SCIENCE SUMMARY:
THINNING TO ENHANCE BIODIVERSITY
IN YOUNG PLANTATIONS WEST OF THE CASCADES

Compiled by Doug Heiken, Oregon Natural Resources Council, dh@onrc.org

Version 1.1 January 2003

[This document is archived here: http://web.archive.org/web/20070206071600/http://www.efn.org/~onrcdoug/THINNING_SCIENCE.htm
Unfortunately, many of the links in this document are stale and lead to dead-ends, but there are enough science excerpts to remain useful.]

INTRODUCTION

The forests west of the Cascades in Oregon and Washington are some of the most productive in the world. This productivity is highly prized for both its economic and ecological values. Industrial clearcutting has dominated federal forest management over the past several decades and caused the severe decline of numerous species associated with old forests, including the northern spotted owl, marbled murrelet, and several species of salmon. There is some level of concern for persistence of several hundred additional species associated with late-successional and old-growth forests.

The 1994 Northwest Forest Plan established large habitat reserves in an effort to provide protected habitat for species associated with old forests, but the reserves were established long after industrial logging had already converted substantial portions of the heterogeneous old forest landscape into homogenous young plantations. The type of industrial clearcutting typically practiced west of the Cascade Crest creates highly simplified second-growth forests that may need to be restored in order to provide the habitat values expected of them under the Northwest Forest Plan.

The Northwest Forest Plan also left about 1 million acres of old forest unprotected and estimated an annual timber harvest of about 1 billion board feet. About 90 percent of this harvest volume was expected to come from these unprotected older forests. Although the Northwest Forest Plan resulted in dramatically reduced timber harvest from the peaks years in the late 1980s, the public controversy over logging old forests has not subsided.

Since the forest plan was approved almost ten years ago several new developments have occurred:

- The Forest Service and BLM initiated implementation of the new forest plan targeting older forests for logging.
- Congress passed the 1995 Rescissions Act "Salvage Rider" that: mandated implementation of several thousand acres of old forest timber sales, further fragmenting the reserves; and exempted all timber sales under the Northwest Forest Plan from administrative appeal and judicial review. This lead to great public outcry over old forest logging that has remained through the present.
- The agencies failed to faithfully implement several key provisions of the Northwest Forest Plan, namely the Aquatic Conservation Strategy and the Survey and Manage requirements. Conservation groups cited these violations to successfully sue and stop much of the federal forest logging program under the plan.
- Due to shifts in log supply and other market forces, most lumber and wood products companies in the region have retooled to process small logs available from non-federal lands, and now very few mills rely on federal log supplies to meet a substantial portion of their raw material needs.
- The NW economy has diversified since 1994 and the region no longer relies on timber (especially not federal timber) as a major driver of economic activity.
- The Forest Service and BLM completed one amendment to the Northwest Forest Plan and they have initiated two more amendments with the intent to reduce protection for species and accelerate old forest logging.
- New science has emerged indicating that passive management alone may not be sufficient to allow the young forests in the reserves to develop old forest characteristics required in order to meet the habitat goals of the Northwest Forest Plan. Some young forest types may need to be thinned to enhance biodiversity.

- Senator Ron Wyden and others in Congress have expressly stated their desire to protect the remaining old growth forests.

Many people see a unique opportunity in the current socio/political/economic/scientific landscape. If the efforts of the agencies are shifted from logging old forests to restoration, including restorative thinning of young plantations, then the old forests can be protected. This shift could allow the agencies to simultaneously meet the ecological, social, and economic objectives of the plan and avoid the controversy associated with logging the older forests.

Framing the issue

This document summarizes the available science regarding thinning dense young plantations that resulted from clearcutting primarily west of the Cascade Crest. The objective is to review the available information on whether restorative thinning is needed and to describe the opportunities and risks associated with passive restoration (i.e. "hands off" and no thinning) or active restoration (i.e. active management using variable thinning and other techniques).

The questions that need to be answered are whether restoration of uniform dense plantations should be passive, or active, or both. The Forest Service and BLM are already thinning young stands and they are still actively suppressing fire, so a purely passive approach, for all practical purposes, appears to be moot. Conversely, it is equally clear that some stands will not be thinned because they are inaccessible, or cannot be thinned due to various resource conflicts, or do not "need" to be thinned given their current state of development and likely favorable trajectory. Therefore, the real question appears to be—

> what portion of the landscape should be actively restored using variable density thinning and other tools, and conversely, what portion of the landscape should be passively restored solely through the passage of time and unmanaged "natural" disturbances?

Some old ideas can be applied with new objectives.

Much of what we know about thinning is based on timber driven studies that may now be applied to restoration efforts, for example thinning young trees can help grow big healthy trees quickly. It used to be done for timber purposes, but now can be done to accomplish habitat objectives.

Some of the traditional thinning regimes that have been studied over the years have focused on fiber production and emphasized full site occupancy by the favored timber species by emphasizing relatively "light" thinning, uniform spacing, and removal of competing species. Such thinning prescriptions might tell us something about the effects of thinning on tree growth rates but may not accurately describe the biodiversity effects of more diverse and creative prescriptions that are only recently being studied.

Analysis from the perspective of fiber production and microeconomic efficiency are not typically part of the calculus used by most conservation groups to evaluate restoration projects. Some of these studies are included in this review because they are part of the body of knowledge potentially relevant to restoration thinning.

New science

Scientists have only recently begun to explore questions about thinning to meet restoration objectives. Some of what we are learning that may be applicable to biodiversity thinning includes:

- There are multiple developmental pathways from young stands to old-growth. Franklin, Poage, Spies, Tappeiner, Winter.
- Much of today's old-growth, when young, was far less dense than most of today's young plantations, i.e. current plantations are highly dissimilar to the early development of today's old-growth. Poage, Tappeiner
- The growing evidence that variable-density thinning leads to "niche diversification" that creates and expands opportunities for diverse plant and wildlife communities to live within young stands. Carey, Hagar, Muir, Wilson.

Multiple Pathways

One of the themes that emerges from the literature is that old-growth likely develops from multiple initial conditions along multiple pathways to multiple old-growth endpoints. It is also clear that today's dense young plantations exhibit unprecedented uniformity of initial conditions which could end up limiting both the diversity of pathways and endpoints. The current uniformity of initial conditions that resulted from high density planting of Douglas-fir following clearcutting and the consequent lack of diversity of pathways could lead to an unknown endpoint or at least an "unnatural" uniformity of endpoints that does not represent the diversity normally associated with old growth forests.

While recognizing that fire and other disturbances will continue to play a role in diversifying and resetting stands, there seems to be a consensus emerging that some form of variable density thinning can help diversify some young forest types in order to reintroduce more diversity of pathways and increase options for future endpoints within and between stands.

No cookie cutters

Another important area of agreement seems to be that we do not fully understand how to create old-growth, nor is there one right way to restoration dense young plantations. There are a variety of tools that should be applied in a variety of ways at a variety of scales, and of coarse, some areas, even dense young plantations, should be left unthinned and undisturbed.

Today's young forests are different

Several differences need to be kept in mind:
- Differences between the initial conditions represented in native forests following fire or other historical disturbances versus the initial conditions that result from industrial clearcutting.
- Differences between the historical disturbance regime and the current disturbance regime.
- Differences between the relative effects of clearcutting versus thinning.

Initial conditions

Naturally regenerated forests carry over abundant legacies from the previous stand and they exhibit patchy and diverse patterns within and between stands that result from variable site influences such as fire intensity, topography, aspect, and proximity to seed sources.

Most plantations are the result of clearcutting or post-fire salvage logging which are atypical of natural disturbances because virtually all the aboveground biomass is removed; the soil is churned and compacted; early seral colonizing plants are suppressed (often with chemicals); then monotypic seedlings are planted in a very dense and uniform pattern; later, competing vegetation may again be controlled; and precommercial and commercial thinning may reimpose spatial uniformity to the young stand and subtract diversity and seed sources.

The point is that our young plantations are starting from initial conditions that do not closely resemble the initial conditions that predate industrial forestry. We have yet to establish just how sensitive to initial conditions our forests are but if they are sensitive to initial conditions then passive restoration applied widely is probably a quite risky strategy.

Past and future disturbances

Several "natural" disturbances will continue to play a role in the development of young plantations, including: fire, wind, snow, insects, disease, floods, landslides, suppression mortality, etc.. However, passive ("hands off") restoration is not entirely "natural." The agencies continue to actively suppress fire and will likely continue to do so. Invasive plants and animals and non-native plant diseases will affect the development of plantations in ways that are not entirely natural.

One of the big differences between historic fire disturbance and recent past harvest disturbance regimes are related to scale. The dominant historic disturbance throughout most of the Westside was fire, and the most influential historical fire disturbance events were relatively large and infrequent compared to timber harvest which tends to be smaller and more frequent. Restoration will need to consider landscapes at larger temporal and spatial scales. Several thought provoking papers address this issue and can inform our thinking about how to implement restoration. Reeves, Cissel, Bormann, Parminter, and Central Cascades AMA.

Consequences of thinning are positive, negative, neutral, and unknown

The available information indicates that thinning causes positive, negative, neutral, and unknown consequences. As with all restoration projects, it will be important to consider the opportunity costs of both action and inaction (i.e., thinning and not thinning). Active management will realize some ecological benefits while causing some unavoidable, hopefully short-term, adverse consequences. Passive management will certainly avoid some negative consequences that may be caused by thinning, but it will also cause some of its own negative consequences (e.g., extended periods of competitive exclusion, unstable height/diameter ratios) and forgo other benefits.

There is a growing body of evidence that thinning in young plantations can enhance development of many features associated with late-successional forests such as large trees, well developed tree crowns and canopies, patchy mosaics of a variety of habitat types, tree size diversity, tree species diversity, understory vegetation development, wildlife habitat development, large woody debris, tree stability, etc.

There are also numerous potential adverse impacts associated with thinning young forests on the Westside of the Cascades, including adverse effects on soil, water quality, snags and down wood, aesthetics, invasive species, some wildlife species, and increase risk of damage from wind. Most of the adverse consequences of thinning will be less intense than the effects of traditional clearcutting and they will usually be temporary.

The challenge

Given that millions of acres of our federal forest lands are covered with uniform dense plantations with relatively low habitat value, the challenge we face is how to prioritize restoration actions and continue to learn so that we can (a) increase the benefits of biodiversity thinning, (b) find ways to avoid, minimize, and mitigate the adverse impacts of thinning, and (c) acknowledge and manage the risks and inherent uncertainty involved in the choices about how to manage young stands.

Recommended reading

For a brief summary of the relevant science on thinning young stands west of the Cascades, I cannot do better than Mathew Hunter did in his "Young Stand Communiqué #3." He does a good job reviewing the influential work of Tappeiner, Poage, and Winter, and Garman. He also summarizes the third-year results of the Willamette Young Stand Study-- a controlled experiment investigating the effects of thinning on vegetation, small mammals, amphibians, detritus, fungi, and birds. Finally, he discusses the implications of current findings and highlights some of the significant issues in the path ahead.

Tips on using this document

The hyperlinks in list of publications under "REFERENCES" below will take you to relevant excerpts that follow. I have included internet links to the original source wherever possible.

Information from the literature comes is several forms, so it's useful to be aware of scientific information that is based variously on observational/descriptive research, retrospective studies, manipulative studies, reviews/syntheses of the literature, and modeling. I have also included useful speculations and recommendations about thinning from a variety of respected sources, and I have excerpted guidance on restoration thinning from policy documents, such as the Northwest Forest Plan and the Regional Ecosystem Office. Knowles, USDA/USDI.

Pay attention to the units of measure. Some of the studies described below use hectares instead of acres. Trees per hectare can be converted to trees per acre by multiplying by .405.

Don't forget to use your browser's "back" button, and if you find yourself lost deep in this document, you can always get back to the top of the document by pressing <control> and <home> at the same time.

Don't confuse westside plantation thinning with eastside fuel reduction thinning.

I have attempted to focus this review on the available literature most directly relevant to young plantation forests west of the Cascades in Oregon and Washington. I have not addressed fuel reduction thinning of eastside forests. There are some useful reports on the topic however, including:

- Nelson, Cara, ed., **Key Elements for Ecosystem Planning, Management Principles, Recommendations, and Guidelines for Federal Lands East of the Cascade Crest in Oregon and Washington**. http://www.subtleenergies.com/ormus/bmnfa/keep.htm
- Brown, Rick. 2000. **Thinning Fire and Forest Restoration,** Defenders of Wildlife, December 2000. http://cbfinfo.com/cbf/wapro/Fire/Brown.pdf http://www.biodiversitypartners.org/Brown/brown01.html
- Peters, Robert L., Evan Frost, and Felice Pace. **Managing for Forest Ecosystem Health: A Reassessment of the "Forest Health Crisis"** Defenders of Wildlife. http://www.defenders.org/bio-fh00.html
- Kitzhaber, John. 2001. **AN 11-POINT STRATEGY FOR RESTORING EASTERN OREGON FORESTS, WATERSHEDS AND COMMUNITIES,** April 13, 2001. http://www.governor.state.or.us/governor/download/final11pts.pdf
- DellaSala, D.A., and E. Frost. 2001. **An ecologically based strategy for fire and fuels management in National Forest roadless areas**. Fire Management Today 61(2):12-23. http://www.fs.fed.us/fire/planning/fmt/fmt-pdfs/fmn61-2.pdf

---

REFERENCES— with hyperlinks to relevant excerpts.

Andrews, S., Perkins, J., Thrailkill, J.A., Poage, N.J., and J.C. Tappeiner II. 2001. Silvicultural approaches to develop northern spotted owl nesting habitat, east central Coast Range, Oregon, *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.

Bormann, Bernard T. and Marc G. Kramer. 1998. Can Ecosystem-Process Studies Contribute to New Management Strategies in Coastal Pacific Northwest and Alaska? Pages 77-83 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).

Bormann, B., P. Cunningham, P. Thomas, M. Brookes, B. Buckley, C. Cloyd, M. Jensen, J. Linares, D. Mummey, E. Obermeyer, J. Sleeper, and C. Snyder. 2001. Plan For the Five Rivers Landscape Management Study. Appendix A, *in* USDA Forest Service. 2001. Five Rivers Landscape Management Project, Final Environmental Impact Statement. Waldport Ranger District, Siuslaw National Forest. March 2001.

Carey, Andrew, B. 2002. Promoting Habitat Complexity in Second Growth Forests, Pacific Northwest Research Station, USDA Forest Service, Forestry Sciences Laboratory, Portland, OR.

Carey, Andrew B., Janet Kershner, Brian Biswell, and Laura Dominguez de Toledo. 1999. Ecological Scale and Forest Development: Squirrels, Dietary Fungi, and Vascular Plants in Managed and Unmanaged Forests, Supplement to the Journal of Wildlife Management, Vol. 63 No. 1. Wildlife Monographs, No 142, January 1999

Carey, A.B.; Wilson, S.M. 2001. Induced spatial heterogeneity in forest canopies: responses of small mammals. Journal of Wildlife Management. 65(4): 1014- 1027.

Carey, Andrew B. 2001. Experimental manipulation of spatial heterogeneity in Douglas-fir forests: effects on squirrels, Forest Ecology and Management. 152:13-30.

Carey, Andrew B. and Constance A. Harrington 2001. Small mammals in young forests: implications for management for sustainability, Forest Ecology and Management. Volume 154, Issues 1-2, 15 November 2001, Pages 289-309

Carey, Andrew B., Todd M. Wilson. 2001. ECOLOGICAL FOUNDATIONS OF BIODIVERSITY 1999–2000 Biannual Report.

Carey, Andrew. 1998. Ecological Foundations of Biodiversity: Lessons Learned from the Natural and Managed Forests of the Pacific Northwest, Northwest Science, Vol. 72, Special Issue No.2, 1998.

CAREY, A.B.; LIPPKE, B.R.; SESSIONS, J. 1999. Intentional systems management: managing forests for biodiversity. Journal of Sustainable Forestry. 9(3/4): 83-125, 1999.

Carey, Andrew. THINKING AND THINNING ECOLOGICALLY, slideshow

Chan, Sam, Maas-Hebner, Kathleen G. and William H. Emmingham. 1999. COMMERCIAL THINNING AND UNDERPLANTING TO INCREASE STRUCTURAL AND SPECIES DIVERSITY IN YOUNG MANAGED DOUGLAS-FIR STANDS. *In* Procedings of the Society of American Foresters 1999 Annual Convention, Portland, Oregon, September 11-15, 1999.

Cissel, John. 2001. Application of Young Stand Research. Central Cascades AMA. April 13, 2001 [Distributed to Willamette Province Advisory Committee, April 2001.]

Cole, Elizabeth. 1996. Managing for Mature Habitat in Production Forests of Western Oregon and Washington, Weed Technology. Volume 10(2):422-428. April-June 1996.

Curtis, R.O., D.S. DeBell, C.A. Harrington, D.P. Lavender, J.C. Tappeiner, and J.D. Walstad. 1998. Silviculture for multiple objectives in the Douglas-fir region. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Gen. Tech. Rep. PNW-GTR-435. 123 p.

Dooley, Jim and Justin Maschhoff, Forest Concepts, LLC. 2002. Technical Products from Small Diameter Timber for Habitat Enhancement and Watershed Restoration, Prepared for presentation at: Small Diameter Timber: Resource Management, Manufacturing and Markets. February 25-27, 2002. Spokane, WA; Jim

Duncan, Sally. 2002. VOLUME, VALUE, AND THINNING: LOGS FOR THE FUTURE, Science Findings, USDA PNW Research Station. November 2002.

Duncan, Sally. 1998. IT'S NOT EASY BEING GREEN: THE TRICKY WORLD OF SMALL-DIAMETER TIMBER. ISSUE FOUR, PNW Research, Science Findings, MAY 1998.

Duncan, Sally. DEVELOPING NEW SILVICULTURAL REGIMES: THE EYES HAVE IT; Science Findings, USDA Forest Service, PNW Research. January 2000.

Duncan, Sally. 2001. INVASION OF THE EXOTICS: THE SIEGE OF WESTERN WASHINGTON. Science Findings, October 2001.

Erickson, Janet L., and Stephen D. West. 2003. Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington, Biological Conservation, Volume 109, Issue 1, January 2003, Pages 95-102

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. PNW-GTR-118. USDA Forest Service. PNW Research Station. February 1981.

Franklin, Jerry F. 1998. The Natural, the Clearcut, and the Future. Pages 134-138 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).

Franklin, Jerry F. 2001. Keynote Comments: Managing Young Stands to Meet LSR and Riparian Objectives; Workshop held at Portland, OR on August 29, 2001.

Franklin, Jerry F., Thomas A. Spies, Robert Van Pelt, Andrew B. Carey, Dale A. Thornburgh, Dean Rae Berg, David B. Lindenmayer, Mark E. Harmon, William S. Keeton, David C. Shaw, Ken Bible, Jiquan 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 (2002) 399–423.

Garman, Steven L. 2001. Accelerating Development of Late-Successional Conditions in Young Managed Stands: A Simulation Study, *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.

Garman, Steven L., 2000. Biodiversity Response to Thinning Young Managed Stands. H.J. Andrews Third Annual Symposium, "Future ecosystem science at the Andrews," Oregon State University, Corvallis, Oregon. March 2, 2000.

Garman, Steven L. 2001. Response of Ground-dwelling Vertebrates to Thinning Young Stands: The Young Stand Thinning and Diversity Study. Submitted To James H. Mayo, John H. Cissel, Cascade Center for Ecosystem Management. December 2001.

Hagar, Joan, Department of Forest Science, OSU; Shay Howlin - West Inc. 2001. Songbird Community Response to Thinning of Young Douglas-fir Stands in the Oregon Cascades - Third Year Post-treatment Results for the Willamette N.F., Young Stand Thinning and Diversity Study, January 4, 2001.

Harrington, Constance A., Dean S. DeBell, and Leslie C. Brodie. 2001. Alternative Silvicultural Treatments for Young Plantations in the Pacific Northwest. Poster.

Harrington, Connie. Potential Pitfalls in Applying Variable Density Management; [preview of future publication]

Harrington, Connie. Tips to Consider in Applying Variable Density Management; [preview of future publication]

Hartley, Mitschka J., Rationale and methods for conserving biodiversity in plantation forests, Forest Ecology and Management , Volume 155, Issues 1-3, 1 January 2002, Pages 81-95

HAVERI, B.A., and A.B. CAREY. 2000. Forest management strategy, spatial heterogeneity, and winter birds in Washington. Wildlife Society Bulletin. 28(3): 643-652.

Hayes, John P., Samuel S. Chan, William H. Emmingham, John C. Tappeiner, Loren D. Kellogg, and John D. Bailey. 1997. Wildlife Response to Thinning Young Forests on the Pacific Northwest, Journal of Forestry, Vol 95(8): 28-33, August 1997.

Hayes, John P. 2001. BIRD RESPONSE TO THINNING *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001.

Hayes, John P., and David Larson. 2001. SMALL MAMMAL RESPONSE TO THINNING *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001.

Helgerson, Ole T. and Jim Bottorff. Thinning Young Douglas-fir West of the Cascades for Timber and Wildlife. EB1927.

Hunter, Matthew G. 1993. Communique #1: YOUNG MANAGED STANDS. Cascade Center for Ecosystem Management. May 1993.

Hunter, Matthew G. 2001. Communiqué #3: Management in young forests. Cascade Center for Ecosystem Management. 28pp.

Kellogg, Loren D., Miller, M. Jr., and Eldon D. Olsen. 1999. Skyline Thinning Production and Costs: Experience from the Willamette Young Stand Study. Research Contribution 21, Oregon State University, Forest Research Laboratory. August 1999.

Kellogg, Loren D., Ginger V. Milota, Ben Stringham. LOGGING PLANNING AND LAYOUT COSTS FOR THINNING: EXPERIENCE FROM THE WILLAMETTE YOUNG STAND PROJECT. Research Contribution 20, Oregon State University, Forest Research Laboratory.

Knowles, Donald R. 1996. Memo to Regional Interagency Executive Committee (RIEC), RE: Criteria to Exempt Specific Silvicultural Activities in Late-Successional Reserves and Managed Late-Successional Areas from Regional Ecosystem Office Review. Regional Ecosystem Office. July 9, 1996

Knowles, Donald R. 1996. Memo to Regional Interagency Executive Committee (RIEC), RE: Amendment to "Criteria to Exempt Specific Silvicultural Activities in Late-Successional Reserves and Managed Late-Successional Areas from Regional Ecosystem Office Review" of July 9, 1996. Regional Ecosystem Office. September 30, 1996.

Larson, D.J., 2001. The Effects of Thinning on Forest-Floor Small Mammals in the Coast Range of Oregon, AN ABSTRACT OF THE THESIS OF David J. Larson for the degree of Master of Science in Forest Science presented on October 31, 2001.

Lindenmayer, David B., and Jerry F. Franklin. 2002. Conserving Forest Biodiversity: A comprehensive multiscaled approach. Island Press, Washington, D.C.

Long, Colin J., Cathy Whitlock, Patrick J. Bartlein, and Sarah H. Millspaugh. 1998. A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study. Can. J. For. Res. 28(5): 774-787 (1998) .

Maas-Hebner, KG, and BA Schrader. 2001. The Effects of Silvicultural Activities on Wildlife and Fish Populations in Oregon and the Pacific Northwest: An Annotated Bibliography from 1960 to 1999. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 32.

McComb, William C., Spies T.A., and W.H. Emmingham. 1993. Douglas-fir forests, Managing for Timber and Mature-Forest Habitat, Journal of Forestry December 1993.

McCune, Bruce, Epiphytes and Forest Management

Muir, P.S., R.L. Mattingly, J.C. Tappeiner II, J.D. Bailey, W.E. Elliott, J.C. Hagar, J.C. Miller, E.B. Peterson, and E.E. Starkey. 2002. Managing for biodiversity in young Douglas-fir forests of western Oregon. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR–2002-0006. 76 pp.

Newton, Michael and Elizabeth C. Cole. 1987. A Sustained-Yield Scheme for Old-Growth Douglas-fir, West. J. Appl. For. 2:22-25, Jan. 1987.

Osborne, Derek R. 2001. A Restoration Strategy for Secondary Forests of Clayoquot Sound, British Columbia, A Joint Project of: Faculty of Forestry, University of Toronto, and Long Beach Model Forest Ucluelet, British Columbia. August 27, 2001

Parminter, John, and Patrick Daigle. 1997. Extension Note 10: Landscape Ecology and Natural Disturbances: Relationships to Biodiversity. B.C. Ministry of Forests Research Program. July 1997. (Text by Susan Bannerman).

Peters, Robert S., Donald M. Waller, Barry Noon, Steward T. A. Pickett, Dennis Murphy, Joel Cracraft, Ross Kiester, Walter Kuhlmann, Oliver Houck, and William J. Snape II; Standard Scientific Procedures for Implementing Ecosystem Management on Public Lands; This paper is the report of a workshop convened in July, 1994, by Defenders of Wildlife at the University of Wisconsin, Madison.

Pilz, David. CHANTERELLE MUSHROOM PRODUCTIVITY, RESPONSES TO YOUNG STAND THINNING

Pilz, David., R. Molina, E. Danell, C. Rose, and R.Waring. 2001. SilviShrooms: Predicting edible mushroom productivity using forest carbon allocation modeling and immunoassays of ectomycorrhizae. Presented at the Second International Workshop on Edible Ectomycorrhizal Mushrooms. Christchurch, New Zealand. 3-6 July, 2001.

Poage, N.J. and J.C. Tappeiner. 2002. Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon. Canadian Journal of Forest Research 32 (7): 1232-1243.

Poage, N.J. 2000. Structure and Development of Old-Growth Douglas-fir in Central Western Oregon, ABSTRACT OF THE DISSERTATION OF Nathan Jeremy Poage for the degree of Doctor of Philosophy in Forest Science presented on November 21, 2000.

Poulin, V.A., Bart Simmons, and Cathy Harris. 2000. Riparian Silviculture: An Annotated Bibliography for Practitioners of Riparian Restoration. B.C. Ministry of Forests. March 2000.

Powell, David C.; Rockwell,Victoria A.;Townsley, John J.; Booser, Joanna; Bulkin, Stephen P.; Martin,Thomas H.; Obedzinski, Bob; Zensen, Fred. 2001. Forest density management: recent history and trends for the Pacific Northwest Region. Technical Publication R6-NR-TM-TP-05-01. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 22 p.

Rapp, Valerie and Carolyn Wilson. 2001 Science Accomplishments of the Pacific Northwest Research Station, USDA PNW Research Station.

Rapp, Valerie. 2002. Science Update— Restoring Complexity: Second growth Forests and Biodiversity, PNW Research, May 2002.

Rapp, Valerie. 2002. Science Update: Dynamic Landscape Management. USDA PNW Research Station, Portland. Oregon.

Reeves, G.H., L.E. Benda, K.M. Burnett, P.A. Bisson, and J.R. Sedell. 1995. A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionary significant units of anadromous salmonids in the Pacific Northwest. Pages 334-349. in: J.L. Nielsen, editor. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium 17, Bethesda, MD.

Reutebuch, Stephen E., Constance A. Harrington, Dean S. DeBell, David D. Marshall, and Robert O. Curtis. 2001. Silvicultural Options for Multipurpose Management of West-Side Pacific Northwest Forests, *in* Beyond 2001: A Silvicultural Odyssey to Sustaining Terrestrial and Aquatic Ecosystems Proceedings of the 2001 National Silviculture Workshop, May 6-10, Hood River, Oregon; PNW-GTR-546

Roni, Philip, Timothy J. Beechie, Robert E. Bilby, Frank E. Leonetti,2 Michael M. Pollock, And George R. Pess. 2002. A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds. *North American Journal of Fisheries Management* 22:1–20, 2002 American Fisheries Society 2002

Scott, W., Meade, R., Leon, R., Hyink, D., and R. Miller, Planting density and tree-size relations in coast Douglas-fir, Can. J. For. Res., 28: 74-78 (1998).

Smith, Jeff P., Michael W. Collopy, R. Bruce Bury, Michael A. Castellano, Stephen P. Cross, David S. Dobkin, Joan Hagar, John D. Lattin, Judith Li, William C. McComb, Karl J. Martin, Jeffrey C. Miller, Randy Molina, J. Mark Perkins, David A. Pyke, Roger Rosentreter, Jane E. Smith, Edward G. Starkey, Steven D. Tesch. 1998. Pacific Northwest *in* Mac, Michael J, Project Director and Paul A. Opler, Science Editor. 1998. Status and Trends of the Nation's Biological Resources, Volume 2, USDI Geological Survey.

Spies, Thomas A. 1998. Forest Structure: A Key to the Ecosystem. Pages 34-39 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).

Spies, Thomas A., John Cissel, Jerry, F. Franklin, Frederick Swanson, Nathan Poage, Robert Pabst, John Tappeiner, Linda Winter, 2002. Summary of Workshop on Development of Old-Growth Douglas-fir Forests along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001. H. J. Andrews Experimental Forest, Blue River, Oregon. 11/15/2002

Starkey, Edward E. and Joan Hagar. 2001.TROPHIC RELATIONS AMONG BIRDS, ARTHROPODS, AND SHRUBS *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001.

Suzuki, Nobuya. 2002. Effects of Thinning on Small Mammals, Symposium: Silviculture Options for Sustainable Management of Pacific Northwest Forest, Oregon State University, March 4-6, 2002.

Tappeiner, John C., 2001. Effects of Density Management of Young Stands on Future Old Forest Characteristics, *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.

Tappeiner, John; Lewis, Rob; Tesch, Steve; Thornburgh, Dale; Weatherspoon, Phil; Birch, Kevin; and others. 1992. Managing Stands for Northern Spotted Owl Habitat. Appendix G In: Recovery plan for the northern spotted owl--draft. Washington, DC: U.S. Department of the Interior: 481-525.

Tappeiner, J.C., D.W. Huffman, D. Marshall, T.A. Spies, and J.D. Bailey. 1997. Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. Can. J. For. Res. 27: 638-648.

Tappeiner, John C., Nathan Poage, and Tom Sensenig. 2001. OLD-GROWTH STAND DEVELOPMENT *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001.

Thysell, D.R., and Carey, A.B. 2000. Effects of forest management on understory and overstory vegetation: a retrospective study. General Technical Report, PNW-GTR-488. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 41 pp.

Thysell, David R., and Andrew B. Carey. 2001. Manipulation of density of *Pseudotsuga menziesii* canopies: preliminary effects on understory vegetation. Can. J. For. Res. 31(9): 1513-1525 (2001)

USDA, USDI. 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl, and Attachment A: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, April 13, 1994.

US Forest Service. 2001. Density Management in Late Successional Reserves, Northwest Forest Plan Area. August 24, 2001

US Forest Service. 2001. Northwest Forest Plan Research Synthesis; Haynes, Richard W. and Gloria E. Perez, Technical Editors; General Technical Report PNW-GTR-498 January 2001.

US Forest Service. 2001. Viable Options for Second-Growth Forest Management in Late Successional Reserves

Unknown. 2002. A Brief Literature Review of the Status of Early Stand Density Management in other Forest Industrialized Countries, Forest Service British Columbia, Forest Practices Branch, Silviculture Practices Section, June 2002.

Unknown. 2002. Landscape Changes Through Young stand Management— A Fall Creek LSR Case Study, Central Cascades Adaptive Management Area, 9/26/2002 DRAFT

Unknown. 2000. Young Stand Study: Year 3 Post-Treatment Initial Results, 4/27/00 - DoubleTree Hotel, Springfield, OR

Wilson, J.S., and C.D. Oliver. 2000. Stability and Density Management in Douglas-fir Plantations, Can. J. For. Res. 30(6): 910-920 (2000)

Wilson, Jeremy. 1998. Wind Stability of Douglas-fir Plantations, Ph.D. Thesis, University of Washington, CFR, 1998

Wilson, Todd M., Andrew B. Carey, Juliann E. Aukema. Thinning to Induce Spatial Heterogeneity: One Step Towards Providing Multiple Values in Managed Stands, slideshow.

Winter, Linda E., Linda B. Brubaker, Jerry F. Franklin, Eric A. Miller, and Donald Q. DeWitt. 2002. Initiation of an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records. Can. J. For. Res. 32(6): 1039-1056 (2002)

Winter, Linda E., Linda B. Brubaker, Jerry F. Franklin, Eric A. Miller, and Donald Q. DeWitt. 2002. Canopy disturbances over the five-century lifetime of an old-growth Douglas-fir stand in the Pacific Northwest. Can. J. For. Res. 32(6): 1057-1070 (2002)

WINTER, L.E., L.B. BRUBAKER, J.F. FRANKLIN, E.A. MILLER AND D.Q. DEWITT. 2000. Five centuries of structural development in an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records.

Symposium: Age-Related Change in Structure and Function of Forests in the Pacific Northwest, Oct. 19, 2000, Oregon State University.

EXCERPTS

Andrews, S., Perkins, J., Thrailkill, J.A., Poage, N.J., and J.C. Tappeiner II. 2001. **Silvicultural approaches to develop northern spotted owl nesting habitat, east central Coast Range, Oregon,** *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.

> We used an individual tree, distance-independent growth model, ORGANON - Southwest Oregon Version, to explore a range of possible stand management scenarios for pole-young stands (age 50 years) that promote the development of within-stand features suitable as northern spotted owl nesting habitat. . . . [S]ilvicultural simulations that modeled heavy thinnings (e.g. to a basal area of 25 ft2/acre at age 50 years), followed by tree planting, and intermediate thinning, developed structures similar to known spotted owl nest sites in the east-central Coast Ranges of Oregon. Our modeling indicates that without silvicultural intervention or natural disturbances, considerable additional time would be needed for the pole-young stands investigated to develop features associated with spotted owl nest sites.

Carey, Andrew B., Janet Kershner, Brian Biswell, and Laura Dominguez de Toledo. 1999. **Ecological Scale and Forest Development: Squirrels, Dietary Fungi, and Vascular Plants in Managed and Unmanaged Forests.** Wildlife Monographs, No 142, Supplement to the Journal of Wildlife Management, Vol. 63 No. 1, January 1999.

> Abstract: Understanding ecological processes and their spatial scales is key to managing ecosystems for biodiversity, especially for species associated with late-seral forest. We focused on 2 species of squirrel (*Sciuridae*: northern flying squirrel, *Glaucomys sabrinus*, and Townsend's chipmunk, *Tamias townsendii*) in a cross-sectional survey of managed and natural stands in southwestern Oregon during 1985-89. We measured vegetation and abundances of squirrels at >2,000 points in 19 stands in 3 seral stages. We described the diets of the squirrels in the stands. We analyzed data at point, stand, and stage scales to identify key processes contributing to biodiversity and scales at which emergent properties (synergistic effects) appeared. Four factors (crown-class differentiation, decadence, canopy stratification, and understory development) accounted for 63% of variance in vegetation structure. Decadence contributed to variation mostly in late-seral forest. Within stands, most habitat variables were poorly correlated. Across stands many variables were highly correlated, suggesting forests developed emergent properties above the point level but at or below stand level (16 ha). Plant species composition was summarized by 21 vegetation site types. Stands had 7-19 site types arrayed in fine scale (point and groups of points 40 m apart). Site types were used to measure habitat breadth (within-stand heterogeneity resulting from disturbance and forest development). Vegetation structure varied on a 0.5-ha scale. Stand-level characteristics were more influential than nominal seral stage for a variety of organisms. Late-seral forests were more moist and complex with greater habitat breadth than 40-70-year-old managed stands. Structural factors, moisture-temperature gradient values (MGV), and habitat breadth were used to describe the habitat space potentially available to squirrels. Correlations between squirrels and habitat variables within stands were low. Linear regressions explained <20% of the within-stand variance in squirrel captures, but logistic regressions correctly classified 74 and 88% of the points according to usage (used, not used) by flying squirrels and chipmunks, respectively. Compared to available habitat space, the realized habitat of flying squirrels had high decadence and complex canopies. The realized habitat of chipmunks had complex canopies and large, dominant trees. Overall, chipmunks were less selective than flying squirrels and used 83% of the habitat space compared to 59% by flying squirrels. Among stands, variance in carrying capacity of flying squirrels was best explained (70%) by decadence, habitat breadth, and MGV. For chipmunks, decadence and canopy stratification provided the best model (72% of variance explained). Both squirrels had mycologically diverse diets; richness was correlated with decadence and canopy stratification. Major dietary fungi were associated with woody debris. Flying squirrels had higher carrying capacities and overlap among foraging patches of individuals, but smaller foraging patches, in late-seral forest than in managed stands. Squirrels were more abundant in late-seral forest than in managed forests. Abundance in some stands deviated markedly from the stage mean - stand character was more influential than nominal seral stage. The 4 structural factors each represented an important ecological process; decadence and canopy stratification apparently had profound influences on other life forms. Carefully timed variable-density thinnings could accelerate crown-class differentiation, canopy stratification, and understory development and increase habitat breadth. Management of decadence is more problematic and may require various interventions, including inducing decay in live trees, conserving biological legacies form previous stands, and ensuring recruitment of coarse woody debris.
>
> Squirrels can be construed as good indicators of function in Pacific Northwest forest ecosystems. . . . [W]e know these animals are more abundant in Oregon than in Washington and more abundant in old growth than in young, closed-canopy, competitive-exclusion-stage forests. [Q]uestions about spatial scales of organization of natural and managed forest communities have not been addressed.
>
> Our goal was to describe the responses of vascular plants, fungi in squirrel diets, and squirrels (flying squirrels and chipmunks) to environmental variation at various scales in a southwestern Oregon landscape. . . . Then, we asked how much variation in use of sites can be explained by the composition and structure of vegetation....

. . .
Our data and the literature (summarized below) suggest that forest development in the Western Hemlock Zone incorporates multiple, general processes that are variously dynamic and stochastic, but also many that are predictable and probable.
. . .
Thus, silviculture can contribute to simplification or to diversification of the ecosystem.
. . .
It is our contention that aggradation and redistribution of biomass, living and dead, results in niche diversification, an expansion of the niche hyperspace of the ecosystem and the community it contains....It is this expansion that may result in emergency properties through symbiosis and synergy. . . . Thus we hypothesize that conservation of biodiversity could be achieved in managed forests through planned human-caused disturbances and gradual change that create a multidimensional space of particular dimensions; it is those dimensions we seek to describe here.
. . .
Crown-class differentiation accounted for more variance in our data set than any other factor. Similarly, Carey et al. (1991b) reported that dbh alone could separate age classes in their sample, and Spies and Franklin (19901) reported that most variance among age classes across the Pacific Northwest could be reduced to a single canonical variate related to the standard deviation of dbh and the density of large trees.
. . .
In our study, crown-class differentiation accounted for 25% of variance in vegetation structure, but proved to be a major dimension of the realized habitat of chipmunk abundance.
. . .
Crown-class differentiation is perhaps the factor of forest development most amenable to management: (1) species composition can be determined managerially at initiation of a new stand by legacy retention, planting, and precommercial thinning, (2) management of stem density and growth rates is well founded (Curtis and Carey 1996), and (3) spacing can be varied tree to tree or patch to patch within stands (Carey 1995, Carey et al. 1996a,b). Growth of large trees and time lead to disease, injury, decay, and death of trees and consequent expansion of multidimensional niche space. Decay processes seem less deterministic; management of decadence is more problematic.
. . .
Of all the habitat elements we measured, coarse woody debris proved to be the best predictor of the realized habitat space, activity; and carrying capacity of northern flying squirrels and carrying capacity for Townsend's chipmunk.
. . .
If catastrophic disturbance sets the stage, it is small-scale disturbances in the canopy that determines the pace of the ecosystem development. Whitmore (1989) claimed that gaps drive the forest cycle in all forests; but the ecological process of tree death (Franklin et al. 1987) is particularly important in expansion of niche space.
. . .
. . . biodiversity is suppressed in competitive exclusion (which historically was rare in many landscapes; Tappeiner et al. 1997a) and there is expansion of niche space and increased biodiversity in understory-reinitiation and niche-diversification stands.
. . .
. . . Ecosystem dynamics . . . suggest active ecosystem management would be more effective than passive management (withdrawals or reserves) for conservation of biodiversity in second-growth forests.
. . .
Thinnings, active promotion of decadence, and legacy retention hold potential in managing forests for biodiversity, but spatial scale of management is important.
. . .
Thinning

In the Pacific northwest, the best opportunities for conservation of biodiversity through ecosystem management lie in the millions of hectares of second growth forest <50 years old. (DeBell et al 1997, Hayes et al 1997). Crown class differentiation, canopy stratification, understory development, and habitat breadth can be enhanced through thinning, but spatial patterning is important. . . . Traditional, light commercial thinning will not preclude or move a stand out of competitive exclusion and will not increase habitat breadth. Heavy thinning with even spacing can cause can cause stands to become drier through increase wind and sunlight, could result in salal brushfields (simple structure with low habitat breadth), and if applied in a dense stand) could disrupt mycorrhizal links and increase probability of massive windthrow (Carey et al 1996b).
. . .
Variable-density thinning on a 0.1-0.5 ha scale that removes subordinate or codominant trees appears to have potential for increasing crown-class differentiation, canopy stratification, understory development, and habitat breadth. . . . [W]e suggest that maintaining relative densities of 0.5 and 0.35 in a ratio of 2:1 over the stand could result in accelerating the development of stand structure and heterogeneity characteristic of late-seral, natural forests. Hagar et al. (1996) recommended variable-density thinning with relative densities of 0.2 -0.7. Actual choice of relative densities should entail consideration of risk of windthrow, potential for creation of salal or salmonberry (*Rubus spectabilis*) brushfields, the silvics of the species being managed, and site conditions. Multiple thinnings would be necessary to (1) keep the disturbance intermediate to small scale, (2) avoid disrupting connectivity among tree crowns (3) prevent excessive drying of the forest floor, (4) avoid development of a sparse overstory with a dense salal brushfield underneath, and (5) keep the canopy from closing into a stage of competitive exclusion.
. . .
. . . Traditional commercial thinning with systematic spacing allowed quick (ca. 10 yr) canopy closure and return to competitive exclusion; biodiversity targets were not met. . . . In forests being restored for late-seral wildlife, biodiversity thinnings appeared to have substantial value in creating late-seral forest relatively quickly. In forest managed for economic values....

. . .
Managing for decadence

Managing decadence is the most challenging aspect of intentional ecosystem management. Our research shows that decadence is more than snags and logs; it is a process that is influential in multiple aspects of ecosystem development from providing cavities for wildlife, to creating gaps in the canopy, to altering forest floor microclimate and structure.

Carey, Andrew B., and S.M. Wilson. 2001. **Induced Spatial Heterogeneity in Forest Canopies: Responses of Small Mammals.** Journal of Wildlife Management 65(4): 1014-1027.

Abstract: We hypothesized that creation of a mosaic of interspersed patches of different densities of canopy trees in second-growth Douglas-fir would accelerate development of biocomplexity. Spatial heterogeneity was expected to lead to a variety of fine-scale plant associations, foliage height diversity, and abundant small mammals. Understory species richness and herb cover were greater 3 years after variable-density thinning than without thinning. Variable-density thinning resulted in larger populations of deer mice, a species associated with understory shrubs; creeping voles, a species associated with herbaceous vegetation; and vagrant shrews, a species usually associated with openings, but common in old growth. No forest-floor small mammal species, including those associated with old-growth forest, declined in abundance following variable-density thinning. Annual variation in population size was not related to treatment. Variable-density thinning holds promise for accelerating the development of biocomplexity in second-growth forest through promoting spatial heterogeneity and compositional diversity in the plant community, increasing diversity and abundance in small-mammal communities while maintaining small-mammal richness, and similarly affecting other vertebrate communities. When combined with long rotations, legacy retention, and management for snags and coarse woody debris, variable-density thinning has broad applicability to enhance biodiversity.
. . .
Conversion of old-growth to managed forest, especially through even-aged management systems, has raised questions about the ability of second-growth forests to continue to provide diverse goods and services. . . . [M]ultiple-rotation forests will become increasingly biologically simplified with corresponding declines in habitat quality for wildlife. . . .

Variable-density thinning has been suggested as a management tool to accelerate the development of biocomplexity in managed forest stands. . . . Thinning to various densities (with corresponding differences in canopy cover) to create a mosaic of patches . . . has been hypothesized to promote processes associated with natural development of diverse fine-scale plant associations, foliage height diversity, and horizontal vegetation patchiness that have concomitant effects on soil and vertebrate communities . . .
. . .
. . . Here we present the results of a replicated, controlled experiment on the effects on forest-floor small mammals of creating a vegetation mosaic with variable-density thinning.
. . .
Our study areas were . . . on [the] Fort Lewis Military Reservation in the Puget Trough . . . All blocks were composed of even-aged stands of Douglas-fir that had regenerated from natural seeding following clearcutting in the 1920s and 1930s. All were in the late competitive-exclusion to early understory reinitiation stages of forest development and all lacked significant shade-tolerant regeneration . . .
. . .
Sampling Small Mammals
We targeted 8 species . . . as characteristic of upland small-mammal communities in Washington: southern red-backed bole (*Clethrionomys gapperi*), creeping vole, deer mouse, Keen's mouse (*Peromyscus keeni*), shrew mole (*Neurotrichus gibbsii*), montane shrew (*S. Monticolous*), Trowbridge's shrew (*S. Trowbridgii*), and vagrant shrew.

RESULTS
Vegetation
Three years following treatment, mosaics had significantly greater plant species richness and greater herb cover than controls . . . .
. . .
Small Mammal Abundance
. . . As predicted, increased spatial heterogeneity resulted in larger populations of small mammals associated with understory shrubs (deer mouse), herbaceous vegetation (creeping vole), and open canopies (vagrant shrew; Fig. 2b, d, h). Deer mice were 1.5 times as abundant, creeping voles >2 times as abundant, and vagrant shrews 6 times as abundant in mosaics as in controls. . . . We had not expected to catch many squirrels in our small traps, but we captured twice as many northern flying squirrels (*Glaucomys sabrinus*) in controls as in mosaics and 1.6 times more Townsend's chipmunks (*Tamias townsendii*) in mosaics than in controls (Table 2).

DISCUSSION
Disturbance, Heterogeneity, and Biocomplexity
We predicted that small mammals would respond positively to inducement of spatial heterogeneity into forest canopies because (1) disturbance in previously unthinned stands would produce quick invasion by herbaceous plants, germination of seeds in the soil seed bank, and increased growth of existing shrubs and ferns (Thysell and Carey 2000; 2001), thereby increasing diversity and abundance of food and cover; (2) disturbance in conventionally thinned stands would increase growth and fruiting of existing low vegetation (Thysell and Carey 2000), again

increasing food; (3) heterogeneity in the canopy would increase diversity of vegetation site types that contribute to biocomplexity and niche diversification (Carey et al. 1999a); and (4) in stands with old-growth legacies, the combination of large live trees, snags, and decaying logs, increased growth of the current even-aged cohort of trees, and a rapidly developing, complex understory and midstory would hasten niche diversification, allowing coexistence of simultaneously high populations of potentially competitive species (Carey et al. 1999 a, b; Carey 2000, 2001; Carey and Harrington 2001). Sufficient time has not passed since experimental manipulation to fully evaluate these predictions; i.e., too little time has passed to allow midstory development (Thysell and Carey 2001).

Four years after treatment, total abundance of small mammals increased. Late-seral species, including the shrew mole, montane shrew, Trowbridge's shrew, red-backed vole, and Keen's mouse (West 1991, Carey and Johnson 1995, Songer et al. 1997) did not decrease in abundance, thus allaying fears that potentially sensitive small-mammal species might suffer short-term negative effects due to the mechanical disruption of thinning (Carey 2001). However, variable-density thinning did not produce small-mammal communities of the same structure and composition found in old-growth forests . . . .
. . .
The increases we observed in small-mammal abundances were consistent with the creation of a mosaic of light, moisture, and temperature conditions leading to a more diverse and abundant understory plant community (Carey et al. 1999d). Numerous ecological benefits accompany increased small-mammal abundance, which include improved prey availability for reptiles, carnivores, and raptors; intensified dispersion of spores of fungi symbiotic with trees across the forest floor; and higher consumption rates of invertebrate pests, including Douglas-fir beetles (*Dendrocinus pseudotsugae*). . . .

