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RIPARIAN BUFFERS AND THINNING DESIGNS IN WESTERN OREGON HEADWATERS ACCOMPLISH MULTIPLE RESOURCE OBJECTIVES

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ABSTRACT

We are investigating headwater riparian and upland forest management to achieve multiple resource objectives, primarily accelerated development of old-growth habitat and rare species management. For stands 40 to 50 yrs old, a control and three density management treatments are under study. Treatments include a mosaic of leave- and clearcut-islands within a matrix of thinning to various densities. Within this template, four no-entry riparian buffer zones also are under investigation. Companion studies utilize these two templates for biota and/or habitat characterizations; in particular, we are examining amphibians, mollusks, fishes, microclimate, and microsite. The balance of resource objectives was apparent during study implementation. For example, >100 species were evaluated by federal field units at the stand scale across 13 study sites, many became conflicts to study implementation. The common methods of conflict resolution involved leaving unthinned areas, such as the study design elements of various sizes of riparian buffers and unthinned leave islands. The mosaic of stand-scale conditions resulting from such designs effectively addresses sustainability. This is a cooperative study between the U.S. Department of Interior, Bureau of Land Management, and the U.S. Department of Agriculture, Forest Service, with companion projects conducted by Oregon State University and U.S. Geological Survey partners.

KEY WORDS: Density management, riparian, buffer, headwater, microclimate, amphibians.

INTRODUCTION

Our western Oregon density management and riparian buffer studies provide an opportunity for managers and scientists to address the balance of multiple resource objectives in forested headwater subdrainages. These studies were developed in direct response to a change in natural resource management in the Pacific Northwest initiated by the federal Northwest Forest Plan (U.S. Department of Agriculture and U.S. Department of Interior 1993, 1994). This regional paradigm for ecosystem management was developed to focus on forest sustainability. On federal lands, sustainability of forest biological resources, such as forest-dependent species and ecosystem functions, became paramount to wood production and its related socioeconomic imperative.

Implementation of forest ecosystem management is ongoing and adaptive. Our joint studies have had several roles in this implementation. Our work initially aided development of regional standards for research and monitoring under the Northwest Forest Plan because it was among the first research projects proposed in the plan area. Our projects also were the first riparian reserves harvested under the plan in many northwestern Oregon field units, again aiding development of procedures for plan implementation. In particular, regional planners and field units implementing our study faced the goal of balancing resource objectives. Numerous key resources were identified and became study "drivers," "pivots," or "barriers" to project implementation. As resource conflict resolution occurred, solutions were available to managers as subsequent analogous conflicts arose in their routine projects. Here, we identify multiple resources that were evaluated and managed for sustainability through implementation of density management and riparian buffer designs. We offer this as an approach for across-scale, multiple-resource forest sustainability.

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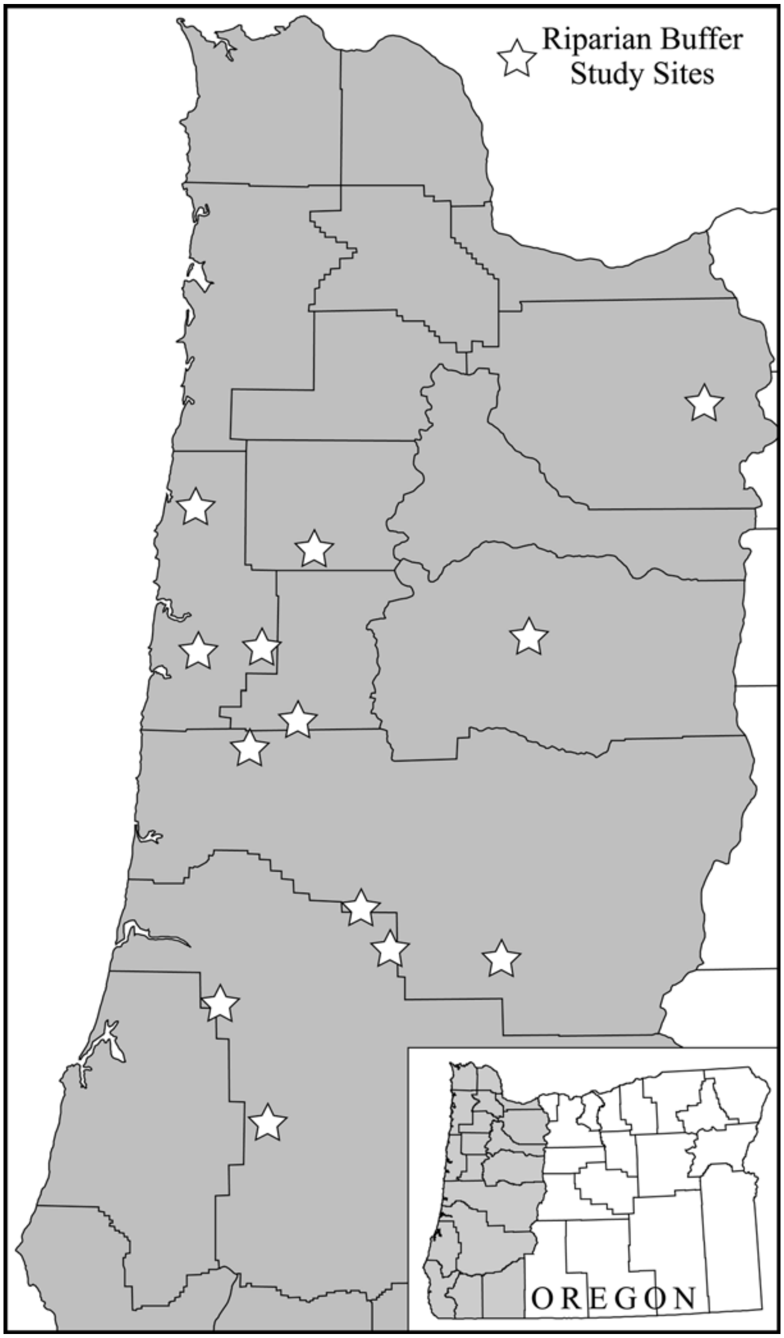

