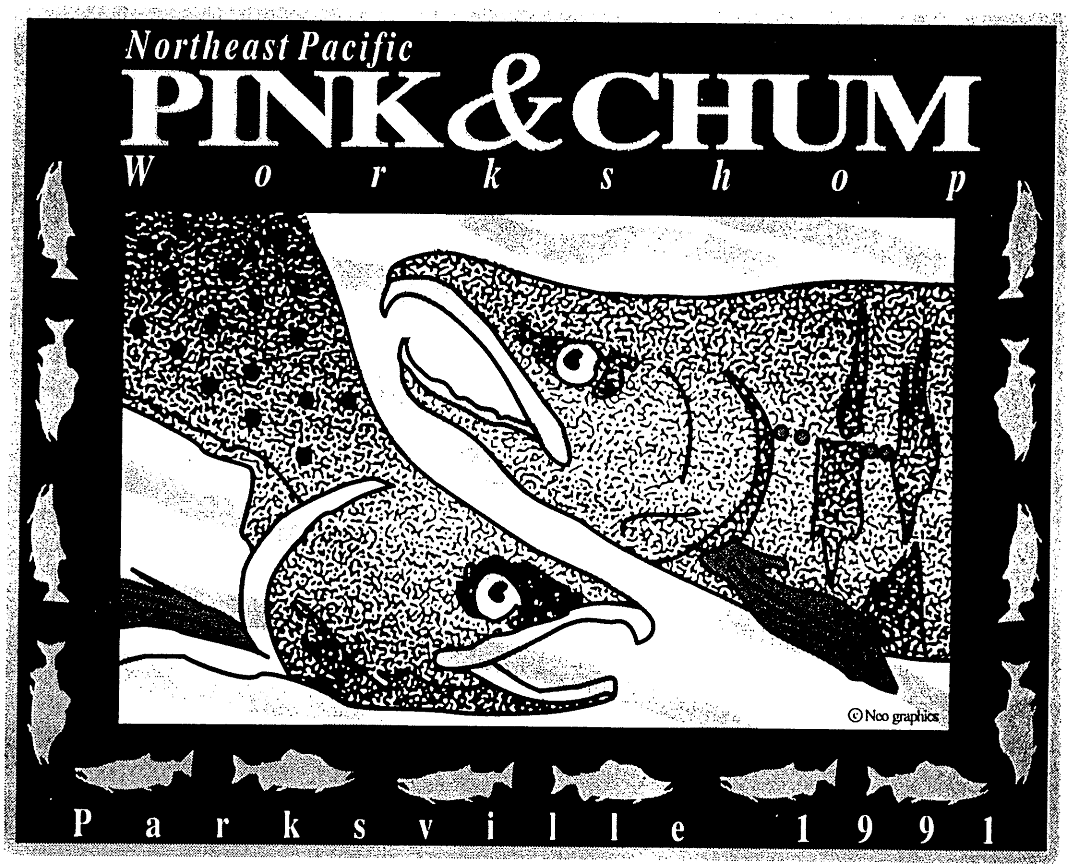
PROCEEDINGS OF THE 15TH NORTHEAST PACIFIC PINK AND CHUM SALMON WORKSHOP



February 27 - March 1, 1991
Tigh-Na-Mara Resort
Parksville, British Columbia

Pacific Salmon Commission
Canada Department of Fisheries and Oceans

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Enhancing Fisheries Resources Through Active Management of Riparian Areas

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Many streams in the Pacific Northwest have experienced a loss of habitat complexity resulting, in part, from the conversion of structurally and biologically diverse riparian vegetation to uniform age stands of red alder following timber harvest. Reduced inputs of large conifer debris from riparian zones in second-growth forests has led to streams with fewer pools, lower sediment and organic matter retention capacities, and increased fine sediment transport potential. Although salmonids with extended freshwater residence have been affected most by these habitat changes, pink and chum salmon spawning success may be influenced by delivery of fine sediment from watersheds with reduced instream sediment storage. By utilizing forestry management techniques, riparian areas can be treated to restore vegetative diversity and provide the types and sizes of woody debris needed to preserve productive stream habitat and provide natural storage and routing characteristics. These techniques include conifer planting, patch cutting, thinning, and other methods of vegetation management. We suggest that timber harvest around streams in second-growth forests based on alternately managed and undisturbed patches of riparian vegetation can potentially accelerate the restoration of diverse and productive stream habitat.

