Density Management in the 21st Century – West Side Story

La Sells Stewart Center
Oregon State University
Corvallis, Oregon
Oct 4 – 6, 2011
Plenary

8:00 am Introduction: Conference Overview (Paul Anderson, Moderator)

8:15 am Density Management and the BLM in western Oregon—Managing forests for the future; A State Office perspective
Mike Haske, Deputy State Director, Resource Planning, Use & Protection, Oregon/Washington BLM

8:30 am Topic: Overarching themes from a Forest Service Region 6 perspective
Jeff Walter, Director, Natural Resources, US Forest Service Region 6

8:45 am Stand density relationships
John Tappeiner, College of Forestry, Oregon State University, (Emeritus)

9:15 am Findings and a model to explain forest density and harvest retention levels associated with the perceived social acceptability of forests in western Oregon and Washington
Robert G. Ribe, Department of Landscape Architecture, University of Oregon

9:45 am Break

Session 1: Upland Forest Management Alternatives and Effects on Vegetation Structure
(Paul Anderson, Moderator)

10:05 am Managing for old-growth forests: a moving target
Thomas A. Spies and Robert J. Pabst, USFS PNW Research Station and Oregon State University

10:30 am Adapting management of shade-intolerant Douglas-fir forests to provide maximum diversity of habitats continuously and productively
Michael Newton, Oregon State University (Emeritus)

10:55 am Over- and understory vegetation responses to thinning treatments: Can we accelerate late successional stand structures?
Klaus J. Puettmann, Adrian Ares, and E. Dodson, Oregon State University

11:25 am Making the little things count: Modeling the development of understory trees in complex stands
Peter J. Gould and Connie A. Harrington, USFS Pacific Northwest Research Station, Olympia, WA

11:50 am Lunch

Session 2: Upland Forest Management Alternatives and Effects on Vegetation Function and Processes (Klaus Puettmann, Moderator)

1:00 pm The theoretical and empirical basis for understanding the impact of thinning on carbon stores in forests
Mark E. Harmon, Oregon State University
Carbon storage, downed wood, and understory species diversity after thinning coniferous forests in western Oregon  
*Julia I. Burton, Adrian Ares, Sara E. Mulford, Deanna H. Olson and Klaus J. Puettmann, Oregon State University, Virginia Tech, and USFS PNW Research Station, Corvallis*

1:50 pm  Thinning effects on tree mortality and snag recruitment  
*Erich K. Dodson, Adrian Ares, and Klaus J. Puettmann, Oregon State University*

### Session 3: Upland Forest Management Alternatives and Effects on Habitats and Species  
(Deanna Olson, Moderator)

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<td>Lichen habitat may be enhanced by thinning treatments</td>
<td><em>Heather Root and Bruce McCune, Oregon State University</em></td>
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<td>Mycorrhizal fungi—Lessons from green-tree retention</td>
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<td>Songbird response to alternative forest density management in young Douglas-fir stands</td>
<td><em>Joan C. Hagar, US Geological Survey</em></td>
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<td>3:30 pm</td>
<td>Thinning effects on Spotted Owl prey and other forest-dwelling small mammals</td>
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<td>Western Washington and Oregon elk foraging: Use and nutritional value by vegetative life form</td>
<td><em>John G. Cook and Rachel C. Cook, National Council for Air and Stream Improvement</em></td>
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<td>4:10 pm</td>
<td>Landscape context for density management: Implications of land ownership and ecological gradients</td>
<td><em>Janet L. Ohmann, USFS, PNW Research Station, Corvallis, OR</em></td>
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<td>A satellite’s view of recent trends in forest harvest intensity in the Pacific Northwest</td>
<td><em>Robert E. Kennedy, Zhiqiang Yang, Justin Braaten, Warren B. Cohen, Peder Nelson, Eric Pfaff, Oregon State University, and USFS PNW Research Station</em></td>
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<td>Geometry of landscape connectivity for low mobility species: Thinking outside the box, diagonally</td>
<td><em>Deanna H. Olson, Kelly Burnett, and Hartwell H. Welsh, Jr., USFS PNW Research Station, Corvallis, OR, and USFS Pacific Southwest Research Station, Arcata, CA</em></td>
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5:30 - 7:00 pm  **Poster Session and Social**
Session 4: Riparian Forest Management: Effects on Riparian/Stream Habitats
(Julia Burton, Moderator)

8:10 am  Riparian microclimate and stream temperature: Thinning and buffer-width influences
Paul D. Anderson, USFS PNW Research Station, Corvallis

8:30 am  Sampling and modeling riparian forest structure and riparian microclimate
Bianca N.I. Eskelson and Hailemariam Temesgen, Oregon State University, and Paul D.
Anderson, USFS PNW Research Station, Corvallis

8:50 am  Stream temperature responses to timber harvest and best management practices—findings
from the ODF RipStream project
Jeremy D. Groom, Oregon State University

9:10 am  Initial riparian down wood dynamics in relation to thinning and buffer width
Paul D. Anderson, Deanna H. Olson, USFS PNW Research Station, Corvallis, and Adrian Ares,
Virginia Tech, Blacksburg, VA

9:30 am  Implications of various riparian management strategies on wood in streams
Mark A. Meleason, Jeremy Groom, and Liz Dent, USFS PNW Research Station, Corvallis,
Oregon State University, and Oregon Department of Forestry

9:50 am  Slope failure as an upslope source of stream wood
Daniel Miller, Earth Systems Institute, Seattle, WA

10:10 am  Break

Session 5: Riparian Forest Management: Effects on Riparian/Stream Species
(Cheryl Friesen, Moderator)

10:30 am  Intrinsic potential: what is it and what is it good for?
Kelly Burnett, USFS PNW Research Station, Corvallis

10:50 am  Four principles of headwater system aquatic biology
Robert Danehy, Weyerhaeuser Company and Sherri Johnson, USFS, PNW Research Station,
Corvallis

11:10 am  Quantifying fish responses to forestry—lessons from the Trask Watershed Study
Jason Dunham, Douglas Bateman, David Hockman-Wert, Nathan Chelgren, and David Leer,
US Geological Survey and Oregon State University

11:30 am  Riparian buffers and thinning in headwater drainages in western Oregon: Effects on
amphibians
Deanna H. Olson, USFS PNW Research Station, Corvallis

11:50 am  Lunch
Wednesday October 5

1:00 pm The Riparian Ecosystem Management Study: Responses of small mammals to streamside buffers
*Martin G. Raphael and Randall J. Wilk, USFS PNW Research Station, Olympia, WA*

1:20 pm Evaluating headwater stream buffers: Lessons learned from watershed-scale experiments in southwest Washington
*Peter A. Bisson, Shannon M. Claeson, Steve M. Wondzell, and Alex D. Foster, USFS PNW Research Station, Olympia, WA*

1:40 pm Integrated watershed analysis: Adapting to changing times
*Gordon Reeves, USFS PNW Research Station*

### Session 6: Socioeconomics and Operations *(Klaus Puettmann, Moderator)*

2:00 pm Growth and yield considerations and implications for alternative density management objectives and approaches
*David Marshall, Weyerhaeuser Corporation*

2:20 pm *Topic:* Role of thinning in providing income and long-term sustainability of timber production on federal lands
*George McFadden, Bureau of Land Management*

Harvest operations for density management: Planning requirements, production, costs, stand damage, and recommendations
*Loren D. Kellogg and Stephen J. Pilkerton, Oregon State University*

2:40 pm *Break*

3:00 pm Managers’ perspectives: Practical experience and challenges associated with variable density operations
*Kurt Steele, Willamette National Forest*

3:40 pm How the Density Management Study has changed my world
*Craig Kintop, BLM Density Management Site Coordinator*

### Session 7: Synthesis and emerging issues and themes *(Paul Anderson, Moderator)*

4:00 pm *Topic:* A Forest Supervisor’s perspective on thinning and the underlying science
*Jerry Ingersoll, Siuslaw National Forest*

4:20 pm A BLM Deputy State Director’s perspective on the strategic management outlook and thinning
*Mike Haske, Deputy State Director, Resource Planning, Use & Protection, Oregon/Washington BLM*

4:40 pm Future directions: Thoughts and discussion
*Klaus Puettmann, Oregon State University, and Deanna H. Olson and Paul D. Anderson, USFS PNW Research Station*

5:00 pm Closing remarks, announcements, and adjourn for the day — *Paul Anderson*
Field Trip

Green Peak DMS Site – Initial Entry Findings, Second Entry Objectives and Post-harvest Conditions

Participants on the field trip should prepare for walking a cleared trail over easy-to-moderate terrain to view experimental forest treatments. **Sturdy boots, long pants, long-sleeved shirt or jacket, rain coat, gloves and drinking water are recommended. Please bring a hard hat if you have one—we will have some extras for those who do not have a hard hat.**

- **8:00 am** Gather at OSU [location TBA in Wednesday’s closing remarks]
- **8:15** Load vans
- **8:30** Depart for Green Peak
- **noon** Lunch on site  *(Order a box lunch at registration or bring your own)*
- **3:30** Depart Green Peak
- **4:15 pm** OSU Drop Off
Stand density relationships. John Tappeiner, College of Forestry, Oregon State University (Emeritus), Corvallis, OR; john.tappeiner@oregonstate.edu

Thinning stands (managing their densities) affects the development of trees and understory plants as individuals, as well as stand-level characteristics like structure, microclimate, and stand growth, habitat for various species, and fuel and potential fire severity. These characteristics and the rate of changes are affected by thinning severity, the reduction in numbers of trees stand density, and also by the number, sizes, species, and growth rates of the trees retained. In addition, site variables like potential for severe wind and ice/snow storms, soil depth/rooting, root diseases, etc. have an effect.

