Harvest Effects on Riparian Function And Structure Under Current Oregon Forest Practice Rules

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Prepared by Liz Dent

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Harvest Effects on Riparian Function And Structure Under Current Oregon Forest Practice Rules

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INTRODUCTION

The purpose of this study was to evaluate the effectiveness of the 1994 Oregon Department of Forestry's Forest Practices Stream Rules. The particular focus was on rules designed to address riparian forest stands along fish-bearing streams. The purpose of the vegetation retention rules is to maintain and promote *desired future riparian stand conditions* that will provide ample shade, an abundance of large wood to the channel, bank stability, snags, nutrient input and nutrient uptake. Under the 1994 stream rules, riparian stands can be managed to the extent that these goals can be met. This study was designed to answer the question:

> *Are the new (1994) forest practices regulations effectively maintaining and promoting riparian conditions that will achieve the desired future condition?*

This technical report summarizes the forest practice (FP) rules and relevant research on riparian function and structure. The study objectives, monitoring questions, and study design are described. The results are presented in detail followed by summary, conclusions, and recommendations.

FOREST PRACTICE RULES

The water protection rules require the establishment of riparian management areas (RMAs) on most streams that are within or adjacent to a harvest unit. The RMA width requirements vary depending on the stream classification (OAR 629-635-300)(Table 1). Oregon Department of Forestry (ODF) classifies streams by "Type" and by stream size. The "Type" designations include Type F for fish-bearing streams, Type N for non-fish-bearing streams, and Type D for domestic water sources without fish presence. Stream sizes are based on average annual stream flow in cubic feet per second (cfs). The stream size classifications are small (< 2 cfs), medium (≥ 2cfs and < 10 cfs), or large (≥ 10cfs).

A landowner has multiple options for harvesting within the RMA. One scenario under which RMAs can be managed is if the existing basal area exceeds the "standard target" for basal area. Normal conifer yield tables from average upland stands were used to develop conifer basal area standard targets. The effects of riparian influences on stocking, growth and mortality were used to lower the basal area targets to a level thought to be reasonable for riparian areas (Lorensen et al. 1994). Landowners have the option to harvest conifer trees within riparian management areas that are in "excess" of the basal area targets while maintaining a 20-foot no-cut buffer zone as measured from the average annual high water mark. This standard target prescription as well as five other prescriptions are described below.

Table 1. Riparian Management Area Widths.

Stream Size	Fish-bearing Stream (Type F)	Domestic Use (Type D)	Non-fish bearing, Non-Domestic Use (Type N)
Large	100 Feet	70 Feet	70 Feet
Medium	70 Feet	50 Feet	50 Feet
Small	50 Feet	20 Feet	--

No-cut Buffer (OAR 629-635-310): The landowner can leave a fixed buffer width and not harvest within the RMA. There were four RMAs managed with a no-cut harvest in this study.

Standard Target Basal Area (OAR 629-640-100): A standard conifer basal area target has been established that varies by stream size, Type and georegion. If the pre-harvest conifer basal area within the RMA exceeds the target, the landowner can harvest to the standard target while retaining a 20-foot no-cut buffer, and a specified minimum number of trees per 1000 feet of stream length, which also varies by stream size. If the basal area is less than the standard target but greater than one-half the standard target, the landowner doesn't have the option to manage. There were 11 RMAs in this study managed with the standard target prescription.

Active Management (OAR 629-640-110): A landowner can place large wood in the stream and receive a basal area credit. Piece size and credit vary by stream size and Type. The credit allows for additional harvest in the RMA but never below the active management basal area target. This option was not used on any of the sites in this study.

Small Type N Streams: (OAR 629-649-200): Most small Type N streams do not have RMA requirements other than equipment and site preparation restrictions. There were no small Type N streams in this study.

Alternative Prescription (OAR 629-640-300): If the basal area is less than one-half the standard target, the landowner can use an alternative prescription. There are two conditions which may warrant an alternative prescription: a catastrophic event or a riparian stand capable of supporting conifers which currently is dominated by hardwoods. Only the second condition was encountered in this study.

On sites that are hardwood-dominated, a riparian conifer restoration (RCR) prescription can be used to convert a hardwood-dominated riparian area to one dominated by conifers. Alternating conversion (maximum 500 feet long) and retention blocks (minimum 200 feet long) are established. In the conversion block, the landowner can harvest all trees to within 10 feet of the stream and must replant conifers. Within retention blocks the landowner may apply general prescriptions if the block meets the basal area targets. If the retention blocks do not meet the standard target, then the landowner can harvest all conifers to within 50, 30, and 20 feet on large, medium and small streams, respectively. There were four RMAs managed with RCR prescriptions in this study.

Site Specific Plan (OAR 629-640- 400): A landowner has the option to develop a site-specific plan for harvesting within the RMA. The goal of this rule option is to encourage landowners to look for opportunities to enhance and restore riparian areas. There were no RMAs managed with a site specific plan in this study.

LITERATURE REVIEW: RIPARIAN STRUCTURE AND FUNCTION

Riparian areas fill a special environmental niche between aquatic and terrestrial systems and provide a unique linkage from the headwaters of a basin to the outlet (Beschta 1991, Gregory et al. 1991). Structural characteristics of riparian areas vary greatly because the plant communities reflect fluvial and fire disturbances, soil and geomorphic characteristics and management practices (Gregory et al. 1991, Hayes et al. 1996). Many of today's forested streams reflect past management strategies that did not require leave trees, but included the use of splash dams and removal of large wood from the stream. They also reflect changes in disturbance regimes that result from fire suppression, flood control and beaver trapping.

Riparian areas provide a variety of functions such as shade and cover over the stream, introduction of large wood and nutrients to the stream, floodplain development, hydrologic controls, and bank stability (Beschta 1991). The structure and functions addressed by this study include coniferous and hardwood distributions, regeneration densities, large wood recruitment (LWR), and shade levels found in RMAs before and after harvesting under the current forest practice riparian rules (adopted in 1994).

Riparian Structure

While there has been ample research on the importance of riparian functions such as large wood and shade to in-stream habitat, relatively few studies have documented riparian stand characteristics such as basal area, species composition and diameter distributions. Additionally, most of the available research in Oregon has focused on the Oregon Coast Range. Studies completed on older riparian forests demonstrate a range of riparian stand structures best described as patchy, with combinations of conifer-dominated, hardwood-dominated and mixed stands. Studies in the Oregon Coast Range show that, in general, conifer density increases with increasing distance from stream, elevation, channel gradient and with decreasing stream size (Minor and Weatherly 1994, Hayes et al. 1996, Nierenberg and Hibbs 1999, Pabst and Spies 1999). Hardwoods remain fairly consistent with distance from stream. In the Oregon Coast Range, hardwoods are more commonly the dominant overstory species on wider streams with floodplains than they are on smaller streams without floodplains (Minor and Weatherly 1994).

Vegetative trends are highly dependent on local geomorphology. Constrained reaches commonly have little variation with distance from stream while unconstrained reaches (wider floodplain systems) have great variation. For example, terraces, meandering channels, abandoned channels, beaver complexes, and wetland areas are common in unconstrained systems. These variable conditions favor some species over others and thus result in patchy vegetation types (Kovalchik and Chitwood 1990, Nierenberg and Hibbs 1999).

Conifer Regeneration

Few studies have documented regeneration characteristics, but the findings consistently show very low conifer regeneration within riparian areas in the Oregon Coast Range (Minor and Weatherly

1994, Hibbs and Giodano 1996). Higher conifer regeneration was associated with higher coniferous basal area in the overstory, proximity to shade-tolerant seed trees, less competition from shrubs, and the presence of nurse logs or mineral soil (Minor and Weatherly 1994, Hibbs and Giodano 1996, Beach and Halpern 2001). Conifer regeneration is an important component of riparian structure. These seedlings represent the future stand characteristics. If study results accurately represent the regeneration rate in riparian areas on a larger scale, land managers may need to intervene to assure a future source of large coniferous wood to stream channels.

Large Wood Recruitment

Large wood controls many of the structural and functional properties of small forested streams in ways that are important to fish (Lisle 1986, Bisson et al. 1987, Bilby and Ward 1989). The benefits of large wood for fish habitat have been well documented. Large wood modifies sediment routing, provides cover to fish from predation, provides unique habitats for invertebrates, and velocity refuges during high flows (Bisson et al. 1987, Gregory et al. 1991). Large wood influences flood plain and bar formation, pool size and frequency (Bisson et al. 1987, Bilby and Ward 1989).

The longevity of wood in streams depends in part on species and size. Large-diameter conifer trees tend to last longer and form pools faster in the aquatic environment than smaller-diameter deciduous trees (Bisson et al. 1987, Bilby and Ward 1989, Beechie et al. 2000). Other factors that influence mobility and wood accumulations include tree length in proportion to the channel width, hydrologic and physical characteristics of the stream, and management and disturbance history (Lienkaemper and Swanson 1987, Carlson et al. 1990, Bilby and Ward 1991, Gurnell and Sweet 1998, Duvall and Grigal 1999). Larger trees are also important because they provide an anchoring point upon which other wood can accumulate to increase the complexity of fish habitat (Keim et al. 2000).

In general, studies have documented that the near-stream area is a critical source of large wood to the stream channel and that wind is a primary agent of delivery (Lienkaemper and Swanson 1987). Efforts to predict wind-firmness of riparian buffer strips have identified many factors that influence the rate at which trees will be delivered to the stream. In an Oregon study, Steinblums et al. (1984) identified direction of prevailing winds, distance to the ridge, orientation, elevation, stand condition, stand mortality, overstory species, channel migration, and water table level as contributing factors to wind-firmness. Regardless of the delivery agent, direction of fall, tree height, distance from stream, slope steepness, and bole breakage determine if a fallen tree will land in the stream (Robison and Beschta 1990, Van Sickle and Gregory 1990). Modeling efforts have shown that the majority of large wood (70% or more) is recruited from within 60 feet of the stream (McDade et al. 1990, Van Sickle and Gregory 1990).

Shade

Riparian vegetation provides cover to the stream surface. In the summer time, shade from forest and shrub cover minimizes the amount of sunlight that reaches the stream surface, thus preventing further increases in stream temperature above background. In the winter time, coniferous cover can serve to reduce long-wave radiation losses that may further decrease stream temperatures below background (Beschta 1991).

Effects of Management

Much of the available research on the effects of harvesting on riparian function and structure is derived from study sites that were harvested prior to the *current* forest practice rules. The harvest practices on these sites typically involved clearcut harvesting down to the stream's edge followed with intense burning. Such studies document dramatic losses in shade and cover, associated increases in stream temperature, and losses in large wood recruitment and loading in the stream channel. Studies on these practices conducted throughout Oregon demonstrate that the impaired functions are typically shown to recover within 5 to 15 years for shade and temperature, depending on the stream size (Brown et al. 1971, Feller 1981, Andrus and Froehlich 1987, Beschta et al 1987, Johnson and Jones 2000). Recovery of both large wood recruitment and instream large wood is expected to take much longer (Beechie et al. 2000).

Fewer studies assess the effects of *current* harvest practices on riparian structure and function. Those that do have demonstrated increased protection of shade and LWR above that provided under previous regulations in Oregon (Brazier and Brown 1973, Hairston-Strang and Adams 1997, Hairston-Strang and Adams 2000) and Southeast Alaska (Koski et al. 1984). Hairston-Strang and Adams (2000) concluded that Oregon Forest Practices Act's current water protection rules adopted in 1994 strengthen protection for riparian forest resources over that provided by the previous rule set. This study aims to test if Oregon's current forest practice RMAs are adequate to promote and maintain large wood recruitment, shade, and conifer regeneration.

MONITORING OBJECTIVES AND QUESTIONS

The objectives of this monitoring project were to determine if the forest practice riparian rules promote riparian conditions that are consistent with levels observed in mature riparian forests and if the rules are effective at maintaining structure that will promote the desired future conditions for large wood recruitment and shade. The specific monitoring questions to be addressed include:

1. *Do estimates of average basal area that were used to craft the standard targets for basal area accurately represent mature riparian forests?*

2. *Do hardwoods dominate the near-stream area on all stream sizes?*

3. *How does the available basal area in riparian management areas compare to standard targets?*

4. *Are the 1994 forest practices riparian rules effective in maintaining potential sources of large wood recruitment for in-stream habitat as compared with pre-harvest condition?*

5. *Are the 1994 stream protection rules effective in maintaining stream shade as compared with pre-harvest condition?*

6. *What are the trends in conifer regeneration within riparian areas?*

MEASURES OF EFFECTIVENESS

BASAL AREA TARGETS, LARGE WOOD RECRUITMENT, AND SHADE

Testing the effectiveness of the water protection rules in meeting resource protection goals is problematic, in part because of a lack of established numeric standards (either regulatory or scientific). This is particularly true when evaluating large wood recruitment and, to some extent, when evaluating shade (Department of Environmental Quality (DEQ) is currently establishing shade standards through the Total Maximum Daily Load process). The goals pertaining to large wood recruitment and shade for forested riparian areas (the primary functions evaluated in this study) are described qualitatively in OAR 629-630-0100 and 629-640-000. The vegetation retention goals for streams are based on the concept of desired future condition. This desired future condition for riparian areas along streams with fish is:

> *" to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands."*

The rule recognizes that the age of a mature forest varies by species but that mature forests "provide ample shade over the channel" and "an abundance of [large wood] in the channel." In turn, the rule articulates numerical standards for riparian structure that were assumed to approximate mature riparian forests and, consequently, the functions they provide to streams. These standards were developed by "*estimating* the conifer basal areas for average unmanaged mature streamside stands" (at age 120) for each geographic region. Estimates were necessary due to a lack of sufficient mature riparian forest data at the time.

