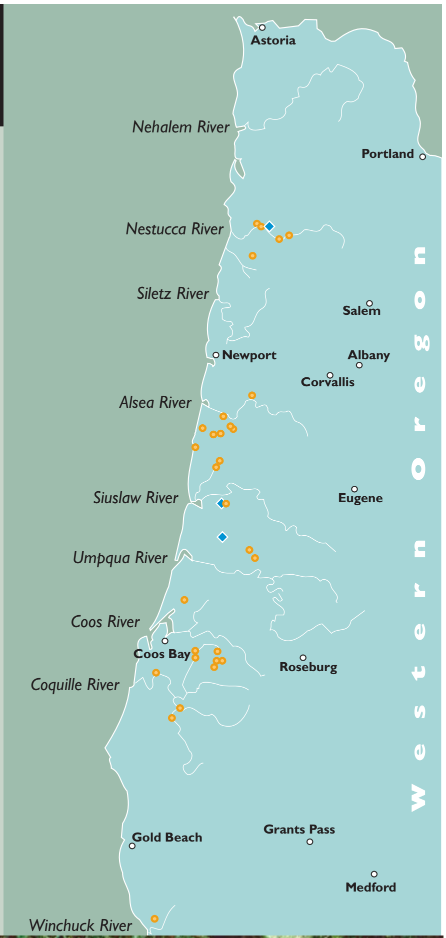
Research Contribution 24

Silviculture Practices for Riparian Forests in the Oregon Coast Range



by

Bill Emmingham

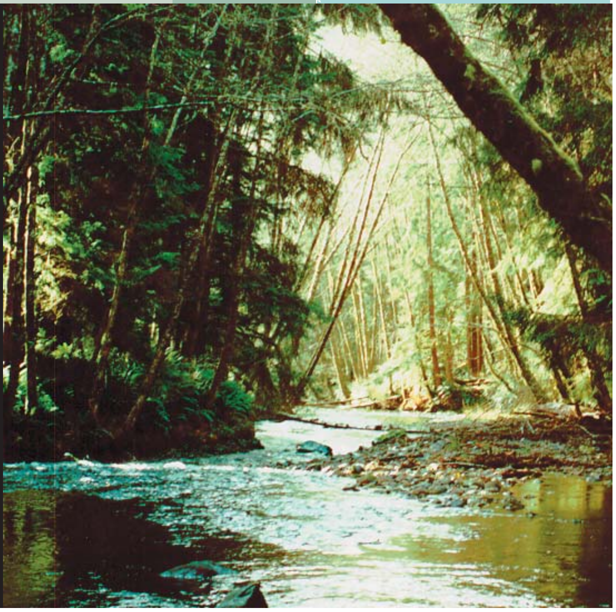
Sam Chan

Dan Mikowski

Pete Owston

Badege Bishaw

March 2000



Oregon State University
College of Forestry

Forest Research Laboratory

The Forest Research Laboratory of Oregon State University was established by the Oregon Legislature to conduct research leading to expanded forest yields, increased use of forest products, and accelerated economic development of the State. Its scientists conduct this research in laboratories and forests administered by the University and cooperating agencies and industries throughout Oregon. Research results are made available to potential users through the University's educational programs and through Laboratory publications such as this, which are directed as appropriate to forest landowners and managers, manufacturers and users of forest products, leaders of government and industry, the scientific community, and the general public.

THE AUTHORS

Bill Emmingham is Professor of Silviculture in the Department of Forest Science, Oregon State University, Corvallis. Sam Chan is Plant Physiologist, Dan Mikowski is General Biologist, and Pete Owston is Supervisory Plant Physiologist (retired) at the Pacific Northwest Research Station, USDA Forest Service, Corvallis. Badege Bishaw is Research Associate in the Department of Forest Science, Oregon State University.

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank William Stein (Scientist Emeritus) and Dean DeBell (Team Leader, Principal Silviculturalist), USDA Forest Service PNW Research Station, Olympia, Washington; Robert Metzger (Fisheries Biologist) and Daniel Karnes (Silviculturalist), USDA Forest Service Siuslaw National Forest, Corvallis, OR; and Walter Kastner Jr. (Silviculturalist), USDI Bureau of Land Management, Salem, Oregon, for their suggestions and review of this manuscript. We wish to extend our appreciation to all the resource managers in the USDA Forest Service, Bureau of Land Management, Oregon Department of Forestry, Oregon Department of Fish and Wildlife, watershed councils, and Oregon State University Extension for providing us with information and insight on their projects. Valerie Banner and Emmalie Goodwin of the PNW Research Station provided considerable assistance with data management.

Support for this project came from the PNW Research Station USDA Forest Service, and the OSU Coastal Oregon Productivity Enhancement Program (COPE).

DISCLAIMER

TO ORDER COPIES

Copies of this and other Forest Research Laboratory publications are available from:

Forestry Publications Office
Oregon State University
256 Peavy Hall
Corvallis, Oregon 97331-5704

Phone: (541) 737-4271
FAX: (541) 737-2668
email: forspub@cof.orst.edu
http://webdata.for.orst.edu/forestry/pubs/frl/

Please indicate author(s), title, and publication number if known.

Cover: Distribution map of riparian restoration sites sampled in this research contribution. Central Oregon Coast Range fish-bearing stream and adjacent hardwood and conifer dominated riparian area.

Research Contribution 24

March 2000

SILVICULTURE PRACTICES FOR RIPARIAN FORESTS IN THE OREGON COAST RANGE

by

BILL EMMINGHAM

SAM CHAN

DAN MIKOWSKI

PETE OWSTON

BADEGE BISHAW

ABSTRACT

Emmingham, WH, SS Chan, D Mikowski, PW Owston, and B Bishaw, 2000. *Silviculture Practices for Riparian Forests in the Oregon Coast Range.* Research Contribution 24, Forest Research Laboratory, Oregon State University, Corvallis.

This publication is aimed at watershed councils, government agencies, and specialists (foresters, wildlife and fisheries biologists) interested in riparian area silviculture or watershed restoration. It contains information on the ecology of riparian forests and a checklist of recommended practices and common mistakes made in restoring conifers to hardwood-dominated riparian forests. Our recommendations are based on 1) an evaluation of 34 riparian restoration projects spanning the Coast Range of Oregon, 2) three case studies of riparian restoration projects, and 3) ongoing research projects aimed at learning how to establish or release conifers in riparian forests. We found that project managers were choosing appropriate conifer species and stock types for planting, but the survival and growth of conifers in the understory were poor. Managers were underestimating the competitive power of shrub and hardwood communities. In some cases, conflicting objectives and lack of priority setting led to the failure of expensive projects. We hope this publication will assist managers in efforts to restore healthy riparian forests and dwindling fish stocks.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Tremendous human energy and financial resources will be expended to protect salmon and steelhead in Oregon through the Governor's Salmon and Watershed Restoration Initiative (Nicholas 1997, IMST 1999) and the Northwest Forest Plan (USDA and USDI 1994). Some of that effort will involve restoration of riparian forests in the Oregon Coast Range. Government agencies will provide regulatory and technical support for these efforts, but most of the work will be accomplished locally. Knowledge gained from recent management experience in riparian forests can help make these efforts more effective both ecologically and economically.

Figure 1. Coastal riparian forest along a fish-bearing stream with a mixture of conifer and hardwood species.

Figure 2. A coastal stream rich in large woody debris provides complex aquatic habitat.

Restoration of conifers to hardwood-dominated riparian forests in the Oregon Coast Range is crucial to the creation of stream habitat favorable to anadromous (seagoing) salmonids (Appendix 1). Riparian forests should contain a mixture of conifer and hardwood species to provide the diverse kinds of vegetative cover, leaf litter, and large wood input to streams that sustain complex aquatic and terrestrial food chains (Hibbs et al. 1991, Hayes et al. 1996, Hibbs and Giordano 1996, Beschta 1997, Gregory 1997, Kauffman et al. 1997, Figure 1). Conifers provide the large logs necessary for complex stream habitat. These large logs are the key elements in debris jams, which foster the development of pools, the accumulation of gravel, hiding cover, and off-channel habitat for fish during high flows (Gregory 1993, Maser and Sedell 1994, Figure 2).

Currently, hundreds of miles of Coast Range riparian areas are deficient in conifers because of early farming practices, homesteads, and timber harvesting (Figure 3). After such distur-

Figure 3. Active farmstead along a stream in the Siuslaw watershed. Past and current practices (including homesteading, clearing, and logging) removed conifers from riparian areas.

We surveyed 34 of these projects to learn more about which management activities worked and which did not. We also studied three restoration projects in detail as case studies, and examined several ongoing research projects. We believe the following observations, discussions, and recommendations will be useful to practitioners, promote more coordination and cooperation among managers, and help focus future research. Our recommendations section is designed to highlight important tips for achieving success in riparian restoration projects.

bance, aggressive hardwoods and shrubs, such as red alder and blackberry, overtopped and killed most conifer seedlings during the early stages of succession (Ahrens et al. 1992, Minore and Weatherly 1994, Hayes et al. 1996, Hibbs and Giordano 1996, Figure 4). The restoration of conifers to riparian forests in hardwood-dominated stream reaches will require both the establishment and the continued vigorous growth of conifers (Newton et al. 1996). This can only be accomplished through the application of sound silviculture to what promises to be a lengthy and costly restoration effort. Lack of understanding or uninformed planning can lead to the creation of poorly designed projects that are expensive in terms of dollars and human energy, but provide few or no long-term benefits (Beschta et al. 1995, Kauffman et al. 1997).

Over the last decade, fisheries biologists and foresters have begun riparian restoration projects and informal trials on federal forests in the Oregon Coast Range. Most of these were small-scale projects initiated by USDA Forest Service or USDI Bureau of Land Management (BLM) to test various restoration approaches. Many projects focused on restoring conifers to riparian areas. Typically, they involved planting conifers in hardwood-dominated forests along streams containing anadromous fish. Many projects also included the reduction of competing shrubs, and some included thinning around conifer seedlings or the creation of gaps in the overstory.

Figure 4. A riparian area (foreground) dominated by red alder and shrubs and deficient in conifer regeneration.

METHODS

SURVEY OF PROJECTS

We contacted Forest Service ranger districts and BLM resource areas in the Oregon Coast Range and requested information on restoration projects. We also contacted the Oregon Department of Fish and Wildlife and the Coquille Watershed Association, who were involved in federally funded restoration work on private lands. Nine of the 10 organizational units we contacted responded by showing us their project sites and completing a survey questionnaire (Appendix 2). A total of 34 riparian restoration projects were documented between mid November 1995 and mid February 1996.

The 34 individual projects were located between the Nestucca River drainage near Tillamook, and the Winchuck River drainage near Brookings (Figure 5). All of the participating organizational units and 29 of the project areas were visited. We asked managers or staff specialists to select projects that had a range of objectives, treatment types, and intensities for inclusion in our study, but not necessarily the largest, most successful, or highest-profile projects. Managers were assured that the information would not be used to criticize the specific management unit or the individual project. Because most projects were initiated too recently to have meaningful long-term results, we focused on the nature of the treatments applied and the reasoning behind them. We selected a variety of projects along perennial fish-bearing streams that managers felt were at least moderately successful and likely to meet their objectives.

The lengthy questionnaire was completed during an interview or independently by one or more project specialists. The questionnaire was designed to obtain standardized information about project objectives, document important physical and biological site conditions, record past and present land use, and examine the silvicultural approaches. It included questions in eight subject areas:

- organizational information
- project objectives
- land use and disturbance

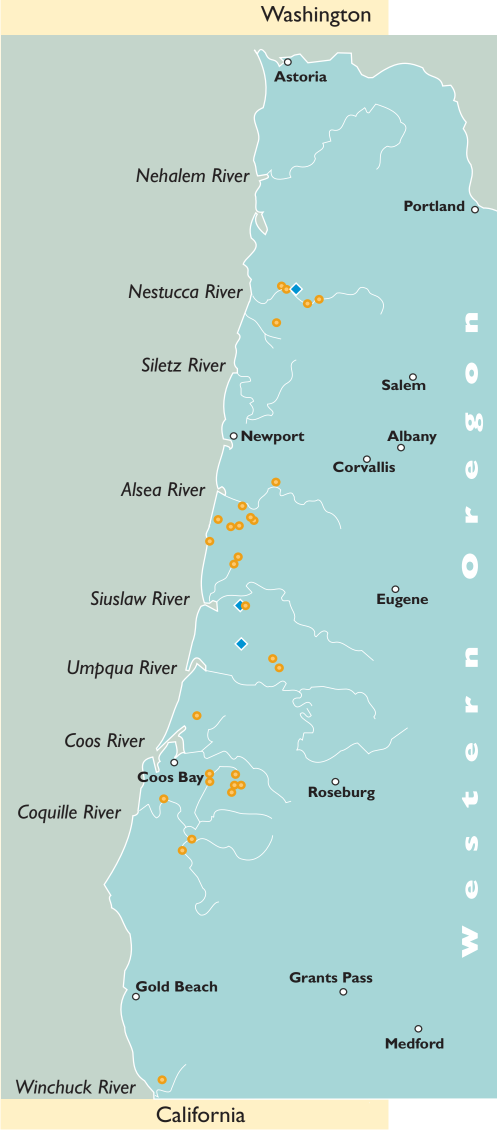


Figure 5. Locations of the major Oregon Coast Range river drainages, as well as the location of 34 surveyed projects (●) and 3 case study sites (◆).

