australia. Unlike the impression given by Attiwill, the results of the array of detailed long-term studies on forest fauna in mountain ash forests that have been completed to date clearly indicate that balancing the multiple values of mountain ash forests will be a complex task requiring major modifications to present multiple forest-use management strategies. This is because of the potential for current forestry activities to both: (1) produce long-term modifications to key components of vegetation structure and thus habitat suitability for fauna (e.g. old growth elements such as trees with hollows) and (2) fragment remaining patches of suitable habitat and create sub-divided populations that may not be viable in the long-term. Moreover, because a given species has survived disturbance regimes in the past, it is premature to suggest that it will persist in the future when new and recent forms of forest perturbation such as clearfelling are intensively and extensively applied throughout large areas of the forest landscape. In mountain ash forests, a conservative basis for forest management will require much more than the creation of a series of ages of regrowth forest as implied by Attiwill, but also the establishment of more and larger areas of old growth forest and/or modifications of clearfelling regimes to better allow for the development of suitable habitat for wildlife that are sensitive to the impact of timber harvesting, such as the endangered arboreal marsupial Leadbeater's possum (*Gymnobelideus leadbeateri*). Until management strategies that are more sympathetic to wildlife conservation are embraced, there remains a high probability that Leadbeater's possum, and other species with similar habitat requirements, could be eliminated from some wood production areas, implying that current forestry practices are not ecologically sustainable in the long-term.

258. Linhart, Y. B. 1988. Ecological and evolutionary studies of ponderosa pine in the Rocky Mountains. In *Ponderosa Pine: The Species and Its Management*, edited by Baumgartner, David M. and James E. Lotan (Pullman, Washington: Washington State University).
Notes: Other Highly Relevant References

259. Little, R. L., D. L. Peterson, D. G. Silsbee, L. J. Shainsky, and L. F. Bednar. 1995. Radial growth patterns and the effects of climate on second-growth douglas fir (*Pseudotsuga menziesii*) in the Siskiyou Mountains, Oregon. *Canadian Journal of Forest Research* 25:724-735.
Notes: Relevant Studies
Abstract: The sites with fire-generated second-growth (70-100 years old) douglas fir (*Pseudotsuga menziesii* Mirb. Franco) in southwestern Oregon were examined using dendroecological techniques to determine (1) temporal patterns of radial growth and (2) the effects of variation in climate on growth. Long-term patterns of radial growth vary among sites, but similar interannual variation in radial growth indicates a common response to regional climate. Growth is positively correlated with the Palmer Drought Severity Index and precipitation during summer. Furthermore, growth is positively correlated with precipitation during autumn prior to the growth year, which suggests the benefits of soil moisture recharge for subsequent stemwood production. Annual precipitation is strongly seasonal, and soil moisture stress in summer is apparently severe enough to be the dominant climatic influence on radial growth. Positive correlations of growth with most monthly temperatures reflect the benefit of warm temperatures on photosynthesis and radial growth during periods of adequate soil moisture. Although coastal Oregon is generally considered to be a high precipitation environment, conditions are clearly dry enough during summer to limit carbon gain in second-growth douglas fir. If future climatic conditions result in increased soil moisture stress during summer, productivity of such second-growth stands may decrease below current levels.

260. Losensky, B. J. 1995. *Historical vegetation types of the Interior Columbia River Basin*. Missoula, Montana: U. S. Forest Service, Contract Report RJVA-94951.
Notes: Other Highly Relevant References

261. Lynch, A. M. and T. W. Swetnam. 1992. Old-growth mixed-conifer and western spruce budworm in the Southern Rocky Mountains. In *Old Growth Forests in the Southwest and Rocky Mountain Regions, Proceedings of a Workshop*, edited by Kaufmann, M. R., W. H. Moir, and Richard L. Bassett (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-213).
Notes: Relevant Studies
Abstract: Thirty-one mixed-conifer stands 98 to 694 years old in the southern Rocky Mountains revealed a history of multiple western spruce budworm outbreaks. Outbreaks were neither more nor less frequent in older stands, nor did outbreaks appear to start in older stands. Western spruce budworm does not appear to directly threaten old growth stands, but management policies that repress natural disturbance regimes and promote budworm-prone forests may result in remnant old growth stands being less likely to survive severe insect outbreaks and potential catastrophic wildfires. Outbreaks may persist longer in older stands, but data from different areas and age groups are inconsistent. The appearance and structure of some stands are different from common perceptions of old growth mixed-conifer. Decadence and dead standing and down trees are probably not useful indicators of old growth in forest types subject to periodic mortality causing insect outbreaks. Two exceptionally old stands in New Mexico, 494 and 694 years old, have tree densities exceeding 1000 trees per ha, have old trees smaller in size than the main canopy trees, and had fewer outbreaks in the last 120 years than most of the stands sampled in northern New Mexico.

262. MacDonald, L. H. and A. W. Smart. 1993. Beyond the guidelines: practical lessons for monitoring. *Environmental Monitoring and Assessment* 26:203-218.
Notes: Supporting Summary Documents
Abstract: A series of workshops have provided extensive feedback on a recently published manual, Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (Guidelines) (MacDonald *et al*, 1991). These workshops and

other discussions have led to the identification of fourteen additional lessons for monitoring. These lessons are concepts which either were not incorporated into the Guidelines, were not sufficiently emphasized, or which are needed to put the Guidelines in context. The topics include: monitoring as a continuum; defining objective and hypotheses; peer review; uncertainly and risk; upslope vs. instream monitoring; photo-sequences; scale considerations; data storage, data interpretation, and data base management; activities monitoring; and personal commitment as a critical component in monitoring projects. Many of these lessons might appear self-evident, but our experience indicates that they are often ignored. Like the Guidelines, these lessons are widely applicable and should be explicitly recognized when formulating and conducting monitoring projects.

263. MacDonald, L. H., A. W. Smart, and R. C. Wissmar. 1991. *Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska*. Seattle, Washington: U.S. Environmental Protection Agency, Region 10, EPA/910/9-91-001.
Notes: Highly Relevant Summary Documents
Abstract: This document provides guidance for designing water quality monitoring projects and selecting monitoring parameters. Although the focus is on forest management and streams in the Pacific Northwest and Alaska, a broader perspective is taken, and much of the information is more widely applicable.

Part I reviews the regulatory mechanisms for nonpoint source pollution and defines seven types of monitoring. A step-by-step process for developing monitoring projects is presented. Because monitoring is a sampling procedure, study design and statistical analysis are explicitly addressed. The selection of monitoring parameters is defined as a function of the designated uses, management activates, sampling frequency, monitoring costs, access, and the physical environment. Approximately 30 parameters are rated with regard to these controlling factors. A qualitative combination of these rankings yields recommended monitoring parameters for various management activities. This parameter selection process has been incorporated into an interactive PC-based expert system called PASSSFA.

Part II is a technical review of the parameters, which are grouped into six categories: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms. The review of each parameter is organized into seven sub-sections: definition, relation to designed uses, and response to management activities, measurement concepts, standards, current uses, and assessment.

264. Mahoney, R. L. 1977.
Notes: Other Works Cited

265. Malcolm, J. R., A. Markham, and R. P. Neilson. 2001. Can species keep up with climate change? *Conservation Biology in Practice* 2, no. 2:24-25.
Notes: Supporting Summary Documents
Abstract: Although species have inherent abilities to respond to climatic shifts, the speed at which they can respond is limited. If climatic conditions shift quickly enough, slower moving species may be left behind - especially if human activities have destroyed and fragmented existing habitat.

Instead of attempting to predict how fast species and biomes might be able to move, we analyzed how fast they might be required to move to keep up with projected warming. We used global climate and vegetation models to address three key questions: (1) How do possible future migration rates compare with past rates? (2) Are migration rates uniform across the planet? (3) How will human behavior influence these future rates?

266. Manion, P. D. 1991. *Tree disease concepts*. Englewood Cliffs, New Jersey: Prentice-Hall.
Notes: Other Highly Relevant References

267. Marion, D. A. 1981. *Landslide occurrence in the Blue River Drainage, Oregon*. Corvallis, Oregon: Masters Thesis, Oregon State University.
Notes: Other Highly Relevant References

268. Martin, K. 1997. *Forest management on landslide prone sites: the effectiveness of headwall leave areas and evaluation of two headwall risk rating methods*. Corvallis, Oregon : Masters Engineering Report, Oregon State University.
Notes: Other Highly Relevant References

269. Maruoka, K. R. and J. K. Agee. 1994. *Fire histories: overview of methods and applications*. La Grande, Oregon: Blue Mountains Natural Resources Institute, Technical Note #2.
Notes: Supporting Summary Documents
Abstract: The two main approaches to developing a fire history are through analysis of point frequencies and area frequencies. Point frequencies assess fire occurrence at one location while are frequencies assess fire occurrence at the scale of the landscape. Although both yield a "fire frequency," the frequencies represent different types of information because of this difference in scale. Selecting the appropriate method depends primarily on the vegetation types and physical features of the study area, as well as the type of fire evidence present.

270. McCullough, D. G., R. A. Werner, and D. Neumann. 1998. Fire and insects in northern and boreal forest ecosystems of North America. *Annual Review of Entomology* 43:107-127.
Notes: Relevant Summary Documents
Abstract: Fire and insects are natural disturbance agents in many forest ecosystems, often interacting to affect succession, nutrient cycling, and forest species composition. We review literature pertaining to effects of fire-insect interactions on ecological succession, use of prescribed fire for insect pest control, and effects of fire on insect diversity from northern and boreal forests in North America. Fire suppression policies implemented in the early 1900's have resulted in profound changes in forest species compositions and structure. Associated with these changes was an increased vulnerability of forest stands to damage during outbreaks of defoliating insects. Information about the roles that both fire and insects play in many northern forests is needed to increase our understanding of the ecology of these systems and to develop sound management policies.

271. McCune, Bruce. 1983. Fire frequency reduced two orders of magnitude in the Bitterroot Canyons, Montana. *Canadian Journal of Forest Research* 13, no. 2:212-218.
Notes: Other Works Cited

272. McDonald, G. I., N. E. Martin, and A. E. Harvey. 1987. *Armillaria in the Northern Rockies: pathogenicity and host susceptibility on pristine and disturbed sites*. Ogden, Utah : U. S. Forest Service, INT-RN-371.
Notes: Relevant Studies
Abstract: Over all plots (disturbed and pristine), incidence of pathogenic Armillaria showed a strong tendency to decrease as habitat type productivity increased. This trend gave rise to a clear separation of plots by climax series. The relatively less productive subalpine fir and douglas fir series exhibited high incidence of root disease and the relatively more productive grand fir, western red cedar, and western hemlock series significantly less. Within these productivity groups, other patterns emerged. Disturbance appeared to be related to a dramatic increase in incidence of pathogenicity, but not occurrence, within the high-productivity grouping of communities. Also, the ability of disturbance to elicit pathogenicity seemed to decline as site productivity increased. Conversely, the pristine plots within the low-productivity series exhibited high incidence of the pathogen in a pathogenic state. This condition seemed to be related to a community structure characteristic of transition between cold-dry to cool-moist and warm-dry to warm-moist. Predicting risk of Armillaria-caused mortality, occurrence of pathogenic species and clones of Armillaria, a possible role for host stress in expression of pathogenicity by Armillaria, and risk rating of host species are discussed.

273. McGreer, D. J. 1996. *Considerations in development of riparian management strategies: potential consequences of wildfire on riparian and aquatic systems. inherent disturbance regimes: a reference for evaluating the long-term maintenance of ecosystems*. Lewiston, Idaho: Unpublished manuscript.
Notes: Highly Relevant Summary Documents
Abstract: Active management strategies that incorporate and carefully manage disturbance processes to achieve desired future vegetation and habitat conditions within watersheds and their riparian areas provide the highest potential for restoring and maintaining ecosystem functions and processes, and for achieving fully functioning riparian systems. Passive riparian management strategies allow riparian vegetation to become unnaturally dense and fire-prone, inevitably and unnecessarily predisposing riparian and aquatic systems to destruction by catastrophic wildfire.

274. McKenzie, D., D. L. Peterson, and E. Alvarado. 1996. *Predicting the effect of fire on large-scale vegetation patterns in North America*. Portland, Oregon: U. S. Forest Service, PNW-RP-489.
Notes: Highly Relevant Summary Documents
Abstract: Changes in fire regimes are expected across North America in response to anticipated global climatic changes. Potential changes in large-scale vegetation patterns are predicted as a result of altered fire frequencies. Condensing Kuchler potential natural vegetation types into aggregated types that are relatively homogeneous with respect to fire regime developed a new vegetation classification. Transition rules were developed to predict potential changes from one vegetation type to another because of increased fire frequency. In general, vegetation currently associated with warmer or drier climates could replace existing vegetation in most biomes. Exceptions ware subalpine forests and woodlands at the Arctic treeline, which are predicted to become treeless. The transition rules provide an ecological perspective on possible new configurations of vegetation types, a set of constraints for steady-state models, and a potential method of calibration for dynamic models of large-scale vegetation change.

275. McNabb, D. H. and F. J. Swanson. 1990. Effects of fire on soil erosion. In *Natural and Prescribed Fires in Pacific Northwest Forests*, edited by Walstad, J. D., S. R. Radosevich, and D. V. Sandberg (Corvallis, Oregon: Oregon State University Press).
Notes: Other Highly Relevant References

276. Meehan, W. R. 1996. *Influence of riparian canopy on macroinvertebrate composition and food habits of juvenile salmonids in several Oregon streams*. Portland, Oregon: U. S. Forest Service, PNW-RP-496.
Notes: Supporting Summary Documents
Abstract: The community composition of macroinvertebrates and the feeding habits of juvenile salmonids were studies in eight Oregon streams. Benthic, drift, sticky trap, and water trap samples were taken over a 3-year period, along with stomach samples of the fish. Samples were taken in stream reaches with and without riparian canopy.

Both main effects--fish diet versus macroinvertebrate composition in the environment, and canopied versus noncanopied stream condition--were highly significant, but probably not practical importance in terms of the amount of preferred food available to the fish.

In all aquatic sample types, including fish stomachs, *Diptera* and *Ephemerooptera* were in predominant invertebrates collected. In sticky trap and water trap samples, *Diptera* and *Collembola* were the predominant orders, reflecting the input of terrestrial invertebrates.

277. Meehan, W. R. 1991. *Influences of forest and rangeland management on salmonid fishes and their habitats*. Bethesda, Maryland: American Fisheries Society, Special Publication #19.
Notes: Other Highly Relevant References

278. Meffe, Gary K. and C. Ronald Carroll. 1997. *Principles of Conservation Biology*. Sunderland, Massachusetts: Sinauer.

Notes: Other Works Cited

279. Megahan, W. F. 1982. Channel sediment storage behind obstructions in forested drainage basins draining the granitic bedrock of the Idaho Batholith. In *Sediment Budgets and Routing in Forested Drainage Basins*, edited by Swanson, F. J., R. J. Janda, T. Dunne, and D. N. Swanston (Portland, Oregon: U. S. Forest Service, PNW-GTR-141).
Notes: Other Highly Relevant References

280. Meyer and others. 1992.
Notes: Other Works Cited

281. Meyer and others. 1995.
Notes: Other Works Cited

282. Miles, D. W. R., F. J. Swanson, and C. T. Youngberg. 1984. Effects of landslide erosion on subsequent douglas fir growth and stocking levels in the Western Cascades, Oregon. *Soil Science of America Journal* 48:667-671.
Notes: Relevant Studies
Abstract: Shallow, rapid landslides are common events in steep terrain of the Pacific Northwest. The effect of landslides on timber growth potential of forest land was estimated by examining a 30-yr history of clearcutting and landslidings in the western Oregon Cascades. The height growth of douglas firs (*Pseudotsuga Menziesii* Mirb Franco] and stocking level of all commercial conifer species on naturally regenerated landslides were compared with the height growth and stocking level in nearby, artificially regenerated clearcut units of similar aspect, elevation, age, and slope position. Average height growth of douglas fir trees 5 to 18 years old on the landslides was reduced 62% compared to trees on clearcuts, and the average stocking level was reduced 25% from the clearcut level. One-third of the landslide area was estimated to be nonstockable because of unstable or impenetrable substrate.

283. Miller and Kean. 1960.
Notes: Other Works Cited

284. Mills, K. A. 1991. *Winter 1989-90 landslide investigations*. Salem, Oregon: Unpublished Report, Oregon Department of Forestry .
Notes: Other Highly Relevant References

285. Minshall, G. Wayne, Christopher T. Robinson, and Deron E. Lawrence. 1995. Postfire responses of lotic ecosystems in Yellowstone National Park, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 54:2509-2525.
Notes: Other Highly Relevant References
Abstract: Wildfire is a major large-scale disturbance affecting terrestrial landscapes and lotic ecosystems in many regions of the world. We examined environmental and biological responses of 20 streams in Yellowstone National Park, U.S.A., over 5 years following extensive wildfires in 1988. Streams of burned catchments displayed increases in dissolved nitrate-nitrogen following the fires. Summer water temperatures often exceeded 20°C in small (first- and second-order) streams of burned catchments compared with <15°C in their unburned counterparts. Habitat heterogeneity decreased in streams of burned watersheds as demonstrated by changes in substrate embeddedness and near-bed velocities. Substantial alteration of channels and major restructuring and movement of large woody debris occurred in fire-impacted but not reference streams. Transported and benthic organic matter, mostly charcoal, increased in burn sites. No major changes were found in macroinvertebrate density, biomass, or richness, although significant changes occurred in relative abundances of miners, gatherers, and scrapers of burned sites. Chironomidae abundance was greater initially (postfire years 1-3), followed by later increases (postfire years 3-5) by the mayfly *Baetis bicaudatus* in burned sites compared with reference streams. Our findings demonstrate an integral relationship over time between a stream and its catchment, following large-scale disturbances such as wildfire.

286. Mitchell. 1987.
Notes: Other Works Cited

287. Mitchell. 1990.
Notes: Other Works Cited

288. Mitchell, R. G. and P. E. Buffam. 2001. Patterns of long-term balsam woolly *Adelgid* infestations and effects in Oregon and Washington. *Western Journal of Applied Forestry* 16, no. 3:121-126.
Notes: Supporting Studies
Abstract: The balsam woolly adelgid (*Adelges piceae*) is an introduced pest discovered damaging grand fir (*Abies grandis*) in Oregon's Willamette Valley around 1930. In 1955, the insect was found infesting and killing Pacific silver fir (*A. amabilis*) near Mt. St. Helens in Washington and subalpine fir (*A. lasiocarpa*) in the Cascade Range in Oregon. In the next 10 yr, the pest dispersed widely throughout western Oregon and Washington, causing significant tree mortality over thousands of acres in the Cascade Range. Observations on trend plots established 35 to 40 yr ago have shown somewhat consistent tends in the patterns of infestation and damage. Infestations and damage were most severe on the best sites and at the lowest elevations where the hosts grown. Tree damage was consistently most severe in the first decade of infestation, but the insect never seemed to disappear from a stand; infestations and tree killing were observed on some plots 40 yr after the initial infestation. An ecological problem with the balsam woolly adeigid is a pattern of attach that I gradually eliminated grand fir from low-elevation landscapes west of the Cascade Range. The adelgid is also removing subalpine fir as a pioneer tree species in many of the important mountain environments.