Nearly seven years after the 1994 rules were adopted more mature riparian forest data are available. The estimates of conifer basal area for unmanaged mature riparian forests are evaluated by comparing the targets to data from mature riparian forests. The attainability of the targets is evaluated by comparing the pre-harvest basal area to the targets themselves.

In light of a lack of agreed-upon, numerical standards for shade and large wood recruitment, this study uses before and after harvest comparisons and evaluates effectiveness by the degree to which potential large wood recruitment and shade are retained. The estimates of conifer basal area for unmanaged mature riparian forests are evaluated by comparing the targets to data from mature riparian forests.

STUDY DESIGN

SITE SELECTION

Landowners and forest practice foresters volunteered sites throughout the state for this study. The only constraint was that the harvest units were adjacent to fish-bearing streams. Data were collected before harvesting on 40 sites. Twenty-five of those 40 sites were revisited one year later after harvesting and the measurements were repeated.

STUDY AREA

This study was conducted at sites distributed throughout the state of Oregon (Figure 1). Fourteen sites were in the Coastal georegion, 12 in the Interior, four in the West Cascades, two in the East Cascades, two in the Siskiyou, and six in the Blue Mountain georegion (Table 2).

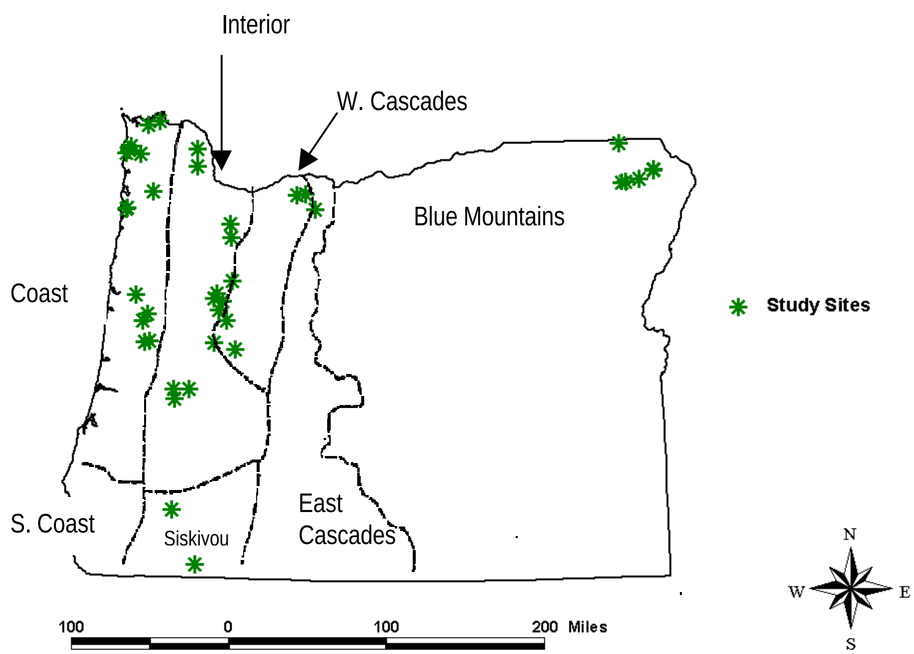

Figure 1. Study Sites and Georegion Boundaries

Table 2. Georegion, stream size, and riparian prescription, if known.

Stream Name (site #)	**Georegion**	**Stream Size**	**Riparian Prescription**
Fish (10)	Coast Range	Small	Unknown
Gnat (11)	Coast Range	Medium	Riparian Conifer Restoration
Hamlet (12)	Coast Range	Small	Riparian Conifer Restoration
Klootchy (13)	Coast Range	Medium	Standard Target
Lake (14)	Coast Range	Large	Riparian Conifer Restoration
NF Beaver (15)	Coast Range	Small	Unknown
Salty (16)	Coast Range	Small	Riparian Conifer Restoration
Yellow Fir (17)	Coast Range	Small	Unknown
^ Bear Creek (18)	Coast Range	Small	Not Harvested
^ Jordan (19)	Coast Range	Large	Not Harvested
^ Wolf Trib (19.1)	Coast Range	Small	Not Harvested
* ^ Shade Bear Creek (19.2)	Coast Range	Large	Not Harvested
* ^ Ecola Creek (19.3)	Coast Range	Large	Not Harvested
* ^ Trib of Necanicum (19.4)	Coast Range	Small	Not Harvested
Blue School (20)	Interior	Small	Standard Target
Cartright (21)	Interior	Large	Standard Target
Cedar (22)	Interior	Medium	No-cut RMA
Cox (23)	Interior	Large	Unknown
Dicky (24)	Interior	Medium	Standard Target
Hopkins (25)	Interior	Medium	Standard Target
Kelley (26)	Interior	Medium	Standard Target
Little Wiley (27)	Interior	Large	No-cut RMA
McClaferty (28)	Interior	Small	Standard Target
Trib A (29)	Interior	Small	Standard Target
^ Ford's Mill (29.1)	Interior	Small	Not Harvested
^ Hunter (29.2)	Interior	Medium	Not Harvested
Deer (30)	W. Cascades	Large	No-cut RMA
Snake (31)	W. Cascades	Large	No-cut RMA
Tony (32)	W. Cascades	Large	Standard Target
^ Green Mountain (33)	W. Cascades	Large	Not Harvested
Ramsey (40)	E. Cascades	Medium	Standard Target
^ Ivanhoe (41)	E. Cascades	Large	Not Harvested
Glade (50)	Siskiyou	Large	Standard Target
Jamison (51)	Siskiyou	Small	Unknown
^ Alder (60)	Blue Mountains	Medium	Not Harvested
Bear (61)	Blue Mountains	Small	Unknown
Sterling (62)	Blue Mountains	Small	Not Harvested
* ^ Elk Creek (63)	Blue Mountains	Medium	Not Harvested
* ^ NF Whiskey Creek (64)	Blue Mountains	Small	Not Harvested
* ^ Tope Creek Trib. (65)	Blue Mountains	Small	Not Harvested

* = Data collection for these sites was conducted under a separate 1999 ODF Shade Study.
^ = Data from these sites are only used in pre-harvest basal area analyses.

Georegion Descriptions

The information for the following georegion descriptions came from two main sources: The ODF rainfall map (www.odf.state.or.us/atlas/maps/rainfall.gif) and the Environmental Protection Agency (EPA) ecoregion map United States Geological Survey (USGS) and descriptions (CEC 1987).

The *Coastal* georegion is characterized by high precipitation (70-200 inches annually) and dense overstory and understory vegetation. Riparian areas are typically dominated by an alder overstory and a salmonberry/sword fern understory. Riparian conifer species typically include western hemlock, western redcedar, and/or Sitka spruce. Douglas-fir is more prevalent farther away from the stream. The parent material is predominately Tyee sandstone and ocean basalts overlain with deep, well-drained soils. Steeper slopes in the mid- and south-coast areas result in extremely shallow soils.

The *Interior* georegion is characterized by high precipitation (from 37 to 120 inches annually) with infrequent snow events on the Willamette Valley floor. Riparian area vegetation varies greatly depending partly on location with respect to the Willamette Valley. Riparian areas on the west-side of the valley are similar to those of the Coast Range with alder-dominated stands and patchy Douglas-fir. Conifers are more common in the riparian overstory on the east-side of the valley. The parent material is predominately volcanic with both deep, well-drained soils and poorly drained soils.

The *West Cascades* georegion is characterized by high precipitation (ranging form 75 to 160 inches) with a transient snow zone around 2,000 to 5,000 feet of elevation. Rain-on-snow events are common. The dominant riparian tree species are red alder, western hemlock, western redcedar, and Douglas-fir. Noble fir, white fir, grand fir and Pacific fir grow at higher elevations. The parent material is volcanic with both poorly drained silt- and clay-textured soils, as well as coarser, better-drained soils.

The *East Cascade* georegion gets substantially less precipitation than the West Cascades due to the orographic effect of cool marine air losing its moisture as it flows over the Cascades. Annual precipitation ranges from 14 to 30 inches except along the crest of the Cascades where it averages 79 inches. The riparian areas are commonly lined with alder and cottonwood and generally have a coniferous overstory of fir and pine species, although these are rare on the floodplains. The parent material is volcanic.

The *Siskiyou* georegion has a mezic/xeric temperature and moisture regime with substantially lower precipitation (ranges from 25 – 70 inches) than the georegions to the north and west of it. The upland vegetation typically includes ponderosa pine, Douglas-fir, Oregon white oak, California black oak, madrone, incense cedar, and grand fir. The riparian areas are more typically red alder, white alder, and conifer-dominated than the Coast or Interior georegions. The geology is fairly diverse throughout the region including basalt, shale, sandstone, and granitics, and the soils range from poorly drained to well-drained.

The *Blue Mountain* georegion is characterized with low precipitation (ranges from 8 to 20 inches annually) most of which falls as snow during the winter. This georegion is distinguished from the neighboring Cascades and Northern Rockies georegions because the Blue Mountains are generally not as high and are considerably more open. Like the Cascades, but unlike the Northern Rockies, the region is mostly volcanic in origin. Only the few higher ranges, particularly the Wallowa and Elkhorn Mountains, consist of intrusive rocks that rise above the dissected lava surface of the region. Unlike the bulk of the Cascades and Northern Rockies, much of this ecoregion is grazed by cattle. Dominant tree species in riparian areas vary and include ponderosa pine, true firs and larch with infrequent cottonwood, red and white alder and Engleman spruce.

<u>Riparian Prescriptions</u>

All the RMAs surveyed for this study were on Type F streams. There were 11 RMAs managed with a standard target prescription, four managed with a riparian conifer restoration prescription, four with a no-cut RMA, six that were unknown, and 15 that were not harvested prior to the second survey. (See introduction for detailed discussion on riparian prescriptions).

FIELD METHODS

A detailed field protocol is available on the ODF website (http://www.odf.state.or.us/internal.htm) and/or upon request. Riparian sample sites were 500 ft long by 100 ft wide, running parallel to the stream. The plot location was placed at a randomized distance from the bottom of the unit. The plot was located on the left side of the stream if both sides were to be harvested (Figure 2). Plot borders and subplots (zones) were established with a hip chain. Flagging was tied at 25-ft. intervals to aid in defining the sampling and cruising areas. Plots were permanently marked at the downstream 20-ft. corner with aluminum tags and tree paint and were referenced with a Global Positioning Systems (GPS) unit where possible.

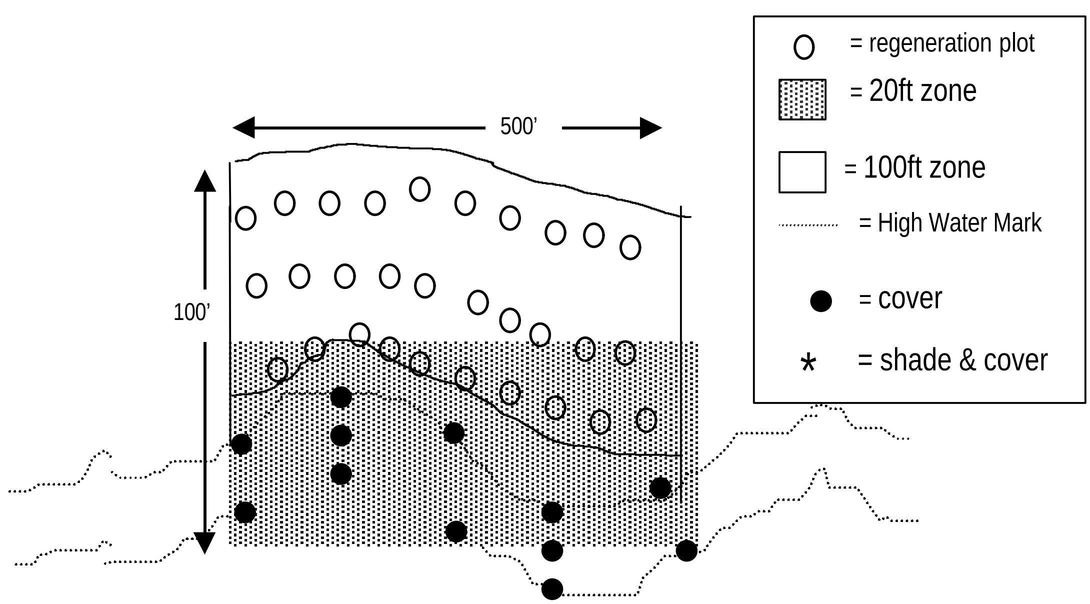

Figure 2. Plot Design

Riparian Structure

The riparian stand was separated into two zones. Within the first 20 feet of the stream channel (20ft. zone), a 100% cruise of trees was conducted. All trees with a diameter at breast height (dbh) greater than or equal to six inches (") were measured. Measurements included: dbh, distance from the stream, degree of lean to the stream, percent slope, and species. In addition, tree height and age were measured for one tree of each species in each diameter class. Diameter classes were 6-10", 11-15", 16-20", and 21"+. Trees smaller than 6" dbh were counted and identified by species.