. . . No consistent negative ramifications of induced spatial heterogeneity on population stability were apparent. None of our demographic results indicated negative effects due to spatial heterogeneity; e.g., we found higher ratios of males to females in controls than in mosaics and greater population sizes in mosaics.

Scope and Limitations
. . . However, the changes we observed in the understory plant community following variable-density thinning, as compared to those following conventional thinning, seem to better mimic gap formation and promote heterogeneity in understory development....

MANAGEMENT IMPLICATIONS
The short-term responses of small mammals to variable-density thinning to accelerate development of late-seral conditions in second-growth forests. . . . Conventional thinnings are designed to (1) forestall mortality of trees due to crowding and remove subordinate, dying, and defective trees (thus decreasing snag production and coarse woody debris recruitment); (2) favor commercially valuable species (resulting in reduced tree species diversity); (3) maintain stocking at levels that maximize wood production (and concomitantly minimize solar energy diverted to understory development); and (4) maintain even spacing to produce an even-aged crop of trees of similar size and quality (and, inadvertently, a homogeneous understory often dominated by aggressive clonal species). All these goals are aimed at timber and fiber production and reduced biocomplexity. Even variable-density thinning with marking guidelines to promote species diversity, however, is not adequate for ecological restoration.

Management for spatial heterogeneity should be used in a management system that includes (1) retention of biological legacies of large, live trees; large, dead, trees; coarse woody debris; and even intact patches of forest; (2) management of decadence to ensure cavity tree, snag, and coarse woody debris recruitment; (3) promotion of tree species diversity in the canopy, midstory, and understory (including deciduous species and shade-tolerant conifers in conifer forests); and (4) rotations $\geq$ 130 years (Carey 1995, Carey and Johnson 1995, Franklin et al. 1997, Carey et al. 1999 a, b, c,). Variable-density thinning should not be standardized for systematic application; the approach must be tailored to site to achieve biocomplexity and biodiversity goals. . . . The long-term postulated effects of variable-density thinning (Carey et al. 1999 d) have not been proven.

Carey, Andrew B. 2001. **Experimental manipulation of spatial heterogeneity in Douglas-fir forests: effects on squirrels**, Forest Ecology and Management. 152:13-30.
http://www.sciencedirect.com/

Abstract: Squirrel communities simultaneously composed of abundant populations of *Glaucomys*, *Tamias*, and *Tamiasciurus* are: (1) a result of high production of seeds and fruiting bodies by forest plants and fungi and complexity of ecosystem structure, composition, and function; (2) indicative of high carrying capacity for vertebrate predators and (3) characteristic of old, natural forests in the Pacific northwest, USA. I hypothesized that silvicultural manipulation of canopies of second-growth forests could result in spatial heterogeneity that would reproduce the biocomplexity and plant-fungal productivity associated with high squirrel populations. I predicted that accelerating biocomplexity would require 20 years, but short-term effects of induced heterogeneity would be apparent in 5 years: initial decreases followed by increases in *Glaucomys* populations, nonlinear increases in *Tamias* populations, and little change in *Tamiasciurus* populations. If my predictions proved accurate, confidence in long-term predictions would be enhanced. I chose 16 13-ha stands with two different management histories for a randomized block experiment and began measuring squirrel populations in 1991. Variable-density thinnings were implemented in spring 1993. Fall and spring populations were measured through fall 1998. Populations responded as predicted, except for a treatment–management history interaction. Previous conventional thinnings altered ecosystem function such that low *Glaucomys* populations failed to respond to treatment. Variable-density thinning, in conjunction with

retention of biological legacies and management of decadence, could possibly accelerate biocomplexity in second-growth forest that mimics that in old, natural forests.
. . .
Introduction
. . .
. . . Intermediate disturbances, either natural or silvicultural, . . . potentially have widespread effects, not only over geographic areas but also across life forms and taxa. Short-term effects may differ significantly form long-term effects. Postulated benefits manipulation of spatial heterogeneity are long-term perturbations, by definition, disruptive of ecosystem processes in the shoter-term. . . . [I]n the Pacific Northwest, USA, the biomass of tree squirrels is a good measure of carrying capacity of forests for predators; the reproductive activity of ectomycorrhizal fungi, trees, and shrubs (i.e. the production of truffles, seeds, and berries); spatial heterogeneity in canopy and understory; abundance of coarse woody debris; and potential dissemination of fungal spores and propagules of mosses and lichens . . .

In 1991, I began an experiment to accelerate development of late seral conditions in young (55-65-year-old), managed Douglas-fir (*Pseudotsuga menziesii*) forest in the Puget Trough of Washington . . .
. . .
In this paper I report on the responses of the three squirrels over 8 years, 3 years pre-treatment and 5 years post-treatment . . .
. . .
Discussion
. . .
. . . Population decreases, followed by recovery to control levels, of flying squirrels in the legacy mosaics is my most significant finding. This finding supports variable density thinning as an aide to restoring late-seral forest conditions (large trees, complex understories) in second-growth forests without significant long-term negative effects on the main prey of the threatened spotted owl (*Strix occidentalis*). But it also suggests caution in simultaneous widespread application of variable density thinning in areas that might be critical to the survival of particular owls. It remains to be seen if flying squirrels will increase to and beyond pre-treatment levels as predicted.
. . .
Recruitment of shade-tolerant trees into the overstory may be necessary to restore canopy connectivity in multiply thinned stands, as Douglas-fir does not have the capacity to develop wide enough crowns to fill canopy gaps between mature trees . . .
. . .
An important feature of late-seral forests is synergy that arises from close spatial juxtaposition of various habitat elements in a mosaic of varying vegetation structure. Many of these elements are low in abundance in second-growth forests. . . .
. . .
Negative short-term effects on flying squirrels (primary prey for spotted owls and many mustelids) should be expected, and widespread simultaneous application of variable-density thinning to forest stands making up habitat conservation areas should be avoided. . . . Repeated conventional thinnings (with even spacing) do not hold this promise [of enhanced squirrel biomass] and may place a stand on undesirable trajectory of forest development with reduced understory diversity . . . . Withdrawing a forest from active management after clearcutting, even with substantial legacy retention, may not achieve multiple ecosystem management goals either . . .

Carey, Andrew B. and Constance A. Harrington. 2001. **Small mammals in young forests: implications for management for sustainability,** Forest Ecology and Management. Volume 154, Issues 1-2, 15 November 2001, Pages 289-309.
http://www.sciencedirect.com/

Abstract: Small mammals have been proposed as indicators of sustainability in forests in the Pacific Northwest and elsewhere. Mammal community composition and species abundances purportedly result from interactions among species, forest-floor characteristics, large coarse woody debris, understory vegetation, and overstory composition. Coarse woody debris is thought to be particularly important because of its diverse ecological functions; covers from 10 to 15% have been recommended based on retrospective studies of forests and small mammals. Unfortunately, ecological correlations are not necessarily indicative of causal relationships and magnitudes depend on composition of finite, usually non-random, cross-sectional samples. Retrospective studies must be replicated to confirm relationships. We conducted a large-scale, cross-sectional survey of 30- to 70-year-old coniferous forests in western Washington to determine if previously reported relationships would hold with an unrelated, larger sample. Coarse woody debris cover was 8.3±0.6% (, n=8 blocks of forest, range 4–13%). Understory cover was too low (18±8% for shrubs) to allow examining interactions between understory and coarse woody debris. Overstory composition covaried with coarse woody debris. One or two of four statistically extracted habitat factors (overstory composition, herbaceous cover, abundance of *Acer circinatum*, and abundance of *Acer macrophyllum*) accounted for 18–70% of variance in abundance of 11 mammal species. Our results support hypotheses that: (1) biocomplexity resulting from interactions of decadence, understory development, and overstory composition provides pre-interactive niche diversification with predictable, diverse, small-mammal communities; (2) these communities incorporate numerous species and multiple trophic pathways, and thus, their integrity measures resiliency and sustainability.

Carey, Andrew B., Todd M. Wilson. 2001. **ECOLOGICAL FOUNDATIONS OF BIODIVERSITY** 1999–2000 Biannual Report.

[The Ecological Foundations of Biodiversity Research Team (EFB) is part of the Ecosystem Processes Research Program of the Pacific Northwest Research Station.]
http://www.fs.fed.us/pnw/olympia/efb/annualreport.pdf

> Purposeful, narrowly-focused management strategies (legacy retention alone, conventional thinning alone) can place stands on hard-to-alter trajectories characterized by incomplete or unbalanced biotic communities, truncated or misdirected developmental processes, invasion by exotic species, simplified vegetation structure, low capacity to support prey bases and predators, low resilience to perturbation, and high susceptibility to disease. . . . Imposition of spatial heterogeneity through variable density thinnings holds promise for promoting biocomplexity, but managing the process of decadence and special management for woody plant species diversity may be necessary to achieve a full range of ecosystem services.

Carey, Andrew. 1998. **Ecological Foundations of Biodiversity: Lessons Learned from the Natural and Managed Forests of the Pacific Northwest**, Pages 127-133 in J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).
http://www.pfc.forestry.ca/ecology/sfrw/40carey.pdf

Abstract
Fifteen years of research on old-growth and managed coniferous forests have provided sufficient understanding of biodiversity to suggest a basis for ecosystem management. First, natural old forests have a metaphysics—values associated with their existence and function can never be addressed fully with the scientific method alone; we cannot recreate old growth. Second, five processes underly forest development: crown-class differentiation, decadence, canopy stratification, understory development, and development of habitat breadth. Habitat breadth results from fine-scale spatial heterogeneity that produces structural and compositional diversity—tree species diversity, foliage-height diversity, and variety of recurring vegetation site-types. Third, the processes shape trophic pathways, lead to niche diversification, and help to structure fungal, invertebrate, and vertebrate communities. The contribution of each process to niche diversification differs in strength from its contribution to variance in forest structure and composition. Decadence seems the most fundamental, unpredictable, and intractable of the processes. Theoretically, ecosystem management based on these processes can produce landscapes that provide habitat for wildlife associated with late-seral forests, sustainable production of timber and alternative forest products, ecological services such as carbon assimilation and sequestration, economic activity that sustains rural communities, and win-win solutions with good cultural fit to conflicts over land use. Fourth, substantial uncertainty exists in every aspect of ecosystem management. Thus, achieving diverse benefits from forests requires active, intentional, adaptive ecosystem management.

. . .

Thus, it appears that old-growth forests and their structural elements function differently from younger forests in providing for biological diversity. Second-growth forests without legacies and in the competitive-exclusion stage of forest development seemed the least diverse in plant and vertebrate communities; some were depauperate in species. It became apparent, however, that biological legacies (large live trees, snags, logs, soil food webs, etc.) from old growth enhanced the value of both naturally young and second-growth managed forests as habitat for various species of wildlife (see various papers in Ruggiero et al. 1991, Carey 1995, Carey and Johnson 1995, Carey et al. 1996a). These reports suggest that old-growth characteristics could be developed in some young managed stands through legacy retention and intentional management. When competitive-exclusion stages without legacies dominated a landscape, even with patches of old growth, the landscape was inhospitable to late-seral wildlife such as the spotted owl (Carey et al. 1990, 1992; Carey and Peeler 1995).

. . .

. . . A true systems approach recognizes that (1) systems can be studied, described, categorized, analyzed, and modeled; (2) systems are hierarchical with emergent properties at each level; (3) humans are limited cognitively and perceptually; (4) the "truth" will never be known, there are different ways of knowing (including science and culture), and adaptive management lends itself well to learning; and (5) learning is integral to managing systems. I call the application of a systems approach to natural resources active, intentional ecosystem management: (1) active because desired future conditions are defined and interventions are planned and implemented to achieve the condition, and (2) intentional because the full range of human wants and needs and all available scientific information are used to (a) formulate very specific, hierarchical objectives, (b) to prescribe a system of interventions, and (c) to design a system of monitoring and feedback, all within the constraints of general sustainability (Goodland 1995).

. . .

Conclusions

• Old growth is a unique, irreplaceable, perishable resource.
• Management of existing landscapes, future landscapes, and second-growth forests offers many opportunities to conserve biodiversity in its broadest sense.
• Active management holds more promise than apportioning the region into biodiversity reserves, matrix lands managed under new forestry principles, and timber production lands managed by agroforestry.
• Substantial scientific uncertainty (predictability under systems management) exists and will continue to exist throughout the lifetimes of those now alive.
• Monitoring and adaptive management will be necessary to achieve human goals for forest ecosystems.
• There are too many taxa potentially sensitive to forest management for species-based monitoring.
• Measures of biotic integrity, ecosystem function, and public acceptability will have to be developed.

• No single silvicultural system is appropriate for all lands; equifinality suggests there are various pathways to achieving any set of objectives; cultural fit should be used as one criterion for selecting the pathway to be implemented.
• Organizations and management are a social phenomena with implied and defined expectations on the part of participants in a social contract. Failure to communicate clearly about expectations can only result in conflict no matter whether the managing organization is private, state or provincial, or federal.
• Emerging cultural streams in the USA (Ray 1996) suggests sustainability is becoming a preeminent cultural value; sustainability, then, is an essential component of management plans and must be demonstrated with high intentionality.
• History has shown that organizations are not independent of their larger social environment; antisocial behavior is eventually rewarded with increased regulation.

Bormann, Bernard T. and Marc G. Kramer. 1998. **Can Ecosystem-process Studies Contribute to New Management Strategies in Coastal Pacific Northwest and Alaska?** Pages 77-83 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2). http://www.pfc.forestry.ca/ecology/sfrw/23borm.pdf

Federal policymakers have assumed that the large acreages of young plantations now being created, mostly on non-Federal lands, means that shortage of early-successional species and processes is not a concern. Plantation management, however, has made great strides in shortening the time that shrubs and hardwood trees occupy the site. Our process research seeks to find out whether early-seral species (especially deciduous shrubs and hardwoods with associated microbes) affect long-term productivity through effects on soil organic matter, water-holding capacity, nitrogen fixation, and weathering. As an example, if dense stands of deciduous shrubs and trees have the same net primary production as dense young conifer stands, then—because conifers are more efficient in converting net production into woody tissue—less organic matter will build up in the soil. If early seral species increase soil organic matter that offsets later declines under pure-conifer stands, then excluding early-seral species may cause loss of associated processes and species and may reduce growth and development of late-seral species and structures. Retrospective analysis of old-growth trees in the Oregon Coast Range suggests that almost all of these stands had very wide conifer spacing during the first 100 years or so (Tappeinier et al. 1997) and, presumably, dense shrub cover.

Controlled experiments have demonstrated large differences in the effects of conifer and hardwood trees on mineral-soil organic matter. In one five year study using common, homogenized soil, mineral-soil organic matter declined 20% under two pine species, and increased 5% under alder (Bormann et al. 1993). Weeding experiments in coastal Oregon have demonstrated the potential importance of deciduous shrubs on mineral-soil organic matter. Small plots with planted Douglas-fir (*Pseudotsuga menziesii*) and dense salmonberry (*Rubus spectabilis*) had 45% more soil C in the top 15 cm of mineral soil than did fully weeded plots after five years. Salmonberry plots also had 34% more soil C than did plots with shrubs removed, leaving Douglas-fir with competition only from the herbs, mostly foxglove (*Digitalis purpurea*) (Kermit Cromack Jr., pers. comm.). The effect of these changes on subsequent stands has not been widely tested. The Long-Term Ecosystem Productivity project (http://www.cof.orst.edu/ research/ltep), a series of replicated management scale experiments in Oregon and Washington, focuses partly on testing differences in processes in young plantations compared to 'natural' early successional assemblages, as well as effects of soil changes on subsequent production (Figure 5; Bormann et al. 1994).

In appropriate areas, changes in vegetation management might include letting shrubs and hardwoods occupy sites longer, planting conifers at very wide spacing, thinning, encouraging deciduous shrubs and hardwoods, planting mixed stands, and creating gaps large enough for shade-intolerant species. A management experiment at Mt. Hebo in the Oregon Coast Range is presented as an example of a research-management partnership, partly designed to evaluate the importance of early-successional species (Figure 6). The Mt. Hebo experiment—starting with an 80-year-old Douglas-fir plantation—compares four prescriptions for growing old growth and producing some timber: a no-cut control (a), a light gap thinning (b), a heavy thinning around the 30 largest trees per acre followed by planting either red alder (*Alnus rubra*) (c) or western hemlock (*Tsuga heterophylla*) (d), where the underplanted trees are grown in short rotations without reducing the Douglas-fir leave trees to less than 10 trees/acre. The alder underplanting and other hardwoods are hypothesized to increase mineral soil organic matter, nitrogen, and base-element nutrients to speed, and later maintain, growth of residual large conifers to meet old-growth standards. The 15-acre management units were established in initially similar areas, and the four treatments were assigned at random with three replications. An additional purpose for this action is learning how to grow old-growth habitat from existing plantations.

Bormann, B., P. Cunningham, P. Thomas, M. Brookes, B. Buckley, C. Cloyd, M. Jensen, J. Linares, D. Mummey, E. Obermeyer, J. Sleeper, and C. Snyder. March 2001. **Plan For the Five Rivers Landscape Management Study.** Appendix A, *in* USDA Forest Service. 2001. **Five Rivers Landscape Management Project, Final Environmental Impact Statement.** Waldport Ranger District, Siuslaw National Forest. http://www.fs.fed.us/r6/siuslaw/5rivers/contents.htm http://www.fs.fed.us/r6/siuslaw/5rivers/feis/feis-app-a.pdf

Introduction
In this study plan, we describe a management study proposed as an integral part of the final Five Rivers Landscape Project Environmental Impact Statement (EIS). The management study is the primary method the Forest Service will

use to meet the need for learning identified in the EIS (EIS, page 2): “Not enough is known for people to agree on a single approach to meet the goals of the Northwest Forest Plan, partly a result of ineffective past monitoring strategies. Especially poorly known is how plantations, riparian zones, and roads can be efficiently managed together through time.” This study plan has been officially peer-reviewed; a reconciliation report is on file at the Forestry Sciences Laboratory, 3200 SW Jefferson Way, Corvallis, OR.

The Five Rivers EIS covers 16,000 acres for this study and 21,000 acres outside the study in the 37,000-acre Five Rivers watershed. The plan is an attempt to meet both the resource and adaptive management goals of the Northwest Forest Plan (ROD 1994) and, as such, must balance resource and learning objectives. Focused on questions facing land managers in coastal Oregon, the study will be implemented as normal business for the Waldport Ranger District, with limited support from the Siuslaw Supervisor's Office and the Corvallis Forestry Sciences Lab. The study is intended to stand alone, although funding for research projects that may help in interpreting the study is being sought separately; its design is based on adaptive management, using a parallel-learning model (Bormann et al. 1999).

The management study differs from a traditional research study in important ways. The questions have been officially posed by managers (with some input from others). And answers are being sought by comparing alternative management pathways applied as part of management. The study applies some techniques normally reserved for research studies, including a study plan, explicit hypotheses, an experimental design, replication, random allocation of treatments, and peer review. The alternative pathways are considered "treatments" in a statistical sense, and monitoring is considered as measuring response to treatments. Applied forestry research experiments often focus on constrained effects of single practices; these sets of practices, combined in time and space, are confounded in the chosen design. Confounding is lessened greatly when the pathways, rather than individual practices, are considered as the treatments. Cause and effect is difficult to establish in all field ecological research, although qualitative information on practices is likely, if sufficient emphasis is given to study design (Shrader-Frechette and McCoy 1993).

A learning strategy based on diversity of management pathways

The learning need can be restated as a series of questions to be answered by creating and comparing a set of management pathways, all geared to achieve late-successional conditions and aquatic conservation:

- Can late-successional habitat and aquatic conservation be achieved in more than one way by managing differently in densely spaced 5- to 60-year-old Douglas-fir plantations, associated roads, and stream reaches in the Five Rivers watershed?
- How fast will various management pathways, and their interactions with natural disturbances, achieve late-successional-habitat and aquatic-conservation objectives?
- Is our approach to integrated landscape planning that uses an EIS—rather than a series of environmental assessments—with a more concise format and with explicit learning objectives workable for implementing the Northwest Forest Plan?

Pathway objectives

Increasing late-successional habitat and improving health of watersheds and associated aquatic ecosystems are broad and difficult-to-achieve goals, given the lack of understanding of these systems. We start with general objectives for previously managed units. The following stand-scale, late-successional habitat characteristics identified by Franklin et al. (1981) are sought:

- At least 25 trees per hectare (10 trees per acre) greater than 70 cm in diameter at breast height;
- A multilayered tree canopy;
- At least 50 tons per hectare of decaying logs; and
- At least 25 standing snags per hectare (10 per acre).

The same stand-scale objectives are sought in the riparian areas to meet the aquatic conservation strategy, adding only that stream temperatures do not rise.

Similar objectives are sought for the mature stands surrounding the managed units, but we assume the mature stands will achieve, or may already have achieved, these conditions without intervention. Larger scale objectives are more difficult to state quantitatively. The Siuslaw late-successional reserve assessment (USDA, USDI 1997), based on the Northwest Forest Plan (ROD 1994), suggests that this area of the Coast Range should serve as a late-successional core area because of its proximity to intensively managed private lands. Thus, the large-scale objective is to achieve late successional and aquatic conservation objectives on entire roadsheds.

Scientific and operational perspectives were merged into a series of pathways that, after monitoring, should be able to help answer our questions, while meeting the other identified problems (EIS, page 2). These pathways must represent a broad set of legal and legitimate ways to achieve both late-successional and aquatic-conservation objectives. Increasing learning efficiency and confidence in the findings depends a lot on the extent of differences between pathways and whether a science-based design can be used in distributing pathways across the Five Rivers project area.

Pathway descriptions (treatments)

A synopsis of pathways is included here. More details are available in the EIS chapters 2 and 4, and also in appendices B and C.

Path A—Passive management. Many concerned citizens believe that any intervention, even in existing plantations, will only result in further environmental damage. Closing roads is associated with this belief. Existing evidence suggests that already dense plantations may stagnate, and individual trees may grow to the 70-cm-DBH, old-growth objective very slowly, if at all. But natural disturbances like windthrow, snow breakage, insects, and diseases may help thin these stands and allow old-growth conditions to develop. Unthinned but disturbed stands might attain old-growth characteristics different from those in thinned stands. Roads are thought by some to be largely incompatible with old-growth conditions and riparian conservation, and funds to maintain them might be better spent on other projects. **Decommissioning** means removing stream crossings and problem culverts and adding water bars and vehicle diversions. Access to two- and four-wheel-drive vehicles will be prohibited, but all-terrain vehicles, horses, and hikers will not be limited unless they are found to cause damage. The Team believes this pathway is applicable and allowed in all land allocations where it is placed.

Path B—Pulsed management. This pathway starts by managing the plantations and streams in an area during just a few years (partly limited by sale contracting rules), closing the road for at least 20 to 30 years, and then reopening it for another management pulse. Road closures are designed to be reversible and to lessen environmental and road maintenance costs. Actions during the pulses have to reflect the lack of access during the years of road closure. Thinning existing plantations to wide spacing (leaving as few as 40 trees per acre) is needed for plantations to promote the fastest diameter growth, avoid stagnation, and to support second-story conifers (fig. A-1). Even wider thinnings might speed growth of residuals further and better produce large-branch habitat for murrelets, but concerns with predation on spotted owls in open stands precludes this option. Alders and deciduous shrubs will be planted—or not removed—between residual trees to improve soil fertility and growth of residual conifers on poor sites. Where hardwoods are not wanted, vegetation control will likely be needed to establish conifer seedlings. Also, trees would be thinned in stages, starting with 50 to 70 trees per acre, followed by a second thinning 5 years later to make snags and fell trees for coarse woody debris objectives. Windthrow risk may be increased in some areas by thinning for several years, but windthrow will be considered a reintroducd natural disturbance, possibly important for some wildlife species and soil processes. Other resources, such as recreation, elk forage, and nontimber products may be affected by this pathway and will be considered, but they are not central to its goals. Road access policy during closures is similar to the passive-management pathway. The Team believes that the pulsed-management pathway is also applicable and allowed in all land allocations where it is placed.

Path C—Continuous management. Continuous access permits actions to be distributed evenly through time, and thereby allows each individual action to be less intense. Thinning can be much lighter, but more frequent than in the pulsed management pathway. Logs in streams can be added gradually instead of all at once. Windthrow risk may be increased in some areas by thinning for several years. This pathway has the advantages of allowing better access for recreation, emergencies, and response to unanticipated changes and catastrophes, for example, salvaging windthrown or insect-damaged trees. These advantages might be partly offset by higher road maintenance costs and environmental effects from roads than in the other pathways. This pathway is supported by foresters who believe in active management to achieve Northwest Forest Plan objectives. The Team believes this pathway is also applicable and allowed in all land allocations where it is placed.
. . .
How do plantations respond to thinning? Densely spaced Douglas-fir plantations, at this age in this area, will very likely respond to thinning—until crowns close again (see, for example, Curtis et al. 1998). Crown closure is expected to be very rapid on these productive sites. More diameter-growth response is likely at wider spacing, up to about 30 feet between residual trees. Larger trees obviously should speed old-growth development, but uncertainties about windthrow, wind snap, thinning shock, and interactions with root disease and insects add uncertainty to predictions. Experience with long-term response to wide thinning (20 to 40 residual trees per acre) is limited, but examples at Black Rock Forest, near Mill City, and on the OSU McDonald Forest (Michael Newton, pers. comm., Oregon State University, Corvallis OR) suggest that widely spaced tree canopies will close faster than expected, so fast that most problems will center around establishing and maintaining a second story of trees. This conclusion is supported in studies of natural stands (Alaback and Tappeiner 1991, Deal et al. 1991).

How did old-growth trees become old growth? Many old-growth trees now growing in the Coast Range were free to grow during their first 100 years or so (Tappeiner et al. 1997). Other large conifers grew slowly at first under shrubs and hardwoods, but after overtopping them and with few other conifer competitors, they grew rapidly (Michael Newton, pers. comm.). Shrubs and hardwoods tend to build soil organic matter, and alders are known to fix nitrogen and weather rock particles, rapidly improving fertility of many soils (Bormann et al. 1993). Current plantations have an extremely different stand- and tree-growth trajectory, and whether plantations can reach old-growth dimensions at all, even with light thinning, has been questioned. Also unknown is what was growing between these trees and what kinds of disturbances contributed to maintaining their free-to-grow status.

How does thinning relate to aquatic conservation? General experience suggests that adding large logs to streams improves habitat for salmonids and other aquatic organisms. Growing large conifers near streams increases the chance that large logs, which last longer than small logs in streams, will be added over time. Thinning speeds growth of residual trees. Underplanting hardwoods may increase energy inputs into stream food chains and may support more beavers, whose dams can add to fish habitat. Thinning may increase landslides, benefiting habitat over the long run with coarse sediments and logs, but harming habitat in the near term with fine sediment.

Carey, Andrew, B. 2002. brochure-- **Promoting Habitat Complexity in Second Growth Forests**, Pacific Northwest Research Station, USDA Forest Service, Forestry Sciences Laboratory, Portland, OR
http://www.fs.fed.us/pnw/pubs/carey_habitat-complexity.pdf

Four Key Structuring Processes

- **Crown class differentiation—**Competition among trees of the same age results in dominant, codominant, subordinate, and suppressed trees.
- **Decadence**—Trees get damaged, infected with fungi, breakdown, and recycle within the eco- system.
- **Understory development**—Variability in light, temperature, and soil moisture pro- motes structurally-diverse growth on the forest floor.
- **Canopy stratification**—Trees of different ages and growth habits produce multiple layers of vegetation, including a well-developed midstory.

Lead to Complexity in...

Individual structures
- Trees of diverse heights, diameters, branch sizes, and bark characteristics
- Large, dead standing trees (snags)
- Coarse woody debris (stumps and logs) in various states of decay

Stand-scale structures
- Vertical heterogeneity—ever-changing distributions of foliage from the forest floor to the tree tops
- Horizontal heterogeneity—patchiness in the overstory, midstory, and understory

Two Key Processes Influencing Species Composition
- **Development of habitat breadth**—Patchy canopies produce variability in light, temperature, and soil moisture, leading to patches of different types in the understory.
- **Pre-interactive niche diversification**—Expansion in forest structure and plant species composition provides diverse niches for animals, plants, and fungi; additional niche separation occurs after species interact.

Lead to Complexity in...

Composition
High abundance and diversity of…
- Fungi
- Vascular plant
- Forest floor invertebrates
- Aquatic organisms
- Terrestrial vertebrates

Complex Structure and Composition Lead to Complexity in Forest Function

- High carrying capacities for diverse animals
- High productivity for plants
- Effective regulation of nutrients and water cycling
- Healthy, resilient forests

The following management tools can help meet multiple values —environmental, economic, and aesthetic— when used collectively and according to a well-devised plan.

Cavity-Tree Creation
Many mammals and birds use trees for denning and raising young. Maintaining existing trees (live and dead) with cavities helps to support these animal populations. Cavities can be created by several methods, such as (a) cutting a hole in the tree bole and covering it with a faceplate, (b) topping a tree to accelerate top rot and growth of new leaders, or (c) inoculating trees with fungi to hasten the establishment of decay.

Leads to...
- Decadence
- Pre-interactive niche diversification

Coarse Woody Debris Augmentation
Terrestrial amphibians, small mammals, and birds depend on large coarse woody debris for protection and foraging for insects, fungi, and seeds. Felling trees of various sizes adds a mix of coarse woody debris to the forest floor. Leaving unmerchantable wood and minimizing site preparation (such as prescribed burning) after harvests helps to conserve, and contributes to creation of, litter and soil organic matter.

Leads to...
- Decadence
- Pre-interactive niche diversification

Underplanting
Planting and seeding multiple species of native trees promotes diversity and structural complexity in a forest. Managed stands often have insufficient tree regeneration to provide a midstory of shade-tolerant trees. The midstory connects the lower branches of the tree crowns to the upper branches of the tall shrubs, establishing a full vertical

foliage profile. Underplanting helps to increase a forest's resistance and resilience to disturbance and also improves its aesthetic value.

Leads to...
- Canopy stratification
- Development of habitat breadth
- Pre-interactive niche diversification

Variable-Density Thinning
Variable-density thinning involves varying the thinning intensity across an ecologically appropriate scale (1/4 to 1 acre in size) to produce a mosaic of unthinned, moderately thinned, and heavily thinned patches. Thinning with skips and gaps can also create this mosaic. Variabledensity thinning helps generate complex structures by promoting tree growth at different rates. It also encourages understory development through a diversity of species, a variety of patch types, and growth of tree seedlings and saplings. Variable-density thinning can improve forest health by increasing (a) resistance to disturbance, (b) ability to recover after disturbance, and (c) biological diversity that allows ecosystems to function well through climatic variation.

Leads to...
- Crown class differentiation
- Understory development
- Canopy stratification
- Development of habitat breadth
- Pre-interactive niche diversification

Conservation of Biological Legacies
Conserving biological legacies at harvest helps to ensure the continued occupancy or recolonization of a forest by fungi, vascular plants, forest floor invertebrates, aquatic organisms, and terrestrial vertebrates. Legacies include (a) soil organic matter and litter, (b) standing dead trees and coarse woody debris, (c) mosses, lichens, forbs, ferns, shrubs, and live trees of the preceding forest, and (d) ectomycorrhizal fungi. Retaining legacies promotes a multiple-age forest with diverse layers of vegetation. Retaining legacies in patches can also jumpstart the development of complex structures.

Leads to...
- Decadence
- Canopy stratification
- Development of habitat breadth
- Pre-interactive niche diversification

Extended Harvest Rotations
Longer harvest rotations can produce healthy, complex forest landscapes. On industrial and private lands, rotations of 40 to 50 years are used to maximize profits and maintain cash flow. Public ownerships, which must consider other values in addition to timber revenues, use rotations of 60 to 80 years or longer. A shift to extended harvest rotations of 70 to 230 or more years has the advantages of (a) producing a variety of tree sizes and wood products over time, (b) improving the age distributions of trees in the landscape, (c) promoting healthier wildlife habitat, (d) increasing carbon storage, and (e) preserving options for adaptive management. Thinnings also help to establish diversity and minimize tree overcrowding.

Lead to...
- Crown class differentiation
- Decadence
- Understory development
- Canopy stratification
- Development of habitat breadth
- Pre-interactive niche diversification

CAREY, A.B.; LIPPKE, B.R.; SESSIONS, J. 1999. **Intentional systems management: managing forests for biodiversity.** Journal of Sustainable Forestry. 9(3/4): 83-125, 1999.
http://www.fs.fed.us/pnw/journals/0065.pdf

> Our goal was to develop the paradigm of conservation of biodiversity into a strategy for forest ecosystem management that could be applied across land ownerships (public and private) and that would provide for joint production of timber and wildlife in the context of environmental, economic, and social sustainability (general sustainability, Goodland 1995) in western hemlock *(Tsuga heterophylla* [Raf.] Sarg.)-Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) forests in the Pacific Northwest United States. This strategy would be sharp contrast to existing *de facto* allocations of land in the Pacific Northwest either to intensive management for timber or to reserves with little active management. In particular, we wanted to develop management pathways that would not only deliberately address the needs of all indigenous wildlife, including wildlife associated with old-growth forests (e.g., Carey 1989), but also diverse societal wants and needs from forests. . . .

We provide principles, procedures, and recommendations for conservation of biodiversity that apply to (1) second growth. forests now managed primarily for wood products (state and private timberlands), (2) second-growth forests managed for restoration of ecological function as habitat for wildlife associated with late seral stages of forest development (late-successional reserves and adaptive management areas on federal lands) and ecological services (e.g., water, carbon sequestration), and (3) streamside, second-growth forests managed as late-successional biodiversity reserves to enhance riparian and landscape function.

. . .

we constructed three approaches to managing riparian areas and three broad strategies for landscape management: (1) no manipulation with protection (NMP), (2) maximization of net present value (npv) through timber and fiber production (TFP), and (3) conservation of biodiversity (CBD).

. . .

. . . we assumed that all stands allowed to develop for >250 years would develop into managerially fully functional or old growth.

. . .

Development of managed forest stands can be divided into as few as four broad stages: stand initiation, stem-exclusion, understory reinitiation, and old growth (Oliver and Larson 1996). Four stages, however, are insufficient for modeling various trajectories biotic communities can follow under different strategies and intensities of management. Here we use a new, expanded classification of forest ecosystem development (Carey and Curtis 1996, Table 2). The classification has eight stages because of the unique longevity, structure (especially the large amounts of coarse woody debris), and organization of Pacific Northwest old growth and the variety of organisms it supports (Franklin et al. 1981, Ruggiero et al. 1991).

TABLE 2. Seven prototypical stages of forest ecosystem development in managed forests the Western Hemlock Zone of Washington and Oregon.

Stage	Code	Description
Ecosystem initiation	EIS	Death or removal of overstory trees by wildfire, windstorm, insects, disease, or timber harvesting leads to the establishment of a new forest ecosystem.
Competitive exclusion	CES	Occurs only when trees fully occupy the site and compete with one another for light, wa nutrients, and space such that most other vegetation is precluded and many trees become suppressed and die.
Understory reinitiation	URS	Light or spatially heterogeneous regeneration or achievement of dominance by some tre and death or removal of other trees (with resultant reduced competition) allows an unders plants to establish.
Developed Understory	DUS	Understory of forbs, ferns, shrubs, and trees developed afterdeath or removal of some dominant trees; time has been insufficient for diversification of the plant community.
Botanically diverse	BDS	Organization and structure of the living plant community becomes complex with time bu of coarse woody debris and other biological legacies preclude a full, complex, biotic community.
Niche diversification	NOS	The biotic community becomes complex as coarse woody debris, cavity trees, litter, soil organic matter, and botanical diversify increase; diverse trophic pathways develop; wildl foraging needs are met.
Fully functional (managed)	FFS	Additional development provides habitat elements of large size and interactions that pro for the life requirements of diverse vertebrates, invertebrates, fungi, and plants.

. . .

The Conservation of Biodiversity Strategy-CBD builds upon experience gained from application of alternative silvicultural practices and recent information from research (Carey et al. 1996a, b; Carey and Curtis 1996; Curtis and Carey 1996). It focuses on integration of the diverse values people derive from forests. Our biodiversity prescriptions arose, in part, out of concerns about the northern spotted owl and other wildlife associated with old forests in Oregon and Washington. Analyses of factors influencing the spotted owl, other wildlife dependent on old-growth forests, and communities of resident forest birds, arboreal rodents, and forest-floor small mammals revealed dependence on multiple and diverse habitat elements, with either overall abundance or species richness of communities increasing with stage of forest development (Carey 1989, 1995, 1996; Thomas et al. 1990; Carey et al. 1991, 1992, 1996a, b; Ruggiero et al. 1991; Carey and Johnson 1995). Old forests have a more complex structure and larger three-dimensional physical space than young forests (Carey 1998, Carey et al. 1999), i.e., increased habitat space and preinteractive niche diversification (Hutchinson 1978). We used this information, and data on growth, yield, and market value of trees, to formulate our specific objectives, or desired future condition, for ecosystem management for CBD and to identify the management practices that would create the desired future condition. A full exposition of this rationale was provided by Carey et al. (1996a).

We developed several management prescriptions and chose the one that provided the best mix of benefits: clearcutting with retention of biological legacies, planting widely-spaced Douglas-fir, natural regeneration of western hemlock and other conifers, precommercial thinning favoring multiple species at 15 years, and variable-density thinnings (Carey 1995, Carey and Curtis 1996) at 30 and 50 years with final harvest at 70 years alternating with variable-density thinnings and 30, 50, and 70 years and final harvest at 130 years with a goal was to achieve and maintain Ž30% of the landscape in late-seral forest (20% niche diversification, 10% fully functional). Variable density thinnings included coarse woody debris augmentation and cavity-tree management costs and benefits. Every hectare of the forest had to be managed except no-entry 9-m buffers on Class 5 streams; the remainder of the riparian zone was managed with biodiversity thinnings only.

Ecological Evaluation of Simulation Scenarios
Karr (1991) concluded that a biological system can be considered healthy when its potential is realized, its condition is stable, its capacity for self-repair when perturbed is preserved, and minimal external support is needed. . . .

We were concerned also with (1) the ability of landscapes under different management systems to support viable populations of indigenous wildlife; (2) ensuring long-term productivity of the forest ecosystems through maintenance of healthy forest-floor communities of microbes, arthropods, and fungi; (3) the capacity of the landscape to support wide-ranging predators; and (4) the capacity of the landscape to support traditional subsistence and sport hunting of wild ungulates. Following Karr's (1991) approach, we developed a suite of four measures with which we could evaluate seral-stage contributions to biodiversity and different landscape management strategies.
. . .
Ecosystems managed intentionally for biodiversity quickly gained ecological advantages over those managed under TFP or NMP . . .
. . .
No manipulation (NMP) required >180 years to cover 30% of the landscape with late-seral forests (Table 9) because numerous habitat elements were missing in the early stages of forest development following clearcutting (Table 3). Early stages had low biodiversity values (Table 10, Figures 1-3). The protected landscape moved through periods dominated by single stages because the initial landscape was relatively homogeneous (Figure 4). Timber pathways produced only 2 stages, ecosystem initiation and competitive exclusion. Competitive exclusion was the least diverse stage-forest-floor function was only 12% of potential, ecological productivity was 19% of potential, and only 64% of vertebrates were provided habitat, with no habitat for 14 upland-forest species (Table 10, Figures 1-3).

Biodiversity pathways achieved 98% of the potential ecosystem health and also produced a larger variety, higher quality (greater dbh), and, sometimes, greater volume of wood products than TFP (Table 1). . . .

First, just protecting the landscape was a poor approach to ecological restoration- the entire landscape, in wave-like fashion, passed through the competitive exclusion stage (then understory reinitiation and developed understory stages) before reaching- a late-seral forest condition, a process that took Ž 180 years to obtain 30% late-seral forest, whereas only 100-120 years were required under management for biodiversity (Figure 4).
. . .
Third, biodiversity thinnings were more profitable than conventional thinnings. This result was unexpected, but should have been obvious. Biodiversity thinnings removed more wood than conventional thinnings at a given age (30 years); later biodiversity thinnings removed higher quality wood than early thinnings. Costs accrued to CBD as rotation age was extended and as thinnings removed more wood than necessary to maximize tree growth (one purpose of biodiversity thinnings was to shunt energy in the form of sunlight to organisms besides trees). . . .

. . . Change from ecosystem initiation and competitive exclusion stages to late-seral forest was accelerated by management for biodiversity . . .

Ecological Values-The competitive exclusion stage had the lowest values of all stages for vertebrate diversity, forest-floor function, ecological productivity (Figures 1-3), and production of deer and elk. . . .
. . .
Management for biodiversity, with its legacy retention, coarse woody debris and cavity tree management, and variable-density thinnings provided stages with maximum values and a landscape with minimal variance in values and no human induced ecological bottlenecks. . . .
. . .
Caveats
Our analyses were carried out making numerous assumptions, both ecological and economic. We recognize that predictive ability in both sciences is poor. But, we modeled only what we considered common conditions. We believe we were conservative in estimating the ecological values of management for biodiversity. . . . The biodiversity management pathways and ecological evaluations, however, were specific to the western Olympic Peninsula and would require fine-tuning to local conditions before use in simulations elsewhere in the Pacific Northwest.
. . .
The environmental sustainability of the strategy for maximizing net present value given the ecological and economic bottlenecks we identified is questionable. We do not know enough to assess the impacts on long-term site productivity, but the ecological indices suggest loss of function. Likewise, we have not evaluated the impacts of continued manipulation of forest ecosystems under the biodiversity pathways, especially impacts from soil compaction or loss of productivity caused by maintaining a proportion of the forest in well-maintained roads. The impacts of repeated thinnings are being studied in experiments and early results show rapid recovery from variable-density thinning (Carey et al. 1996b). The recent exploration of "kinder, gentler" European thinning machinery on the Olympic Peninsula proffers optimism.

. . . In the Forest Ecosystem Study (Carey et al. 1996b), a variety of measurements are being tested, including: measures of soil food webs, measures of ectomycorrhizal fungal fruiting activity, the diversity of fungi that bear fruit above ground, fungal diversity in flying squirrel diets, the composition, abundance, diversity, and growth rates of vascular plants; the integrity and abundance of the forest-floor small mammal community, and the abundance of the arboreal rodent community. All these items being measured are related to trophic pathways, maintenance of diversity in trophic pathways at the levels of decomposers, primary producers, consumers, and, ultimately, predators, and, thus, to ecological integrity. But we do not yet have enough knowledge to model all the communities composing the trophic pathways and their response to alternative management regimes.

. . .

Our goal was to move from a state of ecosystemic degradation due to cultural abuse to a healthy natural/cultural landscape mosaic, not a fully natural state (Regier 1993).

Carey, Andrew. **THINKING AND THINNING ECOLOGICALLY**, slideshow
http://www.fs.fed.us/pnw/olympia/efb/flash/thinking_&_thinning_ecologically.swf

[The following excerpts are from a slide show on the web. Further background on this study is available in Carey, Andrew B., David R. Thysell, Angus W. Brodie; 1999. **The Forest Ecosystem Study: Background, Rationale, Implementation, Baseline Conditions, and Silvicultural Assessment**, Gen. Tech. Rep. PNW-GTR-457. http://www.fs.fed.us/pnw/pubs/gtr_457.pdf]

In this presentation I'm going to summarize research results of the past decade as they relate to management of second-growth forests for late-seral forest characteristics, focusing especially on management of second growth in late-successional reserves. There has been a vast amount of research but I will present only specific examples, usually from the southwestern Oregon Coast Range and the Olympic Peninsula of Washington to illustrate general principles that hold across the Pacific Northwest.

. . .

In 1981, Jerry Franklin and others published a compendium of what we knew and what we thought was true about old-growth forests; they identified some key structural elements: large, live trees; large standing dead trees (snags); large fallen trees (on the land and in trees); and multilayered canopies. After two decades of research by myself, Jerry Franklin, Tom Spies, and many others we now can see the true complexity a little better: diverse tree sizes; abundant cavity trees (live and dead, of various sizes, hardwoods and conifers); abundance of coarse woody debris that varies with forest composition, regional climate, and fire history; horizontal patchiness in the forest canopy and in the vegetation on the forest floor; vertical diversity in the arrangement of foliage with the forest-forming a continuous column from the ground to the tree tops in some place to an absence of foliage till high in the canopy in other places; habitat breadth-an array of fine-scale plant associations that repeat themselves somewhat irregularly throughout a forest; and, in sum, biocomplexity-a complexity of species, structures, and processes the total of which is greater than the simple sum of its parts (synergy).

. . .

The right kinds of thinning can promote crown-class differentiation, canopy stratification, and understory development, and development of habitat breadth.

. . .

But thinning alone can inhibit decadence and Preinteractive niche diversification by leading to a paucity of cavity trees, coarse woody debris, and soil organic matter.

. . .

We've shown conventional thinning may reduce decadence and forestall mortality, restrict habitat breadth, produce incomplete biotic communities, and promote dominance by clonal native plants, globalization of flora, and invasion and establishment of exotic plants.

. . .

The rate of development of late-seral forest was much slower with no management (>150 years) than with active management (70-120 years).

. . .

Conventional thinning alone produced few flying squirrels or Douglas' squirrels, but many chipmunks; high plant species diversity but dominated by clonal natives with many exotic species; relatively abundant winter birds, but few woodpeckers; abundant small mammals but in imbalanced communities; and diverse fungi, low in abundance.

. . .

Variable density thinning enhanced the diversity and abundance of plants, small mammals, and arboreal rodents; produced a temporary reduction in numbers of flying squirrels and fungal abundance; just a slight, probably temporary, increase in exotics; but a decrease in mycotrophic plants suggesting a need to maintain some skips.

. . .

Our research found some pitfalls associated with failing to manage: lack of shade-tolerant trees, low plant species diversity, crowded trees with low vigor, weeds in the soil seed bank, high incidence of disease, failure to respond quickly to remedial treatment late in life, and a lack of capacity to develop into late-seral forest, perhaps until replaced with a more diverse community.

Chan, Sam, Maas-Hebner, Kathleen G. and William H. Emmingham. 1999. **COMMERCIAL THINNING AND UNDERPLANTING TO INCREASE STRUCTURAL AND SPECIES DIVERSITY IN YOUNG MANAGED DOUGLAS-FIR STANDS.** *In* Procedings of the Society of American Foresters 1999 Annual Convention, Portland, Oregon, September 11-15, 1999.

We installed a split-plot study design to examine the effects of thinning and underplanting on the structure of young Douglas-fir stands located on highly productive sites in the Oregon Coast Range. Four overstory treatments were created by thinning in three 30 to 35-year old Douglas-fir plantations. The overstory treatments were an unthinned control (~220 trees per acre, TPA), normal commercial thin (100 TPA), wide thin (60 TPA), and very wide thin (30 TPA). . . .

Response of Understory Vegetation
The number of plant species within our study plots increased with thinning intensity. More importantly, thinning did not eliminate any of the plant species that were observed prior to thinning or in the controls.

After five years, the cover and height of most understory plant species had increased substantially. Yet, . . . vine maple had not recovered to pre-thin heights after 5 years . . . even the vine maples in the unthinned stand were shorter than the heights recorded during the first year . . .

Response to Underplanted Trees
The growth of Douglas-fir and western hemlock planted in the understory was greatest in the wider (heaviest) thinnings . . . while all seedlings planted in the unthinned stands died. Trees planted in the wide and very wide thinned stands were twice the height of those planted in the normal thinned stands where low light availability was a key factor limiting seedling growth. Other species planted (Sitka spruce, western hemlock, western redcedar, grand fir, and red alder) also showed greater growth rates in the widely thinned stands as compared to the normal thinned stands and had failed to become established in the unthinned stands.

Natural Regeneration
. . . As with underplanted trees, the abundance and vigor of these naturally regenerated conifers increased with thinning intensity. No naturally regenerated conifers or hardwoods were found in unthinned stands. Four to seven times as many naturally regenerated conifer seedlings were present in the wide and very wide thinned stands compared to the normal [thinned] stands. . . .

Canopy Closure and Light
. . .
Thinning increase light levels during the first year after thinning but the increase in light was not proportional to the number of trees removed. A key finding during the fifth year was evidence of rapid canopy development in trees that were within the thinned treatments. . . .