289. Mitchell, R. G. and H. K. Preisler. 1991. Analysis of spatial patterns of lodgepole pine attacked by outbreak populations of the mountain pine beetle. *Forest Science* 37, no. 5:1390-1408.
Notes: Relevant Studies
Abstract: Five years of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, attacks on lodgepole pine, *Pinus contorta* Dougl., were analyzed in an early outbreak situation using generalized linear models to shed light on patterns in the colonization process. The chosen logic model indicated three covariates as significant factors in the probability of trees being colonized by the mountain pine beetle. The first covariate related to tree size and spatial relationships among trees colonized the same year; its effect was most obvious for trees in the smaller diameter classes. The other two covariates correlated with tree diameters and vigor, and they indicated a greater probability of attack for larger trees and trees with low vigor. The model showed that the probability of trees being colonized in this stand increased significantly as the outbreak gained momentum, but only as long as the food supply (trees with dbh>23cm) was abundant. It also showed that the pattern of selection of large and small trees did not change significantly as beetle pressure increased over time. Findings suggested that big trees were important to outbreaks beyond simply generating beetles, and that many trees were colonized only because they were close to other trees under attack.

290. Mitchell, R. G., R. H. Waring, and G. B. Pitman. 1983. Thinning lodgepole pine increases tree vigor and resistance to mountain pine beetle. *Forest Science* 29, no. 1:204-211.
Notes: Relevant Studies
Abstract: Thinned and unthinned stands of lodgepole pine in eastern Oregon were evaluated in 1980 to determine their vigor and susceptibility to attack by outbreak populations of the mountain pine beetle. Application of a vigor rating system, based on amount of stem growth per square meter of crown leaf area, showed that thinnings from below improved vigor of residual stand and reduced beetle attack. Beetle mortality was significant in unthinned and lightly thinned stands where current annual growth of stemwood of residual trees averaged less than 80% g/m of foliage. Stands with mean vigor ratings of about 100 were beginning to suffer beetle attack. There was no mortality in heavily thinned stands where vigor ratings exceeded 120. These findings suggest that lodgepole pine can be managed through stocking control to obtain fast-growing, large diameter trees and to avoid attack by the mountain pine beetle.

291. Moeur, Melinda. 1992. *Baseline demographics of late successional western hemlock/western redcedar stand in northern Idaho research natural areas*. Ogden, Utah: U. S. Forest Service, INT-RP-456.
Notes: Other Works Cited

292. Monnig, E. and J. W. Byler. 1992. *Forest health and ecological integrity in the Northern Rockies*.: U. S. Forest Service, FPM Report 92-7, (2nd ed.).
Notes: Other Highly Relevant References

293. Montgomery, D. R. and W. E. Dietrich. 1994. A physically based model for the topographic control on shallow landsliding. *Water Resources Research* 30:1153-1171.
Notes: Other Highly Relevant References
Abstract: A model for the topographic influence on shallow landslide initiation is developed by coupling digital terrain data with near surface through flow an slope stability models. The hydrologic model TOPOG (O'Loughlin, 1986) predicts the degree of soil saturation in response to a steady state rainfall for topographic elements defined by the intersection of contours and flow tube boundaries. The slope stability component uses this relative soil saturation to analyze the stability of each topographic element for the case of cohesionless soils of spatially constant thickness and saturated conductivity. The steady state rainfall predicted to cause instability in each topographic element provides a measure of the relative potential for shallow landsliding. The spatial distribution of critical rainfall values is compared with landslide locations mapped from aerial photographs and in the field for three study basins where high-resolution digital elevation data are available: Tennessee Valley in Marin County, California; Mettman Ridge in the Oregon Coast Range; and Split Creek on the Olympic Peninsula, Washington. Model predictions in each of these areas are consistent with spatial patterns of observed landslide scars, although hydrologic complexities are accounted for in the model (e. g., spatial variability of soil properties and bedrock flow) control specific sites and timing of debris flow initiation within areas of similar topographic control.

294. Moore, M. M., W. W. Covington, and P. Z. Fule. 1999. Reference conditions and ecological restoration: a southwestern ponderosa pine perspective. *Ecological Applications* 9, no. 4:1266-1277.
Notes: Supporting Summary Documents
Abstract: Ecological restoration is the process of reestablishing the structure and function of native ecosystems and developing mutually beneficial human-wildland interactions that are compatible with the evolutionary history of those systems. Restoration is based on an ecosystem's reference conditions (or natural range of variability); the difference between reference conditions and contemporary conditions is used to assess the need for restorative treatments and to evaluate their success. Since ecosystems are highly complex and dynamic, it is not possible to describe comprehensively all possible attributes of reference conditions. Instead, ecosystem characteristics with essential roles in the evolutionary environment are chosen for detailed study. Key characteristics of structure, function, and disturbance - especially fire regimes in ponderosa pine ecosystems - are quantified as far as possible through dendroecological and paleoecological studies, historical evidence, and comparison to undisrupted sites. Ecological restoration treatments are designed to reverse recent, human-caused ecological degradation. Testing of restoration treatments at four sites in northern Arizona, USA, has shown promise, but the diverse context of management goals and constraints for Southwestern forest ecosystems means that appropriate applications of restoration techniques will probably differ in various settings.

295. Morgan, P., G. H. Aplet, J. B. Haufler, H. C. Humphries, M. M. Moore, and W. D. Wilson. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. *Journal of Sustainable Forestry* 2, no. 1/2:87-111.
Notes: Other Highly Relevant References

296. Morgan, P. and R. Parsons. 2001. *Historical range of variability for the Idaho Southern Batholith Ecosystem*. Boise, Idaho: Ecosystem Revised, Final Report, University of Idaho, and

Department of Forest Resources.
Notes: Relevant Studies
Abstract: Describing historical conditions is part of a course-filter management strategy for sustaining biological diversity. It provides a context for interpreting natural processes, especially disturbance, and it allows variability in patterns and processes to be understood in terms of a dynamic system. The overall goal of this project was to estimate the historical range of variability for the forests of the Idaho Southern Batholith. This area encompasses approximately 5.8 million acres in central Idaho, from dry ponderosa pine to high elevation subalpine fir. We used successional models parameterized by expert opinion and available data to estimate the minimum, maximum, and median abundance (percent of potential area occupied) for elements in the ecosystem diversity matrix. These elements are combinations of vegetation growth stage (VGS, a description of tree size and canopy layering) and dominant cover type (forest vegetation named for the species occupying the majority of the stand) for each of eleven habitat type classifications (these represent groups of similar biophysical descriptions).

297. Morrison and Martin G. Raphael. 1993.
Notes: Other Works Cited

298. Morse. 1999.
Notes: Other Works Cited

299. Morse, R. A. 2000. *Topographic and physiographic influences on fire severity in stream valleys of Northern Wenatchee National Forest*. Seattle, Washington: Doctoral Dissertation, University of Washington, College of Forest Resources.
Notes: Highly Relevant Studies
Abstract: This study identified trends in fire severity and pattern that area associated with topography and topographically influenced vegetation in stream valleys on the east side of the Cascade Mountains in Washington State. This study looked at multiple terrain variables within the 56,740 ha. burn perimeter of the 1994 Tyee Fire Complex. It was an observational study that sought to verify previously identified terrain influences on fire across a broader area and to identify issues that could merit further investigation. This study also addressed a particular issue that has not been examined in detail before the influence of stream confinement on fire severity.

300. Murray, M. P., S. C. Bunting, and P. Morgan. 1998. Fire history of an isolated subalpine mountain range of the Intermountain Region, United States. *Journal of Biogeography* 25:1071-1081.
Notes: Relevant Summary Documents
Abstract: Fire has historically been an important ecological component of forests in the Intermountain Region of the northwestern United States. This study is set in a small biogeographically disjunct mountain range. Our research objectives were to (1) investigate the historical frequency, severity, size, and spatial pattern of fire; (2) determine if and how fire regimes have changed since Euro-American settlement; and (3) compare how fire regimes of a small isolated range compare to nearby, but considerably larger, mountain agglomerations. Our findings suggest that this mountain range has historically support fires typified by small size and high frequency, resulting in a high degree of spatial pattern complexity compared to mountain agglomerations. We also found disparity in size and burn severity solely within the study area based on the bisecting Continental Divide. Since the advent of Euro-American settlement in the 1870s, fire frequency and size of individual fire in the West Big Hole Range have significantly decreased resulting in an estimated 87% reduction in area burned. We discuss potential relationships of mountain range isolation and fire regimes in the Intermountain Region. Furthermore, we suggest that the relative small size of this mountain range predisposes it to greater anthropogenic effects upon fire occurrence.

301. Mutch and others. 1993.
Notes: Other Works Cited

302. Mutch, R. W. 1970. Wildland fires and ecosystems: a hypothesis. *Ecology* 51:1046-1051.
Notes: Highly Relevant Studies
Abstract: Plant species which have survived fires for tens of thousands of years may not only have selected survival mechanisms, but also inherent flammable properties that contribute to the perpetuation of fire-dependent plant communities. This concept goes beyond the commonly accepted fire climate-fuel moisture basis of wildland fire occurrence. Plant communities may be ignited accidentally or randomly, but the character of burning is not random. The following hypothesis treats this interaction between fire and the ecosystem: Fire-dependent plant communities burn more readily than non-fire-dependent communities because natural selection has favored development of characteristics that make them more flammable. The hypothesis was experimentally derived following laboratory combustion tests with litter of eucalyptus (*Eucalyptus obliqua* v. L'Herit), ponderosa pine (*Pinus ponderosa* v. Laws.), and tropical hardwood trees.

303. Naiman and others. 1998.
Notes: Other Works Cited

304. Naiman, Robert J., T. J. Beechie, L. E. Benda, D. R. Berg, P. A. Bisson, L. H. MacDonald, and M. D. O'Connor. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. In *Watershed Management: Balancing Sustainability and Environmental Change*, edited by Naiman, Robert J. (New York, New York: Springer-Verlag).
Notes: Other Works Cited

305. Naiman, Robert J., H. Decamps, and M. M. Pollock. 1993. The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications* 3:209-212.
Notes: Other Highly Relevant References

306. Nakamura, F., F. J. Swanson, and S. M. Wondzell. 2000. Disturbance regimes of stream and riparian systems - a disturbance-cascade perspective. *Hydrological Processes* 14:2849-2860.
Notes: Highly Relevant Studies
Abstract: Geomorphological processes that commonly transport soil down hillslopes and sediment and woody debris through stream systems in steep, mountainous, forest landscapes can operate in sequence down gravitational flowpaths, forming a cascade of disturbance processes that alters stream and riparian ecosystems. The affected stream and riparian landscape can by viewed through time as a network containing a shifting mosaic of disturbance paths--linear zones of disturbance created by the cascading geomorphological processes. Ecological disturbances range in severity from effects of debris flows, which completely remove alluvium, riparian soil and vegetation along steep, narrow, low-order channels, to localized paths of trees toppled by floating logs along the margins of larger channels. Land-use practices can affect the cascade of geomorphological processes that function as disturbance agents by changing the frequency and spatial pattern of events and the quantity of size distribution of material moved. A characterization of the disturbance regime in a stream network has important implications for ecological analysis. The network structure of stream and riparian systems, for example, may lend resilience in response to major disturbances by providing widely distributed refuges. An understanding of disturbance regime is a foundation for designing management systems.

307. National Interagency Fire Center. 2002. *Historical wildland fire statistics*. Boise, Idaho: National Interagency Fire Center, http://www.nifc.gov/stats/historicalstats.html.
Notes: Relevant Summary Documents
Abstract: This is a list of some of the most serious wildland fires in U.S. history. Some were significant because of their size, others because of the value of the resources lost. Some small, but very intense, fires were important because of the loss of lives and property. There have been larger fires than some of those included on this list, but few or none with greater impact on lives and resources.

308. Neary, D. G., C. C. Klopatek, L. F. DeBano, and P. F. Folliott. 1999. Fire effects on belowground

sustainability: a review and synthesis. *Forest Ecology and Management* 122, no. 1/2:51-71.
Notes: Supporting Studies
Abstract: The overall effects of fire on ecosystems are complex, ranging from the reduction or elimination of aboveground biomass to impacts on belowground physical, chemical and microbial mediated processes. Since a key component of overall ecosystem sustainability occurs belowground, recovery is tied to the soil's physical, chemical and biological functions and processes. Depending on several fire severity measures, changes in belowground components can be either beneficial or deleterious to the entire ecosystem. Low-impact burning can promote an herbaceous flora; increase plant available nutrients, and thing over-crowded forests, all of which can foster healthy systems. Severe fires can often cause changes in successional rates, alter above-and belowground species composition, generate volatilization of nutrients and ash entrainment in smoke columns, produce rapid or decreased mineralization rates, alter C:N ratios, and result in subsequent nutrient losses through accelerated erosion, leaching or denitrification. In addition, changes in soil hydrologic functioning, degradation of soil physical properties, decreases in micro- and macrofauna, and alterations in microbial populations and associated processes can occur. The direct effect of fire on belowground systems is a result of the burning severity, which integrates aboveground fuel loading (live and dead), soil moisture and subsequent soil temperatures, and duration of the burn. The time for recovery of belowground systems will not only depend on the burning intensity and its effect on key ecosystem processes and components, but also on the previous land-use practices. Thus, the impacts of fire on belowground systems can be highly variable and may not be predictable. Our paper is general review of the effects of fire on belowground systems with emphasis placed on the changes in physical, biogeochemical and biological properties of soils and the resulting consequences these changes have for ecosystem sustainability.

309. Neilson, R. P. and D. Marks. 1994. A global perspective of regional vegetation and hydrologic sensitivities from climatic change. *Journal of Vegetation Science* 5:715-730.
Notes: Supporting Summary Documents
Abstract: A biogeographic model, MAPSS (Mapped Atmosphere-Plant-Soil System), predicts changes in vegetation leaf area index (LAI), site water balance and runoff, as well as changes in biome boundaries. Potential scenarios of global and regional equilibrium changes in LAI and terrestrial water balance under 2 x CO_2 climate from five different general circulation models (GCMs) are presented. Regional patterns of vegetation change and annual runoff are surprisingly consistent among the five GCM scenarios, given the general lack of consistency in predicted changes in regional precipitation patterns. Two factors contribute to the consistency among the GCMs of the regional ecological impacts of climatic change: (1) regional, temperature-induced increases in potential evapo-transpiration (PET) tend to more than offset regional increases in precipitation: and (2) the interplay between the general circulation and the continental margins and mountain ranges produces a fairly stable pattern of regionally specific sensitivity to climatic change. Two areas exhibiting among the greatest sensitivity to drought-induced forest decline are eastern North America and eastern Europe to western Russia. Regional runoff patterns exhibit much greater spatial variation in the sign of the response than do the LAI changes, even thought they are deterministically linked in the model. Uncertainties with respect to PET or vegetation water use efficiency calculations can alter the simulated sign of regional responses, but the relative responses of adjacent regions appear to be largely a function of the background climate, rather than the vagaries of the GCMs, and are intrinsic to the landscape. Thus, spatial uncertainty maps can be drawn even under the current generation of GCMs.

310. Neuenschwander, L. F., H. L. Osborne, and P. Morgan. 1986. Integrating harvest practices and site-preparation activities to manage competing vegetation. In *Weed Control for Forest Productivity in the Interior West*, edited by Baumgartner, David M., R. J. Boyd, D. W. Breuer, and D. L. Miller (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

311. Nierenberg and Dave E. Hibbs. 2000.
Notes: Other Works Cited

312. North, M. and Jerry F. Franklin. 1990. Post-disturbance legacies that enhance biological diversity in a Pacific Northwest old-growth forest. *Northwest Environmental Journal* 6, no. 2:427-429.
Notes: Relevant Studies
Abstract: The importance of the structure-function relationship is demonstrated by two recent spotted owl surveys which located nesting owl pairs in stands that were heavily disturbed by a windstorm near Forks, Washington, and a fire in the Quilcene area of the Olympic Peninsula. Our objective is to quantify structure in these stands to determine how disturbed forests may soon re-establish the function and composition of an old-growth ecosystem.

313. Nyland, Ralph D. 1996. What the forest inventory can and cannot say about forest dynamics. In *Conference Proceedings: the Empire Forest - Changes and Challenges*, (New York, New York: State University of New York, College of Environmental Science and Forestry).
Notes: Other Works Cited

314. O'Laughlin, J. 1994.
Notes: Other Works Cited

315. Oakley, A. L., J. A. Collins, L. B. Everson, D. A. Heller, J. C. Howerton, and R. E. Vincent. 1985. Riparian zones and freshwater wetlands. In *Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington*, edited by Brown, E. R. (Portland, Oregon: U. S. Forest Service).
Notes: Other Highly Relevant References

316. Obedzinski, R. A., C. G. Shaw, and D. G. Neary. 2001. Declining woody vegetation in riparian ecosystems of the Western United States. *Western Journal of Applied Forestry* 16, no. 4:169-181.
Notes: Highly Relevant Summary Documents
Abstract: Riparian ecosystems serve critical ecological functions in western landscapes. The woody plant components in many of these keystone systems are in serious decline. Among the causes are invasion by exotic species, stress-induced mortality, increases in insect and disease attack, drought, beaver, fire, climatic changes, and various anthropogenic activities. The latter include agricultural development, groundwater depletion, dam construction, water diversion, gravel mining, timber harvesting, recreation, urbanization, and grazing. This article examines the factors implicated in the decline and discusses the importance of interactions among these factors in causing decline. It also clarifies issues that need to be addressed in order to restore and maintain sustainable riparian ecosystems in the western United States, including the function of vegetation, silvics of the woody plant species involved, hydrologic condition, riparian zone structure, and landscape features, geomorphology, and management objectives.