In the area from 20 feet to 100 feet (100ft. zone) from the stream channel, an Individual Tree Sampling (ITS) method was conducted. Twenty percent of the stand was sampled, distributed systematically through the 100ft. zone and independent of species. The same tree parameters measured in the 20ft. zone were also measured in this 100ft. zone.

Shade, Cover, and Channel Morphology

Shade and cover were measured along five evenly spaced transects (one every 100 feet) starting at one end of the plot. Cover was measured with a convex densiometer at all five transects at mid-channel and on both banks. Shade was measured with a Solar Pathfinder at the upstream, downstream, and middle transects. Stream gradient, stream orientation, dominant substrate, wetted channel width, and bankfull width were measured at each of the five transects.

Regeneration

Regeneration sampling was done only on those sites that had been replanted prior to the post-harvest survey (n = 10, Interior and Coastal georegions). Seedlings and saplings were counted and identified by species in 20-ft. diameter circular plots. A seedling is defined as a young tree with a diameter less than one inch at breast height and a height of at least 12 inches. A sapling is defined as any tree with a diameter greater than 1 inch and less than 6 inches. At each site, sampling was conducted on a total of 30 plots on three transects running parallel to the stream, 25, 50 and 80 feet from the stream (10 plots per line). Plot centers were spaced systematically 50 feet apart along the transects.

Other Data

Snags, down wood, dominant and co-dominant shrub cover, and instream large wood counts were also conducted. These data are not presented in this paper, therefore the methods are not reported here. However, the methods are described in detail in the field protocol that is available upon request.

LIMITATIONS AND STRENGTHS OF THIS STUDY

One limitation of this study is the use of volunteered sites. Implications of a volunteered sample include a potential bias in the type of sites that were volunteered and the way in which the sites were ultimately managed. One way to evaluate this bias is to compare the percent of sites managed with a standard target prescription in this study to the percent in another ODF monitoring project that relied on a randomly selected sample. Preliminary results from the random selection indicate that 22% of sites (42 out of 182 sites) were managed with a standard target (Josh Robben, ODF, personal communication) compared with 44% (11 of 25) in this study. In general, sites managed with a standard target would have greater coniferous basal area prior to harvest and, potentially, a greater impact on large wood recruitment and shade as a result of harvesting. In addition to the non-random selection, the relatively small sample size is another limitation. A small sample increases the potential that the monitored sites do not represent the range of riparian characteristics across the landscape. Finally, conclusions about rule effectiveness are tempered by the lack of agreed-upon measures of effectiveness.

The strengths of the study are based, in part, on the use of riparian data collected before and after harvesting. Pre- and post-harvest data allow for accurate evaluation of changes that result from harvesting, unencumbered with assumptions about what conditions might have been like before harvesting. Another strength of the study is the use of data collected on sites managed under the current set of forest practice rules on private industrial forestland. There is a great deal of debate about the role that forestry currently plays in the efforts for salmon recovery. While there has been ample research on the role of historic forest management practices, fewer studies rely on data that reflect current practices.

RESULTS

STANDARD TARGETS FOR BASAL AREA

The key monitoring questions addressed in this section include:

1. *Do estimates of average basal area that were used to craft the standard targets for basal area accurately represent mature riparian forests?*

2. *Do hardwoods dominate the near-stream area on all stream sizes?*

3. *How does the available basal area in riparian management areas compare to standard targets?*

Comparing Basal Area Targets to Data from Mature Stands

The desired future condition for streamside areas along fish-bearing streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands (OAR 629-640-0000 [2]). The standard targets were established with limited basal area information for mature riparian stands (Lorensen et al. 1994). Currently available field data (Steinblums 1977, Andrus and Froehlich 1987, Heimann 1988, Carlson et al. 1990, Night 1990, Ursitti 1990, Papst and Spies 1999, Thom et al. 1999) have been compiled from nine studies that documented basal areas of mature riparian stands (Appendix A). Field methods such as plot designs, age, and diameter determinations vary somewhat between the studies, but the compilation is useful for evaluating current basal area standard targets.

During the rule-revision process, it was assumed that if riparian areas were managed with the proposed standard targets, the average basal area within these managed riparian areas would, over time (30-60 years after harvest), equal the average for mature riparian forests. A comparison of mature forest conditions to the assumed basal area for 120-year-old managed stands, indicates the standard targets underestimate conifer stocking for West Cascade and Interior streams, and approximate conifer stocking for Coastal, NE Oregon and Central Oregon areas. (Figure 3).

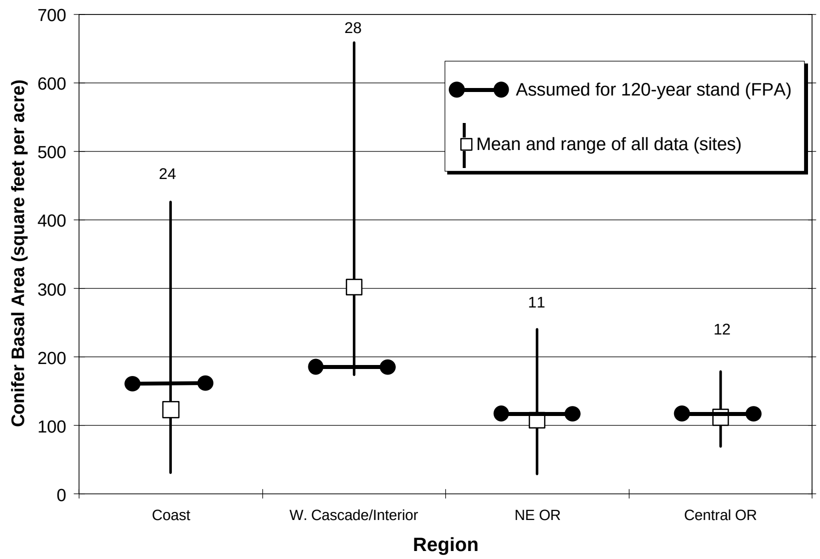

Figure 3. Basal area in unmanaged riparian areas and current basal area standard targets. Numbers above each line represent sample size.

HARDWOOD AND CONIFER DISTRIBUTIONS

When basal area targets were developed in 1994, they were based, in part, on the assumption that hardwood species dominated the first 20 feet of the RMA (Lorensen et al. 1994). Any conifer stocking in this area was assumed to be negligible. Results from this study indicate that in western Oregon, the near-stream area (within 20-40 feet of the high water mark) was commonly dominated by hardwoods (Figure 4). However, the trend was most pronounced on large and small coastal streams.

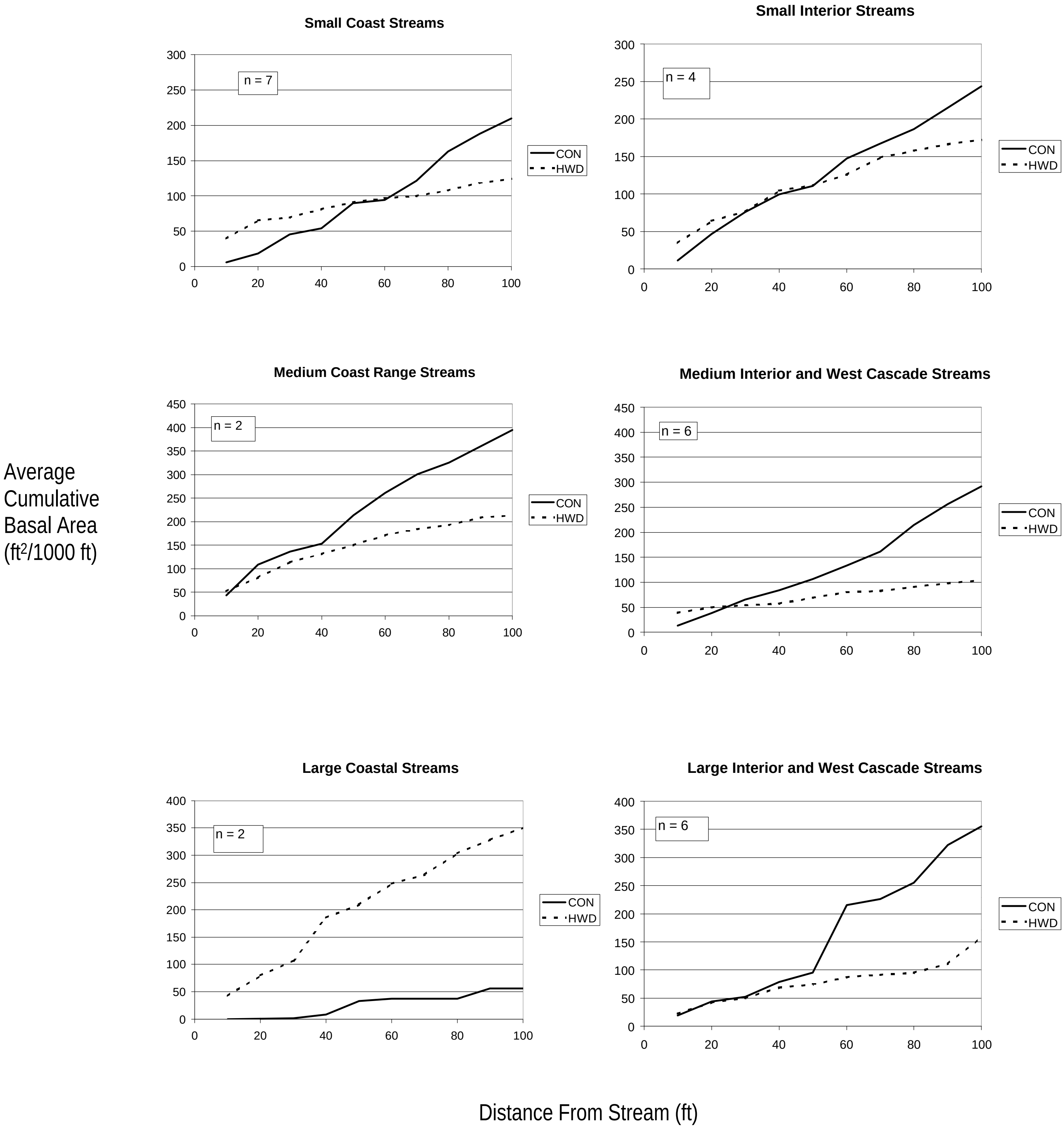

Figure 4. Western Oregon average conifer and hardwood distributions with distance from stream.