Figure 1—Distribution of 13 sites implementing the riparian buffer and density management studies in western Oregon managed federal forests.

BACKGROUND

Density Management in Headwater Forests

The Oregon density management studies address the utility of various thinning designs to achieve accelerated development of late-successional and old-growth (LSOG) conditions in managed stands (see Tappeiner et al. 1997). These studies were designed by the Bureau of Land Management (BLM; C. Thompson, study coordinator) in cooperation with Dr. John Tappeiner (Principal Investigator, U.S. Geological Survey and Oregon State University) after an assessment of the west-side forest management situation. Much of this forestland was regenerated after intensive clearcut harvest, and now resides in the plan's late-successional reserve (LSR) land allocations. Since the LSR lands are meant to emphasize habitat development over wood volume production, the need to develop effective methods to accelerate development of LSOG conditions was war-

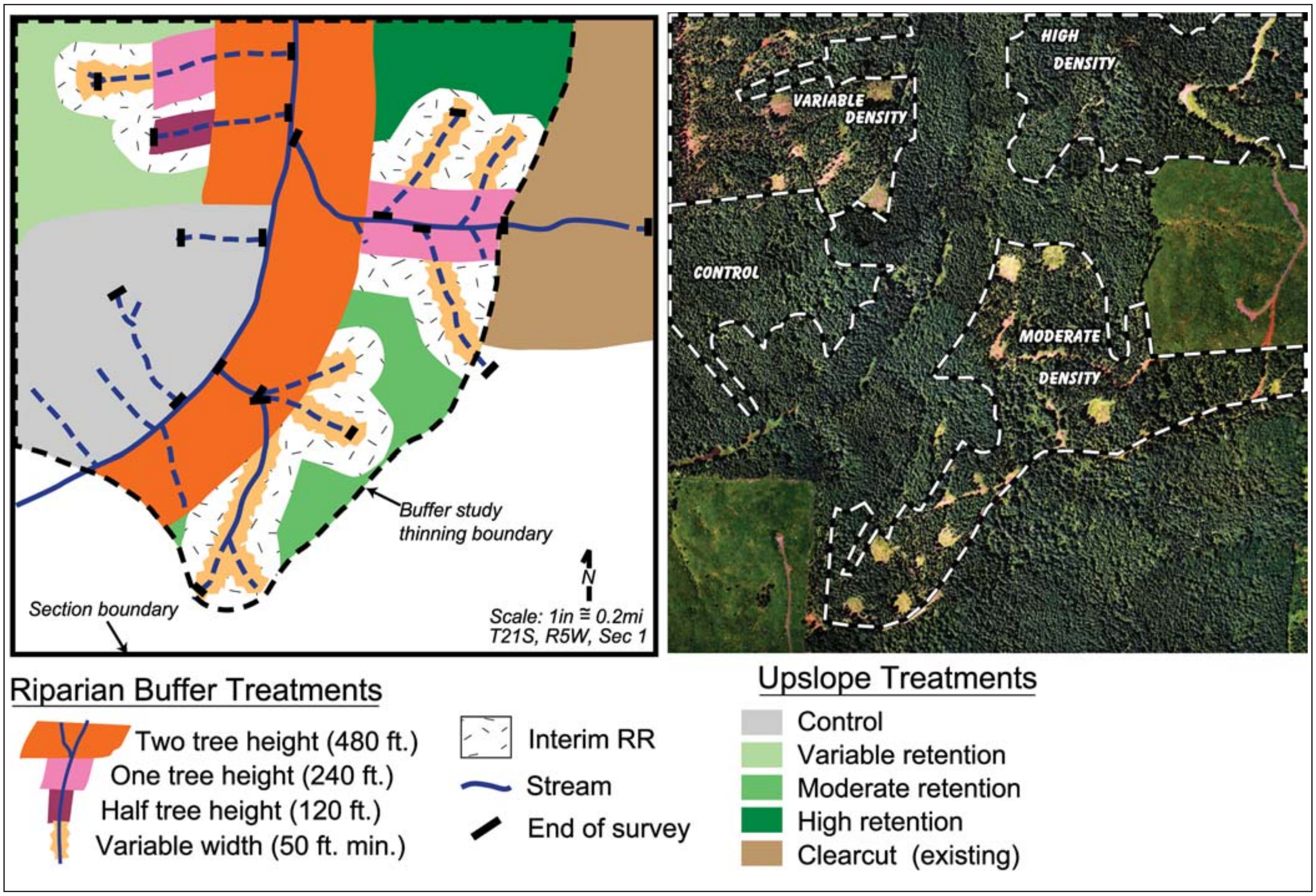

Figure 2—Schematic diagram and aerial photograph of one Bureau of Land Management density management study site showing four upslope treatments: unthinned control; high retention thinning (120 trees per acre [TPA]); moderate retention thinning (80 TPA); and variable retention thinning (with 40, 80, and 120 TPA areas). These views also depict the interim riparian reserve (RR, left) of the Northwest Forest Plan, the portion of those reserves that were planned for thinning (speckling), and the implemented unthinned riparian buffer (right).

ranted. The thinning treatments were designed to generate results to contribute to the dominant forest management decisions expected for this region in the next one-to-three decades. In addition to monitoring the development of stand structure and composition over time in the various silvicultural treatments, evaluation of the wood production, operational and economic constraints of variable thinning designs, and biodiversity assessments were integral components of this work.