Changing stand density simultaneously affects a variety of stand characteristics. For example, thinning to low stand density favors the growth of trees with large stems, crowns, and branches, and may produce considerable volumes of commercial wood in the short term. Thinning stands to low density favors growth of large trees and development of an understory; it may reduce commercial wood production if densities are quite low, and production of snags and dead wood by competition will probably be delayed. Thinning favors development of an understory and a multi-story stand and generally improves wildlife habitat. However, it can lead to a dense understory that may increase risk of severe fire.

Forest stands are often variable in tree spacing, size, and species composition, even in rather uniform plantations, and application of thinning prescriptions may need to be flexible to take advantage of this. Thinning density may vary to release understory trees, avoid damage to wet areas, or leave trees at higher density where wind throw is likely, to protect areas of snags. Presence of root disease “pockets” may require variance from the general prescription. Resistant tree species maybe favored, openings may be left that will fill in with shrubs, or immune tree species may regenerate.

Large dominant and codominant trees are usually left in thinning, because they grow faster. Where the purpose of thinning is growing late-successional stands, these are the trees that are most likely to become the large trees characteristic of old-growth forests. In certain stands some of these trees may be removed to favor minor tree species and help develop a mixed-species stand, or to produce valuable products like poles and pilings that will help pay for the costs of thinning. Several treatments may be needed to meet stand management objectives. Examples: thinning dense stands to low density may require several treatments to avoid damage from wind or ice storms that would cause a single, drastic reduction in stand density; additional treatments may be necessary to manage the dense tree understory that can develop after thinning.

When conducting research on thinning, it is important to specify thinning objectives, and the treatments thinning methods, densities, etc. used to achieve them. Often the literature on the effects of thinning on variables other than wood production does not provide enough detail. To interpret the results or repeat the study, stand density immediately before and after thinning and for a period (5 to 10 yr) after thinning, and effects of variables like root disease, wind/ice damage, and etc. are needed.
Public perceptions of the acceptability of forest conditions are strongly correlated with aesthetic perceptions. Average acceptability perceptions in the Pacific Northwest are most affected by the habitat value intended by managers, scenic beauty, economic and logger-safety benefits, and retention of green trees in harvests and thinnings, which tend in total to garner the most positive responses. Scenic beauty tends to be optimized in forests with about 750 standing stems per acre and/or about 130 square meters basal area per hectare. In regeneration harvests with dispersed retention, scenic beauty levels consistent with just acceptable perceptions of forest management tend to occur at 20% green-tree retention. In regeneration harvests with aggregated retention, scenic beauty levels consistent with just acceptable perceptions of forest management tend to occur at 40% green-tree retention.

The research that generated these findings was instigated by the Northern Spotted Owl (Strix occidentalis caurina) controversy, which presented a necessary and prime opportunity to study public perceptions of the acceptability of forest management methods and plans. Other researchers and authors have generated many important empirical studies, critical analyses, and histories; but not a single, strait-forward practical theory by which forest planners might understand and predict when management programs will likely generate game-changing or shut-down opposition in a democracy. Data collection for this study involved numerous workshops with diverse groups in western Oregon and Washington. Insights gained during these workshops, together with social science literature analyzing the spotted owl controversy, suggests such a theory.

A conceptual model of social acceptability perceptions is offered that focuses on public perceptions of forest management by engaged but “disinterested”, not uninterested, people who care about the economic and environmental health of the region enough to potentially vote or become politically active accordingly. The model also explains perceptions of “interested” people who are vested stakeholders or otherwise strongly engaged in the technical or policy details of forestry. The model seeks to explain how strong ideational and aesthetic affects can combine with affective, transcendent narratives to drive public perceptions past tipping points where they can derail or whipsaw forest managers.

This process is contrasted with the technical trade-off optimization process—subject to financial and legal constraints—that drive the perceptions of scientifically trained forest managers and planners. The details of these more analytic, comprehensive, or “rational” decisions are often not salient to the larger disengaged or disinterested public. Forest thinnings and variable-retention harvests illustrate how analytic problem solving can stay within the tipping-point bounds of public acquiescence.
Managing for old-growth forests: A moving target. Thomas A. Spies and Robert J. Pabst, US Forest Service, Pacific Northwest Research Station, and Dept. of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; tspies@fs.fed.us

Old-growth Douglas-fir (*Pseudotsuga menziesii*) forests are a goal for conservation and restoration across millions of acres of federal forest lands in western Oregon and Washington. Where old growth currently exists, management is typically focused on protecting stands and watersheds from logging and high-severity wildfire. Where old growth was converted to Douglas-fir plantations during the 20th century, the goal is often to actively manage those areas to create ecological diversity and accelerate development of old-growth conditions. What does it mean to use old growth as a target for management? Most old-growth Douglas-fir forests are over 200 years old, and many contain trees over 500 years old. Yet existing empirical studies and our scientific knowledge of forestry is less than a century old and have limited value in projecting how silvicultural manipulations will influence ecosystem function objectives centuries into the future. Old growth as a target can mean using the structure and function of current old-growth stands as a goal for manipulating plantations. This is a challenge because current old-growth stand structure represents centuries of succession, disturbance, and climate change—pathways of development that probably will not be repeated in nature or through silvicultural manipulations. Or, more realistically, it can mean altering conditions in plantations to more closely match what we know about the structure and dynamics of old-growth stands when they were young. In this second approach, managers would manipulate structure and composition to create conditions in young stands that would be more likely to develop the general features of old-growth forests over time than if they were left alone. This approach is based on several areas of knowledge with different degrees of development: (1) a relatively well-developed knowledge of how stand density affects stand development, (2) a moderately good understanding of current old-growth forest structure, (3) a fair understanding of how current old stands developed, and (4) a poor understanding of how any given stand might develop over the next several centuries. We review what is known about current old-growth forest structure and how old-growth forests develop over time and space. We show how regional and local ecological variation can affect old-growth structure and development. We use simulation models to explore how silvicultural manipulations might affect development of old-growth characteristics in the short run. We provide some scenarios of how plantations might develop over centuries. Finally, we propose some rules of thumb to guide management of dense conifer plantations to restore ecological diversity and reset pathways toward desired old-growth structure and composition:

1. Reduce stem densities in plantations to increase rates of diameter growth to produce large-diameter trees and encourage development of large and deep crowns.
2. Use variable-density approaches to create spatial heterogeneity to promote understory development and diversity.
3. Favor hardwoods and other conifer species that would have been eliminated under intensive management for Douglas-fir timber production.
4. Plant shade-tolerant tree species where seed sources of desired species are lacking in the stand or landscape.
5. Don’t use the same prescription everywhere—vary densities and frequency of entries.
Managing overstory forest density is the key to energy that shapes the rest of the resource. The role of the tree layer in westside landscapes over long time-spans is driven by the overwhelming influence of the dominant cover in the environments of lower canopies. The manifestations of this influence vary markedly in even-aged stands after a stand-replacing event by the stage of succession as forests recover. In the example of Douglas-fir (Pseudotsuga menziesii) succession, the nature of the event that removes a mature forest cover and initiates succession has an influence on initial non-coniferous cover. Abundant light near the ground allows diverse species composition in the first one or two decades, depending on stocking, that diminishes at an accelerating rate with the exponential development of crowns of the dominant conifers. When crown closure is nearly complete, a period of very low understory productivity begins that may last 20-50 years, depending on frequency of shade-tolerant conifers in the overstory, distribution of gaps in stands, or hardwood mixtures. Density management by thinning leads to soil disturbance, increase in light in understories, and development of seedlings and sprouts of understory herbs and shrubs. Residual density of overstory crowns influences the length of periods in which shade-intolerant understory species persist and overall diversity and productivity of understory vegetation. Site quality and local overstory density after thinning are major factors in how long each component of understory cover persists. Efforts to create multi-layer canopies by thinning typically encourage understory regeneration of both Douglas-fir and shade-tolerant conifers, as well as tolerant herbs and shrubs. The persistence of each cohort of recruits is dependent on its energy needs and the duration of adequate light before the dominant canopy forecloses shade-intolerant species. In the Douglas-fir Region, expectations for forming uneven-aged stands that retain Douglas-fir may be realistic only on very poor sites, and where overstory stocking is very low or gaps are large. Requirement for gap size to recruit long-lived intolerant species is now under investigation. Fast-growing hardwoods and shrubs are serious limitations on good and some very poor sites.

Where hemlock (Tsuga spp.) or other tolerant conifers and hardwoods are present, they may regenerate and persist to form mixed stands that eventually become dominated by the tolerant species as Douglas-fir matures and senesces. The overwhelming influence of the overstory can be expected to restrict what can survive and remain viable in the stand, including Douglas-fir. In the absence of even-aged management, one may expect management of late-successional reserves to mature as Douglas-fir-dominant forests, leading eventually to hemlock or true fir (Abies spp.) domination after several centuries. Maintenance of a diverse landscape dominated by Douglas-fir will likely necessitate patch-wise periodic stand replacement that re-sets early succession lest shade-intolerant species, and wildlife that depends on them, become rare or threatened. Maintenance of high landscape diversity may require various applications of even-aged management with patch sizes large enough to support the full array of wildlife and understory plants, with cycles long enough and patches large enough to provide both early seral and late-seral features to be present continuously on a rotating basis. Patches of disturbance may presumably be guided in size and location by desired features and continuity of future stands with habitats characteristic of old growth.
Over- and understory vegetation responses to thinning treatments: Can we accelerate late successional stand structures? Klaus J. Puettmann¹, Adrian Ares², and Erich Dodson¹, ¹Department of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; ²Virginia Polytechnic Institute and State University, Blacksburg, VA; klaus.puettmann@oregonstate.edu

