Riparian Silviculture: An Annotated Bibliography for Practitioners of Riparian Restoration

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CONTENT

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1.0 INTRODUCTION

This annotated bibliography was prepared to help direct watershed restoration specialists in British Columbia to information about riparian silviculture and to papers and web sites that provide the scientific rationale for the riparian restoration of watersheds. This work was part of a study undertaken by the authors to improve future planning and implementation of riparian restoration projects funded through Forest Renewal BC (Poulin et al. 2000). That study found that the most significant barrier to riparian restoration in the province was a fundamental lack of understanding about why and how riparian forests must be restored to renew fish habitat, water quality and channel stability. Over 65 of the citations here address that barrier.

The term “riparian restoration” and “riparian silviculture” are used interchangeably in this bibliography. Silviculture in British Columbia is the art of cultivating a commercial forest. Riparian silviculture is the art of using traditional silvicultural methods such as brushing, thinning and planting to speed the recovery of forest attributes needed for restoration of fish habitat, water quality and channel stability.

In British Columbia, riparian forests are considered to be those that occur adjacent to streams, lakes and wetlands. For purposes of forest management, riparian areas are defined by the ***Forest Practices Code of British Columbia Act***. The act refers to the area specified as the riparian management area (RMA), which contains a riparian reserve zone (RRZ) and a riparian management zone (RMZ)—or just a riparian management zone if a riparian reserve zone is not required. Riparian restoration in the province is generally undertaken only in that portion of the RMA designated as riparian reserve zone and in areas that were logged prior to the Act.

The papers, articles and Internet web sites contained in the bibliography speak to the need for riparian restoration. They provide information on silvicultural practices that can speed the recovery of forest attributes needed to restore fish and wildlife habitat, water quality and channel stability. Nearly all of the published work on riparian silviculture comes from the Pacific Northwest, where research on restoring riparian sites has been under way for the better part of the past decade. British Columbia lacks a history of research in this area, but does contain many similar forest ecosystems to which the U.S. work is directly applicable or for which it can be extrapolated.

Riparian specialists in British Columbia can also take strong direction from the knowledge of forest ecosystems pioneered by Dr. Vladimir J. Krajina, as well as from the many tracts of uncut forests that provide ecological templates for riparian restoration. British Columbia's well-developed forest consulting industry has prepared numerous reports describing results of riparian assessments and operational projects for both government and industry. Although the majority of these documents are unpublished, they contain valuable information that describes the ecological characteristics of the province's at-risk stands and both conceptual and operational prescriptions for treatment. These reports are not easily accessed, but a listing of titles provided to the authors is in Appendix 1 of this bibliography.

1.1 Scope of the Bibliography

This annotated bibliography is not an exhaustive search on the subject of "riparian silviculture" or "riparian restoration," although it does attempt to capture the greater part of the most relevant information on the subject. Papers included were those that we felt were most applicable to practitioners of riparian restoration in British Columbia and managers who wanted to be aware of what is being said about the need for this work. Articles and research papers that provide information on silvicultural strategies for brushing, thinning and planting in riparian areas, results of research and operational trials, and the ecological basis for undertaking forest restoration are included. Although it was beyond the scope of this project to cover topics such as riparian management and aspects of forest ecology that link trees to fish and wildlife, we have included a selected number of such papers.

A listing of the World Wide Web sites accessed in the preparation of this bibliography is also provided. There may be others, but those listed are of special interest and will provide practitioners with a wide range of opportunities for further investigation on all aspects of forest management. They will also provide access to many of the excellent papers we considered in this search.

1.2 Bibliography Sources

The references included here are published articles or papers that we found through:

1. computer-based searches using "riparian silviculture" as the key word search engine;
2. direct contact with individual authors;
3. manual library searches; and
4. searches of recommended readings from riparian papers.

World Wide Web sites located at the University of Washington, Oregon State University, University of Montana, Humboldt State University and various government agencies (including the USDA Forest Service, Bureau of Land Management, and the U.S. Geological Survey) provided bibliographic web sites that offered citations and abstracts on riparian silviculture. Sites in British Columbia, including those for the BC Ministry of Forests and University of British Columbia, were accessed, but none was found to contain references on riparian silviculture. This situation will likely soon reverse, given that riparian silviculture is being widely discussed in British Columbia as a much-needed component of watershed restoration and interest is increasing at all academic levels.

In addition to the results of the web search, contact with individual researchers and silviculturalists (some of whom have undertaken the work cited in the listing and others who have not published) provided several other sources of information.

1.3 Annotations

The annotations provided focus on content relevant to riparian restoration as it may be of interest to practitioners in British Columbia. The annotations are not abstracts, nor are they necessarily reflective of all of the content of a given paper. We encourage users of the bibliography to contact the source agency or author of a listing of interest to obtain a copy of the complete document.

1.4 Perspectives Shared within the Bibliography

On the need for riparian restoration

The bibliography reveals a body of evidence that suggests the restoration of watersheds requires healthy riparian systems that function properly and provide the attributes necessary to achieve fish habitat, water quality and channel stability (Sedell and Beschta 1991; Newton et al. 1996; Hobbs et al. 1997; Sedell et al. 1997; Prichard 1998; Poulin and Simmons 1999). Restoring riparian forests is a large job that requires careful consideration of the long-term and complex nature of riparian forest regeneration, as well as cooperation between researchers and managers (Emmingham et al. 1999). An adaptive management approach is recommended, with ecological responses monitored over time and approaches improved by modification and implemented over larger geographical areas (Hayes et al. 1996). Restoration should begin as quickly as possible (Carey et al. 1998). Without active vegetation management, it may take 200 years to begin development of the diverse structure and composition of riparian forests (Chan et al. 1996). Murphy and Koski (1989) further concluded that it might take 250 years or more before large woody debris could return to streams where this material was lost through timber harvesting. Emphasis on watershed restoration should focus on restoring streamside vegetation and shift away from short-term—and often counter-productive—enhancement structures (Beschta and Elmore 1988).

On the Importance of riparian areas to fish and role of wildlife

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

On the challenge to restore riparian forests

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

On techniques for restoring riparian forests

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

On moving forward

In conclusion, riparian areas play a crucial role in maintaining the critical characteristics attributed to watershed stability. These characteristics include the living and non-living materials that are essential to the restoration of fish and wildlife habitat, water quality and channel stability. This annotated bibliography supports present and future actions involved in riparian restoration, but it also identifies the need of further research and development to ensure the credibility and efficacy of riparian restoration techniques.

Understanding the interrelationships that exist within the ecology and processes of floodplain ecosystems will help practitioners deal with the diverse management options posed by restoration. A good starting point in gaining this understanding is provided by the many papers identified in this bibliography.

2.0 ANNOTATED BIBLIOGRAPHY

Bibliography of Recommended Reading

Aber, J., Christensen, N., Fernandez, I., Franklin, J., Hidinger, L., Hunter, M., ManMahon, J., Mladenoff, D., Pastor, J., Perry, D., Slangen, R., and Miegroet, H. Applying ecological principles to management of the U.S. National Forests. Retrieved on April 18/2000 from the World Wide Web: http://esa.sdsc-edu/issues6.htm

The U.S. National Forest System is a diverse and unique resource and represents a large multi-faceted resource of continuing value. This report outlines ecological considerations that should preclude sound forest management. It discusses these ecological considerations under five broad categories: 1. Soil and nutrient cycles, 2. Hydrology, 3. Biodiversity, 4. Landscape level issues, and 5. Global change. It also critiques some of the ecological assumptions that explicitly or implicitly underlie current forest policy. Particularly interesting is a section on the role of forest reserves. It asserts that the value of biological reserves is especially significant as it provides controls for research to determine the ecological effects of various practices that influence, for example, watersheds.

Agee, J.K. (1988). Successional dynamics in forest riparian zones. ***In*** Streamside Management: Riparian Wildlife and Forestry Interactions, pp. 31–43.

This paper discusses the significance of natural disturbance types and their frequency. Human activities such as timber harvesting and road building affect the amount of large residual debris and type and frequency of overbank depositions of fine sedimentation in riparian areas. These changes disturb the natural ecosystem processes. The lack of coarse woody debris in small streams and instability along the stream channel are suggested to be the result of low inputs of large diameter material and a lack of large residual debris. Only recently has this important role of streamside vegetation and coarse woody debris of riparian forests been recognized.

Baily, J., Mayrsohn, C., Doescher, P., St. Pierre, E., and Tappeiner, J. (1998). Understory vegetation in old and young Douglas-fir forests of western Oregon. ***In*** Forest Ecology and Management. Elsevier Science B.V. Department of Forest Science, Oregon State University, Corvallis, OR. Volume 112, pp. 289–302.

This is a study of understory vegetation composition in thinned and unthinned Douglas-fir stands. Total herbaceous cover, density, frequency, and species richness were greater in thinned stands than in unthinned stands. Variable-density thinning within and among stands could create desirable within-stand heterogeneity.

Baily, D.J. and Tappeiner, C.J. (1998). Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. Forest Ecology and Management. Volume 108, pp. 99–113.

Few studies have examined the effects of thinning on understory tree regeneration, and those that have all report increased survival of regeneration and increased growth rates. This paper discusses the composition and structure of the understory in thinned and unthinned Douglas-fir/western hemlock stands on 32 sites in western Oregon. Comparisons were made among operationally thinned, unthinned and old-growth stands in terms of regeneration, understory trees and shrubs. The results demonstrate large differences in understory characteristics among the three stand types. It is suggested that greater thinning intensities created more microsites for seedling establishment over a longer period. However, as shrub cover increased, seedling density decreased. For understory trees, densities were found to be greater in thinned stands than in unthinned or old-growth stands. For shrubs, thinning helps develop the tall and low shrub levels. In particular, the abundance of vine maple and salal growth increased as overstory density decreased. One management implication is that thinning young Douglas-fir stands will hasten the development of multi-story stands by recruiting conifer regeneration in the understory as well as by enabling the survival of small overstory trees and growth of advanced understory regeneration.

Berg, D.R. (1995). Riparian silvicultural system design and assessment in the Pacific Northwest Cascade Mountains, USA. Ecological Applications. Volume 5, Number 1, pp. 87–96.