Two age classes of young stands were included in investigations. Nine of 12 study sites implemented with both density management and riparian buffer designs (Figure 1) were young stands 30-50 years old: six on Oregon BLM lands and three on the Siuslaw National Forest. In the six BLM younger stands, three thinning treatments and a control were implemented (Figure 2). These density management treatments included thinning to 80 trees per acre (TPA; 1 acre = 0.405 ha; “moderate thin treatment”), 120 TPA (“high density thinning treatment,” and a mix of 40, 80 and 120 TPA (“variable thinning treatment”). Patch cuts, leave islands, and underplanted areas were distributed in the thinned areas, and harvest layout and tree marking guidelines were meant to protect stand structural features known to contribute to biodiversity. Three BLM sites were in older managed stands, 60-70 years old. One of these was never thinned. This site represents a case study of a first-entry thinning at an older stand age. Two others were previously thinned, with a second entry implemented with a single treatment and two controls (never-thinned and once-thinned). These two sites conceptually represent a look into the future towards a possible management direction for the previously described younger stands in one-to-two decades, when a second entry thinning may be appropriate. Although there are additional BLM density management study sites in each age class, they did not have sufficient streams within them to implement a riparian buffer component for our study.

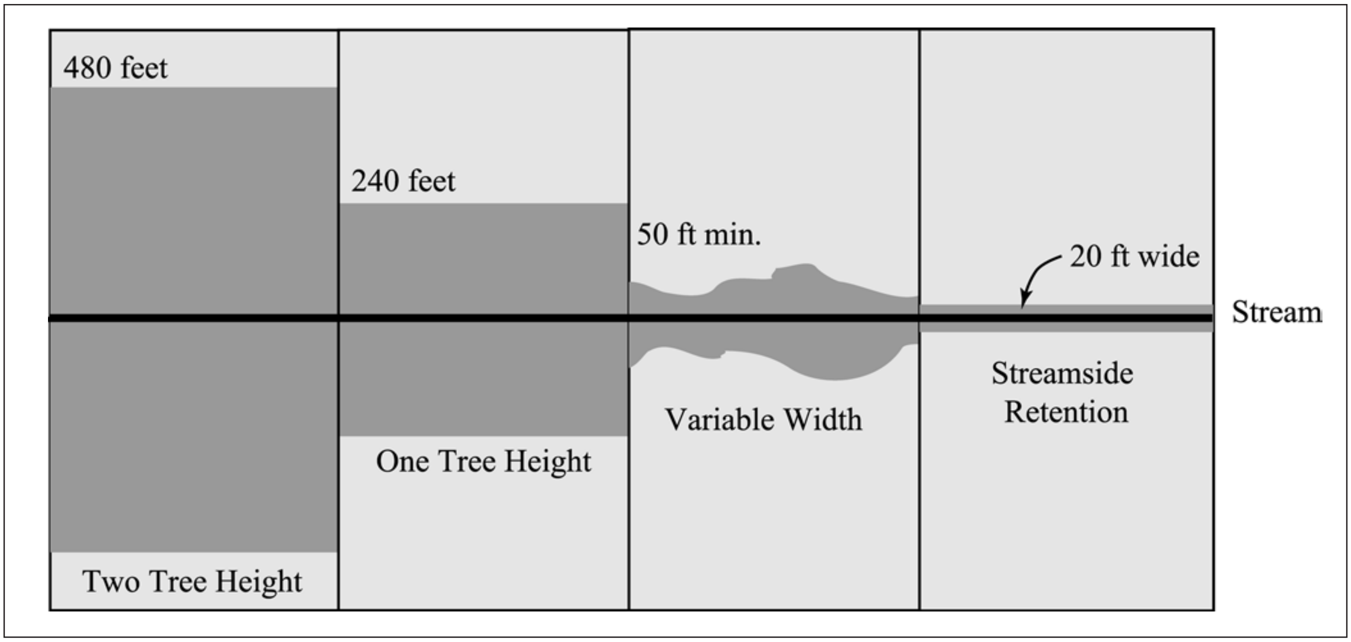

Figure 3—The four unthinned streamside zones under investigation in our joint riparian buffer and density management studies.