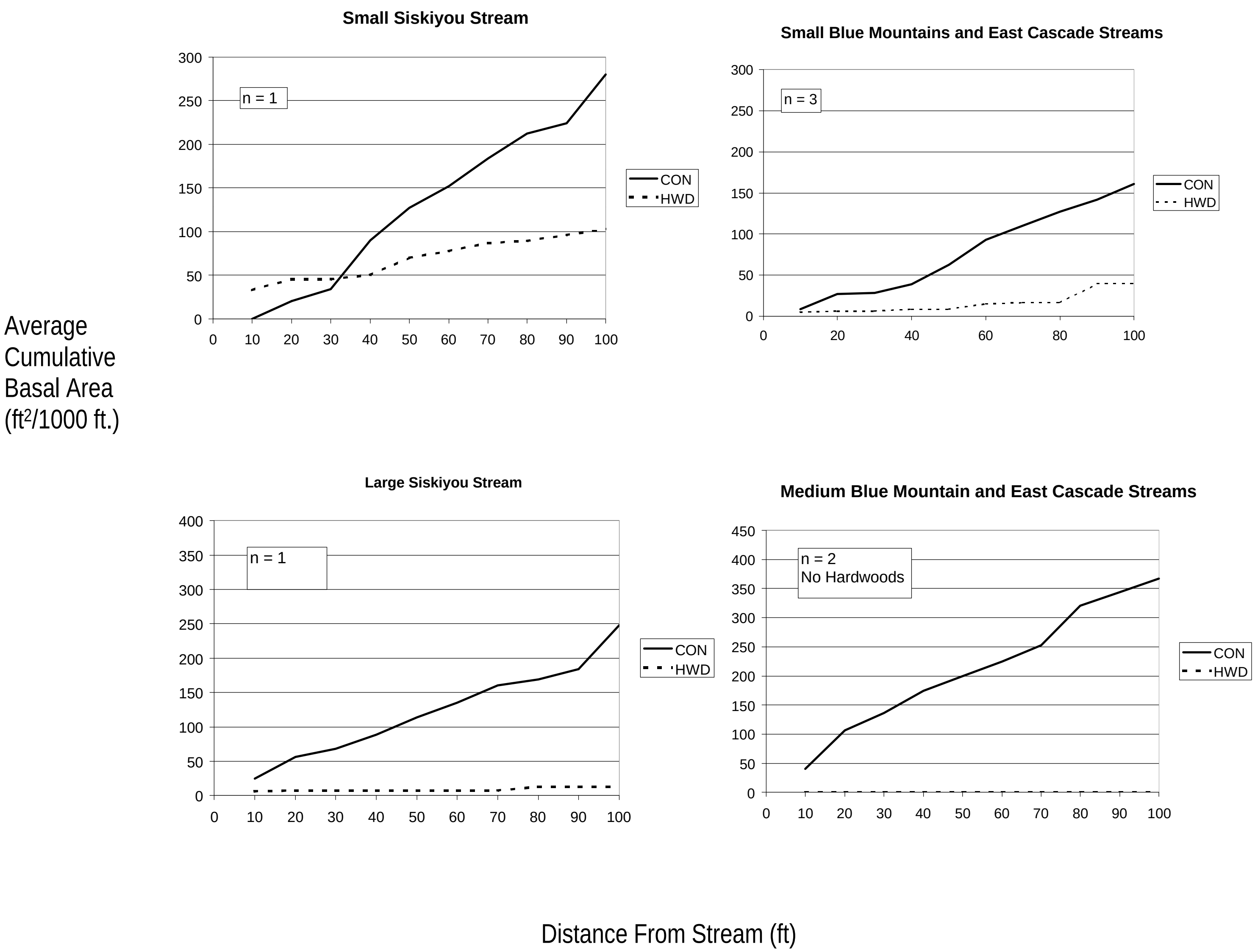

Figure 5. Eastern and Southern Oregon average conifer and hardwood distributions with distance from stream.

Conversely, conifer stocking within 20–40 feet of the high water mark was substantial on medium and Interior streams. The medium and Interior riparian stands are best described as mixed. Conifers comprise slightly less than 50% of the trees within 30 feet of the stream. At about 30 feet from the stream, there is a shift and conifers comprise slightly more than 50% of the stand. Conifers continue to increase in dominance as distance from the stream increases. This finding is consistent with results reported in the literature.

In the Blue Mountain and East Cascade georegions, the hardwood component was very low or, in some cases, absent within the first 20 feet of the stream, as well as the riparian management area as a whole. Results were mixed for the Siskiyou georegion (Figure 5).

The assumption of hardwood domination within the first 20 feet of the stream was reasonable for large and small coastal streams. When these data are stratified by stream size and georegion, the sample size diminishes such that strong conclusions are not possible. However, in the cases of other georegions and medium coastal streams, reducing the standard target to account for hardwood domination was not supported by these data.

Available Basal Area Prior to Harvest

Results indicate substantial variability in conifer stocking within and between georegions and stream sizes (Table 3 and Figure 6). On small streams, coniferous basal area ranged from 0 to 180 ft^2/1000 ft., on medium streams from 42 to 392 ft^2/1000 ft, and on large streams from 0 to 927 ft^2/1000 ft. (For a discussion on standard targets, refer to the introduction section). Even with this kind of variability, the existing basal area commonly exceeded that required to meet standard targets along small and medium streams.

The basal area prior to harvest was compared to the standard target. Standard targets for basal area were commonly exceeded on small (72% of sites) and medium streams (81% percent of sites). On large streams, existing basal area exceeded the target on approximately 54% of the sites (Table 4). The degree to which basal area was exceeded was most pronounced on small streams. On average, the standard target was exceeded by 114% on small streams, by 65% on medium streams, and by 12% on large streams (Figure 7). The forest practice rules allow for harvesting within the RMA to within 20 feet of the high water mark if the standard target can be met within the 20ft. zone. Basal area was met within the 20ft. zone more commonly on small streams (28% of sites) than on medium and large streams (18% and 0% of sites respectively) (Table 4 and Figure 7). The actual total basal area and other RMA data for each site are provided in Appendix B.

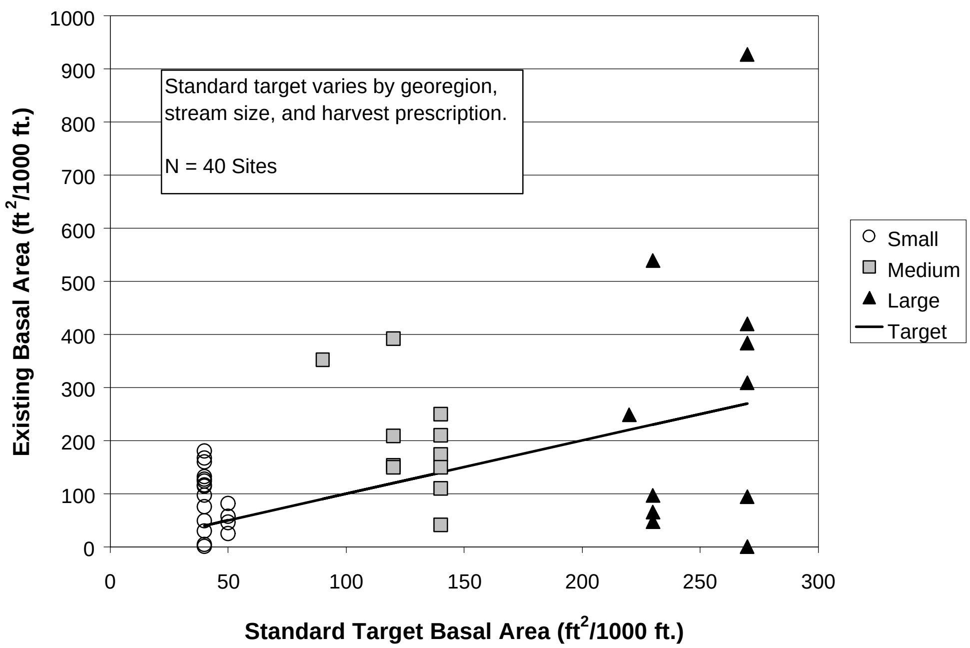

Figure 6. Available basal area versus the standard target for 40 RMAs. The line represents the standard target. Sites that are displayed above the line exceed the standard target while sites that fall below the line do not have enough coniferous basal area to meet the standard target.

Table 3. Average basal area within RMAs.

	Basal Area (ft^2/1000 ft) for Each Stream Size		
	Small	Medium	Large
Minimum Basal Area	0	42	0
Maximum Basal Area	180	392	927
Average Basal Area	88	199	285

Table 4. Percent of sites that exceeded standard basal area targets, exceeded standard basal area targets by more than 50%, met or exceeded within 20 feet, or did not meet standard targets prior to harvest.

Basal Area Statistic	Percent of Sites in Each Stream Size		
	Small	Medium	Large
Exceed the Standard Target within the RMA	72%	81%	54%
Exceed the Standard Target by > 50%	61%	36%	27%
Meet or Exceed within 20 Feet of Stream	28%	18%	0%
Less than the Standard Target within RMA	28%	18%	45%

Cumulative curves illustrate the average distribution of basal area before and after harvesting with relation to distance from stream (Figure 8). This analysis was only done on sites with *both* pre- and post-harvest data (n = 25). While available basal area greatly exceeds the standard target on average, only 44% (11 out of 25 sites) of the sites were known to use a basal area prescription. However, an evaluation of measured buffer widths indicates that fewer than 11 sites entered the RMA. Only 28% (7 of 25 sites) of the sites had average buffer widths less than the RMA widths. Six of these seven sites were in the Interior georegion. Buffer widths are reported in Appendix B.

Riparian areas that were managed with riparian conifer restoration (RCR) prescriptions were generally well stocked with conifers, with the exception of one large Coast Range stream (Figure 9). It is possible the randomly placed sample plots landed in unusually well-stocked conifer patches that were not representative of the entire stand. RCR rules require that well-stocked conifer patches be treated as retention blocks when possible. Within retention blocks, the landowner may apply general prescriptions if the patch meets the basal area target. If the retention blocks do not meet the standard target, the landowner can harvest all conifers to within 50, 30, and 20 feet on large, medium and small streams respectively. This practice should be evaluated on a larger scale and in more detail to determine if the application adequately maintains patches of potential LWR.

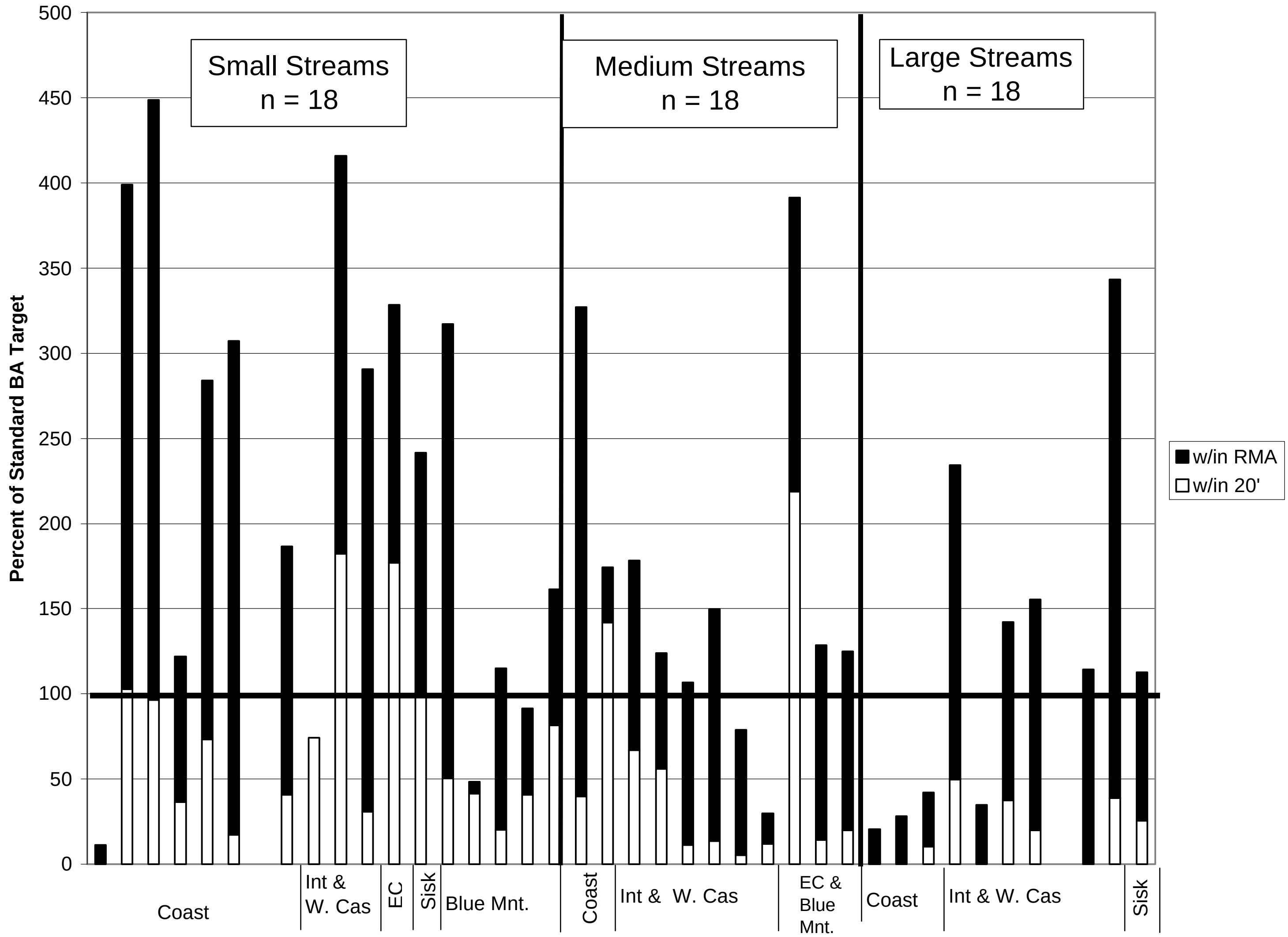

Figure 7. Percent of the standard target for basal area, available prior to harvest, within 20 feet and within the RMA. Georegions are labeled as Coast = Coastal, Int&W.Cas = Interior and West Cascades, EC = East Cascades, Sisk = Siskiyou, Blue Mnt. = Blue Mountain.