317. Ohlson. 2000.
Notes: Other Works Cited

318. Ohlson and others. 2001.
Notes: Other Works Cited

319. Ohlson, P. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

320. Ohlson, P., T. Leuschen, Richard L. Everett, and T. D. Anderson. 1998. Fire hazard of spotted owl neighborhoods on the East Slope of the Washington Cascades. In *Fire Effects on Rare and Endangered Species and Habitats Conference*, edited by Greenlee, Jason M. (Fairfield, Washington: International Association of Wildland Fire).
Notes: Supporting Summary Documents
Abstract: Forest stand types and their configuration within northern spotted owl (*Strix occidentalis caurina*) neighborhoods indicate the potential for destructive crown-replacement fires on the eastern slope of the Cascade Range in Washington. Large contiguous blocks of

dense, multi-layered forest provide suitable owl habitat but also increase the likelihood of large-scale conflagrations should ignition occur. Following the settlement era of the late 1800's fire suppression efforts altered fire regimes and fire-intolerant understory tree species and coarse woody debris increased beyond levels consistent with the former fire regime. Information about fuel conditions, moisture regimes, landscape topography and frequency of lightning for any given area can provide insights into potential fire hazard. Cluster and discriminant analysis separated 34 spotted owl neighborhoods into 6 distinct crown fire severity groups using fire-free interval (potential ignitions), area of high crown fire potential (hazard), and predicted rate of fire spread. Most fire-free intervals range from 6 to 25 years, but 2 neighborhoods in the Pacific silver fir and western hemlock series had intervals near 400 years. Areas of high crown fire potential were calculated to be over 70% in some neighborhoods, and fires were estimated to consume up to 13.3% of a 1200 acre neighborhood within a 24 hour period. We suggest that forest management concerned with the protection of spotted owls and their habitat should recognize the risk of large-scale fire across the landscape and identify those areas and conditions were fuel treatment could reduce that risk while maintaining viable owl populations.

321. Ohmart, R. D., W. O. Dearson, and C. Burke. 1977. A riparian case study: the Colorado River. In *Importance, Preservation, and Management of Riparian Habitat: A Symposium*, edited by Johnson, R. Roy and Dale A. Jones (Fort Collins, Colorado: U. S. Forest Service, RM-GTR-43).
Notes: Other Highly Relevant References

322. Oliver, C. D., L. L. Irwin, and W. H. Knapp. 1994. *Eastside forest management practices: historical overview, extent of their applications, and their effects on sustainability of ecosystems*. Portland, Oregon: U. S. Forest Service, PNW-GTR-324.
Notes: Highly Relevant Summary Documents
Abstract: Forest management of eastern Oregon and Washington began in the late 1800s as extensive utilization of forests for grazing, timber, and irrigation water. With time, protection of these values developed into active management for these and other values such as recreation. Silvicultural and administrative practices, developed to solve problems at a particular time have lingered and created confusion and consternation when knowledge, values, and vegetation conditions have changed. The present condition of most eastern Oregon and Washington forests is the result of disturbance and regrowth processes coupled with historical management practices. Most areas contain high levels of insects, diseases, and fuels. Without many, diverse, creative, and active solutions, large fires and insect outbreaks will occur with local loss of ecosystem and human values.

323. Oliver, C. D. and B. C. Larson. 1990. *Forest stand dynamics*. New York, New York: McGraw-Hill.
Notes: Other Highly Relevant References

324. Olsen. 1981.
Notes: Other Works Cited

325. Olson and Knopf. 1986.
Notes: Other Works Cited

326. Olson, D. L. 2000. *Fire in riparian zones: a comparison of historical fire occurrence in riparian and upslope forests in the Blue Mountains and Southern Cascades of Oregon*. Seattle, Washington: Doctoral Dissertation, University of Washington, College of Forest Resources.
Notes: Highly Relevant Studies
Abstract: Despite the ecological importance of fire in Pacific Northwest forests, its role in riparian forests is not well documented. This study reconstructed the historical occurrence of fire within riparian forests along different stream sizes within three different national forests in Oregon. Two study areas were located in mostly dry, low-severity fire regime forests in the Blue Mountains of northeastern Oregon (Dugout and Baker) and the third study area was located in more mesic, moderate-severity fire regime forests on the western slopes of the southern Oregon Cascades (Steamboat). Fire scar dates and tree establishment dates were

determined from a total of 424 fire scarred tree wedges and 81 increment cores taken from 67 riparian and upslope plots. Based on the data from this study, fire was common historically in the riparian zones of all three study areas. Weibull median probability fire return intervals (WMPIs) for riparian forests in Dugout ranged between 13 and 14 years, and were only slightly longer than those for upslope forests (averaging one year longer). In Baker, differences between riparian and upslope forests WMPIs were greater, ranging between 13 and 36 years for riparian WMPIs, compared to 10 to 20 years for upslope WMPIs. However, further analyses suggested that forest type and slope aspect play a larger role than proximity to a stream when it came to differentiating fire regimes in this study area. For both Dugout and Baker it appeared that stream channels did not necessarily act as fire barriers during the more extensive fire years. Steamboat riparian WMPIs were somewhat longer (ranging from 35-39 years) than upslope WMPIs (ranging 27-36), but these differences were not significant. Fires were probably more moderate in severity and likely patchy, considering the incidence of fires occurring only at a riparian plot or an upslope plot within a pair, but not at both. It is possible that fire return interval lengths were associated with aspect, but more sampling would need to be done to show this. Based on the results from this study, it is evident that: (1) restoring fire, or at least conducting fuel reduction treatments, will be necessary to protect riparian forests in comparable forest ecosystems, (2) forests should be managed according to forest type, not just by proximity to a stream, and (3) historical recruitment of large woody debris was likely small but continuous for low-severity fire regime riparian forests, with a relatively short residence time, and patchy and more pulsed for the more moderate-severity fire regime forests.

327. Ottmar, R. D. and D. V. Sandberg. 2001. Wildland fire in Eastern Oregon and Washington. *Northwest Science* 75:46-54.
Notes: Highly Relevant Summary Documents
Abstract: Wildland fire is a major disturbance agent that shapes the forest health, productivity, and ecological diversity of eastern Oregon and Washington. Fire behavior and the effects of fire on flora, fauna, soils, air, and water are in large part driven by the availability of fuels to consume and the meteorological influences during a fire. Vegetation succession, disturbance processes, and management practices have resulted in an increase of fuels and vulnerability to extreme fire behavior and detrimental fire effects. Hazards of fire are further increased by encroachment of dwellings into forests and rangelands. Prescribed fire, selective logging and mechanical fuel treatment are being used to reduce fire hazard, but there is disagreement as to appropriate balance and efficacy of these actions. New tools to (1) characterize fuelbeds: (2) predict mesoscale meteorology, fire behavior, fire effects, smoke production, and dispersal: and (3) demonstrate tradeoffs between prescribed fire and other fuel treatment methods are continually being improved to assist with wildland fire and prescribed fire decision making in eastern Oregon and Washington.

328. Pacific Biodiversity Institute. 2002. *SAGE pre-fire data*.: Pacific Biodiversity Institute, Unpublished data.
Notes: Highly Relevant Summary Documents
Abstract: Pacific Biodiversity Institute (PBI), under agreement with the Washington Department of Fish and Wildlife, has undertaken to assess the availability of data relevant to fire disturbance regimes in riparian habitats, and to synthesize metadata and contact information on data stewards. The purpose of this project is to enable the Department of Fish and Wildlife to more accurately examine the scientific background of the new forest practice rules.

A database was created in Microsoft Access to store the information collected during the course of this project. A table called ‘SAGE data’ contains records of each piece of information collected the types of information are: GIS data sets, reports, databases, or field reports. Other information stored in the table includes the agency responsible for the data, the availability of the data, an abstract and the purpose of the data, when the data or report was produced or released or when the data was updated, and other relevant facts. Information on data attributes recorded for each entry in a data set and the methods used to collect the data are stored in separate but linked tables, to maintain efficient use of the database. The information is most easily viewed by using the Sage Data Form, which shows related records in all three tables.

This form opens automatically when you open the Access database.

329. Parsons, D. J. 1981. The role of fire management in maintaining natural ecosystems. In *Proceedings of the Conference Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-26).
Notes: Supporting Summary Documents
Abstract: Fire, both naturally ignited and man caused, has long played a role in the evolution of many of the world's natural ecosystems. During the past century, fire has often come to be regarded as a destructive force, leading to efforts to eliminate it as an important ecological factor. Yet, if naturally functioning ecosystems are to be maintained, fire must be allowed to play its primeval role. A growing understanding of this necessity in recent years has led to the implementation of integrated fire management programs in many areas. These programs may utilize lightning-ignited and/or intentionally set or prescribed fires to achieve carefully predetermined resource management objectives. This paper discusses the current status of fire management as well as the background information needed to formulate and implement an integrated fire management program.

330. Parsons, R. 1999. *Historical range of variability estimates for the Idaho Southern Batholith (revised).* Boise, Idaho: Boise Cascade Corporation.
Notes: Relevant Summary Documents
Abstract: Revised historical range of variability estimates are presented by class, cover type and vegetation growth stage for each of the eleven forested habitat types within the Idaho Southern Batholith, an area of 2.4 million hectares located in the mountains of Central Idaho. All changes in outputs or assumptions from prior estimates are explicitly stated. Also includes PowerPoint presentation materials.

331. Payne and others. 1996.
Notes: Other Works Cited

332. Pearson, S. F. and D. A. Manuwal. 2001. Breeding bird response to riparian buffer width in managed Pacific Northwest douglas fir forests. *Ecological Applications* 11, no. 3:840-853.
Notes: Highly Relevant Studies
Abstract: We examined the relative importance of riparian vs. upland habitats to breeding birds by comparing species abundance, richness, and similarity of bird communities in managed douglas fir forests in western Washington State, USA. We also examined whether forested buffer strips along second-and third-order streams effectively maintain the pre-logging riparian breeding bird community by comparing species abundance, richness, and turnover among three treatments: (1) unharvested controls; (2) sites that were clear-cut, leaving a narrow (-14m) forested buffer on both sides of the stream; and (3) sites that were clear-cut, leaving a wide (-31m) forested buffer along both sides of the stream.

Deciduous trees, berry-producing shrubs, and other deciduous shrubs less common in adjacent upland forest characterized streamside zones. Despite different vegetation features, riparian and upland habitats did not differ in any measures of bird species, richness and composition. No species or species group was more abundant in the upland. Neotropical migrants, resident species, and species associated with deciduous trees and shrubs in forested habitats were more abundant in riparian habitats than an adjacent uplands. Total bird abundance and abundance of four species (American robin [*Turdus migratorius*], pacific-slope flycatcher [*Empidonax difficilis*], black-throated gray warbler [*Denroica nigrescens*], and winter wren [*Troglodytes troglodytes*]) were higher in riparian habitats. Abundance of these riparian associates was correlated with percent cover by berry-producing shrubs and the number of deciduous trees in the canopy.

We found that the number of breeding bird species on sites with narrow buffers increased from slightly fewer than controls before harvest to an average of 10 more species than controls after harvest, a change reflected in an average 20% increase in species turnover on narrow-buffer sites relative to controls. Total bird abundance did not differ between treatments and controls. Resident species, those species associated with shrubs in forested habitats and conifer trees, declined on both buffer treatments. Species associated with upland and riparian forests (black-throated gray warbler, golden-crowned kinglet [*Regulus satrapa*], and brown creeper [*Certhia americana*]) decreased in abundance on riparian buffer treatments relative to controls, whereas species associated with open, shrubby, habitats (dark-eyed junco [*Junco hyemalis*], cedar waxwing [*Bombycilla cedrorum*], and song sparrow [*Melospiza melodia*]).

333. Perry, D. A. 1994. *Forest ecosystems*. Baltimore, Maryland: Johns Hopkins University Press.
Notes: Other Highly Relevant References

334. Perry, D. A. 1988. Landscape pattern and forest pests. *Northwest Environmental Journal* 4:213-228.
Notes: Other Highly Relevant References

335. Perry, D. A. 1995. Landscapes, humans and other system-level considerations: a discourse on ecstacy and laundry. In *Ecosystem Management in Western Interior Forests: Symposium Proceedings*, (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Works Cited

336. Peterson, D. L. and K. C. Ryan. 1986. Modeling post-fire conifer mortality for long-range planning. *Environmental Management* 10:797-808.
Notes: Other Highly Relevant References

337. Peterson, William C. and Dave E. Hibbs. 1989. Adjusting stand density management guides for sites with low stocking potential. *Western Journal of Applied Forestry* 4, no. 2:62-65.
Notes: Other Works Cited

338. Pickett, S. T. A., J. Kolasa, J. J. Armesto, and S. L. Collins. 1989. The ecological concept of disturbance and its expression at various hierarchical levels. *Oikos* 54:129-136.
Notes: Supporting Summary Documents
Abstract: Current definitions of disturbance are intuitive, narrow, and only implicitly based on system structure. This is because the concepts are based on experience at particular levels of organization or on systems whose structure is well know. The definitions are thus inadequate for the development of a general theory of ecological disturbance. A universally applicable definition would (1) identify the object disturbed; (2) distinguish between changes in the object that is disturbance versus change that is not; and (3) distinguish between direct and indirect consequences of disturbance. Any persistent ecological object will have a minimal structure, or system of lower level entities that permit its persistence. Disturbance is a change in the minimal structure of an object caused by a factor external to the level of interest. Using these definitions, disturbance can be unequivocally identified and associated with various specific ecological levels of organization. Because of the dependence of the concept of disturbance on recognizing the minimal structure of ecological systems, application of the concept will advance as refined models of the hierarchical structure of ecological systems are elaborated.

339. Pitelka, L. F. 1997. Plant migration and climate change. *American Scientist* 85:464-473.
Notes: Supporting Summary Documents
Abstract: This summary document discusses interdisciplinary research activities related to plant migration. The discussion focuses on rates of migration, invasion of native plant communities by exotic species, natural and human-assisted dispersion mechanisms and disturbances, landscape patterning, regional problems, and global consequences. Computer models are proposed as a means of understanding the complex interactions of biological, climatic, and geographical components.

340. Planty-Tabacchi, A. M., E. Tabacci, Robert J. Naiman, C. M. Deferrari, and H. Decamps. 1996. Invasibility of species-rich communities on riparian zones. *Conservation Biology* 10:598-607.

Notes: Other Highly Relevant References
Abstract: Invasibility of riparian plant communities was estimated by the percentage of alien species found along the Adour River (Southwest France) and along Lookout Creek, McKenzie River and Willamette River (Central Cascades, Oregon, U.S.A.). At the patch scale, the invasibilities of riparian plant communities were compared between one exceptionally rich site of the Adour River and patches selected in the Hoh and Dungeness watershed (Olympic Peninsula, Washington, U.S.A.). Alien species represented 24% of 1396 species for the Adour and 30% of 851 species for the McKenzie. The represented 24% of 148 species for the Hoh drainage along the McKenzie River for changes in total number of species per site and in percentages of alien species per site. These trends may be related to the intermediate disturbance regimes and to the physical structure of the riparian corridors. Climatic and human factors are also involved in these longitudinal changes. Positive linear relationships were found between the total number of species and the percentage of aliens observed in each site. At the patch scale, most of the sampled communities contained alien species. Although mature vegetative patches appeared to be invasible, young communities contained more alien species than older ones. For entire corridors, a positive linear relationship was found between total species richness and percentage of alien species in each patch type for the richest site of the Adour River. This may be partially explained by landscape features considered in a successional context. We suggest the use of empirical rules, and stress the importance of riparian systems for monitoring the conservation of local and regional species pools are suggested.

341. Pleus, A. E. 1999. *Timber Fish & Wildlife Monitoring Program method manual for wadable stream discharge measurement*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-009, DNR 111.
Notes: Supporting Summary Documents
Abstract: The TFW Monitoring Program method manual for the Wadable Stream Discharge Measurement (WSDM) method provides a standard method for the assessment and monitoring of stream discharge on wadable streams. The TFW method follows the USGS protocols (Rantz and others, 1982) with minor modifications for smaller stream systems. Discharge measurements are required for the TFW Habitat Unit and Large Woody Debris Surveys and when conducting portions of the Spawning Habitat Availability and Stream Temperature Surveys.

This introduction section describes the purpose of the WSDM method and describes the cooperator services provided by the TFW Monitoring Pro. Following the introduction, sections are presented in order of survey application including; pre-survey preparation, methods, post-survey documentation, data management, and references. An appendix is also provided that includes: copy masters of field forms; examples of completed field forms; a standard field and vehicle gear checklist, and USGS procedures for float and volumetric discharge measurements.

342. Pleus, A. E. and D. Schuett-Hames. 1998. *Timber Fish & Wildlife Monitoring Program method manual for stream segment identification*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-98-001, DNR 103.
Notes: Supporting Summary Documents
Abstract: This manual provides a standard method for systematically identifying stream segments on the basis on channel morphology and floodplain characteristics. These segments are used as the basic framework for designing monitoring study plans and conducting monitoring surveys for the TFW Monitoring Program, Watershed Analysis, and the Salmon and Steelhead Habitat Inventory and Assessment Process (SSHIAP). The primary stream segment characteristics are: (1) stream order/relative basin drainage area; (2) channel gradient; and (3) channel confinement. The manual provides basic segmenting techniques with clear, step-by-step explanations and examples that illustrate the application of the methods in various stream situations. It is divided into office methods, field verification, post-field documentation, and data management sections. A sub-segmenting process has been included to provide flexibility to address the specific needs of individual studies and as a linkage to other stream classification systems. An extensive appendix section includes a materials and equipment source list, copy

masters of documentation forms and worksheets, examples of completed forms and worksheets, a glossary, a data report example, and segmenting task checklist.

343. Pleus, A. E. and D. Schuett-Hames. 1998. *Timber Fish & Wildlife Monitoring Program method manual for the reference point survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-98-002, DNR 104.
Notes: Supporting Summary Documents
Abstract: This manual provides a standard method for establishing stable reference point sites for monitoring stream segments over time. Referenced points are established at regular intervals along a previously defined stream segment and monumented to be easily relocated. Stream parameters collected during this survey include: (1) segment length; (2) bankfull width; (3) bankfull depth; (4) canopy closure; and (5) optional reference photographs. The manual is divided into pre-survey preparation, field methods, post-field documentation, and data management sections. An extensive appendix section includes a survey task checklist copy master, a materials and equipment source list, field form copy masters, examples of completed field forms, a data report example, and a glossary of terms.

344. Pleus, A. E., D. Schuett-Hames, and L. Bullchild. 1999. *Timber Fish & Wildlife Monitoring Program method manual for the habitat unit survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-003.
Notes: Supporting Summary Documents
Abstract: The TFW Monitoring Program method manual for the Habitat Unit Survey provides a standard method for assessing and monitoring the quantity and quality of habitat in wadable streams. The core Habitat Unit Survey collects information on the frequency and distribution of riffle and pool habitat units. Quantitative criteria are used to distinguish and identify habitat units to ensure consistency between observers. The unit's channel location is identified as primary, secondary, side or tributary channel. Wetland, sub-surface flow, and obscured unit types are also used to characterize portions of the stream that are either flowing through wetland systems, have gone sub-surface, or cannot be identified because visibility is obscured. Additional information is collected on the maximum and outlet depths of pools, and on features associated with pool formation. Guidance is provided for optional collection of sub-unit habitat types. The TFW Monitoring Program database accepts data collected using the Habitat Unit Survey method, performs standard calculations, and generates data summary reports of habitat unit data at 100 meter and stream segment scales.