Riparian Management

Stream networks radiate throughout the west-side forest landscapes of the Pacific Northwest, with headwater streams present in most proposed timber sale areas. Despite their frequency, research focusing on the ecological roles of zero to second-order streams and subdrainages is scarce. In particular, the importance of headwaters to elements of the Aquatic Conservation Strategy Objectives (U.S. Department of Agriculture and U.S. Department of Interior 1994, Sedell et al. 1994) is unclear. For example, are there critical resources or processes associated with headwaters? If so, what are they and how are they spatially distributed in the headwater aquatic network? Are there risks to the integrity of these values with timber harvest, and what management approaches are appropriate to attain critical resource objectives? Upland forest riparian management approaches vary widely, including: 1) no protection; 2) restoration via stand conversion, thinning and underplanting; 3) streamside protection zones of various widths; and 4) patch reserves (e.g., Cissel et al. 1998). Unfortunately few data are available to address the effectiveness of various headwater riparian management actions in protecting aquatic resources. Additionally, most riparian forest management approaches along larger streams were developed within a regeneration harvest context. Limited information is available for the effects of density management thinning designs on riparian values.

Streams at many sites in the Oregon density management studies worked well for exploring riparian management options within a forest thinning context. Four widths for unthinned riparian "buffers" were chosen for study (Figure 3). Two of these stem from the guidance in the Northwest Forest Plan (one and two site-potential tree height buffers; range 200 to 480 ft; 1 ft = 0.305 m), while the other two stem from less conservative guidance matched to site conditions (a 50 ft minimum variable-width buffer which changes with topographic or vegetative conditions, relevant to state forestry approaches, and about a 20 ft streamside-retention buffer which retains the first streamside tree to provide bank stability from rooting strength, referenced in the Augusta Creek Landscape Management Plan utilizing extensive density management treatments, Cissel et al. 1998).

Application of four alternative stream buffers within the three young stand density management treatments plus control unit posed logistical problems due to restrictions on stream length and configuration within a site (often composed of a square mile of BLM-administered land). Hence, we focused the riparian buffer component within one upslope thinning treatment (80 TPA), with matched control stream reaches (Figure 4). Additional criteria for the riparian buffer study included: a minimum of 3 stream reaches, each with a minimum stream length of 2½ site-potential