- ❑ site description
- ❑ stream characteristics
- ❑ animal populations and habitat
- ❑ silvicultural prescriptions
- ❑ results, monitoring, and documentation.

Follow-up telephone calls were made to fill in missing information.

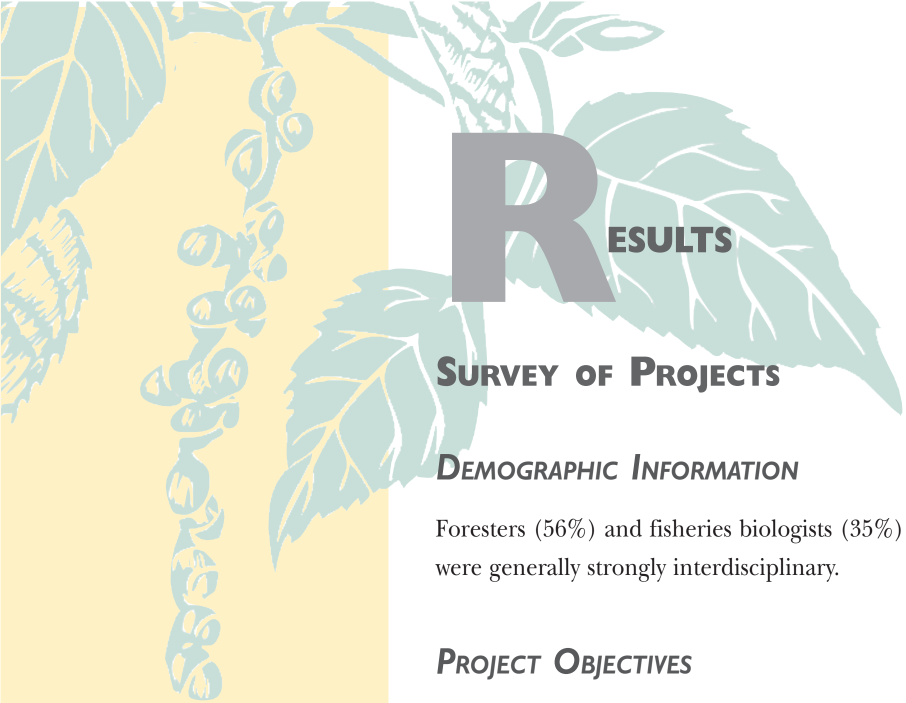
The data were not interpreted statistically because information was collected on subjectively chosen projects. We believe that we obtained a good cross section of projects, but these projects do not represent all federally funded riparian silviculture projects in the Oregon Coast Range.

CASE STUDIES

Three restoration projects were examined 5 years after their establishment in 1991 to determine site conditions, conifer regeneration, and the long-term potential for success. They represented a North-South gradient through the Coast Range (the Nestucca, Siuslaw, and Umpqua River basins; Figure 5). These were among the oldest riparian silvicultural projects reviewed. Our objectives were to (1) assess these projects more completely than the surveyed projects and (2) use them as a basis for discussing the effectiveness of riparian management practices.

In the fall of 1996, we visited the three selected sites and marked out three 0.02-ha (0.05-ac) plots on each of them. We then measured the height and diameter of conifer seedlings and the height of associated shrubs on each plot. We examined three plots at each case study site so that we could measure seedling responses to different overstory and understory conditions. The overstory canopy conditions we measured included percent cover, live crown ratios, and species composition. Fisheye photography (Chan et al. 1986, Rich 1990) was used to estimate the percentage of full light reaching seedlings, and ocular estimates of canopy cover (Howard and Newton 1984) were made at plot centers. Basal area was sampled by using a 20-factor prism. The two dominant understory shrubs and herbs on each plot were measured for cover and potential maximum height.

Data from these plots were used in two ways. First, they were summarized to provide a description of plot conditions. Second, individual seedling responses, such as height growth or height-to-diameter (H/D) ratios were plotted against site variables describing growing conditions for trees measured on each plot (e.g., shrub cover or available light).



RESULTS

Survey of Projects

Demographic Information

Foresters (56%) and fisheries biologists (35%) were often the project leaders, but projects were generally strongly interdisciplinary.

Project Objectives

The primary objectives for sampled projects were to restore riparian forests by improving forest structure in the short term and provide for coarse woody debris in the long run (65%) or restore the diversity of natural plant communities (21%) (Table 1). A primary goal in accomplishing these objectives was to establish or release conifers in hardwood-dominated riparian forests. The improvement of water quality and temperature was not usually a high priority, presumably because both were considered adequate. Commercial wood production was never a priority.

Project areas were selected for treatment mainly for biological/ecological (44%) or social/political (29%) reasons.

Table 1. Objectives of riparian silviculture ranked according to managers' priorities.

	Percent of Managers (n = 34)	
Objectives	1st priority	2nd priority
Woody debris / structures / stream restoration	65	53
Diversity of riparian zone vegetation and structure	21	35
Water temperature and quality	14	6
Wildlife habitat and enhancement	0	6
Future source of commercial wood products	0	0

Land Use and Disturbance

Most of the project sites had been influenced by both human (91%) and natural (85%) disturbance. Human disturbances included homesteading, logging, and road building. Natural disturbances included wildfire, floods, debris torrents, and wind. Managers cited fire suppression, settlement, changes in stream channel morphology, social reasons, and policies of the agency as current or potential constraints on these dynamic "natural" disturbance processes.

SITE DESCRIPTION

Most sites were forested (88%) and situated on benches or terraces with well-drained soils. Forest stands were either a hardwood-conifer mixture dominated by hardwoods (56%) or pure hardwood (26%); 12% were not forested. Surprisingly, about half the stands were classed as uneven-aged because they did have some larger and/or smaller conifers mixed with the dominant hardwoods. About two-thirds were less than 40 years old.

STREAM CHARACTERISTICS

Most projects (88%) were smaller than 8.1 ha (20 ac) and extended along less than 2.42 km (1.5 mi) of fish-bearing stream (Table 2). Restoration activities were concentrated within 30 m (100 ft) of the stream. The streams were partially or totally shaded (88%). Small streams (4th order or less) were selected most often (77%) for treatment (Figure 6, Table 3). The amount of woody debris ranged from low to none in 74% of the stream reaches. None of the stream reaches had abundant woody debris and only 26% of the stream reaches had woody debris >30 cm (12 in.) in diameter (Figure 7).

Table 2. Fish-bearing stream lengths that were treated (both sides) within the project areas.

Length of treated stream		
Kilometers	Miles	% of projects
0.16–0.80	0.1–0.5	42
0.96–2.40	0.6–1.5	32
2.56–4.00	1.6–2.5	13
4.16–5.60	2.6–3.5	10
>5.60	>3.5	3

Table 3. Distribution of stream orders in project sites.

Stream order	% of projects
1st	0
2nd	18
3rd	26
4th	23
5th	21
6th	9
7th	3

Stream orders after Straehler 1957.

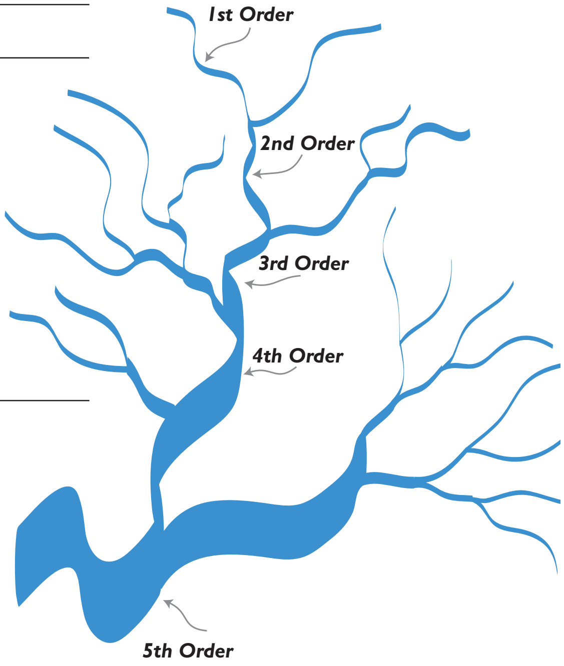


Figure 6. Stream order is judged by the number of tributary streams that join above a stream reach. A fourth-order stream is formed when two third-order streams join (Straehler 1957).

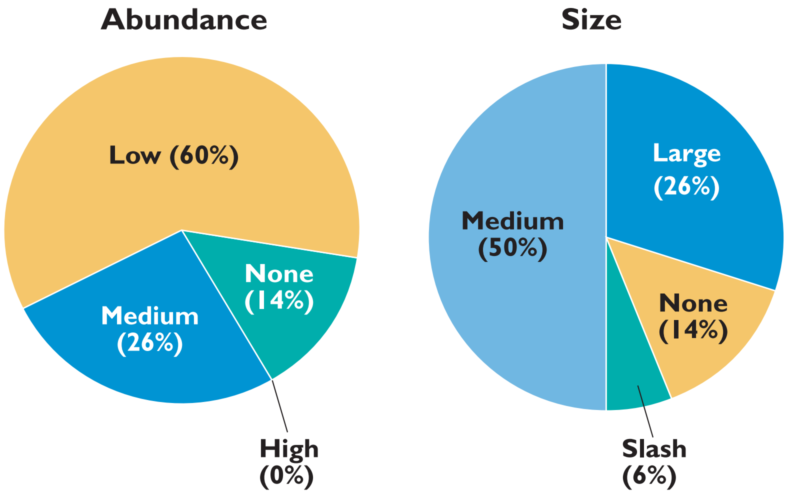


Figure 7. Abundance and size of coarse woody debris in streams on project sites. Professional experience was used to determine abundance. Most streams had low amounts of medium-size woody debris. Size of debris was measured according to the following guidelines: slash <7.5 cm (<3 in.), medium = 7.5–30 cm (3–12 in.), large >30 cm (>12 in.).

SILVICULTURAL PRESCRIPTIONS

The most common silvicultural treatments were release of existing conifers or planting conifer seedlings in the understory. Release of advance conifer regeneration from overstory hardwood cover was prescribed on 44% of the projects (Figure 8). The other 56% of projects had little advance regeneration in the understory. Only 21% of the overstory release sites had advance tree regeneration greater than 10 cm (4 in.) in diameter at breast height (dbh). Most of the advance regeneration released had live crown ratios between 33% and 50% of total tree height.

Underplanting of conifers was prescribed for 97% of the projects. Managers often planted more than one tree species and chose large planting stock (1+1, 2+1, and Plug+2; Figure 9). Douglas-fir, western redcedar, or western hemlock seedlings were commonly planted (59%), however Sitka spruce and grand fir were added to the mixture on a few sites. Coast redwood was planted on the southernmost site. Most trees (90%) were planted at a spacing of 4.5 m by 4.5 m (15 ft by 15 ft) or less, and half the sites were planted at spacing of 3 m by 3 m (10 ft by 10 ft) or less.

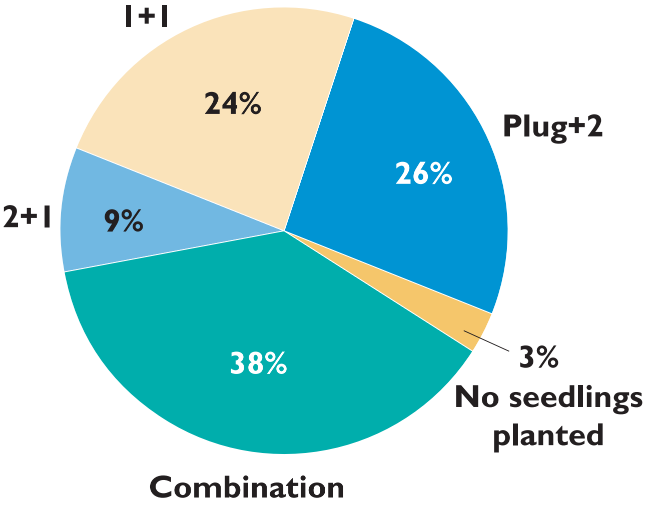


Figure 9. Percentage of projects planted with various seedling stock types. Stock types: 1 + 1 = seedlings grown in a nursery bed (NB) for 1 year, then in a transplant bed (TB) for 1 year; 2 + 1 = seedlings grown in NB for 2 years, TB for 1 year; plug + 2 = seedlings started in plugs, then grown in TB for 2 years.