345. Pollock, M. M., Robert J. Naiman, and T. A. Hanley. 1998. Plant species richness in riparian wetlands: a test of biodiversity theory. *Ecology* 79:94-405.
Notes: Other Highly Relevant References

346. Pyles, M. R. and H. A. Froehlich. 1987. Discussion of “Rates of landsliding as impacted by timber management activities in Northwestern California” by M. Wolfe and Williams, J. *Bulletin - Association of Engineering Geologists* 25:425-431.
Notes: Other Highly Relevant References

347. Pysek, P. and K. Prach. 1994. How important are rivers for supporting plant invasions? In *Ecology and Management of Invasive Riverside Plants*, edited by de Waal, L., L. E. Child, P. M. Wade, and J. H. Brock (New York, New York: John Wiley & Sons).
Notes: Other Highly Relevant References

348. Quigley, T. M. n. d. *Research plan for evaluating silvicultural treatments in fire-created, overstocked, small-diameter forest stands*. Portland, Oregon: U. S. Forest Service, Unpublished Manuscript.
Notes: Supporting Summary Documents
Abstract: Managing densely stocked stands of small-diameter trees (CROP stands) is a complex challenge. Collaboration of land managers and researches is essential to increasing the knowledge of how management activities can be sued to enhance forest health and ecosystem integrity as well as meet diverse societal needs. In 1996, recognizing and opportunity for

stimulating local rural economies while addressing forest health issues, the U.S. Congress (House Report 104-625) provided National Forest Systems with funding and legislative language for "implementation and evaluation of controlled silvicultural treatment in designated fire-generated, overstocked, small-diameter, stagnated forest 'CROP' stands or other stands designated by the Secretary and having 'CROP' characteristics on the Colville National Forest." Forest Service Research was asked to provide research support for adaptive management activities within these stands. This research plan is a specific product referred to in and mandated by the appropriations bill.

Within this plan we have documented the questions we believe should be addressed within the framework of adaptively management CROP stands and landscapes and providing links between the two scales. Current and future work will be undertaken in the context of priority issues rather than specific research studies, with the primary goal being to provide timely information and technology that assists land managers in managing landscapes to ensure ecological integrity and societal benefits. Throughout the plan we have taken an interdisciplinary approach to describing the broad issues and specific researchable questions.

Additionally, we outline the work currently being implemented toward answering some of these questions. Many of the questions we identified cannot be answered by current research, which is focused at the stand level because of the request to begin implementing research within FY97 and because of the necessity for using a site for which NEPA documents exist. That site is the Fritz Demonstration Project where researches will study effects of a variety of harvesting systems on stand conditions such as fuel levels, soil conditions, residual and projected future tree conditions insect and disease risks, and economics. Future work will capitalize on information generated from the Fritz Demonstration Project and begin to address landscape-level and linkage questions along with additional stand-level questions. Additional works initiated in FY97 are two efforts to look at the context of managing CROP stands. One addresses the ecological patterns and relations with a historical perspective and the other looks at the societal desires and needs with a plan to incorporate those findings into the planning for future work.

The development of this plan and the current years research work has already provided an opportunity to bring together the talents and strengths of the management and research branches of the U.S. Forest Service, and that working relationship is another benefit of the adaptive management approach outlined in the document.

349. Raedeke, K. J. 1988. *Streamside management: riparian wildlife and forestry interaction*. Seattle, Washington: University of Washington, Contribution #59.
Notes: Highly Relevant Summary Documents
Abstract: This document is a compilation of papers presented at the "Riparian Wildlife and Forestry Interactions" symposium hosted by the College of Forest Resources and the College of Ocean and Fishery Sciences on February 11-13, 1987 at the University of Washington in Seattle, Washington. The papers are organized into the following categories: Characteristics of Natural Riparian Forest Systems, Ecological Relationships of Riparian Systems and Associated Uplands, Comparisons of Communities in Managed and Unmanaged Riparian Systems, Current Riparian Forest Management Practices and Policies, and Social and Economic Factors That Influence Riparian Forest Management Decisions.

350. Ramakrishnan, P. S. and P. M. Vitousek. 1989. Ecosystem-level processes and the consequences of biological invasions. In *Biological Invasions: A Global Perspective*, edited by Drake, J. A., H. A. Mooney, F. Di Castri, R. H. Groves, F. J. Kruger, M. Rejmanek, and M. Williamson (New York, New York: John Wiley & Sons).
Notes: Other Highly Relevant References

351. Raphael, Martin G. and Michael L. Morrison. 1987. Decay and dynamics of snags in the Sierra Nevada, California. *Forest Science* 33, no. 3:774-783.
Notes: Other Works Cited

352. Reid, L. M. and S. Hilton. 1998. Buffering the buffer. In *Proceedings of the Conference on Coastal Watersheds: the Caspar Creek Story*, edited by Zeimer, R. R. (Albany, California: U. S. Forest Service, PSW-GTR-168).
Notes: Relevant Studies
Abstract: Riparian buffer strips are a widely accepted tool for helping to sustain aquatic ecosystems and to protect downstream resources and values in forested areas, but controversy persists over how wide a buffer strip is necessary. The physical integrity of stream channels is expected to be sustained if the characteristics and rates of tree fall along buffered reaches are similar to those in undisturbed forests. Although most tree-fall-related sediment and woody debris inputs to Caspar Creek are generated by trees falling from within a tree's height of the channel, about 30 percent of those tree falls are triggered by trees falling from upslope of the contributing tree, suggesting that the core zone over which natural rates of tree fall would need to be sustained is wider than the one-tree-height's-width previously assumed. Furthermore, an additional width of "fringe" buffer is necessary to sustain appropriate tree-fall rates within the core buffer. Analysis of the distribution of tree falls in buffer strips and un-reentered stream-side forests along the North Fork of Caspar Creek suggests that rates of tree fall are abnormally high for a distance of at least 200m from a clearcut edge, a distance equivalent to nearly four times the current canopy height. The appropriate width of fringe buffer needed to protect the core zone will need to be determined using an analysis of the long-term effects and significance of accelerated tree-fall rates after logging.

353. Riparian Habitat Technical Committee (RHTC). 1985. *Forest riparian habitat study, Phase 1 Report*. Olympia, Washington: Washington Department of Ecology, WDOE 85-3.
Notes: Other Highly Relevant References

354. Robinson. 1999.
Notes: Other Works Cited

355. Robison, E. G., K. A. Mills, J. Paul and others. 1999. *Oregon Department of Forestry storm impacts and landslides of 1996: final report*. Salem, Oregon: Oregon Department of Forestry, Forest Practices Monitoring Program, Forest Practices Technical Report #4.
Notes: Supporting Summary Documents
Abstract: During the months of February and November 1996, two very large storms affected most of Western Oregon and parts of Northeast Oregon. Both resulted in large numbers of landslides, debris torrents, and altered stream channels. With oversight from a team of experts in the landslide and natural resources fields, the Oregon Department of Forestry implemented a 3-year monitoring project to evaluate the effect of these storms. Ground surveying, aerial photos, and digital elevation models were all used to identify and analyze landslide areas. The study reports several findings relating landslide occurrence and magnitude to forest stand age and management (e.g., timber harvesting, presence of roads). The study also presents information on the impacts of debris torrents to riparian areas.

356. Roche, B. F. 1988. Noxious weeds and other concerns in Eastern Washington forestlands. In *Ponderosa Pine: The Species and Its Management*, edited by Baumgartner, David M. and J. E. Lotan (Pullman, Washington: Washington State University, Cooperative Extension Unit).
Notes: Other Highly Relevant References

357. Roche, B. F. and Talbot. 1986.
Notes: Other Works Cited

358. Rogers, P. 1996. *Disturbance ecology and forest management: a review of the literature*. Ogden, Utah: U. S. Forest Service, INT-GTR-336.
Notes: Relevant Summary Documents
Abstract: This review of the disturbance ecology literature, and how it pertains to forest management, is a resource for forest managers and researchers interested in disturbance theory, specific disturbance agents, their interactions, and appropriate methods of inquiry for specific

geographic regions. Implications for the future of disturbance ecology-based management are discussed.

359. Romme, W. H. and D. H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. *Ecology* 62, no. 2:319-326.
Notes: Highly Relevant Studies
Abstract: Differences in fire frequency and the rate of secondary succession following fire have had a major effect on the present composition of forest vegetation in a 4500ha undisturbed watershed in the subalpine zone of the Medicine Bow Mountains, southeastern Wyoming, USA. Periodic fire coupled with slow secondary succession has perpetuated lodgepole pine forest on the upland, while mature engelmann spruce-subalpine fir forests have developed in sheltered ravines and valley bottoms where fire is less frequent and succession following fire is more rapid and/or more direct. A graphic model is presented showing the relationship between topographic position, fire-free interval, and the occurrence of mature forests dominated by spruce and fir.

360. Rot, B. W. 1995. *The interaction of valley constraint, riparian landform, and riparian plant community size and age upon channel configuration of small streams of the Western Cascade Mountains, Washington*. Seattle, Washington: Doctoral Dissertation, University of Washington, College of Forest Resources.
Notes: Relevant Studies
Abstract: Biophysical factors influencing channel configuration were measured for 21 sites in mature to old forests of the western Cascades Mountains, Washington. The overall goal was to understand the patterns between channel configurations, valley constraint, riparian landform, channel type, and the riparian plant community size and age. Valley constraint was described in terms of the ratio of valley width to channel width. Riparian landform was delineated into four classes, three fluvially derived and organized by elevation above the channel, with the fourth class, slope, originating from non-fluvial processes. The three fluvial landforms were: floodplain (<1m), low terrace (1-3m), high terrace (>3m); with the fourth class, slope (>20% gradient and >15m in width). The overstory species composition, density, and stand age, and understory species composition and percent cover characterized the riparian plant community. Stream channels were classified using a conceptual mode based upon their expected response to changes in sediment supply and discharge.

Both successional processes and fluvial disturbances control riparian plant community composition based upon landform class. Floodplain landforms are dominated by deciduous species, especially red alder (62% of stems), while conifers dominated the other landforms. Conifers are found on low terrace landforms, specifically Pacific silver fir (*Abies amabilis*) and western hemlock (*Tsuga heterophylla*, 77% of stems). High terrace landforms support douglas fir (*Pseudotsuga menziesii*) and western hemlock (72% of stems), while slope landforms supported mostly western hemlock and some douglas fir (73% of stems). In addition, the relative importance of Douglas fir decreased with stand age for the three coniferous landforms indicating the effects of successional processes.

Valley constraint significantly influenced LWD volume within forced pool-riffle channels with the volume increasing as a power function of decreasing valley constraint (r^2=0.58). No relationship was found with the other channel types. The presence of off-channel habitat for aquatic organisms increased exponentially with decreasing valley constraint for all channel types (r^2=0.71).

Within the stream channel, the diameter of LWD was related to the age of the riparian forest. In old growth stands (>300 yrs), LWD diameter was great than average riparian forest diameter for all sites. A mixed relationship between LWD and riparian forest diameter in younger stands reflected a mixture of LWD from previous stands, smaller suppressed stems from existing stands, and a wide range of diameters contributed by bank erosion. Finally, LWD diameter increased overall with stand age (r^2=0.34).

This study was important for several reasons. First, it correlated fish habitat (channel configuration) to biophysical factors across multiple temporal and spatial scales. Second, the importance of successional processes within the riparian forest to channel configuration was also discussed. Finally, the composition of the riparian plant community was related to riparian landform. As a whole, the results suggest that the creation and maintenance of fish habitat results from the complex interaction of a variety of biophysical factors.

361. Roth, L. F. and J. W. Barrett. 1985. *Response of dwarf mistletoe-infested ponderosa pine to thinning: 2. dwarf mistletoe propagation*. Portland, Oregon: U. S. Forest Service, PNW-RP-331.
Notes: Supporting Studies
Abstract: Propagation of dwarf mistletoe in ponderosa pine saplings is little influenced by thinning overly dense stands to 250 trees per acre. Numerous plants that appear soon after thinning develop from formerly latent plants in the suppressed understory. Subsequently, dwarf mistletoe propagates nearly as fast as tree crowns enlarge but the rate differs widely among trees. The greatest increase is in the lower third of the tree crown. Parasite abundance had no measurable effect on height growth during 21 years following thinning, and height growth was faster than ascent of the parasite in the crown. Dominant trees that had 28 percent of crown length above the highest dwarf mistletoe plant in 1956 had 62 percent above in 1974.

362. Roth, L. F. , C. G. Shaw, and L. Rolph. 1977. Marking ponderosa pine to combine commercial thinning and control of Armillaria root rot. *Journal of Forestry* 75, no. 10:644-647.
Notes: Supporting Summary Documents
Abstract: Root rot caused by *Armillaria mellea* Vahl, ex. Fr. Quel, in natural ponderosa pine (*Pinus ponderosa* Laws.) can be reduced by removing diseased trees during commercial thinning. Critically situated infected trees are pushed out to interrupt vegetative spread among the roots and to kill the fungus through exposure.

363. Rothermal. 1983.
Notes: Other Works Cited

364. Rudinsky, J. A. 1962. Ecology of Scolytidae. *Annual Review of Entomology* 7:327-348.
Notes: Supporting Summary Documents
Abstract: An overview of the Scolytidae family, which includes bark beetles and ambrosia beetles, organisms that have inflicted significant ecological and economic damage on forests throughout the world. Included is a discussion of the ecological groups of Scolytidae, the factors influencing larval development, dispersal mechanisms, and population dynamics.

365. Russell, W. H. and J. R. McBride. 2001. The relative importance of fire and watercourse proximity in determining stand composition in mixed conifer riparian forests. *Forest Ecology and Management* 150:259-265.
Notes: Highly Relevant Summary Documents
Abstract: Factors related to the composition of riparian forest stands on three streams in the northern Sierra Nevada mixed conifer forest type were related to proximity to the water course and years since fire. Using a linear regression analysis 46 variables were correlated to the natural log of distance from the thalweg "In (distance)" including a highly significant positive correlation to dominance and percent canopy cover of conifers, and a significant negative correlation to the same variables when applied to hardwoods. Twenty-six variables were correlated to years since fire "years" including similar correlations to the dominance and cover of hardwood and conifer species. However, the significance of the correlation and the degree of sample variability described by fire age was relatively low in comparison to that found for distance from the thalweg. In addition the relative frequency of fire scars increased in a linear fashion with distance from the watercourse. The results of this study indicate that the importance of fire as a determining influence on forest composition declines in proximity to the riparian zone.

366. Rust. 1990.

Notes: Other Works Cited

367. Savage, M. and T. W. Swetnam. 1990. Early 19th-century fire decline following sheep pasturing in a Navajo ponderosa pine forest . *Ecology* 71, no. 6:2374-2378.
Notes: Supporting Studies
Abstract: The objective of this study is the documentation and interpretation of an unusual fire history in a Southwest ponderosa pine community. The fire-scar record from the Chuska Mountains shows an abrupt and persistent reduction in fire frequency at least four decades earlier than in other parts of the Southwest. The difference in land-use history offers an opportunity (1) to assess the strength of the hypothesis that grazing impacts caused fire-frequency decline in the Southwest, and (2) to assess the relationship between fire decline and shifts in forest structure that occurred soon after.

368. Scharpf, R. F. 1993. *Diseases of Pacific Coast conifers*. Washington, D. C.: U. S. Forest Service, Agriculture Handbook #521.
Notes: Supporting Summary Documents
Abstract: This handbook provides basic information needed to identify the common diseases of Pacific Coast conifers. Host, distribution, disease cycles, and identifying characteristics are described for more than 150 diseases, including cankers, diebacks, galls, rusts, needle diseases, root diseases, mistletoes, and rots. Diseases in which abiotic factors are involved are also described. For some groups of diseases, a descriptive key to field identification is included.

369. Scharpf, R. F. and R. V. Bega. 1981. *Elytroderma disease reduces growth and vigor, increases mortality of jeffrey pines at Lake Tahoe Basin, California*. Berkeley, California: U. S. Forest Service, PSW-RP-155.
Notes: Supporting Studies
Abstract: A disease of jeffrey pines (*Pinus jeffreyi* Grev. and Balf.) at Lake Tahoe Basin, California, caused by Elytroderma disease (*Elytroderma deformans*) was studied for 7 years after a severe outbreak of the fungus in 1971. Among 607 jeffrey pines on six plots, about one-half were heavily infected and about one-half were moderately or lightly infected in 1971. No uninfected trees were observed. During the 7-year study, about one-half of the trees remained unchanged in vigor, disease intensity, or both, and about one-half decreased in vigor, became more heavily infected, or both. Of the original 607 trees studied, nearly one-third died before 1978. Average radial growth of surviving trees was less per year after the outbreak than before, and heavily infected trees were growing more slowly than lightly infected trees. Intensity of the disease, however, was not related to stand basal area.

370. Schellhaas, R., D. Spurbeck, P. Ohlson and others. 2000. *Report to the Colville National Forest on the results of the Quartzite Planning Area fire history research*. Wenatchee, Washington: U. S. Forest Service.
Notes: Highly Relevant Studies
Abstract: A total of 1,301 individual fire scars were cross dated from 142 fire scar samples on 7,669 acres of Forest Service land within the Quartzite Planning Area on the Colville National Forest. The earliest fire discovered was in 1384; however, our effective fire history dates from 1671. Mean fire frequency interval (MFFI) within polygons was 8.3 years during the pre-settlement era (1670-1885) and 5.9 years during the settlement period (1886-1920). These fire frequencies are characteristic of a high frequency, low severity fire regime. The longest period between successive fires was 25 years prior to settlement era and 15 years during the settlement period. Fire frequency increased and fire size decreased during the settlement era. Mean fire size within polygons 1-7 was 1,076 acres during the pre-settlement period and 300 acres during the settlement era.

371. Schenk, J. A. and others. 1980. Model for hazard rating lodgepole pine stands for mortality by mountain pine beetle. *Forest Ecology and Management* 3, no. 1:57-68.
Notes: Other Works Cited

372. Scher, S. H. 1991. Post-fire recovery of riparian resources on the Idaho Batholith: a Geographic Information System analysis. In *GIS Applications in Natural Resources*, edited by Heit, M. and A. Shortreid (Fort Collins, Colorado: GIS World, Inc.).
Notes: Highly Relevant Studies
Abstract: This paper reports a GIS analysis of post-fire riparian resources in forested watersheds on the Lowman Ranger District of Boise National Forest. It explores the effects of wildfire on the interaction between streams and the adjacent terrestrial corridor. The paper also documents the contribution of GIS as an analytical tool in fire-recovery studies.