We anticipate the decline in light availability will continue beyond the fifth year [which] . . . will have substantial effects on the successful establishment and vigor of the understory vegetation.
. . .
Microsite conditions
Thinning had relatively minor impacts on the forest floor. Thinning and yarding activities (with suspended cables) did not increase the amount of exposed mineral soil. This was partially due to the increase in slash. . . . Windthrow was minor at all sites and occurred in the first two years after thinning.

. . . The thinned stands warmed up faster than the unthinned stands in the spring and maintained higher soil temperatures in the evenings. Warmer soil temperatures during the spring are generally conducive to the growth, development, and activity of many organisms.

CONCLUSIONS
. . .
- We have found that it takes at least three years for major understory shrubs such as vine maple to begin to recover from damage associated with thinning.

. . .
- Thinned forest canopies grow and close rapidly. Without subsequent thinning in the lightly thinned stand, the canopy closure may hinder further understory development.

. . .
- Establishing a mosaic of small openings, variable spaced thinning to wider spacings, or repeated thinning entries is recommended to promote late-successional stand characteristics.

Cissel, John. 2001. **Application of Young Stand Research.** Central Cascades AMA. April 13, 2001 [handout distributed to Willamette Province Advisory Committee, April 2001.]

Issue:
Are current practices in young stands in Late Successional Reserves (LSRs) consistent with recent research on young stand development? Are land managers taking sufficient actions to meet LSR objectives?

Situation:
Recent presentations to REO and to RIEC by Tom Mills and Mike Collopy made a case that there are new science findings that support more active thinning practices in young stands to meet LSR objectives. An ad hoc science findings technical team was formed to evaluate the situation, consider options, and make recommendations to REO and RIEC at the May RIEC meeting. A group consensus from a recent meting stated:

> "The principles and processes provided by Andy Carey and John Tappeiner indicate very strong support for active management (thinning, selective thinning, and possibly underplanting) in young dense forest stands

that resulted from clearcutting and replanting practices. In order for these stands to develop late successional/old-growth characteristics and associated biodiversity, active management is required to alter the current trajectory of these stands. The group agreed that the principles and practices are sufficiently established to support implementation of management actions for the Northwest Forest Plan area west of the Cascade crest . . ."

New Science:

. . .

John Tappeiner – key points

Management agencies harvest and replanted approx. 3,000 acres of forest per year on the Siuslaw National Forest during the 1980s (converted mid-to-late seral stages to early seral stage). Agencies are currently thinning these converted stands at a rate of approx. 500 acres per year . . . This will result in a large quantity of the landscape [including the presumed habitat in the LSRs] remaining in the dense competitive exclusion stage for a considerable length of time. Tappeiner's and Carey's research indicates that Douglas-fir forests in this stage support very little biodiversity; these stands have very low probability of developing into multi-layered, diverse stands; and these stands will NOT develop characteristics needed (large diameter trees with full open crowns) for the stands to be stable for 150-500 years to serve as long-term reserves for wildlife habitat.

. . .

Andy Carey – some key points:

Important to maintain the normal processes in forest to provide needed ecological services. Don't emphasize stand structure or structure-based management . . . don't force unwanted homogeneity.

. . .

Main point of thinning . . . is to maintain the active ecological processes and functions in order to provide ecological services.

Caveat:

A recently completed Phd. Dissertation by Linda Winter from the University of Washington documents a detailed stand reconstruction in the southern Washington Cascades showing old growth stands can develop out of dense young stands without "intrusive thinning practices."

Cole, Elizabeth. 1996. **Managing for Mature Habitat in Production Forests of Western Oregon and Washington**, Weed Technology. Volume 10(2):422-428. April-June 1996.

Successful establishment of understory regeneration will depend upon regulation of competing species in both the overstory and the understory. Dominant conifers are capable of rapid growth, and full site occupancy can occur quickly after even heavy thinning.

. . .

Near Corvallis, OR. Fifty-year-old Douglas-fir stands were thinning to . . . one-third to one-half of full stocking and then underplanted with Douglas-fir, western hemlock, grand fir, and western red cedar. . . . Three trends in the first year survival data were apparent: (a) survival was greater with a lower density of residual trees; (b) survival of the more tolerant western red cedar and grand fir was greater than Douglas-fir;

Curtis, R.O., D.S. DeBell, C.A. Harrington, D.P. Lavender, J.C. Tappeiner, and J.D. Walstad. 1998. **Silviculture for multiple objectives in the Douglas-fir region**. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Gen. Tech. Rep. PNW-GTR-435. 123 p. http://www.fs.fed.us/pnw/pubs/gtr435/gtr435b.pdf

Shaping Development of Young Natural Stands and Plantations

. . .

Existing young natural stands (or plantations) will not necessarily develop into stands comparable to present old-growth in the absence of human intervention. The desire to retain such features or to produce similar features in managed forests has stimulated interest in various modifications of conventional silvicultural practice (Carey and Curtis 1996, DeBell 1989, DeBell and Curtis 1993, Franklin and others 1986, Kohm and Franklin 1997).

The general nature of silvicultural practices needed to foster structural features similar to those of natural mature and old-growth forests is fairly apparent, but the specifics of implementation are not. It may be obvious, for example, that a given feature (such as a shrub species in the understory) provides important habitat for one or more species. But little is known about the response of the forest ecosystem or of other species to various levels or distribution patterns of that feature. Even less is known about other biological or economic costs and benefits associated with such management. Appropriate practices undoubtedly will differ with forest types, landscapes, specific stand and site conditions, and public preferences. These uncertainties should not be used to justify reluctance or failure to modify conventional practices. But they should foster a skepticism of widespread implementation or legislative requirement of untested, highly specific modifications, particularly in the absence of effective monitoring efforts. And such uncertainties also should stimulate soundly designed experiments to test and compare a range of approaches or options.

The greatest near-term opportunity to develop such management knowledge and experience and to provide more diverse habitat lies in the millions of acres of existing plantations, which range in age from 1 year to 40 or 50 years. Plantations are sometimes disparaged as uniform monocultures of minimal or even negative value for purposes other than wood production. This view arises in part from the fact that many plantations in the Pacific Northwest are now in the early stem exclusion stage, in which relatively uniform and dense canopies have eliminated most understory vegetation. Moreover, plantations usually appear much more uniform when viewed from a highway or forest road than they are in fact (fig. 19). Even without further management, this uniformity is gradually modified by natural processes of stand development and by such agents as root diseases and snow breakage, in a manner similar to that occurring in natural stands (Silviculture Interpretations Working Group 1992). Many plantations established 40 or more years ago are now barely recognizable as plantations. With appropriate management, stand differentiation can be accelerated (Curtis and others 1997). Most of these plantations are now in a highly plastic stage of development, and there are major opportunities to mold them-individually and in a landscape context toward a variety of objectives.

. . . A number of modifications of conventional silvicultural practices merit consideration and some are now being applied by several landowners and organizations.

. . .

A number of modifications [of precommercial thinning prescriptions] to promote biodiversity are possible and have been applied to a limited extent on some public lands. These modifications involve selection criteria for residual trees, spacing distances, and intentional creation of small openings.

. . .

. . . Thinned stands produce larger trees at any given age than do unthinned stands; thinned stands are more open and sometimes more diverse. One recent study in the Pacific Northwest (Marshall and others 1992) showed that over a 20-year period repeated thinning in a young stand on a good site produced increases of 33 to 56 percent in diameter growth of the largest 40 stems per acre, compared to the unthinned condition (fig. 24). Thinning also provides income and timber flow during the intermediate stages of stand development.

Most past thinning studies were oriented to timber production, but thinning also strongly influences other stand attributes. Thinning, depending on how it is done, may or may not promote vertical stratification (figs. 25 and 26). It usually accelerates understory development and succession and movement of the stand into the understory reinitiation stage. If begun early, changes can be striking over comparatively short periods (fig. 27). Operationally, there can be considerable loss of understory from damage during thinning. If understory reduction is considered undesirable, such effects can be minimized by training, use of designated skid trails and corridors, proper equipment, and heavy initial thinning that allows relatively long intervals between subsequent thinnings.

Most thinning research has been done in young and intermediate-aged stands (<60 years). Opportunities to influence tree and stand development through thinning are greatest if thinning is begun early. A first thinning that is delayed until after stands have developed high relative densities and shortened crowns involves an increased risk of windthrow and snow breakage as well as delayed growth response and therefore must be lighter (usually) than an early initial thinning. Crown expansion potential slows with age, and therefore thinnings should generally become lighter and entries less frequent as stands age; however, even late thinning in vigorous, relatively old stands (>100 years) can be effective in capturing some mortality, maintaining stand vigor, and reducing losses from insects and disease (Williamson 1982, Williamson and Price 1971). The maximum age at which thinning is justified in relatively vigorous stands is more a matter of owner objectives than biological limitations. Financial returns and development of specific habitat characteristics may be important considerations.

. . .

Thinning encourages seedling establishment of shade-tolerant conifers (Del Rio and Berg 1979), hardwoods (Fried and others 1988) and shrubs (Huffman and others 1994, O'Dea and others 1995, Tappeiner and Zasada 1993), but it also results in vegetative expansion of shrubs by rhizomes (Tappeiner and others 1991) and layering. By reducing overstory density and providing a seedbed, thinning results in invasion by new plants not previously in the stand (Carey and others 1996b) and the spread of those already established. This generally produces a dense, diverse understory of shrubs, herbs, and tree seedlings and saplings that may provide enhanced wildlife habitat.

Regeneration of understory conifers after thinning often will enhance the development of stands with structures similar to mature and old-growth stands. On some sites, however, thinning may produce dense shrub layers that inhibit later establishment of desired conifers. Dense understories of salal, Oregon grape (*Berberis nervosa* Pursh), salmonberry, vine maple and other shrubs may develop and prevent establishment of a second layer of conifers. Conifer seed will germinate under such shrub layers but few seedlings survive. These shrub layers often are quite persistent. They produce new aerial stems annually that replace older stems as they die, thereby maintaining a dense cover for decades (Huffman and others 1994). On some sites (particularly at low elevations and in the Oregon Coast Range), some disturbance of these brush layers and possibly underplanting of conifers may be necessary to establish multilayer conifer stands.

Providing Diverse Structures and Habitats

. . .

. . . to provide and maintain habitat for a wide variety of species, a balanced distribution of stand structures and developmental stages needs to be developed across landscapes (Oliver 1992).

Because forests are dynamic entities, this implies active management to produce desired structures and regenerate stands as needed to maintain the desired age and stand condition distributions. The biggest current imbalance is the general lack of mature and old-growth stands on non-Federal lands. The recent establishment of large late-successional reserves will, if long continued, produce a similar shortage of early successional stages on Federal lands in the future. These imbalances will not be mutually compensating because of wide geographic separation.

Much recent discussion of biodiversity has focused on old-growth stands and on efforts to shape younger stands toward similar conditions, although this represents only one segment of the needed range in stand conditions. This emphasis on old growth probably arises from the perception that this is the condition in most limited supply and most difficult to replace if lost.

Forest characteristics important for some wildlife and aesthetic values do include some characteristics commonly associated with mature and old-growth stands: (1) large trees; (2) layered structure including some understory trees and shrubs; (3) mixed species composition; (4) presence of large snags and live trees with cavities or other attributes needed for nesting, roosting, and foraging; (5) presence of large woody debris on the forest floor; and (6) within-stand variation in overstory density and corresponding variation in density of the understory. Although these characteristics commonly develop at advanced ages in unmanaged stands, there is abundant evidence that their development can be markedly accelerated in much younger stands by appropriate silvicultural measures (e.g., table 1; Curtis and Carey 1996). Currently heavily stocked young stands may not develop these characteristics without silvicultural treatment (Tappeiner and others 1997). Many of these measures also can produce direct economic benefits through the concomitant production of wood.

. . .

Stand Management for Structural Diversity

Modifications of conventional thinning practice (table 1) might include favoring trees of diverse species and sizes to foster crown stratification and understory development for improved wildlife habitat (Hagar and others 1996). Small openings or gaps can be created, which ultimately will be occupied by younger trees. Root rots, bark beetles, and windthrow often do this independent of human intervention. As stands grow older, dead trees can be retained to provide snags needed for some wildlife species; if needed, additional snags can be created. Tolerant tree species such as western redcedar, grand fir, Pacific yew, western hemlock, and bigleaf maple can be introduced through underplanting, if seed sources of these species are lacking. Most species are more tolerant when young, and conditions suitable at establishment may have to be altered as plants age. Regeneration in riparian areas can be especially challenging; these sites often have substantial existing understory vegetation, and animal damage to young trees may be severe.

Modifications such as irregular thinning and underplanting are being evaluated in the forest ecosystem study recently installed at Fort Lewis, WA (Carey 1993, Carey and others 1996b), the Olympic habitat development study (Harrington and Carey 1994), and the COPE (Coastal Oregon Productivity Enhancement) program (Emmingham 1996). Thinning prescriptions in these studies are designed to increase within-stand variation in crown lengths, tree size, species composition, and understory distribution. . . .

There are many well-stocked young stands (10 to 50+ years) in the Douglas-fir region that have been established after fire or timber harvest. About 30 to 60 percent of many watersheds on Federal land, and a majority of private lands, are stocked with these young stands. For the most part, they have been regenerated and managed at high densities to produce high yields of wood, and not to develop diverse structure. In contrast, old-growth stands often have only 10 to 30 trees per acre in the upper canopy (Spies and Franklin 1991). Thus, if we wish to develop future old-growth-like characteristics in some portion of these young stands, considerable reduction in stocking over time is needed to produce large trees with deep crowns and provide a more open environment for understory development. Seedlings of tolerant species can be established after thinning in young conifer stands, but subsequent reduction in canopy density will be needed to ensure their future development. . . . Alan Berg of Oregon State University thinned a 40-year-old Douglas-fir stand to 50 trees per acre and planted western hemlock in the understory. About 40 years later, this is a well-developed two-storied stand (Curtis and Marshall 1993). At 80 years of age, the overstory of 50 trees per acre is probably too dense for continued understory growth, although the overstory trees are still growing rapidly. Average diameter of the Douglas-fir overstory is about 30 inches. In the nearby unthinned stand, average diameter is only 15 inches with practically no understory.

. . .

Providing Cavities, Snags, and Coarse Woody Debris

In stands managed for wood production, decadent, dying, and dead trees have been viewed as problems to be avoided or at least minimized by harvesting before they deteriorate or contribute to spread of insect pests and disease. . . . Yet dying, dead, and down trees are important components of forest ecosystems, and a variety of organisms are associated with them. These organisms range from cavity-dwellers like squirrels and other small mammals and many birds, to amphibians and invertebrates, to diverse vascular **and** nonvascular plants and microorganisms. Provision therefore should be made for dead wood management in multipurpose forests, particularly those where conservation of biodiversity is a primary management objective.

Other Considerations

. . .

Thinning and alternative regeneration systems, combined with extended rotations, will minimize the influence of the stem exclusion stage and of harvests on dispersal and colonization processes. They will promote development of structural diversity and, with suitable placement and sizes of harvest units, should reduce or eliminate the unfavorable effects often thought to be associated with forest fragmentation into spatially disconnected units of radically different characteristics. . . .

Summary, Diverse Structures

Stand characteristics favorable to some biodiversity, wildlife, and aesthetic goals can be actively enhanced by a number of modifications to conventional silvicultural practices and additional measures. These include:

- Modified thinning practices to develop mixed species stands, multiple canopy layers, and more diverse understories. Irregular thinning and underplanting of openings with tolerant species can be used to promote vertical and horizontal heterogeneity.
- Thinning, especially if begun early, to produce large trees with deep crowns (more nearly comparable to those in existing older stands) and a more open environment for understory development. Early thinning minimizes the duration of the least diverse and least productive (for wildlife) stem exclusion stage of stand development.
- Retention of some hardwoods and minor species in thinning can enhance species and structural diversity.
- Release of existing conifers and underplanting of tolerant species in riparian hardwood stands can provide a more diverse riparian forest and eventually produce the large conifer logs needed to enhance stream channel structure.
- Protection or retention of standing dead and down trees, where feasible, for nest sites and coarse woody debris.
- Protection of live trees with cavities as nest sites.
- Creation of snags, cavity trees, and down trees in stands where they are scarce or absent.
- Retention of scattered trees or (probably preferable) groups of trees at harvest, for future production of snags and coarse woody debris.
- Use of extended rotations (in combination with thinning) and alternative regeneration systems to develop a wide range of stand ages, tree sizes, and structures.

Dooley, Jim and Justin Maschhoff. 2002. **Technical Products from Small Diameter Timber for Habitat Enhancement and Watershed Restoration,** Prepared for presentation at: Small Diameter Timber: Resource Management, Manufacturing and Markets. February 25-27, 2002. Spokane, WA.
http://www.elwdsystems.com/pdf/022702.pdf

An under-appreciated outlet for small diameter roundwood is in watershed restoration, environmental and habitat enhancement programs. Over $2 billion is spent in North America on habitat enhancement and watershed restoration each year. Of that amount, our estimate is that approximately $300 million is spent on materials that could be made from small diameter timber. Products manufactured from forest thinnings and subsequently placed back in the watershed completes the watershed cycle, and at the same time provides income for forest landowners, woods workers in rural communities and environmental restoration contractors. This presentation details a number of technical products that can be manufactured from small diameter timber for use in erosion control, watershed restoration and habitat enhancement.

Duncan, Sally. 2002. **VOLUME, VALUE, AND THINNING: LOGS FOR THE FUTURE,** Science Findings, USDA PNW Research Station. November 2002.
http://www.fs.fed.us/pnw/sciencef/scifi48.pdf

Contrary to some views held in the past, thinning in uniform-aged
Douglas-fir forests will not markedly increase total volume production.
That is, not unless rotations are extended well beyond 50 years. . . .
. . .
The LOGS study consists of nine installations established between 1961 and 1970. The sites range from southern Oregon, all the way north through Washington to Vancouver Island, British Columbia, in Canada. Each installation comprised 27 one-fifth acre plots, carefully selected to be uniform and comparable in site and stocking. Each installation includes three replications of eight thinning treatments, and an unthinned control. Plantations and naturally seeded stands were both represented.
. . .
Findings across all the installations have confirmed that thinning can greatly modify and accelerate development of particular stand structures, and can increase diversity within stands.
. . .
KEY FINDINGS
. . .
• Growth of individual young Douglas-fir trees responds rapidly to thinning. In contrast to stand growth, tree growth decreases sharply as stands become denser.
. . .
• Thinning treatments can produce stands that differ greatly in appearance, tree size, crown development and understory development.

LAND MANAGEMENT IMPLICATIONS
. . .
• Thinning can greatly accelerate stand development and diversity.

Duncan, Sally. **IT'S NOT EASY BEING GREEN: THE TRICKY WORLD OF SMALL-DIAMETER TIMBER. ISSUE FOUR,** PNW Research, Science Findings, MAY 1998.
http://www.fs.fed.us/pnw/sfmay.pdf

> . . .
> [T]he Rocky II sale in the Colville National Forest . . . was used by the Pacific Northwest (PNW) Research Station to investigate the silviculture, ecology, utilization, and economics of small-diameter densely stocked stands. . . .
> . . .
> **KEY FINDINGS**
> . . .
> • Alternative harvesting systems exist that remove small-diameter timber in an ecologically sound manner, but costs are higher than traditional methods.
> . . .
> HARVESTING COSTS AND WOOD PRODUCT VALUE
> . . .
> The forest operations segment of the Colville study evaluated harvesting alternatives for various silvicultural prescriptions and also provided information on the costs and productivity of different harvesting systems. The goal was to minimize soil degradation and any damage to the residual stand.
> . . .
> The study showed that tree diameter does not affect the quality of the wood. Densely packed trees are slower growing, with fewer, smaller branches and proportionately less juvenile wood.
> . . .
> We've learned a lot from techniques in Finland and Sweden, where they've been working with this kind of timber for 200 years," he says.
>
> Processing is basically a linear procedure, with logs traveling through the system at a fixed rate regardless of size. For example, a 10 d.b.h. log takes the same time as a 4 d.b.h. log to be processed, but produces about three times the amount of wood. Thus, although manufacture of a wide range of products from this smaller wood may be feasible technically, costs may be prohibitive.
> . . .
> The number of no-bid sales on densely stocked small-diameter stands is actually dropping slowly, as Forest Service managers and private industry learn, both separately and together, how to approach the world of small-diameter timber. Says Fight, "Barring major policy change, we're going to be plagued with small-diameter timber from here on. We'd better learn how to work with it."
> . . .
> **LANDMANAGEMENT IMPLICATIONS**
> • Opportunities exist to improve ecological health and biological diversity through thinning and other selected silvicultural treatments; with careful presale analysis, commercial logging can be used to underwrite some ecosystem objectives.

Duncan, Sally. **DEVELOPING NEW SILVICULTURAL REGIMES: THE EYES HAVE IT;** Science Findings, USDA Forest Service, PNW Research. January 2000.
http://www.fs.fed.us/pnw/sciencef/scifind21.pdf

> One key finding to emerge early from the study is that foresters, environmentalists, tree farmers, and nonforestry undergraduate students view the aesthetics of many silvicultural practices similarly. The differences of opinion among these groups are mostly in the degree to which they like or dislike a particular practice.
>
> . . . most stands are 60 to 70 years old . . .
>
> Six silvicultural options have been selected for comparison, each option imposed on areas from 35 to 80 acres. Each will be replicated three times on the forest.
>
> The six options applied include a clearcut . . . There is also an extended rotation without thinning—a "nonharvest" option that defers management of any kind, thus providing an experimental control . . .
>
> Between these two ends of the spectrum lie three regeneration alternatives that provide two-aged and multiage forests. A uniform retention option initiates a two-aged system that leaves about 15 trees per acre in the overstory, which would be retained through the next harvest, providing large trees and high-quality wood. A small patch cutting regime would allow regeneration in patches of 1.5 to 5 acres with surrounding areas thinned as needed. Twenty percent of the total stand will be regenerated at 15-year intervals, resulting in five age classes over a 75-year period. Group selection provides an uneven-aged system in which trees are cut in groups occupying less than 1.5 acres. Regeneration harvest to produce gaps will occur at 15- year intervals, and surrounding areas will be thinned as needed.
>
> The sixth alternative is an extended rotation with commercial thinning. Repeated thinnings will be needed to maintain high growth rates for extended periods. Regeneration harvest will be deferred. An understory of tolerant species will develop under this system. This alternative provides a contrast for the extended rotation without thinning.
> . . .

Predictably, the clearcut is usually seen as the "worst" and the nonharvest as the "best" to almost all viewers.

Duncan, Sally. 2001. **INVASION OF THE EXOTICS: THE SIEGE OF WESTERN WASHINGTON. Science** Findings, October 2001.
http://www.fs.fed.us/pnw/sciencef/scifi38.pdf

KEY FINDINGS

• Studies of soil seed banks in young, closed-canopy, second-growth forests revealed that 30 percent of all species were weedy exotics, only 24 percent were natives, and no tree species were present. Thinning these stands could favor exotic species.

• Many of the small mammal communities in uniform second-growth stands are incomplete and differ in structure from communities in naturally young- or old growth stands.

• Variable-density thinning has the potential to increase species richness within a short timeframe, provided it is used in a holistic approach that includes biological legacies, long rotations, and tree species diversity.
. . .
• Invasion by exotics and globalization of flora is a real and present problem, requiring thoughtful landscape-level planning.
. . .
In the early stages of stand development, coniferous forests of the coastal Pacific Northwest commonly pass through a period of dense shade and intense competition. During this phase, the abundance and diversity of understory plants decline dramatically.

This closed-canopy stage represents a critical juncture in the development of the forest understory. Canopy closure may result in the local extinction of some forest species and thus shape longer term patterns of understory composition and diversity, Carey explains.

A prevailing theory is that thinning dense young forests will help stimulate the suppressed understory. But the mechanisms by which understory species persist or reestablish are poorly understood. A cooperative study with Carey and Connie Harrington, a research forester at the PNW Research Station, Charles Halpern, a research associate professor at the University of Washington, and others from the university examined the potential contribution of the bank of seeds retained in the soil. The Olympic Peninsula was selected for its extreme tree densities and light exclusion during early forest regeneration in this wet and productive climate.

"Germination of buried viable seeds is likely to be stimulated by the abrupt increases in light produced by thinning," Carey says. "To what degree this promotes desirable species—such as shade-tolerant, native herbs, shrubs and trees—or encourages the germination of exotic species, depends in part on the composition of the seed bank."

The researchers investigated which species were present in the understory seed bank, and in what relative abundances. They also looked at how the litter layer seeds differed from that of the mineral soil and how seed bank composition differed among different parts of the forest.

In an area where increasing attention is being given to the concept of restoring native understory vegetation via the soil seed bank, the news is not good. In the seed banks of 40- to 60-year-old unthinned, closed-canopy stands, 30 percent of all species were weedy exotics, only 24 percent were typical understory species, and tree species were absent.

"It has been hypothesized that the soil seed bank may provide one source of propagules for recruitment of forest understory species, but our results suggest otherwise: silvicultural thinning will result in limited germination of forest species but will often favor recruitment of exotic species," Carey says. "Moreover, retrospective studies of understory response to thinning suggest that some of these weedy species may be able to persist for decades following treatment."

That's not all. Carey notes that many of the small mammal communities in 37 second-growth forests studied were incomplete and differed in structure from communities in both naturally young stands and old growth. "Simplification of forest structure and composition has had negative consequences on small mammals and, presumably, on numerous ecosystem processes," he says.

Small mammal communities have potential as indicators of healthy forest floor function because they disseminate seeds, spores, and propagules of shrubs, bryophytes, fungi, and lichens, Carey explains. They also physically mix the soil, decomposed organic matter and litter, regulate some invertebrate populations, and provide prey for terrestrial and bird predators.

Not enough attention has been paid to the amounts of understory needed to maintain various food pathways for small mammals because understory development is often simply a by-product of management for high-quality timber. But Carey and others have produced some preliminary studies suggesting that plant species composition and spatial arrangements of plants are important to small mammal communities.

Hence, the arrival and spread of exotics, often to the exclusion of natives, augurs badly for creatures such as Trowbridge's shrew, red-backed and creeping voles, the deer mouse, and the montane and vagrant shrews.

Erickson, Janet L., and Stephen D. West, **Associations of bats with local structure and landscape features of forested stands in western Oregon and Washington**, Biological Conservation, Volume 109, Issue 1, January 2003, Pages 95-102
http://www.sciencedirect.com/

Abstract: Understanding the processes that underlie bat distribution and activity patterns requires examination of habitat associations at multiple scales. We examined the association of both local structure and landscape context with bat activity in forested stands using ultrasonic detectors. Forty-eight stands in western Oregon and Washington were monitored for bat activity on at least six occasions for each of two field seasons. At the stand level, bat activity was negatively associated with tree density. The standard deviation of tree density and the density of newly created snags were positively associated with bat activity. In combination, these three variables explained 46% of the total variance in bat activity among stands. Landscape-level variables did not explain any significant variation among a subset of stands (n=22). Our study suggests that management of forest-dwelling bats should focus primarily on structural attributes at the stand level and the effects of these features on feeding and roosting opportunities.

Franklin, J.F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. **Ecological characteristics of old-growth Douglas-fir forests.** PNW-GTR-118. USDA Forest Service. PNW Research Station. February 1981.
http://www.fs.fed.us/pnw/pubs/gtr118part1.pdf
http://www.fs.fed.us/pnw/pubs/118part2.pdf

Rapid development of large, long crowned trees as early as possible is a key objective of management that can be aided several ways. Selection of under stocked stands of reproduction as sites for creating old-growth stands is one approach since individuals will grow faster and lose lower branches more slowly under open-grown conditions. Many existing old-growth stands may have regenerated slowly (Franklin and Waring 1980); growth patterns of individual trees suggest growing conditions essentially free from competition for a century or more. If initial densities of stands are moderate-at current recommended levels for managed stands -precommercial and commercial thinnings will be necessary during the first 100 years of a long-rotation forest management cycle. Growth rates of individual trees will be too low at high densities, or at moderate densities on less productive sites, to produce desired sizes of stems even after 200 years; thinnings and partial cuttings are essential under those conditions. Great care must be taken, however, to minimize damage to residual trees.

Franklin, Jerry F. 1998. **The Natural, the Clearcut, and the Future.** Pages 134-138 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).
http://www.pfc.forestry.ca/ecology/sfrw/41frank.pdf

Studies of natural, including old-growth, forests have clearly shown that their composition, functional capabilities, and structure are very different from those of plantations and other young stands that are intensively managed for wood production. Natural forest ecosystems have proven to be very rich in specialist organisms that do poorly or are absent from young managed forests although structural legacies from the old forests (such as large rotten logs) have sometimes allowed these species to persist in the first generation of a managed forest.
. . .
Many of the specialized habitats and functional abilities of natural forests are related to their structural complexity. These forests—whether young, mature, or old—typically have a high diversity of individual structures: live trees of various species, sizes, and conditions; standing dead trees or snags of varied sizes and stages of decay; and logs and other coarse woody debris on forest floors and in adjacent streams and rivers. Just as important, natural forests display incredible spatial diversity in both the horizontal and vertical dimensions —they are anything but uniformly spaced stands of trees with simple, umbrella-like foliar canopies!
. . .
Naturalness is the great icon of the environmental community and, based upon this icon, preservation or protection of forest lands is the primary basis for conserving biological diversity. Unfortunately, it is increasingly clear that we cannot achieve the objective of protecting the bulk of forest biodiversity by relying on reserves. In the temperate zones (and probably the tropics as well) we are never going to preserve enough land at appropriate locations to achieve that goal.
. . .
A critical key to sustaining forest biodiversity has to be in the management of the matrix—the unreserved portion of the landscape—so that it also provides suitable habitat for a broad array of species. This is not a message that is well received by either hard-core environmentalists or utilitarians. Who wants to worry about improved (i.e. more ecologically sensitive) silvicultural practices when there are pristine environments to be preserved or greater profits to be made! Who wants to have to work in perpetuity with their antagonists?!
. . .
The plantation model of stand structural development is *not* comparable to the development of most naturally regenerated stands— and for good reasons from the standpoint of timber production! In contrast with a natural model

> of stand structural development the plantation model does not recognize the importance of biological legacies, structural complexity in natural stands, and the extent and importance of structural development . . .

Franklin, Jerry F. 2001. **Keynote Comments: Managing Young Stands to Meet LSR and Riparian Objectives;** Workshop held at Portland, OR on August 29, 2001.
http://www.reo.gov/ama/franklin2001.htm
http://www.fs.fed.us/r6/plan/franklin2001.htm

> My current working hypothesis is that there are many developmental pathways that ultimately produce the structural complexity of old-growth forest. Furthermore, variability in pathways is probably the rule within stands as well as between them, a consequence of the complex burning patterns typical of large wildfires. At this point I want to state clearly that I strongly support the view that well-designed silvicultural activities in the young stands regenerated following logging can accelerate the development of many old-growth structural attributes and is worth doing.
> . . .
> Variable density thinnings are going to be the most appropriate general approach in my view.
> . . .
> Many other silvicultural activities, in addition to thinning, can help accelerate development of structural complexity. 1) Felling trees to create woody debris and killing trees to create snags; many of us feel that the best strategy in creating snags is to leave some live crown behind so that trees die gradually and decay more naturally. 2) Wounding trees to stimulate decay and cavity creation and to generate upper canopy complexity (multiple tops, regenerated branch systems). 3) Underplanting shade-tolerant tree species makes an important contribution to stand development in stands that currently lack a shade-tolerant component.
>
> . . . if nature will eventually do most of the job anyway—why should we proceed with young-stand treatments in LSRs?
>
> Because, by carrying out appropriate young-stand treatments we can contribute greatly to the restoration of old-growth structure. In my view, should do so for the good of both the forest and society. We really do not want to wait several centuries for nature to do the job alone, assuming that she will. Good-quality old-growth forests are in short supply in our region—we need to expand the extent of structurally-complex forests as quickly as possible to achieve our goals, including reduced risks to late-successional forest species. We need to re-establish the integrity and capability of the LSRs as quickly as possible.

Franklin, Jerry F., Thomas A. Spies, Robert Van Pelt, Andrew B. Carey, Dale A. Thornburgh, Dean Rae Berg, David B. Lindenmayer, Mark E. Harmon, William S. Keeton, David C. Shaw, Ken Bible, Jiquan 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 (2002) 399–423.
http://research.eeescience.utoledo.edu/lees/pubs/franklin2002.pdf

> Our purpose is to make clear the challenge of managing forest stand-structure so as to maintain biological diversity and sustain forest productivity. Simplistic structural classifications can lead managers to believe that they can easily replicate examples of natural forests through silviculture (Scientific Panel on Ecosystem Based Forest Management, 2000; Aber et al., 2000). Foresters can and must learn to manage forest stands that sustain biological diversity and a range of essential processes, but they will be most successful if their efforts are based on a comprehensive understanding of the structures and developmental processes in natural forest stands.
> . . .
> We recognize eight such exemplary developmental stages in stand development (Table 3). Disturbance and legacy creation, cohort establishment, canopy closure, biomass accumulation/competitive exclusion, maturation, vertical diversification, horizontal diversification, and pioneer cohort loss.
>
> **Table 2**
> **Some structural processes that are operational during the successional development of forest stands in approximate order of their first appearance**
>
> Disturbance and legacy creation
> Establishment of a new cohort of trees or plants
> Canopy closure by tree layer
> Competitive exclusion (shading) of ground flora
> Lower tree canopy loss
>   Death and pruning of lower branch systems
> Biomass accumulation
> Density-dependent tree mortality
>   Mortality due to competition among tree life form; thinning mortality
> Density-independent tree mortality
>   Mortality due to agents, such as wind, disease, or insects
> Canopy gap initiation and expansion
> Generation of coarse woody debris (snags and logs)
> Uprooting

Ground and soil disruption as well as creation of structures
Understory re-development
Shrub and herb layers
Establishment of shade-tolerant tree species
Assuming pioneer cohort is shade-intolerant species
Shade-patch (anti-gap) development
Maturation of pioneer tree cohort
Achievement of maximum height and crown spread
Canopy elaboration
Development of multi-layered or continuous canopy through
Growth of shade-tolerant species into co-dominant canopy position
Re-establishment of lower branch systems on intolerant dominants
Development of live tree decadence
Multiple tops, dead tops, bole and top rots, cavities, brooms
Development of large branches and branch systems
Associated development of rich epiphytic communities on large branches
Pioneer cohort loss

. . .
. . . plantations created on clearcut sites are much simpler than young stands developed after natural disturbances.

Garman, Steven L. 2001. **Accelerating Development of Late-Successional Conditions in Young Managed Stands: A Simulation Study,** *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.
http://www.fsl.orst.edu/ccem/OGabstracts.pdf

Previous simulation and empirical studies have suggested the importance of thinning in accelerating the development of late-successional conditions in young Douglas-fir stands. This study used the PNWGAP simulation model to examine trade-offs in developmental rates of live and dead-wood attributes among a wide range of thinning treatments, starting with a 40-year old Douglas-fir stand and employing three thinning entries by stand age 80.
. . .
Thinning to 136 [trees per hectare] at age 40 produced more rapid development of large boles (>100 cm dbh) than lighter thinning levels or not thinning at all, regardless of subsequent thinning densities. . . .

Long-term levels of late-successional attributes indicated trade-offs between rapid development and potential levels of attributes. Treatments which promoted the relatively rapid development of large boles (>100-cm dbh) generally produced fewer large boles over the long-term. Snag and shade-tolerant stem densities exhibited somewhat similar trends. Thus, both short-term and long-term goals for a stand need to be considered when selecting thinning strategies.

Garman, Steven L., 2000. **Biodiversity Response to Thinning Young Managed Stands.** H.J. Andrews Third Annual Symposium, "Future ecosystem science at the Andrews," Oregon State University, Corvallis, Oregon. March 2, 2000.
http://www.fsl.orst.edu/lter/pubs/annlsymp/ann3symp/authors/abstract.htm

Recent emphasis on balancing timber production and ecological diversity has motivated alternative silvicultural methods for young managed stands. The Willamette National Forest, in co-operation with Oregon State University scientists, initiated a field study to examine the effects of three replicated thinning regimes for young (40-year old) managed Douglas-fir stands on a range of ecosystem attributes. This study examined the effects on ground-dwelling vertebrates (small mammals and amphibians) 4-5 years after three thinning treatments (heavy thin, light thin, light thin with 20% of the area in canopy gaps) and no thinning (control). Also, this study used simulation modeling of future, potential silvicultural methods to examine stand trajectories, development of late-successional characteristics, and bird-habitat diversity.

Responses to thinning were evident for three species of small mammal and one species of amphibian. The deer mouse exhibited the strongest, positive response to thinning treatments although there were no differences in relative densities of this species among the thinning treatments. Two shrew species exhibited weak, negative response to the heavy thinning treatment. Ensatina exhibited a weak, positive response to heavy thinning. In general, species diversity was not significantly different before or after treatments among thinning treatments.

A gradient of future thinning regimes for each of the three initial thinning treatments illustrated the importance of future thinning levels. For all three initial thinning treatments, rapid development of late-successional characteristics (large boles, large snags and logs, tree-species diversity) was associated with heavy thinning at age 60 followed by very light thinning at age 80 or no subsequent entry. Among the three initial treatments, the heavy thinning treatment resulted in the fastest development of late-successional characteristics followed by the light thin with gaps and the light thin treatments. Long-term modeled bird diversity increased with developmental rate of late-successional attributes. However, short-term trends (first 40 years after treatment) in diversity were inversely related to overall thinning levels. Trade-offs among potential silvicultural approaches in volume production, bird-species diversity, and developmental rate of late-successional attributes are illustrated as a guide for selection of management approaches given desired future conditions.

Garman, Steven L. 2001. **Response of Ground-dwelling Vertebrates to Thinning Young Stands: The Young Stand Thinning and Diversity Study.** Submitted To James H. Mayo, John H. Cissel, Cascade Center for Ecosystem Management. December 2001.
http://www.fsl.orst.edu/ccem/yst/pubs/smallmammals.pdf

About a million hectares of mature and old-growth Douglas-fir (*Pseudotsuga menziesii*) forests in western Oregon and Washington have been converted to young plantations over the past 50 years (Debell et al. 1997).
. . .
Traditional methods involved clearcut harvesting (removal of all trees and snags), burning of residual woody debris, planting of conifer seedlings at close spacing, and manual or chemical control of competing vegetation. Compared to stands regenerated after natural disturbances, these plantations noticeably lack features such as large live trees, large dead wood (snags and logs), vertical and horizontal variation in tree canopies, and a significant component of broadleaf trees (Franklin et al. 1981, Spies et al. 1988).
. . .
There is general consensus that commercial thinning can be used to increase the complexity of young plantations (Spies et al. 1991, DeBell et al. 1997, Tappeiner et al. 1997, Hayes et al. 1997). Increased light levels due to thinning can accelerate diameter growth and crown lengths of residual trees, increase development of multiple canopy layers, and promote development of ground cover.
. . .
Until recently, however, experimental investigation of trade-offs among thinning strategies, stand complexity, and biodiversity were lacking.
. . .
This paper reports on treatment effects for ground-dwelling vertebrates 2-5 yrs after implementation of the thinning treatments.
. . .
Thinning young Douglas-fir stands had little impact on the diversity and evenness of the small mammal community.
. . .
Only the northern flying squirrel was apparently eliminated from a thinning treatment. Relative abundance of the northern flying squirrel generally declined with thinning, especially in the heavy thin treatment where it was not recorded in any of the three post-treatment sampling years. Reduction of flying squirrel densities with overstory removal would be expected given dependence of this arboreal species on trees for nesting and resting (Carey 1991, 1995). Given that ground-based traps are not optimal for recording this species, however, the apparent elimination of the flying squirrel from the heavy-thin stand should be viewed with some caution.
. . .
Of the nine species analyzed, only the deer mice and ensatina exhibited a positive response to thinning treatments,
. . .
The thinning treatments examined in this study had little influence on the structure and composition of the ground-dwelling vertebrate community. Based on three years of post treatment sampling, the deer mouse and ensatina were the only species to exhibit a positive treatment effect. However, this effect was evident only 1-2 years after thinning. The Trowbridge's shrew exhibited a negative response to the heavy-thin treatment, likely due to the loss of shrub and ground cover. In 2001, however, there were no detectable treatment effects for this species suggesting recovery of ground-cover conditions by this time. The northern flying squirrel was the only species eliminated by a thinning treatment. No observations of this species have been recorded on the heavy-thin stands in the post-treatment phase of the study. Thinning, in general, resulted in significantly lower densities of this species compared to the uncut control stand. The Townsend's chipmunk is the only species which appears to have a delayed, positive response to thinning. Although treatment effects were not significant for this species, mean densities on the heavy-thin and gap treatments were about three-times greater than on the uncut control in 2001. However, continued monitoring is critical to determine if this species is in fact responding to vegetative development on these heavier thinned treatments.

Hagar, Joan, and Shay Howlin. 2001. **Songbird Community Response to Thinning of Young Douglas-fir Stands in the Oregon Cascades - Third Year Post-treatment Results for the Willamette N.F., Young Stand Thinning and Diversity Study**, January 4, 2001. http://www.fsl.orst.edu/ccem/yst/pubs/POSTYR3.pdf

Bird species richness and diversity increased in all 3 thinning treatments relative to controls (Table 1). Four species showed evidence ($P < 0.10$) of an increase in density in response to at least 1 thinning treatment. Of these species, Hammond's flycatcher and dark-eyed junco also have been documented as responding positively to thinning in the Oregon Coast Ranges (Hagar et al. 1996, Hayes and Weikel, unpublished data). Density of MacGillivray's warblers and western tanagers increased in heavily thinned and gapped treatments, but not in the lightly thinned treatment. The frequency of detection of 5 additional species increased in thinned stands (Table 2). Although these species were observed too infrequently to permit statistical analyses, we believe that their occurrence in at least 2 post-treatment years, usually in several blocks, and only in treated stands during the post-treatment phase, compared to their rarity during the pre-treatment phase of the study, provides evidence of a positive response to thinning treatments.
. . .
Six species decreased in density in response to thinning (Table 1). All of these species, except the hermit thrush, were common on all our study sites, and are among the most common breeding birds in the study region (Gilbert and

Allwine 1991; Huff and Raley 1991). Therefore, although these species may decrease in density following thinning, their populations are likely to persist. Furthermore, Pacific-slope flycatchers, winter wrens, and golden-crowned kinglets have been associated with old-growth forests (FEMAT 1993; Gilbert and Allwine 1991). Because thinned stands are expected to achieve old-growth structure sooner than unthinned stands (Bailey et al. 1998; Bailey and Tappeiner 1998), thinning is likely to benefit these species over the long term.

Harrington, Constance A., Dean S. DeBell, and Leslie C. Brodie. 2001. **Alternative Silvicultural Treatments for Young Plantations in the Pacific Northwest.** Poster.
http://www.fs.fed.us/pnw/olympia/silv/selected_studies/clearwater/alternative_poster.htm

Many forest plantations have uniform spacing and species composition. Wood production was usually the original management objective.

For some plantations, objectives have changed to include wildlife habitat and recreation. These other values may be produced with treatments that increase diversity in stand structure and species composition.

Silvicultural treatments	Future stand condition
Control	Stand development w/o treatment
Uniform thinning	Uniform size, structure and species composition
Thinning, plant other species	Uniform size and structure, accelerated species diversity
Thinning plus gaps	Diverse size and structure
Thinning plus gaps, plant other spp	Diverse size and structure, accelerated species diversity

When the initial thinning was done, the plantations were mostly Douglas-fir and 10 to 13 years old. Trees were 7 m tall and 11 cm in diameter.
. . .
Treatment differences exist in tree size and growth rate, stand structure, and cover of understory plants.

Cover of herbaceous plants (2 and 5 years after thinning) decreased in the control and increased with thinning and gap creation.

The control treatment had a lower percentage of trees in the larger diameter classes.

Harrington, Connie. **Potential Pitfalls in Applying Variable Density Management;** [sneak preview of future publication]
http://www.fs.fed.us/pnw/olympia/silv/selected_studies/variable/pitfalls.htm

New treatments require learning by both the practitioner/prescriber (forester, silviculturist, wildlife manager, riparian specialist, ecosystem manager, conservationist). Some potential problems:

1. Existing policies or regulations may not be appropriate with new practices. Although policies or guidelines may be changed in the future, they can be difficult to work with in the short term. For example, reporting systems for even-aged management may not lend themselves well to uneven-aged systems. Most organizations will eventually change the reporting system to better reflect what is being accomplished on the ground but it may be frustrating in the short term.

2. When starting a new type of treatment, practitioners have a limited information base to work with so they may be tempted to use a "cookbook" approach to the same treatment each time. It is important to recognize that most variable density prescriptions are based on guesses and should not be applied to large land areas. Adaptive management will be most successful if prescriptions are varied so we can better learn what the advantages and disadvantages are of each one.

3. New practices usually require more information (asking questions, reading, going on tours, training), monitoring, and more record keeping. There is no easy way around this, but managers would be wise to plan for the training and learning time that will be required.

4. Most variable treatments are inherently more expensive to apply than uniform ones (primarily because they require covering more ground to get the same amount of work done. Increases in cost can also result from being low on the "learning curve" but those cost increases should be short-term in nature.

5. Contractors may be unfamiliar with practices so costs may be high, mistakes may be made or a contractor may underbid a job and later default on the contract. Changes in contracts from traditional practices will require more effort to ensure that the contractor or potential contractor understands what is required.

6. Some treatments will require new ways to specify and monitor work. This is especially important when the work will be contracted as there are more limited opportunities for changing the specifications.

7. Increasing "gaps" in forest stands may result in greater windfall.

8. Most growth and yield models were based on uniform stands with one or a few species and a limited number and range of treatments. Most of these models assume the treatments are applied uniformly. Thus, existing models may not be easy to use or give the correct results for treatments applied non-uniformly.

9. Larger scale of application of some treatments may result in less uniformity for comparisons (this may make it difficult to test or easily compare alterative treatments).

10. Variation in marking trees within a unit may increase the sample size needed for a timber cruise (or different approach such as stratified sampling will be needed).

11. Selecting individual trees for release may make them more susceptible to damage or loss; however, loss of these trees is more important as you have invested more money in them. For example, in a pre-commercial thinning operation it will cost more to release a tree to be open-grown than to select it as a future crop tree because more trees have to be cut to create the open-grown condition. However, the open-grown trees may also be more susceptible to bear damage. Other hazards such as windthrow or top breakage may also be greater to widely-spaced trees, especially shortly after treatments.

12. Creating gaps or more open areas may encourage colonization, growth, or retention of exotic plants.

Harrington, Connie. **Tips to Consider in Applying Variable Density Management;** [sneak preview of future publication] http://www.fs.fed.us/pnw/olympia/silv/selected_studies/variable/tips.htm

1. In the past, one funding source may have paid for a project that had benefits to more than one resource area. With declining budgets that may be less feasible. If projects have multiple benefits, consider if it is possible to use multiple funding sources or people from different resource areas to help in accomplishing the work. This approach will be most successful if involvement by others is initiated early in the planning stages.

2. It may be possible to add heterogeneity to a unit without spending a lot of extra time on planning or layout if you use a combination of uniform methods and methods which increase random assignment of treatment. For example, varying size of opening to be created or species to be planted could be done by pacing on a grid and then at the grid point shaking dice, pulling tokens out of a pocket, or using a handheld computer to select treatment size, shape, or species. We have successfully done this operationally with several people involved and it worked very well.

3. If there will be more than one thinning entry into the stand, the first entry might be keyed into laying out openings on N:S lines and the next entry on E:W lines. Although it is important to reuse roads and landings, it may still be possible to add variation into a treatment just by deliberately changing the orientation of treatment layouts.

4. When consistent with the project objectives, consider ways to vary spacing or species without a lot of pre-planning. For example, it may be possible to give some members of a crew marking trees for a timber sale different marking guidelines from others or give tree planters different mixes of species in the planting bag. Rather than vary the size of openings (or spacing for a thinning) within a particular project, another approach would be to select one size opening (or spacing) for each project but vary the target from project to project so each one was internally consistent. If you keep prescriptions for small areas fairly simple it may help minimize the effort involved in setting up and monitoring contracts.