We review and synthesize responses of overstory and understory vegetation to evaluate the efficacy of various thinning regimes at accelerating late-successional structures in young Douglas-fir (Pseudotsuga menziesii) forests. Generally, thinning accelerated development of overstory structures toward late-successional conditions within the first decade by increasing variability in stand conditions, such as overstory and regeneration densities and diameter growth. Thinning also accelerated development of multiple canopy layers by increasing live crown ratios and tree regeneration, including subordinate species such as hardwoods. However, growth of large trees was less responsive to thinning and low mortality rates for larger trees resulted in little recruitment of large snags or coarse woody debris (down wood). In general, thinning increased abundance and diversity of early-seral understory species, with little effect on late-seral species. On sites where shrub cover was already high harvesting initially reduced the cover, but shrubs recovered over time. Exotic species slightly increased in response to treatment initially, but overall abundance remained quite low and declined within a decade. Gaps extended the range of overstory conditions, increased diameter growth of trees on gap edges by about 40% and resulted in distinct understory vegetation communities. However, this influence did not extend far beyond the physical boundaries of the gaps into the neighboring forests. Our results suggest that thinning can rapidly accelerate many attributes of late-successional structure in the overstory, though some features such as large live trees and snags may require longer time periods to develop. Understory vegetation responses in the first decades were largely driven by increases in early seral species and development of late successional communities will likely require additional time to respond to altered overstory conditions. Overall, lower retention levels tended to have larger effects and formation of gaps during harvesting appears particularly beneficial for establishing late-successional characteristics in young forests.
Making the little things count: Modeling the development of understory trees in complex stands.
Peter J. Gould and Connie A. Harrington, US Forest Service, Pacific Northwest Research Station, Olympia, WA 98512; pgould@fs.fed.us; charrington@fs.fed.us

Small trees grow up to become big trees, or do they? And if they do, how long does it take? In the Pacific Northwest most of our experience in following tree growth and survival is in even-aged stands. Few of us have observed growth of small trees in understory positions. In recent decades, a goal of silvicultural treatments on some forest ownerships has been to increase the complexity of future stands. Treatments may be designed with the intent to create conditions that allow for the recruitment and growth of new cohorts, with the ultimate goal of creating multi-species, multi-storied stands. Since we have little experience in creating these types of complex stands by design, we often turn to growth models to ask “What if?” questions. What if we alter overstory density and species? Will it result in achieving the desired characteristics in the future stand? How do we know when we have enough small trees so that at least some will survive to become big trees? To answer these questions, we need a growth model that does a good job of predicting the growth of understory trees.

The Forest Vegetation Simulator (FVS) is a widely used growth model in the Pacific Northwest. We have evaluated the performance of FVS with data from research trials and found that it generally under-predicts growth and over-predicts survival of trees in an understory position. We are in the process of developing new models of understory growth and survival that will be incorporated into FVS. These models will better reflect the higher growth rates and lower survival of small trees that we have found in our research plots. In addition, the understory environment for small trees is more variable, in terms of light and soil conditions, in complex stands than in more simple, even-aged stands. Thus, the new models will predict greater variability in growth rates than previous models. Finally, we expect that environmental variables such as summer precipitation will improve growth predictions for small trees over those based on stand characteristics alone. For example, stands with the same basal area but different amounts of summer precipitation may not provide the same growth environment for small trees. These differences will be reflected in our models. We are putting together a large dataset describing small tree growth from many different studies as well as operational inventory data. We will present some of our general conclusions about small tree growth in the Pacific Northwest and also present examples that show how small trees grow under different types of stand and climatic conditions.
The theoretical and empirical basis for understanding the impact of thinning on carbon stores in forests. Mark E. Harmon, Department of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; mark.harmon@oregonstate.edu

Thinning of forests has been proposed as a means to increase the carbon stores of forests. The justification often offered is that thinning increases stand productivity, which in turn leads to higher carbon stores. While thinning of forests clearly increases the growth of residual trees and increases the amount of harvested carbon compared to an unthinned stand, there is little theoretical or empirical basis for believing that this activity increases the average carbon stores of forests. By removing trees, leaf area is temporarily decreased and carbon input to the forest via photosynthesis is also temporarily decreased. In theory, reducing the input of carbon to a forest will reduce its average carbon stores. Moreover, by increasing the amount of carbon harvested over a rotation, a greater proportion of carbon is removed, which general ecosystem theory also predicts will lower average carbon stores.

The few empirical studies that have examined long-term impact of thinning on carbon stores have indicated that as thinning intensity increases either in amount or frequency the average long-term carbon stores decreases. Simulation models indicate very similar trends. Both results are in line with predictions from general ecosystem theory. Despite the finding that thinning reduces average carbon stores relative to not thinning, this management practice may lead to increases of carbon stores compared to a system of clear-cut harvesting. By replacing clear-cut harvesting with a series of partial harvests, carbon stores in forests could be increased significantly.
Carbon storage, downed wood, and understory species diversity after thinning coniferous forests in western Oregon. Julia I. Burton¹, Adrian Ares², Sara E. Mulford³, Deanna H. Olson³, and Klaus J. Puettmann³, ¹Department of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; ²Virginia Polytechnic Institute and State University, Blacksburg, VA; ³US Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331; julia.burton@oregonstate.edu; aares@vt.edu; klaus.puettmann@oregonstate.edu;

Concerns about climate change have stirred worldwide interest in increasing uptake and storage of carbon in forest ecosystems. Simultaneously, preserving and enhancing structural, functional, and species diversity in forests is also of prime importance. Understanding the inherent tradeoffs and synergies among carbon storage and sequestration and diversity in managed forests is thus key to achieving these multiple objectives. Using the experimental framework of the Density Management Study in western Oregon, we examined the effects of a suite of thinning treatments on above-ground carbon pools and understory plant species richness. The contribution of coarse downed wood (CDW) to C storage was minimal compared to the live overstory. For all treatments, carbon stored in the live overstory > large down wood > snags > stumps > small down wood. Most carbon in CDW is legacy material from the previous clearcutting operation; e.g., 50-95% of snag, stump and large down wood C in intermediate to late stages of decomposition. The spatial distribution of CDW was highly variable and somewhat clustered adjacent to headwater streams. Thinning had a major effect on aboveground tree C but a slight effect on C stored in CDW. Six years after thinning, aboveground C was greater in the control than in all thinning treatments, with stands subjected to fixed- and variable-density thinning storing similar levels of C. Total aboveground tree C was negatively correlated to richness of all vascular plant species, early-seral species, and tall shrub species in the understory. Richness of understory late-seral species and clonal low shrub species was not related to total aboveground tree C. Forest management aimed at increasing carbon storage by maintaining high-density forests may therefore negatively affect aspects of conservation and maintenance of biodiversity within stands.
Thinning effects on tree mortality and snag recruitment. Erich K. Dodson, Adrian Ares, and Klaus J. Puettmann, Department of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; erich.dodson@oregonstate.edu.

Tree mortality directly provides habitat features, such as snags and coarse downed wood, and has important implications for overall development of forest structure and composition. Thinning is expected to affect mortality patterns by altering resource availability and susceptibility to disturbances, such as wind throw and snow damage. We utilized data from four re-thin study sites and seven initial thin study sites of the Density Management Study (DMS) to examine mortality patterns and thinning effects on mortality and compared these results with other published studies from the Pacific Northwest. Mortality rates in the control exceeded those typically found in late-successional forests in the region. However, most of the trees that died in the control treatment were small (<35 cm dbh), consistent with ongoing suppression mortality. Thinning reduced the mortality rates of small trees, especially for the relatively shade-intolerant Douglas-fir (Pseudotsuga menziesii). In contrast, thinning had little effect on mortality of larger trees (>35 cm dbh). Preliminary analyses suggest that tree mortality might be related to local density and likely competition at small spatial scales and gaps did not appear to increase rates of mortality. The reduction of mortality with thinning at even the lower retention levels in this study helps reduce concerns over widespread losses of residual trees. On the other hand, on two sites large clearcutting operations on adjacent properties led to wind-throw problems. Also, the episodic nature of wind or snow events has to be kept in mind, especially if these events happen before trees can adjust to more open stand conditions. In summary, thinning did little to accelerate the development of large snags and coarse downed wood that provide critical wildlife habitat in the short term. The lack of high tree mortality in all thinning treatments supports ongoing plans to enhance coarse woody debris recruitment by felling trees and intentionally creating snags.
Lichen habitat may be enhanced by thinning treatments. Heather T. Root and B. McCune, Department of Botany & Plant Pathology, Oregon State University, Corvallis, OR 97331; rooth@science.oregonstate.edu

Epiphytic lichen communities have become a focus for ecologists concerned with forest health because lichens are particularly responsive to forest management and air quality. Furthermore, they can contribute substantially to the diversity and nitrogen fixation of a stand, and play a valuable role in the food web of many forest-dwelling organisms. Can strategic thinning in Pseudotsuga – Tsuga forests increase biodiversity or hasten the development of late-successional features in young second-growth forests? Approximately 10 years after variable-density commercial thinning, N fixing and forage lichen species richness increased and lichen community composition was detectably different from pre-thinning data and from unthinned controls. At two sites in moist conifer forests of western Oregon, lichen community monitoring plots were established before thinning treatments; the most diverse plots in each treatment were retained as diversity islands whereas the less diverse plots were treated in the thinning prescription. At one site we found that lichen communities in diversity plots were quite similar to those in the surrounding treated forest and that the proportion of Tsuga heterophylla in the stand was negatively associated with alectorioid and cyanolichen richness. At both sites, hardwood gaps and open-grown trees were positively associated with N fixing (cyanolichen) species richness. At the other site, surrounding plots were more like diversity “leave-islands” after thinning than before. Furthermore, thinned plots had more hardwood gaps following the thinning. These thinned plots hosted more Bryoria, Candelaria concolor, Leptogium polycarpum, Peltigera collina, Nephroma laevigatum and Physcia tenella than had been observed prior to thinning. Most of those species are hardwood associates. The forage lichen Bryoria, however, is associated with older remnant trees in these stands. Forage lichens may already be responding positively to the opened canopy in these stands as evidenced by their association with plots having gaps in the canopy colonized by shrubs and increased abundance and frequency in 2007 in thinned plots at one of the two study sites. The retention of lichen hotspots appeared to allow rapid colonization of N fixers onto shrubs in thinned plots. Promotion of gaps in the conifer overstory that are dominated by hardwoods probably stimulated richness of N fixers and forage lichens by providing favorable substrates. We conclude that thinning treatments retaining remnants from previous cuttings, open-grown trees, and hardwood gaps have potential to favor lichen communities rich in cyanolichen and alectorioid species.
Mycorrhizal fungi—Lessons from green-tree retention. Daniel L. Luoma and Joyce L. Eberhart,
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Forest management activities can reduce ectomycorrhizal fungus (EMF) diversity and forest regeneration success; therefore management approaches are needed to sustain these essential forest organisms. Results from experiments that test the biodiversity assumptions behind current guidelines for ecosystem management are presented. We examine contrasts in structural retention as they affect biodiversity and sporocarp production of EM fungi—a functional guild of organisms well-suited as indicators of disturbance effects on below-ground ecosystems.