Forest practice regulations governing treatment of riparian areas during timber harvest in the Pacific Northwest have changed rapidly during the last decade (Oregon Department of Forestry 1987; British Columbia Ministry of Forests 1988; Bilby and Wasserman 1989). Perhaps the most controversial aspect of these changes has been an increasing emphasis on the retention of standing, merchantable timber along streams. One of the primary purposes of leaving these trees is to provide a future source of large woody debris (LWD) for the channel.

Research over the last 20 years has shown that LWD plays a major role in determining the structural and functional attributes of lotic systems (Harmon et al. 1986). Large woody debris strongly influences channel form in many small to medium size streams, causing streambed scour that creates pools (Sullivan et al. 1987; Andrus et al. 1988) and stabilizing channel features such as gravel bars and sediment deposits (Lisle 1986; Bilby and Ward 1989). Tree boles, branches and rootwads also function in the retention of finer organic materials such as needles and leaves (Bilby 1981). In small streams, the vast majority of this type of material is associated with LWD (Naiman and Sedell 1979; Bilby and Likens 1980). In addition, LWD directly affects stream biota by providing a substrate and energy source for some invertebrates (Anderson et al. 1978; Benke et al. 1985) and by providing habitat and creating cover for fishes (Bisson et al. 1987; Shirvell 1990).

Protection of aquatic and riparian resources has clearly improved as a result of the recent changes in riparian management. However, we believe that current riparian management guidelines are failing to achieve desired goals in certain situations. The following discussion will briefly outline some inadequacies of riparian management on forested lands and suggest alternatives to address some of these problems.

CURRENT STATUS OF RIPARIAN SYSTEMS ON FORESTED LANDS

Historically, accumulations of LWD were common in flowing waters in the Pacific Northwest, including many of the major river systems of the region (Sedell and Luchessa 1982). Most of the wood was removed from larger rivers early in this century, as an aid to navigation. Transportation of logs along water courses by splash damming or the use of channels as skid trails also contributed to the loss of wood and destruction of habitat in some streams (Wendler and Deschamps 1955). Deliberate removal of LWD from some channels was done to improve water quality and provide upstream passage for anadromous fishes (Bryant 1983; Bilby 1984). In addition, removal of riparian vegetation, and thus the source of future LWD, during timber harvest or conversion of forest land to other uses has had a widespread influence on LWD in streams (Swanson and Lienkaemper 1978).

As a result of these practices, many streams in the Pacific Northwest contain far less LWD than they did originally (Grette 1985; Bisson et al. 1987; Bilby and Ward *in press*). Features of the channel associated with wood, including pools, sediment and organic matter depositional sites, and waterfalls, have decreased dramatically in these systems (Bilby and Ward *in press*). It is likely that declines in fish populations in these streams are in part attributable to the habitat changes caused by loss of LWD (Murphy et al. 1985; Hicks et al. *in press*; Sedell and Beschta *in press*). Reestablishment of productive habitat in these channels hinges on restoration of LWD.

HABITAT QUALITY IN STREAMS IN OLD-GROWTH AND SECOND-GROWTH FORESTS

Riparian vegetation in areas that have been logged is dominated by smaller trees (Figure 1), often red alder (*Alnus rubra)*. The capacity for this vegetation to supply the size and amounts of LWD necessary for the full range of woody debris functions in streams depends upon a variety of factors, including the size of the channel. Debris produced by second-growth riparian vegetation may be too small to maintain a stable position in larger channels (Bilby and Wasserman 1989; Bilby and Ward 1989). In addition, LWD produced by red alder is much shorter-lived in streams than conifer debris (Harmon et al. 1986).

Stream habitat reflects changes in LWD amount and characteristics associated with altered riparian vegetation in managed areas. Comparison of channel features in streams flowing through unlogged forests with those in second-growth forests illustrates the relative influence of these stand conditions on aquatic systems. Data were from a study of woody debris characteristics and function in streams bordered by different types of riparian vegetation (Bilby and Ward 1989; Bilby and Ward *in press*). Surveys of LWD structure and function in western Washington streams were conducted on 22 sites in undisturbed, conifer-dominated stands and 29 sites in 40 to 60 year old second-growth stands, the typical age of harvest in commercial forests. Variables measured during these stream surveys included species, amount and size of LWD, as well as the frequency, surface area, and type of pool (Bisson et al. 1982) associated with the wood. Also measured were the frequency and surface areas of sediment accumulations associated with LWD, and the frequency and height of LWD-associated waterfalls. A detailed description of methods used in the surveys may be found in Bilby and Ward (1989).