Figure 8. Advance natural regeneration released from the hardwood-dominated overstory.

Most managers (85%) anticipated that animal damage to seedlings would be serious (Figure 10). They were right; browse damage on underplanted trees was reported for 71% of sites. Mechanical protection (Figure 11) in the form of plastic cages was used on 88% of sites, and added protection (garlic, netting, or fencing) was applied on 38% percent of sites. Only one project did not have some form of animal protection.

In all cases, managers treated existing understory shrubs or herbs to reduce competition with conifers. Manual cutting of understory shrubs was almost universal (94%). On 80% of the projects, shrubs were treated annually; the remainder were treated in alternating years. Cutting shrubs in the entire planting block (Figures 12A, 13) was a less com-

Figure 10. Stream beavers often fell riparian trees and damage planted seedlings. Note that the beavers removed the seedling protected by the plastic mesh tube (lower left) and felled the alder tree.

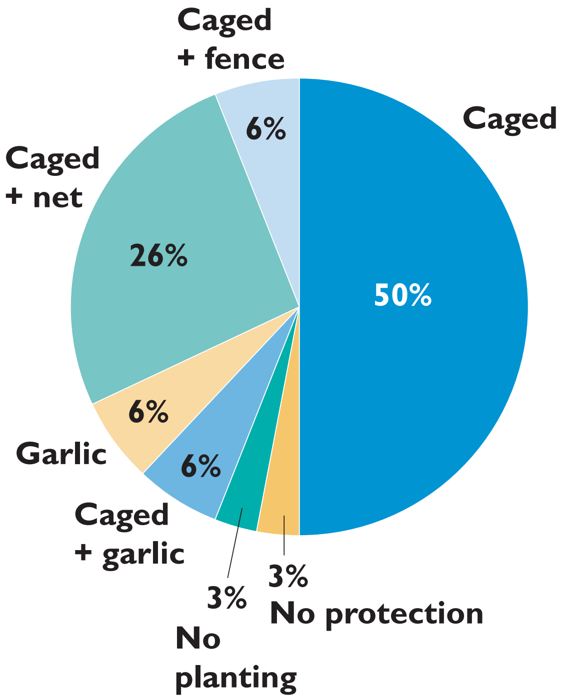


Figure 11. Percentage of projects that included various forms of protection from animals.

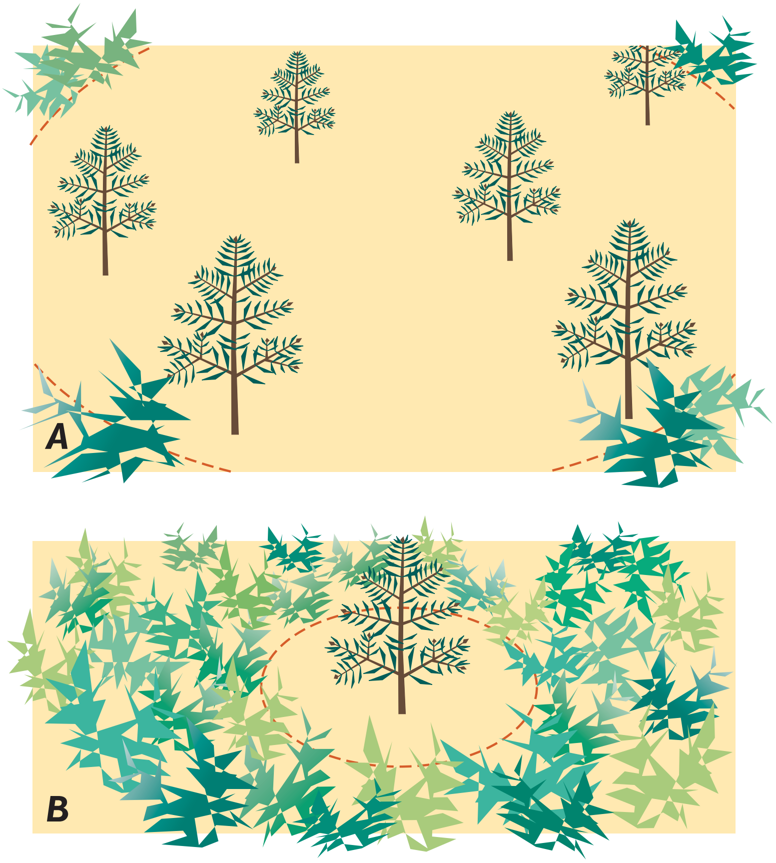


Figure 12. To reduce competition, understory shrubs were (A) cut over the entire planting block (block cut) or (B) cut within a small circle around conifer trees (circle cut). Trees were spaced 2–8 m (8–25 ft) apart in the block cut. In the circle cut, the radius of the circle was 1–1.5 m (3–5 ft).

mon (32%) practice than was cutting them in a small circle around the seedling (62%; Figures 12B. 13). Use of mulch blankets or scalping around seedlings was rare. Shrubs were most often cut within a radius of 0.9 m (3 ft; 29%) or 1.8 m (6 ft; 27%) around the conifer seedling. Most (79%) understory treatments were applied during the spring and summer when manual cutting is most effective in reducing the regrowth of the understory (McDonald et al. 1994, Zasada et al. 1994, Table 2).

The overstory was thinned to release the understory conifers on 53% of the sites. Patch cuts were used to create gaps of up to 0.08 ha (0.2 ac) in 12% of the projects. Most of the overstory treatments were applied during the winter, summer, or both winter and summer (Table 4). Although overstories in 65% of the projects were treated one or more times, in 35% of the projects conifers were underplanted without overstory treatment.

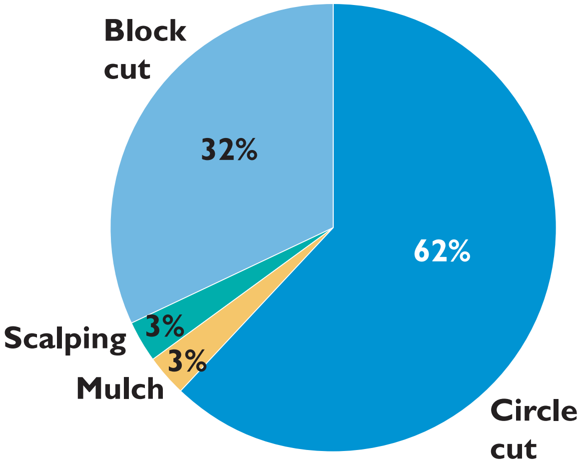


Figure 13. Understory treatments applied around seedlings in projects. Block cut: understory shrubs are cut on an entire block of planted seedlings (Fig. 12A). Circle cut: understory shrubs are cut in a circle around each seedling (Fig. 12B). Mulch: individual seedlings are mulched with heavy cloth. Scalping: Vegetation is removed down to the mineral soil level around each seedling.

Table 4. Season that overstory and understory treatments were applied.

Season	Overstory (%)	Understory (%)
Winter	9	15
Summer	35	53
Spring	18	26
Fall	3	6
Winter and summer	35	0

MONITORING AND DOCUMENTATION

Planned monitoring of the effectiveness of riparian silviculture was not emphasized by the managers.

CASE STUDIES

Characteristics of the three case study sites are listed in Table 3. On each site, conifer seedlings had been planted in gaps in alder-dominated forests along a stream (Figure 14). Overstory treatments varied from none at Cedar Creek, to felling of overstory trees in 0.04-ha (0.1-ac) patches at Spencer Creek, to girdling in 0.08-ha (0.2-ac) patches at East Creek (Figure 15). Understory shrubs had been treated initially to reduce competition at each of the sites. Additional treatment of shrub competition varied in frequency and timing, but included cutting of all shrubs in planted tree blocks near the end of the 5-year period. In every case, conifer seedlings had considerable overhead shading and competition for light after 5 years. There was no effective control of herb competition, which tends to increase as shrubs are reduced.

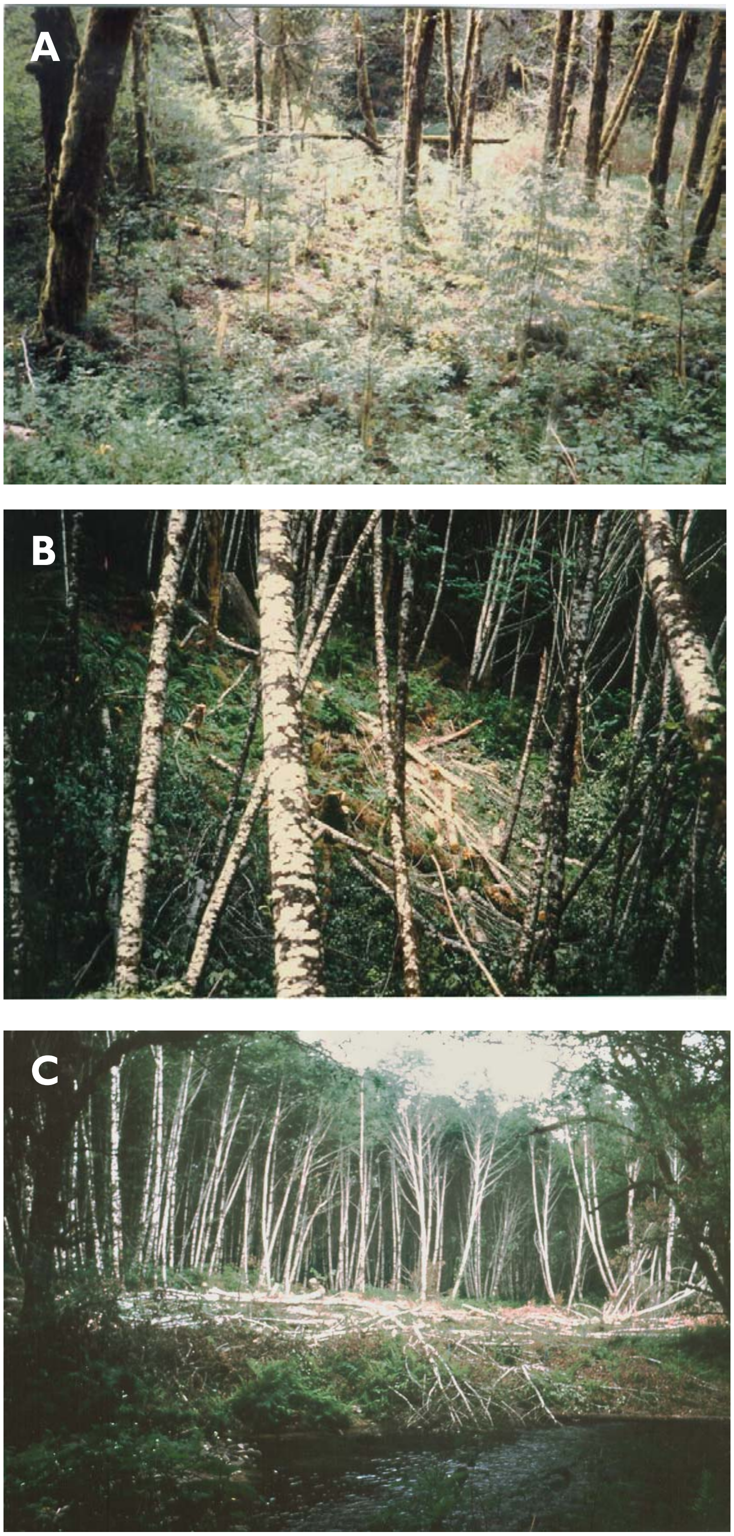


Figure 14. Sites were treated by thinning (A) the overstory or cutting (B) small [0.02 ha- (0.05-ac)] to (C) large [0.08-ha (0.20-ac)] gaps to create more favorable growing conditions for young conifers.

Measurements of height and diameter on 5th-year seedlings revealed that seedlings are affected by competition from both overstory and understory vegetation. Generally, seedlings planted at Cedar Creek in small, natural openings were smaller than seedlings in the 0.04-ha (0.01-ac) opening at Spencer Creek, which in turn were smaller than those planted in the 0.08-ha (0.2-ac) opening at East Creek (Table 5). Fifth-year tree height was less where competing shrubs were taller (Figure 16). One exception was at East Creek, where short redcedar seed-

Table 5. Location, vegetative characteristics, and treatment in three case study areas in the Oregon Coast Range.