Silviculture systems implemented for ecological restoration can be economically and ecologically beneficial to the ecosystems of streams and riparian forests. This work is based on the simulation of riparian forest restoration using forest growth models. The paper describes three scenarios that restore riparian forest functions and reports the economic analysis of each. With the model, logs were generated to be of sufficient size to resist annual floods in salmon habitat on the west side of the Pacific Northwest Cascade Mountains. Economic viability depends on the initial volume removed, costs of regeneration and of monitoring the volume of thinnings, and interest rate. Harvest operations allow for the restoration of forest structure and composition that are beneficial for salmonid habitat in areas where the primary forest has been replaced with early seral hardwood species and fiercely competitive shrubs. This silvicultural system restores natural functions of riparian forests of watersheds in the Pacific Northwest. The paper emphasizes how such an approach not only restores forests, but maintains functional streamside areas, and it offers tools that help maintain and protect public resources.

Berg, R., Brown, T., and Blessing, B. (1996). Silvicultural systems design with emphasis on the forest canopy. Northwest Science. Volume 70 (Special), pp. 31–36.

The purpose of this paper is to offer a new perspective on the application of silviculture. There is emphasis on how the silvicultural manipulation of an individual tree canopy controls the quality and quantity of growth. Silviculture affects ecosystem functions of the forest, particularly in the forest canopy. Only recently have canopy manipulations been viewed from the wildlife perspective. Thinning the canopy density provides two unique benefits: (1) it achieves even-ring diameter growth for improved wood quality; and (2) it results in more efficient use of the live crown by reducing competing trees of inferior quality and lower vigour. Canopy structure of the forest community holds the key to maintaining the populations of a number of plant and animal species. These structures include snags, cavities, thick bark, branches, twigs, foliage, layered canopy, and downed wood. Conventional thinning techniques, combined with new innovations in creating canopy structure, can be used to improve wildlife habitat. A silvicultural system approach is summarized by system design, performance, and tolerance of measurable criteria. Common silvicultural manipulations are used to demonstrate canopy control for wildlife habitat maintenance at the individual tree level. The retention of various amounts and patterns of forest achieve landscape level distribution of habitat structure. The challenge for the future will be to adapt new tools to existing technology in order to meet increasing constraints of land-related regulations.

Beschta, L.R. and Elmore, W. (1988). The fallacy of structures and the fortitude of vegetation. ***In*** D. Abell (ed.). California Riparian Systems Conference: Protection, Management and Restoration for the 1990s. September 22–24, 1988. USDA Forest Service.

This article presents an issue regarding the placement of in-stream structures as a "fast-food" approach to stream management. The primary management focus should be shifted from investing in expensive, short-term and often counterproductive enhancement structures to restoring the streamside vegetation and thus riparian systems. Vegetation recovery is less costly and provides an opportunity for long-term solutions, such as inputting roots, leaves, shade and nutrient cycling. The article concludes that improved management of streamside vegetation, not structural additions to channels, offers the most promise for developing valuable and productive riparian systems.

Bunnell, F. and Dupuis, L. (1995). Riparian habitats in British Columbia: their nature and role. ***In*** Riparian habitat management and research. Proceedings of a workshop, May 4–5, 1993, Kamloops, BC. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network, pp.7–20.

This paper examines the role of riparian habitats for forest-dwelling wildlife. Also discussed is the status of these riparian habitats, as well as their importance to vertebrate wildlife and forestry. Approximately 75% of watersheds in British Columbia have been partially developed. Some biogeoclimatic zones have no underdeveloped watersheds remaining, yet the majority of wildlife species are more abundant in riparian habitats. Riparian areas are characterized by large trees, snags and downed wood, as well as by a large number of deciduous trees and shrubs. These elements contribute to the structural diversity of an area, thereby increasing niche availability. Because the productivity of riparian areas is important to forest resource management, these impacts should be assessed as they relate to the affected species. Winners and losers among these affected species should be determined and tradeoffs evaluated.

Carey, A., Calhoun, J., Dick, B., Jennings, D., O'Halloran, K., Young, L., Bigley, R., Chan, S., Harrington, C., Hayes, J., and Marzluff, J. (1998). Reverse technology transfer: obtaining feedback from managers. Pacific Northwest Research Station, USDA Forest Service, Olympia, WA. 36 p.

This paper is available on request from the USDA Forest Service in Olympia, WA. It summarizes the assessments of experienced forestry practitioners on a number of forestry issues, including riparian silviculture. Conclusions are that silviculture can increase, maintain, or accelerate riparian values. Establishing conifers in riparian areas is a crucial step in enhancing fish and wildlife habitat. Consensus was that riparian area management should begin as quickly as possible, especially in second-growth plantations that are capable of regenerating quickly. As well, variable spaced thinnings and feathering of buffers are strategies that should be employed in riparian areas. Another common point that managers agreed on was that riparian area management should be based on restoring intended functions in riparian areas, not on adopting one-size-fits-all solutions, such as fixed buffers.

Carey, A. and Robert, C. (1996). Conservation of biodiversity: a useful paradigm for forest ecosystem management. Wildlife Society Bulletin. Volume 24, Number 4, pp. 610–620.

This paper presents a summary of theory and empirical data behind a proposed biodiversity pathway for forest management in the Pacific Northwest, along with a summary of new research on stand-development patterns and rotation ages for coastal Douglas-fir. The new model of forest ecosystem development is defined by eight hypothetical stages. There are five sequential steps that form the foundations for the conservation of biodiversity in managed forests. Minimizing site preparation, especially intensive burning, may help preserve biological legacies and reduce invasion by aggressive pioneer species such as red alder. A variable density thinning that is much heavier than commercial thinning will conserve biodiversity in managed forests by encouraging gaps and patches with varying densities. Shifting to longer rotations on some of the land base would provide an ecologically more favourable distribution of stand ages and conditions, and may increase the proportion of late-seral forests.

Chan, S., Bailey, M., Karnes, D., Metzger, R., and Kastner Jr., W. (1997). The role of silviculture in the active management of riparian zone vegetation in the Oregon Coast Range: a partnership between researchers and managers. ***In*** COPE Presentation at the National Silviculture Workshop. Warren, PA, May 21–23, 1997.

Delivered at the National Silviculture workshop in 1997, this paper deals with the role of silviculture in the active management of riparian zone vegetation. Many restoration projects have focused on installing logs in stream channels to improve habitat for fish. This solution is short term, costly and not self-sustaining. Managing riparian areas for recruitment of large trees provides long-term and sustainable options for stream and riparian habitat. Establishing conifers with hardwoods is expected to maintain and enhance riparian function, structure, and productivity. The repeated annual cutting of the understory during the active growing season is effective in preventing the increase in cover and height of most shrubs. One of the key elements found to be limiting tree regeneration in the Oregon Coast Range is light. To create increased light conditions, active management—such as thinning, vegetation management, and tree regeneration—is needed to establish conifers in hardwood and shrub-dominated riparian areas. This paper suggests that managers should focus on using treatments that create adequate light availability, as opposed to aiming for blanket prescriptions to fit all riparian areas.

Chan, S., Mass-Heber, K., and Emmingham, W. (1996). Thinning hardwood and conifer stands to increase light levels: Have you thinned enough? ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 9, Number 4, pp. 2–6.

This paper discusses ways of determining how much conifer and hardwood canopies should be thinned for understory conifer development. Without active diversity management, conifer plantations and hardwood-dominated riparian areas may take 200 years to begin development of diverse structure and composition.

Cole, C.E. (1996). Managing for mature habitat in production forests of Western Oregon and Washington. ***In*** Weed Technology. Volume 10, pp. 422–428.

Techniques are described to increase desirable wildlife habitat features in managed stands. Currently, there is a deficit of stands in the mature (>100 years) age class. Key desirable components are large (>75 cm dbh) conifer trees, coarse woody debris, snags, and vertical structure and spatial heterogeneity. To create large trees, managers can use widely spaced plantings, thinning, weeding, fertilizing, and longer rotations. They can also carry dominant trees past 100 years old. To maintain coarse woody debris, existing coarse woody debris can be left after harvesting and, to balance losses, low-quality trees could be selected and felled as needed throughout the rotation. Snags can be created by a variety of techniques such as girdling, topping, or herbicide or pathogen injection. With injection, snags tend to last for a longer time. To increase structural complexity, silvicultural prescriptions (such as creating gaps in the overstory and underplanting with desired species after heavy thinning) can be done.

Crumpacker, D.W. (1995). The Boulder Creek corridor projects: riparian ecosystem management in an urban setting. ***In*** R.R. Johnson et al. (eds.), Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. USDA Forest Service, General Technical Report RM-120, pp. 389–392.

This article describes how the protection of the 3.5-mile riparian corridor of Boulder Creek (which flows through a 29-acre riparian woodland) is being accomplished. It discusses how the corridor will be managed for the benefit of the community of Boulder Creek. It also shows how riparian ecosystem management can occur in an urban setting.

Douglas, T. and McLennan, D. (1999). Getting ecological bang for the buck: riparian restoration on the Chehalis River. Forest Renewal BC. Streamline: BC's Watershed Restoration Technical Bulletin. Volume 4, Number 1, pp. 2–7.

This article describes a cost-effective and ecologically based approach to developing riparian restoration prescriptions for the Chehalis River. The Chehalis River was examined in three riparian segments. The restoration opportunity of each segment was assessed and outlined in conceptual prescriptions. Some activities of the restoration prescriptions included conifer release by selectively falling or girdling deciduous canopy dominants, accelerating the rate of ecosystem succession by planting suitable trees, shrubs and herbs, and stand thinning. Out of all three sites, Site 3-Statlu site, was considered the highest priority. The main reason for this is that the prescription for this portion of the river called for meeting the dual objectives of acceleration and restoration of full riparian function, as well as for providing spotted owl habitat.

Emmingham, H. W. (1996). Commercial thinning and under-planting to enhance structural diversity of young Douglas-fir stands in the Oregon Coast Range: an establishment report and update on preliminary results. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 9, Number 2&3, pp. 2–4.

This study investigates ways of providing more diverse forests with old-growth-like structures to enhance structural diversity and sustain productivity in young Douglas-fir forests through commercial thinning and underplanting. It is hypothesized that wide thinning would create a bi-canopy structure with large diameter trees, as well as increasing light levels to promote understory development and provide more diverse, old-growth-like habitat. As a result of this study, a number of simulation studies based on growth and yield models have been initiated. These simulations predict stand growth, stand structure, and timber production for 50–100 years.