5. It has been suggested that you can vary prescriptions by using easy ways to break up a unit. For example, if you know about how many trees can be painted with a can of paint, it may be possible to develop guidelines for in-house crews such as "mark this area to spacing X by X until the can you are using runs out, then switch to another spacing or add openings". Or "mark using this prescription or guideline until noon, then switch to this one". Although this approach to project layout takes getting used to, it may be a cost-effective way to increase variability in on-the-ground activities without a lot of detailed planning.

6. Or, instead of using arbitrary breaks such as a paint can or time for lunch, consider using natural breaks such as streams, ridges or roads to delineate units for a treatment or portion of a treatment. This will allow the area of the treated unit to be determined without additional measurement.

7. When planning variable treatments such as openings within a stand, plan to use round areas as much as possible as they are much easier for one person to lay out in the field.

8. Don't underestimate employees or contractors, many can accomplish multiple tasks on a site so different parts of a project don't have to be laid out or contracted differently. This may initially take some training, field trips, extra work with people or just a different way of thinking about a project. It is important to explain the purpose of the job rather than concentrate on specifications.

9. Consider using simple flagging codes for projects with different aspects so that for example, the type of flagging (solid vs. striped vs. dotted) means one thing and the color means something else. We used this on a project where the type of flagging indicated the size of the opening to be created and the color indicated which species or group of species was to be planted.

10. Consider how the use of new technology and tools might increase efficiency. For example, it may be possible to use low elevation photography or GPS to identify possible cut or leave spots on one field visit, then decide in the office how many, what size, or which ones to select and produce a map in GIS. This might be much more efficient than using one field visit to look at the area, then plan in the office, followed by another field visit to flag areas, and then hand-draw maps of locations.

11. Stratify the cruise needed to determine the volume to be offered in a timber sale by the types of prescriptions used. Consider if areas which represent a small portion of the likely volume need to have the same accuracy as areas which represent a larger portion (depending on your employer, there may not be much flexibility in how the cruising work is done).

12. Consider if centers of activities rather than boundaries can be flagged. Or even if they have to be marked on the ground or if marking on a map or photo would be sufficient.

13. Be prepared for the people who will be implementing the work not to understand what you want done when it is a new job. Consider setting up a demonstration area or mark a small portion of the area with more flagging/paint/string than usual to make your intentions clear.

14. Use as many information sources as possible when starting new practices. Talking with co-workers, going to workshops and on tours, reading technical publications and newsletters, and surfing the internet can all be productive ways to add to your information base.

Hartley, Mitschka J. 2002. **Rationale And Methods For Conserving Biodiversity In Plantation Forests,** Forest Ecology and Management , Volume 155, Issues 1-3, 1 January 2002, Pages 81-95
http://www.sciencedirect.com/

Abstract: Industrial forest managers and conservation biologists agree on at least two things: (1) plantation forests can play a role in conserving biodiversity, and (2) plantations will occupy an increasing proportion of future landscapes. I review literature from around the world on the relationship between biodiversity and plantation management, structure, and yield. The dynamics of plantation ecology and management necessarily differ by landscape, geographic area, ecosystem type, etc. This review provides a broad array of management recommendations, most of which apply to most regions, and many patterns are evident. I suggest a new plantation forest paradigm based on the hypothesis that minor improvements in design and management can better conserve biodiversity, often with little or no reduction in fiber production. There is ample evidence that these methods do benefit biodiversity, and can also entail various economic benefits. Adherence to these recommendations should vary by plantation type, and depending on the proportion of the surrounding landscape or region that is or will be planted. Stand-level variables to consider include socio-economic factors, native community type and structure, crop species composition, and pest dynamics. During establishment, managers should consider innovations in snag and reserve tree management (e.g. leave strips), where mature native trees and/or understory vegetation are left unharvested or allowed to regenerate. Polycultures should be favored over monocultures by planting multiple crop species and/or leaving some native trees unharvested. Native species should generally be favored over exotics. Site-preparation should favor methods that reflect natural disturbances and conserve coarse woody debris. Plantations that have already been established by traditional design can also conserve biodiversity via small modifications to operations. Earlier thinning schedules or longer rotations can strongly affect biodiversity, as can reserve trees left after plantation harvest to remain through a second rotation.

HAVERI, B.A., and A.B. CAREY. 2000. **Forest management strategy, spatial heterogeneity, and winter birds in Washington.** Wildlife Society Bulletin. 28(3): 643-652.

As summarized in: http://www.fs.fed.us/pnw/olympia/efb/annualreport.pdf

Ecological management of second-growth forest holds great promise for conservation of biodiversity, yet little experimental evidence exists to compare alternative management approaches. Wintering birds are one of several groups of species most likely to be influenced by forest management activities. We compared species richness and proportion of stand area used over time by wintering birds in 16 second-growth Douglas-fir (*Pseudotsuga menziesii*) stands to determine the effects of management strategy and experimental variable-density thinnings. Management strategies were retaining legacies (large live, dead, and fallen trees from the previous old-growth stand) with long rotations and managing for high-quality timber with multiple thinnings and removal of defective trees. Experimental thinnings were designed to reduce inter-tree competition and monopolization of light, moisture, and nutrients by trees at the expense of other growth forms; reproduce the within-stand spatial heterogeneity found in old-growth forests; and accelerate development of habitat breadth. Proportion of area used and species richness increased with experimental thinnings. Two of the 8 most common winter species increased with use of experimentally thinned stands. No species exhibited greater use of unthinned, competitive-exclusion-stage stands over thinned stands. Variable-density thinnings, in conjunction with other conservation measures (legacy retention, decadence management, and long rotations), should provide habitat for abundant and diverse birds.

Hayes, John P., Samuel S. Chan, William H. Emmingham, John C. Tappeiner, Loren D. Kellogg, and John D. Bailey. 1997. **Wildlife Response to Thinning Young Forests on the Pacific Northwest**, Journal of Forestry, Vol 95(8): 28-33, August 1997.

In western Oregon and Washington, hundreds of thousands of forested acres are in early seral stages (0 to 50 years old). Many of these stands are structurally simple, having a single canopy layer, limited number of tree species, relatively little understory, and in some cases, few standing or fallen dead trees. . . . In this article we examine the effects of thinning on wildlife and their habitat in forests of western Oregon and Washington....

Thinning young stands may provide growing conditions that more closely approximate those historically found in developing old-growth stands.

Large branches develop only on widely spaces trees (Maguire et al. 1991) or on trees adjacent to gaps or openings. Large-diameter branches provide bases for bird nests and platforms for eggs of the marbled murrelet (Hamer and Nelson 1995).

Relative Density – Relative density expresses the actual density of trees in a stand relative to the theoretical maximum density (RD 100) possible for trees of that size. . . . At relative densities above 55 (the mortality zone), some trees become suppressed and die because of competition. For timber production, stands are typically thinned to RD 35 and allowed to grow back to RD 55 before final harvest or additional thinning. We consider thinning to RD 35 or higher a light thinning. Thinning to RD 25 or less (heavy thinning) and thinning again when the stand grows to RD 45 promote understory development and vertical diversity. Bailey (1996) found that of 81 stands he examined, all 22 of the stands with a high frequency of conifer regeneration were at RD 45 or less, and 19 of these were in stands with RD less than 40.

But in general, thinning does not increase numbers of usable snags and logs over the short term.

Surprisingly, populations of some cavity-nesting birds, such as hairy woodpeckers and red-breasted nut-hatches, appear to increase after thinning, despite lower snag densities. . . . The reasons for this are not clear but may be related to changes in availability of forage. . . .

Response of understory vegetation to thinning depends on initial density and species composition, vigor of understory plants before thinning, seed sources and bud banks, thinning intensity, and amount of soil disturbance, but sunlight is the primary factor in western Oregon and Washington. . . . Average canopy cover in young, unthinned stands in the Oregon coast range often exceeds 95 percent, inhibiting growth of most herbs, shrubs, and tree seedlings.

Thinning to moderate densities in closed-canopy stands stimulates modest and temporary development of understory vegetation; heavier thinning favors the establishment and growth of conifer seedlings, shrubs, and hardwood....To maintain understories for prolonged periods, heaving thinning or multiple entries may be necessary in young, rapidly growing stands.

Density of trees – Humes (1996) found that bats preferred young, thinned stands, possibly because the lower density of trees resulted in less cluttered flight paths. In one study, Hammond's flycatchers, a species sometimes considered an old-growth associate (McGarigal and McComb 1995), were found only in thinned stands....

Species composition -- A diversity of trees species in a stand helps support diverse wildlife populations.

Timing and Tradeoffs – No single prescription to promote habitat for wildlife works for all young stands.

Thinning stands before age 15 will encourage wind firmness and large crowns. . . . Thinning dense stands that are in the stem-exclusion stage increases the potential for windthrow. . . . Windthrow . . . also creates beneficial gaps in the canopy and, in the short term, more coarse woody debris for wildlife on the forest floor.

Large crowns may ultimately improve habitat for red tree voles, but increased spacing between crowns may temporarily decrease habitat suitability and inhibit dispersal.

Although thinning can provide benefits, some species, such as the Pacific-slope flycatcher . . . are known to be less abundant in thinned stands. No species is unique to closed-canopy stands with limited understory development.

But our knowledge of long-term responses – where benefits are most significant – to thinning is scant.

Thinning has traditionally been used to maximize wood production; incorporating objectives for wildlife is a relatively new approach in forest management – one with great promise but many unanswered questions.

Hayes, John P. 2001. **BIRD RESPONSE TO THINNING** *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001.
http://www.fsl.orst.edu/cfer/pdfs/CFER_ar01.pdf

There are currently hundreds of thousands of acres of relatively young, densely stocked Douglas-fir (*Pseudotsuga menziesii*) forests in western Oregon. Thinning, a management activity that reduces the density of trees, is planned or being considered for a significant portion of this acreage. Thinning is increasingly used in young forest stands to meet a diversity of objectives. It is often used to reduce competition among trees, thereby increasing growth rate and reducing competition- induced mortality of the remaining trees. Recently, thinning has been identified as a potential approach to enhance wildlife habitat and to accelerate the development of characteristics typical of older forest stands, including presence of large-diameter trees, snags, and logs, a well-developed understory, and multiple levels of the canopy (McComb et al. 1993, *Journal of Forestry* 91(12):31–42; Hayes et al. 1997, *Journal of Forestry* 95(8):28–33).

In the Northwest Forest Plan, thinning has been identified as an acceptable silvicultural practice in stands less than 80 years old in Late Successional Reserves west of the Cascades. Thinning dramatically influences many aspects of stand structure, and consequently could strongly influence presence and abundance of wildlife. Notwithstanding, there are few data documenting the implications of commercial thinning to wildlife populations, and most of those data are the result of observational studies (e.g., Hagar et al. 1996, *Wildlife Society Bulletin* 24:353–366). The purpose of this study is to examine the influence of commercial thinning on bird populations using an experimental approach.

METHODS

Three stands in each of four sites in the Tillamook State Forest, located approximately 14 km east of Tillamook, Oregon, and adjacent lands owned by the Stimson Lumber Company were selected for study. Areas were selected that met the following criteria: 1) stands within a site were relatively homogeneous with respect to tree density, stand age, and proportion of hardwoods; 2) stands were candidates for thinning to meet silvicultural objectives; and 3) stands were a minimum of 24 ha in size. After sites were selected, each stand within a site was randomly assigned one of three treatments: control (no thinning, to remain at preexisting densities with approximately 460–540 trees/ha), moderately thinned (thinned to a relative density of 35, or approximately 240–320 trees/ha), or heavily thinned (thinned to a relative density of 20, or approximately 180–220 trees/ha). Stands were selected in 1993; pretreatment data were collected in 1994; and treatments were installed between fall of 1994 and spring of 1995.

In each of the 12 stands, five sample points were established to assess response of bird abundance to thinning. . . . . . .

RESEARCH RESULTS AND MANAGEMENT IMPLICATIONS

Between 1994 and 2000, 2,940 point count surveys were conducted, during which 19,259 birds of 52 species were counted (Table 3). There were adequate data to analyze results for 22 species of birds. None of the 22 species was extirpated from sites as a result of thinning. Three species that were absent or rare in control stands (Hammond's flycatcher [*Empidonax hammondii*], American robin [*Turdus migratorius*], and Townsend's solitaire [*Myadestes townsendi*]) were regularly observed in thinned stands.

Of the 22 species analyzed, detections of nine species decreased relative to detections in controls following thinning (Table 4). Four of these species (the Pacific- slope flycatcher [*Empidonax difficilis*; Figure 5a], Hutton's vireo [*Vireo huttoni*], golden-crowned kinglet [*Regulus satrapa*], and brown creeper [*Certhia americana*]) decreased in both moderately and heavily thinned stands, but response varied with intensity; numbers of these birds decreased more in heavily thinned stands than in moderately thinned stands. Three species (the hermit warbler [*Dendroica occidentalis*], Swainson's thrush [*Catharus ustulatus*], and black-throated gray warbler [*Dendroica nigrescens*; Figure 5b]) decreased in both moderately and heavily thinned stands, but did not show strong evidence of responding to thinning intensity. intensity.

Two species (the Steller's jay [*Cyanocitta stelleri*] and varied thrush [*Ixoreus naevius*]) appear to decrease only in the heavily thinned stands. Decreases of brown creepers, Hutton's vireos, and golden-crowned kinglets in the heavily thinned stands were particularly pronounced, with average detections of these species in the heavily thinned stands less than 15% of detections in the controls.

Detections of eight species increased relative to detections in controls following thinning (Table 4). Of these, two species (the dark-eyed junco [*Junco hyemalis*] and hairy woodpecker [*Picoides villosus*]) increased in both moderately and heavily thinned stands, but the response varied with intensity; numbers of birds increased more in heavily thinned stands than in moderately thinned stands. Five species (the American robin, Townsend's solitaire, evening grosbeak [Figure 5c], western western tanager [*Piranga ludoviciana*], and Hammond's flycatcher) increased in the thinned stands, but did not show strong evidence of responding to thinning intensity. Numbers of warbling vireos increased only in the heavily thinned stands.

There was no strong evidence of any influence of thinning on numbers of five species of birds (the chestnutbacked chickadee [*Poecile rufescens*], winter wren [*Troglodytes troglodytes*], Wilson's warbler [*Wilsonia pusilla* ; Figure 5d], gray jay [*Perisoreus canadensis*], and red-breasted nuthatch [*Sitta canadensis*; Table 4]). This suggests strong support for the hypothesis that thinning does not substantially influence abundance of these species.

Of the 17 species that showed a numerical response to thinning, five species showed evidence of a change in the influence of thinning over time. Two of these species decreased in numbers following thinning (Pacific-slope flycatcher and golden-crowned kinglet). The Pacific-slope flycatcher showed a trend of divergence through time (differences in numbers in thinned stands and controls became more extreme through time) and the golden-crowned kinglet showed a pattern of convergence through time (numbers in thinned stands and controls became more similar through time). Three species that increased in numbers following thinning demonstrated a temporal trend in response (warbling vireo [*Vireo gilvus*], western tanager, and Hammond's flycatcher). For all three of these species, numbers in thinned stands showed a pattern of divergence from numbers in controls through time, although for warbling vireos this temporal pattern was only evident in the heavily thinned stands.

Our findings demonstrate that thinning enhances habitat for a number of species and provides habitat for some species that are rare or absent in unthinned stands. However, numbers of some species declined following thinning, and although no species were extirpated from stands following thinning, decreases of some species were dramatic. As neither thinned nor unthinned stands provided optimal habitat for all species of diurnal birds, landscapes dominated by younger stands should be managed to retain some densely stocked, unthinned stands to provide refugia for species that are impacted by thinning in landscapes that are managed with biodiversity as an important goal. These results do not provide direct guidance concerning the optimal proportion of a landscape that should be left unthinned to maximize habitat value for birds. However, as the short-term consequences of thinning for most birds are positive, neutral, or of minor negative impact and thinning has the potential to substantially increase structural complexity over the long term, we contend that bird populations in landscapes dominated by young, densely stocked plantations would benefit from thinning over a large proportion of the landscape if done in conjunction with management and retention of legacy structures and dead wood, and other conservation measures.

Many of the principles presented above also apply for management of landscapes in which wood fiber production is the primary goal and biodiversity is a secondary or lesser consideration. However, most stands in landscapes managed to emphasize wood fiber production will be harvested before many of the long-term benefits of thinning to increase structural diversity will be realized. In these landscapes, thinning young stands still will benefit a number of species. However, when thinning is extensively implemented across intensively managed landscapes, special attention should be given to species that are impacted by thinning. Conservation of legacy structures (such as large green trees and snags) may be especially valuable in these conditions. For example, retention of some large trees with deeply furrowed bark may provide preferred foraging habitat for brown creepers (Weikel and Hayes 1999, *The Condor* 101:58–66) and song posts for varied thrush (Beck and George 2000, *The Condor* 102:93–103).

Hayes, John P., and David Larson. 2001. **SMALL MAMMAL RESPONSE TO THINNING** *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001. http://www.fsl.orst.edu/cfer/pdfs/CFER_ar01.pdf

Thinning is increasingly being employed in young forests for commodity production, to increase structural and biological diversity, and to enhance wildlife habitat. Thinning is underway or planned for hundreds of thousands of acres of forests in western Oregon in the coming years. On federal lands, thinning is an approved silvicultural approach to management of stands less than 80 years old in Late-Successional Reserves and on Matrix lands. Thinning is also a central component of Oregon Department of Forestry's management plan for state forest lands. Despite the extensive use of thinning planned for the near future, limited information is available that documents the effects of commercial thinning on wildlife populations, including small mammals. Small mammal communities contribute to the persistence of ecological functions in forested stands by serving as a prey base for other species and by dispersing seeds and mycorrhizal fungi. The purpose of this study is to investigate the effects of different levels of thinning on small mammal communities.

METHODS

This study was conducted in the northern Oregon Coast Range in the Tillamook Burn area. The area is characterized by even-aged Douglas-fir (*Pseudotsuga menziesii*) forest between 35 to 50 years old. The area experienced a series of wildfires between 1933 and 1951 that burned a total of 143,000 ha. Most of the area was salvage-logged and many of the snags that were not harvested were felled to create firebreaks. The forest was replanted or seeded with Douglas-fir between 1949 and 1970. Four forested blocks were selected for study. Three of the blocks are within the Tillamook State Forest and the fourth is on property owned by the Stimson Lumber Company. Within each block, each of three 25- to 40- hectare stands were randomly assigned to receive one of the following treatments: 1) no thinning (460–540 trees/ha), 2) moderate thinning to a relative density of 35 (240–320 trees/ha), and 3) heavy thinning to a relative density of 20 (180–220 trees/ha). The stands were thinned between October 1994 and May 1995.

Trapping grids of 150 traps spaced at 20-m intervals were established in each stand. Each trapping grid encompassed approximately 5 ha (12.5 acres). Small mammals were captured in Sherman live-traps during the late spring (mid-May through June) and early fall (mid-July through mid-September) of 1999 and 2000. Traps were checked daily for seven consecutive days. Each captured animal was identified to species and sex, and was weighed. Shrews were not identified to sex. A subset of species was uniquely marked with numbered eartags to estimate population size, mean maximum distance moved (MMDM), and density.
. . .
We used a randomized complete-block design, using sites as blocks, to statistically compare differences in estimated population means, density, MMDM, sex and age ratios, and body mass between thinned and unthinned stands. We used repeated measures analysis to examine the influence of thinning over time. . . .

RESEARCH RESULTS AND MANAGEMENT IMPLICATIONS

During 50,400 trap nights, 5,293 small mammals were captured representing 18 species (Table 6). Five species of shrews (*Sorex* spp.) comprised 42% of all captures. Of the small mammals captured, 2,979 individuals were ear-tagged and subsequently recaptured 6,719 times. Townsend's chipmunk (*Tamias townsendii*) was the most frequently captured species (48% of ear-tagged captures).

Our results suggest that thinning had a neutral or positive effect on abundance of most species of small mammals that were caught frequently enough for analysis (Table 6). Townsend's chipmunks were 72% and 188% more abundant, and creeping voles (*Microtus oregoni*) were 280% and 440% more abundant in moderately and heavily thinned stands, respectively. Deer mice (*Peromyscus maniculatus*) were 69% more abundant in thinned stands in comparison to unthinned stands. There were no significant differences in abundance among thinned and unthinned stands for jumping mice (*Zapus trinotatus*) and Baird's shrews (*Sorex bairdi*). Abundance of Pacific shrews (*Sorex pacificus*) declined slightly in moderately thinned stands, but increased slightly in heavily thinned stands in comparison to unthinned stands. Of the species analyzed for abundance, only Trowbridge's shrews (*Sorex trowbridgii*) were significantly more abundant in unthinned stands than thinned stands. Northern flying squirrels (*Glaucomys sabrinus*) and western red-backed voles (*Clethrionomys californicus*) appeared to be most abundant in unthinned stands. However, an Analysis of Variance (ANOVA) showed only weak evidence of this trend for flying squirrels ($F_{2,6} = 3.92$, $p = 0.0814$), although our design is not well suited to their capture. In addition, we found little evidence of treatment differences for western red-backed voles ($F_{2,6} = 1.84$, $p = 0.2383$), although a small sample size for this species hinders strong inference. . . .

Abundance may sometimes be a misleading indicator of habitat quality. An understanding of demographic parameters such as body mass and sex/age ratios in conjunction with behavioral attributes such as patterns of movement may be more important indicators of habitat quality than abundance. These parameters were analyzed for Townsend's chipmunks and deer mice.

. . . These results suggest that thinning enhances habitat quality for deer mice, and that heavily thinned stands may increase fecundity of females and body weight of males.

Thinning young second-growth Douglas-fir forests opens the canopy and allows for increases in understory vegetation. It may also be an effective method of accelerating development of desirable structural characteristics in Douglas-fir forests while allowing for short-term benefits of commodity production and timber revenue. This study indicates that thinning has neutral or positive effects on most forest-floor small mammals. Species caught in adequate numbers were found in both thinned and unthinned stands 6 years after thinning had occurred. Demographic characteristics of two abundant species indicate that sex and age ratios are only seasonally dependent, and thinning and thinning intensity may enhance habitat quality. Therefore, thinned and unthinned stands may be able to support viable populations of small mammals over time, but thinning may increase carrying capacity for some species. Although sample sizes were too small for analysis of nine species, several species appeared to be more abundant in unthinned stands. For this reason, it is recommended that unthinned stands be retained as part of the forested landscape until thinned stands have time to reach canopy closure.

Use of both moderate and heavy thinning in secondgrowth Douglas-fir forests along with retention of some unthinned areas may increase habitat diversity. Heavily thinned stands will accelerate development of large-diameter trees and could provide for future input of large-diameter downed wood, snags, and development of mature forest conditions that may provide optimal habitat conditions for many species of small mammals. Moderately thinned stands have the potential to accelerate growth of trees for a second thinning to a lower density. Continued research using experimental studies such as this one may help to determine the long-term (10–25 years) consequences of thinning young Douglas-fir forests.

Helgerson, Ole T. and Jim Bottorff. 2002. **Thinning Young Douglas-fir West of the Cascades for Timber and Wildlife.** EB1927. June 2002.
http://cru.cahe.wsu.edu/CEPublications/eb1927/eb1927abstract.htm

Abstract: This bulletin explores ways of thinning young, even-aged Douglas-fir to benefit wildlife while producing timber in western Washington. Simulations show the effects of thinnings at different ages. Setting aside wildlife trees early in the rotation provides long-term structural value as forest legacies, improving wildlife habitat.

Hunter, Matthew G. 1993. **, Communique #1: YOUNG MANAGED STANDS**. Cascade Center for Ecosystem Management. May 1993.
http://www.fsl.orst.edu/ccem/youngstd/ystd.htm
http://www.fsl.orst.edu/ccem/pdf/comque.pdf

The purpose of this communiqué is to share information, to promote understanding and familiarity with young stands, and to facilitate further communication between those managing and studying young stands. Ecology and management of managed Douglas-fir forests 30-50 years of age are the main focus; however, much information discussed may apply to stands 20-120 years. Although some information is derived specifically from the Willamette National Forest, the topics discussed and information presented are widely applicable to forest management throughout western Oregon and Washington.

Introduction

Young forests have been a part of forested landscapes in the Pacific Northwest for centuries because fire and other disturbances have initiated succession at various times and at various scales. Three things have brought about intense interest in management of young managed forests today:

1) Land area covered by complex old-forest ecosystems has been reduced, while young managed stands now form a significant portion of many landscapes. The bulk of this transformation has occurred in the last 50 years, and is currently highlighted by concerns for viability of species associated with old-forest characteristics.

2) Existing young managed stands are not "equivalent" to similar-aged unmanaged stands (Spies and Franklin 1991), and the former and existing trajectory intended for many of these stands would neither contribute to nor perpetuate old-forest characteristics on landscapes.

3) Management of ecosystems is considered by some managers and scientists to be a better long-term approach to public land management than strict designation of set-aside and intense wood production land.

A Brief History of Managed Stands on the Willamette National Forest.

Approximately 350,000 acres of mature and old-growth forest have been harvested in the last 50 years on the Willamette National Forest (Jim Mayo pers. comm.).
. . .
. . . Spies and Franklin (1991) reported regional variability among old-growth forests and stated that, "variability in oldgrowth forest structure strongly suggests varied developmental histories." A lesson to learn here is that it may be possible to develop desired forest structures and compositions through specific and timed actions in managed stands. . . . Managing within the range of natural variation, as suggested by recent developments in ecosystem management, may be a context with which to develop specific objectives.
. . .

IDEAS FOR INCREASING HABITAT AND ANIMAL DIVERSITY IN EXISTING AND FUTURE YOUNG MANAGED STANDS

This section can be thought of as a tool box. Tools are generally used in particular combinations and in particular sequences to achieve specific purposes. The ideas presented discuss ways to develop the specific feature mentioned, or discuss potential changes induced by a particular practice. Most would agree that implementing any of the following ideas would likely increase both diversity and logging costs. However, few quantitative data are available on economic and ecological consequences of implementing these ideas. Many of the practices and parameters presented here are currently being investigated in stratified designs in several places in western Oregon and Washington. Others are not, and could be operationally tested in demonstration areas or in scientifically designed studies. Some of the ideas are appropriate for current management and are currently being implemented.

Broadleaf Trees. Species regularly occurring at dominant and co-dominant size in managed stands are black cottonwood, bigleaf maple, and red alder; occasionally golden chinquapin and Pacific madrone are present. Smaller trees not often present in the dominant or co-dominant layer include: Pacific dogwood, California hazel, vine maple, cascara, and bitter cherry. Encouragement of deciduous and evergreen broadleaf trees in young managed stands may result in population increases in bird species such as warbling vireos, black-headed grosbeaks, and, at low elevations, black-throated gray warblers and Hutton's vireos. Other species may be tied to the presence and abundance of deciduous trees as well. Deciduous trees, by nature, will allow more light to the forest floor in winter, and provide a different type of detritus to the forest floor.

On the Willamette National Forest, the primary factor needed for maintenance of broadleaf trees is light. Maintenance or enhancement of broadleaf trees in young managed stands may be accomplished by 1) allowing prominence of these species in early regeneration stages, and 2) thinning conifers from around broadleaf trees, or simply opening the conifer canopy.

Snags and Down Woody Material. Young forests are at the age when trees are becoming large enough to be excavated by woodpeckers. However, most trees in young stands contain little decay above the base of the bole. Topping of some trees in these stands may create potential nesting substrate. Topping would probably be most feasible after thinning so that the topped portion would be less likely to get caught in adjacent canopies. Since these trees are likely to decay rather rapidly, leaving several whorls of green limbs below a de-limbed portion of the bole may make for longer-lasting snag habitat. Another approach to long-term development of decayed bole habitat might be to deeply injure live trees at some mid-point up the bole, leaving the tree live and allowing development of rot in the bole. In the long term, it seems most feasible to consistently retain trees from former stands to act as large tree and snag habitat within regenerating stands.

As with snags, young managed stands typically do not have large diameter trees as a source for the forest floor. Some young managed stands have high levels of large woody material remaining from harvest activities in the previous stand. Others have very little. In those stands with little down wood, it may benefit some ground-dwelling species to leave some boles on site during thinning operations. In the long run, as with snags, it seems most reasonable to retain trees in successive generations to act as large tree and log habitat.

Root Rot and Other Fungus. Root rots weaken and kill particular species of trees in a patchlike manner. Unaffected tree species usually prevail in these "pockets." Succession in an area of root rot typically goes something like this:

susceptible trees are killed, producing snags for a short period before they fall; root rot tolerant species, such as cedars or broadleaf species, often seed in or continue growth in the infected areas. Sometimes susceptible species reseed in as well. The rot travels over time through susceptible hosts. The result in the stand is an increase in complexity of both vegetative structure and species composition. Both root and stem-rotting fungi may be valuable agents of diversity in managed landscapes (see Van der Kamp 1991).

Slash Piles. Piling of limbs and other debris produced during thinning operations may provide cover and nesting/denning habitat for small and medium-sized mammals, amphibians, and a few birds (mice, voles, squirrels, weasels, skunks, salamanders, grouse, winter wrens). Piles 5-10 feet tall would probably provide the best habitat and be the most feasible to create.

Underburning. A burn on the forest floor would likely effect a change in herb and shrub composition. The specific vegetative response would likely depend upon the timing and intensity of the burn, the seed or sprout source, and the percent canopy cover. Considerations in using fire in these stands include the ladder fuels and thin bark of these young trees. Controlled burns may be most feasible in heavily thinned areas where stems are farther apart. Spot burning or pile burning may be more reasonable options to put effects of fire in these stands. An occasional fire-killed tree may provide foraging and possibly nesting habitat (depending on size) for cavity-nesting species.

Planting. There are a variety of plantings that could be done. Planting conifer species could form another structural layer. Depending on the openness of the canopy, these may be shade tolerant, intolerant, or a mixture of coniferous species. Indigenous broadleaf and/ or fruit-bearing trees and shrubs (black cottonwood, willow, bitter cherry, blue elderberry, indian plum) may be planted in areas after conifers have been thinned to provide a very open canopy, particularly near streams, ponds, and seeps. At the herb layer, mixes of indigenous grasses and forbs might be planted in areas where the ground has been disturbed or the canopy has been opened up significantly. Methods for collecting seed and seedlings from local areas could be explored. . . .

Variations in Thinning Practices. The Young Stand Study on the Willamette National Forest is implementing two variations from the typical practice (three if you count non-thinning): a heavy thinning (50tpa) with conifer underplanting, and a typical thin (100-120tpa) with inclusions of 1/2 ac gaps (every 5 acres) where all trees are cut and the patch is replanted with conifers. Prescriptions in the young stand study specify all conifer species as being acceptable "crop trees" to be left and allowed to grow in proportion to their presence. Species could be favored in selection of crop trees if a change in composition is desired. Understory trees will be left which may form a shade tolerant understory layer. Another practice not yet demonstrated on the Willamette National Forest is a variable thin.

There are some stands that have had some unevenness implemented in the thinning, but I am referring to something a bit more drastic and noticeable (See **Figure 2**). This pattern would likely result in a wide variety of tree growth rates, sizes, crown shapes, and understory response. Also see McCalmon and Franklin (1992).

Edge Meshing. An occasional large tree from an adjacent older forest could be felled into the younger managed stand. This would put some newer large woody material into the stand, make a "trail" from one stand into the other, and injure some of the younger regenerating trees for future dead and decaying tree habitat.

Retention of Characteristics in Succeeding Stands. Most previous ideas are applicable to development of structure and composition in existing young managed stands. However, many of the things discussed above can be enhanced, or initiated in the "restart" of a stand to gradually build diversity into stands. Live and dead trees and logs can be retained from previous stands, adding valuable diversity to young growing stands. If large tree structure is desired in areas of short rotation, live trees may be retained from each generation of forest and allowed to grow through several rotations.

Alternative Methods of Management of Early Seral Vegetation. Heavier dependence upon natural regeneration may introduce some natural variability into stands. Allowing herbaceous and broadleaf growth early in stand development may enhance diversity in tree sizes and species composition through more significant competition for resources. Precommercial thinning practices could include more variability and selection for diverse characteristics present on sites.
. . .

Hunter, Matthew G. 2001. **Communiqué #3: Management in young forests.** Cascade Center for Ecosystem Management. 28pp.
http://www.fsl.orst.edu/ccem/pdf/Comque3.pdf

Perhaps one of the most influential studies in the 1990s was that of Tappeiner et al. (1997). Using tree-ring analysis of stumps in ten clearcuts (25-74 ac in size) on BLM land in the Oregon Coast Range, this study examined diameter growth rates of trees in former Douglas-fir old-growth stands and nearby young-growth stands (trees 50-70 yrs old) that had regenerated naturally after logging. Growth rates in the young stands (even of the largest trees) were significantly lower than in the old-growth trees at comparable ages. Tappeiner et al. (1997) presented strong evidence that the higher growth rates at early ages in the old-growth trees were the result of low tree densities at early ages. Further, age ranges of dominant Douglas-fir in the old-growth stands spanned a minimum of 66 yrs, up to a maximum of 364 yrs (mean 150 yrs), suggesting that periodic disturbance initiated multiple understory regeneration events. Given this evidence, the authors suggested "When the objective of forest management is to grow stands with old-growth characteristics, it appears that density management (e.g., one or more thinnings to low densities) will be required." In contrast to the above study, Winter (2000) examined a single, 8-ac old-growth stand in the western Washington Cascades using very detailed stand reconstruction techniques. Winter found that the stand appeared to have established over a relatively short period of time (21 yrs), and at a relatively high density (~324 tpa at 70 yrs), similar to the young growth stands examined by Tappeiner et al. (1997). Winter's study indicated that oldgrowth forests can develop, at least in small patches, at higher densities than those examined by Tappeiner et al. (1997), but left unknown the commonness of such forests. More recently, Poage (2001) expanded the work of Tappeiner et al. (1997) with an additional 28 stands (most >40 ac) on BLM land in the Oregon Cascade and Coast Ranges.

The stands examined showed a mean age range in old-growth Douglas-fir trees of 174 yrs. Even in 0.25-ac plots the mean age range was 73 yrs, notably higher than in Winter's (2000) stand. Similar to Tappeiner et al. (1997), Poage observed rapid growth during young ages of the larger diameter old-growth trees, indicating that the contemporary old-growth trees he examined began at low densities compared to contemporary young-growth stands. However, the applicability of these findings to other forests in western Oregon and Washington remains unknown. In young-growth stands, Wilson and Oliver (2000) examined height:diameter (H:D) ratios, which are affected by the density of trees during early stages of growth. Tree shape is crucial to tree stability and related to the physical structure and appearance of forests. This work determined that H:D ratios established by the time a tree is about 33 ft tall strongly determine the H:D ratio of the tree for at least 80-100 ft of additional height growth. Similarly, Poage (2001) found diameter of old-growth trees at 100-300 yrs was strongly related to their diameter and basal area growth at age 50 yrs. Both of these studies indicated that tree and stand characteristics at early stages had profound effects on the character of trees and stands at later stages.
. . .
Based on numerous field studies in western Oregon and Washington in the 1980s and 1990s (Carey et al. 1991, Carey 1995, 2000, 2001, Carey and Johnson 1995, Carey et al. 1996, 1999a, b, c, Colgan et al. 1999, Carey and Wilson 2000, Hayeri and Carey 2000, Thysell and Carey 2000, Carey and Harrington 2000), Carey cautions that management strategies implementing only one or two tools (e.g., only legacy retention or conventional thinning), "can place stands on hard-to-alter trajectories characterized by incomplete or unbalanced biotic communities, truncated or misdirected developmental processes, invasion by exotic species, simplified vegetation structure, low capacity to support prey bases and predators, low resilience to perturbation, and high susceptibility to disease."
. . .
Some argue that, if left alone, stands currently at high densities will not meet timber goals in matrix lands, and will not meet biodiversity goals in reserve lands. Others say "let nature take its course," and that natural disturbances will diversify the stands.
. . .
Citing Isaac (1938, 1940), Tappeiner et al. (1997) speculated that a low supply of seed and a dense cover of shrubs and herbs may have limited conifer establishment after intense fires. Similarly, Phil Jaspers (Willamette NF) suggests that many of our contemporary late-successional forests may have developed subsequent to huge, intense fires that burned five or more centuries ago. Such fires may have created the seed and regeneration conditions that Tappeiner et al. (1997) suggested, with widely spaced forest patches, robust shrub and herb cover, and incremental invasion of conifers. In contrast today, ubiquitous forest cover provides abundant seed to many relatively small stand-replacing disturbances in a relatively short amount of time. The observations of McArdle et al. (1961, see side bar), although likely biased to fully stocked acres, nevertheless support the hypothesis that many forests in the past two centuries have developed at fairly high densities. They noted "these young forests as a rule are even aged, the larger trees in any one forest seldom varying by more than a few years." Others speculate that contemporary old-growth forests did start at high densities, but were "thinned" by repeated low-intensity burns, whereas such repeat burns have not occurred (i.e., were suppressed) in the young-growth forests of today. But would low-intensity burns thin out young stands or would they just create patches of newer regeneration among dense, older regeneration? Or would fires destroy dense patches of regeneration, leaving patches of more widely spaced trees unharmed?
. . .
How transferable are the findings from western Oregon BLM lands (Tappeiner et al. 1997, Poage 2001) to forests in western Washington and at higher elevations (e.g., NFS lands) in the western Cascades? Jerry Franklin (University of Washington) notes "there are several younger age classes of natural forest, including the approximately 300- yr-old stands so common in the Breitenbush and Clackamas drainages and many of the stands that originated following the 1845 burn that have much more even-aged stand characteristics. That is, the Douglas-fir came in a relatively short period of time (25-40 yrs) and quit, just as Linda Winter observed in her 500-yr-old stand" (see Franklin and Hemstrom 1981). Could it be that forests in higher precipitation zones at the north end of the Douglas-fir region and at higher elevations may naturally regenerate at higher densities and experience fewer fires than at southern locations and lower elevations? Further, might similar relationships apply to stand establishment and early growth during wetter climates versus drier climates? It would be valuable to conduct investigations similar to Tappeiner et al. (1997), Winter (2000), and Poage (2001) throughout a wider range of precipitation and forest zones in western Oregon and Washington in order to gain a broader perspective of regional variation in these processes.
. . .
Findings from several sources (e.g., Tappeiner et al. 1997, Carey et al. 1999b, Garman 1999b, Poage 2001, Busing and Garman 2001) support the idea that development of late-successional attributes in young stands can be accelerated with various thinning practices (Franklin and Spies 1991b).
. . .
Garman (1999b) concluded from his modeling experiments "Given the uncertainty in how well thinning treatments will actually perform in terms of stand development, volume production, and habitat quality, it is prudent to manage for a diversity of stand trajectories. . . . Perhaps the most basic principle to grab hold of is that we should not attempt to implement single prescriptions, no matter how diverse in themselves, in a blanket way across landscapes. How long do we have to decide? While we consider the long-term ramifications of today's decisions on future forests, some warn that we are limiting future options by not thinning dense stands. It is well-known that some extremely dense stands with severely reduced crowns, when thinned, show little growth response and are highly susceptible to

blowdown. John Tappeiner (Oregon State University) advises "Thinning of dense stands will broaden the options for future trajectories of these stands, allowing time for discussion of long-term objectives, but options for many densely stocked stands will be limited if they are not thinned soon. Carefully manage and see where we are in 40-50 yrs." Certainly all young stands are not dense, and thinning would not be required on every acre. Probably a variety of thinning practices (including no thinning) would be prudent while considering future options.

THE WILLAMETTE NATIONAL FOREST YOUNG STAND THINNING AND DIVERSITY STUDY: THREE YEARS POST-TREATMENT

Learning to manage young stands for late-successional habitat, biological diversity, and wood production [as reported in Hunter Communiqué #3]

. . .

This study was conceived in the late 1980s by silviculturists and biologists on the Willamette National Forest working with scientists from Oregon State University: John Tappeiner, Loren Kellogg, and Bill McComb. The primary interest was to see if different thinning, underplanting, and snag creation treatments could accelerate development of old-growth characteristics in young managed forests, and to promote more biologically diverse young forests. . . .

The 16 stands were 35-45 yrs of age at the time of treatment, averaging about 11 inches dbh and 250 tpa. The stands were dominated by Douglas-fir, . . .

Vegetation . . . Although no statistically significant treatment effects to bryophytes were observed because of high variation within treatments, bryophyte ground cover (predominantly mosses) was positively correlated with overstory cover (and related measures, e.g., stem density, basal area) both pre- and post-treatment. Tucker et al. (undated) speculated that decreased canopy cover increased sunlight and wind movement, which may have dried out and killed bryophytes. Interestingly, Rambo and Muir (1998) found just the opposite in their study, and concluded that light may have been limiting in the stands they studied. Thus, more investigation is needed with regard to bryophytes over a range of light and moisture conditions.

Herb cover was negatively associated with overstory cover, likely due to associated light conditions and competition for water and nutrients. No responses have yet been observed from low shrubs. Tall shrubs appear to have been set back by logging damage during harvest operations, but are expected to rebound, particularly in stands where light is most available.

. . .

Woody Detritus . . . Total weight [of woody detritus] ranged 123-145 tons/ac and did not vary significantly among treatments. However, as might be expected, fine and moderate-sized detritus was greater in all treatments than the control due to recent slash from logging. Snag mass was significantly greater in the control than any of the thinned stands.

. . .

Mushrooms (chanterelles). . . . Chanterelles were expected to be influenced by (1) food supplies for the fungus (density and health of host trees), (2) environmental conditions near the forest floor that affect fruiting (temperature, humidity, and light levels), and (3) soil conditions (compaction, summer and early autumn moisture levels, distribution of rotted wood and organic matter in the soil profile, litter layer thickness, slash burning, and microbial population shifts). Thus, Pilz hypothesized that chanterelle productivity would decline (but not be eliminated) after treatment, more so in heavier thinnings, and that productivity would then rebound to pre-thinning levels or higher as trees became more vigorous and fully re-occupied the habitat. Results so far have supported these hypotheses, although during the first four years following harvest, productivity has not yet rebounded to previous levels.

. . .

Mammals and amphibians. Thinning had only a few detectable impacts on ground-dwelling populations of small mammals and amphibians so far. This is thought to be due to the variability in hardwoods, shrubs, and other microsite factors that may overshadow changes in overstory canopy cover and tree density for these ground-dwelling species. Deer mouse abundance increased in the light thin and light thin with gaps treatments, but no significant response was detected in the heavy thin treatment. A similar pattern was seen with the ensatina (salamander). Garman (2000b) speculated that the light thin treatments inflicted relatively minimal mechanical damage on the stands while allowing greater production in the understory, compared to the heavy thin stands which experienced more extensive mechanical disturbance of the understory. The strongest response observed was with the Trowbridge's shrew, which decreased in response to heavy thinning. Some differences among years possibly were due to weather conditions.

. . .

Birds. Approximately 72 species of birds have been recorded thus far. Bird species richness and diversity increased in all three thinning treatments relative to controls. Four species increased in abundance in at least one thinning treatment. Hammond's flycatcher and dark-eyed junco increased in all treatments, while MacGillivray's warblers and western tanagers increased in heavily thinned and gap treatments, but not in the lightly thinned treatment.

Changes in abundance of each of these species are generally corroborated by a multi-study analysis of bird density over a range of tree densities in the western Cascades (Hansen et al. 1995). Hammond's flycatchers and dark-eyed juncos also have been documented as responding positively to thinning in the Oregon Coast Ranges (Hagar et al. 1996, Hayes and Weikel unpublished data). Several uncommon bird species were present in the stands after thinning, but were absent or nearly so before thinning: red-breasted sapsucker, western wood-pewee, olive-sided flycatcher, Townsend's solitaire, and brown-headed cowbird (Hagar and Howlin 2001).

Abundance of six species decreased after thinning, but none was eliminated (see table). Each of these species is common in the region and all are expected to persist in these stands. No change in abundance was detected for cavity nesters as a group, neotropical migrants as a group, or eight other species (see table).

. . .

Logging systems. Compaction due to old skid trails (created 30-50 yrs previous) was examined in two units prior to experimental treatment in this study (Allen 1997). Mean bulk density (a measure of compaction) generally remained about 10% higher (within 8 inches depth) on old skid trails than in undisturbed soil, while some areas had higher levels and others showed virtually no difference. Approximately 4-10% of the stand area showed evidence of soil compaction prior to experimental treatment.

Harvester and forwarder traffic (examined in one stand) was found to increase bulk density an average of 11-12% on undisturbed soil (most attributed to the forwarder), but there was no evidence that harvester-forwarder traffic increased bulk density on old skid trails. It was estimated that new skid trails covered 26-29% of the harvested portion of the stand. This level of disturbance exceeds Forest Service regional standards. If this degree of disturbance is typical of this harvesting system, then use of the harvester-forwarder system may not be feasible on National Forests, or the standards would need to be reassessed.

Kellogg, Loren D., Miller, M. Jr., and Eldon D. Olsen. 1999. **Skyline Thinning Production and Costs: Experience from the Willamette Young Stand Study**. Research Contribution 21, Oregon State University, Forest Research Laboratory. August 1999.

This paper summarizes detailed production and cost information for the skyline logging portion of the [Willamette Young Stand] Project. . . .

Total skyline harvesting costs for alternative silvicultural methods can range form approximately 7% to 32% more than those of conventional clearcut methods.

. . .

The study sites are located in the western Cascade Mountains of Oregon, on the Willamette National Forest. . . .

All three sites were second-growth stands of Douglas-fir that had been clearcut during the mid-1940s or early 1950s.

. . .

The silvicultural treatments at each site were designed as follows:

- Control – no thinning . . .
- Light thin (LT) – residual stocking 110-120 trees per acre (tpa)
- Light thin with openings (LTO) - residual tpa same as in LT treatment, but with additional .5 acre openings dispersed . . . to encompass 20% of the total unit area. The average residual stocking was 92 tpa.
- Heavy thin (HT) – residual stocking of 50-55 tpa.

. . .

Total harvesting costs showed no consistent relationship to type of silvicultural treatment.

. . .

The three types of silvicultural treatments studied had no consistent influence on skyline production rates and costs, because initial stocking levels varied among treatments and the volume harvested did not necessarily correlate to the silvicultural treatment. As part of a larger multi-disciplinary project, these factors were not within our control.

. . .

This study provided a good sample of skyline harvesting costs over a range of site conditions, crew size, equipment, and logging methods. The costs differences were small enough, given the range of volumes harvested, that a land manager should choose the most appropriate silvicultural treatment to meet landowner's objectives.

Kellogg, Loren D., Ginger V. Milota, Ben Stringham. **LOGGING PLANNING AND LAYOUT COSTS FOR THINNING: EXPERIENCE FROM THE WILLAMETTE YOUNG STAND PROJECT.** Research Contribution 20, Oregon State University, Forest Research Laboratory.
http://www.cof.orst.edu/cof/pub/home/rc/rc20.pdf

Abstract: Logging planning and layout costs were examined for commercial thinning of 40- to 50-yr-old stands of Douglas-fir on the Willamette National Forest in the Cascade Mountains of Oregon. The study consisted of four replications of three silvicultural treatments. Thinning involved three types of logging systems: mechanized cut-to-length (a combination of single-grip harvester and forwarder), tractor, and skyline. Data for the study came from two sources: activities completed by the Forest Service in preparing sales for bid, and the layout completed by the logging contractor after a contract was awarded. Planning and layout costs showed no consistent relationship to type of silvicultural treatment. Logging contractor layout costs showed a relationship to type of logging system: the mechanized system had the lowest layout cost, followed by the tractor systems, with the skyline systems having the highest costs.

Knowles, Donald R. 1996. **Memo to Regional Interagency Executive Committee (RIEC), RE: Criteria to Exempt Specific Silvicultural Activities in Late-Successional Reserves and Managed Late-Successional Areas from Regional Ecosystem Office Review.** Regional Ecosystem Office. July 9, 1996

. . .
Use of the criteria will expedite implementation of beneficial silvicultural treatments in LSRs [Late Successional Reserves] and MLSAs [Managed Late Successional Areas]. . . .