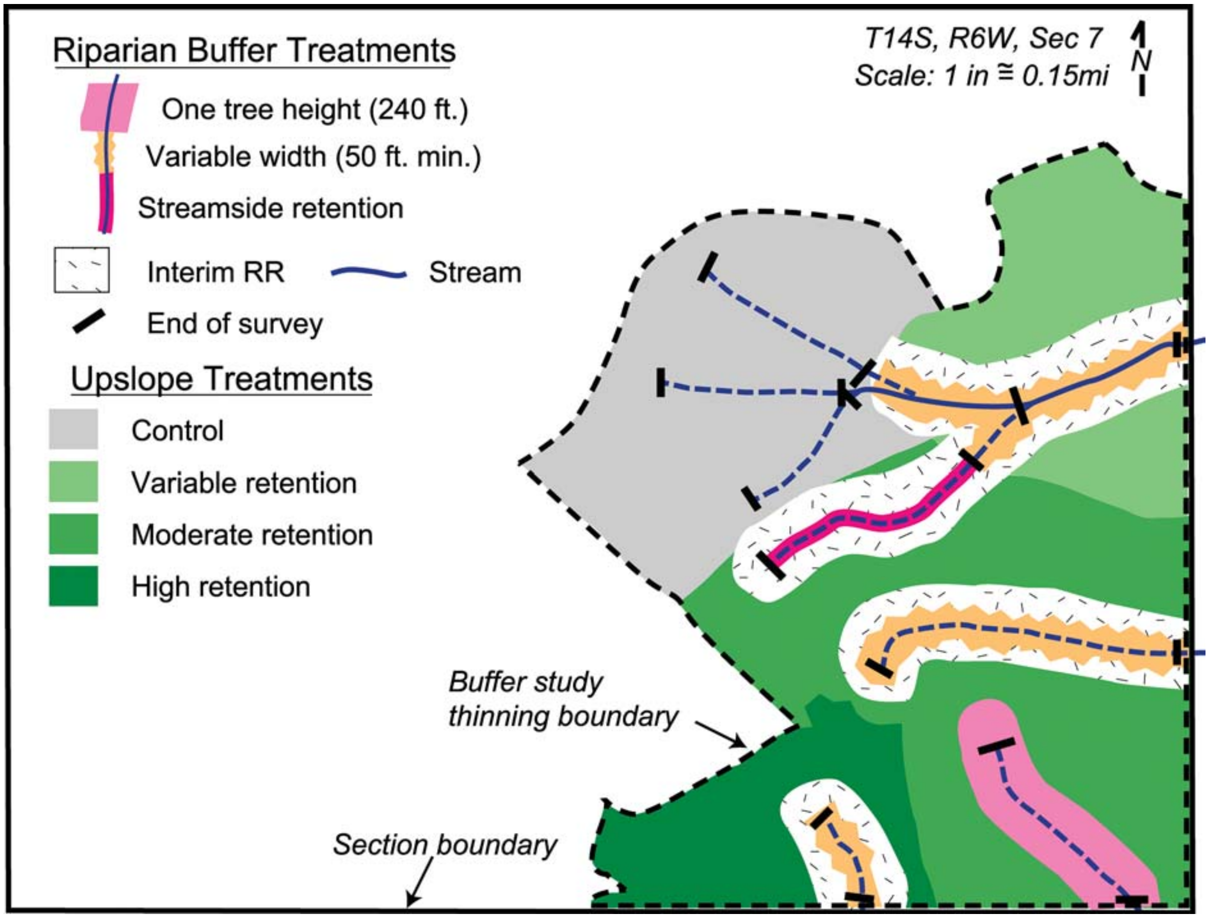

Figure 4—The riparian buffer study is being implemented within the moderate retention thinning treatment (80 trees per acre) at sites that had sufficient stream lengths and upslope forest areas to allow a minimum of two buffer treatments. At this particular site, three headwater streams permitted buffer treatments in the moderate retention unit (a one site-potential tree height buffer, a variable width buffer and a streamside retention buffer).

tree heights (approx. 500 ft) to implement a control and two buffer treatments; at least 200 ft of treatment area was needed adjacent to the buffer; and matched stream sizes and conditions among treatment and control reaches.

Several companion studies are using the joint density and riparian management components as templates to examine specific questions. These include pretreatment characterizations and post-treatment responses of: 1) microclimate and microsite conditions - S. Chan, six sites; 2) aquatic dependent vertebrates and habitats - D. Olson, 12 sites; 3) macro-invertebrates - A. Moldenke, Oregon State University [OSU] and R. Progar, U.S. Department of Agriculture, Forest Service, Boise, ID, selected sites; 4) lichens and bryophytes - P. Muir and B. McCune, OSU, selected sites. Also a new study, initiated in 2001, examines the role of leave islands for diversity of vascular plants, amphibians, mollusks, arthropods and related microclimate and microhabitat features - S. Wessell and D. Olson, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Corvallis, OR, and R. Schmitz, OSU, four sites. Most of these projects are biologically focused because we lack information on headwater biota and habitats, their unknown response to a mosaic of thinned and unthinned areas, and the management need to balance timber harvest approaches with species protection and maintenance of ecosystem functions. Many key findings on the headwater forest characteristics, dynamics, flora, and fauna are emerging in these studies (Table 1), and likely will contribute to the adaptive management process for headwater forest management.

Table 1—Key findings of companion studies implementing research at the western Oregon density management and riparian buffer study sites (from Neitlich and McCune 1997, Olson et al. 2000)

Project	Key Findings
Microclimate and microsite - S. Chan	• Most of the change in microclimate from the stream to the upland forest occurs within the first 45 ft from the stream. • Soil and water temperatures within the riparian buffer are similar between thinned and unthinned stands. • Thinning to 80 TPA resulted in about a 2-6 C increase in air temperature, and about a 15-20% decrease in relative humidity, during the warmest and driest period. • Riparian areas had the most heterogeneous site conditions. • Stands now contain limited large down wood in early stages of decay.
Aquatic vertebrates and habitats - D. Olson	• Headwater vertebrate assemblages differ both longitudinally with stream flow gradients and latitudinally from streams (distinct bank and upslope assemblages). • Several sensitive species and LSOG associated species occur in these managed headwaters; some may be considered critical resources with persistence con cerns; one, in particular, associated with discontinuous flow of upper most stream network. • Faunal responses to treatments are undergoing analysis. • Upslope fauna appears reliant on legacy down wood.
Macroinvertebrates - A. Moldenke and R. Progar	• Headwater invertebrate assemblages differ both longitudinally with stream flow gradients and latitudinally from streams. • Near stream riparian zone arthropod assemblage contained all upslope biota. • Small bodied Chironomidae and Mycetophiliidae dominated emergence from temporary streams. • Larger Ephemeroptera, Plecoptera, and trichoptera dominated emergence in perennial streams.
Lichens and bryophytes - P. Muir and B. McCune	• Diversity and abundance hotspots are associated with gaps, hardwood trees, old remnant trees, and wolf trees. • Relictual species are associated with legacy features, and feature retention can retain such biodiversity

MULTIPLE RESOURCES: FROM CONFLICTS TO DRIVERS, PIVOTS, AND BARRIERS

Although we were involved in these projects as researchers to implement our various studies, our role is often greater. Our studies are part of an active interagency adaptive management process that integrates the joint production and protection of multiple resources. As the thinning and riparian buffer experiments were proposed and implemented in western Oregon, the multiple resources that were addressed spanned wood production, species of concern, habitats, and the politico-socioeconomic. Integration of these multiple resource objectives often were translated into proposed tradeoffs of concerns as single considerations conflicted with others and subsequently became a "driver," "pivot," or "barrier" to implementation.