We also discuss the impacts of green-tree retention on the EMF of seedlings planted after timber harvest. Inoculating bare-root conifer stock with spores of EMF has been advertised to reduce transplant shock, improve growth and nutrient uptake, and improve survival; but has never been rigorously tested on 2-0 bare-root Douglas-fir (*Pseudotsuga menziesii*) out-planted on operational forest management sites. We evaluated the effectiveness of EMF spore inoculum to increase survival and growth. We also compared locally sourced spore inoculum to that obtained from a different ecoregion.

Overstory removal significantly reduced EMF sporocarp production but, in contrast to the initial hypothesis, the effects were not always proportional to basal area retained. The effect of spatial pattern of retention varied between retention levels and mushroom and truffle sporocarp groups. Management implications include the need to address the conservation of rare truffle and mushroom species in a manner that recognizes their different responses to forest disturbance. We also raise the hypothesis that fire suppression may favor mushroom production over truffle production. Because fire seems to be important in the reproductive evolution of EMF, our results add further impetus to the development of management plans that seek to restore forest health from the effects of decades of fire suppression.

Even with spore inoculation, the mean number of ectomycorrhiza (EM) types was consistently lower in burn piles than in the other disturbance treatments. The *Wilcoxina* EM type was more common on the burn treatment seedlings, regardless of inoculum treatment. In the second growing season, there was more *Rhizopogon* colonization per root weight associated with the road treatment than the other disturbance treatments; within the burn treatment, there was more *Rhizopogon* associated with the local inoculum. By the fourth growing season, there were no differences among the treatments in the percentage of *Rhizopogon* EM. We conclude that this green-tree retention site had sufficient EMF inoculum, either as living mycelium or spores, to rapidly colonize the bare-root Douglas-fir seedlings that were used in this experiment.

Across multiple experiments, results suggest that using dispersed green-tree retention in combination with aggregated retention helps to maintain EMF in forest ecosystems and provides for continued sporocarp production. Such a mix ameliorates disturbance effects and may maintain higher levels of sporocarp production in the aggregates by reducing edge effects. It remains unclear how short-term reductions in sporocarp abundance will affect EM fungus populations for future forests. After disturbance, spores are a form of legacy and are a key to enabling future EM formation in the face of environmental change. Long-term silvicultural experiments are essential for monitoring trends in the EM fungus community.
Songbird response to alternative forest density management in young Douglas-fir stands. Joan C.
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Thinning has been increasingly used in the Pacific Northwest to restore structural and biological diversity to densely-stocked young- to mid-aged forests that have been previously intensively managed for timber production. In the short term, thinning promotes development of understory vegetation, which in turn can increase habitat diversity for wildlife, particularly for songbirds. Thinning also has been identified as a potential approach to accelerate the development of characteristics that are typical of older forest stands. Both the immediate and long-term response of wildlife and habitat to thinning is likely to be influenced by thinning intensity and pattern. The BLM Density Management Study (DMS) was designed to compare ecological responses among various thinning intensities. The purpose of our study was to compare songbird abundance among these thinning treatments to demonstrate the range of responses that might occur as a result of different thinning practices.

We sampled breeding songbird abundance using fixed-radius point counts at four of the DMS sites (Bottomline, Green Peak, O.M. Hubbard, and Ten High). We conducted bird surveys one year before treatment and in five non-consecutive years after the first thinning, including surveys at two sites in the first season following a re-thinning treatment. Species richness increased following thinning, but response to thinning varied among species. Although several species differed in abundance between control and thinned stands following treatment, few species responded differentially to thinning intensity. The patterns of songbird abundance and species richness that we observed represent short-term responses to the disturbance of thinning; documenting bird response to variation in structural development among thinning treatments will require long-term monitoring.
Thinning effects on Spotted Owl prey and other forest-dwelling small mammals. Todd M. Wilson and Eric D. Forsman, US Forest Service, Pacific Northwest Research Station, Corvallis, OR, 97331; twilson@fs.fed.us

Since the adoption of the Northwest Forest Plan, thinning young forests has become the management tool of choice for creating late-seral habitat and improving the overall health and function of forests in the Pacific Northwest. Most population studies have shown early and positive responses to thinning by forest-floor small mammals (primarily mice, ground-dwelling voles, and shrews) presumably due to increases in understory plant abundance and diversity that occur within the first decade following thinning. However, virtually all management activities involving thinning have reduced abundances of tree-dwelling rodents, especially Flying Squirrels (Glaucomys sabrinus) and Red Tree Voles (Arborimus longicaudus), two important prey species for Northern Spotted Owls (Strix occidentalis caurina). Recent studies suggest that reductions in Flying Squirrel abundance following thinning may be driven by increased susceptibility to predation created by removal of critical mid-story cover. Predation, lack of canopy connectivity, and reduction in suitable nest substrates may all contribute to reduced Red Tree Vole abundance following thinning. The long-term benefits of some thinning treatments may be positive for both Flying Squirrels and Red Tree Voles, but may not be realized for several decades or more. Thus, there are several temporal and spatial considerations for maintaining and promoting owl habitat under the Northwest Forest Plan. It may be possible to design thinning prescriptions in some forests that lessen the short-term negative effects on arboreal mammals. Empirical models are being built and tested for both Flying Squirrels and Red Tree Voles that can help inform local and regional strategies for managing habitat for Spotted Owls and their prey.
**Western Washington and Oregon elk foraging: Use and nutritional value by vegetative life form.**

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Recent research and modeling of elk habitat selection and nutrition is establishing the key importance of nutritional value (NV, e.g., digestible energy and protein of forage in ungulate diets) of plant communities to habitat use and productivity of elk herds in western Oregon and Washington. These data show that NV of many sites can be improved via active forest management. No exhaustive studies have been conducted in western Oregon and Washington to identify relationships between thinning strategies and changes in NV of plant communities. Our work, however, suggests general patterns of NV that reflect interactions between plant community composition and forage selection capabilities of elk and, in turn, between plant succession patterns and potential natural vegetation (PNV) zones. These have relevance for understanding and predicting effects of thinning on large ungulate nutrition and may include 4 patterns:

I. Thinning significantly changes plant composition in mid- and late seral stages to include more early-seral, shade intolerant species and these species are (A) considerably more nutritious and palatable than pre-thinning shade-tolerant species, or (B) these species are neither more nutritious nor palatable than pre-thinning shade-tolerant species.

II. Thinning invokes little change in plant composition but increases abundance of attendant shade-tolerant species, and (A) these species are nutritious and palatable, or (B) these species offer low nutrition and/or palatability.

Our foraging/nutrition research evidently offers examples of these patterns in Oregon and Washington. For example, many plant association groups may exhibit the IIB pattern in the Western Hemlock (*Tsuga heterophylla*) PNV, particularly those that support primarily Salal (*Gaultheria shallon*) and/or Swordfern (*Polystichum munitum*) understories, and in the Douglas-fir (*Pseudotsuga menziesii*) zone with Madrone (*Arbutus menziesii*), Manzanita (*Arctostaphylos* spp.), and Tanoak (*Lithocarpus densiflorus*) understories in extreme southwest Oregon. Thinning may only increase the abundance of these highly unpalatable species and thus offer little opportunity to improve the NV of these communities. In contrast, our data suggest that thinning increases abundance of a variety of shade tolerant and intolerant species that are palatable and nutritious in the White/Grand Fir (*Abies concolor/A. grandis*) and Mountain Hemlock (*Tsuga mertensiana*) plant associations of the Cascades (west slope) (pattern IA). Thinning in these communities may offer considerable improvement of their NV. Thinning influences on sunlight and soil moisture also may alter plant phenology, chemistry, and thus nutrient levels in ungulate forage. Integrating data of ungulate nutritional ecology and plant succession patterns eventually will be necessary for developing reliable thinning strategies to improve NV and the associated carrying capacity of landscapes for large ungulates.
Density management is implemented at a local (stand) scale, but is based on conservation goals that address a broader landscape. Although regional conservation efforts such as the Northwest Forest Plan (NWFP) focus primarily on public lands, all land ownerships and allocations contribute unique benefits over the regional landscape that need to be considered as context for federal land management. In addition, whereas the NWFP emphasizes older forest and associated species, an ecosystem and multi-species management approach encompasses the full sequence of forest development. Recent results from NWFP Effectiveness Monitoring for late-successional and old-growth forest provide detailed maps of forest composition and structure over all ownerships, and for all stages of forest development, including trends over the NWFP period (1994 to present). More than two-thirds of older forest (overstory conifers >20 inches) was federally owned, whereas most early-seral forest was on nonfederal lands. However, early-seral stands have developed primarily following timber harvest and lacked the structural diversity typical of natural stands. Over the NWFP period, harvesting removed about 13% (491,000 acres [198,700 ha]) of older forest on nonfederal lands, whereas the loss of older forest from federal lands (about 200,000 acres [80,937 ha]) was attributed primarily to wildfire. Overall, the monitoring data suggest there was a slight net loss of older forest on federal lands since the beginning of the NWFP, so losses of older forest to wildfire apparently were roughly balanced by recruitment. However, recruitment was most likely through incremental stand growth over the 20-inch threshold, or from understory disturbances (including thinning) that eliminated smaller-diameter trees and increased average stand diameter, rather than from increases in stands of much larger and older trees. Land ownerships and allocations also were unevenly distributed across regional environmental gradients. Federal forests generally occupied higher elevations and lower productivity sites, and a substantial portion of most of the mid- to high-elevation forest types were contained within reserves and managed for conservation objectives. In contrast, several forest types, such as oak woodlands, occurred predominantly at low elevations on nonfederal lands where they are managed for a variety of objectives, and are not well-represented in reserves. I will discuss potential implications of the monitoring results for stand-level management and for the conservation of older forests and associated species across the region.
A satellite's view of recent trends in forest harvest intensity in the Pacific Northwest. Robert E. Kennedy, Zhiqiang Yang, Justin Braaten, Warren B. Cohen, Peder Nelson, Eric Pfaff, Department of Forest Ecosystems & Society, Oregon State University, and US Forest Service, Pacific Northwest Research Station, Corvallis, OR, 97331; robert.kennedy@oregonstate.edu

As a silvicultural treatment, forest harvest through thinning may serve multiple management goals at the site level. To the extent that these goals affect processes or species populations that span landscapes, their cumulative impacts can only be assessed if landscape-wide patterns of thinning are monitored. This is particularly relevant when policy or management patterns change abruptly for large land ownerships, as was intended with the implementation of the Northwest Forest Plan in 1994.