373. Schmid, J. M. 1988. Insects of ponderosa pine: impacts and control. In *Ponderosa Pine: The Species and Its Management*, edited by Baumgartner, David M. and James E. Lotan (Pullman, Washington: Washington State University).
Notes: Other Works Cited

374. Schmidt, Wyman C. and D. G. Fellin. 1976. Western spruce budworm damage affects form and growth of western larch. *Canadian Journal of Forest Research* 3:17-26.
Notes: Other Works Cited

375. Schmidt, Wyman C., R. C. Shearer, and A. L. Roe. 1976. *Ecology and silviculture of western larch forests*.: U. S. Department of Agriculture, Technical Bulletin #1520.
Notes: Other Highly Relevant References

376. Schmitt, C. L. 2002. *Diseases of conifers associated with riparian communities in the Blue Mountains and Inland West*.: Unpublished manuscript.
Notes: Highly Relevant Summary Documents
Abstract: The incidence and severity of many tree diseases are influenced by the "site hazard" where the host occurs. Often, the moist cool conditions characteristic of lower slope riparian areas are conducive for the effective dispersal and subsequent infection by fungal spores. Most tree diseases, that are often spore-spread, will have higher incidence and infection severity in riparian areas, and these sites are often characterized as being "higher hazard sites" than upper slope locations that often also support the same conifer host species. Differences in disease incidence between riparian and upland sites are probably greatest in continental climates, characteristic of the southern and dryer portions of the Inland West. Maritime climates support mesic plant community types outside of riparian areas, and the gradient in differences in incidence of most diseases, moving upslope or away from riparian zones, should be expected to be less clear. Examples of these differences between disease incidence and severity are clearest in locations such as the Blue Mountains, where continental climate prevails.

377. Schmitt, C. L. 1999. *Effects of stocking level control on the occurrence and severity of conifer diseases in the Blue Mountains of Northeastern Oregon and Southeastern Washington*.: U.S. Department of Agriculture Forest Service, Wallowa-Whitman National Forest, Report BMZ-99-01.
Notes: Highly Relevant Summary Documents
Abstract: Stand management in the Blue and Wallowa Mountains is frequently done to directly address insect and disease activity or risks. Thinning of some form is the most frequently prescribed treatment. Specific guidelines are available for recommended stocking levels. Depending upon stand type and other conditions, there will often be positive and negative effects of these entries. A variety of mitigating measures are available to reduce or eliminate some of the detrimental effects. They just need to be used.

378. Schmitt, C. L. 1997. *Insects and diseases of wetland hardwoods in the Blue and Wallowa Mountains with an emphasis on aspen*.: Unpublished manuscript.
Notes: Relevant Summary Documents
Abstract: Deciduous hardwood trees and woody shrubs comprise dominant vegetation in many wetland communities and are substantial components of most others in the Blue and Wallowa Mountains. Most common are species of alder (*Alnus spp*.), poplar (*Populus spp*.), willow (*Salix spp*.), dogwood (*Cornus spp*.), hawthorn (*Crataegus spp.*), maple (*Acer spp.*) and birch

(*Betula spp.*). Although most prevalent along streams and rivers, these genera are also found in other wet sites including seeps, around springs, and adjacent to meadows. In the Blue and Wallowa Mountains, distribution of these wetland species is usually limited and seldom extends beyond the immediate wet microsites except in some mesic high elevation communities. In this discussion, riparian communities will specifically refer to those sites influenced by streams or rivers.

Future management practices in riparian communities aimed at restoration and regeneration will undoubtedly need to consider insect and disease activity in the hardwood species. Many insect and disease agents affect the establishment, growth, and productivity of hardwood tree species. Most of the research and documentation concerning the biology and epidemiology of insects and diseases of hardwoods has been done in other parts of the United States, where hardwoods have been an important timber commodity. It is known that throughout the Blue and Wallowa Mountains, hardwoods are host to a variety of leaf spots, rusts, shoot blights, stem cankers, stem decayers, and defoliating and wood-boring insects. However, information regarding insect and disease outbreaks, distribution, severity, specific to the Blue Mountains is almost non-existent. Historical records of insect and disease activity on hardwoods in the Blue and Wallowa Mountains, including probable epidemics, are almost non-existent.

Given the information available, the following discussion will center on the insects and diseases believed important to these communities of the Blue and Wallowa Mountains.

379. Schmitt, C. L. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

380. Schmoldt, D. L., D. L. Peterson, R. E. Keane, J. M. Lenihan, D. McKenzie, D. R. Weise, and D. V. Sandberg. 1999. *Assessing the effects of fire disturbance on ecosystems: a scientific agenda for research and management*. Portland, Oregon: U. S. Forest Service, PNW-GTR-455.
Notes: Highly Relevant Summary Documents
Abstract: A team of scientists and resource managers convened 17-19 April 1996 in Seattle, Washington, to assess the effects of fire disturbance on ecosystems. Objectives of this workshop were to develop scientific recommendations for future fire research and management activities. These recommendations included a series of numerically ranked scientific and managerial questions and responses focusing on (1) links among fire effects, fuels, and climate; (2) fire as a large-scale disturbance; (3) fire-effects modeling structures; and (4) managerial concerns, applications, and decision support. At the present time, understanding of fire effects and the ability to extrapolate fire-effects knowledge to large spatial scales are limited, because most data have been collected at small spatial scales for specific applications. Although we clearly need more large-scale fire-effects data, it will be more expedient to concentrate efforts on improving the linking existing models that simulate fire effects in a georeferenced format while integrating empirical data as they become available. A significant component of this effort should be improved communication between modelers and managers to develop modeling tools to use in a planning context. Another component of this modeling effort should be improved communication between modelers and managers to develop modeling tools to use in a planning context. Another component of this modeling effort should improve our ability to predict the interactions of fire and potential climatic change at very large spatial scales. The priority issues and approaches described here provide a template for fire science and fire management programs in the next decade and beyond.

381. Schoonmaker, P. and A. McKee. 1988. Species composition and diversity during secondary succession of coniferous forests in the Western Cascade Mountains of Oregon. *Forest Science* 34, no. 4:960-979.
Notes: Relevant Studies
Abstract: Species diversity and community composition were studied at 23 sites on similar western hemlock/douglas fir forest habitats, in undisturbed old-growth stands and stands at 2, 5, 10, 15, 20, 30 and 40 years after clearcutting, broadcast burning, and planting with douglas fir. Vegetation was sampled with three 5x60m transects at each site. Invading herbs, then invading

and residual shrubs, and finally conifers dominated through the first 30 years. Late seral species, which account for 99% of cover in old-growth stands, are nearly eliminated immediately following disturbance, but account for almost 40% of vegetative cover after 5 years, 66% after 10 years, 83% after 20 years, and 97% after 40 years. After an initial drop following disturbance, species diversity trends weakly upward with heterogeneity peaking at 15 years and richness at 20 years. This initially high diversity (higher than that of old-growth stands) is short-lived. After the tree canopy closes, species diversity declines reaching its lowest values at 40 years. Only two species were eradicated after disturbance, both mycotophs. Pacific Northwest old-growth forests are relatively poor in species, but moderately high in heterogeneity values.

382. Schowalter, T. D., W. W. Hargrove, and D. A. Crossley. 1986. Herbivory in forested ecosystems. *Annual Review of Entomology* 31:177-196.
Notes: Supporting Summary Documents
Abstract: A review of information on the process of herbivory and the nature of insect/plant relationships, focusing on the activities of foliage-consuming (folivorous) and sap-feeding insects. The purpose of the article is to integrate the biochemical and ecosystem views of herbivory, emphasizing factors that influence herbivory in forest ecosystems and the consequences of herbivory at the tree and ecosystem levels of resolution.

383. Schuett-Hames, D., R. Conrad, A. E. Pleus, and K. Lautz. 1999. *Timber Fish & Wildlife Program method manual for the salmonid spawning gravel scour survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-008, DNR 110.
Notes: Supporting Summary Documents
Abstract: The TFW Monitoring Program method manual for the Salmonid Spawning Gravel Scour Survey provides a standard method for assessing and monitoring changes in the depth, frequency and distribution of scour on a stream segment scale. Segments for monitoring scour are selected on the basis of one of three monitoring objectives. Information on frequency and depth of scour is useful when there is a need to evaluate the effect of scour on salmonid incubation, such as in the case of sensitive or declining stocks. It is also useful for evaluating the response of stream channels to changes in peak flow discharge, sediment input, or large woody debris loading due to land-use activities or natural events.

Once objectives are identified and segments have been selected, the spawning gravel is inventoried and categorized by spawning habitat type. Then cross sections are established in a sub-sample of randomly selected spawning gravel areas representing each habitat type. Scour monitors are inserted in potential spawning gravel along each cross section, bed elevations are surveyed and substrate particle size is documented with a pebble count. Data on depth of scour, changes in bed elevation, and substrate particle sizes are collected after each storm event during the monitoring period. Peak flow discharge is documented. Scour data are analyzed in the TFW Monitoring database, which generates reports that characterize the depth, frequency and distribution of scour by cross section and spawning habitat type. Scour data are interpreted in the context of peak discharge events.

The remainder of section 1 describes the purpose of the Scour Survey, reviews scientific background information, and describes the cooperator services provided by the TFW Monitoring Program. The following sections are presented in order of survey application including: study design, pre-survey preparation, survey method, post-survey documentation, data management, and references. An extensive appendixes includes: copy masters of field forms; examples of completed field forms; scour monitor and inserter size and construction detail instructions; a sample size calculation matrix; a sample site selection worksheet example; a standard field and vehicle gear checklist; and a data management example.

384. Schuett-Hames, D., R. Conrad, A. E. Pleus, and M. McHenry. 1999. *Timber Fish & Wildlife Monitoring Program method manual for the salmonid spawning gravel composition survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-006, DNR 108.
Notes: Supporting Summary Documents

Abstract: The Timber Fish Wildlife (TFW) monitoring Program method manual for the Salmonid Spawning Gravel Composition (SG Comp) Survey provides a standard method of the assessment and monitoring of salmonid spawning gravel composition. The method is divided into sample inventory, collection, and processing sections. The inventory process ensures that samples from either riffle crests or gravel patch features are representative of spawning gravel composition on a stream segment scale. There are two options for processing samples through a standard set of sieves. The relatively quicker volumetric method measures the volume (milliliters), and the gravimetric method measures the weight (grams), of sample particles by size class. TFW data management services provides basic data analysis for spawning gravel samples such as calculating the percentage of particles less than 0.85 millimeters ("fine sediments" - volumetric equivalent) and the geometric mean diameter (gravimetric equivalent).

The introduction section describes the purpose of the SG Comp Survey, reviews scientific background information, and describes the services provided by the TFW Monitoring Program. Following the introduction, sections are presented in order of survey application including: study design, sample inventory, sample collection, sample processing, survey documentation, data management, and references. An extensive appendix is also provided that includes an equipment and resource contact list, copy masters of field forms, examples of completed field forms, standard field and vehicle gear checklist, sample bucket data tracking slips, database management examples, and a random number table.

385. Schuett-Hames, D., A. E. Pleus, E. Rashin, and J. Matthews. 1999. *Timber Fish & Wildlife Monitoring Program method manual for the stream temperature survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-005, DNR 107.
Notes: Supporting Summary Documents
Abstract: The TFW Monitoring Program method manual for the Stream Temperature (TEMP) Survey provides a standard method for assessing and monitoring the quantity and quality of stream temperature and thermal reach characteristics. The TEMP Survey provides a standard method for conducting annual maximum temperature monitoring studies to accomplish a variety of objectives, including assessment and monitoring of water temperature changes associated with land management activities, characterization and monitoring of stream reaches of special interest due to their importance for salmonid habitat or water quality, or characterization of temperature regimes throughout a watershed.

The monitoring approach involves collection of water temperature data at temperature stations, and optional characterization of channel and riparian conditions in thermal reaches immediately upstream of the temperature stations to identify factors affecting water temperature. Procedures cover the use of data logger and maximum/minimum temperature instruments for collecting water temperature data. Water temperature data are analyzed in the TFW Monitoring Program database and reports are generated that characterize the temperature regime for each temperature station daily, weekly, monthly and project basis. Cases where water quality standards have been exceeded are identified. Additional information can be collected on factors that affect the maximum water temperature regime, including air temperature, canopy closure (shade), reach elevation, stream width and depth, gradient, channel morphology and groundwater inflow.

The remainder of the introduction section describes the purpose of the TEMP Survey, reviews scientific background information, and describes the cooperator services provided by the TFW Monitoring Program. Following the introduction, sections are presented in order of survey application including: study design, pre-survey preparation, survey methods, post-survey documentation, data management, and references. An extensive appendix is also provided that includes: copy masters of field forms; examples of completed field forms; a standard field and vehicle gear checklist; data management examples; and a copy of the Washington State Water Quality Standards classification list.

386. Schuett-Hames, D., A. E. Pleus, and D. Smith. 1999. *Timber Fish & Wildlife Program method manual for the salmonid spawning habitat availability survey*. Olympia, Washington: Washington Department of Natural Resources, TFW-AM9-99-007, DNR 109.

Notes: Supporting Summary Documents
Abstract: The TFW Monitoring Program method manual for the Salmonid Spawning Habitat Availability (SHA) Survey provides a standard method for the assessment and monitoring of available salmonid spawning habitat. The criteria used to determine spawning habitat includes substrate particle size, substrate depth, water depth, water velocity, and surface area coverage. The SHA Survey has two methods for estimating the amount of spawning habitat on the TFW stream segment scale. The transect method uses dominant substrate information collected along systematically placed transects to estimate the total surface area of potential spawning habitat within the bankfull and wetted channels. The patch method provides detailed information on the surface area and distribution of individual spawning habitat patches within the wetted channel. Monitoring objectives and timing of surveys are used to select whether one or both survey methods are applied.

The remainder of the introduction section describes the purpose of the SHA Survey, reviews scientific background information, and describes the cooperator services provided by the TFW Monitoring Program. Following the introduction, sections are presented in order of survey application including: study design, pre-survey preparation, stream discharge, survey methods, post-survey documentation, data management, and references. An extensive appendix is also provided that includes: field form copy masters; examples of completed field forms; a field code sheet; data management examples, and a standard field and vehicle gear checklist.

387. Schultz, E. , S. Gehr, and S. O`Neal. 1993. *Northeastern Washington national forest health proposal*. ?, Washington: U. S. Forest Service, Okanogan, Colville, and Wenatchee National Forests.
Notes: Highly Relevant Summary Documents
Abstract: The Colville, Wenatchee, and Okanogan national forests in northeastern Washington State are sliding towards imbalance and poor health. Forest plans chart activities to help heal these national forests, but bold measures are required not to reverse the slide. This proposal lists projects which would aggressively implement forest plans in order to address the serious problem of declining forest health.

388. Scott, D. W. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

389. Sidle, Roy C. and Alan J. Campbell. 1985. Patterns of suspended sediment transport in a coastal Alaska stream. *Water Resources Bulletin* 21, no. 6:909-917.
Notes: Other Works Cited

390. Sidle, Roy C., A. J. Pearce, and C. L. O'Loughlin. 1985. *Hillslope stability and land use.* American Geophysicists Union Water Resources Monograph #11.
Notes: Other Highly Relevant References

391. Skinner, Carl N. 1997. Fire history in riparian reserves of the Klamath Mountain. In *Symposium on Fire in California Ecosystems: Integrating Ecology and Management*.
Notes: Other Works Cited

392. Smith, J. K. and W. C. Fischer. 1997. *Fire ecology of the forest habitat types of Northern Idaho*. Ogden, Utah: U. S. Forest Service, INT-GTR-363.
Notes: Relevant Summary Documents
Abstract: Provides information on fire ecology in forest habitat and community types occurring in northern Idaho. Identifies fire groups based on presettlement fire regimes and patterns of succession and stand development after fire. Describes forest fuels and suggests considerations for fire management.

393. Speer, J. H., T. W. Swetnam, B. E. Wickman, and A. Youngblood. 2001. Changes in pandora moth outbreak dynamics during the past 622 years. *Ecology* 82, no. 3:679-697.
Notes: Relevant Studies

Abstract: Episodic outbreaks of pandora moth (*Coloradia pandora* Blake), a forest insect that defoliates ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) and other pine species in the western United States, have recurred several times during the 20th century in forests of south-central Oregon. We collected and analyzed tree-ring samples from stands affected by recent outbreaks of pandora moth to develop a long-term record of outbreaks. Outbreaks were evident in tree-ring series as a characteristic "signature" of sharply reduced latewood width within a ring, followed by reduced ring widths lasting 4-20 yr. We verified that this tree-ring signature was unrelated to drought or other climatic fluctuations by comparing the timing of known and inferred outbreaks with independent climatic data. Using the pandora moth tree-ring signature, we reconstructed a 622-year record of 22 individual outbreaks in 14 old-growth ponderosa pine stands. This is currently the longest regional reconstruction of forest insect outbreak in North America. Intervals between pandora moth outbreaks were highly variable within individual forest stands, ranging from 9 yr to 156 yr. Spectral analyses of a composite time series from all stands, however, showed more consistent intervals between outbreaks, suggesting quaicyclical population dynamics at regional and decadal scales. Wavefoms extracted from the regional outbreak time series had periods ranging over 18-24 yr (39.7% variance explained) and 37-41 yr (37.3% variance explained). The periods and strengths of these cycles varied across the centuries, with the largest outbreaks occurring when relatively high-amplitude periods of the dominant cycles were in phase. Twentieth-century outbreaks were not more synchronous (extensive), severe, or longer in duration than outbreaks in previous centuries, but there was an unusual 60- yr reduction in regional activity during 1920-1980. The changing dynamical behavior of pandora moth populations highlights the need to evaluate historical factors that may have influenced this system, such as climatic variations, forest fires, and human land uses. Although cyclical dynamics in animal populations have most commonly been attributed to endogenous, ecological processes (e.g., “delayed density dependence,” predators, pathogens, and parasites) our findings suggest that exogenous processes (e.g., climatic oscillations) may also be involved.

394. Sprugel, D. G. 1991. Disturbance, equilibrium, and environmental variability: what is ‘natural’ vegetation in a changing environment? *Biological Conservation* 58:1-18.
Notes: Relevant Summary Documents
Abstract: To most early ecologists, the "natural" ecosystem was the community that would be reached after a long period without large-scale disturbance (fire, windstorm, etc.). More recently, it has been realized that in most areas some type of large-scale disturbance is indigenous, and must be included in any realistic definition of "naturalness". In some areas an equilibrium may exist in which patchy disturbance is balanced by regrowth, but in others equilibrium may be impossible because (1) individual disturbances are too large or infrequent; (2) ephemeral events have long-lasting disruptive effects; and/or (3) climate changes interrupt any movement toward equilibrium that does occur. Examples of non-equilibrium ecosystems include the African savannas, the Big Woods of Minnesota, the lodgepole pine forest of Yellowstone National Park, and possibly the old-growth Douglas-fir forests of the Pacific Northwest.