It is important to note that these criteria do not affect the kind of activities the *ROD* permits within LSRs and MLSAs. The criteria simply exempt a specific subset of silvicultural treatments from the requirement for project level REO review of silvicultural activities within LSRs and MLSAs. Please also note that compliance with the *ROD's* standards and guidelines and other statutory and regulatory requirements is not affected by these exemption criteria.
. . .
All silvicultural treatments within LSRs will be conducted according to a silvicultural prescription fully meeting agency standards for such documents. A description of the desired future condition (DFC), and how the proposed treatment is needed to achieve the DFC, are key elements in this prescription. The description of desired future condition should typically include desired tree species, canopy layers, overstory tree size (e.g., diameter breast height), and structural components such as the range of coarse woody debris (CWD) and snags.
. . .
Four other key points about thinning are important to consider when developing thinning prescriptions:

1. We urge caution in the use of silvicultural treatments within LSRs. Silvicultural treatments within old habitat conservation areas (HCAs) and designated conservation areas (DCAs) were extremely limited, and many of the participants in the Forest Ecosystem Management Assessment Team/Supplemental Environmental Impact Statement (FEMAT/SEIS) process advanced good reasons for continuing such restrictions. Only high eastside risks and a case made that late-successional conditions could clearly be advanced by treatments in certain stand conditions led decision makers toward the current S&Gs. Note that the "examples" for the westside (S&Gs, page C-12) are for "even-age stands" and "young single-species stands." Agencies must recognize when younger stands are developing adequately and are beginning to become valuable to late-successional species. Such stands should be left untreated unless they are at substantial risk to large-scale disturbance.

2. Thinning can easily remove structural components or impede natural processes such as decay, disease, or windthrow, reducing the stand's value to late-successional forest-related species. Thinning prescriptions that say "leave the best, healthiest trees" could eliminate structural components important to LSR objectives.

3. While "historic" stand conditions may be an indicator of a sustainable forest, they are not the de facto objectives. The S&Gs require an emphasis toward late-successional conditions **to the extent sustainable.**

4. Treatments need to take advantage of opportunities to improve habitat conditions beyond "natural conditions." For example, exceeding "natural levels" of CWD within a 35-year-old stand can substantially improve the utility of these stands for late-successional forest-related species. Treatments must take advantage of opportunities to optimize habitat for late-successional forest-related species in the short term.

. . .
EXEMPTION CRITERIA
Silvicultural treatments in LSRs and MLSAs are exempted from REO review (*ROD*, pages C-12 and C-26) where the agency proposing the treatments finds that <u>ALL</u> of the following criteria are met:

Objectives

1. The objective or purpose of the treatment is to develop late-successional conditions or to reduce the risk of large-scale disturbance that would result in the loss of key late-successional structure. Further, the specific treatment would result in the long-term development of vertical and horizontal diversity, snags, CWD (logs), and other stand components benefiting late-successional forest-related species. The treatment will also, to the extent practicable, create components that will benefit late-successional forest-related species in the short term.

   Timber volume production is only incidental to these objectives and is not, in itself, one of the objectives of the treatment. Creation or retention of habitat for early successional forest-related species is not a treatment objective.

2. Negative short-term effects to late-successional forest-related species are outweighed by the long-term benefits to such species and will not lessen short-term functionality of the LSR as a whole.

3. The leave-tree criteria provide for such things as culturing individual trees specifically for large crowns and limbs and for the retention of certain characteristics that induce disease, damage, and other mortality or habitat, consistent with LSR objectives. "Healthiest, best tree" criteria typical of matrix prescriptions are modified to reflect LSR objectives.

4. Within the limits dictated by acceptable fire risk, CWD objectives should be based on research that shows optimum levels of habitat for late-successional forest-related species, and not be based simply on measurements within "natural stands." For example, recent research by Carey and Johnson in young stands on the westside indicates owl prey base increases as CWD (over 4") within Douglas-fir forests increases, up to 8- to 10-percent groundcover south of the town of Drain, Oregon, and 15-percent groundcover north of Drain, increasing to 15 to 20 percent in the Olympic Peninsula and Western Washington Cascades. Other references that could help identify initial considerations involving natural ranges of variability in CWD include Spies and Franklin, for

discussions on Washington Cascades, Oregon Cascades, and Coast Ranges; and Graham, et al., for east of the Cascades.

If tree size, stocking, or other considerations preclude achievement of this objective at this time, the prescription includes a description of how and when it will be achieved in the future.

5. Agencies having an interest in LSR projects proposed under these criteria should continue to be given the opportunity to participate in project development.

Stand Attributes

1. The stand is currently **not** a complex, diverse stand that will soon meet and retain late-successional conditions without treatment.

2. West of the Cascades outside of the Oregon and California Klamath Provinces, the basal-area-weighted average age of the stand is less than 80 years. Individual trees exceeding 80 years in those provinces, or exceeding 20-inches dbh in **any** province, shall not be harvested except for the purpose of creating openings, providing other habitat structure such as downed logs, elimination of a hazard from a standing danger tree, or cutting minimal yarding corridors. Where older trees or trees larger than 20-inches dbh are cut, they will be left in place to contribute toward meeting the overall CWD objective. Thinning will be from below, except in individual circumstances where specific species retention objectives have a higher priority. Cutting older trees or trees exceeding 20-inches dbh for **any** purpose will be the exception, not the rule.

3. The stand is overstocked. Overstocked means that reaching late-successional conditions will be substantially delayed, or desirable components of the stand will likely be eliminated, because of stocking levels.

Treatment Standards

1. The treatment is primarily an intermediate treatment designed to increase tree size, crown development, or other desirable characteristics (S&Gs, page B-5, third paragraph); to maintain vigor for optimum late-successional development; to reduce large-scale loss of key late-successional structure; to increase diversity of stocking levels and size classes within the stand or landscape; or to provide various stand components beneficial to late-successional forest-related species.

2. The prescription is supported by empirical information or modeling (for similar, but not necessarily these specific sites) indicating that achievement of late-successional conditions would be accelerated.

3. The treatment is primarily an intermediate thinning, and harvest for the purpose of regenerating a second canopy layer in existing stands is no more than an associated, limited objective as described below under openings and heavily thinned patches.

4. The treatment will increase diversity within relatively uniform stands by including areas of variable spacing as follows:
   - Ten percent or more of the resultant stand would be in unthinned patches to retain processes and conditions such as thermal and visual cover, natural suppression and mortality, small trees, natural size differentiation, and undisturbed debris.
   - Three to 10 percent of the resultant stand would be in openings, roughly 1/4 to 1/2 acre in size to encourage the initiation of structural diversity.
   - Three to 10 percent of the resultant stand would be in heavily thinned patches (e.g., less than 50 trees per acre) to maximize individual tree development and encourage some understory vegetation development.

   The treatment does not inappropriately "simplify" stands by removing layers or structural components, creating uniform stocking levels, or removing broken and diseased trees important for snag recruitment, nesting habitat, and retention of insects and diseases important to late-successional development and processes.

5. To the extent practicable for the diameter and age of the stand being treated, the treatment includes falling green trees or leaving snags and existing debris to meet or make substantial progress toward meeting an overall CWD objective.

6. Snag objectives are to be identified as part of the DFC. Prescriptions must be designed to make substantial progress toward the overall snag objective, including developing large trees for future snag recruitment and retaining agents of mortality or damage. To the extent practicable for the diameter and age of the stand being treated, each treatment includes retention and creation of snags to meet the DFC. Publications useful in identifying snag-related DFCs include but are not limited to Spies, et al.

   To the extent snag requirements for late-successional species are known, one objective is to attain 100 percent of potential populations for all snag-dependent species.

7. The project-related habitat improvements outweigh habitat losses due to road construction.

Knowles, Donald R. 1996. **Memo to Regional Interagency Executive Committee (RIEC), RE: Amendment to "Criteria to Exempt Specific Silvicultural Activities in Late-Successional Reserves and Managed Late-Successional Areas from Regional Ecosystem Office Review" of July 9, 1996**. Regional Ecosystem Office. September 30, 1996.

> After issuance of the July 9 criteria, members of my staff and the LSR Work Group continued to review current research, particularly that of Drs. Andrew Carey and Connie Harrington on commercial thinning in northwest Washington. Based on this additional review, it is apparent that although 1/4 to 1/2 acre openings will add structural diversity in some stands, they are larger than needed to improve small mammal populations (forage species for northern spotted owls), and are larger than normal processes would typically create in the course of naturally developing late-successional forests. "Best guess" thinning studies currently being conducted by the researchers do not include openings this large. Therefore, the second and third bullets under Treatment Standard #4 in the July 9 Exemption Criteria are combined to now read:
>
> > "Three to 10 percent of the resultant stand would be in heavily thinned patches (i.e., less than 50 trees per acre), or in openings up to 1/4 acre in size, to maximize individual tree development, encourage some understory vegetation development, and encourage the initiation of structural diversity."

Larson, D.J., 2001. **The Effects of Thinning on Forest-Floor Small Mammals in the Coast Range of Oregon,** AN ABSTRACT OF THE THESIS OF David J. Larson for the degree of Master of Science in Forest Science presented on October 31, 2001.
http://www.fsl.orst.edu/cfer/pdfs/Larson.pdf

> Thinning of young Douglas-fir forests has the potential to enhance structural diversity and improve habitat for wildlife. I examined the effects of thinning and thinning intensity on abundance and demographic characteristics of forest-floor small mammals in the Coast Range of Oregon 5 and 6 years after thinning had occurred. Thinning resulted in greater densities of Townsend's chipmunks (*Tamias townsendii*), creeping voles (*Microtus oregoni*), and Pacific jumping mice (*Zapus trinotatus*), and densities of chipmunks and creeping voles were greater in heavily thinned stands than in moderately thinned stands. Movement of female chipmunks was less in heavily thinned stands and movement of female deer mice was less in thinned stands. Sex ratios of deer mice and creeping voles were skewed toward females in heavily thinned stands. Body mass of male deer mice was also greater in heavily thinned stands. Thinning had neutral effects on density of deer mice (*Peromyscus maniculatus*) and on populations of Trowbridge's shrews (*Sorex trowbridgii*), Baird's shrews (*Sorex bairdi*), Pacific shrews (*Sorex pacificus*), and shrew-moles (*Neurotrichus gibbsii*). Northern flying squirrels (*Glaucomys sabrinus*) were more abundant in unthinned stands than in thinned stands 5 years after thinning had occurred. Greater amounts of small-diameter down wood and slash, and increases in percent cover of low shrubs after thinning may partially explain the increases in abundance of chipmunks, Pacific jumping mice, and creeping voles in thinned stands.
>
> Thinning young Douglas-fir forests appears to enhance habitat quality for most species of forest-floor small mammals. In addition, heavy thinning may hasten development of mature forest conditions that may provide optimal habitat for these species. However, because some species appear to prefer closed canopy forests, it is recommended that some unthinned stands be retained as a component of the forested landscape.

Lindenmayer, David B., and Jerry F. Franklin. 2002. **Conserving Forest Biodiversity: A Comprehensive Multi-scaled Approach.** Island Press, Washington.

> We agree that active management is often desirable to maintain or re-create decadence as well as other structural features in managed forest stands.
>
> **Some techniques for managing forest stands to create or maintain structural complexity and compositional diversity.**
>
> - Precommercial and commercial thinning to grow large-diameter trees
> - Variable density thinning ("skips" and "gaps") to create structural heterogeneity within stand
> - Thinning "from above" (selectively removing dominant trees) or branch pruning to sustain or release
>   - shade tolerant understory trees
>   - understory shrubs and herbs
> - conservation of tree or other plant species that fulfill different structural or functional roles such as
>   - deciduous hardwood species in evergreen coniferous stands
>   - species hosting nitrogen-fixing bacteria
>   - species with capacity to host epiphytes
>   - species with distinctive bark or branching habits
>   - species with edible fruits
> - Creating decadence
>   - Creating logs and coarse woody debris
>   - Simulating development of decadence in living trees
>   - Creating artificial cavities
> - Installing nest boxes or similar artificial structures
> - Prescribed burning

- Planting desired tree or understory plant species
- Introducing or enriching populations of desired animal species

. . .
Physical removal of trees that are felled or girdled may not be necessary in thinnings aimed at enhancing biodiversity conservation. Some or all of the thinned material may be retained to contribute to stand structural complexity and organic matter. However, where trees have commercial value and are physically accessible, they probably will be removed; this can provide financing for additional stand treatments to further enhance conservation of biodiversity.

Long, Colin J., Cathy Whitlock, Patrick J. Bartlein, and Sarah H. Millspaugh. 1998. **A 9000-year fire history from the Oregon Coast Range, based on a high-resolution charcoal study**. Can. J. For. Res. 28(5): 774-787 (1998) .
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x98-051_28_ns_nf_cjfr5-98

> **Abstract**: High-resolution analysis of macroscopic charcoal in sediment cores from Little Lake was used to reconstruct the fire history of the last 9000 years. Variations in sediment magnetism were examined to detect changes in allochthonous sedimentation associated with past fire occurrence. Fire intervals from ca. 9000 to 6850 calendar years BP averaged 110 ± 20 years, when the climate was warmer and drier than today and xerophytic vegetation dominated. From ca. 6850 to 2750 calendar years BP the mean fire interval lengthened to 160 ± 20 years in conjunction with the onset of cool humid conditions. Fire-sensitive species, such as *Thuja plicata* Donn ex D. Don, *Tsuga heterophylla* (Raf.) Sarg., and *Picea sitchensis* (Bong.) Carr., increased in abundance. At ca. 4000 calendar years BP, increases in allochthonous sedimentation increased the delivery of secondary charcoal to the site. From ca. 2750 calendar years BP to present, the mean fire interval increased to 230 ± 30 years as cool humid conditions and mesophytic taxa prevailed. The Little Lake record suggests that fire frequency has varied continuously on millennial time scales as a result of climate change and the present-day fire regime has been present for no more than 1000 years.
> . . .
> **Conclusions**
> **. . .**
> Fire events at Little Lake were most frequent, with [mean fire return interval] MFI of 110 ± 20 years, in the early Holocene when warm, dry conditions existed. Fire frequency then decreased to a MFI of 160 ± 20 years as the climate become cooler and more humid in the middle Holocene. In the late Holocene a MFI of 230 ± 30 years was established with further cooling and increase precipitation. Increases in Douglas fir, red alder, and other fire-resistant and disturbance-adapted species accompanied periods of high fire incidence. Fire sensitive species, such as Sitka spruce and grand fir, were more abundant during periods of low fire frequency. These results suggest that variations in the frequency of fire have been important in shaping the composition and distribution of Coast Range forests through the Holocene and that changes in both vegetation and fire frequency were controlled by climate.

Maas-Hebner, KG, and BA Schrader. 2001. **The Effects of Silvicultural Activities on Wildlife and Fish Populations in Oregon and the Pacific Northwest: An Annotated Bibliography from 1960 to 1999.** Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 32.
http://www.cof.orst.edu/cof/pub/home/rc/rc32.pdf

> ABSTRACT: This annotated bibliography was compiled to provide forest managers with a comprehensive list of sources on the potential effects of silvicultural activities on wildlife and fish populations in Pacific Northwest forests. The bibliography emphasizes publications directly examining silvicultural activities and responses by these populations. Abstracts from 296 publications are indexed by geographic area, forest type, wildlife or fish species, silvicultural activity, and author. In addition, the appendices list 29 general resource references and 70 World Wide Web links. Forest management activities covered in this bibliography include even- and uneven-aged harvesting systems, site preparation, vegetation management, pest control, fertilization, and road construction and use. The focus of this bibliography is the interface between silviculture and management of wildlife and fish habitat in Oregon; however, applicable literature is included from other regions in western North America.
>
> [Excerpts below are relevant to thinning west of the Cascades.]
>
> **Artman, VL. 1990. *Breeding Bird Populations and Vegetation Characteristics in Commercially Thinned and Unthinned Western Hemlock Forests of Washington*. MS thesis, University of Washington, Seattle.**
> To assess the effects of thinning on bird populations and vegetation composition, Artman compared commercially thinned and unthinned 45- to 50-year-old western hemlock stands in the Washington Cascades. Thinned stands had lower tree densities, more open overstory canopies, more understory growth, and higher bird species diversity than unthinned stands. Total bird density did not appear to be affected by thinning and was positively correlated with the presence of deciduous trees and shrubs in the thinned stands. Artman concludes that vegetation diversity in thinned stands benefited bird populations, and that commercial thinning appears to be an appropriate method for enhancing breeding bird habitat.
>
> **DellaSala, DA, JC Hagar, KA Engel, WC McComb, RL Fairbanks, and EG Campbell. 1996. Effects of silvicultural modifications of temperate rainforest on breeding and wintering bird communities, Prince of Wales Island, southeast Alaska. *Condor* 98: 706–721.**
> Breeding and wintering birds were inventoried in young and old-growth forests in southeastern Alaska to determine the effect of silvicultural treatments on bird communities. Young-growth stands were 20 years old and had naturally

reseeded to western hemlock and Sitka spruce after the previous forest was clearcut; these stands were unmodified, precommercially thinned, or patch cut to create canopy gaps. Old-growth stands were >150 years old and dominated by western hemlock, Sitka spruce, and western redcedar; they were not modified. Stand vegetation was characterized after treatment. Total breeding bird and wintering bird abundance and species richness did not differ among the young stand types. Breeding bird abundance was lower in old-growth than in young stands, but species richness did not vary. Wintering bird abundance and species richness, on the other hand, were greater in old-growth stands. In young-growth stands, the authors recommend using variable spaced thinning instead of uniform thinning to create multiple canopy layers for the benefit of bird communities. Residual old-growth clumps should be retained to lessen the negative impact of thinning on forest canopy birds. Old-growth forests may also serve as important winter refugia for some species. The authors note that the Pacific-slope flycatcher and golden-crowned kinglet should be used as indicator species along with the currently used brown creeper and red-breasted nuthatch.

Doerr, JG, and NH Sandburg. 1986. Effects of precommercial thinning on understory vegetation and deer habitat utilization on Big Level Island in southeast Alaska. *Forest Science* 32(4): 1092–1095.
Twelve years after treatment, the authors studied the effects of precommercial thinning on understory vegetation development and habitat use by Sitka black-tailed deer in stands of Sitka spruce and western hemlock in southeastern Alaska. All unthinned portions of the stands had dense overstory canopy cover, low understory cover, and low deer use. The thinned areas had significantly more deciduous browse cover and more deer use than the unthinned areas. The authors recommend that future thinnings should be done in the precommercially thinned stands to prevent the canopy from closing and reducing understory growth.

Erickson, JL, and SD West. 1996. Managed forests in the western Cascades: The effects of seral stage on bat habitat use pattern, pp. 215–227 in *Bats and Forests Symposium,* RMR Barclay and RM Brigham, eds. B.C. Ministry of Forests, Victoria, B.C.
Habitat use by bats was assessed across a gradient of intensive forest management conditions to determine the possible effects of these practices on bat populations. The study was conducted in Douglas-fir forests in the Washington Cascade Range. Stands included clearcut (2–3 years old), precommercially thinned (12–20 years), young unthinned (30–40 years), and commercially mature (50–70 years) forests. Overall, the most bat echolocation calls were detected in clearcuts; mature stands had the second highest number of detections, with very few calls detected in precommercially thinned stands, and none in young unthinned stands. The big brown bat, silver-haired bat, and Townsend's big-eared bat were detected most frequently in clearcuts and not at all in unthinned or mature stands. *Myotis* species (California myotis, long-eared myotis, fringed myotis, Yuma myotis, long-legged myotis, and little brown myotis) were detected in all stands except unthinned stands, with most detections in mature stands. The authors conclude that young, unthinned, and precommercially thinned stands are not suitable habitat for forest dwelling bats; high tree densities may impede flight and snags may be too small for use as roosts. Activity levels suggest that clearcuts are used strictly for foraging.

Hagar, JC, WC McComb, and WH Emmingham. 1996. Bird communities in commercially thinned and unthinned Douglas-fir stands of western Oregon. *Wildlife Society Bulletin* 24(2): 353–366.
Breeding bird and wintering bird abundance and diversity were compared in thinned and unthinned Douglas-fir stands (40–55 years old) in the Oregon Coast Range. Stands were thinned from below (removing suppressed and intermediate crown classes) 5–15 years prior to sampling. During the breeding season, bird species richness did not appear to be affected by thinning. Species richness was positively related to the densities of hardwoods 31–43 cm DBH, conifers greater than 56 cm DBH, and snags greater than 53 cm DBH, but it was negatively related to distance to patch edges. Winter bird abundance did not differ between thinned and unthinned stands, but species richness was marginally greater in unthinned stands. Hairy woodpeckers, red-breasted nuthatches, Hammond's flycatchers, warbling vireos, dark-eyed juncos, and evening grosbeaks were consistently more abundant in thinned than in unthinned stands. Pacific-slope (western) flycatchers, on the other hand, were consistently more abundant in unthinned stands. Birds inconsistently associated with the two stand types included gray jays, brown creepers, western tanagers, winter wrens, golden-crowned kinglets, and black-throated gray warblers. Species that were not specifically associated with either thinned or unthinned stands were Swainson's thrushes, Hutton's vireos, Wilson's warblers, chestnut-backed chickadees, and hermit warblers. The authors include a fairly in-depth discussion of these birds and the habitat variables they appear to be associated with, as well as management suggestions.

Hansen, AJ, WC McComb, R Vega, MG Raphael, and M Hunter. 1995. Bird habitat relationships in natural and managed forests in the west Cascades of Oregon. *Ecological Applications* 5(3): 555–569.
The authors integrated data from five previous studies conducted in the Oregon Cascades to quantify bird abundance across broad gradients of forest age and management histories. Bird species abundances were compared in recent clearcuts, canopy retention sites, closed canopy plantations, mature stands, and old-growth forests. Stands were dominated by Douglas-fir, western redcedar, and western hemlock. Relationships between bird abundance and stand level characteristics were also studied. Analysis showed that 18 of 23 bird species examined differed significantly in abundance among stand types, with some species primarily associated with each type of stand. Significant habitat functions were generated for 17 of the 23 species. The authors suggest that the habitat functions can be used to predict bird abundance based on habitat measurements derived from field data, remote sensing data, or computer model output.

Humes, ML. 1996. *Activity of Bats in Thinned, Unthinned, and Old-growth Forests in the Oregon Coast Range*. MS thesis, Oregon State University, Corvallis.
Humes examined the effects of thinning Douglas-fir stands on bats by comparing thinned, unthinned (each 50–100 years), and old-growth stands (>200 years) in the Oregon Coast Range. Thinning occurred 10–23 years before sampling. Bats detected included Townsend's big-eared bat, big brown bat, silver-haired bat, hoary bat, California myotis, long-eared myotis, little brown myotis, fringed myotis, long-legged myotis, and Yuma myotis. Most bat

activity occurred in old-growth stands, followed by thinned and unthinned stands. Thinning stands appeared to increase bat activity. Sampling on one site suggested that bat activity may be greater on limited-use roads than in the interior of thinned and unthinned young stands. Snag diameter, shrub cover, and canopy gaps were correlated with bat activity.

Humes, ML, JP Hayes, and MW Collopy. 1999. Bat activity in thinned, unthinned, and old-growth forests in western Oregon. *Journal of Wildlife Management* 63(2): 553–561.
The influence of thinning Douglas-fir stands on bat activity in the Oregon Coast Range was assessed by the authors. Douglas-fir stands were 50–100 years old and thinned 10–23 years prior to sampling. Thinned stands were compared with unthinned stands of comparable age and with nearby old-growth stands (>200 years). The three stand types varied in tree size and density and amount of overstory and understory cover. Bat activity was higher in old-growth stands and thinned stands than in unthinned stands. The authors conclude that structural changes caused by thinning young stands may benefit bats by creating habitat structure that they can use more effectively.

Weikel, JM. 1997. *Habitat Use by Cavity-Nesting Birds in Young Thinned and Unthinned Douglas-fir Forests of Western Oregon*. MS thesis, Oregon State University, Corvallis.
Young Douglas-fir stands (30–45 years old) in the northern Oregon Coast Range were thinned to determine the effects of thinning intensity on cavity-nesting birds. Stands of even-aged Douglas-fir that had regenerated after catastrophic fires were unthinned, moderately thinned (to a relative density of 35), or heavily thinned (relative density 20). Birds were surveyed 1 year before thinning and for 2 years after thinning. Chestnut-backed chickadee abundances were similar before and after thinning and did not differ with thinning intensity. Red-breasted nuthatch abundances varied between years but not between treatments. Hairy woodpecker abundance increased in thinned stands after thinning, but there was no difference between the moderately and heavily thinned stands. The abundance of brown creepers did not appear to be affected by moderate thinning, but it was negatively affected by heavy thinning.

Wilson, TM, and AB Carey. 1996. Observations of weasels in second-growth Douglas-fir forests in the Puget Trough, Washington. *Northwestern Naturalist* 77: 35– 39.
Weasels in second-growth Douglas-fir forests in southwestern Washington were incidentally caught in a study of small mammals. Two second-growth forests were studied—an intensively managed 65-year-old forest that had been thinned twice over the previous 20 years, and a 56-yearold unthinned forest. In each forest, eight stands were delineated for study; half were thinned in 1993. Small mammals were trapped during summer months from 1992 through 1994. Thirty short-tailed weasels were caught; most (23) were caught in thinned stands where the understory was dense but large woody debris was sparse. The remaining seven were caught in unthinned forests. Fifteen long-tailed weasels were caught; 14 were trapped in unthinned stands, which had little understory development but high levels of coarse woody debris; only one was trapped in a thinned stand. The authors conclude that stand management history may influence abundance and diversity of weasels.

McComb, William C., Spies T.A., and W.H. Emmingham. 1993. **Douglas-fir forests, Managing for Timber and Mature-Forest Habitat,** Journal of Forestry December 1993.

This article describes a conceptual basis for silvicultural systems that integrates mature-forest wildlife habitat and timber objectives in managed Douglas-fir (*Pseudotsuga menziesii*) forests of western Oregon and Washington.

Ecological Importance of Disturbance

Size and Shape. . . . An organism may be displaced by disturbances larger than its home range (the area over which it secures resources), but it might not be displaced if the disturbance scale is sufficiently small relative to the home range. Similarly, mature-forest species may be more tolerant of frequent disturbances than those that occur once in many generations. It is likely that species selecting mature Douglas-fir forests have persisted in the region by (1) tolerating fine-scale disturbances that lead to enhanced stand complexity within their home ranges (fine-scale creation of snags, logs, or vertical structure); or, following coarse-scale disturbances, (2) recolonizing stands of sufficient size that regrow and contain residual trees and dead wood. Recolonization might occur over long periods of time following large disturbances, especially for species with low dispersal capability such as small mammals and amphibians (Harris 1984, p. 85). Refugia from coarse-scale disturbances, such as isolated patches of old forest, may have allowed some of these species to persist and recolonize following large disturbances such as fire or windthrow. . . .

Intensity. Disturbance intensity influences the amount of organic material destroyed or redistributed by the disturbance ....The residual organic material after disturbance can influence the direction of succession and the rate of subsequent development (Harmon et al. 1986).

Stand Objectives for Managed Forests.
. . .
This article proposes that a series of stand condition specifications be developed as target objectives for each stand, including diameter distributions for living and dead wood in naturally-occurring young (40-69), mature (70-200), and old-growth (more than 200-year)stands.

Of the many possible silvicultural approaches to developing such stands, four are discussed here – single-story, few-storied, many-storied, and mature-forests restoration. The first two approaches imitate coarse-scale disturbances; the third is patterned after fine-scale natural disturbances that might be tolerated by some mature-forest species; and the fourth develops a young plantation into a stand with mature-forest structures.

. . .

Existing young, even-aged plantations could be accelerated toward a multi-storied condition through precommercial thinning of variable intensity to release some trees. Shade-tolerant species (grand fir, western redcedar, western hemlock) could be underplanted to provide additional layers as the stand develops, but thinning both layers may be necessary to maintain growth in this lower layer . . .

. . .

Plantation Restoration.

Because millions of acres of plantations have been created without retention of large trees, restoration to resemble mature and old-growth stands within some forests should be a high-priority management goal. In attempting to develop a 40-year-old plantation (319 trees/acre) structure resembling unmanaged young, mature, and old-growth stands, the stand was thinned to 81 trees/acre at age 40, removing 12 mbf/acre of timber and allocating 2 mbf/acre of timber and allocating 2 mbf/acre to snag creation (table 3). The stand was planted to 265 trees/acre (28% Douglas-fir, 72% grand fir).

. . . Thinning of the stand at age 90 was simulated by reducing the density of trees less than 30 inches dbh by 40% (13 mbf/acre was removed);

Landscapes by Design. We are inheriting landscapes created by past disturbances and timber-driven management objectives on mixed ownerships that do not consider large-scale habitat patterning. Combining a range of available silvicultural systems on the landscape in a manner that considers size and connectedness of mature stands over landscapes through time would be one step toward designing forest patterns. For instance, harvest of stands within a landscape should not excessively fragment currently suitable habitat. . . .

Hypothesis Testing

. . . New approaches are often being implemented faster than research can provide information on impact and effectiveness. All of the approaches illustrated in this article are based on ecological concepts that need to be tested with long-term studies. A deductive approach to hypothesis testing should be used to asses (1) the likelihood that predicted stand development will be achieved, including disturbances as well as suppression mortality and changes in species composition; (2) economic feasibility of the systems; and (3) responses of mature-forest wildlife to silvicultural systems (Romesburg 1981).

McCune, Bruce. 2001. **Epiphytes and Forest Management**
http://www.onid.orst.edu/~mccuneb/epiphytes.htm

We have learned a lot in the last ten years about how forest management practices are likely to affect lichens in the Pacific northwest.

Can we accelerate the development of old-growth associates [lichens] in young forests by thinning or other management techniques?
http://www.onid.orst.edu/~mccuneb/accellong.htm

Traditional, uniform thinning of already dense forests has relatively subtle effects on lichens and bryophytes (Peterson & McCune 2001a; Rosso et al., 2000a, Thomas et al. 2001). Dense forests rarely have well-developed lower branches (see also Essen et al. 1996). Even heavy thinning would often do little to create new habitat at the bottom of the vertical profile, but if we expand the concept of thinning to include variable densities and promoting lichen hotspots, then we should be able to make significant contributions to lichen diversity 20 to 50 years from now (Neitlich & McCune 1997; Rolstad et al. 2001).

. . .

Enhancing habitat for one group of species often detracts from habitat for another group of species, because diversity of different groups responds to different factors (Berg et al. 1994; McCune & Antos 1981a, b). In this case, however, it appears that the same structural features identified here could have a positive effect on many groups of organisms (e.g. see Pettersson et al. 1995), by reintroducing structural diversity into otherwise relatively monotonous young forests.

Has this idea been tested? No, not in the Pacific Northwest. Clearcutting has been so popular in mesic forests that we have few stands with a long history of uneven-aged management.

Why is this question important?
http://www.onid.orst.edu/~mccuneb/accelwhy.htm

Decades of intensive clearcutting and high-density replanting of Douglas fir have produced large, monotonous, forests in western Oregon and Washington. These stands are typically overstocked, dark, and species-poor -- an ecological black hole. The natural transition to a more open, multilayered canopy structure will be a long slow process.

Can we use selective cutting or creative thinning to enhance re-establishment and expansion of populations of old-growth species by making the structure of the forest more like old growth? If so, we have a possible win-win solution to the apparent conflict between harvesting timber and improving prospects for old-growth associated species.

Muir, P.S., R.L. Mattingly, J.C. Tappeiner II, J.D. Bailey, W.E. Elliott, J.C. Hagar, J.C. Miller, E.B. Peterson, and E.E. Starkey. 2002. **Managing for biodiversity in young Douglas-fir forests of western Oregon.** U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR–2002-0006. 76 pp. http://www.fsl.orst.edu/cfer/pdfs/mang_bio.pdf

Abstract: This project addressed potential contributions of forest thinning to enhancing biodiversity and accelerating development of old-growth characteristics in relatively young Douglas-fir forests typical of those managed according to the Northwest Forest Plan. Studies focused primarily on 32 paired unthinned and thinned stands and 20 associated old-growth stands in the Coast Range and Cascade mountains of western Oregon. Data were collected on vascular plants in most stands surveyed, and on epiphytic lichens and bryophytes, moths, and birds in subsets of these stands. Studies assessed whether or not (1) communities of organisms differed among stand types, (2) communities in thinned stands were more similar to those in old-growth stands than were those in unthinned stands, (3) species diversity or abundance was related to specific stand features, and (4) these specific stand features were shared across taxa. Results indicated that communities differed among stand types, and that communities in thinned stands were not necessarily more similar to old-growth communities than were those in unthinned stands. Variation in stand conditions appeared to enhance biodiversity, and hardwood trees and shrubs were important for many species. These and other results form the basis for general thinning guidelines, which are presented here, and will guide future research.

The Forest

Today the Douglas-fir/western hemlock forests of western Oregon comprise both young-growth stands1 of small, relatively even-aged trees, and older, more complex stands of large trees, including old-growth stands (see Figure 1). Some of these forests are located on federal lands within the area now managed according to the Northwest Forest Plan (USDA and USDI 1994; Figure 2). These federal lands support an estimated 2,335,628 hectares of small conifer stands (trees <53 centimeters in diameter) in Washington, Oregon, and California. Medium/large conifer stands (trees >53 centimeters in diameter2) on these federal lands include 1,623,550 hectares of single-storied stands and 1,821,255 hectares of multistoried stands (FEMAT 1993). Thus, about 40 percent of these federal forests are relatively young-growth stands, many of which have regenerated after timber harvest or forest fire. Nonfederal Oregon forests include those forests managed by state and private industry, most of which have been logged and maintained in young age classes.

. . .

The Project

The *Managing for Biodiversity in Young Forests Project* addresses the need to understand the potential contribution of thinning as a management practice that may be used to increase biodiversity in reserves, as well as on matrix lands. This report presents the project rationale and major results relating biodiversity to stand characteristics for each of the organisms studied. It is intended to supplement work highlighted in the project video, Managing for Biodiversity in Young Forests (Tappeiner et al. 2000), which depicts a day in the field with researchers (see Appendix A4) concerned with managing young Douglas-fir forests for biodiversity. In the video, Joe Lint, USDI Bureau of Land Management Wildlife Biologist, teams up with Oregon State University Professor Pat Muir to visit researchers comparing vegetation and fauna among Douglas-fir stands, including unthinned and thinned young-growth, and old-growth stands in western Oregon. The researchers share their findings on trees, shrubs, and herbaceous vegetation (John Tappeiner), epiphytic lichens and bryophytes (Eric Peterson and Abbey Rosso), moths (Jeff Miller), and birds (Joan Hagar).

Project results have important implications for forest management, and researchers provide selected recommendations for management actions that may enhance biodiversity in young Douglas-fir forests. Recommendations are intended primarily for agencies, groups, and individuals who manage the Douglas-fir forests of western Oregon. Results of complementary research in the region are included, and data and interpretations presented are based on the understanding of young forests and their response to thinning at the time of publication. The young-growth stands studied in this project ranged from 50 to 120 years in age (average 79 years in age). The concepts and recommendations, however, probably apply to stands ranging from approximately 15 to 120 years in age.

Because the project is a retrospective analysis (i.e., stands were studied after they had been thinned, rather than before and after), cause-and-effect relationships between specific stand characteristics and the diversity of the organisms chosen for study cannot be inferred directly from the results. Even so, the project reveals correlations between forest characteristics and biodiversity—correlations that can be tested experimentally in subsequent studies. In addition, results from these and other studies (e.g., Carey et al. 1999a; Colgan et al. 1999, 2000; Carey 2000; Haveri and Carey 2000; Carey and Wilson 2001; Thysell and Carey 2001; Carey et al. 2002) can be used now to help design treatments that may enhance biological diversity in reserves, as well as on matrix lands. Although references are made to current concerns of land managers about implementation of the Northwest Forest Plan, research findings are relevant to the practice of all agencies, groups, and individuals concerned with enhancing biodiversity in young forests typical of those found in western Oregon.

Forest Stand Development

John Tappeiner

According to generally accepted theory, forest stands tend to develop in a sequence from small seedlings and saplings to dense, closed-canopy stands with narrow age ranges, and then to complex, multistoried, oldgrowth stands (see Oliver and Larson 1996). At present, many young forests in western Oregon comprise trees with a narrow range of ages (Figure 5a), in keeping with the first part of this sequence.5 Increasing evidence, however, suggests that existing old-growth forests started under conditions quite different than those found in the dense, closed-canopy stands from which today's young forests generally develop (e.g., Tappeiner et al. 1997; Poage 2001; Figure 6). Based on the 40 stands included in these studies, old-growth stands appear to have comprised trees of a range of ages and sizes. Thus, disturbance and tree establishment may have been ongoing and common processes on sites similar to those on which studies described in this report were conducted. The old-growth stands sampled by Tappeiner et al. (1997) and Poage (2001) at sites in the Oregon Coast Range contained trees that grew under low stocking densities and sustained high growth rates during their first 100 years. The growth and age of large trees in these old-growth forests, measured by counting rings on stumps in stands that have been clearcut (Tappeiner et al. 1997; Poage 2001), indicate that the density of large trees (>75 centimeters) in these former old-growth stands was variable and low—often <50 trees per hectare. Tree-ring analyses also indicate rapid diameter growth rates during the first 50–100 years of growth in these large trees. In addition, tree size and/or growth rate at age 50 years explained >70 percent of the variation in tree size at age 200 years (Poage 2001). Thus, these old trees apparently grew quickly at low densities during early stages of their lives, and maintained diameter growth as they aged (Figure 7). Spies and Franklin (1991) also have reported low tree densities for old-growth forests in western Oregon and Washington. By comparison, current densities of canopy trees in the Oregon Coast Range are much higher in unthinned young-growth stands (Bailey and Tappeiner 1998). In the thinned young-growth stands studied in the *Managing for Biodiversity in Young Forests Project*, tree densities generally were lower than in unthinned young-growth stands, but were quite variable (between 59 and 289 trees per hectare), depending on the thinning prescription. The densities in these thinned young growth stands generally were much higher than densities found in old-growth stands (see Figure 5b).

Comparisons of the diameter growth rates at 50 years of age in trees in unthinned young-growth stands planted for timber production to those of old trees at the same age indicate that the diameter growth of the 50- year-old trees is consistently less than that of the old trees. However, researchers have found that the growth of young trees thinned to about 125 trees per hectare is similar to that of old trees (Curtis and Marshall 1986). These young-growth stands are productive and have accumulated biomass rapidly (Curtis and Marshall 1986). Therefore, the relatively slower diameter growth of trees in unthinned young-growth stands (Figure 8) is likely a result of high tree density (commonly >250 trees per hectare) and competition among trees, rather than a change in site productivity. Density reduction (thinning) will be necessary in young-growth stands if these stands are to develop trees with the characteristics of large trees in old-growth stands quickly.

Another consideration is that trees in current oldgrowth stands appear to have become established over a period of many years, and often vary in age by a range of several hundred years (Figure 5b). For example, in a single plot, large trees can range from 100 to >300 years in age (Tappeiner et al. 1997; Poage 2001). In contrast, the range of ages in young-growth Douglas-fir stands is often quite small, e.g., 5–10 years (Figure 5a). Therefore, the old-growth stands appear to have developed by a gradual establishment of trees over time, probably in conjunction with intermittent disturbances.

These results, and others, support the conclusion that regeneration of these old-growth stands occurred over a prolonged period, and that trees grew at low densities with little self-thinning. In contrast, after timber harvest, young-growth stands often develop with high densities of trees of similar age and considerable self thinning. Young-growth stands today primarily contain trees that were established at about the same time, and thus are developing as a single cohort of even-sized, competing trees (Tappeiner et al. 1997). The rationale for thinning is based, in part, on the contrast between diameter growth rates that trees in old-growth forests achieved when they were young and growth rates that trees in today's young-growth stands achieve. Thinning may help accelerate the development of old-growth characteristics in dense young-growth stands (Tappeiner et al. 1997; Poage 2001; Figure 9). Old-growth characteristics include not only characteristics of the trees themselves but also functional and compositional features of the forest ecosystem.

Douglas-Fir Forests in Western Oregon

Wayne E. Elliott

. . . . Approximately 35 percent of the agency's 890,000 hectares of forest lands in western Oregon have an average tree age of <40 years (Figure 10). Approximately 14 percent of these lands support forests in the 40-, 50-, and 60-year age classes. Current stand age-class distributions reflect past harvest rates and disturbance events such as fire. . . .

These forest stands are young, densely stocked, and relatively uniform in age. Variation in tree age is usually <10 years, . . .

. . .

. . . Stands <40 years old and those in the 40–60- year age class are located primarily in reserves (Figure 11), where treatments, including thinning, are being focused on enhancing biodiversity and accelerating the development of old-growth characteristics. . . .

. . .

Project Objectives

The *Managing for Biodiversity in Young Forests Project* is a retrospective analysis, initiated with studies by John Bailey and John Tappeiner, of forest stands typical of those being managed on federal lands in western Oregon. The main question addressed by the project is whether or not biodiversity tends to increase in areas that have been thinned, an observation often made by people who spend time in forests. Such observations have encouraged managers to consider thinning as a management tool that supports the development of old-growth characteristics, including the increased diversity of organisms often considered to be old-growth-associated, in young forests.
. . .
Materials and Methods

Project Study Area

Description of Study Area

The *Managing for Biodiversity in Young Forests Project* comprises studies conducted primarily in young- and old-growth stands typical of the Douglas-fir forests in the Coast Range and Cascade mountains of western Oregon. Stands chosen for research (Table 1; Figure 12) included 32 pairs of unthinned and thinned young-growth stands and 20 old-growth stands originally inventoried by Bailey (1997). The old-growth stands usually were located within 10 kilometers of, and were similar in site conditions to, 20 of the 32 paired unthinned-thinned stands. This group of stands, i.e., the unthinned-thinned pair of young-growth stands and the associated old-growth stand, is referred to as a "stand triad." Additional stands were included for several of the studies (see Table 2; Figure 13). Most of the stands inventoried were located on federal lands managed by BLM.
. . .
Thinning was completed through BLM timber sales, generally 10–20 years before the project was initiated (Table 1).

Stands were thinned only once, and thinning ranged from heavy to light. Typically, approximately 25–30 percent of the stand volume was removed during thinning operations, and removal ranged from 8 to 60 percent across all stands. Relatively large dominant and codominant trees were left in the stands, and relatively small trees of commercial size were removed from the main canopy to favor the development of conifers with large crowns and stems (i.e., "thinning from below").
. . .

Study Objectives, Results, and Recommendations for Management

Trees, Shrubs, and Herbaceous Vegetation

*Researchers: John Bailey and John Tappeiner*10
. . .
Thus, thinning appeared to promote the development of multilayered stands (Bailey and Tappeiner 1998), primarily by providing conditions that favored the establishment of shrubs, hardwoods, and conifers in the understory after thinning (e.g., see Figure 19), and by releasing saplings and intermediate-crown class trees in the stand. The number of seedlings and amount of shrub cover established depended on stand density, both before and after thinning, and on the productivity of the site (Figure 20). Unlike thinned stands, unthinned stands had very few seedlings or saplings in the understory, and no or little initial development of a multilayered stand (Figure 8).
. . .

Conclusions

1. Commercial thinning practices conducted for timber production apparently helped initiate development of diverse, multilayered stands, which should provide habitat for a variety of plant and animal species. Specifically, thinned young-growth stands often had better-developed understories and more tree regeneration than did unthinned young growth stands. Furthermore, small trees that had no commercial value were freed from some level of competition by thinning, and grew to enhance forest structure.

2. Thinning practices, particularly relatively heavy thinnings early in the development of a stand, may maintain or enhance stand-level, plant species diversity. For example, species richness for herbaceous species (Table 3) and total species richness across trees, shrubs, and herbaceous vegetation (Bailey et al. 1998) were greater in thinned stands than in unthinned and old-growth stands. A portion of this increased species richness was associated with exotic species, but grasses and nitrogen-fixing species also were more abundant in thinned stands. All of the native species that were found in old-growth stands, plus additional species, were found in the thinned and many of the unthinned stands.

3. Many old trees grew rapidly when they were young (30–100 years), and produced large stems and crowns. Recent evidence (Tappeiner et al. 1997; Poage 2001) suggests that old-growth stands developed with low densities. In contrast, most young-growth stands in the region today are developing as dense, uniform, even-sized stands. Thinning of these dense, young-growth stands is likely to promote rapid growth of trees with some characteristics normally associated with old trees in old-growth stands.

4. Thinning of young-growth stands may be useful from the perspective of enhancing both wood production and forest biodiversity.

Recommendations for Management

1. Thin young (<60 years old), dense forests12 that have regenerated after harvest to promote biodiversity and abundance of understory plants in young-growth stands.13 Although many years may be needed to achieve the full benefits of this practice for biodiversity, thinning simultaneously allows for commercial wood production.

2. Modify some thinning practices to maintain or enhance forest biodiversity. Variable-density thinning (which also entails leaving some areas unthinned) will provide habitat for a diversity of plants.14 Some plants thrive in relatively open conditions, whereas others find desirable habitat in relatively closed-canopy forests. Take into account habitat features, such as remnant old trees, and hardwood trees and shrubs, such as vine maple, bigleaf maple, oceanspray, and chinquapin. In particular, consider protecting the following:

* Large (≥50 centimeters in diameter) dead wood on the forest floor that may be present from the previous stand.15

*Remnant old trees that provide important substrate for epiphytes and habitat for other organisms as well.

* Hardwood trees and shrub species that provide important substrate for epiphytes, food for arthropods that are prey for birds, and cavities for cavity-nesting birds.

3. Pay attention to exotic species that may enter stands after thinning has taken place.

4. Adapt thinning prescriptions, including variable density thinning, to individual site and stand conditions (e.g., the current stand structure and species composition, and the vulnerability of the site to wind and root disease) and specific management objectives.

5. Consider multiple thinning entries over time in some stands, because the canopy may close quickly in young Douglas-fir forests located on highly productive sites.

Epiphytic Lichens and Bryophytes

Macrolichens on Trees and Shrubs

Researcher: Eric Peterson

. . .

Conclusions

1. Thinned stands supported a slightly higher abundance of forage lichens (some of which are considered to be associated with old-growth stands) than did unthinned young-growth stands. In contrast, total species richness summed across all thinned stands was lower than that summed across all unthinned stands.

2. Although average species richness per stand differed little among stand types, the communities (i.e., the particular species occurring and relative abundances of each) differed greatly among stand types. Thus, comparisons of this type should include community analyses, in addition to simple measures such as species richness.19 Macrolichen communities in thinned stands generally were similar to those in unthinned young-growth stands, but differed from those in old-growth stands and landscape-level hotspots.

3. Old-growth stands supported higher species diversity and abundance of forage lichens and a higher abundance of *Lobaria oregana* than did other stand types.

4. Hotspots supported more rare or unusual macrolichens, and a higher diversity and abundance of cyanolichens, than did other stand types.

Recommendations for Management

1. Retain old and relatively mature or structurally developed trees in young-growth stands. These trees provide a means to retain and promote the growth and reinvasion of dispersal- and substrate limited macrolichen species.

2. Allow some young trees to remain on-site for the long term (e.g., for centuries), where they can acquire characteristics of old trees. Strong evidence exists that certain types of macrolichens, particularly those that are dispersal-limited, simply need time to colonize, rather than require specific late-successional stand characteristics. Allowing some trees to age on the site also will help provide adequate habitat for certain types of lichens that depend on particular bark and tree characteristics.

3. Protect landscape-level hotspots. These areas provide habitat for, and may help sustain, many sensitive species, which often are associated with these unusual forest structures.

4. Retain a legacy of hardwoods and shrubs, and favor the old shrubs on a site. Hardwoods provide important habitat for macrolichens, possibly because macrolichens grow during the wet season, when hardwood leaves are not present. In particular, many nitrogen-fixing species are hardwood-associated, for reasons that are not yet well understood.

5. Focus on increasing structural diversity in managed forests by providing both gaps and dense areas. Such diversity should foster the development of diverse macrolichen communities.

Macrolichens and Bryophytes on Shrubs

Researcher: Abbey Rosso
. . .
Conclusions

1. In dense young-growth stands with few epiphytes in the understory, thinning may have led to increased diversity and cover (abundance) of macrolichens on shrubs, and to increases in the similarity of macrolichen communities on shrubs between young- and old-growth stands.