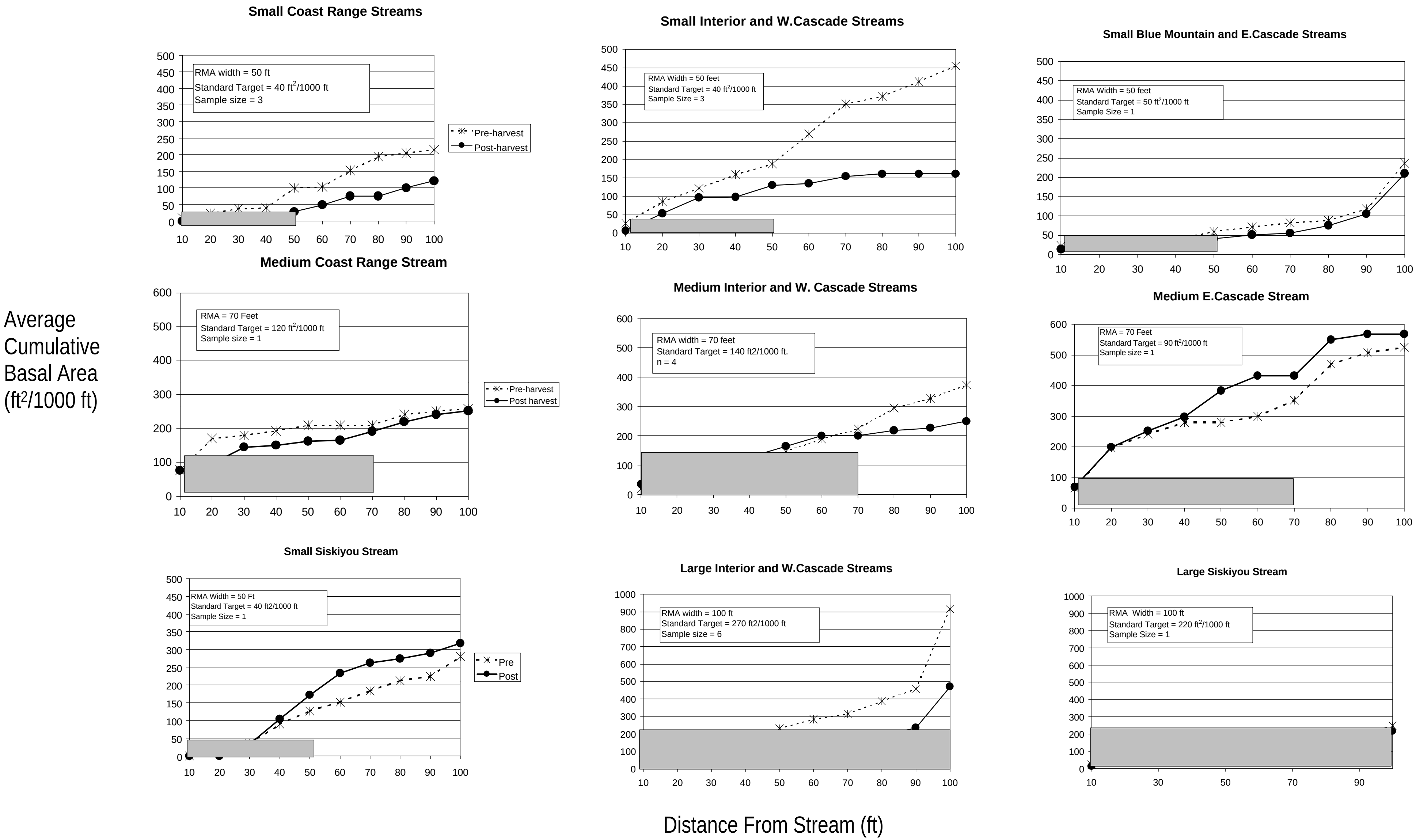

Figure 8. ***Average cumulative coniferous basal area versus distance from stream before and after harvesting for RMAs managed with unknown, no-cut or basal area prescriptions. The tops of the gray boxes represent the standard target and the right-hand sides of the gray boxes represent the RMA width. The area between the curves represents the basal area removed with harvesting.***

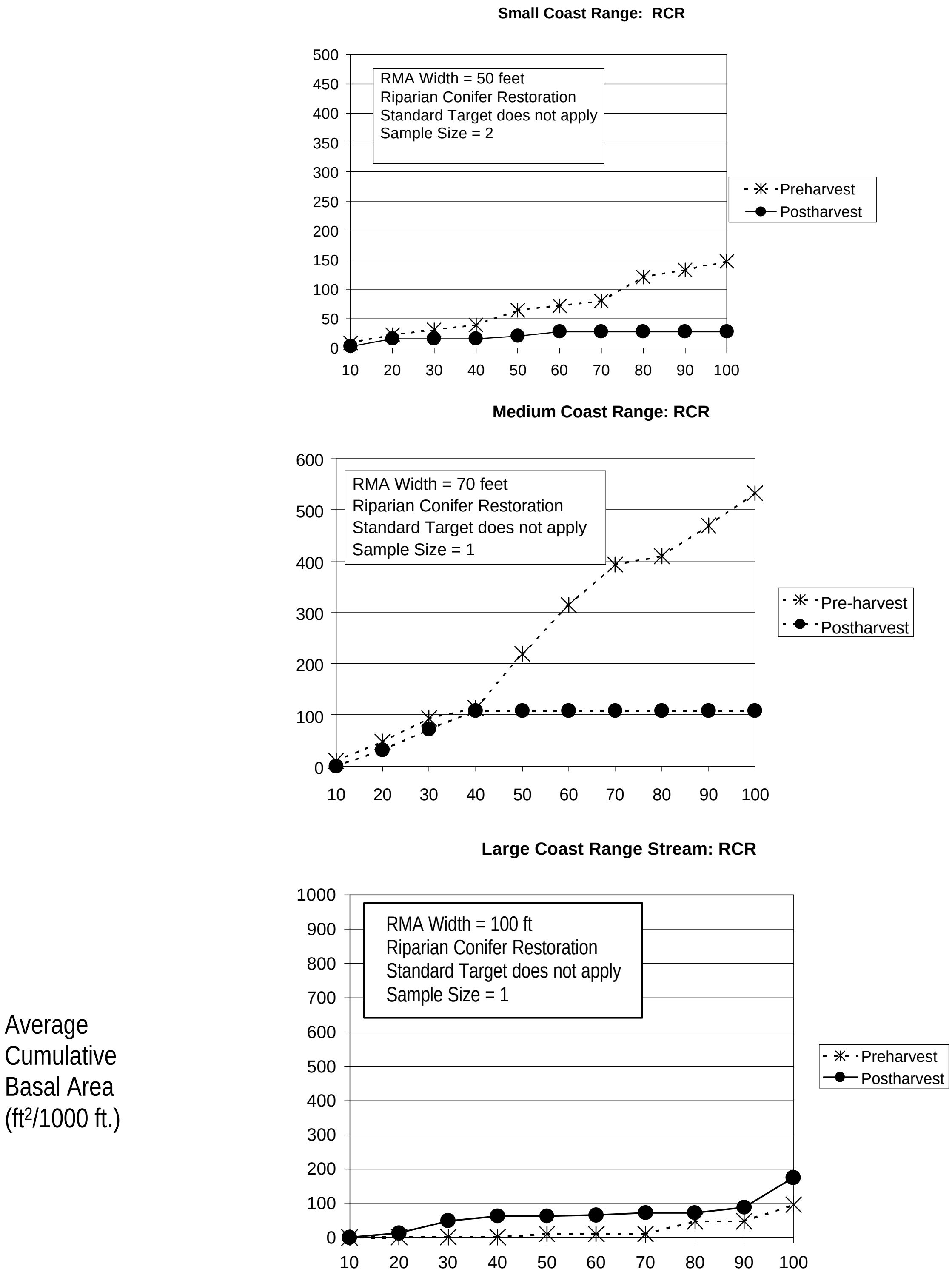

Figure 9. Average cumulative coniferous basal area before and after harvesting for sites managed with riparian conifer restoration (RCR) prescriptions.

Large Wood Recruitment

Large wood recruitment (LWR) is a key function of riparian areas that can be affected by harvesting. Diameter distribution data and a probability analysis were used to answer the question:

4. *Are the 1994 forest practices riparian rules effective in maintaining potential sources of large wood recruitment for in-stream habitat as compared with pre-harvest condition?*

Diameter Distribution Before and After Harvesting

Research has shown that large-diameter conifer trees in riparian areas are important sources of future large wood to the stream. Large conifer wood tends to last longer in the stream and provide an anchoring point upon which other wood can accumulate to increase the complexity of fish habitat.

Diameter distributions of RMAs were evaluated to determine if the numbers of large coniferous trees were disproportionately harvested. Average diameters were compared before harvesting and after harvesting with a two-sample t-test. The average diameter distributions within RMAs (within 50, 70 and 100 feet) of small, medium, and large streams did not change significantly with harvesting (p-value = 0.74, 0.48, and 0.18 respectively) (Figures 10 and 11). While the average diameter was not affected by harvesting, the very largest conifer trees were harvested on small and large streams. Small streams lost the 50-inch class and large streams lost the 60-, 70- and 110-inch diameter classes. Detailed results from the statistical analyses are provided in Appendix C.

The number of very large trees within RMAs was limited to begin with. Generally lacking were the largest diameter (>31 inches) conifers. Specifically, on average for small streams, there were nine and six trees/1000 ft. and for medium streams there were six and five trees/1000 ft. before and after harvesting, respectively. For large streams there were nine trees/1000 ft. prior to harvest and six trees/1000 ft. after harvesting.

This analysis demonstrates that, in general, large trees are not disproportionately harvested, and that diameter distributions are maintained. However, the question still remains of how harvesting in RMAs affects numbers of large conifer trees that could have potentially fallen in the stream.

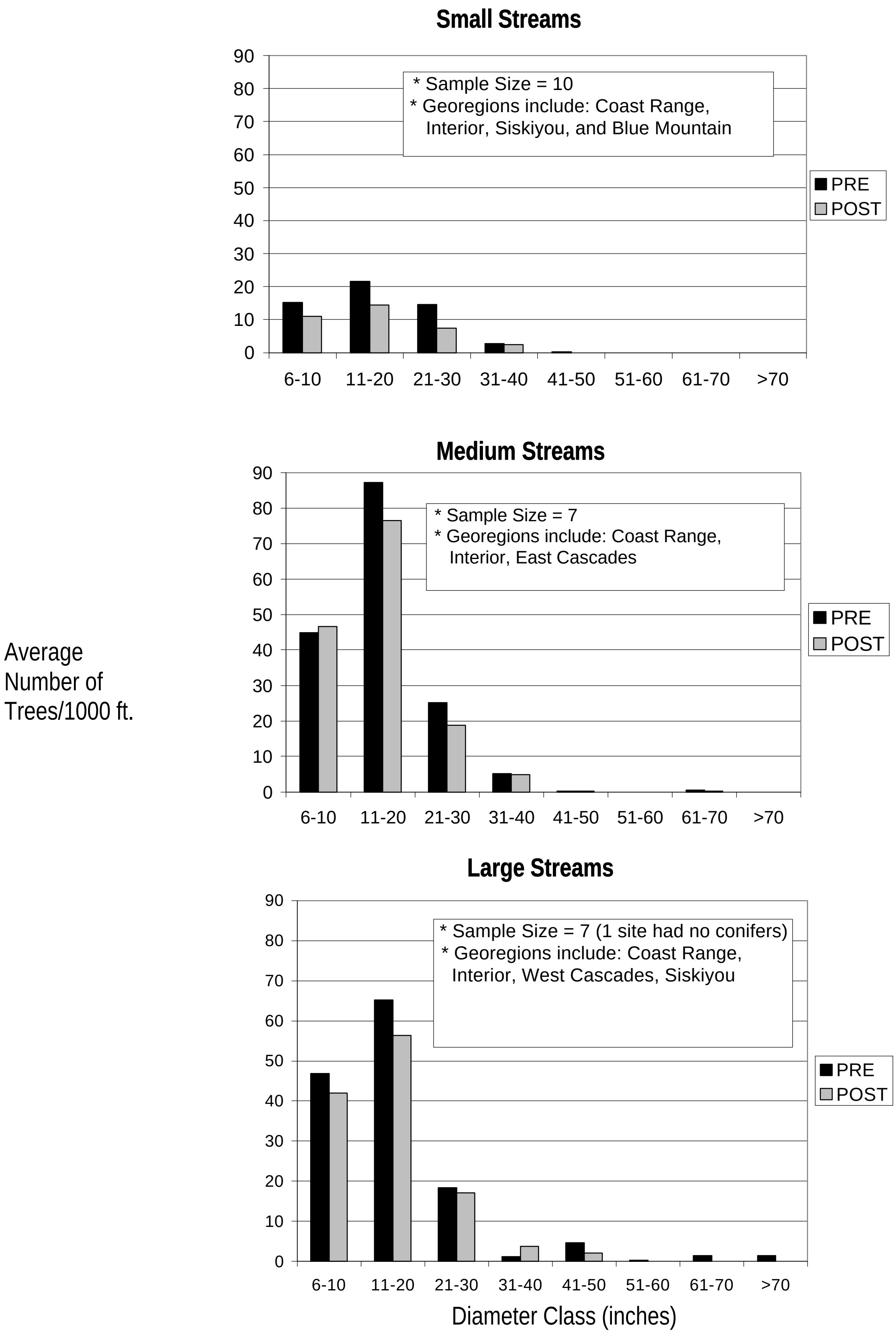

Figure 10. Average conifer diameter distributions before and after harvesting on small, medium, and large streams.