Where equilibrium does not exist, defining the "natural" vegetation becomes much more challenging, because the vegetation in any given area would not be stable over long periods of time even without man's influence. In many areas it may be unrealistic to try to define the natural vegetation for a site; one must recognize that there are often several communities that could be the "natural" vegetation for any given site at any given time.

395. Starker, T. J. 1934. Fire resistance in the forest. *Journal of Forestry* 32:462-467.
Notes: Other Highly Relevant References
Abstract: A rating scale of the resistance to fire would be helpful knowledge in the management of a forest in any region. The author has combined his wide knowledge of conditions with the best available information in the various regions of the United States. A comparison is made in regard to the development of scales of tolerance and of fire resistance. The need for more detailed and accurate knowledge is pointed out.

396. Steele. 1994.
Notes: Other Works Cited

397. Steele, R., S. F. Arno, and K. Grier-Hayes. 1986. Wildfire patterns change in Central Idaho's ponderosa pine-douglas fir forest. *Western Journal of Applied Forestry* 1:16-18.
Notes: Other Highly Relevant References

398. Stephenson, N. L. 1999. Reference conditions for giant sequoia forest restoration structure, process, and precision. *Ecological Applications* 9, no. 4:1253-1265.
Notes: Relevant Summary Documents
Abstract: National Park Service policy directs that more natural conditions be restored to giant sequoia groves, which have been altered by a century of fire exclusion. Effects to find a reasonable and practical definition of "natural" have helped drive scientists and land managers to use past grove conditions as reference conditions for restoration. Extensive research aimed at determining reference conditions have demonstrated that past fire regimes can be characterized with greater precision than past grove structures. Difficulty and imprecision in determining past grove structure has helped fuel a debate between "structural restorationists," who believe that forest structure should be restored mechanically before fire is reintroduced, and "process restorationist," who believe that simple reintroduction of fire is appropriate. I evaluate old and new studies from sequoia groves to show that some of the fire without a preceding mechanical restoration may restore the pre Euro-American structure of sequoia groves, at least within the bounds of our imprecise knowledge of past grove structure. However, the same may not be true for all forest types that have experienced lengthily fire exclusion. Our ability to draw robust generalizations about fire's role in forest restoration will depend heavily on a through understanding of past and present interactions among climate, fire, and forest structure. Use of reference conditions will be central to developing this understanding.

399. Stoszek. 1988.
Notes: Other Works Cited

400. Stoszek. 1994.
Notes: Other Works Cited

401. Stuart, J. D., J. K. Agee, and R. I. Gara. 1989. Lodgepole pine regeneration in an old, self-perpetuating forest in South-Central Oregon. *Canadian Journal of Forest Research* 19:1096-1104.
Notes: Other Highly Relevant References

402. Suzuki, W., K. Osumi, T. Masaki, K. Takahashi, H. Daimaru, and K. Hoshizak. 2002. Disturbance regimes and community structures of a riparian and an adjacent terrace stand in the Kanumazawa Riparian Research Forest, Northern Japan. *Forest Ecology and Management* 157:285-301.
Notes: Relevant Studies
Abstract: Riparian forests and adjacent upland forests often exhibit differences in composition and diversity. This variation should be due in part to difference in site condition and in part to difference in disturbance regime. To understand relative roles of these differences, structure, composition and diversity were compared between a riparian forest and an adjacent terrace forest through analyzing topography-specific guild structure referring to disturbance regime in an old-growth temperate deciduous forest in northern Japan.

The study plot (4.71ha) was topographically divided into four units: a riparian area (RP) and a terrace (TR) as major parts, and a colluvial slope (CS) and a denuded slope (DS) as minor parts. The riparian area included various microsites, such as an active channel, and lower and higher floodplains, which have been formed by multiple types of natural disturbances: flooding debris flow and tree-fall. In contrast, in the terrace, only tree-falls were the prevailing disturbance and homogeneous site conditions (a gentle slope and deep organic soil) developed. In the riparian area, a species-rich stand with higher diversity indices (e.g. equitability), mainly composed of

Cercidiphyllum japonicum, Aesculus turbinata and *Pterocarya rhoifolia*, developed. In contrast, the terrace stand was dominated by a single species, Fagus crenata, and showed lower species richness and diversity. Three topography-specific guilds (RP-type, nine species; TR-type, eleven species; DS-type, three species) and one guild of generalist (five species) were found. Other 13 species were infrequent. The higher species richness and equitability in the riparian stands were attributed to the facts that the riparian stands include many species of non-riparian-specific guilds and many infrequent species as well as RP-type species, and that the terrace stand, in contrast, were mainly composed of TR-type species and a few generalists. In the riparian area heterogeneous site condition created by multiple disturbance regimes allowed species with different niche to coexist. In addition, there was some evidence in the riparian area that the geomorphic processes with infrequent and large-scale disturbances formed mosaics of various successional stages, suggesting non-equilibrium species coexistence in the riparian community.

403. Swanson. 1972.
Notes: Other Works Cited

404. Swanson and others. 1981.
Notes: Other Works Cited

405. Swanson. 1988.
Notes: Other Works Cited

406. Swanson, F. J. 1981. Fire and geomorphic process. In *Proceedings of the Conference Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-26).
Notes: Highly Relevant Summary Documents
Abstract: Fire, geomorphic processes, and landforms interact to determine natural patterns of ecosystems over landscapes. Fire alters vegetation and soil properties, which change soil and sediment movement through watersheds. Landforms affect fire behavior and form firebreaks, which determine burn boundaries. Geomorphic consequences of fire in a landscape-ecosystem type are determined by (A) characteristics of the fire regime, mainly frequency and intensity; and (B) geomorphic sensitivity or erodibility of the landscape.

407. Swanson, F. J., L. E. Benda, S. H. Duncan, G. E. Grant, W. F. Megahan, and L. M. Reid. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. In *Streamside Management: Forestry and Fishery Interactions*, edited by Salo, E. O. and T. W. Cundy (Seattle, Washington: University of Washington, College of Forest Resources).
Notes: Other Highly Relevant References

408. Swanson, F. J. and Jerry F. Franklin. 1992. New forestry principles from ecosystem analysis of Pacific Northwest forest. *Ecological Applications* 2, no. 3:262-274.
Notes: Relevant Summary Documents
Abstract: Forest management practices on federal lands in the Pacific Northwest of the United States have been the center of intense controversy. Conflicting value systems, new information, and new perspectives have fueled the debate over the balance between timber production and preservation of natural ecosystems. In this paper we consider examples from three aspects of forest management: (1) management of forest stands, (2) management of the patchwork of forest stands at the landscape scale, and (3) management of streams and riparian networks. In each of these cases we examine: management practices and perspectives of the recent past, findings from ecosystem research that are leading to change in those practices, resulting changes in management practices, and future research directions. We also suggest a path for future change, including systems for managing in the face of uncertainty.

Results of research in natural and managed forest and stream ecosystems have been pivotal in reassessment and redesign of management practices to provide a broader range of management options for society to consider. Results of studies of natural disturbance processes and their effects are used as reference points for management systems intending to sustain biological diversity and ecosystem productivity. Stand management practices, for example, are being modified to retain some live trees and greater amounts of dead woody debris, both standing and down, in areas that would instead be clear-cut under intensive plantation forestry practices. The motivations for these modified practices are to sustain biological diversity, including key wildlife species, and to maintain soil productivity. Models of alternative forest-cutting patterns at a landscape scale are being used to examine shift from the previous system of dispersing cutting units to a system involving greater aggregation of unites using designs to provide for species preferring forest interior habitat as well as species favoring edge and early seral habitats. As a result of ecosystem research, the management of stream and riparian networks can now be based on understanding of forest-stream interactions and designed within a drainage-basin context. Overall, emphasis in research and management seems to be in early stages of shifting from featured species--e.g. douglas fir (*Pseudotsuga menziesii* Mirb. Franco) and northern spotted owl (*Strix occidentalis caurina*)--to ecosystems, and from the scale of forest stand to landscapes and the entire region.

In addition to the contributions of ecosystem research to redesign of management techniques, ecosystem scientists also have roles in the social processes for determining the future course of management of natural resources. An important medium for scientist participation is establishment of adaptive management programs, in which management activities are conducted as experiments to test hypotheses and develop information needed for future natural resource management.

409. Swanson, F. J., S. L. Johnson, S. V. Gregory, and S. A. Acker. 1998. Flood disturbance in a forested mountain landscape: interactions of land use and floods. *BioScience* 48:681-689.
Notes: Other Highly Relevant References

410. Swanson, F. J., T. K. Kratz, N. Caine, and R. G. Woodmansee. 1988. Landform effects on ecological processes and features. *BioScience* 38:92-98.
Notes: Other Highly Relevant References

411. Swetnam, T. W., C. D. Allen, and J. L. Betancourt. 1999. Applied historical ecology: using the past to manage for the future. *Ecological Applications* 9, no. 4:1189-1206.
Notes: Supporting Summary Documents
Abstract: Applied historical ecology is the use of historical knowledge in the management of ecosystems. Historical perspectives increase our understanding of the dynamic nature of landscapes and provide a frame of reference for assessing modern patterns and processes. Historical records, however, are often too brief or fragmentary to be useful, or they are not obtainable for the process or structure of interest. Even where long historical time series can be assembled, selection of appropriate reference conditions may be complicated by the past influence of humans and the many potential reference conditions encompassed by nonequilibrium dynamics. These complications, however, do not lessen the value of history; rather they underscore the need for multiple, comparative histories from many locations for evaluating both cultural and natural causes of variability, as well as for characterizing the overall dynamical properties of ecosystems. Historical knowledge may not simplify the task of setting management goals and making decisions, but 20th century trends, such as increasingly severe wildfires, suggest that disregarding history can be perilous.

We describe examples from our research in the southwestern United States to illustrate some of the values and limitations of applied historical ecology. Paleoecological data from packrat middens and other natural archives have been useful for defining baseline conditions of vegetation communities, determining histories and rates of species range expansions and contractions, and discriminating between natural and cultural causes of environmental change. We describe a montane grassland restoration project in northern New Mexico that was justified and guided by an historical sequence of aerial photographs showing progressive tree invasion during the 20th century. Likewise, fire scar chronologies have been widely used to justify and

guide fuel reduction and natural fire reintroduction in forest. A southwestern network of fire histories illustrates the power of aggregating historical time series across spatial scales. Regional fire patterns evident in these aggregations point to the key role of interannual lags in responses of fuels and fire regimes to the El Nino--Southern Oscillation (wet/dry cycles), with important implications for long-range fire hazard forecasting. These examples of applied historical ecology emphasize that detection and explanation of historical trends and variability are essential to informed management.

412. Swetnam, T. W. and J. L Betancourt. 1997. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. *Journal of Climate* 11:3128-3147.
Notes: Highly Relevant Studies
Abstract: Ecological responses to climatic variability in the Southwest include regionally synchronized fires, insect outbreaks, and pulses in tree demography (births and deaths). Multicentury, tree-ring reconstructions of drought, disturbance history, and tree demography reveal climatic effects across scales, from annual to decadal, and from local (10^2 km^2) to mesoscale (10^4-10^6 km^2). Climate-disturbance relations are more variable and complex than previously assumed. During the past three centuries, mesoscale outbreaks of the western spruce budworm (*Choristoneura occidentalis*) were associated with wet, not dry episodes, conventional wisdom. Regional fires occur during extreme droughts but, in some ecosystems, antecedent wet conditions play a secondary role by regulating accumulation of fuels. Interdecadal changes in fire-climate associations parallel other evidence for shift in the frequency or amplitude of the Southern Oscillation (SO) during the past three centuries. High interannual, fire-climate correlations (r=0.7 to 0.9) during specific decades (i.e., circa 1780 to 1830) correspond with a decreased in SO frequency or amplitude inferred from independent tree-ring width, ice, core, and coral isotope reconstructions.

Episodic dry and wet episodes have altered age structures and species composition of woodland and conifer forests. The scarcity of old, living conifers established before circa 1600 suggests that the extreme drought of 1575-95 had pervasive effects on tree populations. The most extreme drought of the past 400 years occurred in the mid-twentieth century (1942-57). This drought resulted in broadscale plant die offs in shrublands, woodlands, and forest and accelerated shrub invasion of grasslands. Drought conditions were broken by the post 1976 shift to the negative SO phase and wetter cool season in the Southwest. The post-1976 shows up as an unprecedented surge in tree-ring growth within millennia-length chronologies. This unusual episode may have produced a pulse in tree recruitment and improved rangeland conditions (e.g., higher grass production), and the post-1976 wet period and their aftermaths offer natural experiments to study long-term ecosystem response to interdecadal climate variability.

413. Swetnam, T. W. and A. M. Lynch. 1993. Multicentury, regional-scale patterns of western spruce budworm outbreaks. *Ecological Monographs* 63, no. 4:399-424.
Notes: Highly Relevant Studies
Abstract: Tree ring chronologies from 24 mixed-conifer stands were used to reconstruct the long-term history of western spruce budworm (*Choristoneura occidentalis*) in northern New Mexico. Temporal and spatial patterns of budworm infestations (within-stand occurrences) and outbreaks (more-or-less synchronous infestations across many stands) were investigated to identify local-scale to regional-scale forest disturbance patterns. Nine regional-scale outbreaks were identified from 1690 to 1989. One ancient stand of douglas fir trees (*Pseudotsuga menziesii*) exceeding 700 yr in age revealed that budworms and overstory trees could coexist for extraordinary lengths of time. Using spectral analysis we found that the regional outbreak record contained important cyclical components with periods varying from ~20 to 33 yr. The statistically significant ($P < .05$) but variable periodicity of regional outbreaks suggests the forest-budworm dynamic is pseudoperiodic (i.e., a stable limit cycle or damped oscillator perturbed by noise).

Duration of infestations within stands was ~11 yr and has not obviously changed in the 20th century; however, infestations tended to be more synchronous among stands in this century than

during earlier centuries. Regional budworm activity was low from the mid-1920's to late 1930's and mid-1960's to late 1970's, and the most recent outbreak, beginning in the late 1970's, was unusually severe. These results, and contrasting infestation patterns in mountain ranges with different land use histories, generally support a hypothesis that human-induced changes in Southwestern forests have led to more widespread and intense budworm outbreaks in the late 20th century.

Despite human-induced changes in the 20th century, climate variation also appears to have been important to budworm regimes in this century as well as in earlier times. Regional outbreaks in the 20th century tended to occur during years of increased spring precipitation, and decreased budworm activity coincided with decreased spring precipitation. No clear association with temperature was identified. Comparisons of regional outbreak history since AD 1600 with a reconstruction of spring precipitation from limber pine (*Pinus flexilis*) ring width chronologies also shows that periods of increased and decreased budworm activity coincided with wetter and drier periods, respectively. This finding contrast with results from shorter time-scale studies conducted in northwestern U.S. and Canada (western spruce budworm) and eastern Canada (spruce budworm *C. fumiferana*), where low precipitation and/or warmer temperatures were generally associated with outbreaks. Different patterns of budworm population response to changing moisture regimes might be due to differences in regional forest-budworm systems, or to differences in spatial and temporal scales of observation.

We conclude that changes in forest structure in the southwestern U.S. may have shifted the spatial and temporal pattern of budworm outbreaks. The dynamic behavior and statistically significant association between multi-centuries, regional budworm and climate time series also suggest that complex budworm dynamics are driven by a combination of internal and external factors.

414. Swetnam, T. W. and A. M. Lynch. 1989. A tree-ring reconstruction of western spruce budworm history in the Southern Rocky Mountains. *Forest Science* 35, no. 4:962-986.
Notes: Supporting Studies
Abstract: Tree-ring width chronologies from ten mixed-conifer stands in the Colorado Front Range and New Mexico Sangre de Cristo Mountains were used to reconstruct the timing, duration, and radial growth impacts of past outbreaks of western spruce budworm (*Choristoneura occidentalis* Freeman). At least nine outbreaks were identified in the stands from 1700 to 1983. Severity and timing of outbreaks was highly variable. The average duration of reduced growth periods caused by budworms was 12.9 years and ranged from 5 to 26 years. The average interval between initial years of successive outbreaks was 34.9 years and ranged from 14 to 58 years. The average maximum and periodic radical growth reductions were 50% and 21.7%, respectively. There was a relatively long period of reduced budworm activity in the first few decades of the twentieth century, and since that time outbreaks have been markedly more synchronous among the sampled stands. It was hypothesized that the increased synchronicity of outbreaks in the latter half of the twentieth century is due to changes in age structure and species composition following harvesting and fire suppression in the late ninetieth and early twentieth centuries.

415. Swetnam, T. W., B. E. Wickman, H. G. Paul, and C. H. Baisan. 1995. *Historical patterns of western spruce budworm and douglas fir tussock moth outbreaks in the northern Blue Mountains, Oregon, since A.D. 1700*. Portland, Oregon: U. S. Forest Service, PNW-RP-484.
Notes: Highly Relevant Studies
Abstract: Dendroecology methods were used to reconstruct a three-century history of western spruce budworm and Douglas-fir tussock moth outbreaks in the Blue Mountains of northeastern Oregon. Comparisons of 20th century Forest Service documentary records and host and nonhost tree-ring width chronologies provide an objective basis for distinguishing climatic effects from insect-caused defoliation effects. Budworm outbreaks were more confidently reconstructed than were tussock moth outbreaks. Since A.D. 1700, at least eight regional budworm outbreaks have occurred at intervals of about 21 to 53 years. Reduced radial growth caused by defoliation lasted from about 13 to 17 years. Two regional budworm outbreaks occurred during the 19th

century, and at least three and possibly four regional outbreaks have occurred during the 20th century. These findings generally support the hypothesis that budworm outbreaks have increased in the frequency and severity in the 20th century in northeastern Oregon.

416. Swezy, D. M. and J. K. Agee. 1991. Prescribed fire effects on fine root and tree mortality in old growth ponderosa pine. *Canadian Journal of Forest Research* 21:626-634.
Notes: Other Highly Relevant References
Abstract: Old-growth *Pinus ponderosa* stands were surveyed at Crater Lake National Park, Oregon. Mortality of trees >22cm dbh was higher in burned areas (19.5%) than in unburned areas (6.6%), and early-season burns had over 30% mortality. Mortality was associated with fire severity, as measured by scorch height and ground char, season of burning, and tree vigor. Pines of high, moderate, and low vigor were subjected to a prescribed burn in June; half of the trees had debris raked from tree bases as an additional treatment. Lethal heat loads (>60°C) occurred in >75% of samples at the soil surface and at 5 cm soil depth, with duration exceeding 5 h. Burning reduced fine-root dry weight 50-75% 1 and 5 months after burning; raking and burning reduced fine-root dry weight more than burning alone after 1 month and had similar effects to burning after 5 months. Present fuel loads may be too high to burn during spring if old-growth *P. ponderosa* are to be protected.