Satellite images provide consistent views of large landscapes and thus have the potential to monitor forest harvest, but these have typically focused only on stand-replacing harvest. Recent improvements in data access, computing power, and algorithms, however, have led to more robust mapping of partial harvest.

Here, we show how these new mapping methods can be used to characterize trends in harvest intensity across large areas and over more than two decades. We focus on contrasts between private and public ownerships, among states, and over time, with particular emphasis on changes to harvest on public lands after the implementation of the Northwest Forest Plan.
Geometry of landscape connectivity for low mobility species: Thinking outside the box, diagonally.
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Landscape designs for connectivity of habitats used by low-mobility species in a managed forest system require addressing several basic conservation concepts, including critical habitat protection and redundancy of connections. These species may move slowly and require refugia among years as they may move between optimum habitat patches. Redundancy of dispersal corridors may be needed where multiple populations occupy different patches across the landscape. Here we explore riparian linkage areas as landscape-scale links for both riparian and low-mobility species.

Streams in western Oregon forests provide habitat for aquatic species of concern, including salmonid fishes and amphibians. Many amphibian species are found in and along small headwater streams, with cool, wet conditions being critical for their occurrence. Furthermore, these streams can be sources of wood, boulders, and spawning gravel, important attributes of salmon habitat downstream. Our studies have examined these species-habitat associations and designs for habitat management. Riparian reserves can be effective management provisions along the aquatic continuum but are not always extended into headwaters and do not encompass amphibian habitats outside riparian corridors. Streamside areas may be dispersal funnels or runways for a variety of species. For example, we have seen terrestrial salamanders moving predominantly through near-stream areas. For overland-overridge dispersal, headwaters offer the shortest distance links among riparian zones in adjacent drainages. We developed alternatives for headwater linkage areas aimed at managing headwater debris-flow-prone areas for downstream fish habitat attributes, and overland connectivity for amphibians. Our criteria for selecting linkage areas identified landscape-, drainage basin-, and forest stand-scale considerations that include locations of target species, land ownership patterns, total number of links established, connectivity among discrete major river basins, and climate change predictions. Placement of linkages also could emphasize discrete large watersheds having no downstream aquatic connectivity, and in particular, headwater “triads” where 3 discrete, large (> 4th-field HUCs) watersheds join at the headwaters; there are 23 such areas in the Oregon Coast Range Province. At finer spatial resolutions, we modeled one linkage area connecting adjacent 7th-field HUCs for the Oregon Coast Range Province, which yielded connectivity of ∼15% of the headwater streams and ∼5,000 links.

At the forest-stand scale of a single project or proposed timber sale, geometric considerations that may apply to retaining riparian over-ridge connectivity include managing habitats: 1) perpendicular to streams for over-ridge cover to enhance dispersal, such as by tree retention or directional felling of logs toward streams; and 2) diagonally toward adjacent federal ownerships, such as to connect the BLM checkerboard landscape from stream-to-stream along diagonals, again via either tree retention or directional felling of logs. Although our proposed linkage areas target headwater species by design, the resulting web of connection across the landscape is expected to benefit numerous forest-dependent species. In particular, because this design connects the entire aquatic network, its adjoining riparian system and over-ridge areas, travel paths for migration of low mobility species would likely be established.
Riparian microclimate and stream temperature: thinning and buffer-width influences. Paul D. Anderson, US Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331; pdanderson@fs.fed.us

Thinning of 30- to 70-year-old Douglas-fir (Pseudotsuga menziesii) stands is a common silvicultural activity on federal forest lands in Washington and Oregon west of the Cascade crest. Decreases in forest cover lead to alterations of site energy balances resulting in changes to understory and stream channel microclimates. Uncut vegetative buffers are commonly used to mitigate upland harvest effects on aquatic and riparian habitats and functions. To create effective buffers, we need to better understand the relationships among thinning treatments, different riparian buffer widths, channel topography, and riparian and aquatic microclimates.

As a component of the Density Management and Riparian Buffer Study (DMS) we investigated buffer width and thinning effects on riparian microclimates of headwater streams in western Oregon. Spatial variations in stand density, canopy cover, and microclimate were measured 2-4 years following harvest along transects extending from stream center upslope into thinned stands, patch openings, or unthinned stands, with riparian buffers ranging from ~5-150 m width. For treated stands, the summer mean daily maximum air and soil temperatures increased and mean daily minimum humidity decreased with distance from stream. Small headwater streams exerted a distinct cool, moist influence on riparian microclimate that extended about 10 m upslope from stream center. Thinning resulted in subtle changes in microclimate as mean air temperature maxima were ~1-4°C higher than in unthinned stands. With variable-width buffers 17 m or wider, daily maximum air temperature above stream center was less than 1°C greater, and daily minimum relative humidity was less than 5% lower than for unthinned stands. In contrast, air temperature was significantly warmer within patch openings (+6-9°C), and within buffers adjacent to patch openings (+3°C) than within unthinned stands. Variable-width buffers defined by the transition from riparian to upland vegetation or topographic slope breaks appear sufficient to mitigate the impacts of upslope thinning on the microclimate above headwater streams.

Intensive studies such as DMS, combined with broader-scale operational monitoring can provide much-needed empirical data and analyses to inform management and regulatory strategies to conserve important aquatic and riparian functions of headwater streams in managed forests west of the Cascades.
Sampling and modeling riparian forest structure and riparian microclimate. Bianca N.I. Eskelson, Hailemariam Temesgen, and Paul D. Anderson; Department of Forest Engineering, Resources & Management, Oregon State University, Corvallis, Oregon; Landscape and Ecosystem Management Team, US Forest Service Pacific Northwest Research Station, Corvallis, Oregon; bianca.eskelson@oregonstate.edu.

Riparian areas are extremely variable and dynamic, and represent some of the most complex terrestrial ecosystems in the world. The high variability within and among riparian areas poses challenges in developing efficient sampling and modeling approaches that accurately quantify riparian forest structure and riparian microclimate. Data from eight stream reaches that are part of the Density Management Study were used in a variety of recent studies that explored sampling and modeling approaches for riparian forest structure and microclimate, and the results are summarized below. When sixteen sampling alternatives were compared based on their performance at accurately estimating the number of conifer trees per hectare, conifer basal area per hectare, and height to diameter ratio in headwater stream reaches, rectangular strip plots outperformed all other plot shapes. Understory vegetation layers form a critical component of forest ecosystems. Hence, accurate estimation of their attributes (e.g., percent shrub cover) is gaining increasing importance. When percent shrub cover was modeled as a function of distance to stream and leaf area index, a copula model based on the beta distribution easily accounted for spatial dependence within and among riparian areas. The distinct ecological processes, habitats, and biodiversity of riparian areas are due in part to microclimate characteristics such as air temperature ($T_{air}$) and relative humidity (RH) that differ from upland forests. Improved sampling designs and predictive models are needed to characterize riparian microclimates and their response to forest management. Height above stream and distance to stream were found to be the most important covariates in predicting mean maximum $T_{air}$ in riparian areas. For small sample sizes, optimized sample patterns for $T_{air}$ outperformed systematic sample patterns. Mean maximum $T_{air}$ and mean minimum RH are strongly correlated, and mean minimum RH can be modeled as a function of mean maximum $T_{air}$ and other covariates such as height above stream. Mixed-effects models can account for within- and among-stream-reach variability in RH. Application of these results can improve the quantitative estimates and reduce the costs associated with riparian forest structure and microclimate monitoring efforts.
Studies over the past 40 years have established that riparian buffer retention along streams protects against stream temperature increase. This protection is neither universal nor complete; some buffered streams still warm, while other streams’ temperatures remain stable. Oregon Department of Forestry developed riparian rules in the Forest Practices Act (FPA) to protect fish-bearing streams from temperature increases, but it did so with acknowledgement that its rules might be insufficient. It developed the Riparian and Stream Function project, otherwise known as RipStream, to validate the effectiveness of these rules. The FPA stipulates that for Small and Medium fish-bearing streams no cutting is to occur within 6 m adjacent to the stream and limited entry may occur within 15 and 21 m, respectively. The Oregon State Forest Management Plan (FMP) builds upon the FPA but includes additional protections in order to meet multiple management objectives. State forest riparian protections include an 8-m no-cut zone, an 8- to 30-m zone to be managed for producing mature forest conditions, and limited harvest between 30 m and 52 m. Harvest on state forest can differ from private lands, as state forest stands may be subject to thinning instead of clear-cutting. The RipStream project represents a joint effort between State and Private Forest divisions at Oregon Department of Forestry to quantify the effects of timber harvest on stream temperatures. The study includes 15 state forest and 18 private sites. Data on stream temperature, riparian vegetation, channel characteristics, and channel shading were collected at every site for two years pre-harvest and five years post-harvest. Each site included an upstream unharvested control reach and a treatment reach that was harvested after year two. All private sites were clearcut; seven out of eight state sites were thinned. By the second year post-harvest we found no change in maximum temperatures for state forests while private sites increased pre-harvest to post-harvest on average by 0.7°C with an observed range of response from -0.9 to 2.5°C. State sites additionally demonstrated no difference in temperatures between clear-cut and thinned treatments. The observed changes in stream temperature were most strongly correlated with shade levels measured before and after harvest. Treatment reach length, stream gradient, and changes in the upstream reach stream temperature were additionally useful in explaining treatment reach temperature change. Shade was best predicted by riparian basal area and tree height. These findings suggest that riparian protection measures that maintain higher shade, such as those followed in state forests, were more likely to maintain stream temperatures similar to control conditions.
Initial riparian down wood dynamics in relation to thinning and buffer width. Paul D. Anderson¹, Deanna H. Olson¹, and Adrian Ares²,³; ¹US Forest Service Pacific Northwest Research Station, Corvallis OR 97331; ²Dept. of Forest Ecosystems & Society, Oregon State University, Corvallis, OR 97331; ³Virginia Polytechnic Institute and State University, Blacksburg, VA; pdanderson@fs.fed.us