Emmingham, H.W., Bondi, M., and Hibbs, D. (1989). Underplanting western hemlock in a red alder thinning: early survival, growth, and damage. New Forests. Volume 3, pp. 31–43.

This paper gives the results of a study on the survival of western hemlock planted beneath an overstory of thinned alder. Experiments were completed to test the feasibility of thinning hardwoods to final crop-tree spacing to increase their growth and marketable volume, thus releasing the site resources to support conifers planted in the understory. Survival of hemlock seedlings was found to be higher in the chemically thinned plots which had wider spacing than in the mechanically thinned plots and unthinned areas. As well, height growth was demonstrated to be greater on the chemically thinned plots. Observations also show that released hemlock seedlings demonstrated shock when the overstory was removed. One recommendation is to thin alder in the dormant season so understory hemlock can gradually adapt to light conditions. The data observed from this study indicate that it is biologically possible to establish a viable hemlock stand beneath a thinned alder stand.

Emmingham, H.W., Chan, S., Mikowski, D., Owston, P., and Bishaw. B. (1998). Riparian silviculture practices on non-industrial and public lands in the Oregon Coast Range. Draft Report. Oregon State University, College of Forestry and USDA Forest Service PNW Research Station. 43 p.

This draft report is available on request from Oregon State University in Corvallis, OR. The paper discusses the results of 34 riparian silviculture projects in the Oregon Coast Range. A common goal for the projects is to establish or release riparian forest conifers and restore vegetative diversity. Treatments consist mostly of releasing existing conifers or planting young conifers. Results from overstory treatments indicate that drastically reducing competition from overstory hardwoods is essential for the satisfactory growth of understory conifers. Reducing overstory competition to allow a minimum of 40% full sunlight penetration will stimulate vigorous tree growth. Regarding understory treatments, results show that annual treatments of understory shrubs often stimulate the growth of herbaceous vegetation. The use of herbicides is a method of controlling both herb and shrub competition.

Emmingham, H.W. and Hibbs, D. (1997). Riparian area silviculture in Western Oregon: research results and perspectives. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 10, Number 1&2, pp. 24–27.

This paper reports on the results of COPE studies that deal with riparian silviculture management. Several studies indicate that: (1) the relative importance of conifers and hardwoods in Coast Range riparian areas changed with time; (2) at some times and in some streams, conifers were probably not too common; and (3) the relative importance of conifers and hardwoods varied across this landscape. The knowledge that, in some streams, the majority of wood came from debris flows reinforced the objective for a more complete understanding of how the whole stream system works. Another objective significant to managing riparian areas is the restoration of conifers in riparian areas. Three approaches to establishing conifers were: (1) releasing already established suppressed conifers; (2) underplanting conifers in hardwood-dominated riparian areas; and (3) clearing the hardwood stand and planting conifers in the opening. The authors' research showed that it is difficult to establish conifers in riparian areas and that vegetation management and reduced stand density are treatments needed to shorten the time to reach large diameter conifers.

Emmingham, H.W. and Maas, K. (1994). First-year performance of five conifer species under-planted in commercially thinned Douglas-fir stands. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 7, Number 4, pp. 6–7.

This study, presented by Adaptive COPE, addresses the viability of manipulating Douglas-fir plantations through commercial thinning and under-planting to create multi-storied stands. This article provides a summary of the first-year survival and growth of the planted seedlings. The first-year survival and growth of planted Douglas-fir, grand fir, western redcedar, and Sitka spruce, were examined under different thinning regimes. Observations showed that Sitka spruce was the only survivor in the unthinned treatment. Twenty-one percent of surviving Douglas-fir, 17% of surviving western redcedar, and 13% of planted western hemlock experienced height loss. It was found that the species to survive with the best physiological growth characteristics was Sitka spruce. Browse severity affected this study because it was difficult to predict.

Emmingham, H.W., Maas-Hebner, K., and Bateman, D. (1997). Active management of riparian zones for multiple resources: II. Release of suppressed and intermediate conifers in alder-dominated riparian zones of the Oregon Coast Range. October 1, 1997–January 31, 1999 Annual Report and Bibliography: Coastal Oregon Productivity Enhancement Program, Corvallis, OR. J. Thomas (ed.), pp. 77–80.

Many alder-dominated riparian zones contain over-topped conifers that have little chance of growing to become large trees. This study examines the efficacy of releasing these conifers by creating gaps in the hardwood canopy. The results show that the girdling and felling treatments demonstrated increases in growth. The more shade-tolerant species (western hemlock, western redcedar and Sitka spruce) immediately responded to the felling treatments, whereas Douglas-fir showed increased growth only 2–3 years after the treatments. The two treatments, girdling and felling, produce different release patterns and may have different advantages. Girdling kills trees gradually. The dying trunks provide snag habitat for a period of 3–5 years for woodpeckers, and the lack of on-ground debris facilitates easier movement for wildlife. Felling overstory hardwoods provides the most immediate release for understory conifers, but may damage releasable conifers as well as creating a maze of downed logs. Long-term growth patterns of released trees, and the effect of this on conifer crown position in riparian forests, must be further studied.

Emmingham, H., Maas-Hebner, K., Cloughesy, M., Duddles, R., and Newton. M. (1997). Establishment and growth of conifers under existing riparian vegetation. October 1, 1997–January 31, 1999 Annual Report and Bibliography: Coastal Oregon Productivity Enhancement Program, Corvallis, OR. J. Thomas (ed.). pp. 82–84

This article focuses on restoring conifers to riparian zone forests through thinning or cutting gaps in hardwood stands, planting conifers, and managing competing vegetation. The authors' studies demonstrate that the best success of conifer survival was found under the treatment regime that involved overstory thinning or removal, along with the treatment of understory vegetation competition. With the implications of the difficulty in regenerating planted seedlings, managers should give higher priority to releasing established conifers, rather than to planting established conifers that respond quickly to overstory removal. Planting should be an option only in long reaches that are devoid of conifers.

Enhanced Forest Management Pilot Project. Spatial silviculture investment planning: process and methodology. MacMillan Bloedel Ltd. TFL 39 Block 2. 11 p.

This paper is meant to complement the analysis document covered in the 1998 Enhanced Forest Management Pilot Project Progress report and to assist users interested in developing similar planning processes. A description of the riparian restoration strategy treatment involved variable density spacing with deciduous retention, variable density spacing with snag recruitment/deciduous retention, and thinning with snag recruitment/deciduous recruitment/cavity creation.

Flessner, T.R., Darris, C.D., and Lamber, M.S. (1991). Seed source evaluation of four native riparian shrubs for streambank rehabilitation in the Pacific Northwest. Symposium on "Ecology and Management of Riparian Shrub Communities, May 29–31, 1991, Sun Valley, ID.

Degraded Streamside ecosystems are often dominated by weedy grass species. To improve the varieties of native riparian shrubs and enhance vegetative restoration efforts, Sitka alder (***Alnus Sinuata [Regel] Rydb.),*** Pacific serviceberry ***(Amelanchier alnifolia var. semiintegrifolia [Hook.] Hitchc***.), Oceanspray (***Holodiscus discolor [Pursh] Maxim***.), and vine maple (A***cer circinatum Pursh***) have been evaluated in this paper. Sitka alder is used to improve riparian areas and increase site productivity, control certain root diseases, and enhance wildlife habitat. Pacific serviceberry is an excellent candidate for streambank restoration because it tolerates many soil types and suckers well. Oceanspray has tolerance to wide moisture regimes, sun or shade, and many soil types. This make it useful for landscaping and low-maintenance riparian plantings. Lastly, vine maple has a natural adaptation to streambanks, and its vigorous fibrous root systems make it an excellent candidate for riparian restoration within the region.

Gomez, M.D. and Anthony, G.R. (1996). Amphibian and reptile abundance in riparian and upslope areas of fire forest types in western Oregon. Northwest Science. Volume 70, No 2, pp. 109–117.

Riparian vegetation with the adjacent upland habitat provides increased structural diversity of vegetation for wildlife, amphibians and vertebrates. Changes in the waters of first- to third-order streams may influence the structure and productivity at higher levels of the riparian-associated plants and animals. This study compares the species composition and relative abundance of herpetofauna between riparian and upslope habitats among five forest types in western Oregon. Ten of 24 native species of herpetofauna in the Oregon Coast Range are often found in riparian habitat. The results suggest that small riparian systems provide important habitat for tailed frogs, Dunn's salamanders, rough skin newts, and Pacific giant salamanders in the Oregon Coast Range. The abundance of the first three species drastically declined at 50-100 m away from streams. In order to maintain these sensitive species, it is suggested that riparian management zones be 75-100 m minimum width on each side of the stream to encompass all areas of these species' habitat.

Green, R.N. and Klinka, K. (1994). A field guide for site identification and interpretation in the Vancouver Forest Region. BC Ministry of Forests, Land Management Handbook Number. 28. Victoria, BC.

The guide presents site identification and interpretation information for forest ecosystems of the Vancouver Forest Region. This guide consists of six main sections. Following the Introduction, Section 2 provides an overview of the biogeoclimatic ecosystem classification system. Section 3 outlines procedures for assessing sites (e.g., "site diagnosis"). Section 4 describes the biogeoclimatic units in the region, emphasizing their distinguishing features. Section 5 provides a synopsis of all site units recognized in the Region, presented with edatopic grids and vegetation summary tables. Section 6 provides management interpretations. Lastly, there are several appendices that contain additional information on indicator plant analysis and site description.

Hall, D.J., Brown, W.G, and Lantz, L.R. (1987). The Alsea watershed study: a retrospective. Streamside Management: Forestry and Fishery Interaction. E.O. Salo and T.W. Cundy College of Forest Resources, University of Washington, Seattle, WA, pp. 399–416.

The Alsea Watershed Study was the first long-term watershed study to consider the impact of timber harvest practices on the biological characteristics of streams, including their anadromous fish populations, coho salmon and cutthroat trout. Selected for the study were three small watersheds on the mid-Oregon coast. One watershed (71 ha) was clearcut, one (304 ha) was patch-cut with buffer strips, and the third (203 ha) remained as the control. This paper discusses the major physical and biological results and provides management implications. In terms of physical characteristics, observed were small changes in the patch-cut watershed and large changes in suspended sediment, dissolved oxygen, and temperature on the clearcut. There is evidence of a significant reduction in numbers of migrants following logging in the clearcut watershed. The paper concludes that the challenge for managers is to keep future management options open and to use process-oriented research as a management tool.