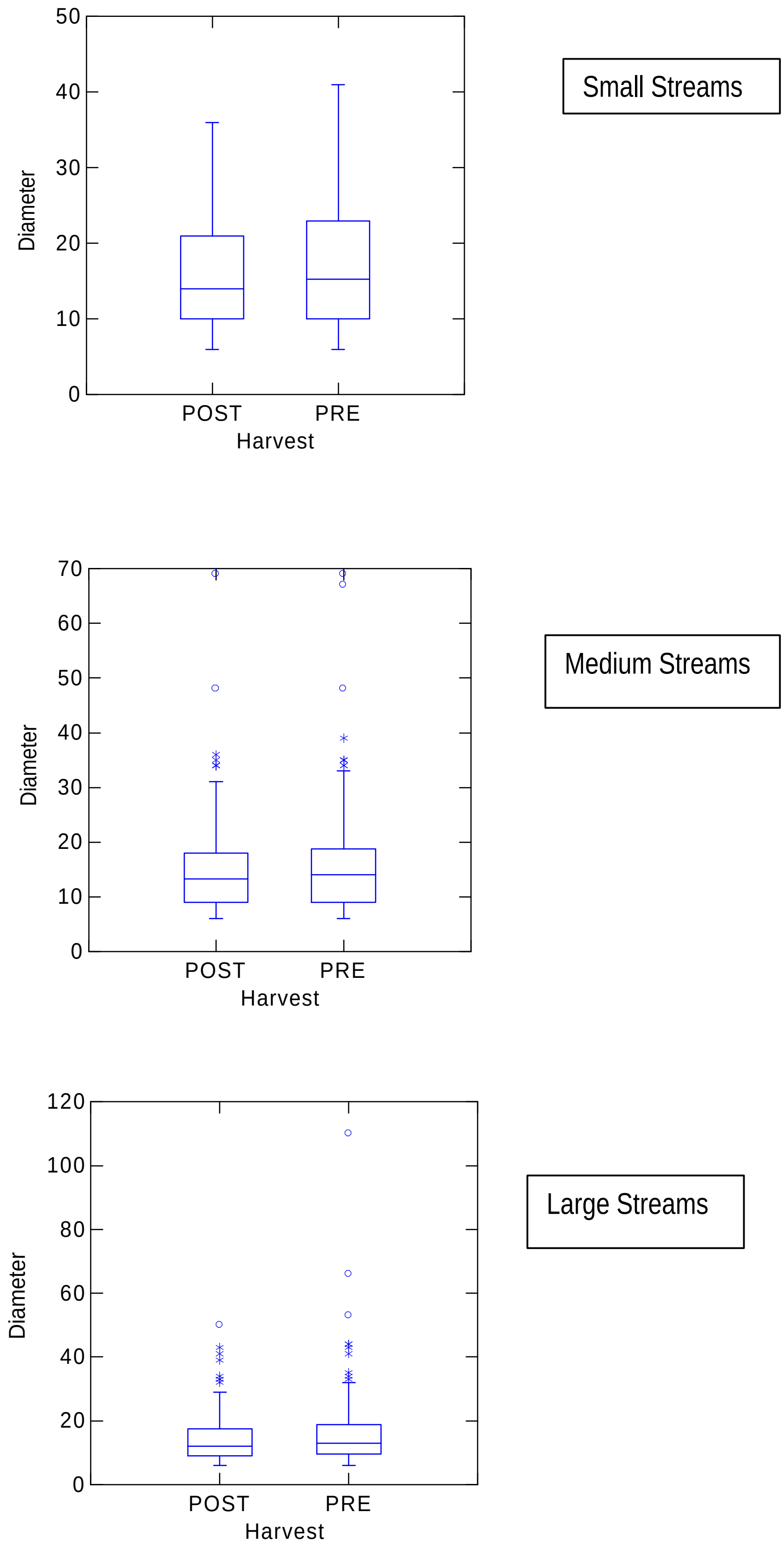

Figure 11. Box plots of conifer diameter distributions before and after harvesting on small, medium, and large streams before and after harvesting.

Probability of Large Conifer Trees Falling Into the Stream

The effect of harvesting on large trees that could potentially fall into the stream was evaluated using calibrated height-prediction models and a probability prediction function. Tree heights were predicted for unmeasured trees based on Equation 1 (Hanus et al. 1999). The prediction equations were calibrated using Equation 2 (Hanus et al. 1999) based on the measured tree-height data that were collected for each species in each diameter class. The calibrated equations performed well for predicting tree heights ($r^2 = 0.79$, Figure 12). Tree height/diameter relationships will vary by species, site index, and stand characteristics. Therefore, heights were predicted for each species in each stand.

Equation 1: *Predicted Tree Height* $= 4.5+\exp(a_0 + a_1 DBH^{a_2})$

Where:
a_0, a_1, and a_2 are coefficients that vary with tree species (Appendix D).
DBH = diameter at breast height

Equation 2: *Calibrated Predicted Height* $= 4.5+B\,(X_i)$

Where:

B = Yxs/Xss

$$Yxs = \sum_{i=1}^{n} (Y_i * X_i / Wt_i) \text{ (summed for each stand)}$$

$$Xss = \sum_{i=1}^{n} (X_i^2 / Wt_i) \text{ (summed for each stand)}$$

Y_i = Measured Height – 4.5 ft.
X_i = Predicted Height – 4.5 ft.
WT_i = Measured /DBH
n = number of trees with measured heights and DBH

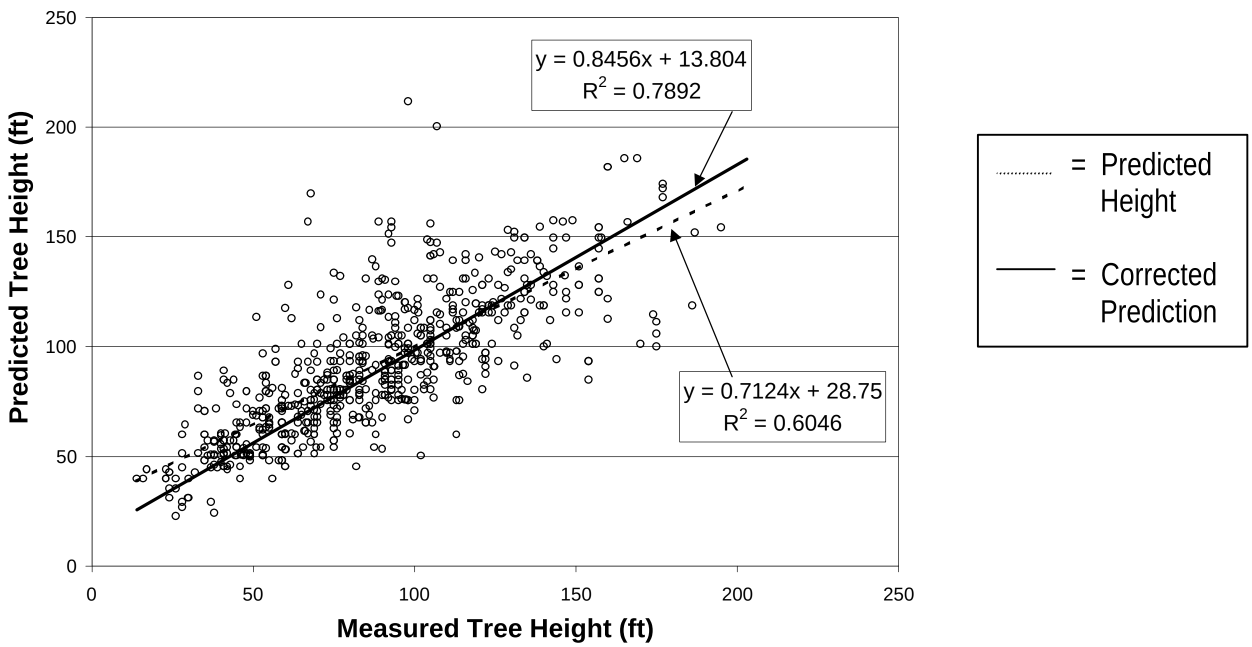

Figure 12. Predicted heights versus measured tree height for measured trees.

Next, the probability of an individual tree falling into the stream was calculated based on Equation 3 (Robison and Beschta, 1990). This analysis was done for all coniferous trees over 20 inches in diameter.

Equation 3: $P = \frac{\cos^{-1}(D/H_e)}{180°}$

Where:

P = probability that the tree will fall in the stream
D = distance away from the stream
H_e = effective tree height (predicted with Equation 2)

Equation 3 was developed with the assumptions that trees have an equal chance of falling in any direction, that the average diameter of the stand also represents the median diameter, and without considering breakage. Also, use of Equation 3 only provides an evaluation of potential LWR at the time the trees were measured. This potential will change over time as trees grow, channels migrate and/or when other disturbances such as wind, fire and flood are accounted for. Finally, because there is some evidence that trees are more likely to fall downhill (towards the stream) on steep slopes, it is likely that the probabilities resulting from Equation 3 underestimate LWR on steeply-sloped riparian areas. However, for relative comparisons between pre-harvest and post-harvest conditions, the use of Equation 3 is adequate.

Given the assumption that trees have an equal chance of falling in any direction, trees right on the bank would have, at best, a 50% probability of falling in the stream when other sources of disturbance are not accounted for (wind, debris torrents, fire). Evaluation of riparian stands using Equation 3 indicated that the greatest reductions on potential LWR immediately after harvest were on small and medium streams (Figure 13). This analysis was only conducted with regard to numbers of potential wood recruitment from the RMA and does not address the volume of potential wood recruitment.

In comparison to unharvested RMAs, harvested RMAs are predicted to have reductions in the average potential LWR of 59%, 32%, and 18% respectively for small, medium, and large streams. The greatest reductions on small streams were on trees that had a 21 to 50% chance of falling into the stream. The greatest reductions in LWR for medium streams were on trees that had a 21 to 40% chance of falling in the stream (Figure 13 and Table 5). Statistical significance of these reductions was tested using a paired t-test. The only statistically significant changes were on small streams associated with trees that were predicted to have a 41 to 50% chance of falling in the stream (p-value = 0.04). See Appendix E for detailed statistical results.

Table 5. Average number of trees/1000 ft. in each probability class before and after harvesting and the *percent change after harvesting.

Probability of Falling into Stream (%)	Small Streams		Medium Streams		Large Streams	
	# Trees/1000ft		# Trees/1000ft		# Trees/1000ft	
	Pre	Post (percent change)	Pre	Post (percent change)	Pre	Post (percent change)
0-10 (percent change)	2.0	1.0 (-50%)	0.0	1.4 (+)	0.0	1.4 (+)
11-20 (percent change)	2.0	1.0 (-50%)	29	1.4 (-50%)	5.7	2.9 (-50%)
21-30 (percent change)	9.0	4.0 (-56%)	14.3	4.3 (-70%)	10.0	5.7 (-43%)
31-40 (percent change)	21.0	8.0 (-62%)	24.3	15.7 (-35%)	5.7	7.1 (+25%)
*41-50 (percent change)	10.6	4.2 (-60%)	14.6	15.1 (+3%)	10.0	8.6 (-14%)
Total (percent change)	44.6	18.2 (-59%)	56.0	38.0 (-32%)	31.4	25.7 (-18%)

***** The only statistically significant change in LWR was on small streams within the 41 to 50% probability of falling in the stream (p-value = 0.04).