Down wood plays many functional roles in aquatic and riparian ecosystems. Simplification of forest structure and low abundance of down wood in stream channels and riparian areas is a common legacy of historical management in headwater forests west of the Cascade Range in the US northwest. Contemporary management practices emphasize the implementation of vegetation buffers adjacent to streams, and on federal lands thinning has become a predominant form of timber harvest. The combined effects of thinning and riparian buffer width on the down wood dynamics in stream channels and riparian areas are being assessed in young, managed headwater forests of the Density Management Study of western Oregon.

The riparian buffer component of our study includes four buffer configurations embedded within upslope thinning treatments and unthinned controls applied to 35- to 80-year-old stands at multiple locations in western Oregon. Buffer configurations include one- and two-site potential tree height buffers and two less conservative configurations, streamside retention (minimum 20 foot [6 m] width) and variable width (minimum 50 foot [15.2 m] width), allowing for tree harvest within riparian areas. Our assessments include pre- and post-treatment analyses of down wood volumes and decay classes within stream channels, origin of instream down wood (distance from stream), and down wood cover along transects extending from streams into upslope forests.

Along transects extending from streams through buffers into upslope forest stands, pre-treatment mean percent cover of large down wood (> 30 cm dia.) ranged from ~4-17% in buffers and from 5-10% in the upslope. Pre-treatment cover of small down wood (5-30 cm dia.) ranged somewhat less, ~4-13%, and also varied less than large large wood both within and among treatment units. Post-treatment, 2-5 yrs following thinning, mean down wood cover in the buffers differed less among treatments and tended to be less variable within treatments. The decreased variation among buffer treatments was due primarily to a decrease in the maximum mean cover of small down wood in streamside retention buffers, and in variable-width buffers adjacent to patch openings.

In streams, thinning and buffer configuration only affected down wood (>10 cm dia.) volumes in decay classes 1 and 2 (fresh or slightly decomposed detritus). Down wood volume was greater in the streamside buffer treatment than in the control one year after thinning, and greater than in the control and variable-width buffer treatments 2 years after thinning.

We determined the source distance-from-stream of 2,323 down wood pieces in headwater stream channels ~10 yrs post-thinning along a total of 25 stream reaches at 4 study sites. Mean distance from stream ranged 2.6 to 9.0 m, and maximum distance was 41 m. Most of this wood was in decay classes 3+4, and only 9% of 9,550 instream pieces observed were in decay classes 1+2.

Recent second thinning entries conducted 10-12 years following the initial harvest provide a new opportunity to spatially assess stream and riparian large wood dynamics in relation to direct inputs associated with harvest as well as the longer-term stability of the original buffers.
Implications of various riparian management strategies on wood in streams. Mark A. Meleason¹, Jeremy Groom², and Liz Dent³, ¹US Forest Service Pacific Northwest Research Station, Corvallis, OR, ²Department of Forest Engineering Resources & Management, Oregon State University, Corvallis, OR, ³Oregon Department of Forestry, Salem, OR; mmeleason@fs.fed.us

Wood influences physical, chemical and biological components in streams. Recent and current timber harvest practices have reduced the amount of wood in many of Oregon’s streams and may be limiting the ability of riparian areas to produce future additions of large wood pieces. The Oregon Department of Forestry’s (ODF) State Forest Program has enacted management plans that are specifically designed to enable riparian areas to accommodate the long-term recruitment of wood to streams. In 2002, ODF embarked on its Riparian Function and Stream Temperature project, also known as RipStream, to test the sufficiency of these rules.

A major focus of RipStream was to determine whether timber harvest rules provided desired future conditions for riparian areas, including the ability of harvested lands to provide large woody debris to streams. The study included 33 sites within the Coast Range, 15 on state forest and 18 on private lands. All sites had an upstream control reach that remained unharvested and a treatment reach immediately downstream. The treatment reaches were harvested after two years of data collection, followed by five more years of data collection in both reaches. In-channel, understory, and overstory vegetation data were collected on either side of the stream for both reaches in 152 x 52 m plots pre-harvest, post-harvest, and 5 years post-harvest. Data collection was designed to inform timber growth and yield models.

The goal of this research was to explore the relative performance of current and alternative riparian management prescriptions at selected sites managed by ODF. We used the output of several forest growth models as input to the OSU StreamWood model to predict the consequences of these practices on stream wood standing stock over an 80-year time period. OSU StreamWood was developed in the coniferous forests of the Pacific Northwest but has also been applied to small streams in New Zealand. OSU StreamWood is an individual-based stochastic model that operates on an annual time step at the reach scale. Stream wood dynamics considered are tree entry, breakage, movement, and decomposition. We defined riparian management prescriptions in three subzones parallel to the stream to replicate current state forest management practices. We examined riparian forest dynamics using the results from FVS and ORGANON to ensure simulation consistency. Results from these simulations will provide ODF with the first sufficiency information regarding its riparian management practices to promote wood recruitment in Coast Range streams.
Slope failure as an upslope source of stream wood. Daniel Miller, Earth Systems Institute, Seattle, WA; dan@earthsystems.net

Large woody debris is now recognized as an important component of stream geomorphology and stream ecosystem function, and forest-land management is recognized as an important control on the quantity (and size and species distributions) of wood available for recruitment to streams. Much of the wood present in streams comes from adjacent forests, and riparian management practices now reflect our understanding of the role these forests play in modulating and maintaining stream environments. In steep terrain, slope failures also carry wood (and sediment) to streams from upslope source areas. In these environments, periodic inputs of wood and sediment from landslides and debris flows also play an important role in stream geomorphology and ecosystem dynamics.

Channel environments are naturally dynamic systems. Depending on where you are in the channel network, discharge can vary from none in the summer to bed-scouring, channel-avulsing floods in the winter. Slope failures also drive variability in this system. Deposition of wood and sediment occur at discrete points in time and space, thereby creating temporal and spatial variability in channel environments. Redistribution and decay of deposited materials over time further add to this variability, and act to hide the original source of these materials, thereby masking the role of landsliding in setting stream environments. Landslide effects thus depend on when and where you look, and can be difficult to discern if the landslide occurred some time ago. This makes efforts to anticipate the effects of landsliding very challenging. Are we interested in the short term? The long term? Are we interested in a single reach? Or effects over a basin? Observations also suggest that landslide effects depend on a host of factors, including valley geometry, channel geometry, the quantity and size of sediment and wood in the deposit, the amount of wood and sediment already in the channel, and the amount of wood and sediment that enter the channel over the lifespan of the landslide deposit.

This sets the stage for considering slope failure as an upslope source of stream wood, particularly if we are to consider in-stream wood in the context of a stream ecosystem. I will briefly review the evidence on which to base conceptual and empirical models for identifying and characterizing up-slope landslide source areas, and for placing them into a channel-network context. Then I’ll illustrate the data-analysis and modeling approaches that we and our collaborators have been experimenting with to identify up-slope source areas for stream wood and for anticipating the in-stream consequences of management decisions in those areas. These methods span a range of complexity. At the most basic, we use digital elevation data coupled with empirical models to identify the source areas and runout tracks for landslides that could potentially carry material to specified portions of the channel network (e.g., fish-bearing streams). To gain insights to effects of management, we couple stand-growth, wood recruitment, and landscape dynamics models to estimate wood abundances over time and space.
Intrinsic Potential: What is it and what is it good for? Kelly M. Burnett, US Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331; kmburnett@fs.fed.us

Landscape characteristics are commonly invoked to explain or predict salmonid abundances and stream habitat conditions. Such characteristics may be relatively static (e.g., hill slope, rock type, and drainage density) or change over time (e.g., forest cover, land use, and road density). Ultimately, how landscape characteristics affect a particular fish species may vary with the underlying capacity of a stream to provide high-quality habitat for that species, or in other words, the intrinsic potential of a stream. Intrinsic potential is derived from reach-scale stream attributes (gradient, stream size, and valley constraint) that influence availability of the fine-scale habitat features (e.g., pools, spawning gravel, and large wood) preferred by salmonids. Collecting data on these fine-scale habitat features in all streams throughout a region is impossible with current technology and budgets. However, intrinsic potential can be mapped over large areas using digital elevation and climate data to generate a high-resolution stream network and the necessary reach-scale stream attributes. The approach and models, though targeted for salmonids, can be adapted to any stream-dwelling species for which links to reach-scale stream attributes are known.