	Overstory				Understory[1]					
Site/Drainage basin	Dominant species	Canopy cover (%)	Basal area m^2/ha (ft^2/ac)	Treatment/ type of opening	Dominant species	Cover (%)	Height (cm)	Available skylight	Tree seedlings planted	5th-yr conifer ht (cm)
Cedar Creek/ Siuslaw	Alder, maple	75	45.3 (220)	None/ small natural	Salmon-berry	85	367	25	Sitka spruce, western redcedar	145
Spencer Creek/ Umpqua	Alder, hemlock	27	27.2 (120)	Felling/ 0.04 ha (0.10 ac)	Elderberry	73	393	45	Douglas-fir, grand fir	222
East Creek/ Nestucca	Alder	15	18.1 (80) 0.08 ha (0.20 ac)	Girdling, felling/	Trailing blackberry	17	83	53	Douglas-fir, Sitka spruce	256

[1] Understory treatment on all sites was a block cut.

Figure 15. Openings in the overstory can be made by felling or girdling (A) selected trees. Girdled trees die and fall within a few years, creating openings (B). Falling trees can damage planted conifers. The seedling in this photo has been pinned beneath the fallen tree (C).

lings had been heavily browsed by elk despite the lowest level of shrub competition. The second exception was at Spencer Creek, where trees that had grown to 2.0–3.4 m (6.6–11.1 ft) tall during 3 years with low competition, were then overtopped by 6-m (20-ft) tall shrubs after release treatments ceased. Timely and repeated release of young conifer seedlings from shrub competition appeared critical to survival and growth.

None of the trees sampled received >62% of full light in the open (estimated from fisheye hemispherical photography), and over half of the trees had <40% of full light. The shortest unbrowsed seedlings were found at the lowest light levels (Figure 16). The H/D ratios of the 5th-year seedlings (including Douglas-fir, Sitka spruce, and western redcedar) showed a marked increase (from about 70 to about 120) when available light dropped below 40% of full light (Figure 17). We found no Douglas-fir trees with height-to-diameter ratios >100 in our case study sites.

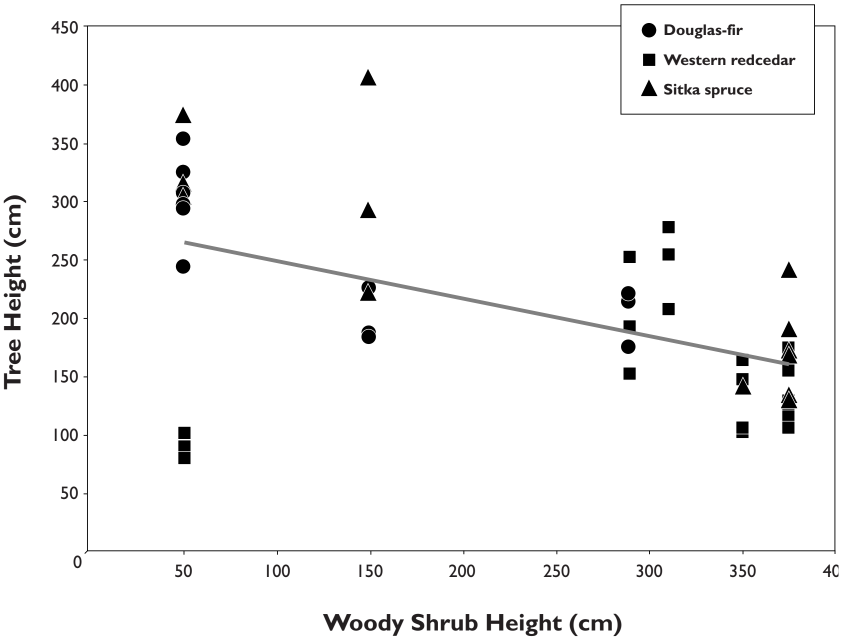


Figure 16. Height of trees 5 years after planting in relation to understory shrub height. The exceptions are western redcedars (in the lower left portion of the figure) that were repeatedly browsed by elk.

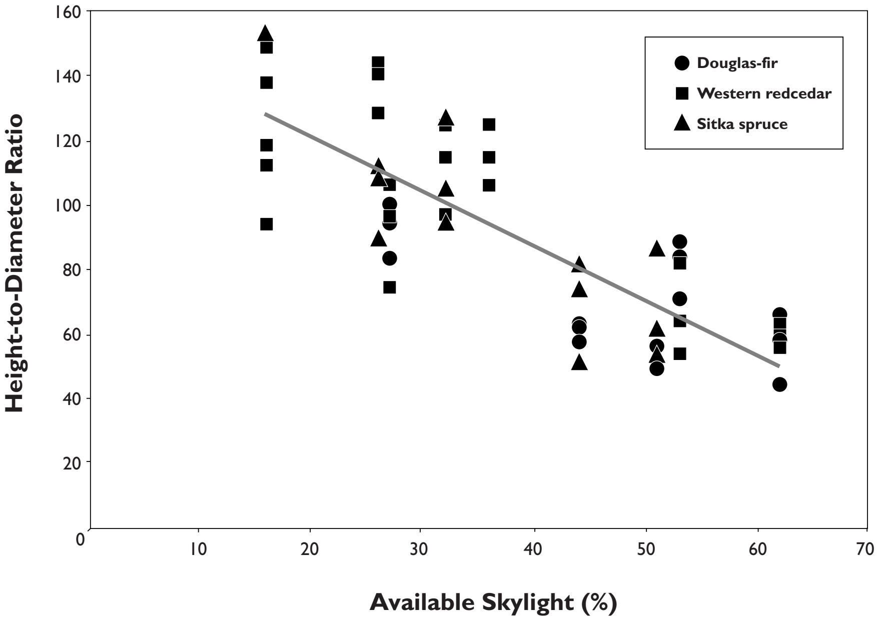
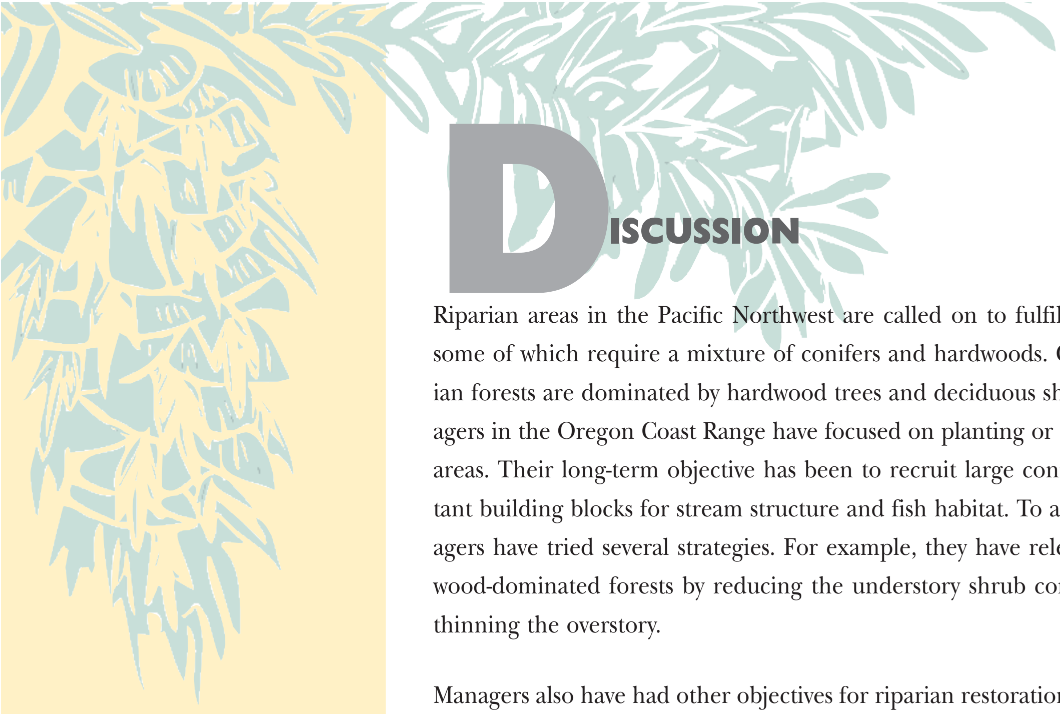


Figure 17. The height-to-diameter (H/D) ratio of seedlings 5 years after planting shows a negative relationship to percentage of available light. Trees with a ratio of <60 are considered vigorous, 60–100 are adequate, >100–120 are at risk, and those above 120 face imminent mortality. Thus, light levels above about 40% have favored healthy growth patterns in all three tree species planted.



DISCUSSION

Riparian areas in the Pacific Northwest are called on to fulfill many ecological functions, some of which require a mixture of conifers and hardwoods. Currently many coastal riparian forests are dominated by hardwood trees and deciduous shrubs. Therefore, forest managers in the Oregon Coast Range have focused on planting or releasing conifers in riparian areas. Their long-term objective has been to recruit large conifer debris to provide important building blocks for stream structure and fish habitat. To achieve these objectives, managers have tried several strategies. For example, they have released conifers beneath hardwood-dominated forests by reducing the understory shrub community and, in most cases, thinning the overstory.

Managers also have had other objectives for riparian restoration projects, such as rebuilding natural plant communities and creating wildlife habitat. Improving water quality or temperature was seldom an objective, because most project sites were considered adequately shaded. In no case was restoration work directed toward commercial wood production.

These goals and objectives appear to be logical given the high societal demand to restore salmon runs (Nicholas 1997) and our understanding of stream ecology (Gregory et al. 1991, Maser and Sedell 1994, Gregory 1997, Naiman et al. 1998).

It is important, however, to realize that successful restoration of conifers will require an active approach, including marked reduction of competing shrub and overstory trees, at least in patches. The conservative nature of the silvicultural approaches applied in many projects suggests that some managers ignored the high probability of failure without aggressive and effective control of competing vegetation. Our survey of competing vegetation revealed a basic conflict in carrying out the objective of growing large conifers: one-quarter of the projects were at the same time trying to minimize impact on the existing overstory. In addition, we observed that thinnings or creating gaps were done so conservatively that they failed to provide adequate release of existing or underplanted conifers. The message is clear: It is a waste of time and resources to attempt restoration of conifers in areas where other resource values will preclude an aggressive approach to establishing conifer dominance. Since conifer restoration can be applied in patches, such conflicts should be easy to avoid.

Unfortunately, the growing conditions provided by the conservative treatments applied in many restoration projects will not lead to development of large conifer trees [dbh 60 cm (>2 ft)] in the 21st century. Most of the conifers will not survive the combination of poor growing conditions and animal damage. Active management of both overstory and understory to give conifers plenty of growing space is the only way to promote conifers into a dominant (free-to-grow) position.

KEY ECOLOGICAL CONCEPTS

Knowledge of Coast Range forest ecology and stand dynamics is important in planning for success. An understanding of several ecological concepts is critical:

1. Coast Range hardwoods are fast growing and capable of dominating riparian forest sites (Hibbs et al. 1994, Biring et al. 1996). Red alder and bigleaf maple will dominate most sites for a century after conifers have been removed, either selectively or in clearcuts. Both of these situations are widespread in areas logged prior to changes in Oregon Forest Practices Act Rules in 1973 and 1994 (Carlton 1988, Minore and Weatherly 1994, Hayes et al. 1996, Hibbs and Giordano 1996, Chan et al. 1997). The large area of hardwood-dominated riparian forest in the Coast Range today is testimony to the reproductive capability of hardwoods and their ability to dominate sites for long periods.
2. Conifers do not necessarily regenerate and succeed hardwoods naturally without additional disturbance. Tall shrubs in the Coast Range, such as salmonberry, are capable of dominating sites for decades or even centuries (Carlton 1988, Froyd 1993, Pabst and Spies 1998). Nierenberg (1996) found that half of the areas along “undisturbed” (no human disturbance) Coast Range streams had no trees.
3. None of the northwestern conifers are adapted to grow through hardwood-dominated stands in time frames of a few decades. Growth studies indicate that with active management, such as thinning or creating gaps, it may take a century to grow conifer trees large enough [60 cm (24-in.) in diameter] to provide keystone material for stream structure.
4. Alder stands are extremely dynamic, and can reach full site occupancy from relatively low stocking levels in a decade or two (Emmingham et al. 1989, Puettmann et al. 1993, Hibbs et al. 1994, Hibbs 1996). Alder tree crowns can expand through tree height and branch growth, as well as through epicormic branching along the entire length of the tree bole. Thus, the ability of hardwoods to reoccupy a site following thinning should not be underestimated.
5. The large body of knowledge about regenerating upslope areas after clearing can be applied to restoration of riparian forests. Competitive relationships, for example, are similar in upslope and riparian forests.
6. Large conifer material useful for stream structure comes from headwall areas (see Figure 18), as well as from the immediate vicinity of the lower stream reaches. The floods of 1996 provided a forceful reminder of the importance of headwall wood supply and energy-packed debris avalanches and floods for modifying stream structure. Such events, though dramatic and apparently destructive, deliver gravel and large woody debris that are important building blocks for structurally complex streams (Reeves et al. 1995). Thus, it is not necessary to grow all future large conifer debris in the immediate streamside.