We found that whether a resource conflict resulted in a resource becoming a driver, pivot, or barrier was often contingent upon when in the process (Figure 5) it was recognized as an issue. Conflicts first arose during planning, in 1993-1995, as the study design intersected the path of the Northwest Forest Plan. At the landscape level, the role of federal land-use allocations was questioned. Which allocations were appropriate for study sites; for example, could

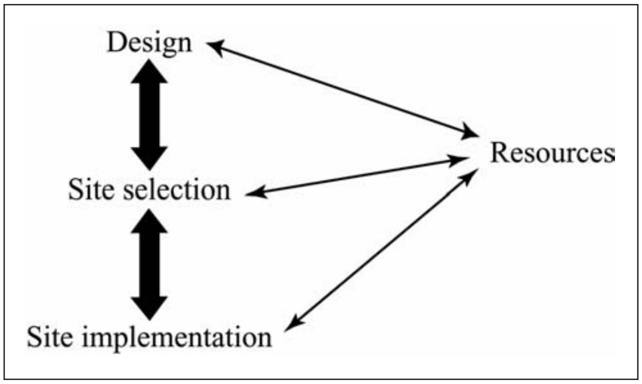

Figure 5—Iterative resource evaluations occurred during project planning and implementation.

we implement sites in Late Successional Reserves (LSR's) because we were working to improve LSOG conditions? Initially, sites in Tier 1 Key Watersheds and LSR's were deferred from eligibility due to the early "hands-off" view of these lands under the Northwest Forest Plan. Later, it was decided that research objectives were consistent with management objectives for these allocations. One potential Matrix site was disqualified because the timeframe of the study and its proposed monitoring might have affected later entry to the site. Thus, LSR and Matrix allocations were perceived as both study "drivers" and "barriers" in different contexts.

Resource conflicts that were considered barriers to implementation generally were recognized at the larger spatial scales during the screening of the landscape for potential sites. Landscape screening criteria were primarily species and habitat concerns. They reflected precautionary principles applied during the early implementation of the Northwest Forest Plan. For example, the following conditions were identified and often avoided for site selection: key watersheds for listed fish, the zone of the marbled murrelet, known activity areas of northern spotted owls, and areas with extensive root rot, likely wind damage, soil erosion and landslide potential. Serious concerns sometimes resulted in the honing of study objectives, or a pivot in study implementation. Potential sites in the Coast Range and western Cascade Range with extensive riparian reserves also were initially perceived as potential conflicts to site selection before they were recognized as research-opportunities.

Once landscapes were screened for potential eligibility for site selection and individual sites were assessed, a new set of issues arose. For example, while areas with known northern spotted owl or marbled murrelet nests generally were avoided during landscape screening, dispersal habitats for owls and murrelets emerged as a concern for other sites. Socioeconomics of sites also were projected relative to operational constraints and implementation costs; marketability of sales units were weighed with the complex harvest design, need for new road construction, and the potential logging system impacts (e.g., helicopter, suspension). To make a density management site marketable, the economics of patch openings and inclusion of neighboring parcels became important as mechanisms to increase yield and market value. One site harvested primarily via helicopter methods was estimated as not worth selling within later market conditions. Two other sites did not sell when first offered, again due to market values of timber and the cost of implementing the complex study design. They later sold to a single bidder at the government-appraised price.

A preliminary assessment of the wood production in these project areas is compiled in Table 2. Implementation of the density management prescriptions resulted in greater volume removed when compared to traditional thinnings, largely due to the patch cuts ranging in size from ¼ to 1 acre. At one site, the environmental assessment stated that lumber was provided to the public while maintaining or increasing the vigor and volume growth of the stand through time. An increased timber benefit to the economy of the county was projected. These increased timber benefits would apply to all study sites.

Stand- or project-scale implementation was the finest scale at which the balance of resources was addressed. This scale was much more involved, adaptive, and instructive for the resource balancing act. Field units implementing study sites evaluated a myriad of site conditions and concern topics for their environmental assessments. Across all study sites, these included evaluations of species (n=103 species of 13 taxa; Table 3) and specialized habitats (e.g., wetlands, downed wood, snags, soil conditions, meadows). Many of these conflicted with the study, some serving as barriers to proceeding until an adequate resolution was determined.

Application of the study's various design elements was the dominant mode of stand-level conflict resolution. In particular, unthinned areas were used to mitigate for many sensitive species and special habitats; protection was provided with unthinned riparian buffers, leave islands, and control areas (Table 4). For example, protection of lichen diversity "hotspots" (Neitlich and McCune 1997) was implemented at some sites via leave islands. For some potential conflicts, the thinning treatment was expected to be either a relatively benign disturbance, or a short-term

Text continues on page 10.