Hanley, T.A. and Hoel, T. (1996). Species composition of old-growth and riparian Sitka spruce-western hemlock forests in southeastern Alaska. Canadian Journal of Forest Research.National Research Council of Canada, Ottawa, ON. Volume 26, Number, 9, pp. 1703–1708.

The purpose of this study was to compare the patterns of overstory species composition, tree regeneration, and understory composition in riparian and upland forests. The three types of old-growth forests examined were: (1) an old-growth riparian floodplain forest; (2) an old-growth, upland forest; and (3) a 40-year-old red alder forest that succeeded a floodplain forest that was clearcut harvested. The results of this study highlight two implications for forest management: (1) riparian old-growth forests may differ substantially from upland old-growth forest in overstory composition, tree regeneration, understory composition and successional patterns; and (2) red alder-dominated stands have a very different potential for wildlife habitat than do stands of similar age in this region.

Hayes, J., Adam, M., Anthony, R., Emmingham, H.W., Gomez, D., Larson, D., Maas-Hebner, K., Suzuki, N., Thies, W., Westlind, D., and Weikel, J. (1994). Effects of commercial thinning on stand structure and wildlife populations: a progress report, 1994–1997. Department of Forest Science, Oregon State University, Corvallis, OR. 150 p.

This 150-page report is produced in a spiral bound 8.5” x 11” format. It is available on request from the Coastal Oregon Productivity Enhancement Program at the College of Forestry, Oregon State University in Corvallis, OR. This progress report is a collection of studies on the thinning effects on stand structures and wildlife populations. This is a multi-disciplinary approach to determine if thinning will accelerate the development of old-growth forest characteristics. Papers in this report emphasize wildlife populations and their habitat.

Hayes, J., Adam, M., Bateman, D., Dent E., Emmingham, W., Maas, K., and Skaugset, A. (1996). Integrating research and forest management in riparian areas of the Oregon Coast Range. ***In*** Western Journal of Applied Forestry, Volume 11, Number 3, pp. 85–89.

This technical paper summarizes research by COPE in riparian forests of the Oregon Coast range. The work recognizes the need for riparian silviculture to promote conifer development in areas dominated by hardwoods. Mixed-conifer stands can have up to twice the woody debris as streams in hardwood-dominated riparian areas. The majority of LWD is in streams with alder-dominated riparian areas. However, most of the pool habitat in these streams is associated with remnant conifer debris. This paper also identifies 11 research topics that are fundamental to improving riparian management decisions.

Hayes, J., Adam, M., Suzuki, N., and Weeks, J. (1995). A new COPE study examining the influence of commercial thinning on wildlife habitat and diversity. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon’s Coast Range Forests Through Research and Education. Volume 8, Number 1, pp. 2–5.

This study is presented by Adaptive COPE to address questions concerning the response of wildlife populations, habitat structure, and plant communities to thinning activities and snag creation. Commercial thinning has been proposed as a way of enhancing structural and wildlife diversity, and of maximizing wood fibre production. The study is aimed at examining influences of commercial thinning at varying intensities on the habitat and abundance of different wildlife species. Additional studies include deer and elk exclosures, ***Phellinus***, and snag creation. Data collection will continue up to 10 years post-logging.

Hayes, J., Chan, S., Emmingham, H.W., Tappeiner, J., Kellog, L., and Bailey, J. (1997). Wildlife response to thinning young forests in the Pacific Northwest. ***In*** Journal of Forestry, pp. 28–33.

This study examines the effects of thinning on wildlife and their habitat in forests of western Oregon and Washington. Thinning young stands may provide growing conditions that more closely approximate those historically found in developing old-growth stands. Large crowned trees provide larger areas for some species of birds to nest and forage. Thinning in 20- to 50-year-old stands promotes development of large crowns on dominant and co-dominant trees if done early in the stand's development. The article introduces the term "relative density." Relative density expresses the actual density of trees in a stand relative to the maximum density (RD 100) possible for trees of that size. Heavy thinning (RD 25) and thinning again when the stand grows to RD 45 promotes understory development and vertical diversity. Better understanding of the relative density diagram enables one to grow large trees in a relatively short time.

Hibbs, E.D. and Chan, S. (1997). The dynamics and silviculture of riparian vegetation. ***In*** J. Thomas (ed.). Annual Report and Bibliography: Coastal Oregon Productivity Enhancement Program, Corvallis, OR, pp. 43–47.

The results of four case studies on riparian silviculture are presented. Especially significant is a study on tree regeneration requirements in alder-dominated riparian zones. Results indicate that even with 85% of alder trees removed, the canopy closed back within seven years. Full canopy removal is recommended to prevent canopy closure and achieve sunlight conditions that will maintain the high growth rate necessary for conifers to release. In addition, it was found that the reduction of plant competition also accelerated growth rates. Data indicates that when the understory was cut once or twice a year to reduce plant competition, relative growth rates were twice as high as rates where the understory had not been cut. Vegetation management aids in successful tree regeneration in hardwood- and shrub-dominated areas. The studies have found that, if practitioners manipulate both the overstory hardwoods and the understory shrubs, they can achieve higher survival and growth rates of planted understory trees.

Hibbs, E., Emmingham, W., and Bondi, M. (1989). Thinning red alder: effects of method and spacing. Forest Science. Volume 35, pp. 16–29.

This article discusses the results of a red alder thinning study. The study investigated: (1) how growth changes with thinning intensity; (2) how tree response differs from chemical to mechanical thinning; (3) how epicormic branching is affected by thinning; and (4) how growth and yield are affected over the long term. Results show that thinning increased individual-tree radial growth 49–100% and decreased tree height growth by 56%. Thus, no significant change in tree volume growth was observed. Diameter increased 50% on the thinned versus the control plots. The larger (>12 cm dbh) injected alder did not break at the injected point. Rather, it gradually melted from the top down over a five-year period. A combination of girdling near crop trees with the cheaper injection for alder crop trees greater than 1.2 m may be the most economical way to go. Tests showed that trees in chemically thinned plots had more crown damage than the manually thinned plots. As well, there was a 54% increase in diameter growth on the chemically thinned plots and a 100% increase on the manually thinned plots. As a result of thinning, epicormic branches did not increase in number, but the size of branches did become larger. The only exception to this was in the intermediate age of red alder trees. Overall, the diameter and basal area growth per tree increased with thinning, but tree volume increment remained small. A red alder density management diagram is presented in this paper. The graph shows density and stem volume relationships in self-thinning, as well as maximum and minimum density bands for stand management.

Hibbs, D.E. and Giordano, P. (1996). Vegetation characteristics of alder-dominated riparian bugger strips in the Oregon Coast Range. Northwest Science. Volume 70, Number 3, pp. 213–222.

This study examined the effects of harvesting the adjacent forest on tree regeneration, understory development, and overstory dynamics in riparian buffer strips, and compared them with undisturbed riparian communities in the western hemlock zone of the Oregon Coast Range. All sites were alder dominated and contained an understory of dense salmonberry. Tree regeneration (seedlings younger than the overstory) was scarce. It is suggested that the high shrub cover in buffer strips and the increase in salmonberry dominance may explain this scarcity. The alder-dominated riparian community appeared to be resistant to environmental changes associated with becoming buffer strips. The scarcity of tree regeneration indicates that future tree cover may be limited after alder senescence. The results of this study suggest that, in order to regenerate trees successfully, intensive overstory thinning or creation of moderate-size or larger canopy openings is required.

Hobbs, D.S. (1994). COPE report: Coastal Oregon Productivity Enhancement Program. Special Symposium Issue: The ecology of management of Oregon Coast Range Forests. Volume 7, Number 2&3, pp. 5–23.

This report has a number of abstracts and presentations from the special symposium entitled "The Ecology of Management of Oregon Coast Range Forests." There are two presentations specifically related to riparian management. One is by Hayes and Hounihan, called "Habitat Relationships and Riparian Zone Association of Bats in Managed Forests in the Oregon Coast Range: A New Adaptive Cope Study." The objectives of these ongoing studies are to identify bat species using riparian zones in Coast Range forests and to determine the influences of landscape structure, stand structure, and stream and riparian characteristics on patterns of habitat utilization by bats. The other significant presentation is by Emmingham and Maas, called "Survival and Growth of Conifers Released in Alder-Dominated Coastal Riparian." The results of survival trials report that shad- tolerant species (e.g., western hemlock) responded to best release, but Douglas-fir was also improved when released, and it should be considered for release treatments.

Hobbs, D.S., Hayes, J., Johnson, R., Reeves, G., Spies, T., and Tappeiner, J. (1997). Forest and stream management book. ***In*** J. Thomas (ed.). Annual Report and Bibliography: Coastal Oregon Productivity Enhancement Program, Corvallis, OR, pp. 36–40.

The Forest and Stream Management Book is a synthesis of the COPE research in the ecology and management of forest and streams. This paper briefly describes each chapter and its status. Its major objective is to provide practitioners with a better understanding of disciplines other than their own that are necessary for forest and stream management. Included in chapter 7 are discussions on the topics of shrub management, riparian silviculture, and hardwood stand management. In addition, chapter 4 discusses habitat relationships and alternative forest management practices for restoring degraded habitat quality.

Hunter, C.W., Anderson, W.B., and Tollefson, E.R. (1989). Bird use of natural and recently re-vegetated cottonwood-willow habitats on the Kern River. USDA Forest Service General Technical Report PSW-110, pp. 332–337.

This paper compares the responses of bird species on revegetated habitats to their responses on naturally occurring riparian. All data was collected on the Kern River Preserve administered by the Nature Conservancy. The results of this study show that birds in every natural-history category were clearly more abundant in natural riparian habitat than on all revegetated sites. Notably, the numbers of the cavity-nesters, late breeders and canopy foragers were also greater in natural riparian habitats than on revegetated sites. These species are most closely associated with riparian forest habitat. The authors recommend that long-term surveys be developed to determine whether revegetation mitigates habitat losses.

Iverson, B. and Epps, D. (1998). The San Juan Watershed Agreement. Forest Renewal BC. Streamline: BC's Watershed Restoration Technical Bulletin. Volume 3, Number 4, pp. 5–11.