Amount of LWD decreased with increasing stream size in both old-growth and second-growth forests; however, more LWD was found in streams at unlogged sites than at second-growth sites for all stream sizes (Figure 2; $P<0.05$, t-test). Pool frequency also decreased with increasing stream size for both stand types (Figure 3). LWD-associated pools were more common at old-growth sites than at second-growth sites, with the greatest differences observed in larger streams ($P<0.05$). Pool types were much more diverse at the unlogged sites (Figure 4). Over 90% of the pools in second-growth sites were scour pools. Scour pools were also the most prevalent type at the unlogged sites, accounting for approximately 45% of the pools, but plunge, backwater and dammed pools were all more common in old-growth than in second-growth sites.

Sediment routing in streams is influenced by LWD through the formation of depositional areas and the creation of waterfalls. Waterfalls reduce stream power with little erosion of bed or banks, and thus represent an inefficient energy expenditure from the standpoint of material movement (Heede 1972). Depositional areas were much more common at the unlogged sites than at second-growth sites (Figure 5). This difference was in large part due to the greater abundance of LWD in streams at unlogged sites. The old-growth forested streams also contained more waterfalls than the second-growth sites (Figure 6). Sediment routing through channels in the unlogged conifer-dominated riparian zones was likely slowed as a result of the greater numbers of depositional areas and waterfalls.

Since pink and chum salmon utilize streams almost exclusively for spawning, the rate and timing of delivery of fine sediment to stream reaches used for spawning is of critical importance. The greater efficiency of sediment transport in LWD-impoverished headwater channels suggests that delivery of fine sediment to downstream areas used by pink and chum salmon could occur at relatively low discharges. Intrusion of sediment into streambed gravel is more apt to occur at reduced streamflow than during periods of high discharge, when fine sediment tends to be flushed from the substrate (Beschta and Jackson 1979). Thus, lack of LWD may impact downstream spawning gravel by enabling transport of fine sediment at times when intrusion and deposition is most likely to occur.

MANAGEMENT OPTIONS TO ENCOURAGE RIPARIAN RECOVERY

Current conditions in many Pacific Northwest riparian zones are insufficient to meet a key objective of fish habitat managers: creating and maintaining structurally complex stream channels (Bisson et al. *in press*). Because channel complexity is strongly influenced by interactions between the stream and riparian zone, streamside management should focus on preservation of structurally and vegetatively complex riparian areas. Unfortunately, some prescriptions currently being applied to streamside management areas may impede the establishment of desired riparian conditions. Since timber harvest throughout the region will focus increasingly on second-growth forests, methods especially suited to managing riparian areas in these forests need to be developed.

Even in those cases where riparian zones presently exhibit the characteristics needed to ensure maintenance of productive stream habitat, long-term successional consequences of retaining a relatively narrow strip of trees along the stream should be considered. One possible outcome of this management approach is creation of riparian zones dominated by shrubs resulting from increased light reaching the forest floor following harvest of upland forests (Hibbs 1987). A dense shrub layer could hinder or preclude reforestation, ultimately yielding a riparian zone that contains very few trees. In most cases, such riparian conditions would not favor the restoration of productive stream habitat.

These problems suggest that an active approach to managing riparian vegetation in second-growth forests might be better suited to meeting fish habitat objectives than the current approach of leaving unmanaged buffer strips, often composed chiefly of red alder. The first and most important step in the development of an active riparian management program is determination of aquatic habitat objectives for the site. These objectives may vary due to key stream features including fish species present, size of the stream, morphology and substrate of the channel, previous history of disturbance, and downstream conditions. Some goals might include the development and long-term maintenance of complex channel structure, increased amounts of LWD, creation of pool habitat, deposition of gravel, or retention of sediment.

Once a set of aquatic objectives has been established, riparian conditions necessary to meet these objectives can be determined. Riparian objectives appropriate for meeting some of the aquatic habitat goals listed above might include production of large trees to provide stable LWD, increased diversity of riparian plant species, and creation of a more varied distribution of tree age classes. These objectives would also be influenced by the type of vegetation present at the site at time of timber harvest.