A WATERSHED PERSPECTIVE

A watershed perspective is helpful when considering management options. Headwater drainages with first- and second-order streams (Figure 18A, B) form a large part of the forest landscape. Storm events can trigger headwall failures and debris flows that transport huge amounts of large woody debris, sediment, gravel, and boulders to lower stream reaches. These materials provide important elements of complex riparian and aquatic habitat. Headwater forest areas are often nearly pure conifers, and thinning these forests will promote the development of large trees.

Second- and third-order streams (Figure 18B, C) often flow through narrow, constrained reaches with steep hillsides. Floodplains and terraces are usually narrow. Where hardwoods dominate the forest, suppressed conifer regeneration may be released by overstory thinning or creating gaps. Where conifers are planted, they will benefit from reduction of heavy shrub or herbaceous competition. The steep terrain often provides topographic shading of streams.

Higher-order streams (Figure 18D) form alluvial valleys that provide more complexity, including wide terraces and side channels or pools that are important for fish refuges during high-water periods. Complex microsites create both challenges (shrub competition and animal browsing and clipping) and opportunities (deep soils for planting and tending conifers) to provide a diverse mix of trees to enhance riparian functions. Stream shading can be created by planting on the south side of streams, or retained by placing gaps, thinning stands, or releasing conifers on the north side of the stream. Many of these areas are farmed or pastured, so securing active cooperation from private landowners is critical.

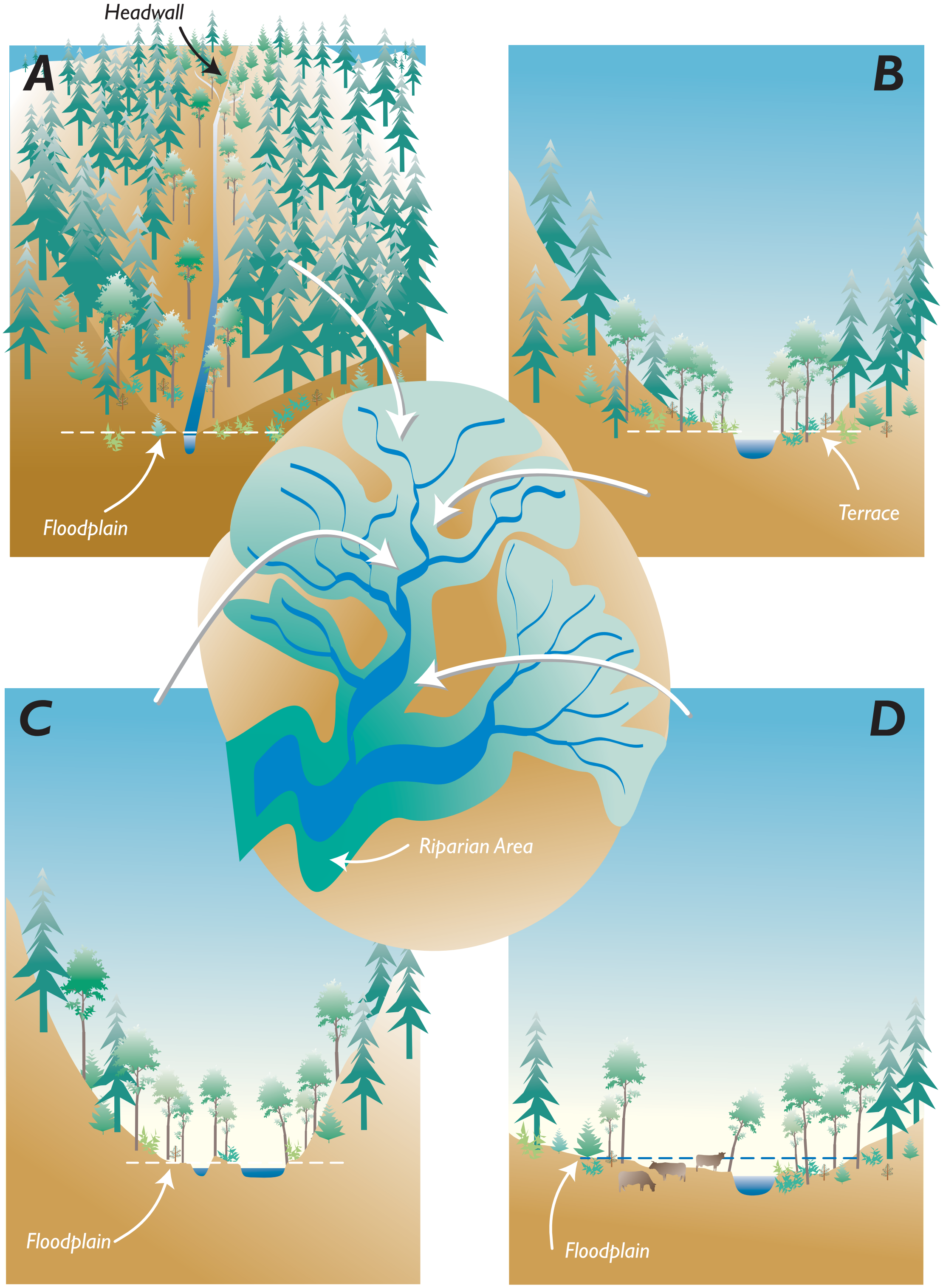
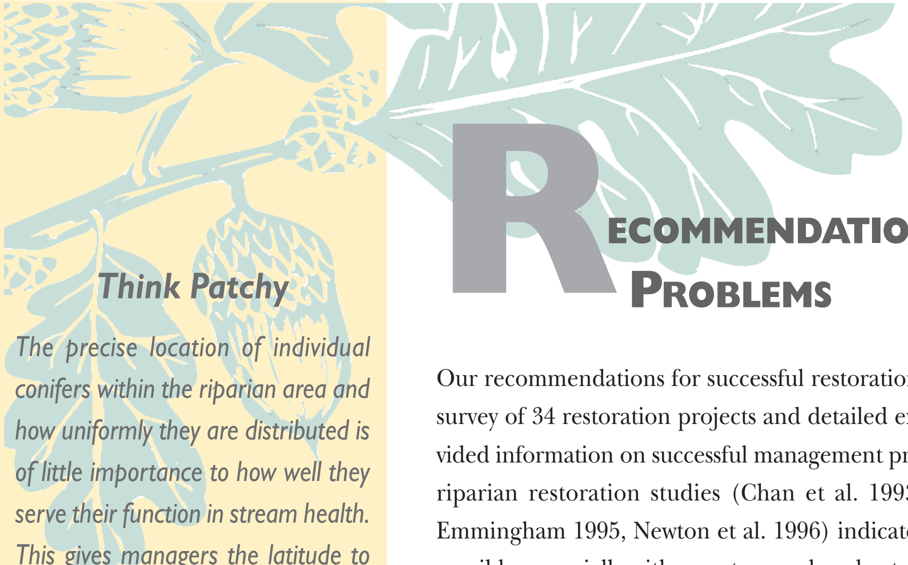


Figure 18. Site selection and silviculture options and opportunities: geomorphic characteristics of a small watershed showing A) first-order streams and headwalls; B) second- and third-order streams and terraces; C, D) fourth- and fifth-order streams and associated floodplains. Hardwood species dominate terraces and floodplains; mixed hardwoods and conifers dominate toeslopes near streams with few conifers for release; conifers dominate headwalls.



RECOMMENDATIONS AND COMMON PROBLEMS

Think Patchy

The precise location of individual conifers within the riparian area and how uniformly they are distributed is of little importance to how well they serve their function in stream health. This gives managers the latitude to capitalize on opportunities for release of conifers where they occur. Thinnings or gaps created to enhance light for understory conifers may be done on the north side of the stream, where they do not provide direct shade on the stream during the heat of the day, to preserve the shading canopy on the south side. Thinning just outside a narrow no-cut buffer of 6–9 m (20–30 ft) would have minimal impact on stream shading (Newton et al. 1996).

Management of small clusters of conifers (either planted or released) in gaps of 0.10–0.41 ha (0.25–1.0 ac) or more in size can provide needed conifers. Try planting clusters of 5–10 trees at a close spacing [1.8–2.4 m (6–8 ft)] to capture growing space for conifers. Eventually, only one or two of the planted trees need grow to a large size to provide ample conifer woody debris. In the meantime, capturing the local site resources for conifers will ensure that conifers occupy that small site.

Our recommendations for successful restoration projects are based on several sources. Our survey of 34 restoration projects and detailed examination of three additional projects provided information on successful management practices. In addition, preliminary results from riparian restoration studies (Chan et al. 1993, Emmingham and Mass 1994, Maas and Emmingham 1995, Newton et al. 1996) indicate that successful establishment of conifers is possible, especially with overstory and understory treatments to reduce competition. Long-term studies of reforestation of upland sites (e.g., Curtis et al. 1998) provided useful information.

Once a decision to restore conifers to hardwood-dominated areas is reached, the following guidelines will be useful.

SITE SELECTION

Select areas to be treated carefully, after considering the needs of the entire stream system (Figure 18). High priority should be given to areas with releasable conifers, especially if they have grown above the shrub layer. Restrict project size to what can be maintained decades into the future.

Common Problems: Because selection of treatment sites is often tied to funding from harvest units, the sites chosen are not necessarily those with the highest need for restoration or the highest potential for success.

PLANTING

Plant large stock types (Newton et al. 1993). Good seedlings have abundant root mass in proportion to tops, average 30–45 cm (12–18 in.) in length, and have a stem caliper of 5 mm (0.2 in.) or more. Good stock types include Plug +2, 1+1, and 2+1. Western hemlock, western redcedar, Douglas-fir, and grand fir are widely appropriate where overstory and understory competition is to be effectively treated. Sitka spruce and western hemlock are appropriate within the fog belt. Planting Douglas-fir should be avoided in the fog belt or other areas where Swiss needle cast (*Phaeocryptopus gaeumanii*) is prevalent and in areas that will be inundated during winter flooding (Minore 1970, 1979, Zaerr 1983). Western redcedar and Douglas-fir are prone to heavy damage by deer, elk, and mountain beaver.

Common Problems: Planting seedlings that are too small, planting large trees with poorly balanced ratios of shoot-to-root, and poor planting practices. Planting trees, especially Douglas-fir, in chronically flooded, low-lying areas. Planting western redcedar and Douglas-fir without protection from deer, elk, and mountain beaver.

RELEASE

Release any conifer species that has become established on stable ground near streams. Early results from studies on releasing advance conifer regeneration in hardwood-dominated riparian zones (Emmingham and Maas 1994, Maas and Emmingham 1995) indicate that all conifer species with a live-crown canopy to tree-height ratio of 30% or greater can be successfully released. In judging the vigor of conifer seedlings or saplings, long live-crown ratios (over 40%) and relatively small (<60) H/D ratios are good (Figure 19). Overstory canopy should be reduced to permit a minimum of 40% full sunlight (Chan et al. 1996, 1997).

Wherever partial hardwood canopy is to be retained, give preference to shade-tolerant species (hemlock, redcedar, spruce). Where Douglas-fir has established, however, it will respond to release nearly as well as the more shade-tolerant species (Emmingham and Maas 1994). All northwestern conifers will grow best under the higher light levels associated with heavy overstory thinning.

Common Problems: Too little reduction of overstory and understory vegetation will relegate overtopped conifers to extremely slow growth indefinitely. Slow-growing conifers are at high risk of mortality from beaver girdling, suppression, or breakage when larger overstory trees die and fall.

OVERSTORY TREATMENT

Reduce overstory density. Thin to space alder or maple trees to at least 9 m (30 ft), or thin to 6 m (20 ft) apart, and plan for repeated thinning every decade. Use large gaps, or better yet, combine gaps with thinning. Where gaps alone are used, start with a minimum size of 0.2 ha (0.5 ac). Treatments that drastically reduce competition from overstory hardwoods are essential for satisfactory growth of understory conifers (Emmingham and Maas 1994, Minore and Weatherly 1994, Maas and Emmingham 1995, Chan et al. 1996, Hibbs and Giordano 1996, Newton et al. 1996, Chanet al. 1997).

Creating larger gaps will promote better seedling growth for longer periods. A gap of 0.2 ha (0.5 ac) has a radius of 24.9 m (83 ft). Since gap size is measured from tree bole to tree bole, the effective gap for light is actually much

Judging Tree Vigor Using Height-to-Diameter Ratios

The height-to-diameter (H/D) ratio of trees is a sensitive measure of tree vigor and response to competition from overtopping and encroaching vegetation (Cole and Newton 1987). Height-to-diameter ratio is determined by measuring a tree's height and diameter in the same units of measurement. A low H/D ratio (<60) indicates a sturdy tree with enough girth to support the tree. A high ratio (>100) indicates a tall skinny tree, with possible support problems, and low vigor (Figure 19). Understory conifers with a high ratio are likely to have a poor root system and may topple over during snow or wind storms.