2. Macrolichens and bryophytes on shrubs appeared to respond differently to thinning of the types used in these stands. Macrolichen species richness may have increased in response to thinning, whereas richness of bryophytes was not greater in thinned than in unthinned young-growth stands.

3. Thinning associated with a loss of old shrub stems may have had negative effects on some shrub epiphytes, particularly on the abundance of matforming bryophytes and macrolichens associated with relatively old shrub stems.

4. Landscape-level hotspots (e.g., riparian areas and hardwood gaps) were rich in shrub epiphytes, and supported communities that were distinctly different from those in surrounding forest areas (similar to findings for epiphytic macrolichens on trees and shrubs).

5. In addition to stand structure, the age of shrubs and stands had important relationships to shrub epiphyte communities.

6. Community composition, which focuses on which species are present and their relative abundances, was important for distinguishing differences in shrub epiphytes among stand types. Species richness alone tells only part of the story.24

Recommendations for Management

1. Incorporate variable-density thinning prescriptions that leave both gaps and dense areas. Variability in overstory density is likely to promote variability in shrub epiphyte communities.25

2. Minimize impacts of thinning on shrubs, particularly old shrubs with well-developed epiphyte cover. Leave a legacy of old shrubs available on a site. The age of shrub stems is an important consideration for shrub epiphytes, and for functions and species that depend on them.26

3. Protect a variety of landscape-level hotspots, both riparian and upslope, such as rocky outcrops and hardwood gaps.

4. Collect epiphyte species-abundance data during studies describing and documenting the condition of epiphyte communities, and in situations in which epiphyte communities are to be monitored. Note that time and funding constraints generally make it impractical to collect abundance data during routine predisturbance surveys.

Moths

Researcher: Jeff Miller
. . .
Conclusions

1. Geometrids and noctuids were the most numerous moth taxa collected, and thus were the most important moth taxa for ecological comparisons based on abundance and species-richness indices.

2. Thinned young-growth stands did not have lower species richness than did unthinned stands. However, the functional group composition of moths did differ between unthinned and thinned young-growth stands. This difference suggests that compositional changes took place after thinning, probably in response to a change in availability of host plants, particularly of hardwoods.

3. Both abundance and species richness of moths exhibited seasonal trends. Thus, sampling must occur frequently throughout the flight season.

4. Hardwood shrub densities often were higher in thinned than in unthinned young-growth stands, and these hardwoods were important food sources for moths. Caterpillars prefer to feed on fresh foliage, irrespective of stem age.33

5. Sampling moths in forest ecosystems required the use of specialized equipment and protocols, such as frequency of sampling and expertise in the taxonomy of this relatively less well-studied group of animals.

Recommendations for Management

1. Maintain a variety of stand types and densities across the landscape to promote a diversity of plant species and associated fauna.

2. Ensure taxonomic expertise when dealing with moth species (e.g., issue contracts for moth work only to persons known to be competent in moth taxonomy).34 Also, when designing sampling protocols for moths, be aware of strong seasonal trends in moth abundance. Half of all the species present over a year can be collected from the end of July through August.

3. Categorize moths by functional groups in addition to species-based categorizations. Grouping by hostplant categories provides ecologically useful information, because such groupings are tied directly to the structure and composition of forests.

4. During thinning and other forest-management activities, favor plants that support a high number of caterpillars, e.g., chinquapin and oceanspray, as well as members of the genera *Alnus*, *Arctostaphylos*, *Ceanothus*, *Quercus*, *Salix*, and *Vaccinium*. This can be accomplished by protecting established individuals during thinning or other forest-management activities. Although it is not possible to identify a set number of plants to retain per unit area, any removal of these species likely will have a corresponding effect on moth populations and communities.

5. Be aware that a high frequency of uncommon species in a stand might be a positive indicator of forest health.

Birds

Researchers: Joan Hagar and Ed Starkey

. . .

Conclusions

1. The total abundance of birds was greater in thinned young- and old-growth stands than in unthinned stands. The relatively well-developed understory vegetation in both thinned and old-growth stands (Bailey 1997) provided vertical heterogeneity that probably best explains this finding.

2. Habitat conditions for most bird species in thinned young-growth stands differed from conditions in old-growth stands. Thus, a diversity of stand types and conditions across the landscape is necessary to provide habitat for all bird species.

3. Bird species richness was positively associated with hardwood components of stand structure, which indicates the important contribution of hardwoods to stand-level diversity.

4. Wilson's warblers were more abundant in thinned than in unthinned young- or old-growth stands. Bracken fern supported a high abundance and diversity of arthropods, including those found to be part of the diet of Wilson's warblers, as did several tall-shrub species.

5. The relationship between abundance and habitat quality is unclear for many species. Preliminary evidence indicates that the abundance of some birds may be an indicator of habitat quality, because bird abundance was correlated positively with the abundance of food (arthropods).

Recommendations for Management

1. Use thinning as a tool to manage young forests to improve habitat for some bird species, but leave some unthinned areas for species associated with dense conifer canopies. The size of unthinned and thinned areas depends on management goals and objectives, and on the overall landscape context. Because breeding bird territories often encompass 5–10 hectares, management at this scale, or larger, likely will be beneficial when providing habitat for birds is a consideration.

2. Retain and promote the growth of understory and midstory vegetation, particularly tall shrubs and other hardwoods. Relatively heavy thinnings and irregular spacing of residual trees should help encourage understory development.

3. Maintain a diversity of stand types and conditions across the landscape. Results from this study indicate clearly that no one kind of stand condition is optimal for all species.

Project Conclusions

Common Themes

The *Managing for Biodiversity in Young Forests Project* was established in recognition of the need to understand the probable consequences for forest biodiversity of contemporary shifts in the goals and objectives of forest management, and specifically to explore the contribution of thinning to management of forests for biodiversity. As noted by Hayes et al. (1997), "Thinning has traditionally been used to maximize wood production; incorporating objectives for wildlife is a relatively new approach in forest management—one with a great deal of promise but many unanswered questions." Thinning young-growth stands in an effort to promote native biodiversity of all types of organisms over the long term raises additional questions. The effectiveness of thinning (of various types) in promoting the development of understory vegetation, tree growth and regeneration, and biodiversity of associated and interdependent organisms must be evaluated over the long term to provide answers to these questions. Fortunately, several such long-term studies are in progress (e.g., Harrington and Carey 1997; Carey et al. 1999b; Franklin et al. 1999; Carey and Harrington 2001; Reutebuch et al. 2002).

Young-growth stands vary in structure, composition, and tree density. When young forests are thinned, the resulting stand structure and composition depend on past and current tree density, the thinning treatments used, site conditions, volume of coarse woody debris, and other factors. Thinning prescriptions vary widely: some thinnings are heavy, some are light, and some are variable-density; some retain remnant trees and shrubs, whereas others do not; and some call for removal of downed wood, whereas others do not. Interpretation of studies involving thinned young-growth stands, such as those presented in this report, is complicated by the wide range of stand conditions encompassed by the term, "thinned young-growth stands." This variability among stands and site conditions needs to be considered in evaluating results from these studies, and in making decisions about appropriate thinning prescriptions for a given forest stand.

Despite differences in the organisms and conditions of stands studied, and in the relationships of the various organisms to existing stand conditions, the conclusions of the studies that are part of the *Managing for Biodiversity in Young Forests Project* exhibit a number of common themes. Some of the most important of these common themes are listed as follows:

* Variation in stand conditions, both within stands and at the landscape level, is important in providing habitat for a diversity of forest organisms.

* Hardwoods are important for many species, whether through providing habitat substrate (e.g., for epiphytes), food sources (e.g., for moth larvae), or foraging substrate (e.g., for birds)—or other habitat conditions. Hardwood shrubs, in particular, were identified as being important contributors to forest biodiversity.

* Hardwoods, particularly shrubs, were generally more abundant in thinned than in unthinned young growth stands 10–20 years after thinning.

* The abundance of some types of organisms, individual species, and functional groups was sometimes more similar between thinned and oldgrowth stands than between unthinned and oldgrowth stands; however, many exceptions to this pattern were found. No overall generalization can be made that thinned stands have an abundance of organisms or species richness more similar to oldgrowth than do unthinned young-growth stands—at least in the first 10–25 years after thinning and for the kinds of organisms studied in this project.

* Analyses of communities, which take into account species composition and relative abundance of species, often were better able to reveal differences among stand types than were comparisons of summary measures, as, for example, species richness or abundance.

* Community analyses generally indicated that communities differed more by geography (site) than by stand type.

Proposed Thinning Guidelines

Thinning of the young forests surveyed during this project was completed under forest-management protocols prevailing 20–30 years ago. At that time, managers typically made no attempt to provide for development of shrub cover or multiple layers in the canopy, and took no special measures to promote biodiversity. The primary objective was wood production. Some positive influences of thinning under these earlier protocols (as inferred retrospectively) on a variety of forest organisms are apparent, however. Because of variation in the type and degree of thinning possible and the existing condition of young-growth stands, thinning prescriptions clearly need to be developed on a case-by-case basis (Figure 28). Nonetheless, based on current understanding of young-growth Douglas-fir stands in western Oregon, the following general management guidelines for thinning are proposed:

* Retain all existing old, remnant trees, snags, and large woody debris.

* Leave a legacy of large trees with large limbs extending low into the crown ("wolf trees").

* Favor hardwood trees across a range of size classes, including large trees that occupy midcanopy and higher positions.

* Protect and encourage a legacy of tall hardwood shrubs, especially those with old stems.

* Leave sufficient understory conifer regeneration, which, along with hardwoods, will provide for the development of multistoried stands.

* Create conditions that provide for the presence of herbs and grasses in forest stands.

* Use variable-density thinning, including heavy thinning (e.g., to 50 trees per hectare) in portions of young-growth stands. Heavily thinned areas will encourage understory development, as well as development of trees characteristic of those found in old-growth stands.

* Foster both within-stand and landscape-level diversity in stand densities; thus, leave some areas unthinned to provide a wide range of stand densities at both spatial scales. Studies assessing responses of biodiversity to various spatial scales of management are ongoing, and results that can inform forest management will not be available for several years. Thus, recommendations for specific sizes of areas thinned to various degrees and unthinned areas are not available. Decisions about spatial scale must be guided by management objectives and site or stand conditions.

At this time, the impacts on stand structure and forest biodiversity of thinning young Douglas-fir forests of western Oregon according to the proposed guidelines are uncertain; however, results from this project and others (see Appendixes F–G) suggest that adoption of these proposed guidelines is likely to enhance native biodiversity and encourage the development of oldgrowth characteristics in comparison to what is found in unthinned young-growth stands and those thinned according to conventional prescriptions.

In 1977, Marion Clawson wrote that "the importance of forests tend generally to be underestimated in the United States, but is better understood in the Pacific Northwest than almost anywhere else in the country." This understanding requires ongoing research, interpretation, application, and evaluation (i.e., adaptive management; see Figure 4) to further management goals, such as those set in managing for biodiversity in young forests. The findings of this project should assist in planning for management of western Oregon's young forests. Although the findings and guidelines from the *Managing for Biodiversity in Young Forests Project* apply specifically to young Douglas-fir forests of western Oregon, they also may help guide research direction and focus in forests elsewhere.

Newton, Michael and Elizabeth C. Cole. 1987. **A Sustained-Yield Scheme for Old-Growth Douglas-fir,** West. J. Appl. For. 2:22-25, Jan. 1987.

. . . Our purpose here is to describe some findings that may clarify ways of producing forests that are much like old-growth, yet provide high levels of timber production in reasonable rotations.
. . .
They [two stands selected for study] were selectively logged in 1914. In 1959, . . . mature bigleaf maple were experimentally removed . . .
. . .
In 1914 the stands were even-aged, 50 and 70 yr old, and residual stump diameters indicate that most of the trees cut at that time were probably 14 to 24 in. dbh.
. . .
The 120 and 140-yr-old stands are at 29 and 31 stems/ac, respectively...
. . .
Average diameters are 7.5 and 10.8 in. greater than those of comparable numbers of the largest trees in normal stands.
. . .
The remarkable feature of this summary is the clear picture of increasing absolute diameter and basal area growth during an age span when both are expected to decline after a period of normal stocking.
. . .
Current trends indicate that growth will probably stay at or above present levels for 3 to 5 more decades, which will lead to volumes substantially greater than 100,000 bd ft/ac by ages 170 to 190 yr (Figure 1), and to average diameters of 50 to 52 in.
. . .
Amenity values of these stands approach those of old-growth. Size distributions, numbers of trees, and frequency of damaged tops are well within the range proposed by the Old-Growth Definition Task Force (1985). There are fewer downed logs and softwood snags than proposed, but these can be augmented or removed in the course of management. Damaged tops, rotten knots (such as those from *Fomes pini* infection), and downed logs are habitat components that favor various cavity-nesting birds and rodents. The area of our stands was too limited for a useful inventory of these features, but their occurrence in stands with these histories is evidence that such conditions could be reproduced under deliberate management according to quantitative standards.
. . .
There are enough damaged or defective conifers to provide for some snags and downed logs in the future but probably at a lower ate than that defined for "true" old growth.
. . .
This "accidental" achievement, in 120 to 140 yr, of stands resembling old growth can probably be improved on if forest managers make early decisions on what they eventually want in their stands. Given adequate time, Douglas-fir clearly has the ability to occupy growing space after thinning from below. . . .
. . .
Examples have been noted in which thinning to 50 Douglas-fir/ac at age 37 leads to full site occupation by low-density stands of high quality and yield by age 50 (Berg 1970). The final intermediate harvest can be at any age, but 50 yr appears to be early; the nature of our stands suggests that 70- yr or later will lead to high yields from thinning and to development of good quality in residual dominant trees. Thinning to the desired density might be done in several entries . . .
. . .
...[L]ow stand densities would make cable yarding feasible for intermediate harvests on steep slopes. Cutting stumps very short would reduce visible evidence of management; very high stumps would serve as habitat for certain birds.

Osborne, Derek R. 2001. **A Restoration Strategy for Secondary Forests of Clayoquot Sound, British Columbia,** A Joint Project of: Faculty of Forestry, University of Toronto, and Long Beach Model Forest Ucluelet, British Columbia. August 27, 2001
http://www.lbmf.bc.ca/publications/Restoration%20Strategy%20for%20Secondary%20Forests%20of%20CS.pdf

There is no assurance that secondary-growth resulting from past harvesting activities will develop similarly to ecosystems developing after natural disturbances, since secondary forests are often overstocked and lacking in biological legacies. The presented upland restoration strategy implements thinning practices that move coniferous secondary stands out of the stem exclusion phase and accelerates the development of conditions associated with late-seral forests. Variable density thinning (VDT) is recommended to generate a mosaic of overstory and understory conditions, thus creating an admixture of habitats. An alternating spatial arrangement of light-, heavy-, and gap-thinnings based on naturally occurring patterns will mimic natural disturbance regimes.

. . .

Among its numerous recommendations, the Scientific Panel [for Sustainable Forest Practices in Clayoquot Sound] suggests:

> "Develop restoration plans for areas where forest values have been degraded.
> Restoration plans should initially target:
> - The restoration of hydroriparian zones; and
> - Large areas which have been clearcut in the past without retention of late
>
> successional features (e.g., large, old living trees; snags; and downed logs).

. . .

As such, the purpose of this report is to provide a restoration methodology for Clayoquot Sound based on the current literature and opinions of experienced professionals in the fields of restoration and forest management. It must be stressed that the information presented in this report should be viewed as general in nature. The goal is not to provide a cookie cutter approach to the restoration of secondary forests. No single prescription to promote habitat for wildlife works for all young stands.

. . .

As with riparian restoration, much of our current understanding about upland forest restoration originates south of the border. A number of field trials of alternative stand management regimes are currently underway in the Pacific Northwest (Carey, 1998). Many of these studies are the result of concerns for the habitat needs of the endangered northern spotted owl (*Strix occidentalis*). The Olympic Habitat Development Study (OHDS) tests alternative treatments in 30-70 year-old forests to accelerate the development of stand structures and plant and animal communities associated with late successional forests. Among those treatments being evaluated are thinning, understory enrichment, and CWD augmentation (USDA Forest Service, website). The Forest Ecosystem Study (FES) came about as an early response to the need for innovative silvicultural methods designed to stimulate development of late-successional attributes in managed forests. In 1991, scientists with the FES applied experimental, variable-density thinning (as explained later in this report) to even-aged Douglas-fir forests on the Fort Lewis Military Reservation in western Washington after having first accumulated extensive baseline data on arboreal rodents, small mammals, trees and other vascular plants, and fungi. Since thinning, further research elements have been incorporated into the FES, including top rot fungal inoculation and soil web response to thinning, in addition to the ongoing prey base, vegetation, fungal, and silvicultural assessment investigations (Carey *et. al.,* 1999). Despite differences in forest type, the results of the FES are particularly relevant in developing a strategy for Clayoquot Sound.

. . .

Some forest managers assume that late-seral forests will develop automatically when second-growth forests are placed in reserves, particularly if biological legacies such as standing live and dead trees and fallen trees and logs have been retained (Carey, 2000). The objective of this "protection-no management" strategy is to allow biotic communities to develop unhindered and unaided by direct, conscious, human intervention and to minimize disturbance and risks associated with active management activities such as road building and timber harvests. However, an often unstated consequence of this strategy is a slow rate of forest development. There is no assurance that second-growth forests resulting from harvesting activities will develop similarly to ecosystems developing after natural, catastrophic disturbances because second growth forests are often overstocked with trees and lacking in biological legacies (Carey *et. al.,* 1999). Many young secondgrowth stands are now in a very plastic stage of development, and there are many opportunities to mold them – individually and in a landscape context – toward a variety of objectives (DeBell *et. al.,* 1997), including the accelerated development of habitat for species associated with late-seral conditions.

The young stands resulting from clearcutting activity may be on a different developmental trajectory than that followed by many existing old-growth stands. Oldgrowth trees grew rapidly when young (i.e., <100 years). However, by age 50, diameter growth of trees in today's well-stocked stands is generally slower than that of old-growth trees when they were the same age (Tappeiner *et. al.,* 1997). Based on comparisons with growth rates of young trees, Tappeiner *et. al.* (1997) surmised that the density of trees in old-growth Douglas-fir stands was typically about 100-120 trees per ha throughout much of their early development. This is consistent with very low densities of larger trees (>100 cm dbh) found in many old-growth stands. Thinning young stands may provide growing conditions that more closely approximate those historically found in developing old-growth stands. Thus, thinning can move stands out of the stem exclusion phase and accelerate the development of conditions found in late-seral forests (Hayes *et. al.,* 1997).

However, conventional thinning may not be the most suitable technique for restoration purposes. Thinning with even spacing can retard crown-class differentiation and development of habitat breadth. Light thinning may fail to advance understory development significantly before the canopy closes. On the other hand, heavy thinning may disrupt canopy connectivity, increase wind flow within the forest, and cause the forest to become drier and warmer (Carey, 2000b). As such, the benefits to biodiversity under conventional thinning may be limited.

Variable-density thinning (VDT) provides an alternative technique to conventional thinning methods that may prove quite suitable in the restoration of Clayoquot Sound's secondary forests. VDT is a relatively new silvicultural technique that was devised to create patchiness or spatial heterogeneity in composition and structure that would mimic conditions found in old-growth forests (Carey *et. al.,* 1999). The spatial heterogeneity observed in natural old-growth forests may have resulted from a combination of three different processes: (1) suppression of subordinate trees in densely stocked stands; (2) gap formation resulting from the breakage of trees with top rot infestation or death of individual trees from senescence, windthrow, lightning strikes, disease, insects, or other causes; and (3) gaps resulting from small-scale catastrophic disturbance such as fire, windthrow. VDT is designed to simulate these processes: (1) "light-thinning" simulates suppression mortality; (2) "heavy-thinning" simulates gap formation as a result of individual tree breakage or death; and (3) "gap-thinning" mimics small-scale catastrophic disturbance. As such, VDT presents a novel strategy that is based on empirical studies on natural and managed forest communities formed through self-thinning and gap formation (Carey, 2000).

Recommendation: Where possible, implement a variable-density thinning (VDT) strategy rather than conventional thinning methodologies. VDT generates a mosaic of overstory and understory conditions, thus creating an admixture of habitats.

. . .

A key aspect of VDT is the spatial arrangement of treatments. Alternating light-, heavy-, and gap-thinnings should produce highly variable light regimes on the forest floor that result in a mosaic of vegetation site types, some with a high degree of vertical layering, and some with simple structure (Carey *et. al.,* 1999). The spatial extent and arrangement of treatments should aim to mimic natural patterns.

. . .

Proper tree selection is crucial in ensuring that the residual stand is optimal for biodiversity purposes. Many of the guidelines for tree selection outlined for riparian ecosystems may also apply to upland sites. Mortality of retained trees at harvest should be expected, but risk of windthrow can be reduced by leaving trees with low height-to diameter (H/D) ratios. The live crown ratio may be another indicator of wind resistance and could be used to make decisions about retention (Berg *et. al.,* 1996). This same characteristic can also be used to estimate tree vigour. As discussed for riparian restoration, deciduous tree species play an important role in maintaining biodiversity, including the provision of food (seeds) and shelter (cavities) for wildlife. As such, the deciduous component should be maintained (Carey and Johnson, 1995). Where possible, heavy- and gap-thinning operations should be concentrated in Douglas-fir stands.

. . .

The development of late-seral characteristics (i.e., large diameter stems with large crowns and branches) could be hastened if the largest trees of the stand were retained. As such, only suppressed and sub-dominate trees of the current cohort should be selected for removal. This equates to a "thinning from below" strategy with a d/D3 ratio of <1.0. Trees in the understory and not part of the main cohort should not be removed, as their presence will add structural diversity to the residual stand (Carey *et. al*., 1999).

. . .

Thinnings should be applied as early as possible to prevent stand stagnation and hasten the development of forest stature and structure (Carey and Johnson, 1995). Thinning dense stands that are in the stem-exclusion stage increases the potential for windthrow, particular in exposed sites along ridgetops (Hayes *et. al.,* 1997). This is particularly evident in gap-thinnings, which could potentially "trap" high winds during storms (Carey *et. al*., 1999). Thinning before age 15 will encourage wind firmness and the development of large crowns. Thinning in stages (as recommended for VDT) can also minimize windthrow problems (Hayes *et. al.,* 1997).

. . .

VDT alone may not be sufficient to produce the desired structural elements. Naturally or management-induced canopy openings can produce a vertical array of vegetation (i.e., a column of vegetation from the forest floor to the canopy). However, VDT alone may not be enough to achieve this desired outcome. Undesirable structures that may possibly result from VDT include large vertical gaps between the lower crown and understory vegetation, an absence of understory vegetation, and a continuous, dense cover of low shrubs. Indeed, one of the most difficult aspects of producing the desired future structure is stimulating vegetation to fill intermediate heights. This potential problem may be ameliorated through the planting of shade tolerant conifers and understory deciduous trees in order to fill the gaps where subordinate and co-dominate trees were removed by thinnings (Carey *et. al*., 1999). Seedlings should be planted only in heavy- and gap-thinnings to retain the desired open understory conditions in the remaining light-thinnings.

. . .

Competition-induced mortality in dense stands is generally of small-diameter trees. And although small-diameter snags and downed wood provide some habitat, many species associated with old-growth require large diameter stems. Damage to trees during logging can create snags and CWD, but in general, thinning does not increase numbers of usable snags and woody debris over the short term. In fact, they are often removed for logistical and safety reasons (Hayes *et. al.,* 1997). As well, the removal of living trees through VDT forestalls natural mortality of the residual trees and their resulting contribution to the snag and CWD component. Thus, as trees reach a large size (>50 cm dbh), techniques to accelerate the development of cavity trees may have to be applied, and some trees may have to be felled to provide a continuing abundance of CWD (Carey and Johnson, 1995). Cavities can be created with a chainsaw in large diameter trees and/or induced through artificial inoculation of decay fungi. Artificial cavities can also be provided through supplemental nest boxes (Carey *et. al*., 1999). Kerr (1999) recommends snag creation through girdling, while Deal (1998) suggests using excavators to "plant" large logs (with a high proportion of decay) in a vertical fashion to produce artificial snags.

. . .

It is essential to note that the strategies presented in this report should not be viewed as a direct replacement for the protection of old-growth forests. Rather, the outlined techniques provide a means to hasten the development of late-seral features and support the conservation of biodiversity in the managed landscape . . .

Parminter, John, and Patrick Daigle. 1997. **Extension Note 10: Landscape Ecology and Natural Disturbances: Relationships to Biodiversity**. B.C. Ministry of Forests Research Program. July 1997. (Text by Susan Bannerman). http://www.for.gov.bc.ca/hfd/pubs/docs/en/en10.pdf

> . . . [S]cientists have increasingly recognized that forest, shrub, and grassland ecosystems are dynamic entities. This view, referred to in ecology as the "non-equilibrium model," considers ecosystem structure to be determined by interactions between the long-term forces of ecological succession, fluctuations in climate, and the more immediate effects of natural disturbances.
>
> Natural disturbances are defined as relatively distinct events in time that disrupt ecosystem, community, or population structure and that change resources, the availability of suitable habitat, and/or the physical environment. These events occur at varying intensities across various space and time scales and have contributed, along with climate, soils, and geomorphology, to producing the diverse landscape patterns we see today.
> . . .
> **Seven Generalizations about the Importance of Disturbance**
> Disturbances are fundamentally important in controlling landscape pattern and ecological function. Peter White (1987) listed seven generalizations that help to explain natural disturbances and their effects on ecosystems.
>
> **1. Disturbances occur on a variety of spatial and temporal scales.**
> Landscape mosaics reflect the temporal and spatial distributions of disturbances. Disturbances can be of:
> • small spatial scale (e.g., an individual tree dies or falls, creating a treefall gap), or
> • large spatial scale (e.g., fire may return a large forested area to an early seral stage or wind may advance succession by releasing an understorey of shade-tolerant advanced regeneration).
>
> Both small- and large-scale disturbances can occur, resulting in landscape mosaics with patches of varying size, species composition, and age structure.
>
> Disturbances can affect an ecosystem for:
> • a relatively short time period (e.g., a tree falls; subsequent canopy closure occurs within a decade), or
> • a relatively long time period (e.g., a landslide or intense wildfire; complete ecosystem recovery to pre-disturbance conditions may take centuries).
>
> **2. Disturbances affect many levels of biological organization.**
> Most biological communities are recovering from the last disturbance. The effects of disturbance are felt at many levels of biological organization —from the individual to ecosystem-wide. Natural disturbances can:
> • disrupt ecosystem and stand development,
> • return areas to earlier stages of succession, and
> • change habitat mosaics.
>
> For example, severe fires may consume organic matter in soils, kill dominant tree species, change stream chemistry, and shift the patterns of mammal movements, thus affecting ecological, physiological, and behavioural processes and landscape patterns.
>
> **3. Disturbance regimes vary, both regionally and within one landscape.**
> Disturbances vary among specific geographic areas and biogeoclimatic zones. Some regions or landscapes are subject to wind, landslides, and flooding, while fire, insects, and disease affect others more.
>
> For example, damage during severe wind events is strongly associated with elevation and aspect, as well as vegetation structure. Extremely large areas can be disturbed, especially along or near the west coast, where large-scale storms with hurricaneforce winds come ashore. Some 80% of individual tree mortality in coastal Sitka spruce–western hemlock forests is wind-induced, compared to less than 15% in interior ponderosa pine forests where conditions are different and fire is the prevalent disturbance agent.
>
> Small-scale wind events may create disturbances of varying size in the landscape because of specific topographic or vegetation conditions.
>
> Trees susceptible to blowdown include those that are:
> • situated in rain-saturated soils;
> • located where airflow may be funnelled and thus accelerated (e.g., on a mountain ridge, at the head of a valley, or next to clearcuts); and
> • weakened by age, root disease, or insect damage.
>
> **4. Disturbances overlay environmental gradients, both influencing and being influenced by those gradients.**
> Underlying environmental gradients affect some natural disturbances. For example, fires have the potential to burn more intensely when moving across dry terrain as opposed to moister areas, where less fuel might burn. Some disturbances, however, operate independently of physical gradients, as when severe windstorms randomly destroy

trees over wide areas. The landscape patterns that result from this type of disturbance are thus patchy and unrelated to the underlying environmental gradients. Alternatively, some disturbances reinforce changes in landscape composition and structure along physical gradients. Such events are important mechanisms for energy flow and nutrient cycling and for maintaining age, species, genetic, and structural diversity.

5. Disturbances interact.
Various disturbance agents affect an already diverse physical and biological landscape to create and maintain ecosystem diversity. Some disturbance agents may promote or inhibit the occurrence and effects of other disturbance agents.

For example, windthrow may affect areas with root rot, or insect attack may increase in fire-damaged trees. Or, stands regenerating after a wildfire may be less prone to bark beetle attack for several decades, at which time the trees may become susceptible.

6. Disturbances may result from feedback between the state of the plant community and its vulnerability to disturbance.
Certain landscape characteristics reinforce either shorter or longer disturbance return intervals because of the composition and structure of the vegetation. So while the frequency and intensity of disturbances can influence the types of ecosystems, and thus the vegetation present, these ecosystems can also develop distinct feedback reactions that can, in turn, control the nature of the disturbance.

For instance, stand-maintaining surface fires were common in interior Douglas-fir and ponderosa pine forests. Historically, these forests were all-aged and consisted of distinct groups (or clumps), usually of similarly aged trees, with a relatively open understorey and interspersed grasslands. Such fires maintained these forests in this condition by essentially fire-proofing them: their vulnerability to crown fires was reduced, which effectively reduced the potential for succession to communities composed of later seral plant species.

7. Disturbances produce variability in communities.
Disturbances can impact a stand or landscape unevenly. Natural disturbances (and those created by human action) can promote plant and animal diversity by influencing the species composition, age, edge characteristics, and distribution of stands across the landscape.

Because disturbance regimes can be variable, resulting successional pathways may also vary. For example, a stand-destroying wildfire may favour the establishment of early seral species. In contrast, windthrown forests may be accelerated towards a later seral stage if shade-tolerant advanced regeneration forms the bulk of the next stand.

Peters, Robert S., Donald M. Waller, Barry Noon, Steward T. A. Pickett, Dennis Murphy, Joel Cracraft, Ross Kiester, Walter Kuhlmann, Oliver Houck, and William J. Snape II. 1994. **Standard Scientific Procedures for Implementing Ecosystem Management on Public Lands**; This paper is the report of a workshop convened in July, 1994, by Defenders of Wildlife at the University of Wisconsin, Madison.
http://www.rsl.psw.fs.fed.us/projects/wild/noon/noon6.PDF

Ecosystem management demands a much broader vision than have historical management practices. It requires that managers

- widen their focus from a few species of economic or other value to all the species within the ecosystem;
- focus on understanding and preserving not only species per se but also the interactions between species that collectively maintain the ecosystem and provide ecosystem services (e.g., Meyer, this volume);
- enlarge the management time frame to include long-term ecosystem processes, such as cycles of forest fires and succession to old growth;
- widen the planning process to encompass entire ecosystems, communities, and populations, including portions extending off-site onto adjacent nonfederal lands;
- pursue solutions to threats that originate off-site, such as nonnative pests and pollution;
- accommodate the needs of nontraditional users of federal lands, including nonconsumptive users; and use adaptive management.

. . . [W]e recommend standardized procedures that we consider essential to any management planning program1. The procedures are organized as four main activities: inventory and identification, evaluation of threats to diversity, management design, and monitoring and evaluating effects of management . . . Under these headings we identify and explain the importance of identifying communities and species at risk, choosing appropriate indicator species, measuring and mapping abundances, ranges, and other indicators of species and ecosystem health, calculating minimum viable population sizes for key species, calculating minimum dynamic areas for communities (defined later), and measuring edge effects.

7. Determine How the Biological Communities Respond to Disturbances. Managers should understand how disturbance patterns affect community structure and composition. For each major community type, managers should determine

- the immediate effects of the disturbances,
- the species composition and dynamics of communities that colonize after disturbance,
- the nature and composition of the intermediate successional communities that follow,
- the length of time necessary for "recovery" to old-growth conditions via succession,

- the predictability of successional sequences, and
- how disturbance size and intensity affect successional patterns.

Managers should pay particular attention to how indicator species and endangered and other “at risk" species respond to the type and intensity of both natural and anthropogenic disturbance, including rates and mechanisms of reestablishment.

Large areas may be managed by
- letting natural disturbance regimes and other natural processes reassert themselves;
- generally letting natural regeneration of damaged communities occur rather than using active restoration techniques;
- allowing limited commodity production in some areas, provided evidence demonstrates that such activities will not threaten elements of diversity and provided that close monitoring occurs; and
- cooperating with other agencies and private land owners because the necessary large areas of habitat are likely to extend across management boundaries.

Management can be successful on small areas provided that the desired communities and species- have attributes that allow them to persist in small areas. Such management can include:
- generally using more active management than for larger reserves (e.g., using prescribed burning to maintain small patches of prairie or pine barrens);
- often using active restoration;
- generally excluding extensive or intensive commodity production; and
- protecting small reserves under suitable programs such as Research Natural Areas and Wild and Scenic Rivers. Such reserves are often created to conserve specific species or communities at risk.

Management on both local and regional scales requires planning to maximize landscape connectivity.

Pilz, David. **CHANTERELLE MUSHROOM PRODUCTIVITY, RESPONSES TO YOUNG STAND THINNING**
http://www.fsl.orst.edu/mycology/youngstndthin/Yss.html

As predicted, chanterelle productivity significantly ($p<0.05$) declined (but was not eliminated) immediately after thinning and the level of decline was greater in the heavily thinned stands than in those lightly thinned.

Pilz, David., R. Molina, E. Danell, C. Rose, and R. Waring. 2001. **SilviShrooms: Predicting edible mushroom productivity using forest carbon allocation modeling and immunoassays of ectomycorrhizae**. [Presented at the Second International Workshop on Edible Ectomycorrhizal Mushrooms. 3-6 July, 2001. Christchurch, New Zealand]

Stand Conditions and Silvicultural Choices
http://www.fsl.orst.edu/mycology/ss/Silviculture.htm

Clear-cutting a forest interrupts the fruiting of edible [Ectomycorrhizal] EM fungi for 1-3 decades as the new stand becomes established.
…
Heavy thinning dramatically reduces chanterelle fruiting for up to 4 years; light thinning, less so.

Poage, N.J. and J.C. Tappeiner. 2002. **Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon.** Canadian Journal of Forest Research 32 (7): 1232-1243.
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x02-045_32_ns_nf_cjfr7-02

Abstract: Diameter growth and age data collected from stumps of 505 recently cut old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees at 28 sample locations in western Oregon (U.S.A.) indicated that rapid early and sustained growth of old Douglas-fir trees were extremely important in terms of attaining large diameters at ages 100–300 years. The diameters of the trees at ages 100–300 years (D100–D300) were strongly, positively, and linearly related to their diameters and basal area growth rates at age 50 years. Average periodic basal area increments (PAIBA) of all trees increased for the first 30–40 years and then plateaued, remaining relatively high and constant from age 50 to 300 years. Average PAIBA of the largest trees at ages 100–300 years were significantly greater by age 20 years than were those of smaller trees at ages 100–300 years. The site factors province, site class, slope, aspect, elevation, and establishment year accounted for little of the variation observed in basal area growth at age 50 years and D100–D300. The mean age range for old-growth Douglas-fir at the sample locations was wide (174 years). The hypothesis that large-diameter old-growth Douglas-fir developed at low stand densities was supported by these observations.
. . .
DISCUSSION

Support for the hypothesis that large diameter old-growth Douglas-fir developed at low stand densities comes from observations of (i) rapid early and sustained basal area growth of large-diameter Douglas-fir [i.e., since it is well-

established that trees grow faster at lower densities, rapid growth in young stand suggests less dense growing conditions for these stands], (ii) weak relationships between growth and site factors [i.e., other factors that may have caused large tree growth have been ruled out], and (iii) wide age ranges of old-growth Douglas-firs at different sample locations [i.e., Douglas-fir requires abundant light to become established, so light must have been abundant for long periods in the early life of these stands]. The early diameters and, more significantly, basal area growth of the old Douglas-fir in the study were extremely important in terms of attaining the large diameters typical of old-growth trees at ages 100-300. Our results suggest that trees attaining large diameters typical of old-growth at age 100-300 years generally did so because they were able to: (i) accelerate basal area growth more rapidly and for a longer period of time during the first 50 years of life than did trees with smaller diameters at ages 100-300, and (ii) sustain high basal area growth rates after age 50 years. Because the diameters and basal area growth of individual trees are inversely correlated with stand density, large diameters and rapid growth rates when trees are young strongly suggest that the large-diameter old-growth trees developed with relatively few neighbors.
. . .
Stand density had a greater effect on tree diameter than did site productivity in these studies.
. . .
The results of this study have implications for young-growth stands where the acceleration of the development of late-successional forest characteristics is a management objective. Young-growth stands of Douglas-fir within the study area typically have stand densities by age 50 of over 500 trees/ha and in young plantations tend to be spaced evenly and are far more uniform in age than even the 21-year age range of old-growth Douglas-fir noted by Winter . . .

Poage, N.J. 2000. **Structure and Development of Old-Growth Douglas-fir in Central Western Oregon,** ABSTRACT OF THE DISSERTATION OF Nathan Jeremy Poage for the degree of Doctor of Philosophy in Forest Science presented on November 21, 2000.
http://fresc.fsl.orst.edu/online/online_docs/poage/abstract.pdf

The hypothesis that large-diameter, old-growth Douglas-fir in central western Oregon developed at low stand densities was supported by patterns of long-term diameter and basal area growth of trees, wide mean within-site age ranges (95% CI for mean = 134-214yr), and stem and crown characteristics. The diameters of the oldgrowth trees at ages 100 to 300yr were strongly, positively, and linearly related to their diameters at age 50yr and, more importantly, to their basal area growth rates as young, 50 year-old trees. Rapid and sustained growth by age 50yr was strongly correlated with large diameters at older ages, particularly at ages 100-200yr.

Low heights to live and dead meristematic branches suggest that many of the old-growth trees grew at low stand densities. Live branches occurred on over 50% of the bole, on average. Average height to diameter ratios of the old-growth trees were below 50 (unitless), indicating high mechanical stability. Compared to young-growth trees in high-density stands, young-growth trees in low-density stands have crowns and height-to-diameter ratios more similar to oldgrowth trees.

Poulin, V.A., Bart Simmons, and Cathy Harris. 2000. **Riparian Silviculture: An Annotated Bibliography for Practitioners of Riparian Restoration.** B.C. Ministry of Forests. March 2000.
http://www.clayoquot.org/cwfs%2002%20images/Riparian%20Silviculture%20An%20Annotated%20Bibliography%20for%2

. . . Nearly all of the published work on riparian silviculture comes from the Pacific Northwest, where research on restoring riparian sites has been under way for the better part of the past decade. . . .

On the Importance of riparian areas to fish and role of wildlife
Riparian vegetation regulates stream temperatures by shading, cycles nutrients through the input of leaves and needles, and dictates the morphology of streams by regulating the input of large and small woody debris and the sediment that flows through it (Sedell and Beschta 1991; Newton et al. 1996). These are essential components of fish habitat (Stevens et al. 1995). Wildlife are an important ecological attribute of riparian areas that work to help restore fish habitat. They build soil, disperse seeds, and inoculate trees with pathogens that hasten the decay of organic materials and thereby increase the productivity and complexity of riparian habitats for fish (Bunnell and Dupuis 1995). In their own right, they are legitimate forest users whose habitats can be enhanced through riparian restoration (Cole 1996; Hayes et al. 1994, 1995, 1996, and 1997). Removal of natural riparian vegetation by timber harvesting impairs the functional role of riparian areas by taking away attributes vital for the physical and biological processes required by fish and wildlife (Koning [editor] 1999).

On the challenge to restore riparian forests
Riparian areas are transitional zones, linking aquatic and terrestrial habitats. Because of the unique ecology of these zones (Pabst and Spies 1999) and their rapid change to shrub and deciduous communities following logging, it has proven challenging on riparian sites to restore the type of forest that existed on them prior to logging (Chan et al. 1997; Emmingham et al. 1997 and 1998; Emmingham and Hibbs 1997; Emmingham and Maas (1994). Attributes of riparian forests most needed to affect restoration are large diameter trees, dead and dying trees, snags, trees with large live crowns, abundant coarse woody debris, multistoried and multi-species canopies and increased diversity and cover of understory species (Sedell et al. 1997; Tappeiner et al. 1997). These characteristics can be maintained, improved or created by using silvicultural techniques.

On techniques for restoring riparian forests
Most of the annotated bibliography deals with methods of restoring watersheds using riparian management and silvicultural techniques. Thinning of hardwood- and conifer dominated stands (Hibbs et al. 1989; Emmingham 1996; Hibbs and Chan 1997; Tappeiner et al. 1997; Baily and Tappeiner 1998), release of understory conifers (Emmingham and Maas 1994; Maas and Emmingham 1995; Emmingham et al. 1997), recruitment of large woody debris (Mcdade et al. 1990), revegetation of floodplains and stream banks (McLennan 1995; Swenson and Mullins 1985; Muhberg and Moore 1998), planting of suitable conifers (Emmingham et al. 1989) and establishment of understory riparian shrub communities (Baily et a. 1998) are all techniques being used and tested by silviculturalists and researchers. Adaptive management is strongly recommended as a means of implementing these diverse techniques.

Powell, David C.; Rockwell, Victoria A.; Townsley, John J.; Booser, Joanna; Bulkin, Stephen P.; Martin, Thomas H.; Obedzinski, Bob; Zensen, Fred. 2001. **Forest density management: recent history and trends for the Pacific Northwest Region**. Technical Publication R6-NR-TM-TP-05-01. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 22 p.
http://www.fs.fed.us/r6/FDMwhitepaper.pdf
[This white paper is not limited to the Westside of the Cascades. It describes young stand thinning needs in Oregon and Washington both east and west of the Cascades.]

Key Findings
• Timber stand improvement (TSI) attainment was 56,913 acres in fiscal year 2000—60% lower than 12 years before (FY1988)
• The trend for TSI funding has been downward over the last 12 years.
• The trend for TSI unit cost (treatment cost, in dollars per acre) has been upward over the last 12 years. Unit cost increased substantially during the last 2 fiscal years.
• The need for forest density management work (thinning and release) was 423,646 acres in fiscal year 2000— 61% higher than 12 years before (FY1988).
• Forest density management attainment was 50,670 acres in fiscal year 2000—55% lower than 12 years before (FY1988).
• The net result of these trends is that a backlog of FDM work accumulated on Pacific Northwest national forests. Projections indicate that if recent trends continue, the FDM backlog will increase by at least 50,000 acres (13%) between fiscal years 2000 and 2005.
• One implication of these trends is that not enough acres are receiving a forest density management treatment to have a noticeable impact on fire risk at a landscape scale.

In the context of this white paper, forest density management refers to thinning and similar active restoration treatments that can be used to address a variety of ecosystem goals:
• Reduce fire risk and improve forest health;
• Develop or protect vertical and horizontal forest structure;
• Encourage undergrowth vegetation and wildlife forage;
• Develop shade and large wood for aquatic habitat;
• Develop large trees, snags and down wood for terrestrial habitat;
• Promote patch- and landscape-level diversity;
• Improve water yield and hydrologic function;
• Promote late-successional characteristics and biological diversity.
. . .
Natural processes and their silvicultural analogues can be grouped into two distinctly different categories: releasing disturbances such as wind or insect outbreaks that kill from the 'top down,' and maintenance disturbances such as low-intensity fire that kill from the 'bottom up.' Thinning emulates natural processes that kill trees from the bottom up. Therefore, thinning supports this central axiom of ecological forestry: any manipulation of a forest ecosystem should mimic the native disturbance processes of a region, as they existed prior to extensive human alteration.
. . .
Thinning makes more sunlight, water and nutrients available for the remaining trees, which quickly improves their physiological condition and vigor. High-vigor trees produce more resin and defensive chemicals than low-vigor trees, allowing them to better repel insect and disease attacks. . . .

Unlike old forests, young forests change rapidly. Silvicultural intervention can influence the speed and direction of that change to accelerate development of desired forest structure,
. . .
During the 1970s and 1980s, regeneration cutting contributed to establishment of dense conifer forests. Recent research suggests that thinning and other restoration techniques may be needed to accelerate development of late successional characteristics in these young forests. Today, a mosaic of young forest patches with heightened fire and insect hazard surrounds many old-forest remnants. In these situations, forest density management would not only speed up development of large-diameter trees, but could also help protect remnant old-forest patches from stand-replacing wildfire and insect or disease outbreaks.

Rapp, Valerie and Carolyn Wilson. **2001 Science Accomplishments of the Pacific Northwest Research Station**
http://www.fs.fed.us/pnw/pubs/ar2001.pdf

Thinning Second-Growth Stands to Accelerate the Development of Old-Growth Characteristics

Currently, dense plantations of Douglas fir, established after clearcutting, cover extensive areas of the Pacific Northwest. Many acres of young stands are in the late-successional reserves established under the Northwest Forest Plan. Management objectives for these reserves emphasize the development of old growth attributes.

Station scientists developed a synthesis of over 30 studies of vegetation, wildlife, and other topics in young stands. The synthesis suggests ways that the development of old-growth characteristics can be accelerated as young stands grow. Retrospective analyses of the early stages of old-growth development indicate that some of these stands began with low stocking levels—much lower than in today's plantations of the same age. The alternative futures of today's dense plantations are being examined through various modeling studies and long-term, multidisciplinary silvicultural experiments. Although the field experiments are in early stages, at this point some evidence indicates that thinning may encourage the development of old growth old growth forest characteristics, such as large live and dead trees and multistory stands with shade-tolerant tree species.

Rapp, Valerie. 2002. **Science Update— Restoring Complexity: Second Growth Forests and Biodiversity,** PNW Research, May 2002.
http://www.fs.fed.us/pnw/scienceupdate1.pdf

. . . many areas dedicated to old-growth values on federal lands are fragmented by patches of second growth forests planted after timber harvest. These second-growth forests are often dense stands of Douglas-fir with little structural diversity.

When—and if—these conifer plantations develop the characteristics of old-growth forests, then large parts of the forested landscape will function as complex, old forests. Such complex forests would more likely support the full range of biodiversity associated with old-growth forests than would stands with simple structure.

Recent research by scientists with the USDA Forest Service Pacific Northwest Research Station (PNW) and by other scientists offers intriguing insights into the processes of forest development. These findings suggest that managers have options. One option is to let conifer plantations develop old-growth characteristics as a result of natural events over time. Another option is to thin stands in order to restore habitat diversity more quickly.

. . .

Key Findings

• Many old-growth trees grew more rapidly in their first 50 years than young trees in unthinned conifer plantations are growing today. Tree-ring studies show that in many old-growth forests, the dominant trees often gained diameter rapidly in their first 50 years.

• In dense, uniform, conifer plantations, one or more variable-density thinnings could promote increases in biological diversity in the next one to three decades. The thinning likely would accelerate the development of some old-growth characteristics, perhaps by decades (compared to stand development without the thinning).

• Habitat improvement activities can increase the likelihood that stands develop the vertical and horizontal complexity typical of old-growth forests. These activities include creating snags, adding large pieces of wood when necessary, and underplanting with several tree species, especially shade-tolerant conifers where they are absent.

• Trees grown in dense plantations are most responsive to thinning when they are less than 80 years old. The options for accelerating forest development may diminish substantially if stands are not thinned when young.

. . .

In plantations, small to intermediate disturbances can lead to structural diversity or can begin to unravel the stands, depending on many variable factors. Root rot and windthrow could create small openings, which could lead to structural diversity if seeds of shade tolerant trees are present. This response depends on the plantation's size and the stands surrounding it. Trees in dense stands often are not very sturdy and are prone to blowdown or "snowdown." Again, the stand may respond by developing complexity or may begin to unravel, depending on many factors. If trees over a large area are destroyed, it can be a major setback in that forest's development.

"Society doesn't appear to be willing to let nature use all of its tools. Generally society is not willing to let wildfires change these stands the way nature did in the past, for example," comments Mills.

. . .