This article is a description of the San Juan River watershed and riparian enhancement activities undertaken on southern Vancouver Island. The San Juan project is one of the earliest riparian restoration projects undertaken in the province. A variety of techniques was employed, including conifer release by felling and girdling alder overstory, sandbar and riverbank planting, and conifer establishment by planting.

Koning, W. (editor). (1999). Riparian assessment and prescription procedures. BC Ministry of Environment, Lands and Parks, Watershed Restoration Program, Vancouver, BC. Watershed Restoration Tech. Circ. No. 6. 77 p.

This technical circular describes the riparian assessment and prescription procedures developed by the Watershed Restoration Program. It outlines the standards and information requirements to conduct overview, level 1 and level 2 riparian assessments. Instructions for completing riparian field forms, undertaking vegetation plots, and data requirements are provided, as well is advice on conceptual prescriptions.

Maas, K. and H.W. Emmingham (1995). Third-year survival and growth of conifers planted in red alder-dominated riparian areas. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 8, Number 1, pp. 5–7.

This study, presented by Adaptive COPE, was undertaken to determine efficient means of planting conifer seedlings in alder stands with minimal disturbance to the riparian areas. Several overstory and understory treatments were tested. Four conclusions were drawn from the three-year trial. (1) Managing understory vegetation in the first season increases survival and growth of conifer seedlings. (2) Survival and growth of conifer seedlings increases when alders are girdled. (3) Managing understory vegetation and girdling 50% of the alders resulted in the best survival and growth for all species of conifer seedlings. (4) Western hemlock had the best overall performance under the experimental conditions of the study. The authors noted that the results are preliminary and may not predict the long-term success of planted seedlings. They also cautioned that one year of vegetation management of shrubs would be inadequate to ensure long-term survival of the planted trees.

McDade, H.M., Swanson, J.F., Mckee, A.W., Franklin, F.J., and Sickle, V.J. (1990). Source distances for coarse woody debris entering small streams in western Oregon and Washington. Canadian Journal of Forest Research. Volume 20, pp. 326–330.

Information on source distance for coarse woody debris is essential in defining the areal extent of the zone of this forest stream interaction that plays biological and physical roles in stream ecosystems. The purpose of this study was to determine the source distance patterns of coarse woody debris in selected streams flowing through natural conifer forests in the Cascade and Coast Mountains of western Oregon and Washington. The results of this study can be used to interpret the effects of buffer strips of various widths on future amounts of coarse woody debris entering streams. The study found that the diameter pieces from gentle slopes were significantly smaller than those pieces from steep slopes and, conversely, the steep-side slopes yielded significantly shorter pieces than did gentle-sided ones. The percentage of pieces and distance moved was also greater on steep slopes. Observations also show that the distributions of distances from rooting site to bank were similar among streams—that is, 11% of the total number of debris pieces originated within 1 m of the channel, and over 70% originated within 20 m. In addition, a model was developed to provide a general representation of the relation between source distance and tree height.

McLennan, D. (1995a). Silviculture options on alluvial floodplains in coastal British Columbia. ***In*** Riparian habitat management and research. Proceedings of a workshop, May 4–5, 1993, Kamloops, BC. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network. pp. 119–131.

Due to unpredictable flooding and the vigorous post-logging growth of deciduous trees and shrubs that occurs after logging, alluvial sites are among the most difficult to regenerate to conifers. The most effective method of controlling competing vegetation on alluvial plantations is by applying ground-based herbicides. However, on the down side, their use is affected by such factors as nearness to fish-bearing streams, reduced forage values, and the need for continuous applications. In addition, in many Forest Districts in coastal British Columbia, applying herbicides has been seriously curtailed by public concerns. Therefore, alternatives to traditional silvicultural practices on alluvial floodplains are needed. This paper outlines the reliability of hardwood management, mixed hardwood-conifer systems (nurse tree shelterwoods), and clumped spacing approaches. The advantages of using these silvicultural alternatives are evaluated in the context of silvicultural, integrated resource management and biodiversity objectives.

McLennan, D. (1995b). Vegetation dynamics and ecosystem classification on alluvial floodplains in coastal British Columbia. ***In*** Riparian habitat management and research. Proceedings of a workshop, May 4–5, 1993, Kamloops, BC. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network. pp. 33–42.

Alluvial floodplains in coastal British Columbia support productive ecosystems that are highly important for both consumptive and non-consumptive resource values. Critical environmental processes that are occurring are identified and categorized to provide a first step in developing ecologically based and sound management practices. The structure, composition, growth and pattern of alluvial plant communities are largely determined by flooding and sedimentation. Effects on plant communities are a function of flooding frequency, duration and seasonality, as well as of sediment depth, texture and mineralogy. The flooding characteristics of a site depend on its elevation relative to the river's flooding regime. As aggradation elevates fluvial benches and the effects of flooding subside, alluvial plant communities undergo primary succession. Disturbances such as logging superimpose secondary loops. Due to harvesting, most alluvial plant communities are in a state of secondary succession. Site classification separates the flooding gradient into low, middle and high benches, each of which exhibits similar physical effects due to site inundation of sedimentation. These site classifications can be used to manage alluvial floodplains within a uniform ecological framework.

Marcus, L. (1988). Riparian restoration and watershed management: some examples from the California Coast. ***In*** D. Abell (ed.). California Riparian Systems Conference: Protection, Management and Restoration for the 1990s. September 22–24, 1988. USDA Forest Service.

This article demonstrates how the preservation and restoration of riparian systems helps protect coastal marshes and estuaries. The two examples used are from rural and urban areas: Buena Vista lagoon and Tomales Bay. The repairs cited in these two examples involve stabilizing the stream system using riparian forest and limited structural control measures. This study indicates that the natural functions of a riparian forest aid in slowing floodwater, stabilizing streambanks, and trapping sediments to restore disturbed creek systems and preserve coastal wetlands.

Marquis, D.A. (1965). Controlling LIGHT in small clearcuttings. USDA Forest Service, Northeastern Forest Experiment Station, Res. Paper NE-39. Upper Darby, PA. 15 p.

This study discusses slope and orientation of small clearcut patches to control light incidence and silviculture regeneration. This article suggests that the watershed manager might alter streamflow patterns by using cuttings to affect snow accumulation, snow melt, and other moisture relationships. Light has tremendous implications in riparian silviculture, where treatment areas are small by virtue of the width of riparian zone normally treated.

Morgon, K.H. and Lashmar, M.A. (editors). (1995). Riparian habitat management and research. Proceedings of a Workshop, May 4–5, 1993, Kamloops, BC. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network. 139 p.

The 10 papers and two abstracts in these proceedings are organized by the following categories: The Value of Riparian Habitats; Riparian Habitats; Riparian Wildlife; and Management and Research in Riparian Habitat. Topics include the importance of riparian habitats to fish, bats and small mammals; the use of riparian areas by fishers; vegetation dynamics and classification on alluvial floodplain; livestock impacts on grassland riparian ecosystems; alternative timber harvesting to maintain grizzly bear habitat; and a riparian habitat problem analysis.

Muhlberg, A.G. and Moore, J.N. (1998). Streambank revegetation and protection: a guide for Alaska. The Alaska Department of Fish and Game and the Alaska Department of Natural Resources. Technical Report No. 98-3, Washington, DC. 51 p.

This is an excellent “how to” field guide for streambank revegetation and protection. It describes techniques and their installations to effectively accomplish revegetation projects. Use of dormant cuttings is explained. Dormant cuttings are used for live staking, brush layering, live siltation fences, brush mats, and bundles. The guide also outlines techniques such as vegetated cribbing, grass rolls, and transplanting. Plant species suitable for stream bank revegetation are described according to their commercial availability, applicability, characteristics, fishery/habitat value, revegetation uses, and range.

Murphy, L.M. and Koski, V.K. (1989). Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal of Fisheries Management. Volume 9, pp. 427–436.

Large woody debris recruitment to streams provides structure to stream ecosystems and fish habitat. Resource managers need information on input and depletion rates to ensure that management practices will allow for enough trees to be left to replace the LWD that disappears naturally after each timber-cutting rotation. The study uses LWD mean age to estimate input and depletion rate by size class and stream type. As well, a model was developed to calculate LWD input and depletion rates in streams to assess long-term changes in LWD after timber harvest. It was found that 90 years after clearcut logging without a stream-side buffer strip, large woody debris would be reduced by 70% and recovery to pre-logging levels would take greater than 250 years. Because the majority of LWD is derived from within 30 m of a stream, managers can apply these equations to different channel types to ensure that enough trees of appropriate size will be left in stream-side buffer strips.

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

This paper outlines a series of management principles illustrating the feasibility of deliberate management in enhancing most riparian forest values. The paper discusses rehabilitation goals for enhancing riparian habitat. Management of certain wildlife populations is suggested to be essential in meeting long-term vegetation goals. The specific role of vegetation management is to assist in reaching forest rehabilitation goals while providing stream protection and other benefits that accrue to the wildlife and fish environment. Of the functions of streamside cover, protection from radiation-induced stream warming, bank stabilization, and provision of sources of small and large woody debris in streams are the ones that most need to be understood.

Nierenberg, R.T. and Hibbs, D. (1999). A characterization of unmanaged riparian areas in the central Coast Range of western Oregon. Forest Ecology and Management. Elsevier Science B.V. Department of Forest Science, Oregon State University, Corvallis, OR. Volume 4847, pp. 1–13.

This paper is available on request from the Department of Forest Science at OSU, Corvallis. The study describes the riparian vegetation along unmanaged streams in central Oregon's Coast Range. A number of different attributes of the riparian forests in this region were found, including widely spaced trees, hardwood-dominated stands that were composed mainly of red alder, the presence of conifers (which are less flood-tolerant than red alder) on riparian terraces, and regenerated conifers (except Douglas-fir) following the initial post-fire colonization period. These findings suggest that any riparian management model should incorporate this variability indicative of riparian areas. Results also suggest that competition from hardwoods and shrubs is the biggest limiting factor to conifer growth.

Pabst, J.R. and Spies, A.T. (1999). Structure and composition of unmanaged riparian forests in the coastal mountains of Oregon. Paper 3321. Oregon State University, Corvallis, OR. 54 p.