The condition of riparian vegetation at time of harvest also would influence the silvicultural approaches most appropriate to achieving riparian objectives. For example, a primary objective for sites dominated by even-aged stands of red alder could be the establishment of conifer species. Silvicultural options appropriate for this goal include thinning and underplanting or cutting patches and planting (Emmingham et al. 1989). Objectives and silvicultural treatments would be different for sites dominated by second-growth conifers. In these locations, encouraging the development of large trees, diversifying the age-class distribution, and increasing species diversity would be appropriate riparian objectives. Goals could be achieved through selective thinning (Berg 1990), cutting small patches in the riparian zone and planting desired species, or creating conditions conducive to hardwood establishment.

Application of this approach permits land managers to design riparian zones composed of alternating patches of actively managed and undisturbed forest. Undisturbed patches would be located in areas most apt to be sensitive to disturbance, for example, near tributary junctions, and in areas of unstable streambanks or around riparian wetlands. Since some amount of timber removal will occur from the managed patches, the undisturbed patches could be considerably wider than required by current regulations without any consequent loss in total amount of timber harvested.

There are a number of potential advantages of active management of riparian areas over current streamside prescriptions. Accelerating the growth of trees in riparian zones by thinning (Berg 1990) may greatly speed the production of larger pieces of LWD. Larger pieces of wood are needed to maintain position in wider stream channels, and they have a greater influence on channel form and function than small pieces (Bilby and Ward 1989). Windthrow risk, often increased by current riparian management regulations, may be reduced by leaving undisturbed or thinned patches in windfirm areas, or by cutting patches in locations prone to windthrow (Steinblums et al. 1984). Elevated light levels reaching the stream from patch cutting or thinning may increase algal production, producing greater amounts of food for fish (Hawkins et al. 1983; Bilby and Bisson *in press*). In some situations, trees cut from patches or during thinning could be deliberately added to the channel to provide an immediate source of LWD.

Water quality problems associated with active management of riparian vegetation can be minimized by applying this strategy only along suitable stream reaches and carefully locating the patches to be managed. For example, active management may be inappropriate along streams where aquatic resources are considered to be highly temperature sensitive. In less thermally sensitive systems, the proportion of managed and undisturbed areas can be adjusted to reflect the relative sensitivity of the system. Cut or thinned patches can be located where there is natural topographic shading, on the north side of the stream and along narrow riffles to reduce exposure to direct sunlight. Streambank erosion and sedimentation can be ameliorated by locating undisturbed patches along stream sections with actively eroding banks, by retaining trees with root systems that stabilize streambanks, and by preventing soil compaction caused by use of heavy equipment in riparian zones.

There are also potential advantages of active riparian management from a forestry perspective. This system does enable recovery of some of the currently unavailable timber from the riparian zone. However, this advantage would be partially or wholly offset by increasing the size of undisturbed patches. Yarding corridors through riparian zones could be established, provided sufficient deflection is available to lift logs completely as they cross the channel to avoid damage to the banks. This approach would permit the return to reforestation and harvesting of a portion of the area within riparian zones.

Many of the fisheries benefits associated with the riparian management approach outlined above will take decades to be realized. Nonetheless, establishment and maintenance of productive fish habitat will ultimately depend upon structurally complex and vegetatively diverse riparian communities. Application of well established silvicultural methods may significantly reduce the time required to achieve these conditions.

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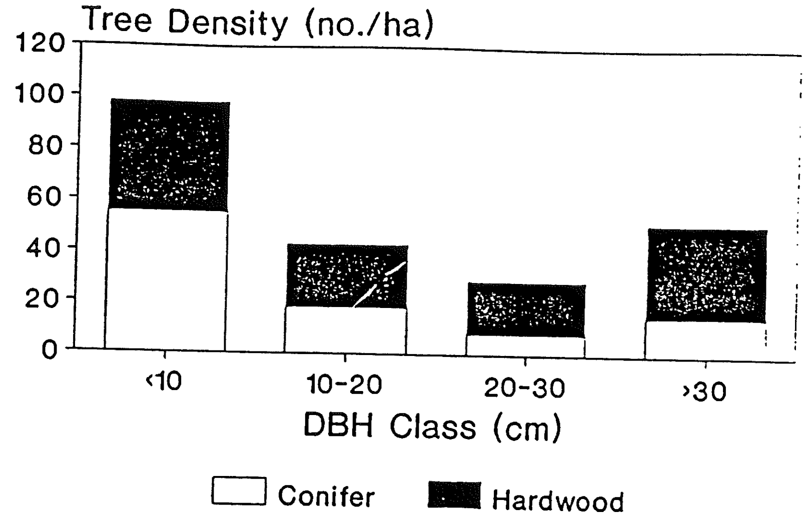

Figure 1. Proportion of hardwood and conifer trees in four diameter classes remaining in riparian areas in western Washington after timber harvest (Washington Department of Wildlife, unpublished data).