417. Tansley, A. G. 1924. The classification of vegetation and the concept of development. *Journal of Ecology* 8:118-149.
Notes: Other Highly Relevant References

418. Taylor. 1990.
Notes: Other Works Cited

419. Taylor, A. H. and M. N. Solem. 2001. Fire regimes and stand dynamics in an upper montane forest landscape in the Southern Cascades, Caribou Wilderness, California. *Journal of the Torrey Botanical Society* 128, no. 4:350-361.
Notes: Relevant Studies
Abstract: Fire is the most frequent and widespread disturbance affecting forests in the Pacific Northwest and identifying the frequency, extent, and severity of fires is essential for understanding the role of fire in long term forest dynamics. This study quantifies presettlement fire regimes (i.e. fire return interval, fire extent, fire severity, fire rotation) and successional patterns in a 950ha upper motane forest using 39 cross-dated fire scar samples, tree ages and radial growth patterns in cores, and tree diameters distributions in 112 plots. Forest species composition varied with potential soil moisture and there was variation in some fire regime parameters among forest compositional groups. Mean fire return intervals were shortest in red fir-white fir forests (41 yr), and longer in white fir-jeffrey pine, lodgepole pine, lodgepole pine-red fir, and red fir-western white pine forests (59-70 yr). Lodgepole pine and lodgepole pine-red fir forests experienced more high severity (38-75%) fire than other forest types (13-25%). Fire rotation varied by time period, and wash shortest in the pre-Euro-American period (76 yr), longer in the settlement period (177 yr), and longest in the fire suppression (577 yr) period. The average extent of a fire was small (150ha). Lodgepole pine-red fir, white fir-jeffrey pine, and red fir-white fir forest are changing in composition but lodgepole pine and red fir-western white pine forests are compositionally stable. Recurring fire in the presettlement period maintained fire-dependent pines but fire suppression is now causing shifts in species composition and changes in landscape scale vegetation patterns similar to those in lower montane forests.

420. Tholen, R. D. 1999. *Modeling fire effects on stand composition and structure within riparian buffers in dry douglas fir/ponderosa pine forests*. Moscow, Idaho: Doctoral Dissertation, University of Idaho.
Notes: Highly Relevant Studies
Abstract: The USDA, Forest Service and USDI, Bureau of Land Management have adopted riparian buffer systems to maintain and restore coldwater fish habitats. The FIRESUM successional model was used to project the long-term effects of these buffers on forest

ecological health and aquatic habitat conditions. FIRESUM was calibrated using stand data from sties along the North Fork Boise River, in southcentral Idaho, along with local weather and fuels information. The model's ability to replicate actual fire mortality as measured on the study plots was tested using chi square, ANOVA comparisons using the F-statistic, and Pearson's correlation statistical tests. These tests suggest that the model, as calibrated, accurately predicts tree mortality from fire within the study area.

Following model validation testing, three fire management scenarios were modeled for a 150 year period: low-intensity fire every thirty years, determined to be the historic fire regime; high-intensity fire at year 75; and no fire. Simulated forests were compared for their ability to persist following fire, and their ability to provide large woody debris and shade for aquatic habitats. Model results suggest that reinitiating of the native fire regime of low-intensity fire at a 30 year return interval will produce a forest more likely to persist and repeat following fire, and that will provide a more consistent amount of large woody debris recruitment and shade than the other scenarios tested. FIRESUM is a useful tool for managers to better understand the effect of their decisions on forest and aquatic habitats.

421. Thomas, J. W. 1979. *Wildlife habitats in managed forests in the Blue Mountains of Oregon and Washington*. Washington, D. C.: U. S. Forest Service, Agricultural Handbook #553.
Notes: Other Highly Relevant References

422. Thomson, A. J., R. F. Shepherd, J. W. E. Harris, and R. H. Silversides. 1984. Relating weather to outbreaks of western spruce budworm, *Choristoneura occidentalis* (*Lepidoptera*: Tortricidae), in British Columbia. *Canadian Entomologist* 116:375-381.
Notes: Relevant Studies
Abstract: The relationship of western spruce budworm outbreaks and population collapse to weather parameters was examined using long term weather records from two stations in the budworm outbreak area of British Columbia and outbreak patterns obtained from Forest Insect and Disease Survey records and from tree stem analyses.

Outbreaks were associated with warm dry summers in conjunction with synchrony of larval emergence and bud flush. Collapse of the last two outbreaks was clearly associated with extreme high temperatures following moth flight. Collapse of the earlier outbreaks may have been due to asynchrony between larval emergence and bud flush.

423. Thomson, A. J. and D. M. Shrimpton. 1983. Weather associated with the start of mountain pine beetle outbreaks. *Canadian Journal of Forest Research* 14:255-258.
Notes: Other Works Cited
Abstract: Extreme weather conditions associated with mountain pine beetle outbreaks were evaluated by graphical techniques for six locations throughout British Columbia. Three major associations of extreme weather patterns with lodgepole pine growth and mountain pine beetle outbreaks were identified. Weather effects prior to, or early in, the growing season can reduce growth without releasing the beetle population. Weather conducive to beetle establishment and early brood development can occur too late in the season to have a noticeable effect on tree growth and therefore will not be recorded in the annual growth rings. Warm, dry periods during the summer are associated with tree growth reduction and the beginnings of outbreaks. In each of these three cases, extreme low precipitation levels were involved. Average precipitation in some months did not compensate for the effects of unfavorable extremes in other months on tree growth.

424. Thomson, A. J. and D. M. Shrimpton. 1984. Weather associated with the start of mountain pine beetle outbreaks. *Canadian Journal of Forest Research* 14:255-258.
Notes: Relevant Studies
Abstract: Extreme weather conditions associated with mountain pine beetle outbreaks were evaluated by graphical techniques for six locations throughout British Columbia. Three major associations of extreme weather patterns with lodgepole pine growth and mountain pine beetle

outbreaks were identified. (I) Weather effects prior to, or early in, the growing season can reduce growth without releasing the beetle population. (II) Weather conducive to beetle establishment and early brood development can occur too late in the season to have a noticeable effect on tree growth and therefore will not be recorded in the annual growth rings. (III) Warm, dry periods during the summer are associated with tree growth reduction and the beginnings of outbreaks. In each of these three cases, extreme low precipitation levels were involved. Average precipitation in some months did not compensate for the effects of unfavorable extremes in other months on tree growth.

425. Tiedemann, A. R., C. E. Conrad, J. H. Dieterich, J. W. Hornbeck, W. F. Megahan, L. A. Viereck, and D. D. Wade. 1979. *Effects of fire on water: a state of knowledge review*. Washington, D. C.: U. S. Forest Service, WO-GTR-10.
Notes: Other Works Cited

426. Tkacz, B. M. and F. A. Baker. 1991. Survival of *Inonotus tomentosus* in spruce stumps after logging. *Plant Disease* 75:788-790.
Notes: Supporting Studies
Abstract: Survival of *Inonotus tomentosus* was investigated by isolating the fungus from excavated stumps of blue spruce (*Picea pungens*) and engelmann spruce (*P. englemannii*) that had been harvested 9, 13, and 20 yr-old stumps, respectively. The diameter of the smallest roots that yielded *I. Tomentosus* ranged from 1.3cm (9 yr-old stumps) to 2.5cm (13 and 20 yr-old stumps). The maximum distances that *I. Tomentosus* was found from the stumps were 3.4, 6.1, and 5.5m for 9, 13, and 20 yr-old stumps, respectively. Isolates of *I. Tomentosus* from stumps of all ages killed artificially inoculated Engelmann spruce seedlings.

427. Torgersen, T. R. 2001. Defoliators in Eastern Oregon and Washington. *Northwest Science* 75:11-20.
Notes: Relevant Summary Documents
Abstract: Defoliating insects are major disturbance agents affecting forest health and productivity in eastern Oregon and Washington. Information on the four main defoliators of conifers in eastern Oregon and Washington is abundant. Because of concerns about growth suppression and mortality of trees during widespread defoliator outbreaks, much research effort has been focused on these species. They are western spruce budworm (*Choristoneura occidentalis*), douglas fir tussock moth (*Orgyia pseudotsugata*), pandora moth (*Coloradia pandora*), and larch casebearer (*Coleophora Laricella*). Various interactions of defoliators with other system components and natural regulatory processes have been described, as have monitoring and suppression techniques using pheromone traps. Large-scale suppression projects using both chemical and biological materials have been used in attempts to control some defoliator outbreaks. While such suppression projects have prevented some tree mortality and growth loss, they have been largely ineffective in changing the outbreak behavior of these insects. Some suppression materials have undesirable side effects on non-target insects such as sensitive or endangered moths, butterflies, and skippers, or on other ecological processes. Successful control of larch casebearer has been achieved by introduction of parasitic wasps. For most defoliators, the recommended strategy is preventative: silvicultural treatment to promote a diversity of tree species, stand structures, and moderate stocking levels. Decision-support tools UPEST and UTOOLS analyze insect and disease risks, and the Forest Vegetation Simulator models effects of insects and disease on stand growth.

428. Toth, S. 1991. *A road damage inventory for the Upper Deschutes River Basin*. Seattle, Washington: University of Washington, Timber, Fish and Wildlife Report TFW-SH14-91-007.
Notes: Other Highly Relevant References

429. Touchan, R. , C. D. Allen, and T. W. Swetnam. 1996. Fire history and climatic patterns in ponderosa pine and mixed-conifer forests of the Jemez Mountains, Northern New Mexico. In *Fire Effects in Southwestern Forests: Proceedings of the Second La Mesa Fire Symposium*, edited by Allen, C. D. (Fort Collins, Colorado: U. S. Forest Service).
Notes: Relevant Studies

Abstract: We constructed fire history in ponderosa pine and mixed conifer forests across the Jemez Mountains in northern New Mexico. We collected fire-scarred samples from ten ponderosa pine areas, and three mesic mixed-conifer areas. Prior to 1900, ponderosa pine forests were characterized by high frequency, low intensity surface fire regimes. The mixed-conifer stands sustained somewhat less frequent surface fires, along with patchy crown fires. We also examined the associations between past fires and winter-spring precipitation. In both ponderosa pine and mixed-conifer forests, precipitation was significantly reduced in the winter-spring period immediately prior to fire occurrence. In addition, winter-spring precipitation during the second year preceding major fire years in the ponderosa pine forest was significantly increased. The results of this study provide baseline knowledge concerning the ecological role of fire in ponderosa pine and mixed-conifer forests. This information is vital to support ongoing ecosystem management efforts in the Jemez Mountains.

430. Townsend, C. R., M. R. Scarsbrook, and S. Doledec. 1997. The intermediate disturbance hypothesis, refugia, and biodiversity in streams. *Limnology and Oceanography* 42, no. 5:938-949.
Notes: Relevant Studies
Abstract: The intermediate disturbance hypothesis has been influential in the development of ecological theory and has important practical implications for the maintenance of biodiversity but has received few rigorous tests. We tested the hypothesis that maximum taxon richness of macroinvertebrates will occur in communities subject to intermediate levels of disturbance at 54 stream sites that differed in the frequency and intensity of flood-related episodes of bed movement. Our results support the intermediate disturbance hypothesis, with both highly mobile and relatively sedentary taxa conforming to the predicted bell-shaped curve. Taxon richness was not related to habitat area (stream width), distance from the headwater, or the diversity of microhabitats (particle size categories) but was significantly and negatively related to the proportion of the substratum made up of small particles. Of all the factors measured, however, bed disturbance was by far the best at accounting for variation in taxonomic richness. We also quantified several kinds of potential refugia for invertebrates and found a positive relationship between richness and refugia axis that combines amount of dead space with proportion of large substratum particles.

431. Turner, M. G., W. H. Romme, and R. H. Gardner. 1993. A revised concept of landscape equilibrium: disturbance and stability on scaled landscapes. *Landscape Ecology* 8:213-227.
Notes: Other Highly Relevant References

432. U. S. Forest Service. 1992.
Notes: Other Works Cited

433. U. S. Forest Service. 1997. *An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins*. Portland, Oregon: U. S. Forest Service, PNW-GTR-405, 4 Volumes.
Notes: Highly Relevant Summary Documents
Abstract: The Assessment of Ecosystem Components in the Interior Columbia Basin and portions of the Klamath and Great Basins provides detailed information about current conditions and trends for the biophysical and social systems within the Basin. This information can be used by land managers to develop broad land management goals and priorities and provides the context for decisions specific to smaller geographic areas. The assessment area system lands, 10 percent of the Nation's BLM-administered lands, and contains about 1.2 percent of the Nation's population. This result in a population density that is less than and generally has a robust, diverse economy. As compared to historic conditions, the terrestrial, aquatic, forest, and rangeland systems have undergone dramatic changes. Forested landscapes are more susceptible to fire, insect, and disease that under historic conditions. Rangelands are highly susceptible to noxious weed invasion. The disturbance regimes that operate on forest and rangeland have changed substantially, with lethal fires dominating many areas where non-lethal fires were the norm historically. Terrestrial habitats that have experienced the greatest decline include the native grassland, native shrub land, and old forest structures. There are areas within the

assessment area that have higher diversity than introduction of non-native fish species has complicated current status of native fishes. Core habitat and population centers do remain as building blocks for restoration. Social and economic conditions within the assessment area vary considerably, depending to a great extent on population, diversity of employment opportunities, and changing demographics. Those counties with the higher population densities and greater diversity of employment opportunities are generally more resilient to economic downturns. This assessment provides a rich information base, including over 170 mapped themes with associated models and databases, from which future decisions can benefit.

434. U. S. Forest Service. 2000. *Environmental effects of postfire logging: literature review and annotated bibliography*. Portland, Oregon: U. S. Forest Service, PNW-GTR-486.
Notes: Highly Relevant Summary Documents
Abstract: The scientific literature on logging after wildfire is reviewed, with a focus on environmental effects of logging and removal of large woody structure. Rehabilitation, the practice of planting or seeding after logging, is not reviewed here. Several publications are cited that can be described as "commentaries," intended to help frame the public debate. We review 21 postfire logging studies and interpret them in the context of how wildfire itself affects stands and watersheds. Results of this review are summarized in 16 major conclusions at the end of the text, most of which are based on results of no more than a handful of studies. The review is followed by an annotated bibliography and an index. Copies of all papers reviewed here are held by the Blue Mountains Natural Resource Institute, at the Forestry and Range Sciences Laboratory, Pacific Northwest Research Station, La Grande, Oregon.

435. U. S. Forest Service. 2001. *The Interior Columbia Basin Ecosystem Management project: project data*. Portland, Oregon: U. S. Forest Service.
Notes: Highly Relevant Studies
Abstract: In July 1993, President Clinton directed the Forest Service to "develop a scientifically sound and ecosystem-based strategy for management of eastside forests." Responding to this direction, the project was initiated by the United States Department of Agriculture, Forest Service and the United States Department of Interior, Bureau of Land Management.

Project Mission: Develop a scientifically sound and ecosystem based strategy for forest and rangelands administered by the Forest Service and Bureau of Land Management in the interior Columbia River basin and portions of the Klamath and Great Basins.

The project has compiled a CD-ROM set (series of five CD-ROMs) that includes digital versions of the spatial data, databases, metadata, and major scientific publication graphics compiled in support of the project.

436. U. S. Forest Service. 1996. *Use of fire in forest restoration*. Ogden, Utah: U. S. Forest Service, INT-GTR-341.
Notes: Highly Relevant Summary Documents
Abstract: The 26 pages of this document address the current knowledge of fire as a disturbance agent, fire history and fire regimes, applications of prescribed fire for ecological restoration, and the effects of fire on the various forested ecosystems of the north-western United States. The main body of this document is organized in three sections: Assessing Needs for Fire in Restoration; Restoration of Fire in Inland Forests; and Restoration in Pacific Westside Forests. These papers comprise the proceedings from a general technical conference at the 1995 Annual Meeting of the Society for Ecological Restoration, held at the University of Washington, Seattle, September 14-16, 1995.

437. Ubelecker, M. 2002. *Personal communication with Richard Everett*.
Notes: Other Highly Relevant References

438. Van der Kamp, B. J. 1995. The spatial distribution of Armillaria root disease in an uneven-aged spatially clumped douglas fir stand. *Canadian Journal of Forest Research* 25:1008-1016.

Notes: Relevant Studies
Abstract: The location, species, and infection status of all tees and stumps in nine 40 by 40 m plots located in a single large Armillaria root disease (caused by *Armillaria ostoyae* Romagnesi Herink) infested area in the interior douglas fir zone in British Columbia were recorded. The area was logged to a diameter limit in 1963 and then left undisturbed. Spatial analysis using variance over mean ratios of number of trees per grid square for a series of grid sizes showed that stumps were randomly distributed, trees were strongly clumped, and infected trees occurred in small clumps that were themselves randomly distributed. Analysis of intertree distances showed that clumps of infected trees ranged from 1 to 29 trees (average 3.2 trees). Incidence of infection did not decline with distance from old stumps. Infection incidence in spatial domains surrounding each stump ranged from 0 to 100%. Nevertheless, variation in incidence among stump domains could not be attributed to variation in inoculum potential at the time of logging. It is concluded that in the experimental area, 30 years after the last major disturbance by partial cutting, Armillaria occurs in small domains, largely on the root systems of trees regenerated since logging. In these circumstances, bridge tree removal spacing, which removes all trees from a band around each infected tree, may isolate most of the viable *Armillaria inoculum* colonies from the remainder of the stand.

439. Varty, I. W. 1975. Forest spraying and environmental integrity. *Forestry Chronicle*:146-149.
Notes: Supporting Summary Documents
Abstract: An overview of the environmental consequences of chemical insecticide spraying as a means of managing pest outbreaks in Canadian forests. Presents both the positive and negative consequences of such spraying, and answers several questions regarding the regulatory oversight of spraying activities, its impacts to fish and wildlife, and its role in maintaining a balanced ecological system.

440. Wallner, W. E. 1987. Factors affecting insect population dynamics: differences between outbreak and non-outbreak species. *Annual Review of Entomology* 32:317-340.
Notes: Supporting Summary Documents
Abstract: A review and comparison of the factors affecting insect population dynamics. Emphasis is placed upon phytophagous insects of perennial plant habitats, since extended temporal observations are essential for describing endemic populations and the processes by which populations change from latent to endemic. The voluminous literature on insects from varied habitats dictates that this review be focused on: (A) how ecological factors such as natural enemies, weather, host, and site of perennial plant habitats (mainly forest) influence endemic and epidemic insect dynamics; and (B) how heritable features of individual populations are important in differentiating between endemic insect and epidemic pests.

441. Washington Department of Natural Resources. 1999. *Forests and fish report*. Olympia, Washington: Washington Department of Natural Resources.
Notes: Other Highly Relevant References

442. Washington Department of Natural Resources, Forest Health Program. 2002. *Forest health in Washington, 2000*. Olympia, Washington: Washington State Department of Natural Resources, Forest Health Program, http://www.wa.gov/dnr/htdocs/rp/forhealth/.
Notes: Relevant Summary Documents
Abstract: An on-line summary of insect and disease information relevant to forests of Eastern Washington. Contains information about recent outbreaks of defoliators, bark beetles, root diseases, needle diseases, other miscellaneous diseases, and animal damage. Also includes a list of strategies to improve forest health.