This paper examines the structure and composition of unmanaged riparian forests in three river basins in the coastal mountains of Oregon. The primary objective of the study is to evaluate stand attributes at three spatial scales: between basins, by location in the drainage network, and by proximity to the stream site. Results showed that in all three subregions, basal area of conifer trees increased with distance from the stream, whereas that of hardwood trees was relatively constant. As well, conifer snag density was highest along second-order streams in the north subregion, highest along first-order streams in the central subregion, and showed no clear trend in the south subregion. The results also showed that the association between canopy covers and topographic position was similar in each subregion. Percent cover of deciduous hardwoods and amount of open sky decreased from terrace to hill slopes, whereas cover of conifers decreased. Conifer tree regeneration was generally scarce, but was most prevalent in the south subregion. Its occurrence was associated with shade-tolerant conifers. A primary mechanism limiting conifer regeneration appears to be competition from shrubs. Patterns in stand structure likely reflect species' competitive abilities and their adaptations to factors that vary with topography, hydrology, geomorphology, and regional climate or geology. This study of unmanaged forest provides baseline ecological information for managed riparian forests where restoration of terrestrial and aquatic habitat is an objective.

Poulin, V.A. and Simmons B. (1999). Restoration of fish habitat and water quality requires riparian silviculture. Forest Renewal BC. Streamline: BC's Watershed Restoration Technical Bulletin. Volume 4, Number 1, pp. 17–19.

This article presents the results of riparian assessments of streams in coastal watersheds. Assessments show that low-cost silvilculture treatments in the order of $2000/ha (conifer release and thinning) can improve conifer growth and produce large trees in 25–50 years. Results indicate that the most prevalent riparian condition on the four watersheds studied was overstocked conifer plantations, for which a one-entry thinning can lead to dramatic improvements in tree height and diameter. The second most frequently observed stand condition was conifers under alder, for which a one-entry girdling or felling treatment can release understory conifers that will respond quickly to increases in light and nutrient availability.

Prichard, D. (1998). A user guide to assessing proper functioning conditioning and the supporting science for lotic areas. USDA Forest Service and National Resources Conservation Service. Riparian Management TR 1737-15, Denver, CO. 125 p.

This book describes the steps in assessing proper functioning condition (PFC) for lotic areas. The procedure is a 17-step approach that assesses the functionality of a riparian area based on three components: hydrologic, riparian vegetation, and erosion deposition. A properly functioning riparian zone will: (1) dissipate stream energy in peak flows, reducing erosion and improving water quality; (2) filter sediment, capture bed load and aid in floodplain development; (3) improve floodwater retention and ground water release; and (4) develop root masses that stabilize stream banks against cutting actions. Depending on the results of the 17 questions, areas are rated as either functional, functional–at risk, or non-functional. The ratings provide managers with the basis for making management choices.

Raedeke, K.J, Taber, D.R., and Paige, K.D. (1988). Ecology of large mammals in riparian systems of Pacific Northwest forests. ***In*** Streamside Management: Riparian Wildlife and Forestry Interactions, pp. 113–132.

Field biologists believe that riparian systems help support a significant portion of the Pacific Northwest regional fauna. This review relates the ecological needs of large, free-living mammals to characteristics of the riparian environment to determine their degrees of need and particular habitat characteristics. Members of the "large mammals" category include: Virginia opossum, snowshoe hare, Nuttell's and eastern cottontail, mountain beaver, beaver, muskrat, nutria, red fox, grey fox, fisher, mink, striped skunk, western spotted skunk, river otter, bobcat, elk/wapiti, mule/black-tailed deer, white-tailed deer and moose. The species that are considered to be the most dependent on riparian habitat are those that are aquatic (i.e., beaver, muskrat, nutria, mink and river otter) and raccoons. Also included are those species that are dependent seasonally on riparian areas for critical habitat (i.e., grizzly bears, west-side elk, and white-tailed deer). The study concludes that the lowland riparian areas that were once highly productive wildlife habitat have become less suitable for wildlife habitat needs.

Robinson, G.R. and Beschta, L.R. (1990). Identifying trees in riparian areas that can provide coarse woody debris to streams. Forest Science. Volume 36, pp. 790–801.

The natural continuous fall of trees into streams over time requires a sustainable supply of coarse woody debris from the adjacent forest. Some methods for achieving this involve the direct placement of trees into streams, but such methods are cost-inefficient and biologically unnatural. This study uses geometric and empirical equations, based on tree size and distance from the stream, to determine the conditional probability of a tree falling into a stream. Furthermore, the use of these equations can aid in the selection of specific trees that can potentially add woody debris to the stream. Thus, it is recommended that resource managers use these probabilities and corresponding basal area factors to design effective riparian buffer strips.

Sedell, J.R. and Beschta, L.R. (1991). Bringing back the “bio” in bioengineering. American Fisheries Society Symposium. Volume 10, pp. 160–175.

The management of streamside vegetation provides a basis for an interactive approach to fisheries enhancement and leads to a more productive, diverse and stable biotic community. Managing streamside vegetation is managing fish habitat. Managers have attempted to restore damaged habitat with various engineered types of in-stream structures. Bioengineering approaches to fish habitat management strive to complement the natural dynamics of functional riparian communities. This paper identifies the physical role that streamside vegetation plays in the stream channel and floodplain areas, and discusses how streamside vegetation allows streams to function in ways that in-stream structures cannot replicate. It is well emphasized throughout the paper that streamside vegetation management is a vital component of riparian management because it plays a multi-faceted role by interconnecting soil and fluvial systems to improve streambank characteristics.

Sedell, J.R., Everest, F.H., and Gibbsons, D. (1997). Streamside vegetation management for aquatic habitat. Proceedings of the National Silviculture Workshop: Silviculture for All Resources, Sacramento, CA.

This paper discusses the important components of a riparian management area, and compares some of the management variability between agencies and National Forests along the West Coast of North America. It examines the trends in composition of some streamside forests, and argues the dependence of the restoration, maintenance, and enhancement of stream habitat on silviculture rather than on structural improvement of instream channels. The authors conclude that managing streamside vegetation is managing fish habitat. The maintenance of biological diversity and fish habitat for several salmonid species and other game fish involve more than set-aside leave strips.

Sedell, J.R., Reeves, H.G., and Burnett, M.K. (1994). Development and evaluation of aquatic conservation strategies. Journal of Forestry, Bethesda, MD, Society of American Foresters. Volume 92, Number 4, pp. 28–31.

The topic of this paper is an aquatic conservation strategy that strives to maintain and restore ecosystem health at watershed and landscape scales. The four components of this strategy include: 1) riparian reserves, 2) key watersheds, 3) watershed analysis, and 4) watershed restoration. Most notable in this paper is an article contributed by Weyerhaeuser. It calls specifically for an alternative view of riparian area management. It reports that watershed assessments reveal that 75% of the fish-bearing stream length does not currently meet desired conditions for forest or in-stream habitat conditions. It asserts that the question of concern should not be if riparian areas should be maintained in late-successional forests, but how best they can be managed to achieve that state as rapidly as possible. This requires an adaptive management approach. Suggested are implementing "smarter systems" as opposed to widely prescribed buffers. Recommendations include planting different species, manipulating stand dynamics and enhancing woody debris content.

Shaw, C.D. and Bible, K. (1996). An overview of forest canopy ecosystem functions with reference to urban and riparian systems. Northwest Science. Volume 70, Special Issue, pp. 1–5.

The forest canopy encompasses living biotic components, residues of biota, dead wood and abiotic components in conjunction with photosynthetic, hydrologic and reproductive functions. This paper compares the urban and riparian systems in terms of these functions. The urban environment functions to buffer noise, shade surfaces, filter atmospheric contaminants, modify microclimates, conserve energy and provide biological diversity. Riparian forests have a direct influence on aquatic ecosystems. Their canopies provide shade, which in turn affects stream temperature, animal activity, amount of water oxygen and rate of decomposition. Leaf litter and coarse woody debris inputs play a role in influencing the quantity and quality of aquatic communities. Microclimates also affect distinct habitat communities such as birds and epiphytes.

Stevens, V., Backhouse, F. and Eriksson, A. (1995). Riparian management in British Columbia: an important step towards maintaining biodiversity. Province of British Columbia, Ministry of Forests Research Program. Working Paper 13/1995, 30 p.

This 30-page booklet is intended to increase awareness and understanding of biodiversity, promote the importance of conserving biodiversity, and communicate provincial government initiatives related to biodiversity. The booklet has two goals: 1) to explore the importance of riparian ecosystems to the broader landscape; and 2) to outline a management strategy for sustaining the biological functioning of riparian areas while providing for human needs at the same time. Also provided is a list of selected readings pertinent to riparian management.

Swenson, E.A. and Mullins, C. (1985). Revegetating riparian trees in southwestern floodplains. ***In*** R.R. Johnson et al. (eds.). Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. USDA Forest Service, General Technical Report RM-120, pp. 135–138.

This study was implemented to investigate the success of using cottonwood and willow to revegetate floodplains with deep water tables. The results indicate that cottonwood and willow poles can successfully be used to re-vegetate floodplains with deep (7–12 feet) water tables. By placing large dormant cuttings into holes below ground surface, practitioners can revegetate floodplains simply and inexpensively.

Tappeiner, C.J. and Bailey, J.D. (1998). Effects of thinning on structural development in 40-to 100-year-old Douglas-fir stands in western Oregon. Forest Ecology and Management. Elsevier Science B.V. Department of Forest Science, Oregon State University, Corvallis, OR. Volume 108, pp. 99–113.

This study focuses on the composition and structure of the understory in thinned and unthinned Douglas-fir/western hemlock stands on sites in western Oregon. It was found that conifer regeneration density and frequency were consistently greater in thinned than unthinned stands, and tall shrub cover was significantly less in unthinned stands than in either thinned or old-growth stands. The management implications of this study are that thinning initiates and promotes tree regeneration, shrub growth, and the development of multi-story stands even when treatments focus on overstory density and spacing.

Tappeiner, C.J., Huffman, D., Marshall, D., Spies, T., and Bailey, J.D. (1997). Density, ages, and growth rates in old-growth and young-growth forests in coastal Oregon. ***In*** Canadian Journal of Forest Research, Volume 27, pp. 638–648.

The results of this study suggest that thinning is necessary in dense young stands where the management objective is to speed the development of old-growth characteristics. The results show that the density of young-growth stands in this study was greater than that of old stands, and diameter growth rates of individual trees were much less, even in the thinned stands. Stand simulations also indicated that young stands with even as few as 250 trees/ha will develop along a different pathway than the old stands.