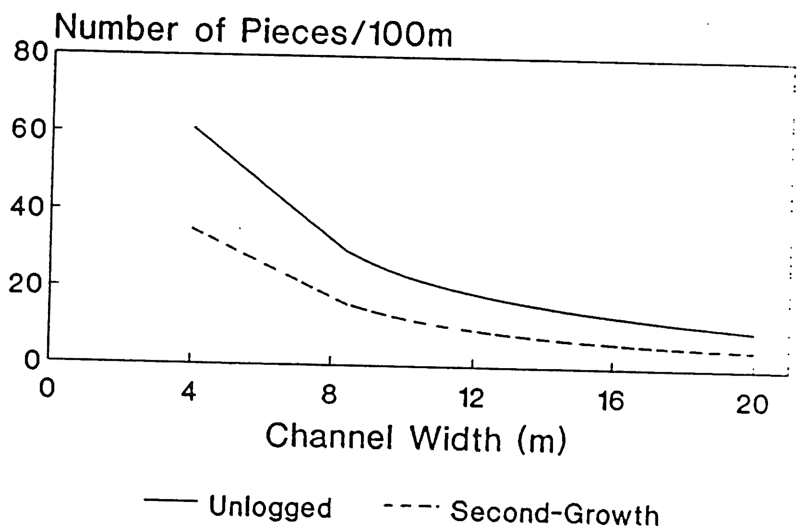

Figure 2. Abundance of pieces of large woody debris as a function of channel width at unlogged and second-growth sites. Regression equations for the relationships are:
Unlogged; $\log_{10}$LWD frequency=-1.12$\log_{10}$channel width+0.46, r^2=0.69
Second-Growth; $\log_{10}$LWD frequency=-1.23$\log_{10}$channel width+0.28, r^2=0.75.

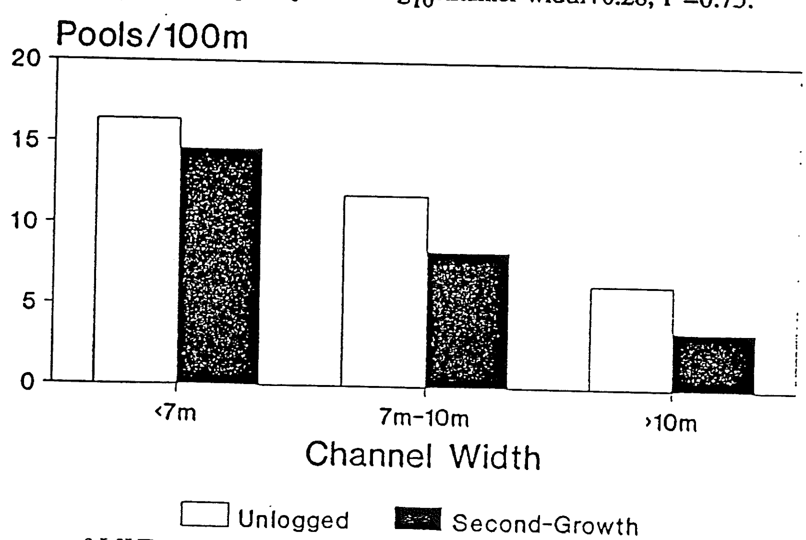

Figure 3. Frequency of LWD-formed pools at unlogged and second-growth sites.