Thinning to develop old-growth characteristics is different from thinning to maximize timber production. Timber management uses evenly spaced thinning to produce uniform stands, and removes just enough trees to maximize the growth in volume of the stand as a whole, rather than maximize the growth in volume per tree. The complex structure of old-growth forests is the result of variability. Variable spacing allows some trees the chance to gain diameter rapidly in their early decades, not just height, and to keep more live branches. Patchy mortality makes holes in the developing forest, allowing other trees to grow. These trees begin to create a forest of many species, ages, and sizes. Therefore, if thinning treatments are intended to accelerate the development of old-growth characteristics, the spacing should vary.

When the goal is forest complexity, "there is no one standard procedure," comments Carey. But he offers some suggestions. Variable-density thinning can be done by thinning to different densities in 4- to 1-acre patches, by leaving small 4- to 2-acre unthinned areas, and in other places creating very small—up to 4 acre at most—gaps. The small gaps will let in light without increasing susceptibility to windthrow. In young plantations, small gaps will encourage the growth of herbs, shrubs, and understory trees, and large, open-grown trees. In the unthinned or lightly thinned areas, shade tolerant trees like hemlocks will grow under the dominant trees. Just as natural processes are variable, a thinning design is site-specific and depends on the characteristics and landscape context of the individual stands.

Studies show that when variable-density thinning is used, thinned stands usually have better developed understories, higher shrub densities, a greater richness of understory plant species, and more plant cover than unthinned stands. Well-developed understories provide habitat for birds such as the dark-eyed junco, Hammond's flycatchers, and chestnut-backed chickadees.

There are risks. Exotic plant species such as English holly and thistles can invade thinned stands. However, one result of thinning is the development of richer understories, and exotic plants may be less likely to get established in stands with well-developed understories of conifers, hardwoods, and native plants.

Studies show that thinned forest plantations provide growing conditions similar to those historically found in some developing old-growth forests. However, the studies also show that old-growth forests are highly variable and that they developed along many different pathways. Given the uncertainty, one option would be to manage for a diversity of pathways rather than to apply one uniform prescription, such as heavy thinning, across the landscape. The use of multiple pathways is also a good way to spread risks, as long as all pathways are equally well thought out.

Natural disturbances will still occur. Uncertainties still exist. We have learned much from decades of research, but there is clearly much we don't know. Scientists stress the importance of observing how forests respond to management and learning from these results.

. . .

Does it matter how old the plantations are when they are thinned?

Yes. Trees grown in dense plantations are most responsive to thinning when they are young—less than 80 years old. Thinning before this age generally results in a surge of growth.

The diameters of 100- to 300-year-old trees have been found to be strongly related to their diameter and growth rates when the trees were 50 years old. In some old-growth forests studied, the biggest trees had their fastest diameter growth rate when they were young.

. . .

For many densely stocked stands, the options will be more constrained if the stands are not thinned soon. Because some forest plantations are already 50 years old, there may be only a few years left before the option is greatly diminished for accelerating the development of old-growth characteristics.

"Doing nothing is a choice that has consequences too," says PNW Station Director Mills. "There will be fewer options if we wait until later to do something."

If we thin plantations and speed up their development of old-growth characteristics, are there any other benefits produced?

Yes, there can be. In stands 30 to 80 years old, some trees could be removed for forest products. In some stands less than 30 years old, some thinned trees could be removed for posts and poles. The timber revenue could defray some of the cost of the work, while contributing to rural economies.

"This is a good example of compatibility between wood production and ecological objectives," says Mills. "Multiple values, including ecological and economic values, don't always have to be at odds if we are creative." The biodiversity thinnings done so far in research studies have been profitable. This encouraging result suggests that foresters can develop old-growth characteristics and wildlife habitat diversity, while simultaneously generating some economic values from plantations.

In other plantations, the trees are too small to be commercially valuable. On federal forest lands, precommercial thinning in these smaller stands would be paid for with funds appropriated by Congress as part of the USDA Forest Service annual budget.

Rapp, Valerie. 2002. **Science Update: Dynamic Landscape Management**. USDA, PNW Research Station, Portland. Oregon.
http://www.fs.fed.us/pnw/scienceupdate3.pdf

IN SUMMARY

Pacific Northwest forests and all their species evolved with fires, floods, windstorms, landslides, and other disturbances. The dynamics of disturbance were basic to how forests changed and renewed. Disturbance regimes, as scientists call the long-term patterns of these events—what kind of event, how often, how large, and how severe—created the landscape patterns seen historically in the forests. Forest management is creating new landscape patterns in the forests of western Oregon and Washington. In some cases, the large-scale patterns are unplanned because management focus has been on actions and consequences at smaller scales. In other cases, managers did plan landscape patterns, but some of the results are now considered undesirable.

Dynamic landscape management uses historical disturbance regimes as a reference. By emulating key aspects of the historical disturbance regimes through forest management practices, scientists and managers expect to sustain native species and habitats and maintain ecological processes within their historical ranges, while providing a sustained flow of timber.

Scientists from the USDA Forest Service Pacific Northwest (PNW) Research Station and managers from the Willamette National Forest are using this approach in the Blue River Landscape Study, a 57,000- acre experiment in forest management in the Oregon Cascade Range. In this study, if the approach is carried out for the long term, dynamic landscape management should result in a less fragmented landscape, with more mature and old forest than would be produced by the matrix-and-reserves approach of the Northwest Forest Plan.
. . .
What are the consequences of managing landscapes?
. . .
Various management approaches have created and are creating landscape patterns that never existed before in west-side forests in Oregon and Washington (see table 1). In some cases, the large-scale patterns are an unintentional byproduct of management decisions at a smaller scale, usually the stand level (see sidebar on page 6). In other cases, managers were thinking about landscape patterns. They spread small harvest units across the landscape in order to minimize effects in any one watershed, disperse the ecological effects, establish road systems, reduce visual impacts, and provide deer and elk with high-quality forage close to forest cover. The resulting landscape patterns are now considered to be undesirable in some ways, such as increased forest fragmentation and excessive roading.

[more info available at: http://www.fsl.orst.edu/ccem/brls/brls.html and http://www.fsl.orst.edu/ccem/brls/BRLPV2.pdf]

Reeves, G.H., L.E. Benda, K.M. Burnett, P.A. Bisson, and J.R. Sedell. 1995. **A disturbance-based ecosystem approach to maintaining and restoring freshwater habitats of evolutionary significant units of anadromous salmonids in the Pacific Northwest.** Pages 334-349. in: J.L. Nielsen, editor. Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium 17, Bethesda, MD.

Within watershed, recovery programs for ESUs [salmon] must address not only root causes directly responsible for the immediate loss of habitat quantity and quality but also ecosystem processes that create and maintain habitats through time In developing an ecosystem approach to the conservation and restoration of endangered ecosystems it must be recognized that ecosystems are generally dynamic in space and time because of natural disturbances, particularly at large spaciotemporal scales.

. . . Attempts to view and manage systems and resources in a static context may increase the rate of extinction of some organisms . . .

. . . In dynamic environments, '. . . some patches are empty (but liable for colonization), while others are occupied (but liable to extinction.) In such circumstances, the lights of individual patches wink on and off unpredictably, but the overall level of illumination—the overall density of the metapopulation—may remain relatively ___ .' (May 1994).
. . .
An Oregon Example

The natural disturbance regime in the central Oregon Coast Range includes infrequent stand resetting wildfires and frequent intense winter rainstorms. Wildfire reduce the soil-biding capacity of the roots. When intense rainstorms saturate soils during periods of low root strength, concentrated landsliding into channels and debris flows may result. Such naturally occurring disturbances in stream channels can have both immediate impacts on and long-term implications for anadromous salmonids. Immediate impacts include direct mortality, habitat destruction, elimination of access to spawning and rearing sites, and temporary reduction or elimination of food resources. Longer-term effects may be positive, however; landslides and debris flows introduce essential habitat elements, such as large wood and sediment, into channels and affect storage of these materials. The configuration of channel network, the delivery, storage, and transport of sediment and wood, and the decomposition of woody debris interact to create, maintain, and distribute fish habitat over the long term.
. . .
These field observations and a simulation model developed by Benda (1994) indicate that under the natural disturbance regime, variation in the timing and location of erosion-triggering fires and storms results in episodic delivery of materials that cause stream channels to alternate between aggraded and degraded sediment states. . . .

. . . These channels experience cycles of accumulation and flushing as sediment is transported in waves into and then out of them. . . .

Juvenile salmonid assemblages are likely associated with each state predicted by the model. . . .
. . .
In summary, the natural disturbance regime of the central Oregon Coast Range is described by the frequency, size, and spatial distribution of wildfires and landslides, and this regime has been responsible for developing a range of channel conditions within and among watersheds. The structure of and composition of anadromous salmonids assemblage varies with channel conditions. A disturbance regime that resembles this natural regime must be incorporated into any recovery plan for freshwater habitats of ESUs of anadromous salmonids.

. . .
Anadromous salmonid populations in the Pacific Northwest are well adapted to dynamic environments. Adaptations include straying by adults, high fecundity, and mobility of juveniles. . . .
. . .
. . . In the short term, reserves should be established in watersheds with good habitat conditions and functionally intact ecosystems to provide protection for these remaining areas. Reserves of this type are likely to be found within wilderness and roadless on federal lands. . . .

Identification of watersheds that have the best potential for being restored should also be a short-term priority of any recovery strategy. These watersheds could serve as the next generation of reserves. . . . Restoration programs implemented in these watersheds should be holistic in their approach. They should address instream habitat concerns, prevent further degradation, and restore ecological processes that create and maintain instream habitats.

. . . [I]n dynamic landscapes, reserves may act as holding islands that persist only for relatively short ecological periods (100-200 years). Reserves should be large enough to allow operation of the natural disturbance regime and to support a mosaic of patches with different biological and physical attributes.

. . . Specifically, there is a need for a shifting mosaic of reserves that change location in response to the ability of specific watersheds to provide suitable habitat conditions.

. . . We believe that returning the entire landscape to a natural wildfire regime will not be possible. Therefore, Human activities will have to be molded into an analogous disturbance regime. . . . anthropogenic disturbance will have to be shifted from a press to a pulse disturbance . . .

Disturbance caused by timber harvest differs from stand-resetting wildfire in the central Oregon Coast Range in several respects. One . . . Wildfires left large amounts of standing wood which was often delivered to channels along with sediment in storm-generated landslides. . . . the potential for developing complex habitats is much lower when small rather than large amounts of wood are in the channel. Consequently, channels may be simpler following timber harvest than they are after wildfires.

[Second] The interval between events also affects the conditions that develop after a disturbance. . . . .Wildfires occurred on average once very 300 years in the central Oregon coast Range. . . . Timber harvest generally occurs at intervals of 60-80 years on public land and 40-50 years on private timberland. This may not allow sufficient time for the development of conditions necessary to support the array of fishes found under natural disturbance regimes.

A third difference between timber harvest and a disturbance regime dominated by wildfire is the spatial distribution of each. Benda (1994) estimated that on average about 15-25% of the forest in the central Oregon coast Range would have been in early successional stages because of recent wildfires. In contrast, the area affected by timber harvest is much greater. . . .

A fourth difference between natural fire disturbance and the current harvest-driven regime is the size of the disturbance and landscape pattern generated by the disturbance. Timber on federal lands has typically been managed by widely dispersed activities; . . . many millions of hectares have been affected by small harvest of approximately 16 ha. Wildfires, on the other hand, often generate a larger but more concentrated disturbance. . . . Consequently, the spatial pattern and amount of sediment delivered to channels would likely be different under these two disturbance regimes. In naturally burned areas, storms occurring during periods of low root strength would generate large volumes of sediment from nearly synchronous hillslope failures and channels would become aggraded. . . . In unburned watersheds, sediment delivery rates would remain low. In contrast, timber harvest activities are dispersed; thus we presume that mass wasting would be more widely distributed and would deliver sediment at elevated rates in most managed watersheds. Storm generated landslides would be asynchronous, being governed through time by timber harvest schedules. Cycles of channel aggradation and degradation would not be apparent and sediment delivery, at a landscape scale, would be chronic rather than episodic.
. . .
The new disturbance regime created by timber harvest should address these concerns just listed. . . . Increasing the extent of riparian protection along streams [that favor the delivery of desirable material to fish-bearing channels], as proposed by Thomas et al (1993), obviously increases the potential delivery of wood. . . .

Longer intervals between harvest rotations could be another component of this new disturbance regime. . . .

Concentrating rather than dispersing management activities could be another element of the new disturbance regime. This would more closely resemble the pattern generated by natural disturbances tan does the current practice of dispersing activity in small areas.

The propose new disturbance regime could be applied to areas outside any such reserve system. . . .
. . .
. . . In the long-term, a static reserve system is unlikely to meet the requirements of these fish. Management must also be directed at developing the next generation of reserves.

. . . Expectations about habitat conditions in streams must change; a stream will not always have suitable habitats for anadromous salmonids.

Finally, disturbance must be recognized as an integral component of any long-term strategy. . . .

Reutebuch, Stephen E., Constance A. Harrington, Dean S. DeBell, David D. Marshall, and Robert O. Curtis. 2001. **Silvicultural Options for Multipurpose Management of West-Side Pacific Northwest Forests**, *in* Beyond 2001: A Silvicultural Odyssey to Sustaining Terrestrial and Aquatic Ecosystems Proceedings of the 2001 National Silviculture Workshop, May 6-10, Hood River, Oregon; PNW-GTR-546
http://www.fs.fed.us/pnw/pubs/gtr546.pdf

> **Abstract:** The Westside Silvicultural Options Team of the Pacific Northwest Research Station has established an array of long-term research studies to develop and assess a wide range of silvicultural options. In this paper, we review three large-scale studies that focus on three major stages in the life of managed stands— early development (precommercial thinning), midrotation (commercial thinning), and regeneration harvest. These studies will provide information about stand development that will be useful in managing for wood production, wildlife habitat, and other forest resource values in large portions of the Pacific Northwest Westside forests. All three studies measure the response of both overstory trees and understory plant species. Additionally, several other aspects of concern to forest managers, such as coarse woody debris, residual stand damage, soil disturbance, economics, and public acceptance of treatments, are investigated. [results not available yet]

Roni, Philip, Timothy J. Beechie, Robert E. Bilby, Frank E. Leonetti,2 Michael M. Pollock, And George R. Pess. 2002. **A Review of Stream Restoration Techniques and a Hierarchical Strategy for Prioritizing Restoration in Pacific Northwest Watersheds.** *North American Journal of Fisheries Management* 22:1–20, 2002 American Fisheries Society 2002
http://yosemite.epa.gov/R10/ECOCOMM.NSF/adea00f56cb8903f88256ab6007a3a6f/a10e063e194cecbb88256c0900743686/

> Beechie et al. (2000) [i.e. Beechie, T., S. Bolton, G. Pess, R. Bilby, and P. Kennard. 2000. Rates and pathways of recovery for woody debris recruitment in northwestern Washington streams. North American Journal of Fisheries Management. 20:436–452] provided guidance for determining when thinning is appropriate and when it will result in a loss of near-term recruitment of LWD that may create fish habitat. Their model predicts that thinning of the riparian forest does not increase recruitment of pool-forming LWD where the trees are already large enough to form pools in the adjacent channel and that thinning reduces the availability of adequately sized wood. Conversely, thinning increases LWD recruitment in riparian areas where trees are too small to form pools within the adjacent channel.

Scott, W., Meade, R., Leon, R., Hyink, D., and R. Miller. 1998. **Planting density and tree-size relations in coast Douglas-fir**, Can. J. For. Res., 28: 74-78 (1998).

> Capturing the full productive potential of a site for tree growth requires prompt establishment of a uniform stand of trees.
>
> [Results 5 or 6 years after planting]
>
> The two highest densities averaged better percent survival than lower densities.
>
> On average, trees reached breast height 2 yeas sooner at 2960 than at 300 tph [trees per hectare].
>
> Surprisingly, mean DBH also increased with closer planting density.
>
> Trees in denser spaced plots averaged greater DBH and height than those in plots of lower density.
>
> If these plantations are not thinned, DBH differences and later height differences among spacing will reverse, so that trees n closer sped stands will average shorter and smaller in diameter than those in wider spaced stands.
>
> Some hypotheses to explain initially larger trees at closer spacings include:
> (1) Greater likelihood of planting favorable microsites.
> (2) Improved microclimate.
> (3) Less animal damage.
> (4) Earlier crown closure, resulting in less interspecies competition for nutrients and water. . . .
> (5) Enhanced interactions in the rhizosphere among trees and other vegetation . . . .
> (6) Favorable intraspecies interactions: more root grafting, mycorrhizal interconnections among Douglas-fir.
> (7) Earlier response to future competitors through alterations in red – far-red light reflected from foliage . . . or through root contact. . . .

Smith, Jeff P., Michael W. Collopy, R. Bruce Bury, Michael A. Castellano, Stephen P. Cross, David S. Dobkin, Joan Hagar, John D. Lattin, Judith Li, William C. McComb, Karl J. Martin, Jeffrey C. Miller, Randy Molina, J. Mark Perkins, David A. Pyke, Roger Rosentreter, Jane E. Smith, Edward G. Starkey, Steven D. Tesch. 1998. **Pacific Northwest** *in* Mac, Michael J, Project Director and Paul A. Opler, Science Editor. 1998. **Status and Trends of the Nation's Biological Resources, Volume 2**, USGS.
http://biology.usgs.gov/s+t/SNT/noframe/pn169.htm

Fifty years of even-age timber management by clear-cut logging and replanting greatly altered the structure of forests in the region (Franklin and Forman 1987; Spies and Franklin 1988, 1991; Morrison and Swanson 1990; Ripple 1994; Spies et al. 1994). Today's forests are composed primarily of intermixed patches of stands less than 50 years old with small trees (average diameter at breast height less than 51 centimeters) and older stands with much larger trees (average diameter greater than 102 centimeters, height greater than 70 meters).

Spies, Thomas A. 1998. **Forest Structure: A Key to the Ecosystem.** Pages 34-39 *in* J.A. Trofymow and A. MacKinnon, editors. Proceedings of a workshop on Structure, Process, and Diversity in Successional Forests of Coastal British Columbia, February 17-19, 1998, Victoria, British Columbia. Northwest Science, Vol. 72 (special issue No. 2).
http://www.pfc.forestry.ca/ecology/sfrw/10spies.pdf

TABLE 2. Idealized patterns of change for forest structural characteristics during natural succession in Douglas-fir forests (ada from Spies and Franklin 1988).

Characteristics following a 'u-shaped' curve	Characteristics following an 's-shaped' curve
Amount of coarse woody debris	Average size of dominant trees
Number of large snags	Diversity of tree sizes
Dead trees as a percentage of ecosystem biomass	Incidence of broken tops and other signs of decadence
Spatial heterogeneity of herbs, shrubs, and tree regeneration	Forest floor depth
Plant species diversity	Surface area of boles and branches
Vertebrate species diversity	Vertical foliage diversity
Susceptibility to fire	Live biomass

However, even-aged stands tend to have relatively narrow bell-shaped size distributions, whereas in uneven-aged stands, diameter distributions approximate negative exponential functions or exhibit a series of peaks that represent establishment events (Smith 1986).
. . .
If similar forest structures can arise from different stand histories then there may be options to create desired stand structures through silvicultural practices. It is becoming increasing clear that traditional forest management practices will not produce the structures found in old-growth stands or will not produce them at the same rate as in natural stands. For example, Tappeiner et al. (1997) found that growth rates of individual young trees in dense forest plantations are much slower than those of old-growth trees in unmanaged forests when those trees were young. If the objective of management is produce old-growth structures from forest plantations, future forests will probably not have the same structural characteristics as current natural old-growth forests, unless stand densities in plantations are reduced now.
. . .
Conclusion
Forests are a three-dimensional complex of structures, many of which are linked through growth, disturbance, and decay processes. Forest structures vary over time and space and are quite sensitive to disturbance history. Studies of natural forests also indicate that there are many developmental pathways to a particular forest structure. Consequently, it might be possible to use alternative silvicultural practices to imitate the structure and dynamics of natural forests and thereby retain desired elements of biological diversity in managed stands and landscapes. While we know much about the ecological roles of forest structure, there is much we do not know. For example, the role of coarse woody debris in site productivity is not well known and our knowledge of its habitat role comes from only a few localities. Finally, it is below ground and at landscape scales where our lack of understanding of the roles and variability of forest structure is often most apparent.

Spies, Thomas A., John Cissel, Jerry, F. Franklin, Frederick Swanson, Nathan Poage, Robert Pabst, John Tappeiner, Linda Winter, 2002. **Summary of Workshop on Development of Old-Growth Douglas-fir Forests along the Pacific Coast of North America: A Regional Perspective.** November 7-9, 2001. H. J. Andrews Experimental Forest, Blue River, Oregon. 11/15/2002
http://www.fsl.orst.edu/ccem/old-growth.pdf

A fundamental question that has Arisen is "Do findings from recent studies of old-growth history and development require reformulating our conceptual scientific models of old-growth forests and/or our strategies for conserving and restoring ecological values associated with old forests?" A small workshop was held recently on old-growth forest development to address the above question.
. . .
Multiple pathways
Many at the workshop believed that the spatial and temporal diversity of old-growth conifer forest development in the coastal Douglas-fir region argues for broadening our conceptual models of old-growth development. Models of old-growth development based on central western Cascade forests dominate both scientific thinking and policy-making in the region. The workshop revealed that not only are these models inadequate to explain old-growth structure and development across the region but they may even be too simple to explain old growth within the central western Cascades where much recent research has been conducted. For example, Swanson pointed out that low severity relatively frequent fires could sustain old-growth characteristics. One approach to incorporating this newly appreciated complexity is to use a multiple pathway approach to characterizing old-growth. Spies presented such a framework for Douglas-fir forests in the central western Cascades (Figure 1).
. . .

Management of existing forest plantations. Many stands within late successional/old-growth reserves contain dense young plantations originally intended for timber production. There was some discussion in the workshop of the prospect for these stands to develop old-growth characteristics in the future without thinning, although thinning effects in plantations were not a major theme of the workshop. Opinions differed about the likelihood that dense plantations would eventually develop old-growth structures (e.g. relatively large old trees, relatively large accumulations of dead trees, and patchy distribution of live vegetation) without careful thinning to restore spatial heterogeneity and increase diameter growth rates in these stands. If left unthinned, retrospective studies indicate that development of very large old-growth trees (e.g. >150 cm) in dense plantations would be retarded unless some natural disturbance such as wind, pathogens or partial fires open the stands up in the near future. In some cases, very dense stands may have a high risk of severe disturbance from blowdown. On the other hand, some existing old-growth probably developed from relatively dense young stands that were subsequently diversified by natural disturbances. Some current old-growth stands have relatively small diameter live and dead old-growth trees suggesting that they developed along a dense-young- forest pathway. Garman and Poage presented results of model simulations suggesting that the onset of some features of old growth and northern spotted owl habitat could be accelerated by 30 to 100 years by certain thinning actions. The greatest gains in these modeling studies came in the development of large trees and complex forest canopies from one or two heavy thinnings between stand ages 40 and 80 in dense stands. However, modeling studies also indicate that very high levels of thinning could reduce the numbers of large trees and the accumulation of large dead and down wood. The most immediate and certain benefit to thinning in plantations was to diversify the live and dead structure of young plantations which can make up as much as 40-50% of some federal landscapes. While most of the workshop attendees supported silvicultural manipulations to diversify young plantations, they also cautioned against doing the same thing everywhere across the landscape (including thinning all plantations) and supported the practice of using variable-density thinnings within stands rather than simple heavy thinnings. Similar ideas have been expressed by Andrew Carey (PNW Research Station) in his “biodiversity pathways” approach to managing second-growth stands for ecological goals. Managers cautioned that increased complexity and costs associated with variable-density thinnings would significantly reduce the area that could be thinned.

Landscape management. Sustainability old growth forests requires planning and evaluation at landscape and regional scales and over long time frames. Simulations of landscape dynamics on public lands managed under the Northwest Forest Plan by Cissel and Reger indicate that over the long run (200+ years) the extent of mature forests (about 80-200 years old) will decline to low levels which could be a problem because this age class is the source of future old growth. They argue that some planned cutting of stands will be needed to create younger age-classes, both as a replacement for old-growth Douglas-fir stands that are lost through succession or disturbance and as a means of maintaining successional diversity in the landscape. The significance of this concern was questioned by some who felt that we are not going to have a problem maintaining old forests during the next several centuries. The group debated the source of future young stands. Many felt that they would come from unplanned events such as wildfires. However, data from the Willamette N. F. showed that fire suppression has been very effective at greatly reducing the area burned. It is not clear how many wildfires there would be in the future and if they would be extensive enough to maintain the diversity of all forest stages. From a multi- ownership perspective the forest structure/age class distribution in the region will become increasingly bimodal-young plantations for timber production on private lands and old-growth forests on federal lands. This could result in a net decline in forest diversity as diverse, early successional stages and mature forest age classes decline because neither of the large landowner groups will explicitly produce them. This also produces a relatively static landscape in which stands experience short cycles on private lands and old forest accumulates on federal lands with fire suppression. The presentations at the workshop of landscape simulation studies by Cissel and Spies indicate that planners and managers need to take a broad spatial and temporal perspective to help insure that the goals of biodiversity policies will be met.

Conclusion

The findings from recent studies of old growth suggest that our conceptual models need to be updated to incorporate the variability that occurs in old-growth Douglas-fir structure and development at regional and landscape scales. For example, old-growth Douglas-fir forest development in the region did not follow just one or two courses, but has followed numerous pathways that vary regionally. The concept of “age classes” of old growth does not serve us well in situations where the Douglas-fir trees have a wide range of ages and the beginning of the stand it is difficult to determine. In some landscapes old growth is structurally distinct from younger natural forests but in other landscapes patches of old forest and young forest are intermingled in heterogeneous mixtures that can appear relatively uniform at one scale and very patchy at another. Repeated fires have been important in creating and maintaining old growth in some landscapes but not in others. Developing policies and management practices to maintain or restore this complexity is a major challenge because policy makers typically seek rules that that are simple and easy to implement. We need new ways of conceptualizing and communicating the complexity and heterogeneity of forests. We hope this workshop is a start of a process that meets those needs.

Starkey, Edward E. and Joan Hagar. 2001.**TROPHIC RELATIONS AMONG BIRDS, ARTHROPODS, AND SHRUBS** *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001. http://www.fsl.orst.edu/cfer/pdfs/CFER_ar01.pdf

Forest management practices influence habitat for birds by altering stand structure. Stand structure may be a proximate factor in habitat selection by birds, indicating the availability of an ultimate factor: food. Information on the influence of silvicultural practices on food resources for birds would be useful to ecosystem managers. However, even basic knowledge of functional relationships among plants, insects, and birds is extremely limited. The purpose of this study is to focus on the role of understory vegetation to determine how it contributes to diversity of arthropods and birds in conifer-dominated forests.

. . .

Using foraging data collected in 2000 and shrub cover data from line transects collected in 1999, two preference indices were calculated to determine if birds exhibited preference for or avoidance of shrub species when foraging: . . .

. . .

The preference indices described above were used to detect foraging preferences within a stand. However, birds must also select among stands in a landscape. Therefore, we compared the cover of shrubs used for foraging among stands to determine if characteristics of stands occupied by each of the three warbler species were different from those not occupied. . . .

. . .

These results indicate that in general, birds select stands with high percent cover of the species upon which they prefer to forage, then forage on those species in proportion to their availability within a stand.

. . .

The results of this analysis indicate that deciduous vegetation is a key foraging substrate for Wilson's , MacGillivray's, and orange- crowned warblers. Therefore, to provide breeding habitat that will sustain populations of these species, managers need to maintain and promote cover of deciduous trees and shrubs. According to our results, approximately 50% cover of deciduous vegetation appears to provide suitable habitat for Wilson's and MacGillivray's warblers.

Suzuki, Nobuya. **Effects of Thinning on Small Mammals,** Symposium: Silviculture Options for Sustainable Management of Pacific Northwest Forest, Oregon State University, March 4-6, 2002.
http://www.cof.orst.edu/cof/extended/conferen/silvopt/abstracts/suzuki.htm

Because of fires and intensive logging practices, young forest stands dominate much of the landscape of the Pacific Northwest. Most of young stands were reforested with Douglas-fir (*Pseudotsuga menzeisii*) trees at high densities. During 1994–1996, we conducted experimental and observational studies to assess effects of thinning intensity on abundance and reproduction of small mammals in Douglas-fir forests of the Oregon Coast Range. In the experimental study, we assessed the short-term effects of thinning stands to moderate (100 trees/acre) and to low (50 trees/acre) tree densities on small mammals during the first 2 years following thinning. In the observational study, we assessed potential long-term effects of thinning by comparing relative abundance and reproductive performance of small mammals in previously thinned (7-24 years prior to the study) and unthinned stands. Among the 12 species of small mammal we examined in the experimental study, number of captures increased for 4 species and decreased for 1 within 2 years of thinning; however, responses were similar between moderately and heavily thinned stands. Among the 9 species we examined in the observational study, number of captures was greater for 5 species and lower for none in previously thinned than in unthinned stands. Furthermore, total number of small mammals captured was higher in previously thinned than in unthinned stands. Effects of thinning on 2 species, creeping voles (*Microtus oregoni*) and Pacific jumping mice (*Zapus trinotatus*), were consistent in the short and long term; number of captures for both species increased in the first 2 years following thinning and were greater in stands thinned 7-24 years previously than unthinned stands. Number of western red-backed voles (*Clethrionomys californicus*) captured decreased within 2 years of thinning but was similar in stands thinned 7-24 years previously and in unthinned stands. In the observational study, the reproductive output of western red-backed voles was higher in thinned than in unthinned stands. Overall, thinning did not have substantial detrimental effects on any of the species we investigated and had positive effects on several. We suggest that potential negative effects of thinning could be minimized with a careful planning based on ecological factors.

Tappeiner, John C., 2001. **Effects of Density Management of Young Stands on Future Old Forest** Characteristics, *in* Abstracts of Presentations - Development of Old-Growth Forests Along the Pacific Coast of North America: A Regional Perspective. November 7-9, 2001 – H.J. Andrews Experimental Forest.

Many of the following effects of thinning that help to encourage old-growth characteristics in young stands in western Oregon have been documented.

1. Increase in understory cover. This can be beneficial for many ecosystem functions, but too dense and continuous and understory may not be desirable. Increase in the fruiting of understory plants will also likely occur. Understory shrubs are important substrates for insects used by birds.
2. Increase native vascular plant species diversity—species abundance. Can also increase abundance of exotics on some sites. Different effects on non-vascular plants—short-term decreases for some species.
3. Initiate the beginning of a multiple layered stand, because conifers and hardwoods become established or are released after thinning. In some cases a very dense understory might be established (i.e. western hemlock). In addition to initiating multiple story stands, understory trees may help suppress and "break up" dense shrub layers.
4. Increase diameter growth rate, crown length and width, branch size and stability or overstory trees. When damage or mortality from root disease, insects, ice storms, wind, etc. occurs, large snags, logs on the floor, etc. will result.
5. Can increase/decrease susceptibility to fire, windthrow, insects, root diseases, etc.
6. Overall, I believe that the effects of density reduction are positive, A stand-by-stand evaluation of pre- and post-thinning effects is recommended.

7. Avoid uniform prescriptions; use thinning to promote variability in understory and overstory characteristics.

Tappeiner, John; Lewis, Rob; Tesch, Steve; Thornburgh, Dale; Weatherspoon, Phil; Birch, Kevin; and others. 1992. **Managing Stands for Northern Spotted Owl Habitat.** Appendix G In: Recovery plan for the northern spotted owl--draft. Washington, DC: U.S. Department of the Interior: 481-525.

This report discusses management of forest stands for northern spotted owl habitat. We present examples of silvicultural systems and treatments which resemble natural forest disturbances. These systems can be used to accelerate the development of stand structures used by owls and to grow habitat in stands where it is not likely to occur through natural stand development. We use stand structure (density, stocking by tree species and size class, snags, logs on the forest floor) of stands that contain owl nest sites as goals (or desired future conditions) for these silvicultural systems. We use data from actual stands to develop examples of silvicultural systems which will produce owl habitat.
. . .
Not all these stands need to be "treated" to develop into suitable habitat. Some stands already provided habitat or will provide it in a short time without intervention.
. . .
The following key points emerge from the review of stand development history and literature (II and III) and from developing silviculture prescriptions (IV):

1. Disturbances of various sizes and intensities are a natural part of long-term forest stand development.

2. Many stands within the range of the owl are growing at high densities (many trees per area). Thinning these stands will increase growth rates, sizes of crowns, and diameters of remaining trees.

3. Mortality caused by suppression and crowding among trees is not likely to provide large snags or logs on the forest floor because only the smaller trees die. Thinning of stands will shift the size of a tree that dies from disease, insect, fire, and other causes, to large sizes.

4. To provide large snags and logs on the forest floor in young (30 to 80+ years) conifer stands, it often may be necessary to kill some of the larger trees in the stand. This is particularly true for stands regenerated after harvesting or reforestation following a fire.

5. Development of a multistories stand from single-story conifer stands generally will require thinning, small openings in the canopy, or some other disturbance to reduce overstory density. If a dense layer of shrubs is present, disturbance or control of this layer likely will be required to establish conifers or hardwoods which can form the additional layers.

6. Young stands (10 to 80+ years) on productive sites develop quite rapidly. To treat them most effectively, treatment should begin early in the life of the stand when they are most "plastic", before crowns become short and stands become susceptible to wind damage, insects, and diseases. Failure to treat stands before they become too dense will reduce options for future treatments and will delay substantially the development of stand structures used by owls.

. . .

. . .
Windthrow is a natural part of stand development which will occur in thinned and unthinned stands. It is not necessarily a concern after thinning....
. . .
Thinning old, dense stands likely will increase risk of damage on windy sites, while thinning younger stands may decrease the risk at later stages of development. Leaving wind firm edges that do not channel wind and unthinned buffers is important on exposed sites because they are likely to decrease the risk of blowdown progressing throughout a stand.

IV. Examples of Silviculture Prescriptions

. . . the following points should be evaluated to see if they apply to the stand in question....The list is not exhaustive....

- Favor some large trees with many limbs for potential nest sites.
- Use hardwoods to help develop a multilayered stand.
- Encourage the growth of advanced regeneration of shade-tolerant conifer and hardwood species, even in young (30 to 50+ years old) stands.
- Establish new regeneration by planting or seeding in young (50+ year-old) stands after making small openings or reducing overstory density in parts of a stand.

- Consider varying the distribution of overstory trees when thinning. Vary spacing and tree density, make openings for new regeneration and release advanced regeneration.

- When thinning, leave some trees in the smaller crown size classes (intermediate and suppressed) to help promote a layered stand.

- In stands with irregularly spaced trees, consider a crown thinning to release individual trees while maintaining the regular spacing.

Tappeiner, J.C., D.W. Huffman, D. Marshall, T.A. Spies, and J.D. Bailey. 1997. **Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon**. Can. J. For. Res. 27: 638-648.

[As summarized here: http://www.fs.fed.us/pnw/3q98.pdf]

The ages, diameters, and diameter growth rates of trees in former old-growth stands were studied and compared with young-growth stands (50-70 years) that regenerated after timber harvest. Development of young-growth Douglas-fir stands was quite different from oldgrowth development.

Tappeiner, John C., Nathan Poage, and Tom Sensenig. 2001. **OLD-GROWTH STAND DEVELOPMENT** *in* The Cooperative Forest Ecosystem Research Annual Report 2001. Janet Erickson, Editor, CFER, Corvallis, Oregon. December 2001. http://www.fsl.orst.edu/cfer/pdfs/CFER_ar01.pdf

Managed reserves have been established on many federal forests in western Oregon to provide habitat for species associated with late-successional forests. Specifically, these reserves were created to provide structural elements of older forests such as large-diameter overstory trees, large standing and fallen dead trees, and one or more understory layers. Currently, however, many of the reserves are young (<40 years), structurally simple Douglas- fir stands that originally were established for timber production. Little is known about how growth and development of these stands compares with old-growth forest development.

The purpose of this study is to compare growth rates of trees growing in young stands to rates of growth old-growth trees experienced when they were young. Understanding differences in development between oldgrowth and young-growth stands may aid in developing silvicultural prescriptions for managing young stands to achieve old-forest characteristics.

METHODS

Old-growth stumps in clearcuts throughout western Oregon (Coast Range, western Oregon Cascades, and the Siskiyous) have been measured to determine ages, sizes, and growth rates of old-growth trees, and to compare these values with nearby young-growth trees. For each stump, the diameter and radial growth rates were measured by counting xylem rings in 10-year increments from 0 to 100 years, and 25-year increments from 100 years to total tree age. Trees ranged in age from 100 to 500 years. Growth rates in even-age, young growth stands on nearby sites that were managed for timber production were also measured. Live-crown ratios and height-diameter ratios were determined on samples of 20 trees in both young- and old-growth stands. On the southwestern Oregon sites, fire scars have also been dated. Here we provide results based on the dissertation work by Poage (2001, Structure and Development of Old-Growth Douglas-fir in Central Western Oregon, Ph.D. dissertation, Oregon State University, Corvallis, OR), one of two Ph.D. theses associated with this project.

RESEARCH RESULTS AND MANAGEMENT IMPLICATIONS

The hypothesis that large-diameter, old-growth Douglas-fir in central western Oregon developed at low stand densities was supported by patterns of long-term diameter and basal area growth of trees, large withinsite age ranges (95% CI for mean = 134–214 years), and stem and crown characteristics. The diameters of the old-growth trees at ages 100 to 300 years were strongly, positively, and linearly related to their diameters at age 50 years and, more importantly, to their basal area growth rates as young, 50 year-old trees. Rapid and sustained growth by age 50 years was strongly correlated with large diameters at older ages, particularly at ages 100 to 200 years. Average periodic basal area increments (PAIBA) of all trees increased for the first 30 to 40 years and then plateaued, remaining relatively high and constant from age 50 to 300 years. Over a third of the trees > 300 years old had not reached culmination of mean annual basal area increment (MAIBA) by age 300 years.

Low heights to live and dead meristematic branches suggest that many of the old-growth trees grew at low stand densities. Live branches occurred on over 50% of the bole, on average. Average height to diameter ratios of the old-growth trees were below 50 (unitless), indicating high mechanical stability. Compared to young growth trees in high-density stands, young-growth trees in low-density stands have crowns and height-to-diameter ratios more similar to old-growth trees.

If stand differentiation within dense young-growth stands can lead to local dominance by a small number of individual trees, heavy thinnings may not be an absolute prerequisite for the general development of oldgrowth structural characteristics within dense young growth stands. However, it is clear that specific structural characteristics such as large-diameter meristematic branches low on the bole of old-growth Douglas-fir can only develop at low-stand densities. The current developmental trajectory of the stand and the trees within it must be assessed if the development of such specific structural features in a young stand is desired.

Thysell, D.R., and Carey, A.B. 2000. **Effects of forest management on understory and overstory vegetation: a retrospective study**. General Technical Report, PNW-GTR-488. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 41 pp.
http://www.fs.fed.us/pnw/pubs/gtr488.pdf

A great deal of attention has been paid to management of biological diversity in forested ecosystems of the Pacific Northwest and elsewhere (see papers in Gilliam and Roberts 1995). Emerging and related concerns are the homogenization of the world's floras and the threat to native species posed by exotic species that spread in response to human activities (Soule 1990; United States Congress, Office of Technology Assessment 1993;Wilcove and others 1998;Wiser and others 1998). Recent shifts in thinking about forest management coincide with increases in human population, decreases in timber harvests, and concerns about sustainability of managed forests (Carey 1998; Kohm and Franklin 1997; McGinnis and others 1996, 1997; Perry 1998) and are manifested by a divergent paradigm of active, adaptive, and site specific management versus passive, protective management in efforts to hasten development of late-seral forest attributes and to increase native biodiversity (Carey 1998, Carey and Curtis 1996). Though certainty of outcome is impossible, combining knowledge of past management practices, contemporary manipulations, and previously accumulated research with retrospective and experimental investigations can increase the likelihood of meeting specific objectives while retaining a wide range of future options (Carey and others 1996a, 1996b, 1999b; Spies 1997;Walters and Holling 1990).
. . .
Several replicated silvicultural experiments in developing late-seral conditions in managed stands are underway in the Pacific Northwest but are in the early phases of their response monitoring (Aubry and others 1999; Carey and others 1999b). Though there is little published information on the efficacy of silvicultural interventions in accelerating forest development in young stands (Hayes and others 1997, McComb and others 1993), preliminary data suggest that thinning can stimulate understory development and the establishment and growth of shrubs and conifer seedlings, increase diversity of understory vascular plants (Bailey and Tappeiner 1998; Carey and others 1996a, 1999b; North and others 1996) and hypogeous ectomycorrhizal fungi (Colgan 1997, Colgan and others 1999), and increase abundance of some forest floor small mammals (Carey and others 1996b).

Our purpose in this paper is to consider the effects at ≥55 years in stand age of two commonly proposed management strategies on tree size, density, and size-class diversity and on current plant species diversity and abundance in forests of financial rotation-age, and to reflect on how past management and current conditions may affect the development of native biodiversity and late-seral attributes and the establishment of exotic species after future silvicultural entries.
. . .
Both tracts were even-aged Douglas-fir forests that had established by natural seedfall. Neither tract had experienced natural or prescribed fire since harvest,
. . .
We refer to the two strategies as management with thinnings (MT) and management with legacies (ML).
. . .
Old growth in the two management units in the MT tract was clearcut in 1923-27; the subsequent regeneration was commercially thinned in the early 1970s and again in the late 1980s. During harvests in the two MT units, live and recently dead trees were removed and slash was piled and burned; few snags or residual trees, and little cover of CWD, remained in 1992 (table 1). At the time of our sampling, MT (fig. 1) was dominated by well-spaced Douglas-fir 55 to 65 cm in diameter at breast height (d.b.h.) with small numbers of black cottonwood (*Populus balsamifera* ssp. *trichocarpa* [Torr. & Gray] Brayshaw) and red alder (*Alnus rubra* Bong.).

In contrast, old growth in the two management units in ML was cut in 1935-39 and was not further manipulated; moderate CWD and numerous legacy trees and snags remained in 1992 (table 1). In 1992, ML (fig. 2) was a closed-canopy forest dominated by closely spaced Douglas-fir 30 to 45 cm d.b.h., with a few western redcedars (*Thuja plicata* Donn ex D. Don) and Pacific yews (*Taxus brevifolia* Nutt.). Trees killed by suppression and trees with small crowns were abundant.
. . .
[Summary] The MT tract had fewer and larger trees and had higher tree size-class diversity than ML. Species richness and diversity were significantly higher in MT than in ML. Total vascular plant species richness in MT (94 species) was twice that in the more densely stocked ML (47 species). Average total understory cover was much higher in MT (88 percent) than in ML (34 percent). Both tracts lacked shade-tolerant understory trees and had minimal foliage height diversity. Numerous exotic species were found in MT, but these were virtually absent in ML.
. . .
Management-induced disturbances are now the most common type of disturbance in many Pacific Northwest forests and have initial and lasting effects that differ from historical disturbance patterns. Many managed, Douglas-fir forests in the Pacific Northwest differ along continua defined by (1) amount of coarse woody debris, snags, and previous-stand trees retained after harvest and (2) initial and subsequent tree density. These two factors also typically are associated with continuous variation in ground-disturbance intensity (e.g., harvest-related disturbances and site

preparation). Past management that resulted in forests definable along such continua also brought about variability in the operational factors (Spomer 1972) affecting species distributional patterns. Our ordination implies that availability of water and light for understory plants (axes 1 and 2, fig. 7a) are the major operational factors affected by such management and thus affecting distribution and abundance of the understory species.
. . .
A complete randomized block experiment is now in progress in the MT and ML tracts that uses the same experimental template reported herein to begin addressing aspects of these three challenges. It incorporates variable-density thinning, underplanting of shade-tolerant conifers, direct wildlife habitat augmentation in specific tests of hypotheses concerning enhancement of species and patch-type diversity, and development of late-seral forest attributes through active, adaptive, site specific, and intentional management (Carey and others 1999b).

Thysell, David R., and Andrew B. Carey. 2001. **Manipulation of density of *Pseudotsuga menziesii* canopies: preliminary effects on understory vegetation**. Can. J. For. Res. 31(9): 1513-1525 (2001)
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x01-085_31_ns_nf_cjfr9-01

Abstract: Managing second-growth forests to conserve biodiversity has been proposed by both foresters and conservation biologists. Management, however, can have unintended consequences, including reduction in native species diversity and increased invasion by exotic species. Our goal was to determine if inducing heterogeneity in managed forest canopies could promote a diversity of native species without contributing markedly to invasion by exotic species. We examined 1- and 3-year responses of understory plants to variable-density thinning of 55- to 65-year-old stands of *Pseudotsuga menziesii* (Mirb.) Franco. Our study stands had been managed either with retention of old-growth legacies (large live trees, dead trees, and fallen trees) and no thinning or with removal of legacies and twice-repeated conventional thinning. Variable-density thinning initially resulted in decreased understory cover but increased importance of 20 native species, including 2 species of trees. Two native species, however, decreased in importance, and 11 exotic species increased in importance. Within 3 years, understory cover recovered, species richness increased by >150%, only four exotic species persisted with increased importance, eight native species (including four graminoids) increased in importance, and seven native species decreased in importance. Variable-density thinning shows promise as part of holistic silvicultural systems applied across landscapes throughout stand rotations and as a technique to restore vegetative complexity to closed-canopy second-growth forests.

. . .
Experimental effects on plant species diversity
Plant species richness was greater in VDT [variable density thinning] than in controls, including total species per plot, native species per plot, native shrub species per plot, and species per block . . . . Percent exotic species was significantly greater in VDT than in controls, markedly in year 1 with differences decreasing somewhat by year 3 . . . Richness of mycotrophs . . . in plots was less in VDT than in controls.
. . .
Experimental effects on understory cover
. . . Cover was less in VDT than in controls immediately after treatment but increased in VDT (but not controls) during the next two years. Covers of native shrubs and dominant perennials were reduced in CDT compared with controls but recovered to equivalent or greater covers than in controls. . . . Cover of exotic species was substantially greater in VDT than in controls 1 year after VDT . . ., but the difference declined over the next two years along with a decline in the percentage of species that were exotic. . . .
. . .
Discussion
. . .
. . . It is too early to tell if newly established exotic species will persist through time.
. . .
Exotic Species
. . . Some exotic species, notably some sod-forming grasses . . . increased from 1994 to 1996, suggesting novel life forms could become increasingly abundant in [Douglas-fir] forests in response to frequent and widespread managerial disturbance. Grasses that form dense sods are not normal components of these forests . . . and may compete with native grasses and herbs.

. . . Exotic shade-tolerant species . . . portend forested associations of the future that differ from those of the present. . . . Shade-tolerant conifers in the understory might be necessary to create the kind of patchy, competitive environment that promotes healthy native species diversity at the expense of exotics. . . .

. . . It has yet to be determined if increasing heterogeneity in within-stand environmental conditions will promote diversity of vegetation site types, including shade-tolerant trees, that will promote resistance to invasion by exotics, even in the face of minor to moderate disturbance.

Native Species
. . . Native species richness increased in response to VDT in 1994 but, unlike exotic richness, did not decline from 1994 to 1996. Richness and life-form diversity of native shrubs and trees was promoted by VDT, thus building our confidence in effects of CDT on hastening structural diversification. . . . Frequent disturbance can lead to dense, homogenous understories, including overwhelming dominance by clonal natives . . . Clonal natives are a normal and desirable component of Pacific Northwest managed and unmanaged stands . . . Our concerns lie in the abilities of these species in conjunction with certain exotic species, to create unwanted homogeneity and dominance by a few

species to the extent that they reduce vegetation site type diversity and preclude regeneration of shade-tolerant species.

. . . Natural forest development leads to contrast of high-light and low-light patches compared to homogenous second growth forests . . . Variable density thinning also increases the complexity through a wide variety of patch types, thus potentially increasing vegetation site-type diversity. Thus, VDT should also provide niches for rare species that are not abundant elsewhere. Mycotroph species, however, were more abundant in legacy controls that in stands that had been thinned. This suggests that VDT should be modified to incorporate a no-disturbance subtreatment, perhaps 10-15% of the stand in 0.2-ha patches. . . . In contrast, promoting vascular plant diversity through conventional thinnings may fail to meet conservation goals because of increased homogeneity, dominance by a few aggressive clonal natives, increased exotics, and, perhaps, extirpation of native species with restricted ranges . . .