Intrinsic potential models have been evaluated using sensitivity analysis and against field data, and so model performance and reliability are relatively well understood. Sensitivity of intrinsic potential model outputs to model inputs can vary by geographic location, by the form of the model, and by species. For example, outputs of intrinsic potential models are most sensitive to gradient for steelhead and coho salmon but to stream size for Chinook Salmon (*Oncorhynchus tshawytscha*). Because reach-level data on historical fish abundances are rare, model outputs at the reach level have been evaluated against: 1) current population abundance; 2) field and expert-opinion based maps on the current distribution of spawning adults; and 3) results from the Ecosystem Diagnosis and Treatment (EDT) model. However, model outputs at the basin scale have been evaluated against historical cannery records.

Models of intrinsic potential exist for several salmonid species and regions. These include Steelhead (anadromous *O. mykiss*) and Coho Salmon (*O. kisutch*) in western Oregon, Steelhead, Coho Salmon, and Chinook Salmon in northern and central California, and Chinook Salmon in the lower Columbia River. Intrinsic potential models can benefit, and have been used in, a variety of regional land-management and regulatory efforts, such as highlighting areas that may contribute disproportionately to aquatic conservation; prioritizing locations to improve fish passage or to restore streams from the legacy of splash dams; evaluating the distribution of potential fish habitat relative to land ownership, use, and cover; establishing how much high-quality habitat may be sufficient to support a “recovered” fish species; and estimating salmonid population abundances prior to European settlement. Intrinsic potential models differ from other fish-habitat suitability models in attempting to estimate the potential to provide high-quality habitat and not the actual condition of habitat. Thus, intrinsic potential models can open windows into the past and unlock possibilities for the future.
Headwater systems, including the channel and the adjacent riparian forest, are a dominant landscape feature in forested watersheds, draining most of the watershed area, and comprising the majority of channel length in drainage networks. Being at the upper extent of watersheds, these systems are smaller and steeper than large streams, and create microhabitats that support diverse instream communities distinct from those in larger streams.

Forest management can disturb headwater streams through changes in physical structure, sediment, light, and riparian detrital inputs. Locally the extent of the buffer surrounding the system mediates disturbance intensity and responses. At broader scales, the effect of the shifting mosaic of stand ages across a landscape is less well described. In addition, as watersheds are periodically harvested, long-term impacts of repeated canopy removal are unclear.

We synthesize recent research from western Oregon focused on forest effects on headwater stream ecology. We draw on over twenty published or in-progress studies. Findings from those studies and others were used to formulate causal principles of biotic conditions and summarize the research findings in a manner relevant to land planners and managers.

The research suggests these four principles as important considerations when managing forests near streams:

**System** – Riparian conditions matter. There are tight aquatic-terrestrial interactions with headwater systems as stream flows and habitat volume are low. Typically, allochthonous inputs greatly exceed autochthonous production.

**Flow** – Presence and duration of flow are a primary driver of aquatic biota composition and abundance. In addition, non-flowing wet channels provide important habitats for amphibians and some insects. Springs, common in the Oregon Coast Range, can support aquatic communities close to ridgelines.

**Disturbance** – The structure and biota of riparian systems are shaped by many facets of disturbance. In Coast and Cascades streams, periodic debris flows and floods shape the channels, rearrange substrates, and impact riparian vegetation over long and short cycles. Fire disturbance is less frequent for streams in western Oregon than streams in eastern Oregon, but when fires do occur, they fundamentally change the composition and trophic organization of headwater systems.

**Topography** – Elevation, gradient, and aspect differences contribute to biotic diversity. Biotic development is keyed to temperature and elevation and aspect influence both seasonal and daily thermal regimes. As streams steepen, substrate coarsens, altering available habitats for macroinvertebrates and vertebrates, and opportunities for algal colonization.

The local influences of these principles vary, with landscape scale variability even greater, yet the underlying influences to headwater ecology are repeatedly demonstrated in recent work. Consideration of these principles in planning ongoing forest management activities can promote the stewardship of headwater systems.
Quantifying fish responses to forestry—lessons from the Trask Watershed Study. Jason Dunham¹, Douglas Bateman², David Hockman-Wert¹, Nathan Chelgren¹, and David Leer², ¹US Geological Survey, Corvallis, OR; ²Department of Forest Ecosystems, Resources, & Management, Oregon State University, Corvallis, OR 97331; jdunham@usgs.gov

We describe demographic processes and species interactions that influence coastal cutthroat trout (*Oncorhynchus clarkii clarkii*) in small streams that are part of an effort designed to evaluate forest harvest impacts in the Trask Watershed, an industrial forest located in northwest Oregon, USA. Spatial variation in recruitment, individual growth, survival, and movement were quantified during summer low flows for four years (2007-2010). The phenology of recruitment varied substantially among sites and years. Movement during summer was limited, and varied inconsistently among sites. Individual growth and survival showed consistent size-related patterns, with variability in growth showing more consistent differences among sites in different years. Processes driving these patterns are challenging to identify, but companion studies of instream cover selection and seasonal diets of trout and other fishes suggest strong roles for predators, species interactions, and seasonal food limitations. Based on these findings, we find a process-based understanding of forestry impacts may prove more useful than traditional trend-based monitoring and impact assessments.
Riparian buffers and thinning in headwater drainages in western Oregon: Effects on amphibians.
Deanna H. Olson, US Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331; dedeolson@fs.fed.us

In 1993-1994, ecological knowledge was synthesized to develop the one and two site-potential tree height interim Riparian Reserves of the Northwest Forest Plan. These Reserves were derived from the science and expert opinion of the time, although they had not been field tested. The Riparian Buffer Study of the Density Management Study (DMS) of western Oregon also was being developed in 1994, and by design sought to test the effects of these new Riparian Reserve widths on aquatic-riparian resources. Two other treatments were designed to address thinning within Riparian Reserve boundaries, a variable-width buffer (with a 50-ft [15.2 m] minimum width on each streamside) and a streamside retention buffer (~20-ft [6 m] width on each side). Additionally, the study was being implemented in headwater sub-drainages, and relatively little was known about the headwaters ecology at the time. With this as the “back-story,” my aspect of the Riparian Buffer Study, which examines aquatic habitats and vertebrates, now includes completed analyses of pre-treatment conditions and post-treatment conditions in years 1, 2, 5, and ~10 after thinning. Key objectives of the study were to characterize the ecological values of headwaters and the effects of the thinning and buffer treatments on aquatic biota.

Small streams and their drainage basins at our west-side forest sites are habitat for about one-third of the amphibian species in the region, and these species are organized into 5 different assemblages based on habitat associations, predominantly the availability and flow regime of water. Of these animals, torrent salamanders (Rhyacotriton species) are highly associated with the uppermost headwater reaches of streams with discontinuous flow. These stream types are frequent in our study. Because torrent salamanders are Northwest endemics, occurring nowhere else on Earth, and are species of concern, they and their stream habitats with discontinuous flow are ecological values warranting consideration relative to forest management in headwaters.

There have been mixed effects on headwater amphibians of the thinning and buffer treatments. In years 1-2 post-thinning, we detected no reduction in species abundances in and along streams. In year 5, reduced abundance was detected for streambank Plethodon vehiculum (Western Red-backed Salamander) and mixed effects were detected for other species. In year 10, more complex analyses using the entire time series of data among years detected effects on both instream and stream-bank animals, with buffers and interacting factors accounting for the differences in animal abundances over time. Among analyses, sample sizes, diverse analytical approaches, and a lag-time in effects of thinning may account for some of our observed mixed effects. Nevertheless, the strongest take-home message emerging from this long-term dataset is the overall resiliency of these assemblages to the treatments. All assemblages have remained intact. Case studies on upland salamanders at these sites tell the same story, although some small effects on abundances have been observed, the assemblages have remained intact. Although the value of the different buffer widths with thinning for this biota is still under investigation, there is support that thinning near streams may be conducted at a relatively minor cost to these animals.
The Riparian Ecosystem Management Study: Responses of small mammals to streamside buffers.

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One of the fundamental concepts behind the conservation strategy embodied in the Northwest Forest Plan is the importance of habitat buffers in providing functional stream and streamside ecosystems. To better understand the importance of riparian tree buffers in providing habitat for associated organisms, we initiated (1996 – 1999) a retrospective study at 49 first- to third-order streams on state, federal, and private lands of the Olympic Peninsula to investigate responses of small mammals (and other vertebrates not presented here) to various streamside management options (Raphael et al. 2002). Streams represented six site conditions: old unmanaged, buffered old, mature, thinned mature, buffered mature, and young. Because of high variability among sites within each condition, we found few differences in responses of mammals to site condition. In hopes of reducing site variability, we subsequently undertook an experimental study on state lands in western Washington along 23 first- and second-order headwater streams to evaluate conditions both before and after treatment (Wilk et al. 2010).

The treatments, grouped within blocks of adjacent catchments, included an unlogged control, continuously buffered, patch buffered, and unbuffered streams. We sampled small mammals in 2003 before logging and then for 2 years following logging. Results from this experimental study design were much more robust than those we observed from the retrospective study. We found significant changes in abundance of several species following logging, including a larger decline in abundance of the Northwestern Deer Mouse (*Peromyscus keenii*) in all treatments relative to controls, and increases in abundance of the Creeping Vole (*Microtus oregoni*), the Southern Red-backed Vole (*Myodes gapperi*), and Townsend's Chipmunk (*Tamias townsendii*). Relative to controls, diversity of small mammals (including total captures, species richness and species evenness) did not change significantly following logging in any of the treatments. Although we observed significant effects of alternative buffer designs on abundance of several species, the experimental approach did present challenges. Treatments were not assigned randomly due to logistical constraints associated with roads and anticipated costs of treatments. Furthermore, treatments did not occur when originally planned, due to realities of timber markets driving the timing of timber sales. Finally, windstorms caused blowdown of trees within buffers on many of the treated sites, causing changes in habitat structure that obscured some differences among treatments. We also found that capture rates of some of the more specialized species were too low to allow conclusions about treatment affects. For these rarer species, more focused autecological studies will be needed to better evaluate their habitat relationships along headwater streams and their potential responses to streamside buffer treatments.
Evaluating headwater stream buffers: Lessons learned from watershed-scale experiments in southwest Washington. Peter A. Bisson, Shannon M. Claeson, Steve M. Wondzell, and Alex D. Foster, US Forest Service, Pacific Northwest Research Station, Olympia, WA 98512; pbisson@fs.fed.us

To assess whether streamside buffer width and time after logging affected the presence and abundance of aquatic and riparian biota of headwater streams, we initiated an experiment in which alternative buffer treatments were applied in a BACI design to very small (~5 ha) headwater catchments in two clusters of watersheds in southwest Washington. The treatments compared continuously buffered, patch buffered, and unbuffered streams, to an adjacent unlogged control catchment. Of six total treatment clusters, three were located in the Black Hills (Capital Forest) and three in the Willapa Hills of the Coast Range. Monitoring took place from 2001 through 2006, with logging occurring in 2004 or 2005. Although non-fishbearing, the study streams harbored amphibians and aquatic/riparian invertebrates. In addition to biota, we examined water quality, organic matter dynamics, and flow.