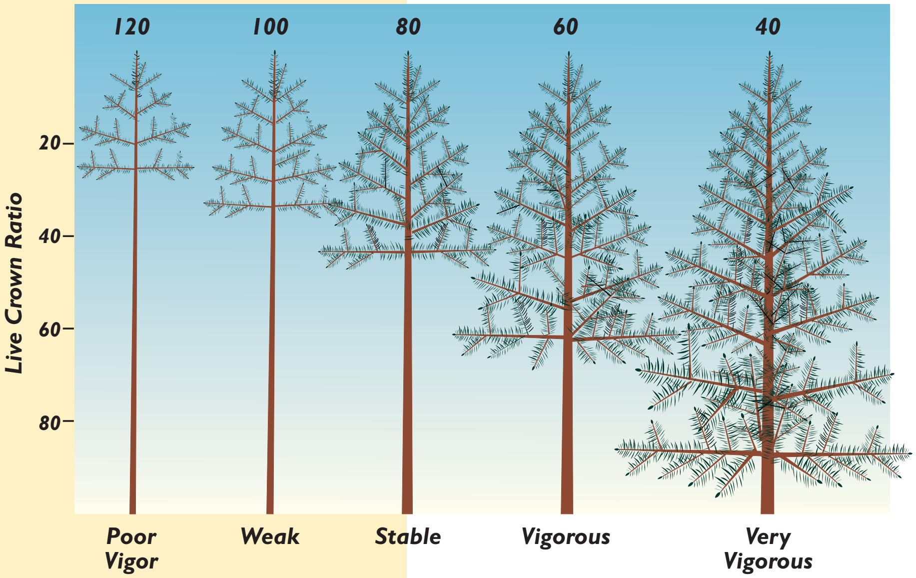


Figure 19. Morphological characteristics of heavily shaded to open-grown conifer seedlings/saplings: height-to-diameter ratios of (A) 120 = poor vigor, (B) 100 = marginal, (C) 80 = stable, intermediate vigor, (D) 60 = vigorous, and (E) 40 = very vigorous. The live crown ratio is also used as an indicator of vigor. Live crowns more than 40% of the total tree height are considered good.

smaller. Hardwoods commonly have a crown radius of 4.5–7.5 m (15–25 ft), so effective gap size for light penetration is only 0.12–0.10 ha (0.33–0.25 ac).

Common problems: Not reducing overstory cover. Thinning too little with no follow-up thinning. Creating gaps that are too small.

UNDERSTORY VEGETATION MANAGEMENT

SHRUBS

Reduce shrub competition for conifers less than 3 m (10 ft) tall. If shrub control is restricted to manual cutting, cut large gaps [1.8–3.0-m (6–10-ft) radius] around conifers or, better, cut all shrubs in the planting areas. Cut annually in June or July, because vigorous salmonberry, blackberry, and thimbleberry shrubs can grow to most of their initial height within one year of cutting. Herbicides, where acceptable to the owner, are very cost effective. Choose a mix appropriate for the shrub component and follow US Environmental Protection Agency (EPA) and herbicide label guidelines.

Overstory reduction will stimulate the growth of understory shrubs and herbs. The shrub layer will grow taller and denser following overstory thinning or gap creation. This will create the need for further treatment of the understory (Figure 20).

Common problems: Not treating shrubs. Too conservative reduction of shrub cover. Clearing too small an area [<1.8-m (<6-ft) radius] around conifers, or cutting less often than annually, or cutting outside the optimum times (June-July). Not using herbicides when they are available.

Figure 20. With 6 years of active vegetation management to reduce salmonberry shrubs, conifers planted in a heavily thinned alder stand are well established.

Herbicide Notes

Perhaps the most significant challenge small conifers face in the riparian forest comes from competing overstory and understory plants. Manual methods of controlling competing vegetation are very expensive and often only marginally successful without repeated treatments. There is also a substantial safety risk for workers. Although for various reasons many managers are reluctant to use herbicides, proper application of herbicides offers an effective alternative method for controlling both herb and shrub competition (Knowe and Stein 1995, Newton et al. 1996, Radosevich et al. 1997). Herbicides are also effective in selectively killing hardwood trees by injection (Emmingham et al. 1989, Helgerson 1990, Newton et al. 1996). Accident rates are lower than with chainsaw felling of trees. A study on the application of glyphosate (N-(phosphoromethyl) glycine) in buffer areas dominated by red alder indicated that the levels of glyphosate applied in the study did not have a direct effect on sampled amphibian species (Cole et al. 1997). Changes in the abundance and diversity of amphibians sampled were directly attributed to changes in the plant community habitat. A foliar-active herbicide, such as Accord, will kill many herbs and shrubs, and effects will last for a year. Some effects of a soil-active herbicide, such as Velpar (hexazinone(3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione), would last into the second growing season. In contrast, shrubs or herbs cut by mechanical means begin growing new shoots immediately. Herbicides must, however, be carefully applied according to registration labels to be effective and to prevent damage to seedlings or non-target species.

HERBACEOUS VEGETATION

If restricted to manual control methods, use large mulch mats that last several years. However, if herbicides are available, they are more cost effective.

Annual treatment of understory shrubs often stimulates the growth of herbaceous vegetation (Chan and Walstad 1987, Wagner 1989, Wagner and Radosevich 1991a,b, Harrington and Parendes 1993, Newton et. al. 1996, Chan et al. 1997, Radosevich et al. 1997). Although mechanical treatment of herbaceous vegetation is notoriously ineffective (Harrington and Parendes 1993, McDonald et al. 1994), mulch cloth (McDonald and Fiddler 1994) can be somewhat effective.

Common problems: Assuming that scalping during planting is an effective vegetation-management practice. Not using more effective vegetation-management alternatives to manual release, e.g., herbicides.

ANIMAL DAMAGE MANAGEMENT

Use good vegetation management to promote rapid growth. Plant larger trees because they are not as vulnerable to animal damage. Use mesh tubing (e.g., Vexar) in areas of high deer or elk population. Use solid plastic (e.g., Tubex) protectors where mountain beaver or stream beavers are present. Build chicken-wire protectors where stream beavers prey on conifers. Tree protectors, such as Tubex, may offer the best change of getting conifer seedlings past clipping and browsing animals.

Common problems: Wasting money on ineffective measures, e.g., use of Vexar tubing or garlic repellent without demonstrated benefit. Protection of seedlings that have inadequate light for vigorous growth. The lack of a good beaver-proof expandable shelter or fence to protect trees beyond 10 cm (4 in.) dbh.

PROJECT COMPLETION

Monitor planting and release projects annually, and be prepared to conduct maintenance operations. Restoring conifers to hardwood-dominated riparian forests requires long-term, concerted effort.

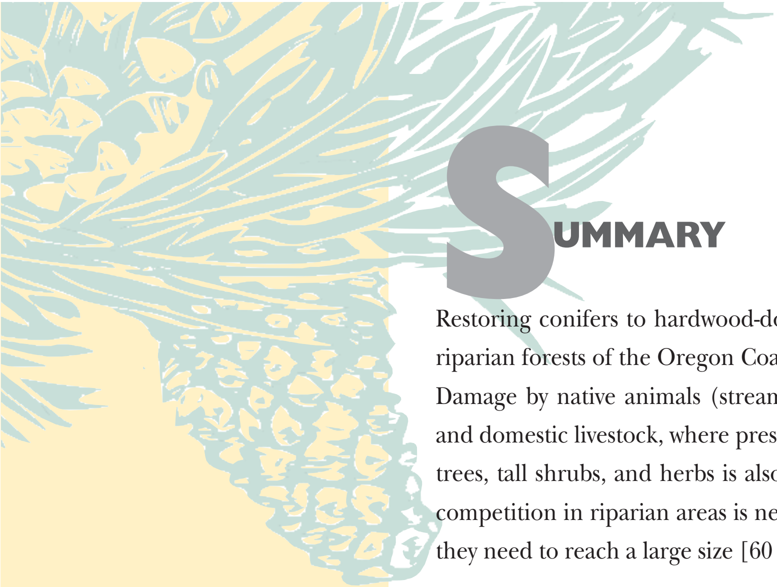
Common Problems: Lack of follow-up maintenance. Changes in personnel, poor project tracking, and poor record keeping and monitoring.

Protecting Riparian Conifers

Animal damage to conifers is highly likely in riparian settings, because both stream and mountain beavers have access and tend to work systematically through their food supply. Plastic mesh tubes (e.g., Vexar) are often effective against deer and elk but merely provide handy ladders for beaver to reach seedlings. A strategy of planting and tending fewer trees may be more cost effective (Oester et al. 1995). Instead of using relatively cheap but ineffective protectors to try to save many plantation trees, protect fewer trees (at wider spacing) by using solid plastic tubing (tree shelters) up to a height of 1.2–1.8 m (4–6 ft). This protects seedlings effectively from both browsing and clipping by elk, deer, stream and mountain beavers, mice, and voles. By acting as small greenhouses, tree shelters also accelerate height growth. Just after emerging from the shelter, trees are "top heavy" (H/D ratio >100), so do leave the shelters in place for a couple of years. Where stream beavers are present, leave shelters in place until trees grow to fill the tubes, then slit each tube vertically so it will not constrict the tree as it grows, but leave it in place to provide some protection for a few more years.

In upland areas, effective herbicide treatments can provide vigorous seedlings that withstand moderate to heavy browsing damage by dear and elk without impairment of growth (Gourley et al. 1990). Vigorous seedlings can outgrow any damage and become large enough to escape further browsing and clipping (White et al. 1986, Newton et al. 1993, Loucks et al. 1996). This approach may also work in riparian forests where really effective vegetation management is possible, and ungulates are the problem.

In studies of seedlings planted in cleared areas, protection with Vexar tubes has been found to be effective for enhancing survival and growth of planted trees in clearings (Black 1992, Owston et al. 1992, Stein 1995). Mesh tubing was not effective in riparian areas (Maas and Emmingham 1995), probably because the seedlings were growing at lower light levels, and there were many other potential clippers and browsers. We found no reliable research that supported the use of garlic clips.



SUMMARY

Restoring conifers to hardwood-dominated, coastal riparian forests is a big challenge. The riparian forests of the Oregon Coast Range are risky places for conifers to survive and grow. Damage by native animals (stream beavers, mountain beavers, deer, elk, mice, and voles) and domestic livestock, where present, is extreme. Competition from fast-growing hardwood trees, tall shrubs, and herbs is also extreme. Active management to reduce tree and shrub competition in riparian areas is necessary to give small conifers the growing space and time they need to reach a large size [60 cm (24 in.) in diameter] and help create healthy streams.

Where conifers are not found in hardwood-dominated forests, it makes sense to plant them. In general, managers have chosen to plant appropriate, larger stock types of adapted species. They also have recognized the need to control competing vegetation, but often have adopted conservative management approaches that do not provide enough growing space for small conifers.

Those involved in restoration can increase the probability of success by becoming familiar with the ecology of riparian forests. The complex nature of projects and the decades-long time frame needed for success should be carefully considered during planning and initiation. A decision to grow conifers in riparian forests requires the resolve to use an active approach to help them survive and grow. Where active management is not possible because of competing resource values, restoration of conifers is unlikely; in such a case, resources would be better spent elsewhere. Following the management recommendations found in this publication can increase the probability of success.

Policy and incentives, such as those in the Oregon Coastal Salmon, Watershed Restoration Initiative, and the Northwest Forest Plan (USDA and USDI 1994) are critical to promoting the cooperation among agencies necessary for wise riparian-area management. Cooperation between researchers and managers can help in project design, and careful monitoring and realistic evaluations will help ensure timely maintenance.

REFERENCES

Ahrens, GR, A Dobkowski, and DE Hibbs. 1992. *Red Alder: Guidelines for Successful Regeneration.* Special Publication 24, Forest Research Laboratory, Oregon State University, Corvallis.

Beschta, RL. 1997. Riparian shade and stream temperature: An alternative perspective. *Rangelands* 19(2): 25–28.

Beschta, RL, WS Platts, JB Kauffman, and MT Hill. 1995. Artificial stream restoration—money well spent or an expensive failure?, pp. 76–104 in *Proceedings, Environmental Restoration, UCOWR 1994 Annual Meeting, August 2–5.* The Universities Council on Water Resources, Southern Illinois University, Carbondale IL.

Biring, BS, PG Comeau, and J Otchere-Boateng. 1996. *Effectiveness of Forest Vegetation Control Methods in British Columbia.* FRDA Handbook 11, Canadian Forest Service, British Columbia Ministry of Forests, Victoria BC.