Table 2—Species evaluated during study site implementation

Taxonomic Group (no. species or taxa)	Species (common or scientific names)
Birds (13)	northern spotted owl, marbled murrelet, bald eagle, northern goshawk, raven, pileate woodpecker, saw whet owl, American kestrel, western bluebird, peregrine falcon, snowy plover, brown pelican, Aleutian Canada goose
Mammals (12)	Bats: Townsends big eared bat, pallid bat, fringed bat, long eared myotis, Yuma myotis, long legged myotis, Pacific western big eared bat Others: red tree vole, white footed vole, American marten, deer, elk
Amphibians (5)	red legged frog, southern torrent salamander, Oregon slender salamander, clouded salamander, tailed frog
Fishes (5)	coho salmon, steelhead trout, cutthroat trout, resident cutthroat trout, sculpin spp.
Mollusks (2)	blue gray tail dropper, papillose tail dropper
Lichens (20)	*Hypogymnia oceanica, Lobaria oregana, L. pulmonaria, L. scrobiculatea, Nephroma bellum, N. helveticum, N. laevigatum, N. resupinatum, Pannaria leucostichtoides, P. saubinetii, Parmotrema chinense, Peltigera collina, P. pacifica, Plastimatia lacunosa, Pseudocyphellaria anomala, P. anthraspis, P. crocata, Ramalina thrausta, Sticta fulginosa, S. limbata.*
Mosses (2)	*Buxbaumia piperi, Antitrichia curtipendula*
Fungi (17)	*Gymnopilus punctifolius, Aphaeocollybia sp., Ramaria aurantiisiccescens, Otidea leporina, Sarcosoma mexicana, Cantharellus formaosus, C. subalbidus, C. ciberius, Clavariadelphus liqula, Phaeocollybia sp., Ramaria cyaneigranosa, Gomphus clavatus, G. floccosus, Hydnum repandum, Phaeocollybia attenuata, Canthatellus tubaeformis, Helvella compressa*
Vascular plants (9)	*Orobanche pinorum, Monotropa uniflora, Hypopitys monotropa, Pityopus californica, Pleuricospora fimbriolata, Hemitomes congestum, Sparassis crispa, Botrychium virginianum, B. multifidum*
Minority tree species (8)	pacific yew, western hemlock, western red cedar, red alder, big leaf maple, myrtlewood, cherry, tanoak
Tree diseases/pests (4)	laminated root rot, black stain root disease, Douglas-fir bark beetle, swiss needle cast
Noxious weeds (6)	scotch broom, bull thistle, Klamath weed, tansy ragwort, Canadian thistle, hemlock dwarf mistletoe
Other (1)	Oregon silverspot butterfly

Table 3—Examples of resource conflict resolutions (continued)

Resource	Resolution of Conflict
Northern Spotted Owl	Sites excluded from study if a nest was found. Seasonal restriction of activities to reduce disturbance to foraging and nesting. Majority of treated area > 40% canopy closure.
Marbled murrelet	Seasonal restriction, daily timing restriction to activities, majority of treated area > 40% canopy closure.
General wildlife	Patch cuts positioned to benefit wildlife (1 site), defective trees left (1 site), 2 residual trees per acre topped (1 site), seasonal restrictions, retention of previously topped trees, roads blocked or gated to reduce disturbance, falling/girdling of additional trees, maintain untreated area along main creek for amphibians and mollusks.
Fish	Streamside retention buffer was not placed on streams with fish concerns (1 site), seasonal restriction (2 sites), trees felled into creek for habitat (1 site). Helicopter log instead of 6,300 ft new road construction, build new roads along ridges.
Blue gray tail dropper, Papillose tail dropper, other Mollusks	Helped locate leave islands, untreated riparian area designated.
Douglas fir bark beetle	Seasonal restriction outside the adult beetle flight.
Laminated root rot	Sites with heterogeneous forest condition from this disease were excluded from study, presence at a site was incorporated into patch clearcut islands. Treatment was the same as the rest of the stand in several cases.
Monotrope plants (5 spp)	Unthinned control located to preserve one species, two one-half acre leave islands located for other species, 3-4 trees retained around site centers (maple clumps), some unit boundaries were changed to provide protection.
Orobanche pinorum (Vascular plant)	Reserve island established.
Minority tree species	Retained in study area, patch cuts positioned to assure regeneration of desirable seedlings, reserve patches represent unique characteristics, reserved hardwoods and conifer < 5 in. Dbh, retain limby/wolf trees, seasonal restriction and 40 ft max. log length to protect residual stands, minimize landing size.
Buxbaumia piperi, Antitrichia curtipendula (Mosses)	Thirty sites, some protected by control unit, protected by retention of downed logs (1 site). Leave island designated. Mosses located in control and high density thinning treatment.
Fungi (15 spp.); *Sparassis*	Helped locate leave islands, application of density management treatments rather *crispa* than patch cuts where feasible, reserve clumps of trees, if leave islands bisected by logging corridors then they would be < 15 ft wide, protection by stream buffer zones; Retention of 5-6 trees adjacent to or hosting the population.
Lichens	Helped leave island placement, protected by stream buffer zones.