Thomas, D.K. and Comeau, G.P. (1998). Extension Note: Effects of bigleaf maple (***Acer macrophyllum***) on growth of understory conifers and the effects of coppice spacing on the growth of maple (MOF EP 1121.02). BC Ministry of Forests, Research Branch, Victoria, BC. Volume 24, pp. 1–4.

This paper discusses the competitive nature of the interactive relationship between maple and conifers. Even though bigleaf maple is a desirable ecosystem component that adds to the structural and species diversity of British Columbia's forest, it is a deciduous species that intervenes with the growth of conifers. Maples reduce light levels for conifers below, cause physical damage with their shoots, and smother small conifers with their heavy leaf litterfall. The study design focuses on understory light at different maple densities and re-sprouting growth after coppice thinning.

Weikel, M.J. and Hayes P.J. (1997). Habitat use by cavity-nesting birds in young commercially thinned and unthinned forests. ***In*** COPE Report: Coastal Oregon Productivity Enhancement Program: Promoting Integrated Management of Oregon's Coast Range Forests Through Research and Education. Volume 10, Number 3, pp. 2–6.

This study, presented by Adaptive COPE, suggests that commercial thinning provides positive opportunities for enhancement of habitat required by cavity-nesting birds. The authors' study examined four cavity-nesting bird species: Chestnut-backed Chickadee, Hairy Woodpeckers, Red-breasted Nuthatches, and Brown Creepers. The design of the study tested the effects of three thinning regimes on the survival and foraging of the four bird species. The work demonstrated that commercial thinning in young forests did not negatively impact the abundance of the four cavity-nesting bird species. These cavity-nesting birds were also found to use a variety of substrates for foraging. Large-diameter conifers, large-diameter hardwoods, and large-diameter decayed snags and logs were important for cavity-nesting species. A combination of thinning, retention of hardwood patches, and retention of large-diameter snags and logs provides suitable foraging and nesting habitat for cavity- nesters.

Woudenberg, A. (1995). Livestock impacts on grassland riparian ecosystems: a study proposal. ***In*** Riparian habitat management and research. Proceedings of a workshop, May 4–5, 1993, Kamloops, BC. A Special Publication of the Fraser River Action Plan. Environment Canada and the British Columbia Forestry Continuing Studies Network. pp. 89–100.

Riparian habitats in dry grassland ecosystems are critical to both livestock and many species of wildlife. Conventional range management guidelines for uplands are unsuitable for mesic to hygric areas. Riparian borders surrounding ponds are used disproportionately by cattle and horses and may be more sensitive to disturbance. Livestock can reduce the integrity of riparian habitats through overgrazing, trampling and waste production. The combination of soil compaction, decreased vegetation structure and changes in vegetation species composition can reduce habitat suitability for indigenous wildlife species. The objective of this study is to derive sustainable management strategies for grassland riparian ecosystems. Fence exclosures will allow comparative analyses of grazed and ungrazed riparian ecosystems. Use of a baseline inventory of wildlife and vegetation communities is recommended to derive suitable pond pairs based on criteria of similar species and biophysical features. Long-term monitoring of paired fenced and unfenced ponds should include sampling of bird, small mammal, herpetofauna and vegetation communities, as well as soils and water quality. When species abundance and evenness in exclosures exhibit little or no further change over time, grazing treatments should be tested for impact. From these results, management strategies specific to riparian habitats can be developed.

3.0 World Wide Web Sites

World Wide Web list of recommended reading:

Berg, D.R., Stevenson, P., and Hashisaki, S. Riparian Silvicultural Trials in Washington State. Retrieved on January 13, 2000 from the World Wide Web: http://www.fish.washington.edu:80/people/glasgow/W-I-P/Berg.html

This site presents a management oriented study that is geared to describe the effectiveness of riparian forest regeneration techniques. It is hypothesized that the active management of alder and brush dominated riparian forests will accelerate the process of cultivating large diameter conifer trees from a developed coniferous riparian forest. The study design involves manipulating two variables: regeneration planting pattern and overstory retention. For managers, this project provides information about the effectiveness of riparian stand regeneration strategies.

Canadian Journal of Forest Research. NRC Research Press. Retrieved on February 2, 2000, from the World Wide Web: http://www.nrc.ca/cisti/journals/tocfor.html

This site is a full text on-line library of the monthly editions of the Canadian Journal of Forest Research from January 1996 to December 1999.

College of Forestry at Oregon State University. The Adaptive COPE Program. Retrieved January 25, 2000, from the World Wide Web: http://www.cope.hmsc.orst.edu/

This site provides information on events, projects and newsletters of the Coastal Oregon Productivity Enhancement Program. The site also includes a link to the Adaptive COPE

personnel, where there is background information on each of the persons and their related works.

College of Forestry at Oregon State University. COPE Report. Retrieved January 25, 2000, from the World Wide Web: http://www.cope.hmsc.orst.edu/newsletr/cr_intro.htm

The COPE Report is produced quarterly as a contribution of Adaptive COPE. This particular site provides the bibliography of all past article titles and authors, as well as extended abstracts of recent publications.

College of Forestry at Oregon State University. Hardwood Silviculture Cooperative. Retrieved January 25, 2000, from the World Wide Web: http://www.cof.orst.edu/coops/hsc/

The purpose of this cooperative is to conduct high priority silvicultural research on hardwood species and mixed hardwood/softwood stands in the Pacific Northwest. Its goal is to provide information that will improve the management of these stands. This site also provides information about the history of the HSC, information for the members, a list of HSC Cooperators, a map and matrix of sites, and the annual report and publications.

College of Forestry at Oregon State University. Research Partnerships and Cooperatives. Retrieved January 25, 2000, from the World Wide Web: http://www.cof.orst.edu/coops/

This site lists the names of partnerships and cooperatives within the College of Forestry at Oregon State University. To name a few, there is the VRMC (Vegetation Management Research Cooperative), which is a research program that focuses on plant competition, vegetation control, and early growth of forest stands; the ORGANON (Growth Model), which is a model that projects stand development for several species mixes, stand structures and management activities; the NTC (Nursery Technology Cooperative) program on nursery management and seedling production and performance, which emphasizes reforestation planting systems; and the AMA (Adaptive Management Areas), which designates landscape units to encourage the development and testing of technical and social approaches to achieving desired ecological, economic, and other social objectives.

Eugene District-Bureau of Land Management (1999). Siuslaw Watershed Analysis Siuslaw Watershed Analysis Table of Contents. Retrieved January 25, 2000, from the World Wide Web: http://www.edo.or.blm.gov: 80/watersheds/contents.htm

This site includes many chapters about the Siuslaw Watershed. In particular, Chapter 3 discusses those ecological interrelationships and processes that are necessary to understanding the Siuslaw Watershed and are relevant to the issues identified in Chapter 1. There is emphasis on issues regarding: (1) the silvicultural practices in riparian reserves; (2) the condition of habitat for late-successional forest related species; (3) the condition of anadromous fish habitat; and (4) road and road densities. Chapter 4 provides reasonable forecasts of the future.

Habitat Restoration Group. Habitat Restoration Information Center. Retrieved January 25, 2000, from the World Wide Web: http://www.habitat-restoration.com/

The mission of the HR information centre is to provide private landowners, river and watershed groups, environmentally conscientious businesses, environmental and conservation organizations, land and resource managers, teachers and students with

information that can further focus their efforts at restoring the environment. This site contains a bibliography that describes riparian restoration/revegetation projects, programs, techniques and standards in the Western United States (with emphasis on California), as well as links to Restoration Professional Organizations and Environmental Information sites.

Manci, K.M. (1989). Riparian Ecosystem Creation and Restoration: A Literature Summary. U.S. Fish and Wildlife Service Biological Report, Volume 89, Number 20, pp. 1-59, Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. (Version 16 July 1997). Retrieved January 24, 2000, from the World Wide Web: http://www.npwrc.usgs.gov/resource/literatr/ripareco/ripareco.htm

This summary provides an overview of the status of riparian ecosystems in the U.S., a discussion of several riparian functions, and a review of some techniques used for planning, implementing, monitoring, and measuring project success of riparian ecosystem creation/restoration efforts. Case studies of various riparian ecosystem creation or restoration projects are used to demonstrate these techniques and to report some results of their use. Several well-documented case studies are discussed in detail to illustrate more extensive efforts to plan, implement, or monitor riparian ecosystem creation/restoration projects. In addition, a six-page reference list is provided.

Montana Forest and Conservation Experiment Station, School of Forestry at the University of Montana, Missoula. Riparian and Wetland Research Program. Retrieved January 25, 2000, from the World Wide Web: http://www.rwrp.umt.edu/

This site presents projects that deal with the issues relating to the ecology and management of riparian and wetlands of the state and the region. The research and outreach services performed by RWRP address growing concerns over Montana's riparian and wetland areas. These lands are among the most productive and important in the state, yet much remains to be learned about their ecology and management. The site includes links and a search engine to find online databases. Under the Research Projects link, the 1998 Spring Conference pages discuss practical approaches to riparian and wetland restoration.

Pacific Northwest Research Station USDA Forest Service. Retrieved on February 2, 2000, from the World Wide Web: http://www.fs.fed.us/pnw/pubs.htm

This site provides online publications in Portable Document Format (PDF). The publications are listed either as current inventory, quarterly recent publications, special publication, general technical reports, research note, research papers, miscellaneous publications, plans or projects.

University of Alberta, Edmonton, Alberta. TROLS Research Program. Retrieved on March 20, 2000, from the World Wide Web: http://www.biology.ualberta.ca/trols/trolweb.html

This is the web site for the TROLS study. The study is the first and most comprehensive study undertaken to investigate the full implications of forested buffer strips on the conservation of both aquatic and terrestrial communities in northern Alberta. The project is currently in its fourth year of a six-year project. The objectives of the study are to: determine the effects of removal of riparian forest adjacent to lake and streams in the western boreal regions; determine effects of newly created edges on vegetation, insects, and small vertebrates; evaluate community and population level responses to varying riparian buffer strip widths; examine the resilience of these ecosystems to disturbance; and provide recommendations on minimum riparian buffer widths and/or watershed harvest intensity required to prevent major changes in aquatic and riparian terrestrial communities as a contribution to sustainable forest management.