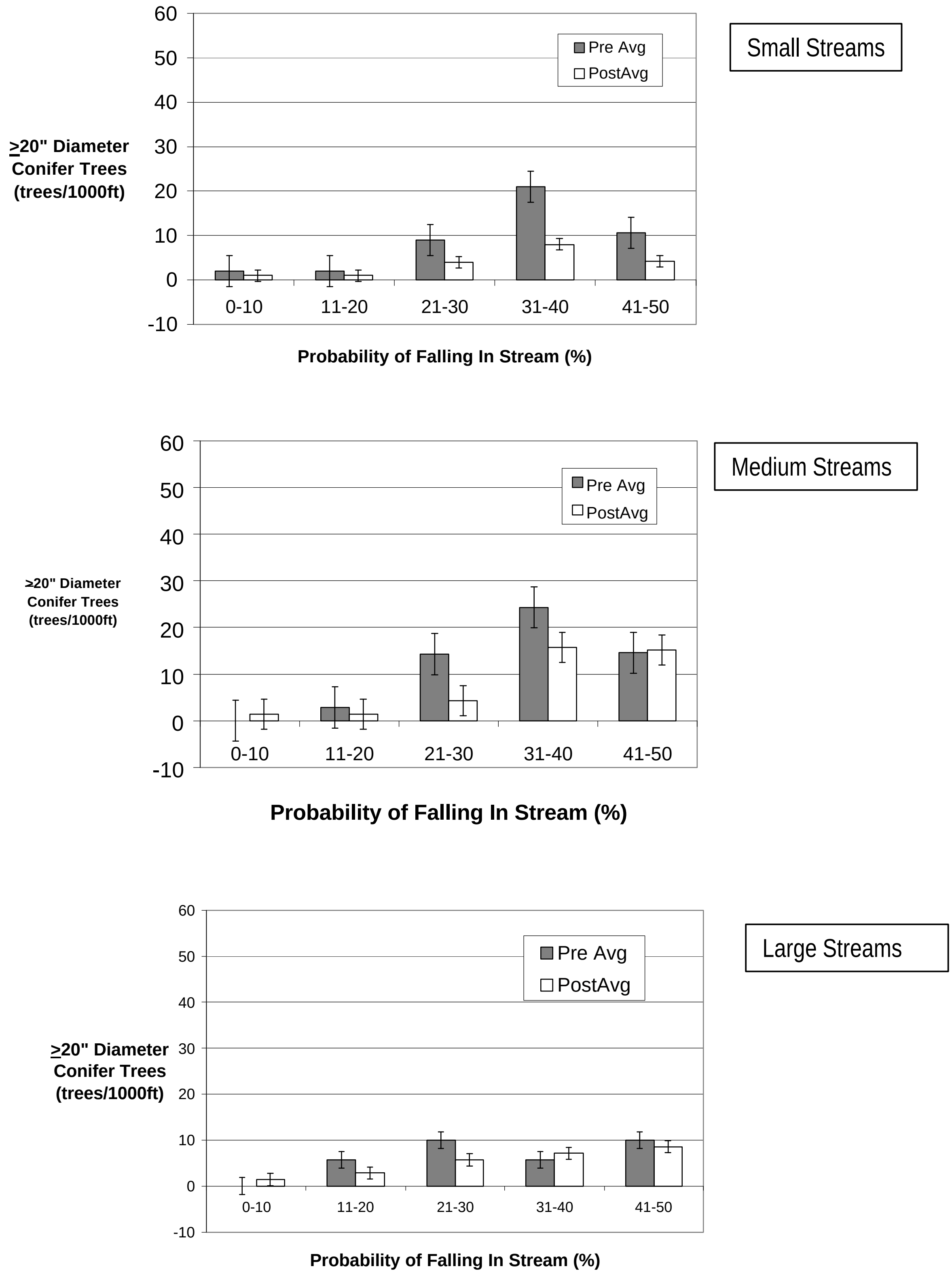

Figure 13. Average predicted large wood recruitment before and after harvesting for small, medium and large streams. Vertical lines represent the standard error.

Significant blowdown was documented on site #17, a small stream in the Coast Range. A survey of instream wood was conducted before and after harvesting. After harvesting, approximately 39% of the instream wood at site #17 was comprised of new blowdown. However, only 13% of the total wood was newly recruited *conifer* wood. Therefore, at site #17, 13% of the predicted reductions in future LWR has already contributed to the stream system. When site #17 is eliminated from the above analysis, the average reduction for small streams changes to 52%. While significant blowdown was not documented at any of the other sites, it is possible that, as in the case of site #17, some percentage of the predicted reduction in LWR has already contributed to the stream channel.

COVER

Although often spoken of interchangeably, shade and cover are not the same parameter. Shade is the amount of solar energy that is obscured or reflected by vegetation or topography. It is expressed in units of energy per unit area per unit time, or as a percent of total possible energy. Canopy cover is the percent of the sky covered by vegetation or topography. Shade-producing features will cast a shadow on the water while canopy cover may not. While both shade and cover were measured for this study, this analysis focuses on cover measurements because there was greater repeatability with the cover field methodology (+/- 10%). Therefore, the cover data will be used to answer the question:

5. *Are the 1994 stream protection rules effective in maintaining stream shade as compared with pre-harvest condition?*

Reductions in cover of greater than 10% were common for small streams, were uncommon for medium streams, and were not observed on large streams (Figure 14). The average reduction in cover was 12%, 7%, and 1% for small, medium, and large streams respectively. Statistical significance of these changes was tested with a paired t-test. The only statistically significant change in average cover was associated with small streams (p-value = 0.03). See Appendix F for detailed statistical results.

Although cover reductions were greatest for small streams, the average cover was still relatively high (78%) and is expected to recover over a relatively short period of time (2-3 years). This is because shrub cover, which can recover relatively quickly, has a greater effect on narrow streams. Cover in small streams before harvesting ranged from 83 to 95%, and after harvesting, ranged from 60 to 95% (Table 6).

The two greatest reductions in cover (-36 and 34%) were observed on two out of four of the RCR sites (one medium stream and one small stream). No measurable change in cover occurred on the other two RCR sites (one large and one small stream) (Table 6). The remaining cover reductions greater than 20% were all observed on narrow streams (<5 feet). The observed reductions in cover decreased as stream width increased (Figure 15).

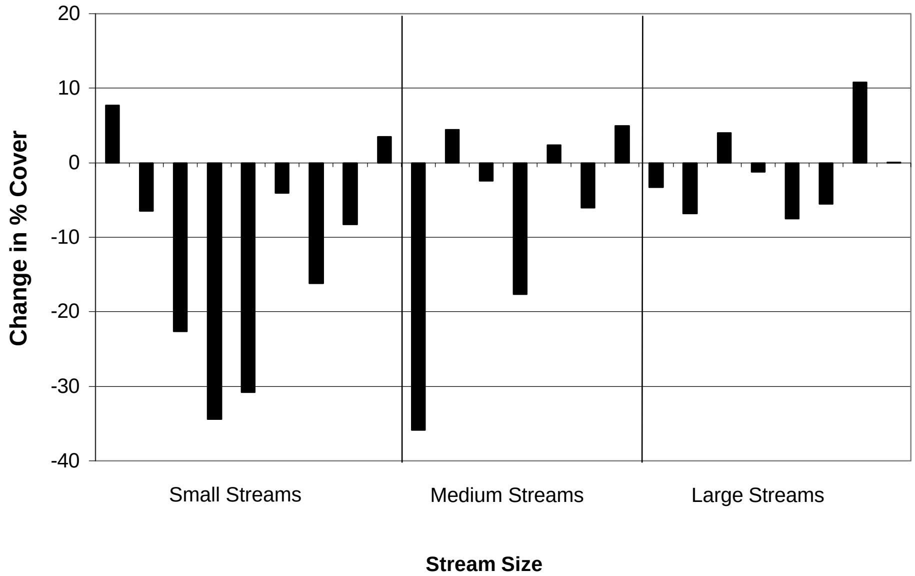

Figure 14. Change in cover after harvesting.

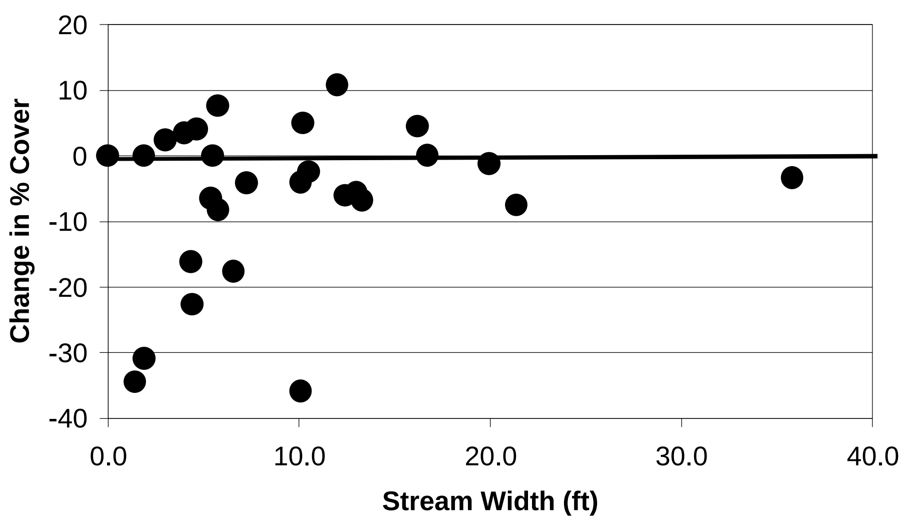

Figure 15. Change in percent cover after harvesting versus stream width.

Table 6. Percent cover before and after harvesting on 24 streams.

Site Number	* Riparian Prescription	Stream Size	Stream Width (ft)	Change in Cover	Pre-Harvest Cover (%)	Post-Harvest Cover (%)
10	Unknown	Small	5.8	8	88	95
12	RCR	Small	5.4	-6	91	84
15	Unknown	Small	4.4	-23	83	60
16	RCR	Small	1.4	-34	97	63
17	Unknown	Small	1.9	-31	95	64
20	BA	Small	7.3	-4	86	82
28	BA	Small	4.4	-16	94	78
29	BA	Small	5.8	-8	94	85
51	Unknown	Small	4.0	4	91	94
11	RCR	Medium	10.1	-36	91	55
13	BA	Medium	16.2	4	90	95
22	BW	Medium	10.5	-2	93	91
24	BA	Medium	6.6	-18	90	73
25	BA	Medium	3.0	2	88	90
26	BA	Medium	12.4	-6	83	77
40	BA	Medium	10.2	5	81	86
14	RCR	Large	35.8	-3	90	86
21	BA	Large	13.3	-7	94	87
23	Unknown	Large	4.7	4	76	80
27	BW	Large	20.0	-1	80	79
30	BW	Large	21.4	-8	76	69
31	BW	Large	13.0	-6	94	88
32	BA	Large	12.0	11	80	91
50	BA	Large	16.7	0	80	80
Average Cover Levels:						
				Small	91	78
				Medium	88	81
				Large	84	82

* Riparian prescriptions are described in detail under the forest practice rules section on pages 6 through 8.

BA = Harvested within RMA using the standard target for basal area prescription.
BW = No harvest within the RMA.
RCR = Riparian conifer restoration.

REGENERATION WITHIN 100 FEET OF THE STREAM

Regeneration is an important component of streamside vegetation because it dictates the long-term structure and function of riparian areas. Regeneration surveys were conducted on 10 sites at which the adjacent harvest unit had been planted prior to the post-harvest survey. Five sites were in the Coast and five sites were in the Interior georegions. Surveys consisted of seedling and sapling counts in 20-foot diameter circular plots. Number of plots per site ranged from 30-48 with a total of 336 plots. The plots were established on three transects, one each at 20, 50, and 80 feet from the stream. Because plot locations span areas that both do and do not require reforestation, the results cannot be used to evaluate compliance with reforestation rules. These data are used to address the question:

6. *What are the trends in conifer regeneration within riparian areas?*

Both conifer and hardwood regeneration in the Coast and Interior georegions is best described as highly variable, both within sites and between sites (Figure 16). There were 165 plots in the Coast and 171 plots in the Interior georegions. The total number of seedlings observed per site ranged from 5 to 70 in the Coast and 19 to 163 in the Interior. While all sites had some regeneration, two of the five sites in the Coast had less than 10 seedlings and saplings (sites 11 and 12), while two of the five sites in the Interior had less than 20 seedlings and saplings (sites 25 and 28).

The median number of trees/plot was zero for both georegions (Table 7). On two out of five sites in the Coast, the median number of trees/plot was zero. On three out of five sites in the Interior, the median number of trees/plot was also zero. The number of trees/plot varied from 0 to 14 and 0 to 24 in the Coast and Interior georegions respectively. Fifty-one percent and 58% of the plots had no regeneration in the Coast and Interior georegions, respectively (Table 8). Conifer regeneration was present on more plots than hardwood regeneration in both georegions, 45% and 26% of the plots in the Coast and Interior georegion, respectively. Hardwood regeneration was more common in the Interior than in the Coast: 15% and 4% of plots, respectively. Summary statistics for individual sites are reported in Appendix G.