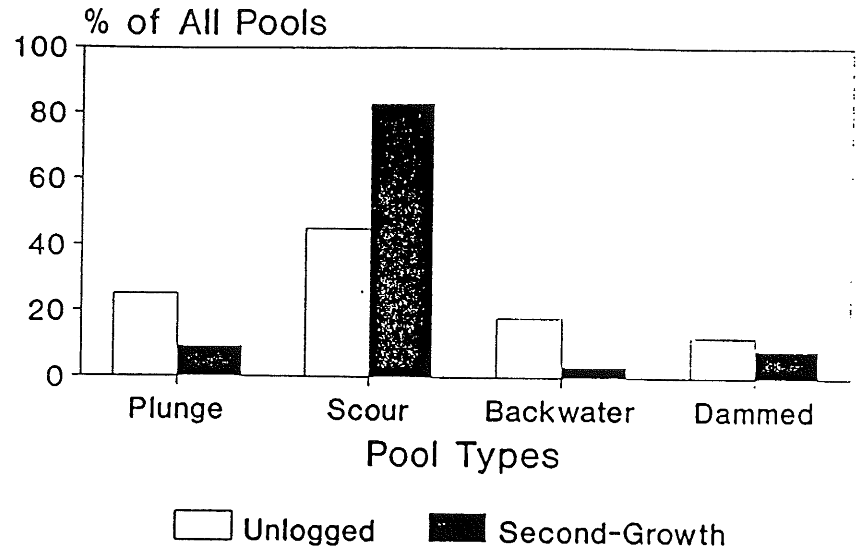

Figure 4. Types of pools associated with LWD in streams at unlogged and second-growth sites. Pool types were classified according to the method of Bisson et al. (1982).

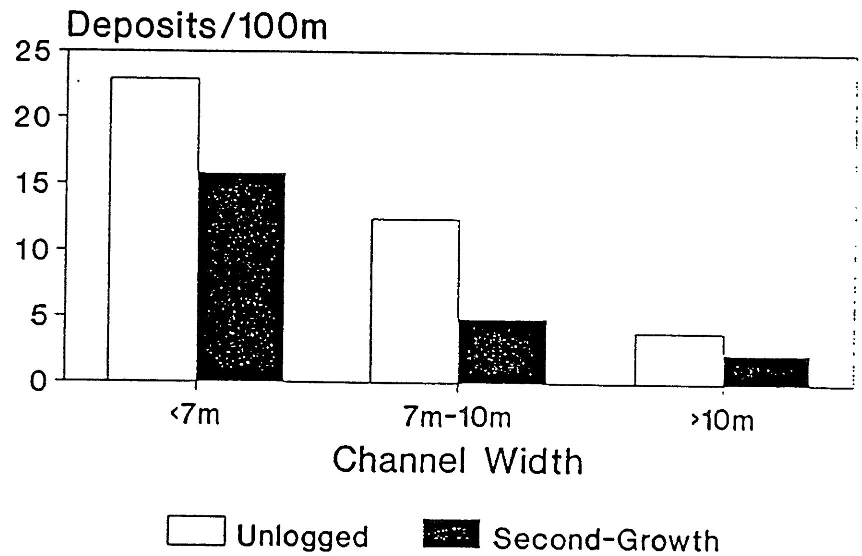

Figure 5. Abundance of depositional sites formed by LWD at unlogged and second-growth sites.

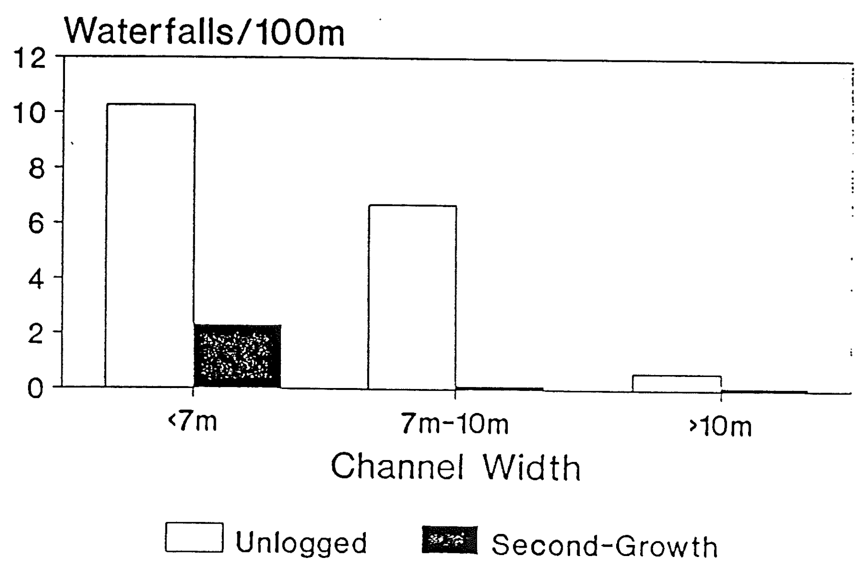

Figure 6. Abundance of LWD-formed waterfalls at unlogged and second-growth sites.