The results suggested that relatively small but measurable changes in ecological condition occurred in catchments where streams were not buffered: summer water temperature increased, organic matter inputs declined, and invertebrates increased or decreased depending on their trophic guild. Changes in catchments with discontinuous patch buffers were often complex and generally less detectable, and streams with continuous fixed-width buffers tended to exhibit relatively little change in aquatic communities and organic matter inputs relative to control sites. We found that analyses of ecological response metrics, both physical and biological, were fraught with difficulty. Problems could be categorized as follows: (1) Operational planning and scheduling—we had originally planned for the treatments to be implemented in the same year and in a randomized fashion, but this turned out to be impractical. (2) Spatial and temporal variability—we were surprised by the variation between even closely spaced catchments and from year to year; this made it hard to demonstrate treatment differences using a BACI approach within the time frame of the study. (3) Unplanned environmental disturbances—several large wind storms and one debris flow caused extensive damage in some of the buffer treatments, causing them to change to conditions more resembling other treatment types.

Based on our experience we offer suggestions for future studies of riparian management in small watersheds. First, determine if possible the amount of time and number of replicates needed to detect a significant treatment effect, using power analysis or other means of establishing statistical confidence. Quite likely this will involve a substantial investment in pre-treatment monitoring, which will increase the duration of BACI study designs and may suggest a different experimental approach. Second, if the study covers several locations, adequately characterize differences in physical and biological features of the sites before treatments are applied to avoid misinterpretation of results. Third, be prepared to accommodate uncontrolled environmental disturbances (e.g., droughts, floods, wildfires, etc.) that are inevitable in multi-year investigations. Fourth, once the basic experimental layout is established, stick with it and resist the temptation to switch treatments midway through the study, which will only confound the analyses. Finally, when surprises occur, be flexible enough to monitor their effects to maximize learning opportunities.
Resource managers are increasingly required to conduct integrated analyses of aquatic and terrestrial ecosystems before undertaking any activities. There are a number of research studies on the impacts of management actions on these ecosystems, and a growing body of knowledge about ecological processes that affect them, particularly for aquatic ecosystems, that are used to guide the analyses. Additionally, new tools are available to assist in the analyses. These developments have advanced the potential to do these analyses. However, there are some critical issues that need to be included in an integrated analysis that are not readily recognized or acknowledged at this time. Two of the more important factors are space and dynamics. Watershed, and landscape, analysis requires consideration of a different set of rules for considering context and potential effects of proposed actions than do analyses that conducted at smaller scales. The failure to recognize these issues can result in a misinterpretation of the analyses and a failure to understand potential impacts. Watershed analysis also focuses on identifying the location of, and accessing the magnitude of, various ecological processes in the watershed. Consideration of processes that affect aquatic ecosystems as dynamic is relatively new, but the implications of these dynamics are not fully recognized by many managers and regulators. The consequences of both these factors are that there is a mismatch between the expectations for management of aquatic and terrestrial systems that limits our ability to develop and implement new approaches to integrated management.
Growth and yield considerations and implications for alternative density management objectives and approaches. David Marshall, Weyerhaeuser Corporation; david.marshall2@weyerhaeuser.com

Density management through thinning is the most important tool foresters have to affect stand development and stand structure of existing stands. Reducing stand density by thinning increases the growing space and resource availability (e.g., light, water, and nutrients) to the remaining trees. This can result in increased average tree growth. More available site resources can also encourage the development of understory vegetation and trees. Alternatively, the highest amounts of stand volume (or tree biomass) growth will generally occur when the site is fully occupied. The competition levels of this high level of site occupancy will lead to self-thinning mortality of the less vigorous trees and reduced net stand growth. Reducing stand density reduces site occupancy, growing-stock, and total leaf area and generally results in reduced stand volume growth.

The impact of thinning on stand growth rates will depend on the amount of residual growing stock retained and the vigor of the trees that remain. Thinning younger stands with adequate crown and rapid height growth can be expected to build crown, leaf area, and growing stock rapidly. Vigorous trees in older stands may also respond to thinning. Higher average tree growth rates and lower mortality in thinned stands maintain rapid growth rates and flatten out the annual increment curve and push culmination of mean annual increment to older ages.

Growth-growing stock relationships have been studied in the Pacific Northwest since the 1960s and demonstrate the trade-off between individual tree growth and stand growth. Thinning to variable densities (growing space) and gaps will also follow these basic growth-growing stock principles. Understanding these relationships is important for foresters to achieve desired stand production, economic, and structural development goals.
Topic: Role of thinning in providing income and long-term sustainability of timber production on federal lands

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Harvest operations for density management: Planning requirements, production, costs, stand damage, and recommendations. Loren D. Kellogg and Stephen J. Pilkerton, Department of Forest Engineering, Resources, & Management, Oregon State University, Corvallis, OR 97331; loren.kellog@oregonstate.edu; pilkerts@onid.orst.edu

Since the early 1990s, several studies have been undertaken to determine the planning requirements, productivity, costs, and residual stand damage of harvest operations in thinning treatments designed to promote development of complex forest structure in order to enhance ecological functioning and biological diversity. These studies include the OSU led cooperative Coastal Oregon Productivity Enhancement (COPE) project, the Willamette (National Forest) Young Stand Project (WYS), and the Siuslaw (National Forest) Thinning and Underplanting for Diversity (STUDS) project. Treatments focused on 35-50 year old stands with density management targets included light thinning (100 - 120 residual trees per acre, tpa), heavy thinning (50 - 60 residual tpa), very heavy thinning (30 residual tpa), and light thinning with gaps. A second treatment was applied to the STUDS stands which had light and heavy treatments on the first entry.

Logging planning and layout costs were studied for the WYS project. Production and costs results for harvest operations include skyline yarding, ground based skidding, and mechanized cut-to-length systems. Damage to the residual stand was studied for the STUDS stands.

Planning and layout efforts are beneficial to efficient and successful harvest operations. Harvest production influences related to the density management treatment were relatively small. More importantly, these studies have demonstrated important aspects of successful harvest operations for density management in planning, conducting and assessing residual stand damage. Results of the stand damage assessments shows high incidence of tree damage close to the yarding corridor / skid trail. A stand damage assessment methodology, DAMQUICK, was developed.

This presentation and paper will (1) summarize what we have learned from the harvesting studies for successful planning and implementation of density management stand treatments, and (2) report the cable harvesting production and stand damage results from the STUDS second thinning entry.
Variable-density thinning has received a lot of public attention in recent years and has subsequently become standard language in most of the Willamette National Forest’s timber management projects. Many techniques have been tried, with varying on-the-ground successes. To accomplish variable-density thinning, the McKenzie River Ranger District currently uses combinations of techniques such as skips, gaps, dominant tree releases, variable thinning prescriptions, designation by description (DxD), and individually marked trees within the same harvest unit. The major challenge associated with implementing variable-density thinning occurs during pre-sale. Depending on the level of variability within the harvest unit, it is estimated that it takes up to twice as long to complete a timber sale package from layout through the final contract. Issues for pre-sale resulting from variable-density thinning include: 1) more complex physical layout on the ground; 2) increased GPSing; 3) increase in cruising time; 4) increased complexity in the maps; and 5) increase in requirements of the contract.

In a recent project the McKenzie River Ranger District has also incorporated an uneven-aged management approach for Douglas-fir (*Pseudotsuga menziesii*) in many of the proposed harvest units. This has added yet another complicated element into the planning and implementation of the project. During the planning process, consideration of current and possible future logging systems as well as layout design must be analyzed early. For example, if a unit requires intermediate supports to cable log, more thought must be given to when and where the gaps are placed within the unit’s rotation. If a group select (gap) is placed around the intermediate support trees and those support trees are damaged or removed by harvesting or wind throw, future cable logging opportunities may be compromised for 30-45 years. Locations of the group selects (gaps) may be critical to design prior to first implementation. The increased complexity of an uneven-aged management rotation and variable-density thinning across the landscape will also increase future data management costs. Units will need to be stratified further in stand exams and cruises to maintain quality data. Although the increased cost may not be an issue on a relatively small scale, when applied to a landscape, such as a whole project area, it may be more problematic, especially with the Forest Service’s budget continuing to decline. Increased stratification will likely require more plots per acre, which in turn, requires an increase in person-hours. It is also recommended that locations of skips and gaps (group selects) should be tracked to allow for enhanced management in the future.
How the Density Management Study has changed my world. Craig Kintop, Density Management Site Coordinator, US Bureau of Land Management, Roseburg, OR; craig_kintop@or.blm.gov

Topic: A Forest Supervisor’s perspective on thinning and the underlying science. Jerry Ingersoll, Forest Supervisor, Siuslaw National Forest, Corvallis, OR 97333; jingersoll@fs.fed.us

A BLM Deputy State Director’s perspective on the strategic management outlook and thinning. Mike Haske, Deputy State Director, Resource Planning, Use & Protection, Oregon/Washington BLM, Portland, OR; mhaske@blm.gov