443. Wheeler and Critchfield. 1985.
Notes: Other Works Cited

444. White. 1987.
Notes: Other Works Cited

445. Whittaker, R. H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs* 30:279-338.
Notes: Other Highly Relevant References

446. Wicker, E. F. and F. G. Hawksworth. 1991. *Upward advance, intensification, and spread of dwarf mistletoe in a thinned stand of western larch.* Fort Collins, Colorado: U. S. Forest Service, RM-RN-504.
Notes: Supporting Studies
Abstract: From 1978 to 1988 western larch (*Larix occidentalis*) in a thinned, 35-year-old stand in the Coram Experimental Forest, Flathead National Forest in northern Montana, grew an average of 37cm per year in height. This growth rate was over 4 times the rate of upward advance of dwarf mistletoe (*Arceuthobium laricis*) in these trees, which was only 9cm per year. Currently levels of dwarf mistletoe infection are too low (dwarf mistletoe ratings of only 1 or 2) to reduce tree height or diameter growth, although spread from inoculated trees to previously uninfected ones has occurred at all three spacing levels tested. These findings are discussed in relation to management of dwarf mistletoe in young monocultures of western larch.

447. Wickman. 1990.
Notes: Other Works Cited

448. Wickman. 1994.
Notes: Other Works Cited

449. Wickman, B. E. 1978. *Tree mortality and top-kill related to defoliation by the douglas fir tussock moth in the Blue Mountains outbreak.* Portland, Oregon: U. S. Forest Service, PNW-RP-27.
Notes: Other Highly Relevant References

450. Wickman, B. E., R. R. Mason, and T. W. Swetnam. 1994. Searching for long-term patterns of forest insect outbreaks. In *Individuals, Populations and Patterns in Ecology*, edited by Leather, S. R., K. F. A. Walters, N. J. Mills, and A. D. Watts (Andover, Hampshire: Intercept Ltd.).
Notes: Relevant Summary Documents
Abstract: Climate and the anthropogenic transformation of forest ecosystems are important extrinsic influences on insect and host communities. When most of the forested areas come under the management of the Federal Government, around the start of the 20th century, all fires were suppressed where possible. This has been followed by the intensive harvesting of ponderosa pine, western larch, and douglas fir during the last 80 years, which has drastically changed the species composition of forest landscapes. Historically, the large expanses of open ponderosa pine forests, either in pure stands or dominated by that species, were probably regulated by bark beetles in old-age forests or fire in immature forests, resulting in mosaics of age classes. According to historic descriptions and inventory records, the stands were mostly old-age, open-grown, and dominated by pine as a disclimax species. The remaining old-growth, mixed-conifer forests at higher elevation and mesic sites have left tree-ring histories that indicate about 7 to 10 outbreak episodes of either budworm or tussock moth over the last 2 centuries. These outbreaks were often synchronous over large areas in the Blue Mountains and, according to tree rings, were often characterized by heavy defoliation.

The current forests have been altered so that shade-tolerant fir grows on many pine sites formerly maintained in a seral state by fire. These 90 to 140-year-old fir stands now appear to be regulated by forest insects and diseases, especially budworm and tussock moth. Intensive population studies of tussock moth over the past 20 years indicate a pattern of periodic increases and declines caused by delayed density-dependent factors (Mason and Wickman, 1988). The outbreak patterns of budworm are not as clear. In some stands, both fir-invaded pine and historically mixed-conifer, the current outbreak has killed most of the host trees. This level of insect population and resulting host damage is highly unstable and probably new to the ecological history of the Blue Mountain landscapes.

The search for patterns in this study has been fruitful. Descriptions of forest composition were found in pioneer journals and inventory records. Prehistoric patterns in tree rings, indicating old outbreaks of defoliating insects were found. Patterns of short-term cyclical outbreaks of tussock moth were also found, but little evidence of regular outbreaks of budworm. The predictability of these patterns for use by pest managers, modelers and ecologists however, is clouded by major perturbations now occurring on a landscape scale, and by the changing composition of the forests as restoration projects are planned for vast areas of Blue Mountains.

451. Williams, B. E. and T. R. Lillybridge. 1983. *Forested plant associations of the Okanogan National Forest*. Portland, Oregon: U. S. Forest Service, R-6-Ecol-132-B.
Notes: Other Highly Relevant References

452. Williams, C. B. 1968. *Juvenile height growth of four upper slope conifers in the Washington and northern Oregon Cascade Range*. Portland, Oregon: U. S. Forest Service, PNW-RP-70.
Notes: Supporting Studies
Abstract: A study that compares the juvenile growth rates of noble fir, Pacific silver fir, douglas fir, and western white pine on six areas in the Washington and northern Oregon Cascade Range. The study found douglas fir to have the greatest juvenile growth rate and Pacific silver fir the lowest. However, it was noted that these juvenile growth rates might not be sustained throughout the species' life cycle.

453. Williams, G. W. 1994. *References on the American Indian use of fire in ecosystems*.: Unpublished manuscript.
Notes: Supporting Summary Documents
Abstract: A bibliography that lists published works on Native Americans and their use of fire. Includes a brief introduction and documents several reasons Native Americans used fire primarily to promote diversity of habitats.

454. Williamson, N. M. 1999. *Crown fuel characteristics, stand structure, and fire hazard in riparian forests of the Blue Mountains, Oregon*. Seattle, Washington: Doctoral Dissertation, University of Washington, College of Forest Resources.
Notes: Highly Relevant Studies
Abstract: This study investigated a number of factors (height to crown base, heat of ignition, foliar moisture content) that influence fire behavior and in particular influence crown fire behavior. This study also compared crown fire hazard between riparian and upslope stands in the Blue Mountains of northeast Oregon. The study area included forest stands in the Wallowa-Whitman National Forest in Northeastern Oregon, the Malheur National Forest in Eastern Oregon, and Payette National Forest in Central Idaho.

455. Williamson, N. M. and J. K. Agee. 2002. *Crown fire potential in riparian and upland stand of dry Pacific Northwest forest*. Seattle, Washington: Unpublished manuscript.
Notes: Highly Relevant Studies
Abstract: The potential for crown fire initiation (torching) and active crown fire spread was evaluated for riparian and upland forests of the Blue Mountains of northeastern Oregon. Torching potential was high in the *Pinus ponderosa*/*Pseudotsuga menziesii*, *Abies grandis*, and *Abies lasiocarpa* forest series, and in both riparian and upland forests under 90-percentile fire weather. The potential for active spread of crown fires was considerably less (in only 15 of 76 stands) with two-thirds of the susceptible stands in the Abies lasiocarpa series. Treatment priorities to reduce crown fire potential should focus on low elevation forests, and on the reduction of surface fuels and increase in height to live crown.

456. Wilson, J. S. and C. D. Oliver. 2000. Stability and density management in douglas fir plantations. *Canadian Journal of Forest Research* 30:910-920.
Notes: Relevant Studies
Abstract: Limited tree size variation in coastal Oregon, Washington, and British Columbia douglas fir (*Pseudotsuga meniesii* (Mirb.) Franco) plantations makes them susceptible to

developing high height to diameter ratio (H/D same units) in the dominant trees. The H/D of tree is a relative measure of stability under wind and snow loads. Experimental plot data from three large studies was used to evaluate the impact of initial planting densities and thinning on plantation H/D values. The H/D predictions from the experimental plot data match spacing trial results closely but are substantially different than distance-independent growth model predictions. The results suggest that plantation H/D values can be lowered and stability promoted though reduced planting densities or early thinning; however, later thinning may not be effective in promoting stability, since they do not appear to lower H/D values. Higher initial planting densities shorten the time period during which thinning can be expected to effectively lower future H/D values. Time-sensitive thinning requirements in dense plantations make their management inflexible. The flexibility with which a stand can be managed describes the rigidity of intervention requirements and (or) potential range of stand development pathways.

457. Wischnofske, Merle G. and David W. Anderson. 1983. *The natural role of fire in Wenatchee Valley*. Wenatchee, Washington: U. S. Forest Service, Wenatchee National Forest.
Notes: Highly Relevant Studies
Abstract: The purposes of this study were to determine the natural frequency of fire and to recommend uses for prescribed fire in the habitats observed. Tables, photographs and drawings clearly illustrate the relationship of fire to vegetation succession in these habitats, relationships that can be used in scheduling fire prescriptions.

458. Wissmar, R. C. and F. J. Swanson. 1990. Landscape disturbances and lotic ecotones. In *The Ecology and Management of Aquatic-Terrestrial Ecotones*, edited by Naiman, Robert J. and H. Decamps (Paris, France: UNESCO and the Pathenon Publishing Group).
Notes: Other Highly Relevant References

459. Wondzell, Steven M. 1999. Floods, channel change and the hyporheic zone. *Water Resources Research* 35, no. 2:555-567.
Notes: Other Works Cited

460. Wright, C. S. 1996. *Fire history of the Teanaway River Drainage, Washington*. Seattle, Washington: Doctoral Dissertation, University of Washington.
Notes: Highly Relevant Studies
Abstract: The fire history of the mixed-conifer forests of the lower Teanaway River drainage was reconstructed using dendrochronological techniques. Results confirmed that fires were a common disturbance in the watershed for at least the last 450 years, and that the fire regime was historically of low to moderate severity. Systematic fire-scar surveys conducted at 92 different points within the 30,000 ha study area revealed that fire frequency was quite variable, with Weibull median probability intervals ranging from 7.1 to 43.2 years (mean fire intervals ranged from 7.7 to 48.4 years). In addition, fire size varied widely; the majority of fires (51%) were less than 1000 ha, however, 11 fires (8%) greater than 5000 ha have occurred since 1720. Large fire years may be related to periods of below-average precipitation of varying length. Fire occurred in the late summer or fall, as indicated by the almost exclusive presence of fire scars in the latewood portion of the annual ring, or at the ring boundary. The study area experienced a dramatic decline in fire occurrence ca. 1900; natural fire rotations were 26, 29 and 369 years in the 1700s, 1800s and 1900s, respectively. This decline coincided with the beginning of a period of commercial timber harvesting and related management activates. Historically, fire was an important process that influenced the structure and composition of the mixed-conifer forests of the Teanaway River drainage. An understanding of the effects and influences of fires within this ecosystem type contributes valuable information that can be used for future forest planning and management activities.

461. Wright, H. E. 1981. The role of fire in land/water interactions. In *Proceedings of the Conference Fire Regimes and Ecosystem Properties*, edited by Mooney, H. A., T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners (Washington, D. C.: U. S. Forest Service, WO-GTR-26).

Notes: Relevant Studies

Abstract: Forest fires cause a temporary increase in runoff to streams and lakes, in part because of decreased evapotranspiration, according to studies in Washington (Entiat Fire), Minnesota (Little Sioux Fire), and Ontario (Experimental Lakes Area). Mass transport of nutrients and cations also increases, but no algal blooms were detected. Natural firebreaks provided by lakes and streams commonly limit extent of fires. The charcoal and pollen stratigraphy of annually limited lake sediments provides a record of past fire frequency. Lake-sediment studies also document forest history over thousands of years, showing the shift from fire-adapted forests to fire-resistant forests, or the reverse.

PART

3

APPENDICES

Appendix

A

Contacts

CTC Project Team Contacts

The *CTC* project team attempted to contact the following individuals over the course of this project. Attempts to contact these individuals were not always successful. In some cases, highly relevant and current information was obtained.

Andy Youngblood, U.S. Department of Agriculture Forest Service
Ann Camp, U.S. Department of Agriculture Forest Service
Blake Rowe, Longview Fibre
Brion Salter, U.S. Department of Agriculture Forest Service
Bruce A. Keleman, Okanogan & Wenatchee National Forest Service
Bruce Lippke, University of Washington
Bud Kovalchik, U.S. Department of Agriculture Forest Service (retired)
Candy Parr, Boise Cascade
Carl Davis, U.S. Department of Agriculture Forest Service
Carl Davis, Wenatchee National Forest
Chad Oliver, Yale University
Charlie Johnson, U.S. Department of Agriculture Forest Service
Craig Schmitt, U.S. Department of Agriculture Forest Service
Darlene Zabowskii, University of Washington
David Sandberg, U.S. Department of Agriculture Forest Service
Dennis Ferguson, U.S. Department of Agriculture Forest Service
Diana Olson, U.S. Department of Agriculture Forest Service
Domoni Glass, CMER SAGE
Don Scott, U.S. Department of Agriculture Forest Service
Duane Vaagen, Vaagen Brothers Lumber Incorporated
Ed DePuit, U.S. Department of Agriculture Forest Service
Fred Ebil, Society of American Foresters
G. Elton Thomas, Okanogan & Wenatchee National Forests
Gardner Johnston, University of Washington
Geoff McNaughton, Washington State Department of Natural Resources
Greg Filip, Oregon State University
Jan Henderson, U.S. Department of Agriculture Forest Service

Jeff Light, Plum Creek Timber
Jerrry Franklin, University of Washington
Jim Agee, University of Washington
John Bassman, Washington State University
John Beebe, Tufts University
John St. Pierre, Colville Tribe
John Townsley, U.S. Department of Agriculture Forest Service
Larry Irwin, National Council for Air and Stream Improvements, Incorporated
Maurice Williams, CMER SAGE
Mike Liquori, Campbell Group
Paul Flanagan, U.S. Department of Agriculture Forest Service
Paul Hessburg, U.S. Department of Agriculture Forest Service
Penny Morgan, University of Idaho
Richard Schellhaas, U.S. Department of Agriculture Forest Service
Rod Clausnitzer, Okanogan Valley Office, Okanogan-Wenatchee National Forests
Ron Neilson, Oregon State University
Ronald P. Neilson, U.S. Department of Agriculture Forest Service
Shari Miller, U.S. Department of Agriculture Forest Service
Sondra Collins, Upper Columbia United Tribes
Susan Bolton, University of Washington
Terry Hardy, Boise National Forest
Terry Lillybridge, U.S. Department of Agriculture Forest Service
Tom Swetnam, Arizona Tree Laboratory
Wallace Covington, Northern Arizona University
Wayne Padgett, U.S. Department of Agriculture Forest Service

Additional Contacts

In addition to the calls and emails made by the *CTC* project team, Domoni Glass, CMER SAGE Co-Chair was kind enough to distribute an email requesting assistance on the project to members of the CMER SAGE mail group. Members of the mail group are listed below with affiliation when known.

Ash Roorbach, Northwest Indian Fisheries Commission
Blake Rowe, Longview Fibre
Charles Chesney, Washington State Department of Natural Resources
Charlie McKinney, Washington State Department of Natural Resources
Cindy Confer, Washington State Department of Fish and Wildlife
Dave Schuett-Hames, Northwest Indian Fisheries Commission
Dennis Parent, Inland Empire Paper Company
Doug Martin, Martin Consulting
Dwight Opp, Stimson Lumber
Eric Krausz, Colville Tribe
gnenema@knrd.org (name unknown)
Heather Rowton, Washington Forest Protection Association
Jean Parodi, Washington State Department of Ecology
Jeff Grizzel, Washington State Department of Natural Resources
Jeff Light, Plum Creek Timber Company
Jim Matthews, Yakima Tribe
Jim Preist, Colville Tribes
Jim VanderPloeg, Boise Cascade
Joe Maroney, Kalispell Tribe
Joe Weeks, Washington State Department of Natural Resources
Joni Sasich, Independent Contractor
Ken Bevis, Washington State Department of Natural Resources
Lynda Hofmann, Washington State Department of Natural Resources
Maurice Williamson, Williamson Consulting and WFFA
Mike Liquori, The Campbell Group
Pete Peterson, Upper Columbia United Tribes
Ron Simon, Longview Fibre
Sondra Collins, Spokane Tribe
Steve McConnell, Northwest Indian Fisheries Commission
Steve Stinson, Washington State Department of Natural Resources
T. Anderson, Kalispell Tribe
Terry Jackson, Washington State Department of Fish and Wildlife
Todd Baldwin, Kalispell Tribe
Wade Pierce, Stimson Lumber

Section 3 – Scientific Review Committee Response

SAGE Discussion Paper:
SRC Review of: ***A Review and Synthesis of Available Information on Riparian Disturbance Regimes in Eastern Washington*** July 12, 2005

The Letter of Transmittal from Associate editor, Douglas G. Sprugel to Managing Editor, Dr. Daniel Vogt detailed a number of important deficiencies relating to unprofessional annotation and heavy reliance on unreferenced reports and studies. It pointed out data gaps and over looked science of a serious and poignant nature that was identified specifically and generally by the reviewers. Mr. Sprugel praised the evaluations as, "*Not only are their overall evaluations thoughtful and perceptive, but their comments on individual sections point out many specific issues that should be studied and reflected on by anyone intending to use the Review (Literature Review and Synthesis) to develop policy or regulations.*" While the criticisms contained in the letter are welcome and without contest for their validity, the sentence above might explain some reason for over reaction to the document's deficiencies. The Review itself was not intended to be used in the development of policy or regulation. In the Request for Proposals for this project it was explicitly stated on Page 4 under **Purposes**: *"**The contractor is specifically NOT asked to make a determination of effectiveness.** Rather, we ask the contractor to tell us what information is available that could be drawn on to evaluate rule effectiveness. The evaluation and determination will be completed through other processes."* There may have been misinterpretation of the document's purpose judging from reviewer comments. The Transmittal Letter and reviewer comments contained many favorable statements about the effort put into the document. They found no intentional bias but the view was expressed that the science used or omitted may have introduced some bias.

All three reviewers not only gave constructive additions and criticism to the original work but also went further to expand the document with more recent and overlooked literature. It was particularly useful that the reviewers gave attention to the Forest and Fish Report eastside approach of managing riparian disturbance with harvest prescriptions. The issue of designing prescriptions using Historical Reference Conditions was given far more attention in the literature search than had originally been anticipated. The reviewers offered general agreement on the concepts presented and further professional views on the issue. The fact that the authors and subsequent reviewers took on this added challenge enhances the value of the document.

All three of the reviewers brought new literature to bear on the various subjects. They viewed the Review and Synthesis questions (and responses) in a broader perspective than were negotiated under the original contract. In doing so, they provided a much-expanded list of references and ideas that will enhance the formulation of future CMER investigation.

New and meaningful information was provided, expanding the knowledge base contained in the document, including information on the following:

- Climate change and forest evolution over the long-term.

- Contradictory Science regarding “frequent fire” importance
- New (and neglected) science illuminating the potential significance of animals as a part of the riparian ecosystem.
- An expanded view of other anthropogenic activities that influence the riparian condition
- Neglect of nutrient cycling may be a serious flaw when considering future riparian recovery