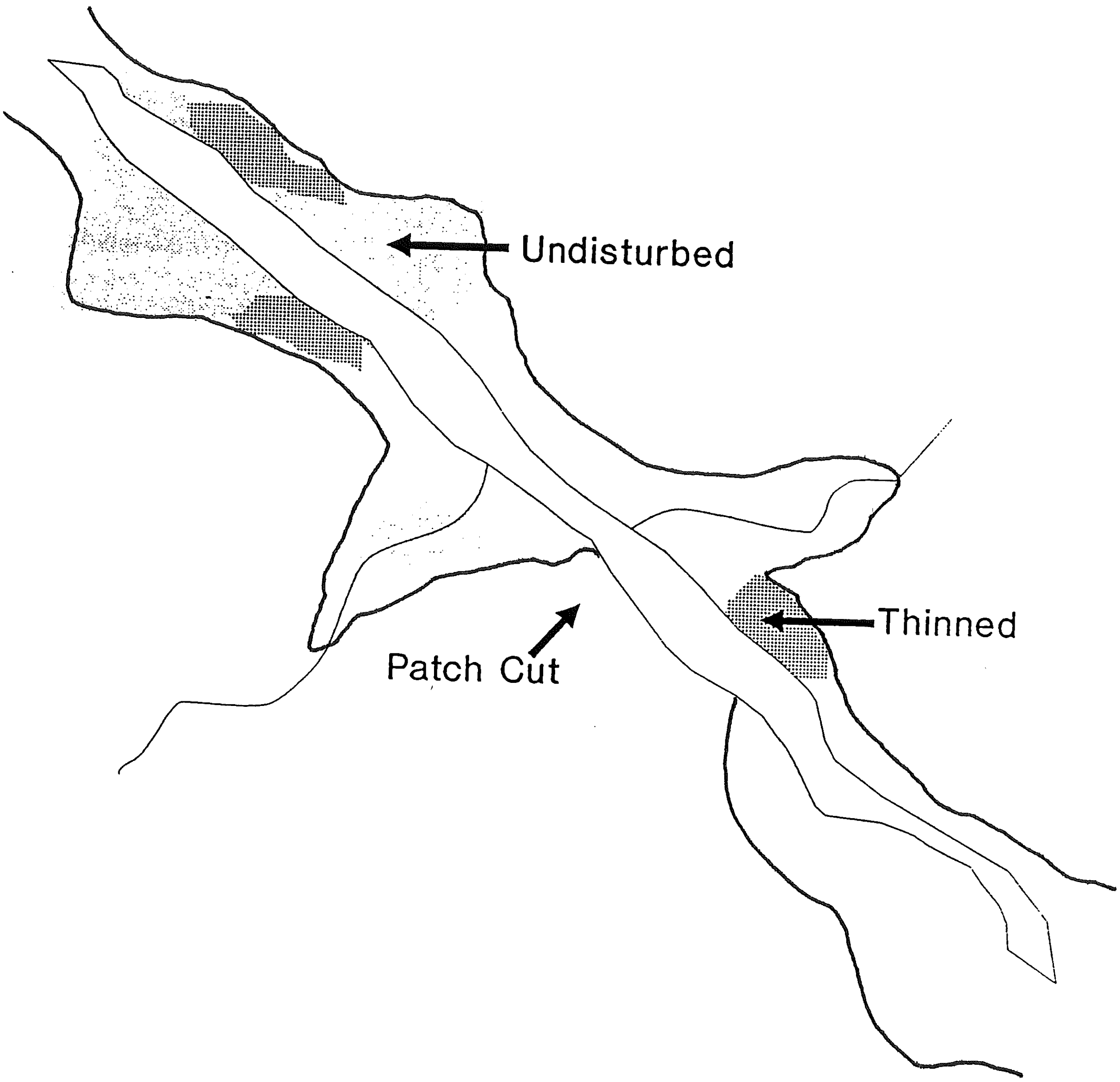

Figure 7. Illustration of a hypothetical riparian treatment utilizing some of the options outlined in this paper.