Black, HC. 1992. *Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests.* General Technical Report PNW-GTR-287, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Carey, AB, JM Calhoun, B Dick, K O'Halloran, LS Young, RE Bigley, S Chan, CA Harrington, JP Hayes, and J Marzluff. 1999. Reverse technology transfer: Obtaining feedback from managers. *Western Journal of Applied Forestry* 14: 153–163.

Carlton, GC. 1988. *The Structure and Dynamics of Red Alder Communities in the Central Coast Range of Western Oregon.* MS thesis, Oregon State University, Corvallis.

Chan, SS, and JD Walstad. 1987. Correlations between overtopping vegetation and development of Douglas-fir saplings in the Oregon Coast Range. *Western Journal of Applied Forestry* 2: 117–119.

Chan, SS, RW McCreight, JD Walstad, and TA Spies. 1986. Evaluating forest cover with computerized analysis of fisheye photographs. *Forest Science* 32: 1085–1091.

Chan, S, D Hibbs, and P Giordano. 1993. Regeneration of coastal riparian areas: Second year tree performance. *COPE Report* 6(3): 42–44.

Chan, S, D Minore, P Owston, D Hibbs, and P Giordano. 1993. Regeneration of riparian areas: Interaction of site and vegetation factors, pp. 6–7 in *Program Proceedings Abstracts: Creating a Forest for the 21st Century, August 24–26, 1993,* Portland OR.

Chan, S, K Maas-Hebner, and B Emmingham. 1996. Thinning hardwood and conifer stands to increase light levels: Have you thinned enough? *COPE Report* 9(4): 2–6.

Chan, SS, M Bailey, D Karnes, R Metzger, and W Kastner. 1997. Riparian silviculture in the Oregon Coast Range: A partnership between management and research, pp. 190–198 in *Proceedings of the 1997 National Silviculture Workshop.* General Technical Report GTR-238, USDA Forest Service, Northeastern Forest and Range Experiment Station, Radnor PA.

Cole, EC, and M Newton. 1986. Nutrient, moisture, and light relations in 5-year-old Douglas-fir plantations under variable competition. *Canadian Journal of Forest Research* 16: 727–732.

Cole, EC, and M Newton. 1987. Fifth-year responses of Douglas-fir to crowding and non-coniferous competition. *Canadian Journal of Forest Research* 17: 181–186.

Cole, EC, WC McComb, M Newton, CL Chambers, and JP Leeming. 1997. Response of amphibians to clearcutting, burning, and glyphosate application in the Oregon Coast Range. *Journal of Wildlife Management* 61: 656–664.

Curtis, RO, DS DeBell, CA Harrington, DP Lavender, JB St. Clair, JC Tappeiner, and JD Walstad. 1998. *Silviculture for Multiple Objectives in the Douglas-fir Region.* General Technical Report PNW-GTR-435, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Emmingham, WH, and K Maas. 1994. Survival and growth of conifers released in alder-dominated coastal riparian zones. *COPE Report* 7(2&3): 75–77.

Emmingham, WH, M Bondi, and DE Hibbs. 1989. Underplanting hemlock in a red alder thinning: Early survival, growth, and damage. *New Forests* 3: 31–43.

Forest Service, British Columbia. 1995. *Riparian Management Handbook.* Forest Practices Code of British Columbia, Forest Service, British Columbia, [Victoria BC].

Froyd, CA. 1993. *Effect of Riparian Buffer Strips on Salmonberry* (Rubus spectabilis) *Community Structure in Alder Stands of the Oregon Coast Range.* MS thesis, Oregon State University, Corvallis.

Gourley, M, M Vomocil, and M Newton. 1990. Forest weeding reduces the effect of deer-browsing on Douglas-fir. *Forest Ecology and Management* 36: 166–185.

Gregory, SV. 1997. Riparian management in the 21st century, pp. 69–86 in *Creating a Forestry for the 21st Century: The Science of Ecosystem Management*, KA Kohm and JF Franklin, ed. Island Press, Washington DC.

Gregory, SV, FJ Franklin, WA McKee, and KW Cummins. 1991. An ecosystem perspective of riparian zones. *Bioscience* 41: 540–551.

Hagar, JC. 1999. Influence of riparian buffer width on bird assemblages in western Oregon. *Journal of Wildlife Management* 63: 484–496.

Hairston-Strang, AB, and PW Adams. 1997. Oregon's streamside rules: Achieving public goals on private lands. *Journal of Forestry* 95(7): 14–18.

Harrington, TB, and LA Parendes, ed. 1993. *Forest Vegetation Management without Herbicides: Proceedings of a Workshop, February 18–19, 1992.* Forest Research Laboratory, Oregon State University, Corvallis.

Hayes, JP, MD Adams, D Bateman, E Dent, WE Emmingham, KG Maas, and AE Skaugset. 1996. Integrating research and forest management in riparian areas of the Oregon Coast Range. *Western Journal of Applied Forestry* 11: 85–89.

Helgerson, OT. 1990. Response of underplanted Douglas-fir to herbicide injection of sclerophyll hardwoods in southwest Oregon. *Western Journal of Applied Forestry* 5: 86–89.

Hibbs, DE. 1996. Silviculture in red alder stands, pp. 137–138 in *Ecology and Management of BC Hardwoods, Workshop Proceedings, December 1–2, 1993,* BC Richmond, PG Comeau, GJ Harper, ME Blache, JO Boateng, and KD Thomas, ed. FRDA Report No. 255, Canadian Forest Service, Victoria BC.

Hibbs, DE, and PA Giordano. 1996. Vegetation characteristics of alder-dominated riparian buffer strips in the Oregon Coast Range. *Northwest Science* 70: 213–222.

Hibbs, DE, P Giordano, and S Chan. 1990. Managing riparian vegetation. *COPE Report* 3(3): 7–8.

Hibbs, DE, P Giordano, and S Chan. 1991. Vegetation dynamics in managed coastal riparian areas. *COPE Report* 4(4): 3–5.

Hibbs, DE, DS DeBell, and RF Tarrant. 1994. *The Biology and Management of Red Alder.* Oregon State University Press, Corvallis.

Howard, KM, and M Newton. 1984. Overtopping by successional Coast Range vegetation slows Douglas-fir seedlings. *Journal of Forestry* 82: 178–180.

IMST (Independent Multidisciplinary Science Team). 1999. *Recovery of Wild Salmonids in Western Oregon Forests: Oregon Forest Practices Act Rules and the Measures in the Oregon Plan for Salmon and Watersheds.* Technical Report 1991-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem.

Jensen, EC, DJ Anderson, JC Zasada, and JC Tappeiner II. 1995. *The Reproductive Ecology of Broadleaved Trees and Shrubs: Salmonberry* Rubus spectabilis *Pursh.* Research Contribution 9e, Forest Research Laboratory, Oregon State University, Corvallis.

Kauffman, JB, RL Beschta, N Otting, and D Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. *Fisheries* 22(5): 12–24.

Knowe, SA, and WI Stein. 1995. Predicting the effects of site preparation and protection on development of young Douglas-fir plantations. *Canadian Journal of Forest Research* 25: 1538–1547.

Knowe, SA, WA Stein, and LJ Shainsky. 1997. Predicting growth response of shrubs to clear-cutting and site preparation in coastal Oregon forests. *Canadian Journal of Forest Research* 27: 217–226.

Leidholt-Bruner, K, DE Hibbs, and WC McComb. 1992. Beaver dam locations and their effects on distribution and abundance of coho salmon fry in two coastal Oregon streams. *Northwest Science* 66: 218–223.

Loucks, DM, HC Black, ML Roush, and SR Radosevich. 1990. *Assessment and Management of Animal Damage in Pacific Northwest Forests: An Annotated Bibliography.* General Technical Report PNW-GTR-262, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Loucks, DM, SA Knowe, LJ Shainsky, and AA Pancheco. 1996. *Regenerating Coastal Forests in Oregon: An Annotated Bibliography of Selected Ecological Literature.* Research Contribution 14, Forest Research Laboratory, Oregon State University, Corvallis.

Maas, K, and B Emmingham. 1995. Third-year survival and growth of conifers planted in red alder-dominated riparian areas. *COPE Report* 8(1): 5–7.

Maser, C, and JR Sedell. 1994. *From the Forest to the Sea: The Ecology of Wood in Streams, Rivers, Estuaries, and Oceans.* St. Lucie Press, DelRay Beach FL.

McComb, WC, TA Spies, and WH Emmingham. 1993. Douglas-fir forests: Managing for timber and mature habitat. *Journal of Forestry* 91(12): 31–42.

McDonald, PM, and GO Fiddler. 1994. Mulching and grubbing techniques in forest vegetation management: A research synthesis, pp. 92–98 in *Forest Vegetation Management without Herbicides, Proceedings of a Workshop, February 18–19, 1992.* TB Harrington and LA Parendes, ed. Forest Research Laboratory, Oregon State University, Corvallis.

McDonald, PM, GO Fiddler, and HR Harrison. 1994. *Repeated Manual Release in a Young Plantation: Effect on Douglas-fir Seedlings, Hardwoods, Shrubs, Forbs, and Grasses.* Research Paper PSW-RP-221, USDA Forest Service, Pacific Southwest Research Station, Albany CA.

Minore, D. 1970. *Seedling Growth of Eight Northwestern Tree Species over Three Water Tables.* Research Note PNW-115, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland OR.

Minore, D. 1979. *Comparative Autecological Characteristics of Northwestern Tree Species... A Literature Review.* General Technical Report PNW-87, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland OR.

Minore, D, and HG Weatherly. 1994. Riparian trees, shrubs, and forest regeneration in the coastal mountains of Oregon. *New Forests* 8: 249–263.

Naiman, RJ, KL Fetherston, S McKay, and J Chen. 1998. Riparian forests, pp. 289–323 in *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*, RJ Naiman and RE Bilby, ed. Springer-Verlag, New York NY.

Newton, M, and EC Cole. 1991. Root development in planted Douglas-fir under varying competitive stress. *Canadian Journal of Forest Research* 21: 25–31.

Newton, M, EC Cole, and DE White. 1993. Tall planting stock for enhanced growth and domination of brush in the Douglas-fir region. *New Forests* 7: 107–121.

Newton, M, R Willis, J Walsh, E Cole, and S Chan. 1996. Enhancing riparian habitat for fish, wildlife, and timber in managed forests. *Weed Technology* 10: 429–438.

Nicholas, JW. 1997. Coastal salmon restoration initiative: The Oregon Plan; Restoring an Oregon legacy through cooperative efforts. State of Oregon, Salem.

Nierenburg, TR. 1996. *Characterization of Unmanaged Riparian Overstories in the Central Oregon Coast Range.* MS thesis, Oregon State University, Corvallis.

Oester, PT, W Emmingham, P Larson, and S Clements. 1995. Performance of ponderosa pine seedlings under four herbicide regimes in northeast Oregon. *New Forests* 10: 123–131.

Owston, PW, SP Smith, and WI Stein. 1992. Stand establishment, pp. 143–165 in *Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests*, HC Black, ed. General Technical Report PNW-GTR-287, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Pabst, RJ, and TA Spies. 1998. Distribution of herbs and shrubs in relation to landform and canopy cover in riparian forests of coastal Oregon. *Canadian Journal of Botany* 76: 298–315.

Perry, DA. 1995. Forests, competition and succession. *Encyclopedia of Environmental Biology* 2: 135–153.

Poage, NJ. 1995. *Comparison of Stand Development of a Deciduous-Dominated Riparian Forest and a Coniferous-Dominated Riparian Forest in the Oregon Coast Range.* MS thesis, Oregon State University, Corvallis.

Poage, NJ, and TA Spies. 1996. A tale of two unmanaged riparian forests. *COPE Report* 9(1): 6–9.

Puettmann, KJ, DS DeBell, and DE Hibbs. 1993. *Density Management Guide for Red Alder.* Research Contribution 2, Forest Research Laboratory, Oregon State University, Corvallis.

Radosevich, S, J Holt, and C Ghersa. 1997. *Weed Ecology: Implications for Management.* John Wiley & Sons, Inc., New York NY.

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

Reeves, GH, PA Bisson, and JM Dambacher. 1998. Fish communities, pp. 200–226 in *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*, RJ Naiman and RE Bilby, ed. Springer-Verlag, New York NY.

Rich, PM. 1990. Characterizing plant canopies with hemispherical photographs, pp 13–30 in *Instrumentation for Studying Vegetation Canopies for Remote Sensing in Optical and Thermal Infrared Re-*

gions, NS Goel and JM Norman, ed. Remote Sensing Reviews 5, Harwood Academic Publishers, New York NY.

Spittlehouse, DL. 1990. *Seedling Microclimate.* Land Management Report 65, BC Ministry of Forests, Victoria BC.

Stein, WI. 1995. *Ten-year Development of Douglas-fir and Associated Vegetation after Different Site Preparation on Coast Range Clearcuts.* Research Paper PNW-RP-473, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Steinblums, IJ, HA Froehlich, and JK Lyons. 1984. Designing stable buffer strips for stream protection. *Journal of Forestry* 82(1): 49–52.