Management Implications

The concept of VDT (Carey 1995) was developed to be part of a complex ecosystem management system that incorporates (i) variable-retention harvest systems (Franklin et al. 1997) that retain biological legacies from the preceding forest, including understory plants, and that reduce site disturbance, including burning, in preparation for planting; (ii) planting trees to ensure a mix of trees species; (iii) precommercial thinning to maintain vascular plant diversity, including tree species diversity; (iv) series of VDTs to promote spatial heterogeneity and vegetation site type diversity; (v) management of decadence (e.g., decay in live trees, snags, and coarse woody debris); and (vi) long rotations in conjunction with large-scale landscape management (Carey 1995); Carey and Johnson 1995; Carey et al. 1999a, 1999b, 1999c). Our experiment results support this kind of management. Experiences managers in western Washington find this approach pragmatic and operational (Carey et al. 1999a).

. . .

To maintain native species diversity and to limit invasion by exotic species, changes in present silvicultural systems are warranted. . . . Conventional thinning in competitive exclusion stages originating after clear-cutting may revive ruderal plants stored in soil seed banks.

USDA, USDI. 1994. **Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl**, and **Attachment A: Standards and Guidelines for Management of Habitat for Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl,** April 13, 1994.

Standards and Guidelines

. . .

Late Successional Reserves: . . . No programmed timber harvest is allowed inside the reserves. However, thinning or other silvicultural treatments inside these reserves may occur in stands up to 80 years of age if the treatments are beneficial to the creation and maintenance of late-successional forest conditions. [ROD 8]

. . .

The Selected Alternative

. . .

Alternative 9 allows silvicultural activities, such as thinning young monoculture stands, in late-successional reserves when those activities will enhance late-successional conditions. . . . According to the Final SEIS, Alternative 1 did not rate as high as Alternative 9 in providing the likelihood "of maintaining and enhancing late-successional ecosystems at levels that approach typical long-term conditions," because Alternative 1 "lacks restoration silviculture in the reserves" (Final SEIS, p. 2-69). [ROD 28]

. . .

Response to Comments on the Draft SEIS

. . .

The Assessment Team found that "without restoration silviculture, late-successional conditions would be retarded in development." (Final SEIS, pp. 34- 46). Silvicultural treatments are limited to those that will be beneficial to late successional forest conditions. [ROD 62-63]

. . .

Response to Comments on the Final SEIS

. . .

Any road construction associated with silvicultural treatments inside late-successional reserve would be subject to the overall "beneficial" requirement for such activities. That is, if the value of a thinning was negated by the habitat lost through road construction to the thinning, the activity should not proceed. [ROD 68]

. . .

Standards and Guidelines
Attachment A to the Record of Decision

. . .

General Ecological Basis for Forest Management

. . .

In Late-Successional Reserves, standards and guidelines are designed to maintain late successional forest ecosystems and protect them from loss due to large-scale fire, insect and disease epidemics, and major human impacts. The intent is to maintain natural ecosystem processes such as gap dynamics, natural regeneration, pathogenic fungal activity, insect herbivory, and low-intensity fire. These standards and guidelines encourage the use of silvicultural practices to accelerate the development of overstocked young plantations into stands with late-successional and old-growth forest characteristics, and to reduce the risk to Late-Successional Reserves from severe impacts resulting from large-scale disturbances and unacceptable loss of habitat. [S&G B-1]

. . .

Ecological Processes
Ecological processes include those natural changes that are essential for the development and maintenance of late-successional and old-growth forest ecosystems. Although the processes that created the current late-successional and old-growth ecosystems are not completely understood, they include: (1) tree growth and maturation, (2) death and decay of large trees, (3) low-to-moderate intensity disturbances (e.g., fire, wind, insects, and diseases) that create canopy openings or gaps in the various strata of vegetation, (4) establishment of trees beneath the maturing overstory trees either in gaps or under the canopy, and (5) closing of canopy gaps by lateral canopy growth or growth of understory trees. [S&G B-2]
. . .
Late-Successional Reserves
. . .
Late-successional forest communities are the result of a unique interaction of disturbance, regeneration, succession, and climate that can never be recreated in their entirety through management. The structure, species composition, and function of these forests are, in their entirety, not fully understood. However, silvicultural restoration in early-successional forests can accelerate the development of some of the structural and compositional features of late successional forests. Because early-successional forests will regenerate by different processes during a different time period than existing late-successional forests, silviculturally created stands may look and function differently from current old-growth stands that developed over the last 1,000 years. Consequently, conservation of a network of natural old-growth stands maintains biodiversity into the future.

Desired late-successional and old-growth characteristics that will be created as younger stands change through successional development include: (1) multispecies and multilayered assemblages of trees, (2) moderate-to-high accumulations of large logs and snags, (3) moderate-to-high canopy closure, (4) moderate-to-high numbers of trees with physical imperfections such as cavities, broken tops, and large deformed limbs, and (5) moderate-to high accumulations of fungi, lichens, and bryophytes. Although they may not be duplicates of existing old-growth forests, these stands could provide adequate habitat for many species in the long term. [S&G B-4]
. . .
Stand Management
Forests within Late-Successional Reserves are composed of managed stands from 2 to more than 80 years old, as well as unmanaged, late-successional, and old-growth stands. The younger stands were usually established following fire or timber harvest. Some of these stands will develop old-growth characteristics without silvicultural intervention. However, current stocking and structure of some of these stands were established to produce high yields of timber, not to provide for old-growth-like forests. Consequently, silviculture can accelerate the development of young stands into multilayered stands with large trees and diverse plant species, and structures that may, in turn, maintain or enhance species diversity.

Stand management in Late-Successional Reserves should focus on stands that have been regenerated following timber harvest or stands that have been thinned. These include stands that will acquire late-successional characteristics more rapidly with treatment, or are prone to fire, insects, diseases, wind, or other disturbances that would jeopardize the reserve. Depending on stand conditions, treatments could include, but should not be limited to: (1) thinning or managing the overstory to produce large trees; release advanced regeneration of conifers, hardwoods, or other plants; or reduce risk from fire, insects, diseases, or other environmental variables; (2) underplanting and limiting understory vegetation control to begin development of multistory stands; (3) killing trees to make snags and coarse woody debris; (4) reforestation; and (5) use of prescribed fire. Thinning prescriptions should encourage development of diverse stands with large trees and a variety of species in the overstory and understory. Prescriptions should vary within and among stands. [S&G B-6]
. . .
Standards and Guidelines
. . .
Thinning or other silvicultural treatments inside reserves are subject to review by the Regional Ecosystem Office to ensure that the treatments are beneficial to the creation of late-successional forest conditions. The Regional Ecosystem Office may develop criteria that would exempt some activities from review. [S&G C-12]
. . .
West of the Cascades - There is no harvest allowed in stands over 80 years old (110 years in the Northern Coast Adaptive Management Area). Thinning (precommercial and commercial) may occur in stands up to 80 years old regardless of the origin of the stands (e.g., plantations planted after logging or stands naturally regenerated after fire or blowdown). The purpose of these silvicultural treatments is to benefit the creation and maintenance of late-successional forest conditions. Examples of silvicultural treatments that may be considered beneficial include thinnings in existing even-age stands and prescribed burning. For example, some areas within Late-Successional Reserves are actually young single-species stands. Thinning these stands can open up the canopy, thereby increasing diversity of plants and animals and hastening transition to a forest with mature characteristics. [S&G C-12]

US Forest Service. 2001. **Density Management in Late Successional Reserves, Northwest Forest Plan Area.** August 24, 2001

New Scientific research underway at the Pacific Northwest Research Station and the U.S. Geological Survey now indicates that many young stands in Late Successional Reserves (LSRs) need active management (usually thinning of a portion of the trees, referred to as density management) in order to attain or enhance old-growth.
. . .

The objective of thinning treatments in LSRs is to enhance wildlife habitat and old-growth characteristics. The agency's top priority for thinning will be those stands that are least likely to move toward old-growth conditions on their own.
. . .
These plantations are different than the young stands that evolve naturally after a fire.
. . .
Currently, the FS in Regions 5 and 6 manages approximately 1,629,000 acres of dense stands under 80 years of age in the LSRs.
. . .
The FS estimates that it would cost approximately $32 million to initiate a LSR thinning program. Of this $32 million, $21 million will help supplement the existing budget for precommercial thinning, allowing the agency to treat an additional 15,000 acres of commercial thinning in the short term....

US Forest Service. 2001. **Northwest Forest Plan Research Synthesis;** Haynes, Richard W. and Gloria E. Perez, Technical Editors; General Technical Report PNW-GTR-498 January 2001; http://www.fs.fed.us/pnw/pubs/gtr498.pdf

Ecological processes and function—New findings about ecological processes and functions have significant implications for management and research. For example, the Pacific Northwest is much more dynamic than previously considered. In the southern part of the region, frequent low-intensity fires have been common in the past, and old growth likely persisted through multiple disturbances. Great variability exists throughout the region, thereby implying that a single prescription for the developing future oldgrowth stands will not be suitable or successful. Research also has shown that old growth developed at much lower densities, thereby supporting the concept of wide thinnings as an important tool in stand development.

ECOLOGICAL PROCESSES AND FUNCTIONS
Frederick J. Swanson and Randy Molina
Stand reconstruction studies provide new information on developing old-growth stands. Tappeiner and others (1997) observed that old-growth forests in parts of the Oregon Coast Range were established over longer periods and with much lower tree densities than is common in contemporary, young plantations. Lower tree densities apparently contributed to higher rates of diameter growth and rapid development of old-growth characteristics. The implication for management is that for sites where developing old-growth characteristics is a primary objective, thinning prescriptions may be most beneficial if set at much lower stocking than used traditionally.

Studies of transitions from single-story, mature stands to multistory, old-growth stands indicate that seed dispersal may limit the rate of developing western hemlock (*Tsuga heterophylla* Raf. Sarg.) and Douglas-fir forests (*Pseudotsuga menziesii* (Mirb.) Franco) (Schrader 1998). This limitation suggests that managing tree density alone may not accelerate old-growth forest development, if seed sources of late-successional species, such as western hemlock, are absent.

Many additional potential advantages accompany extended rotations and the associated thinning and regeneration options (Curtis 1995, Curtis and Carey 1996, Curtis and Marshall 1993). These include:
• Reduced visual impacts
• Lower regeneration costs
• Improved habitat for some wildlife species
• Increased carbon storage
• Enhanced hydrological functioning
• Possible long-term benefits to soil productivity
• Opportunities to adjust present unbalanced stand age-class distributions
• Increased flexibility to adapt to unknown future changes in social desires, political regimes, economic situations, technology, and biological or ecological knowledge and events

---

US Forest Service. 2001. **Viable Options for Second-Growth Forest Management in Late Successional Reserves**

Issue – A key component of the Northwest Forest Plan (NWFP) is a network of late successional reserves (LSRs). These reserves were established to provide late successional old growth conditions essential to the northern spotted owl recovery plan and old growth associated species. Recent research results by the Pacific Northwest Research Station and U.S. Geological Survey scientists indicate that early active management is required to alter the current stand trajectory to achieve the desired late successional old growth habitat and biodiversity conditions.

Conclusions from research findings – Future projections for young dense forests stands in late successional reserves strongly suggest that they are not likely to develop late successional old growth habitat or biodiversity conditions through passive management.

Stand development trajectories that lead to late successional old growth habitat and biodiversity conditions are characterized by much lower stand densities and greater habitat diversity than occurs under timber production practices. The results also show that changing stand trajectories requires much earlier thinning and different prescriptions (to restore habitat diversity) than previously held management guidance.

Associated findings indicate that the opportunity to change stand trajectories closes sooner than previously believed.

Findings indicate very strong scientific support for active management (density management, increasing tree species mix, creating habitat diversity) in young stands that resulted from previous timber production practices.

Initial estimates on magnitude of the issue – During the last 5 years, the Pacific Northwest Region of the Forest Service has had a need to actively manage of treat annually about 350,000 acres of westside young forest stands. During that same time period, they have been treating about 50,000 acres. The Bureau of Land Management (BLM) has about 850,000 acres in western Oregon designated as late successional reserves. Initial estimates indicate that about 210,000 acres are in young (0 to 30 years) dense stand conditions and potentially need active management. The BLM is currently anticipating treating about 17 percent of that acreage during the next decade.

Unknown. 2002. **A Brief Literature Review of the Status of Early Stand Density Management in Other Forest Industrialized Countries**, Forest Service British Columbia, Forest Practices Branch, Silviculture Practices Section, June 2002.
http://www.for.gov.bc.ca/hfp/pubs/stand_density_mgt/World%20Summary.pdf

Early stand density management provides diversity and increased flexibility to manage our forests for a myriad of resource objectives.

Unknown. 2002. **Landscape Changes Through Young stand Management— A Fall Creek LSR Case Study,** Central Cascades Adaptive Management Area, 9/26/2002 DRAFT

Thinning treatments are accepted as a potentially useful too for accelerating vegetative development toward late seral conditions. . . . Although much debate still remains on the best treatments or stand level designs to use. Thinnings can be used to influence species composition, stem growth, canopy complexity, and understory communities in residual stands.

While thinning in LSR's may generally be confined to established plantations, managers till need to understand the temporal and spatial roles these plantations can contribute toward improving the landscape pattern of late successional habitat.

The Fall Creek Case study explores the connections between landscape habitat patterns and young stand management.

. . . 89,794 acre analysis area . . . 45% of the analysis area occurs in plantations. Only about 1/3 of these plantation acres have been thinned prior to age 20, with another 1/3 of the acres beyond the optimal age range for precommercial thinning.

The Willamette National Forest does not expect to have sufficient funding or staff to thin all available acres over the next 50 years. Specific resource objectives (e.g., interior habitat) should be used to focus development of late successional habitat where resource benefits are greatest.

Management Scenarios

The **Owl Sites scenario** focuses thinnings around known nesting activity centers and nesting success for prioritizing treatments.

The **Roads scenario** focuses on decommissioning roads and habitat improvement in landblocks (roadsheds) possessing high aquatic habitat risks. . . .

The **Natural Fire scenario** uses thinning to create habitat conditions resulting from defined fire regimes. Prescriptions used fire frequency and intensity of regimes to define resulting habitat conditions. . . .

The **Interior habitat scenario** focuses on young stands surrounded by or next to the largest interior habitat blocks. Thinning intensity was varied to minimize edge effects on existing late successional habitat.

Finally, a **Two-thin benchmark** was applied to all young stands to serve as a upper benchmark for comparing against the other scenarios. This scenario was the most aggressive thinning strategy.
. . .
The analysis team used spatial mapping and simulation modeling tools to assess the effects of thinning treatments on LSR habitat patterns over a 200 year period.
. . .

Landscape Attributes for Comparing Management Scenarios

- Hectares of late seral habitat
- Hectares of interior habitat
- Kilometers of inactive roads

- Hectares thinned per decade
- Volume of harvested per decade

Results

Resource scenarios thinned between 8,600 and 13,000 hectares over a 70-year time interval.
. . .
Location of improved habitat on the landscape varies by scenario.
. . .
At some point between ages 80 and 120, thinned plantations contribute to interior habitat and improve adjacent late successional habitat by mitigating edge effects. Scenarios varied considerably I the expansion of interior habitat and overall habitat pattern.

Conclusions

While landscape modeling can test and compare resource strategies for the scheduling of thinning projects, such modeling is still generally to simplified for making final decisions without specific project analysis.

Location of the late successional habitat on the landscape can be just as important as the total hectares of habitat created. Large-scale resource objectives should help drive the placement of habitat improvement projects.

Next Steps in the Future

Model additional resource scenarios of interest to the forest.

- Combine several resource scenarios into one scenario.
- Allocate different resource scenarios to different sections of the LSR and pursue simultaneously.
- Use model results to help create a five-year action plan.

Unknown. 2000. **Young Stand Study: Year 3 Post-Treatment Initial Results,** DoubleTree Hotel, Springfield, OR. 4/27/00.
http://www.fsl.orst.edu/ccem/yst/april2000wkshp.html

II. Songbirds - Joan Hagar (Oregon State University)

Background:

Dense pole plantations do not support a high diversity of bird species because they are structurally simple. Extensive existing cover (millions of acres) of dense pole stands is probably is unlikely to occur "naturally" in western Oregon under a natural disturbance regime. We hypothesized that by opening up the canopy and promoting the development of understory layers of vegetation, thinning could increase the diversity of niches available to songbirds, both in the short- and long-term. We tested the effect of 3 different intensities and patterns of thinning: light, heavy, and light with gaps, against unharvested controls. We used standard point count methodology to estimate densities of songbirds for 2 years prior to - and 3 years after application of experimental thinning to 4 blocks of young Douglas-fir stands in the Willamette N.F.

Results:
. . .
14 species were observed during the post-treatment phase but not during the pre-treatment phase: American crow, blue grouse, house wren, mountain quail, northern pygmy owl, northern oriole, olive-sided flycatcher *, red-breasted sapsucker*, red-tailed hawk, Townsend's solitaire*, white-crowned sparrow, western bluebird, willow flycatcher, and western saw-whet owl. Species with * were observed consistently enough across treatments and years to conclude a positive treatment response.
. . .
Conclusions:

- At least 4 species were gained as a result of thinning treatments, and no species appear to have been lost.
- Species richness and diversity of songbird communities increased in response to thinning.
- Some of the species that decreased in density are likely to increase again as canopy closes, and their abundance in treated stands may eventually surpass that in controls, if treated stands develop old-growth like structures more quickly.
- Thinning adjacent to pastures and settlements should be avoided because the rate of brood parasitism by cowbirds may increase and be detrimental to populations of some songbird species.

. . .

III. Small mammals - Steve Garman (Oregon State University)

Summary

Thinning young Douglas-fir stands had little effect on the ground-dwelling community. Deer mice and Ensatina exhibited a statistically significant numerical increase to the light-thin treatments, at least in 1 of the 2 post-treatment years. Trowbridge's shrew exhibited a significant decline in the heavy thin treatment in both post-treatment years. However on average, no species was eliminated from a treatment type compared to pre-treatment conditions. An exception was the northern flying squirrel in heavy thin stands, but the variability in capture rates of this species among treatments and all years of the study resulted in a non-significant treatment effect.

Wilson, J.S., and C.D. Oliver. 2000. **Stability and Density Management in Douglas-fir Plantations,** Can. J. For. Res. 30(6): 910-920 (2000)
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x00-027_30_ns_nf_cjfrnull

Abstract: Limited tree size variation in coastal Oregon, Washington, and British Columbia Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) plantations makes them susceptible to developing high height to diameter ratios (H/D same units) in the dominant trees. The H/D of a 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 through reduced planting densities or early thinning; however, later thinnings 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.

Conclusions

Early Douglas fir density in plantations is critical to future stand stability. Stands planted at high densities develop high H/D_{L250} values that reflect increased susceptibility to wind and snow damage. In addition, high density stands have limited stand-height window during which thinning can be used to improve future stand stability substantially. A stand planted at very low density can be managed more flexibly, because thinnings are not required to maintain stand stability. Thinnings can be incorporated at any time during the rotation if specific timber markets are good or certain stand structure is desired. . . .

There is no one H/D_{L250} value that guarantees stand stability; rather, increasingly severe storms will damage increasingly stable stands. The goal of forest managers and landowners should be to strike a balance between developing greater stand stability and the myriad other objectives that have been identified for a forest.

Wilson, Jeremy. 1998. **Wind Stability of Douglas-fir Plantations,** Ph.D. Thesis, University of Washington, CFR, 1998
http://www.cfr.washington.edu/research.smc/research/jwilson2ndqtr99.htm

In most plantations, even-aged seedlings of a single species are planted in a regular pattern. This practice may limit variation of tree sizes, making plantations susceptible to stagnation and/or instability.
. . .
Naturally regenerated stands tend to develop greater variation of tree sizes compared to plantations (Wilson 1998). Limited size variation in plantations makes them more susceptible to developing high height-to-diameter ratios (H/D same units) in the dominant trees (Figure 1). The H/D of a tree is a relative measure of stability under wind and snow loads. As H/D increases trees become increasingly unstable (Cremer et al. 1982, Becquey and Riou-Nivert 1987, Lohmander and Helles 1987). Young Stand Thinning and Diversity Study Workshop

---

Wilson, Todd M., Andrew B. Carey, Juliann E. Aukema. 2002. **Thinning to Induce Spatial Heterogeneity: One Step Towards Providing Multiple Values in Managed Stands.**
http://www.cof.orst.edu/cof/extended/conferen/silvopt/posters/THINNING_TO_INDUCE_SPATIAL__files/v3_document.htm
http://www.fs.fed.us/pnw/olympia/efb/flash/thinning_to_induce.swf

The Forest Ecosystem Study (FES) was designed to test the feasibility of accelerating forest developmental processes in second-growth Douglas- fir forests [55-60 years old with various management histories] to mimic the complexity, biological diversity, and ecological function found in old-growth forests and to simultaneously provide wood and other forest products to meet human consumptive demands. The core experiment on the FES tests the use of variable-density thinnings, designed specifically to develop a mosaic of vertical and horizontal heterogeneity within the forest. We chose a spatial size and scale for the thinnings that was similar to the heterogeneity observed in old, natural forests in the Pacific Northwest.

Understory Vegetation
Forest understory provides habitat for various vertebrates and invertebrates in the form of shelter, hiding cover, and food. A complex association of plant species supports a complex array of organisms; stands depauperate in understory often lack biological diversity found with high plant diversity.

- Legacy stands initially had low plant and tree diversity; Commercial stands had high plant species diversity, but were dominated by clonal natives with many exotic species.
- VDT initially resulted in decreased understory cover but increased importance of 20 native species. Two native species decreased in importance and 11 exotic species increased in importance.
- Within 3 years after VDT, understory recovered, species richness increased by >150%, only four exotic species persisted with increased importance, eight native species increased in importance, and seven native species decreased in importance.
- Regardless of management history, VDT enhanced diversity and abundance of plant species.
- Presence of aggressive exotic and clonal natives may require additional management intervention to achieve spatial heterogeneity goals, especially promotion of vertical foliage profiles.

Coarse Woody Debris and Snags
Coarse woody debris (CWD) provides organic material to the forest floor, stores carbon, and supports a rich assemblage of fungi, bacteria, protozoans, nematodes, and a diversity of other invertebrates and vertebrates. In the Pacific Northwest, CWD is an important correlate of small mammal abundance, terrestrial salamander abundance, mycorrhizal colonization and truffle abundance, and diversity of mycorrhizal fungi in flying squirrel diets.

- Intensive management in the Commercial forest reduced CWD and snags to exceptionally low levels.
- Retention of legacies in the Legacy forest provided moderate levels of CWD, but was less than that found in biologically complex old growth stands on the Olympic Peninsula.
- Abundant small dbh snags in Legacy stands were a result of stem exclusion and root rot infestation; these small structures were of little value to cavity-nesting wildlife.
- VDT significantly reduced the amount of well-decayed fallen trees on the forest floor.
- VDT also reduced the numbers of large-diameter stumps left from the previous harvest. These structures were used as maternal dens by flying squirrels and by many other small mammals and invertebrates.

Mycorrhizal fungi enhance the ability of trees to absorb water and nutrients from the soil and they move photosynthetic carbohydrates from trees to the soil. In turn, this carbon supports a vast array of microbes, insects, nematodes, bacteria, and other organisms in the forest floor. A diverse fungal community may help support a diverse and complex community of trees and shrubs thus adding to the forest biocomplexity.

- Mean standing crop biomass of truffles did not differ between Legacy and Commercial stands, but truffle species diversity was higher in Legacy stands.
- Dominant genera of truffles differed between forests. *Gautieria*, an important component of flying squirrel diets but not chipmunk diets, was more abundant in Legacy than in Commercial stands. *Melanogaster*, eaten by both chipmunks and flying squirrels, was more abundant in Commercial stands.
- Truffle standing crop varied greatly but generally was highest in spring with a smaller peak in the fall.
- At least some sporocarps were found year round, with winter having the lowest biomass and species richness.
- Overall standing crop biomass was significantly lower in VDT stands compared with control stands.
- VDT increased fungal diversity in treated stands.

Forest-floor Arthropods
"Indicators of Forest-Floor Integrity"
Invertebrates represent the bulk of biodiversity in forest ecosystems. These organisms are highly responsive to changing environmental conditions and can greatly alter forest structure and function. They represent one of the primary food sources for a variety of small mammals.

- Community structure [of forest floor arthropods] changed after VDT.
- Some beetles showed decrease abundance with increasing intensity of thinning and decreasing abundance of large coarse woody debris.
- Spider abundance was greater in legacy VDT stands than in other stands, suggesting that the combination of decadence and understory vegetation may enhance spider abundance.

Resident Songbirds
"Indicators of Ecosystem Niche Development"
Resident birds are one of several groups of species most likely to be influenced by forest management activities. As a community, these birds partition the resources within the ecosystem into numerous niches, with ground-nesting members like winter wrens to canopy-gleaning members like golden-crowned kinglets. Unlike neotropical birds which only use regional forests seasonally, and when resources are at their peak, resident birds are more apt to reflect year-round stability within the ecosystem.

- Proportion of area used and species richness increased with degree of thinnings; thinning produced stands that supported more winter birds and more species of winter birds than legacy retention.
- No species exhibited greater use of unthinned Legacy stands over VDT or commercially-thinned stands.
- Increased bird abundance was observed when VDT was applied to commercially-thinned stands.
- VDT thinnings, in conjunction with other conservation measures, should provide habitat for abundant and diverse birds.

Forest-floor Small Mammals
"Indicators of Forest-floor Function"
The small mammals that inhabit the forest floor serve as prey for reptiles, carnivores, hawks, and owls. They consume invertebrates, vegetation, fruits, and seed, and they also disperse fungal spores. These mammals are generally more abundant in complex, natural forest than in simplified, managed forest.

- Commercial stands had 1.5 times as many individuals as Legacy stands.

- Commercial stands also had 1.7 times more mammal biomass than Legacy stands.
- Neither conventional thinning nor legacy retention alone produced communities typical of late-seral forests.
- Increased spatial heterogeneity due to VDT resulted in larger populations of small mammals associated with understory shrubs (deer mouse), herbaceous vegetation (creeping vole), and open canopies (vagrant shrew).
- No species declined in abundance following VDT.

Arboreal Rodents
"Indicators of Ecosystem Productivity"
"Complete" squirrel communities are composed of abundant populations of northern flying squirrels, Douglas' squirrels, and Townsend's chipmunks and are: (1) a result of high production of seeds and fruiting bodies by forest plants and fungi and complexity of ecosystem structure, composition, and function; (2) indicative of high carrying capacity of vertebrate predators and (3) characteristic of old, natural forests in the Pacific Northwest.

- We observed initial decreases followed by increases in flying squirrel populations after VDT.
- Genetic diversity of squirrel populations can quickly return to areas treated with VDT provided adjacent, undisturbed areas exist that are permeable (allow unimpeded movement) for flying squirrels.
- Promiscuity and large male breeding ranges allow for quick recovery of populations after VDT.
- Rapid, nonlinear increases occurred in chipmunk populations after VDT; chipmunk populations responded positively to VDT and subsequent understory development.
- Initially low populations fluctuated during the study period, likely in response to cone crops, but not to management strategy, including VDT.

OVERALL IMPLICATIONS

- ✓ Variable-density thinnings in conjunction with other conservation measures such as legacy retention, decadence management, underplanting, and long rotations could accelerate biocomplexity in second-growth forests, mimic the biocomplexity found in old, natural forests, and provide habitat for abundant and diverse plants and animals.
- ✓ Purposeful, narrowly-focused management strategies (legacy retention alone, conventional thinning alone) can place stands on hard-to-alter trajectories characterized by incomplete or unbalanced biotic communities, truncated or misdirected developmental processes, invasion and dominance by exotic species, simplified vegetation structure, low capacity to support prey bases and predators, low resilience to perturbation, and high susceptibility to disease.
- ✓ Extensive management may also result in ecosystems with missing pieces. If the management is not purposeful, results could be highly variable and may include simplified structure, reduced soil seed banks depauperate in native species but rich in weeds, and reduced species composition, including reduced capacity to develop shade-tolerant and deciduous understory trees.
- ✓ Because not all second growth is equal, stand management is an important part of landscape management; differently structured stands will provide markedly different ecological services at the same age and nominal seral stage.
- ✓ Creating spatial heterogeneity through variable density thinnings holds promise for providing a full range of ecological services and economic goods but may require legacy management, management to ensure multiple species of trees, including deciduous trees, management for spatial heterogeneity, and management for decadence to attain the biocomplexity that provides for rich biodiversity.

Winter, Linda E., Linda B. Brubaker, Jerry F. Franklin, Eric A. Miller, and Donald Q. DeWitt. 2002. **Initiation of an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records.** Can. J. For. Res./Rev. Can. Rech. For. 32(6): 1039-1056 (2002)
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x02-031_32_ns_nf_cjfr6-02
http://www.cfr.washington.edu/classes.esc.521a/WinterCJFR021.pdf

Abstract: We used tree-ring records to reconstruct the stand initiation of an old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stand in the western Cascade Range of southern Washington. All tree-ring samples were prepared and crossdated. Following a stand-replacing fire, the stand initiation period lasted from 1500 to 1540, with gradual filling-in of growing space over this period. All sampled Douglas-fir were initial colonizers, establishing (at stump-height) 1500–1521 under open conditions. A small number of the sampled western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) were also initial colonizers. Growing space filled as tree crowns widened, and by 1540, closed forest conditions had developed. At this time, Douglas-fir were spaced about 3.5 m from equivalent competitors (ca. 800 trees/ha). In the centuries following canopy closure, considerable natural thinning of the initial colonizers occurred, but the canopy never opened enough again to allow further Douglas-fir establishment. Surviving Douglas-fir developed deep crowns despite the narrow initial spacing, and without epicormic branching from the bole. Most western hemlock that were canopy trees in 1992 established after 1540, originating in the understory. This reconstruction provides an example that may be useful where management policies emphasize the development of old-growth structures.

. . .

Multiple pathways for the development of old-growth Stands
Yellowjacket is just one site. By chance, its early history may represent an exception rather than a common occurrence for old-growth stands. Nonetheless, the fact remains that this stand initiated quickly and at close spacing but developed typical old-growth structures. In marked contrast, previous reconstructions have suggested that other oldgrowth stands started out very slowly and at low density. The ecological causes of these contrasting initiations are not clear but may be related to regional gradients in climate, environmental conditions, and disturbance

characteristics across the large geographic area covered by the various studies (i.e., Coastal Range of Oregon, Cascades of Oregon, and southern Washington; Spies and Franklin 1991). Regardless of the ecological causes, the strong contrasts between the stand initiation for Yellowjacket versus other previously reconstructed old-growth Douglas-fir stands shows that typical old-growth structures can develop by multiple pathways. The likelihood of different developmental pathways for oldgrowth stands has been suggested previously based on the variability in overall old-growth structure across the large geographic area where these forests are found (Spies and Franklin 1991). Differences between Yellowjacket and past reconstructions provide empirical evidence for varied pathways. It is also possible that there is a range of early histories that do not support the eventual development of typical old-growth structure, for example, early histories where initial spacing is too narrow or where there is little size differentiation (Wilson 1998).

Management implications
Knowledge about initial histories of old-growth forests is of considerable importance to forest managers faced with policies that emphasize maintenance and development of old-growth stands in the Pacific Northwest. In pursuing these policies, managers must ask whether current young stands are likely to develop old-growth structures or whether silvicultural treatments might be required (e.g., Halpern and Raphael 1999; Aubry et al. 1999; Thomas 1997; Kohm and Franklin 1997; DeBell et al. 1997; Tappeiner et al. 1997; McComb et al. 1993). The past offers the only time-tested guide to answering such questions. It was for reasons such as these that Tappeiner et al. (1997) also reconstructed oldgrowth stands in the Oregon Coast Range, concluding that the trees in these stands established and grew at much lower densities compared with trees in modern young stands and suggesting that young stands may need to be aggressively thinned to enable them to develop into stands with oldgrowth characteristics.

The results of the current study suggest caution about applying thinning on a widespread basis. Natural young stands that are not overly dense and that are developing strong differentiation of tree sizes may require only time to develop old-growth structures, with no intrusive management required. Although it is not clear where the overly dense boundary lies, the Yellowjacket reconstruction suggests that currently young stands with dominant Douglas-fir DBH and height structures similar to Butte are likely starting on a developmental pathway similar to the early history of Yellowjacket dominants. This leaves little reason to doubt that some young stands like Butte can develop old-growth characteristics, although others may not. In some cases, intervention may be considered because a stand is very dense or to speed the development of greater size variability and complexity, but the gains of such intervention should be weighed carefully against the ecological costs of silvicultural interventions.

Spies and Franklin (1991) have suggested that "... management of old growth in western Oregon and Washington should be sensitive to the regional diversity of old-growth conditions." The current study suggests that management should also be sensitive to the diversity of pathways that lead to old-growth conditions. Variability in the pathways to old-growth structures, as well as variability in the endpoints themselves, may be important in maintaining diversity in habitat and ecosystem functions at many scales (spatial and temporal) across the landscape. For example, very different ecological characteristics would be expected for prolonged versus short stand initiations, particularly when considered at the scale of multiple forests across the landscape (e.g., Franklin et al. 1989) or for a stand with a single Douglas-fir cohort versus multiple cohorts. It would be unwise to apply simple generalizations as to how current old forests developed, or how the current young forests will develop, and risky to implement a simple management prescription at the landscape scale. Rather, as Kohm and Franklin (1997) have suggested, we need an "array of tools and ideas" as to how these forests develop and an appreciation of their complexity. Where the objective is to maintain and develop oldgrowth structures, many approaches are being suggested, and the "menu" of ideas is continually growing (e.g., Halpern and Raphael 1999; Aubry et al. 1999; Thomas 1997; Kohm and Franklin 1997; DeBell et al. 1997; Tappeiner et. al 1997; McComb et al. 1993). The current study, together with the reconstruction of canopy disturbances for Yellowjacket (Winter 2000; Winter et al. 2002), provides the most detailed currently available "real-time" (as opposed to chronosequence) history for the entire lifetime of an old-growth Douglas-fir stand.

Winter, Linda E., Linda B. Brubaker, Jerry F. Franklin, Eric A. Miller, and Donald Q. DeWitt. 2002b. **Canopy disturbances over the five-century lifetime of an old-growth Douglas-fir stand in the Pacific Northwest**. Can. J. For. Res. 32(6): 1057-1070 (2002)
http://www.nrc.ca/cgi-bin/cisti/journals/rp/rp2_abst_e?cjfr_x02-030_32_ns_nf_cjfr6-02
http://www.cfr.washington.edu/classes.esc.521a/WinterCJFR022.pdf

Abstract: The history of canopy disturbances over the lifetime of an old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stand in the western Cascade Range of southern Washington was reconstructed using tree-ring records of cross-dated samples from a 3.3-ha mapped plot. The reconstruction detected pulses in which many western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) synchronously experienced abrupt and sustained increases in ringwidth, i.e., "growth-increases", and focused on medium-sized or larger (0.8 ha) events. The results show that the stand experienced at least three canopy disturbances that each thinned, but did not clear, the canopy over areas 0.8 ha, occurring approximately in the late 1500s, the 1760s, and the 1930s. None of these promoted regeneration of the shade-intolerant Douglas-fir, all of which established 1500–1521. The disturbances may have promoted regeneration of western hemlock, but their strongest effect on tree dynamics was to elicit western hemlock growth-increases. Canopy disturbances are known to create patchiness, or horizontal heterogeneity, an important characteristic of old-growth forests. This reconstructed history provides one model for restoration strategies to create horizontal heterogeneity in young Douglas-fir stands, for example, by suggesting sizes of areas to thin in variable-density thinnings.

Discussion
Reconstructed Disturbances

. . .

We conclude that each of these disturbances likely thinned but did not clear the canopy over the affected areas, based on (*i*) the lack of Douglas-fir regeneration following these disturbances, (*ii*) the knowledge that Douglas-fir can establish on mesic sites in gaps >0.075 ha (Spies and Franklin 1989; Spies et al. 1990), yet no Douglas-fir established after any of the disturbances, and (*iii*) the distribution of Douglas-fir still living in 1992 (Fig. 8). . . .

The three reconstructed canopy disturbances span much of the life of the stand. It is likely that over this long time span, the causes of the disturbances varied; however, they cannot be determined from the data, particularly for the two oldest disturbances. Potential causes would include insects, wind, ice storms, or disease. Judging from the absence of fire scars and charred bark, fire was not a likely agent for any of the canopy disturbances. . . .

Other minor disturbances The three reconstructed events were the strongest canopy disturbances that occurred over the life of the stand, involving relatively large numbers of surviving trees covering large portions of the plot and, thus, were capable of leaving credible evidence, even after centuries. Additional, less evident, canopy and non-canopy disturbances likely occurred. Eighty percent (619) of the western hemlock growth-increases were relatively individual events, not related to the 3 reconstructed disturbances or part of visually obvious spatial groupings. Many of these individual western hemlock growth-increases may be due to canopy disturbances below the 0.8-ha resolution of the study, involving injury or mortality to a single or small number of canopy trees. However, many of these isolated increases may represent random variations or may have had causes not related to canopy disturbances.

Pulses of other types of sudden changes in ringwidth (i.e., Douglas-fir growth-increases and sudden decreases in the ringwidths of western hemlock or Douglas-fir) were observed in the samples and evaluated but are not reported in this paper, because they did not contribute to the interpretation of the canopy disturbances. However, they may represent other kinds of disturbances (Winter 2000).

. . .

Although the amount of thinning of the pioneer trees was substantial over the life of the stand, the thinning never created canopy gaps large enough to allow further Douglas-fir establishment. Some of the thinning was brought about by the three reconstructed canopy disturbances that thinned, but did not clear, the canopy over medium-sized areas. Other thinning likely occurred via individual tree deaths that left no or small canopy gaps, such as might occur due to competitive interactions.

. . .

. . . the effects of the canopy disturbances on western hemlock establishment were minimally detectable or uncertain. This is not surprising because, as noted by Lorimer and Frelich (1989) age distributions of shade-tolerant trees “may bear no meaningful relationship to disturbance history because disturbance is not a prerequisite for germination in most shade-tolerant species”. The successful establishment of western hemlock likely involves cumulative interactions among many factors, including understory light conditions, seedbed conditions, presence of woody debris, and competition. Regardless of the lack of a strong effect on western hemlock establishment, the canopy disturbances did have strong effects on the growth of western hemlock.

. . .

The reconstruction of canopy disturbances at Yellowjacket necessarily dealt only with trees. There are many other important effects of canopy disturbances we could not directly reconstruct. However, based on previous work in current small-sized gaps, some impacts of canopy disturbances are known to include release of resources, i.e., light and nutrients; alteration of microclimate; establishment and (or) release of trees, hence influence on the population dynamics of trees; understory growth; and creation of snags, logs, and rootwads (e.g., Spies et al. 1990; McComb et al. 1993; Van Pelt and Franklin 1999; Gray and Spies 1996, 1997). Snags provide essential habitat for many species of vertebrates and invertebrates. Logs provide long-term sources of energy and nutrients, sites for nitrogen fixation, physical stability, essential habitat for many plant and animal species, and seedbed sites.

Because of these many effects, canopy disturbances can create patches that differ from the adjacent forest, producing a high degree of spatial patterning, i.e., horizontal heterogeneity (Franklin et al. 2002). Douglas-fir stands typically initiated following catastrophic disturbances and likely each started as an extensive patch of uniform and even-aged trees. Over time, canopy disturbances can break up the large uniform patch into multiple structural units, thus evolving the stand into one that is both horizontally and vertically diverse with a high level of niche diversity. An example of such disturbance-induced patchiness could be seen at Yellowjacket in the area of the 1930s canopy disturbance. The forest in this patch stood out for its relatively high densities of small western hemlock, and its relatively low densities of Douglas-fir and large western hemlock. This patch was also characterized by its large accumulations of coarse woody debris and abundant western hemlock regeneration, particularly on the many large logs and rootwads.

In the Pacific Northwest, with the increased emphasis on maintaining and developing old-growth stands, researchers and managers are asking whether and what silvicultural interventions may be needed to promote modern young stands to eventually develop old-growth structures (e.g., McComb et al. 1993; DeBell et al. 1997; Tappeiner et al. 1997; Aubry et al. 1999). Although many young stands, especially typical natural young stands, may not require silvicultural interventions (Winter 2000; Winter et al. 2002), for others, especially plantations, active management may be appropriate for increasing structural diversity. It has been suggested that for such cases, development and disturbances in natural stands can serve as models for management (e.g., McComb et al. 1993). The results of the current study adds to our menu of available models to aid in the design of restoration strategies, with the caveat that no single model should be used to guide management across large areas of forest. For example, the results support the practice of variable density thinning, which is being carried out in some stands in the region. In this approach, different areas in a stand are thinned to varying degrees, and some areas are not thinned at all. Such a practice would help to create structurally differing patches and hence horizontal spatial heterogeneity, much as canopy disturbances would. For some cases, the sizes of the patches could be guided by the Yellowjacket reconstruction. The reconstruction results also suggest that in cases where a restored stand is to mimic a natural stand similar to Yellowjacket, the thinned patches should not be heavily thinned nor viewed as “clearcuts”, the matrix surrounding the patches should be only lightly thinned or not thinned at all, and Douglas-fir should not be promoted to regenerate in the thinned areas. Instead, western hemlock already in the understory should be allowed to respond with increased growth, eventually contributing to both vertical and horizontal heterogeneity. Other silvicultural activities could be guided by what we have learned from currently disturbed areas. Above all, structural complexity and heterogeneity should be promoted within and between stands.

WINTER, L.E., L.B. BRUBAKER, J.F. FRANKLIN, E.A. MILLER AND D.Q. DEWITT. 2000. **Five centuries of structural development in an old-growth Douglas-fir stand in the Pacific Northwest: a reconstruction from tree-ring records.** Symposium: Age-Related Change in Structure and Function of Forests in the Pacific Northwest, Oct. 19, 2000, Oregon State University.
http://www.fsl.orst.edu/~bond/age-symposium_files/ABSTRACTS.htm

Widespread loss and fragmentation of old-growth ecosystems in the Pacific Northwest region of the United States has generated intense controversy in recent decades, leading to management policies with increased emphasis on maintaining and developing old-growth ecosystems across the current and future landscapes. In response to current policies, Pacific Northwest forest managers are asking if modern young forests can develop old-growth characteristics, and if so, what silvicultural interventions may be required. Information concerning the developmental history of existing old-growth forests would help answer such questions by providing examples from the past of how old-growth structures did develop.

This study used tree-ring records to reconstruct the history of an old-growth Douglas-fir stand in the western Cascade Range of southern Washington. Prior to a scheduled harvest, a 3.3 ha plot was inventoried and mapped. After felling in 1992, samples were collected from stumps of all mapped trees, and from multiple additional heights of a subset of these trees. One tree was intensively dissected to locate and extract embedded branches. Data taken from crossdated samples were used to reconstruct a history that focused on stand initiation and canopy disturbances, but also included diameter, height and crown development.

All sampled Douglas-fir were initial colonizers, establishing (at stump height) 1500-1521 under open conditions following a stand-replacing fire. A minor component of sampled western hemlock were also initial colonizers. Growing space filled as tree crowns widened, and by 1540 closed forest conditions had developed. At this time, Douglas-fir were spaced about 3.5 m from equivalent competitors (ca. 800 trees/hectare).

In the centuries following canopy closure, considerable natural thinning of the initial colonizers occurred. Although the canopy never opened enough to allow further Douglas-fir establishment, at least three disturbances thinned the canopy across areas large enough to reliably reconstruct, each affecting areas >= 0.8 ha. Surviving Douglas-fir increased in stature and developed long crowns despite the narrow initial spacing, and without epicormic branching from the bole. Most western hemlock that were canopy trees in 1992 established after 1540, originating in the understory where they grew slowly for years to decades before ascending to the canopy through multiple abrupt increases in growth.

This reconstruction provides a case history, extending across centuries, that may be useful where management policies emphasize the development of old-growth structures. The quick establishment at close spacing by Douglas-fir in the study stand is similar to establishment patterns for typical young natural stands in the region, and is very different from the prolonged establishment at wide spacings found for Douglas-fir in other reconstructed old-growth stands. Such differences show that old-growth structures can develop by multiple pathways, and that intrusive management may not be required to allow many typical young natural stands to develop old-growth structures.

OTHER REFERENCES

THINNING YOUNG STANDS FOR DIVERSITY: Important Studies
http://www.cof.orst.edu/cof/extended/conferen/silvopt/tucker.htm

Stand Structure and Biotic Responses to Changes in Structure of Young Forests of Western Oregon, Cooperative Forest Ecosystem Research.
http://www.fsl.orst.edu/cfer/research/resproj/structr/structr.html

Silvicultural Options for Interdisciplinary Decision Making
http://www.cof.orst.edu/cof/extended/conferen/silvopt/presentations.htm
http://www.cof.orst.edu/cof/extended/conferen/silvopt/posters.htm

The Biodiversity Enhancement Demonstration Forest; Evergreen College Campus Stewardship Option; Sustainable Forestry Program; February 1, 2001; Chris Dowling, David Weyte, Mark Baltzel, Miranda Benvenuti, Josh Pearce, Patrick Sullivan, Makiko Yuki, and Joseph Quinn
http://academic.evergreen.edu/curricular/susfor/CSO%20Hand-in/diversity%20revision.pdf

YOUNG STAND THINNING AND DIVERSITY STUDY REPORTS & PUBLICATIONS
http://www.fsl.orst.edu/ccem/yst/pubs/pubs.html

Westside Silvicultural Options Team
http://www.fs.fed.us/pnw/olympia/silv/wsonstud.htm

Cissel, J. H., Swanson, F. J., Swindle, K. A., and others. 1998. **A landscape plan based on historical fire regimes for a managed forest ecosystem: the August Creek study**. General Technical Report, PNW-GTR-422. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.
http://www.fs.fed.us/pnw/pubs/gtr422.pdf

Carey slideshows
http://www.fs.fed.us/pnw/olympia/efb/slide_shows.htm

Aukema, Carey, Wilson; **Ecosystem Management: An experiment in Managed Stands**
http://www.fs.fed.us/pnw/olympia/efb/flash/ecosystem_management.swf
[slideshow includes a nice explanation of the keystone complex: spotted owl, flying squirrel, fungi, Douglas fir.]

Hayes, J.P., S.S. Chan, W.H. Emmingham, J.C. Tappeiner, L.D. Kellogg, and J.D. Bailey. 1997. **Wildlife response to thinning young forests in the Pacific Northwest.** Journal of Forestry; 95(8):28-33.

Omule, S.A.Y., **Growth And Yield 35 Years After Commercially Thinning 50 Year Old Douglas Fir,** BC Min. For., Res. Br., Victoria, BC, FRDA Report 021, January 1988; http://www.for.gov.bc.ca/hfd/pubs/Docs/Frr/Frr021.pdf

Omule, SAY 1988. **Growth and yield 32 years after commercial thinning 56-year-old western hemlock.** BC Min. For., Res. Br., Victoria, BC. FRDA Rep. No. 029.

Some Past Adaptive COPE projects
http://www.cope.hmsc.orst.edu/projects/index.htm

NRDC. 1999. **End of the Road, The Adverse Ecological Impacts of Roads and Logging: A Compilation of Independently Reviewed Research**
http://www.nrdc.org/land/forests/roads/eotrinx.asp

NRDC. 1999. **Wildlife Species and Their Habitat: The Adverse Impacts of Logging**
http://www.nrdc.org/land/forests/eotrsupp.asp

Stokes, Bryce J. 1992. **An Annotated Bibliography of Thinning Literature,** USDA Forest Service, General Technical Report so-91. December 1992.
http://www.srs.fs.fed.us/pubs/gtr/gtr_so091.pdf [This bibliography is a general review of thinning, with an emphasis on harvesting in the Southern United States.]

Hansen, A. J.; Spies, T. A.; Swanson, F. J.; Ohmann, T. L. 1991. **Conserving biodiversity in managed forests.** BioScience 41(6):382- 392.

Monte Carlo Thinning 2
Bureau of Land Management, Eugene District Office
http://www.edo.or.blm.gov/nepa/ces/montecarlo2CE.pdf