Table 3—Examples of resource conflict resolutions

Resource	Resolution of Conflict
Streams and riparian areas	Patch cuts positioned away from stream channels, no yarding in no-cut areas, marshy area protection by one row of conifers around perimeter, yarding away from streams, inner gorge no cut zone, trees felled in leave areas are to be left. Ninety-three trees >15” dbh identified for coarse woody debris and snag creation (1 site), minimize use of riparian zone trees for anchoring or hanging cables, full suspension over streams or wetlands.
Water quality, sedimentation	landing construction > 50 ft of streams, yarding perpendicular to streams, one-end sus pension.
Wetlands	Diverted roads, affected riparian reserve boundaries, and affected leave island place ment (1 site).
Meadow lithosol	Habitats excluded from treatment (1 site).
Downed wood/snags	Remain on site, damaged trees retained, snags created, trees felled for downed wood after first winter storm season.
Special forest products	Selection of trees to 10 in. dbh made by silviculturalist to focus on suppressed trees and intermediate crown classes (1 site). Firewood permits allowed.
Recreation	No harvest uphill of main trail, no harvest within 50 ft of trail where possible, slash piles >100 ft from trail, no marking paint on trail side of trees, flag persons employed during logging.
Fire	Felling away from roads, slash piles burned by U.S. Department of Agriculture, Forest Service, 4 ft wide fuel break along private property boundary (1 site). Slash pulled back 25 ft from roads (1 site), debris burned at landings, patch openings, and within 50 ft of haul roads (1 site).

risk but a long-term gain in habitat conditions. After site selection, almost all conflicting resource issues were resolved. Interestingly, some of the resource conflicts that were barriers at larger scales were resolved at the fine scale. Development of standard scale-dependent criteria for resource evaluations is warranted. Which resource-management objectives should be attained at the landscape scale, and which objectives are better addressed at finer spatial scales? As we have noted, landscape scale resource attainment could result in precautionary approaches. Alternatively, landscape planning could heighten site-level risks for selected areas.

COMPATIBILITY

Resolving resource conflicts helped achieve the compatibility of multiple resources for joint production and protection. This occurred in similar ways at each spatial scale by either reserving lands for individual resources (in some cases, for combinations of resources) or accepting risk relative to a resource.

At the finest scale, resolving resource conflicts included excising portions of the study site, or allocation of unthinned treatments (control units, no entry riparian reserves, leave islands, tree clumps) to some areas. Conflicts were addressed during site implementation with marking guidelines and operational changes. The complexity of the experimental design, involving various riparian buffer widths, thinning densities of 40, 80, or 120 TPA with patch openings and leave islands of various sizes, and an untreated control, provided flexibility to accommodate potentially conflicting resources. Additionally, the spatial scale of the treatments often were considered small enough to have acceptable risks to some resources.

Table 4—Estimated volume of timber harvest (mmbf) and area treated for seven density management study sites (30-50 yrs) and three older "rethin" study sites (70-80 yrs)[1]

Wood Production (mmbf)	Area
8.4 mmbf	389 acres thinned
1.5 mmbf, average 10 mbf/acre	220 acre project area, 163 acres thinned
1.3 mmbf	246 acre project area, 145 acres commercially thinned
1.8 mmbf	380 acre project area, 261 acres thinned
1.6 mmbf	403 acre project area, 135 acres thinned
1.9 mmbf	244 acre project area, 157 acres thinned
3.5 mmbf	312 acres project area, 241 acres thinned
0.94 mmbf	406 acre project area, 94 acres treated (70-80 yrs)
1.6 mmbf	182 acres thinned, 1 acre road clearcut (70-80 yrs)
4 mmbf	230 acre project area, 140 acres thinned (70-80 yrs)

[1] Data come from environmental assessments

At the intermediate scale of site selection, the result of resource conflicts also was the reserving of lands. In this case, a site was either categorized as eligible or ineligible for the silvicultural treatments of the study design. During site selection, such eligibility decisions occurred in two spatial units: 1) the project area - often a single section in the BLM checkerboard ownership pattern; or 2) the larger landscape as defined by the distribution of a resource. Exclusion of areas with known resource conflicts was the main resolution of conflicts at this level.

During the early study design, as the objectives were honed and the geographic scope of the study defined, a similar conceptual reserving of the landscape was conducted to restrict the eligibility of lands for site selection. This large scale reserving also was contingent on large scale resource distributions.

MODEL FOR SUSTAINABLE FORESTRY

Implementation of these interagency density management studies can model adaptive forest management and sustainable forestry. Forest managers, resource specialists, and scientists' procedures to resolve conflicting resource production and protection goals are noticed and adopted elsewhere. Combined techniques such as leave trees, leave islands, patch openings, multiple thinning densities, and flexible riparian buffers are merged to tier harvests to site and microsite conditions. For example, careful examination of stream channels led to our variable width riparian buffer zones, which bulge or narrow with topographic and vegetative conditions along stream channels. The site quickly becomes a mosaic of conditions, reflecting the normal range of conditions found in a watershed, province, or region. At multiple spatial scales, areas identified for preservation are retained while areas in which risk to various resources is not apparent or appears acceptable, different forest prescriptions are applied.

A challenge for the broad use of this fine-toothed comb approach to "grooming" site-to-landscape conditions is identifying the resources that should be screened per scale and identifying the scale-specific and across-scale approaches for their integrated management. Our combined density management and riparian buffer studies are providing new information relative to unique resources in headwater subdrainages, to contribute new knowledge relevant to this challenge.

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