Straehler, AN. 1957. Quantitative analysis of watershed geomorphology. *Transactions, American Geophysical Union* 38: 913–920.

Suzuki, N. 1992. *Habitat Classification and Characteristics of Small Mammal and Amphibian Communities in Beaver-Pond Habitats of the Oregon Coast Range.* MS thesis, Oregon State University, Corvallis.

Tesch, SD, and SD Hobbs. 1989. Impact of shrub and sprout competition on Douglas-fir seedling development. *Western Journal of Applied Forestry* 4: 89–92.

Tappeiner, JC, and JC Zasada. 1993. Establishment of salmonberry, salal, vine maple, and bigleaf maple seedlings in the coastal forests of Oregon. *Canadian Journal of Forest Research* 23: 1775–1780.

Tappeiner, JC, J Zasada, P Ryan, and M Newton. 1991. Salmonberry clonal and population structure in Oregon forests: The basis for a persistent cover. *Ecology* 72: 609–618.

Thomas, JW. 1994. FEMAT: Objectives, processes, and options. *Journal of Forestry* 94: 12–20.

USDA and USDI. 1994. *Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl.* USDA and USDI Interagency Team, Portland OR.

Vesely, D, and B McComb. 1996 Terrestrial amphibian abundance in riparian buffer strips in the Oregon Coast Range. *COPE Report* 9(4): 6–7.

Wagner, RG. 1989. *Interspecific Competition in Young Douglas-fir Plantations of the Oregon Coast Range.* PhD thesis, Oregon State University, Corvallis.

Wagner, RG, and SR Radosevich. 1991a. Interspecific competition and other factors influencing the performance of Douglas-fir saplings in the Oregon Coast Range. *Canadian Journal of Forest Research* 21: 829–835.

Wagner, RG, and SR Radosevich. 1991b. Neighborhood predictors of interspecific competition in young Douglas-fir plantations. *Canadian Journal of Forest Research* 21: 821–828.

White, DE, T Harrington, and T Hughes. 1986. Effects of herbs and brush on growth of young conifers, pp. 41–45 in *Forest Pest Management in Southwest Oregon, Proceedings of a Workshop.* Forest Research Laboratory, Oregon State University, Corvallis.

Zaerr, JB. 1983. Short-term flooding and net photosynthesis in seedlings of three conifers. *Forest Science* 29: 71–78.

Zasada, JC, JC Tappeiner II, BD Maxwell, and MA Radwan. 1994. Seasonal changes in shoot and root production and in carbohydrate content of salmonberry (*Rubus spectabilis*) rhizome segments from the central Oregon Coast Range. *Canadian Journal of Forest Research* 24: 272–277.

Zwieniecki, MA, and M Newton. 1999. Influence of streamside cover and stream features on temperature trends in forested streams of western Oregon. *Western Journal of Applied Forestry* 12: 106–113.

APPENDIX I—LIST OF SPECIES DISCUSSED IN THIS PUBLICATION

Common name	Scientific name
Fauna	
Birds	
Marbled murrelet	*Brachyramphus marmoratus*
Northern spotted owl	*Strix occidentalis*
Fish	
Coastal cutthroat trout	*Oncorhynchus clarki clarki*
Chinook, king salmon	*Oncorhynchus tshawytscha*
Chum, dog salmon	*Oncorhynchus keta*
Coho, silver salmon	*Oncorhynchus kisutch*
Steelhead	*Oncorhynchus mykiss*
Mammals	
Black-tailed deer	*Odocoileus hemionus columbianus*
Elk	*Cervus* spp.
Mice	*Microtus* spp.
Mountain beaver	*Aplondontia rufa*
Stream beaver	*Castor canadensis*
Voles	*Phenacomys* spp.

Common name	Scientific name
Flora	
Bigleaf maple	*Acer macrophyllum*
Blackberry	*Rubus* spp.
Coastal redwood	*Sequoia sempervirens*
Douglas-fir	*Pseudotsuga menziesii*
Elderberry	*Sambucus racemosa*
Grand fir	*Abies grandis*
Red alder	*Alnus ruba*
Salmonberry	*Rubus spectabilis*
Sitka spruce	*Picea sitchensis*
Thimbleberry	*Rubus parviflorus*
Western hemlock	*Tsuga heterophylla*
Western redcedar	*Thuja plicata*

APPENDIX 2—SURVEY QUESTIONNAIRE

DATE

ORGANIZATIONAL INFORMATION

I. ORGANIZATION

- A. Address:
- B. City:
- C. State, Zip:
- D. Phone:
- E. DG/Fax:
- F. E-mail:

II. CONTACT PERSON

- A. Title:
- B. Discipline:

PROJECT OBJECTIVES

III. GEOGRAPHIC LOCATION, BASIS, HISTORY, DISTURBANCE OF PROJECT

- A. Project goal:
- B. Site name:
- C. Legal description
  - 1. Township:
  - 2. Range:
  - 3. Section:
- D. Geography
  - 1. Elevation:
  - 2. Aspect:
  - 3. Slope:
- E. Size (acreage):
- F. Basis for selecting sites (circle all that apply):
  - 1. Biological
  - 2. Integration with other management activities
  - 3. Social/political
  - 4. KV funds
- G. Basis for selecting the prescription:
- H. Time frame for completion
  - 1. Current state of completion:
- I. Watershed analysis (yes/no):
  - 1. EA?
  - 2. BA?
  - 3. BE?
- J. Length of stream being treated (miles & tenths)
  - 1. FB:
  - 2. NFB:
- H. Objectives (rank in terms of priority):
  - a. Future source of LWD
  - b. Stream restoration/woody debris/structures
  - c. Future source of wood products
  - d. Diversity of riparian zone vegetation and structure
  - e. Riparian wildlife habitat enhancement
  - f. Water temperature and quality
  - g. Other (describe):

LAND USE AND DISTURBANCE

IV. LAND-USE HISTORY AND DISTURBANCE PATTERNS

- A. Previous land uses (circle all that apply):
  - 1. Homesteading
  - 2. Logging
  - 3. Road/trail
  - 4. Other (describe):
- B. Current land use and designation (circle all that apply):
  - 1. Matrix
  - 2. Riparian reserve
  - 3. Late successional reserve
  - 4. Other (describe):
- C. Natural disturbance history (circle all that apply):
  - 1. Debris torrent
  - 2. Flood
  - 3. Fire
  - 4. Other (describe):

D. Constraints to natural disturbances (circle all that apply):
    1. Dams
    2. Fire suppression
    3. Settlement
    4. Policy
    5. Channelizing
    6. Other

E. Human-caused disturbance (circle all that apply):
    1. Logged
    2. Homestead/pasture
    3. Road
    4. Other (describe):

SITE DESCRIPTION

V. DESCRIPTION OF RIPARIAN ZONE SITE CHARACTERISTICS PRIOR TO PROJECT

A. Overstory
    1. Stand composition (circle all that apply):
        a. Alder
        b. Alder/maple
        c. Alder/conifer
        d. Alder/maple/conifer
        e. No overstory
        f. Conifer
    2. Stand age
    3. Even/uneven aged?

B. Stream shade
    1. Type of shade?
    2. Degree of shading (choose one):
        a. None
        b. Partial
        c. Total

C. Coarse wood
    1. Abundance (choose one):
        a. None
        b. Low
        c. Medium
        d. High
    2. Source (circle all that apply):
        a. Local
        b. Flood
        c. Debris torrent
    3. Relative integrity (circle all that apply):
        a. Sound
        b.
        c.
        d.
        e. Rotten
    4. Size classes present (circle all that apply):
        a. Large
        b. Medium
        c. Slash
    5. Snags or cavity trees present (Y/N)?

A. Geomorphology and environment
    1. Constrained or unconstrained stream channel?
    2. Topography (choose one):
        a. Slope
        b. Terrace
        c. Toe
        d. Floodplain
        e. Bench
        f. Alluvial fan
    3. Soil drainage (choose one):
        a. Swampy
        b. Poor
        c. Well
    4. Soil texture
    5. Parent material
    6. Sub-watershed

STREAM CONDITIONS

VI. DESCRIPTION OF STREAM CONDITIONS PRIOR TO PROJECT

A. Stream order

B. River drainage

C. Description of stream using Oregon Riparian Forest Practices Act terminology
    1. Size
    2. Flow rate
    3. Fish-bearing status

- D. Stream habitat
  - 1. In-stream characteristics:
    - a. Percent bedrock? Gravel? Silt?
    - b. Percent glides? Pools? Riffles?
    - c. Pieces of woody debris per mile per size class?
    - d. Side-channel present or absent?
  - 2. Qualitative rating of habitat by fisheries biologist:
    - a. Excellent
    - b. Good
    - c. Fair
    - d. Poor
- E. Fish species and populations
  - 1. Chinook:
    - a. High
    - b. Average
    - c. Low
  - 2. Coho:
    - a. High
    - b. Average
    - c. Low
  - 3. Steelhead:
    - a. High
    - b. Average
    - c. Low
  - 4. Cutthroat:
    - a. High
    - b. Average
    - c. Low
  - 5. Other:
    - a. High
    - b. Average
    - c. Low

ANIMAL POPULATIONS AND HABITAT

VII. ANIMAL POPULATIONS AND HABITAT PRIOR AND CURRENT

- A. Unique habitat characteristics for (circle all that apply):
  - 1. Native fish populations
  - 2. Spotted owl habitat
  - 3. Marbled murrelet
  - 4. Deer/elk
  - 5. Beavers
  - 6. Other birds
  - 7. Other rodents
  - 8. Plants
- B. Animal presence/use/activity
  - 1. Species:
    - a.
    - b.
    - c.
    - d.
    - e.
    - f.
  - 2. Use:
  - 3. Activity:
  - 4. Benefits:
  - 5. Anticipated problems:

SILVICULTURAL PRESCRIPTIONS

VIII. PRESCRIPTIONS

- A. Overstory vegetation treatments
  - 1. Type:
  - 2. Shape, size (acres):
  - 3. Species and size of trees selected for retention:
  - 4. Time of year, frequency:
  - 5. Distribution along stream:
- B. Understory treatments
  - 1. Type:
  - 2. Shape, size (acres):
  - 3. Species and size of trees selected for retention:
  - 4. Time of year, frequency:
  - 5. Distribution along stream:
- C. Release of existing conifers
  - 1. Age:
  - 2. Size:
  - 3. Crown vigor:
  - 4. Species (circle all that apply):
    - a. *Pseudotsuga menziesii*
    - b. *Tsuga heterophylla*

- c. *Thuja plicata*
- d. *Picea sitchensis*
- e. *Abies grandis*

5. Distribution (choose one):
   - a. individuals
   - b. clumps

D. Regeneration

1. Spacing:
2. Site prep:
3. Species (circle all that apply):
   - a. *Pseudotsuga menziesii*
   - b. *Tsuga heterophylla*
   - c. *Thuja plicata*
   - d. *Picea sitchensis*
   - e. *Abies grandis*
4. Stock type:
5. Animal protection:

E. Snag retention/creation:

F. Disposition of thinned/cut overstory trees:

G. Rationale for selecting treatment?

1.
2.
3.

IX. COSTS

A. Planning, contract administration:

B. Site preparation:

C. Planting and tubing:

D. Release and maintenance:

E. Number of planned re-entries:

F. Who is contracted to do the work?

G. Monitoring:

RESULTS, MONITORING, AND DOCUMENTATION

X. CURRENT RESULTS AND OTHER FORMS OF DOCUMENTATION

A. Unit records (yes/no)?

B. Reports/publications?

1.
2.
3.

XI. OTHER RELATED RESTORATION ACTIVITIES (describe)

A. Stream structures:

B. Creation of pools:

C. Alcoves:

D. Road removal:

E. Other:

XII. REVIEW PROCESS

A. Who has input?

1.
2.
3.

B. Who reviews project after implementation?

1.
2.
3.

C. How will success be determined?

1.
2.
3.

XIII. MONITORING PLAN (who will carry out monitoring?)

A. Type of information collected (environmental, vegetation, water, fish, cost, etc.):

B. Frequency of monitoring:

C. Data management and analysis:

D. Data summaries:

1. Who prepares?
2. What format for distribution?
3. Who will the information be distributed to?

XIV. POTENTIAL OBSTACLES IN IMPLEMENTING AND MONITORING (describe)

A.

B.

C.

XV. COOPERATORS ON THIS SITE:

A.

B.

C.

Forestry Publications Office
Oregon State University
227 Forest Research Lab
Corvallis, OR 97331-7401

Address Service Requested

USDA
United States
Department of
Agriculture

Forest Service

75th
PNW
PACIFIC NORTHWEST
RESEARCH STATION
1925 2000

Coastal Oregon
Productivity
Enhancement
Program