University of Washington Center for Streamside Studies (CSS) and the Olympic Natural Resources Center (ONRC). Pacific Northwest Riparian Areas: Annotated Bibliography. Retrieved February 2, 2000, from the World Wide Web: http://www.fish.washington.edu/people/glasgow/ripbib.html

This site provides an annotated bibliography for several topics related to Pacific Northwest riparian areas. These topics include the following: Riparian Silviculture and Active Management, General Ecology of Riparian Areas, Riparian Influence on Aquatic Biota, Riparian Influence on Physical Properties of Streams, Riparian-Terrestrial Fauna Interaction, and Riparian Models. There are also additional riparian literature resources links to "Riparian Topics Bibliography and Riparian Ecosystem Creation and Restoration: A Literature Summary."

University of Washington, Center for Streamside Studies and the U.S. Forest Service, Stream Systems Technology Center, Rocky Mountain Research Station. Stream Riparian Bibliography. Retrieved February 2, 2000, from the World Wide Web :http://wwwdev.cfr.washington.edu/ris/html/Intro.htm

This site is a comprehensive bibliography covering over 11000 riparian publication citations. It also provides a database search engine to find an annotated bibliography by author, title, keywords, dates or publications.

U.S. Geological Survey's (USGS) Biological Resource Division. (1998). The Biological Research Resource. Retrieved January 24, 2000, from the World Wide Web: http://biology.usgs.gov/news/brr-02-9.htm

This site is a project review, listing a number of the forest-related research efforts by the Biological Resources Division. Some subjects include the Bat Activity in Thinned, Unthinned, and Old-Growth Forests in the Oregon Coast Range and the Disturbance History and Restoration of Riparian Corridors in Redwood-Dominated Watersheds. Research conducted fosters an increased understanding of the ecology of America's forests and woodlands, including the species that live in these habitats.

Walters, C. (1997). Challenges in Adaptive Management of Riparian and Coastal Ecosystems. Conservation Ecology, Volume 1, Number 2, p. 1. Retrieved January 21, 2000, from the World Wide Web: http://www.consecol.org/vol11/issue2/art1

Many case studies in adaptive-management planning for riparian ecosystems have failed to produce useful models for policy comparison or good experimental management plans for resolving key uncertainties. Management stakeholders have shown self-interest, viewing adaptive-policy development as a threat to existing management regimes, rather than as an opportunity for improvement. Results of many failures suggest that management experimentation should be seen as an opportunity rather than a threat.

Watershed Management Council. (1999). Potential Problems, Pitfalls, and Possible Solutions in Watershed Restoration. Watershed Management Council Newsletter, Fall 1993, Volume 5, Number 3. Retrieved January 25, 2000, from the World Wide Web: http://glinda.crns.humboldt.edu/wmchome/index.html

This site presents different problems that surfaced during the watershed restoration work at Redwood National Park and the Trinity River Fish and Wildlife Restoration Program. It offers possible solutions for similar problems that will most likely arise during any large-scale watershed restoration program within the range of the Northern Spotted Owl.

World Wide Web Virtual Library. Forestry Events**.** Retrieved on February 2, 2000, from the World Wide Web: http://www.metla.fi/info/vlib/Forestry/Category/Events/

This site provides information on past and upcoming forestry events. Included are the dates, places, and scheduled topics of past and future forestry-related congresses and conferences, workshops and courses, seminars and symposia, exhibitions, and events.

Appendix 1. Selected listing of "gray literature" that provides support documentation for riparian assessments or riparian restoration projects undertaken in British Columbia. Refer to Poulin et al. (2000) for a complete list of riparian restoration projects and assessments undertaken. Contact names are provided in that report. For information on these reports or others that may be available, contact the people indicated in the listing or the regional Watershed Restoration Program coordinators.

BioTerra Consulting. 1998. Watershed and site level riparian assessment of Cogburn Creek watershed, March 1998. Prepared for BC Ministry of Environment. 10 p. plus appendices.

Dillon Consulting Limited. 1998. Squamish area watercourses: riparian assessment and prescriptions, June 30, 1998. Prepared for Steelhead Society Habitat Restoration Corporation. 34 p. plus appendices.

EBA Engineering Consultants. 1998. Integrated watershed restoration assessment: Phillips River watershed. April 1998. Prepared for Steelhead Society Habitat Restoration Corporation. 72 p. plus appendices.

Enviro-Pacific Consulting. 1999a. Squamish River watershed: riparian overview assessment of Mamquam River and tributaries. March 1999. Prepared for Squamish River Watershed Society. 25 p. plus appendices.

————. 1999b. Squamish River watershed. As-built report on riparian restoration works in the Chance Creek watershed, 1998. February 1999. Prepared for Squamish River Watershed Society. 12 p. plus appendices.

Forrester and Associates. 1999. Fish, channel, riparian assessment and prescriptions: Orford River watershed. March 1999. Prepared for International Forest Products Ltd., Kingcome Enhanced Forestry Division. 121 p. plus appendices.

Harris, C. 1999. Narrowlake Implementation Project. A report prepared for BC Ministry of Environment, Lands and Parks, Prince George, BC. Aquafor Consulting Ltd. RR7, S16, C7, Prince George, BC. V2N 2J5; email: auafor@mg-net.com

Hatfield Consultants Ltd. 1999. Level 1 channel assessment, fish habitat and riparian assessment and prescriptions: Eldred River. March 1999. Prepared for MacMillan Bloedel, Stillwater Division. 100 p. plus appendices.

Oikos Ecological Services Ltd. 1998a. Riparian assessments and prescriptions for Silverhope and Slesse Creeks in the Chilliwack Forest District, BC, March 1998. Prepared for Steelhead Society Habitat Restoration Corporation. 23 p. plus appendices. Oikos Ecological Services Ltd - Donald McLennan, Tel: 250-847-1946 Box 985, 3855 2nd Avenue, Smithers, BC V0G TN0; email: oikdon@bulkley.net

————. 1998b. RAPP overview and general riparian prescriptions, Slesse Creek, Silverhope Creek, and Pitt River. February 5, 1998. Prepared for: Steelhead Society Habitat Restoration Corporation. 19 p. plus appendices.

————. 1999a. Conceptual stand management prescriptions to accelerate the development of desirable old growth attributes in immature conifer stands. May 1999. Prepared for BC Ministry of Environment, Lands and Parks. 29 p.

————. 1999b. Riparian overview and conceptual restoration prescriptions for selected sub-drainages of the Chehalis River, south-western British Columbia. March 1999. Prepared for BC Ministry of Environment, Lands and Parks. 22 p. plus appendices.

Page, N, J. Millar, K. Rood, and K. Christie. 1999. Indian River watershed: overview fish and riparian habitat assessment. March 1999. Prepared for International Forest Products Ltd, Empire Logging Division. Coast River Environmental Services Ltd., Northwest Hydraulic Consultants Ltd., and Talisman Land Resource Consultants Ltd. 71 p. plus appendices.

Poulin, V.A. 2000. Restoration of riparian forests in Tzoonie River: speeding recovery of mature forest characteristics. Prepared for: Dennis Lozinsky, Kingcome Enhanced Forestry Division, Sechelt Field Office, International Forest Products, 208-5760 Teredo Street, Sechelt, BC. 40 p. plus appendices: V.A. Poulin, 2153 West 46th Avenue, Vancouver, BC V6M 2L2; email: vpoulin@istar.ca

Poulin, V.A. and B. Simmons. 1998a. Riparian assessment: Malksope River: recommended prescriptions for lower 3.0 km of the river. March 1998. Prepared for Warren Warttig, International Forest Products, Kingcome Enhanced Forestry Division, Box 36, Campbell River, BC. 73 p. plus appendices: V.A. Poulin, 2153 West 46th Avenue, Vancouver, BC V6M 2L2; email: vpoulin@istar.ca ; and Bart Simmons, Quillicum Forestry Services Ltd, 1258 Haywood Avenue, West Vancouver, BC V7T 1V1; email: barts@bc.sympatico.ca

————. 1998b. Riparian assessment: Little River: recommended prescriptions. November 1998. Prepared for Karen Campbell, Weldwood of Canada Limited, Williams Lake, BC. 73 p. plus appendices. Weldwood of Canada Limited, P.O. Box 4509, Williams Lake, British Columbia V2G 2V5

————. 1999a. Riparian assessment: Atleo River: recommended riparian silvicultural plan. February 1999. Prepared for Warren Warttig, International Forest Products, Campbell River, BC. 65 p. plus appendices. International Forest Products Ltd. Kingcome Enhanced Forestry Division, Box 36, Campbell River, BC.

————. 1999b. Riparian assessment: Kootowis Creek: recommended preliminary silvicultural plan. March 1999. Prepared for: Warren Warttig, International Forest Products, Campbell River, BC. 32 p. plus appendices.

—————. 1999c. Keogh River (Western) riparian assessment and recommendations for riparian silviculture along 4.2 km of river being restored for fish habitat. August 1999. Prepared for Ken Hall, Western Forest Products Limited, 118-1334 Island Highway, Campbell River, BC. 49 p. plus appendices.

—————. 1999d. Buck Creek riparian assessment and recommendations for restoration of riparian areas between 1.2 km and 6.0 km. August 1999. Prepared for Warren Warttig, International Forest Products, Campbell River, BC. 52 p. plus appendices.

—————. 1999e. Tzoonie River riparian assessment and recommendations riparian silviculture. September 1999. Prepared for Dennis Lozinsky, International Forest Products, Sechelt, BC. 47 p. plus appendices.

Poulin, V.A., B. Simmons, and T.K. Brown. 2000. Keogh River riparian restoration project: February 2000: Interim Report. Prepared for: Mike DesRochers, Western Forest Products Limited. 1594 Beach Avenue, Port McNeill, BC. 7 p.

Poulin, V.A., C. Harris, and B. Simmons. 2000. Riparian restoration in British Columbia: what's happening now, what's needed for the future. Prepared for: Brendan Holden, Ministry of Forests. 3 rd Floor, 1450 Government Street, Victoria, BC. 71 p.

Steelhead Society Habitat Restoration Corporation. 1999a. Shop Creek, 36 Mile Creek and Ashlu Creek Side Channel: riparian rehabilitation as-built report. March 31, 1999. 15 p.

—————. 1999b. Silverhope and Hicks Creeks: riparian rehabilitation as-built report, March 31,1999. 11 p.

—————. 1999c. Slesse Creek: riparian rehabilitation as-built report, March 31, 1999. 5 p.