The percents of plots with conifer regeneration observed in this study are comparable to those reported by Beach and Halpern (2001). They evaluated regeneration on *managed* riparian stands in Washington and reported 59-18% of plots with conifer regeneration as compared with 45-26% of plots in this ODF study. Higher conifer frequency in the Washington study was attributed to closer proximity to shade-tolerant seed trees. These ODF data can also be compared to two studies that measured regeneration in the Oregon Coast in *unmanaged* riparian areas: Pabst and Spies 1999, and Nierenberg and Hibbs 2000. Pabst and Spies, and Nierenberg and Hibbs both reported remarkably higher percentages of plots with no regeneration (82-98%) than this ODF study. In addition, the greater presence of conifer regeneration than hardwood regeneration observed in this ODF study was not observed by Pabst and Spies (Table 8). Pabst and Spies concluded that higher conifer regeneration was associated with higher basal area of shade-tolerant conifers and was limited by shrub competition. It is likely that the greater prevalence of conifer regeneration and fewer plots lacking regeneration in the ODF study is attributable to reforestation efforts required after harvesting.

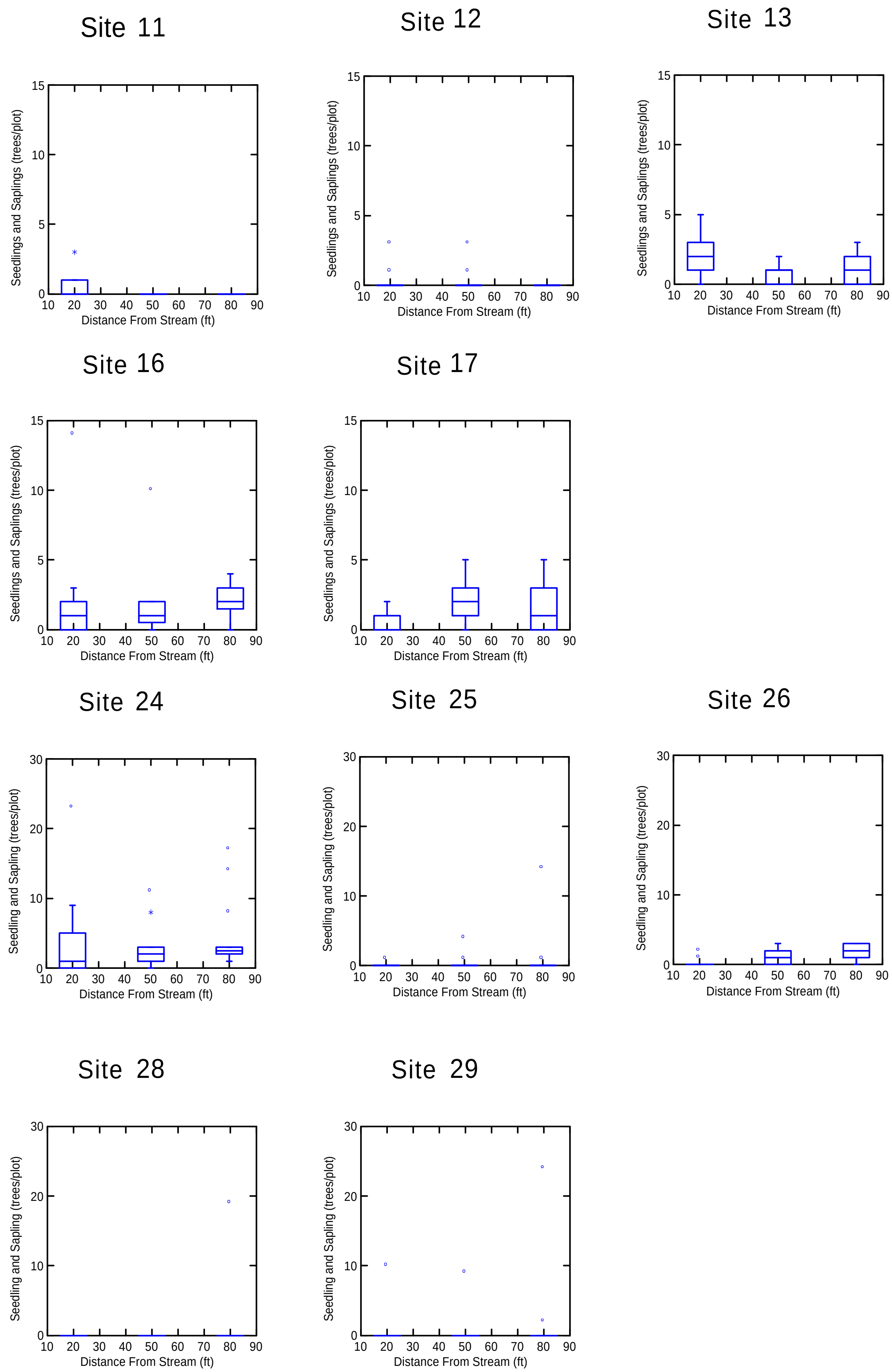

Figure 16. Regeneration density (number of trees/plot) versus distance from stream for the Coast (Sites 11-17) and Interior georegions (Sites 24-29).

Table 7. Regeneration summary statistics by georegion.

Coast Georegion	Seedlings and Saplings(trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	165	165
Minimum	0.0	0.0
Maximum	14.0	1941.0
Median	0.0	0.0
Mean	1.1	153.8
Standard Deviation	1.7	242.1
Interior Georegion	**Seedlings and Saplings(trees/plot)**	**Seedlings and Saplings (trees/acre)**
N of cases	171	171
Minimum	0.0	0.0
Maximum	24.0	3328.0
Median	0.0	0.0
Mean	1.7	229.5
Standard Deviation	3.8	531.1

Table 8. Percent of plots with conifers or hardwoods present, or an absence of regeneration.

Study	Sub-Groups	Coast Range Georegion (Number of Plots)			Interior Georegion (Number of Plots)		
		Conifers Present	Hardwoods Present	No Regeneration	Conifers Present	Hardwoods Present	No Regeneration
ODF (this study)	20ft. from stream	25	2	29	7	7	41
	50ft. from stream	24	5	25	19	10	32
	80ft. from stream	25	0	30	19	9	27
	Total	74 (45%)	7 (4%)	84 (51%)	45 (26%)	26 (15%)	100 (58%)
Pabst and Spies (1999)	North Coast	9 (6%)	13 (13%)	122 (85%)	--	--	--
	Central Coast	10 (1%)	5 (1%)	939 (98%)	--	--	--
	South Coast	24 (8%)	29 (10%)	247 (82%)	--	--	--
*Beach and Halpern (2001)	With seed tree	(59%)	--	--	--	--	--
	Without seed tree	(18%)	--	--	--	--	--
Nierenburg and Hibbs (1999)			21 (18%)	97 (82%)	--	--	--

* = Beach and Halpern study sites were in the coastal and Cascade Mountains of Washington. Results were not reported by georegion.

Due to the patchy nature of regeneration in the near-stream area, representation of the data in terms of trees/acre has the potential to inflate perception regarding overall regeneration density. However, used cautiously, the metric does provide a standard statistic with which to compare riparian regeneration trends observed in this study with other studies.

The average conifer regeneration densities were 277 and 324 trees/acre in the Coast and Interior georegions respectively (Table 9). The average hardwood regeneration densities were 693 and 949 trees/acre in the Coast and Interior georegions respectively. Minore and Weatherly (1994) measured regeneration in managed riparian areas in the Coast. They reported lower average stocking densities (101 conifer seedlings/acre, and 303-506 hardwood seedlings/acre) than this ODF study. Beach and Halpern studied regeneration in managed riparian stands in the coastal and Cascade Mountains of Washington. They reported higher conifer densities, 648-931 trees/acre, than observed in this study and concluded that the higher densities were associated with proximity to shade-tolerant seed trees. The regeneration densities observed in *managed* riparian forests dwarfed those observed by Hibbs and Giordano (1996) in a study conducted on *unmanaged* riparian areas in the Coast Range. Hibbs and Giordano reported a total of 6.5 trees per acre out of the 4.25 acres surveyed. Conifer seedling density was 4 trees/acre and hardwood density was 2 trees/acre. Plots of regeneration densities for each ODF site are provided in Appendix G.

Table 9. Regeneration stocking for conifers and hardwoods.

Study	Sub-groups	Coast Georegion Regeneration (trees/acre)		Interior Georegion Regeneration (trees/acre)	
		Conifer	Hardwood	Conifer	Hardwood
ODF (this study)	20ft. from stream	272	1,179	713	574
	50ft. from stream	254	499	219	652
	80ft. from stream	305		285	1,571
	Average	277	693	324	949
Minore and Weatherly (1994)	16ft. from stream	101	303	--	--
	33ft. from stream	101	303	--	--
	49ft. from stream	101	506	--	--
*Beach and Halpern (2001)	With shade-tolerant seed source	931			
	Without shade-tolerant seed source	647			
Hibbs and Giordano (1996)	Not reported	4	2	--	--

* = Beach and Halpern study sites were in the coastal and Cascade Mountains of Washington. Results were not reported by georegion.

Regeneration trends varied greatly between species (Figures 17 and 18). Species diversity was greatest on site 17 in the Coast (1 hardwood and 4 conifer species observed) and site 24 in the Interior range (2 hardwood and 4 conifer species observed). Western hemlock and Sitka spruce were observed on more sites than any other species in the Coast georegion. Red alder and bigleaf maple were observed on more sites than any other species in the Interior georegion.

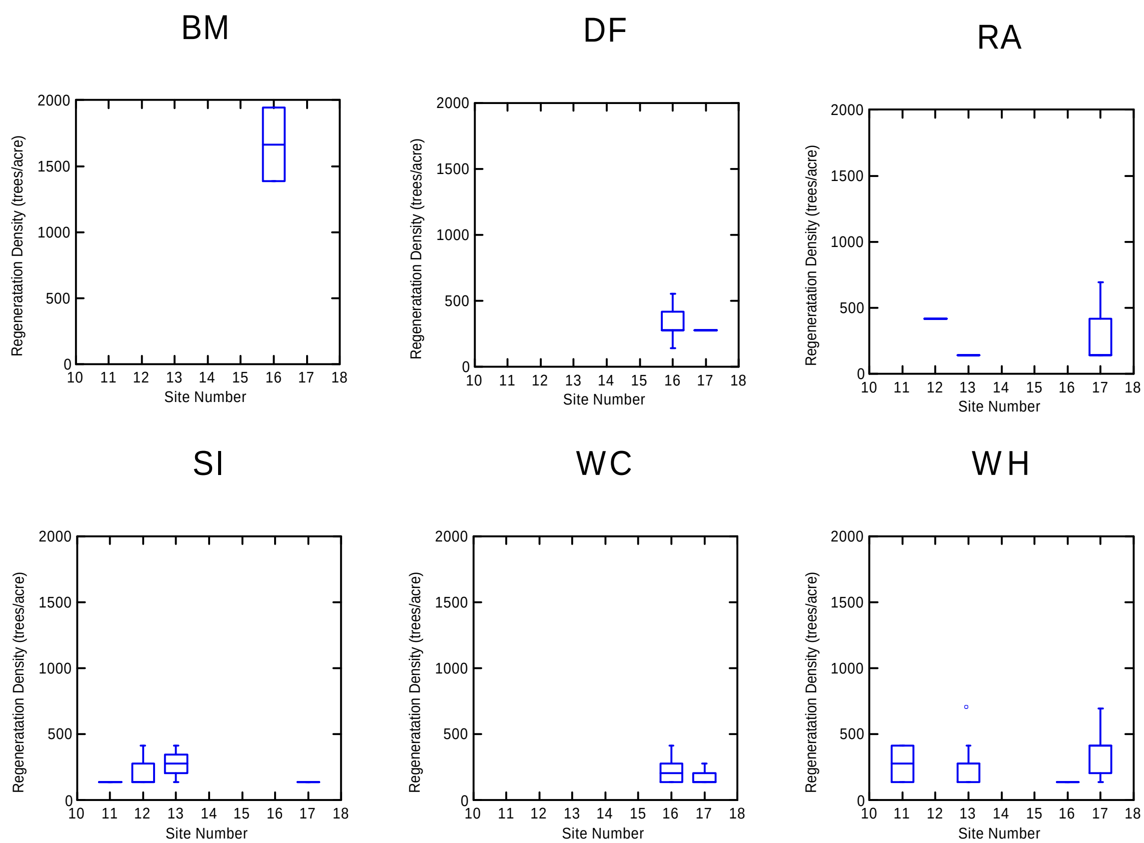

Figure 17. Coast Georegion: Seedling and sapling density (trees/acre) for each site by species. BM = bigleaf maple, DF = Douglas-fir, RA = red alder, SI = Sitka spruce, WC = western redcedar, WH = western hemlock.

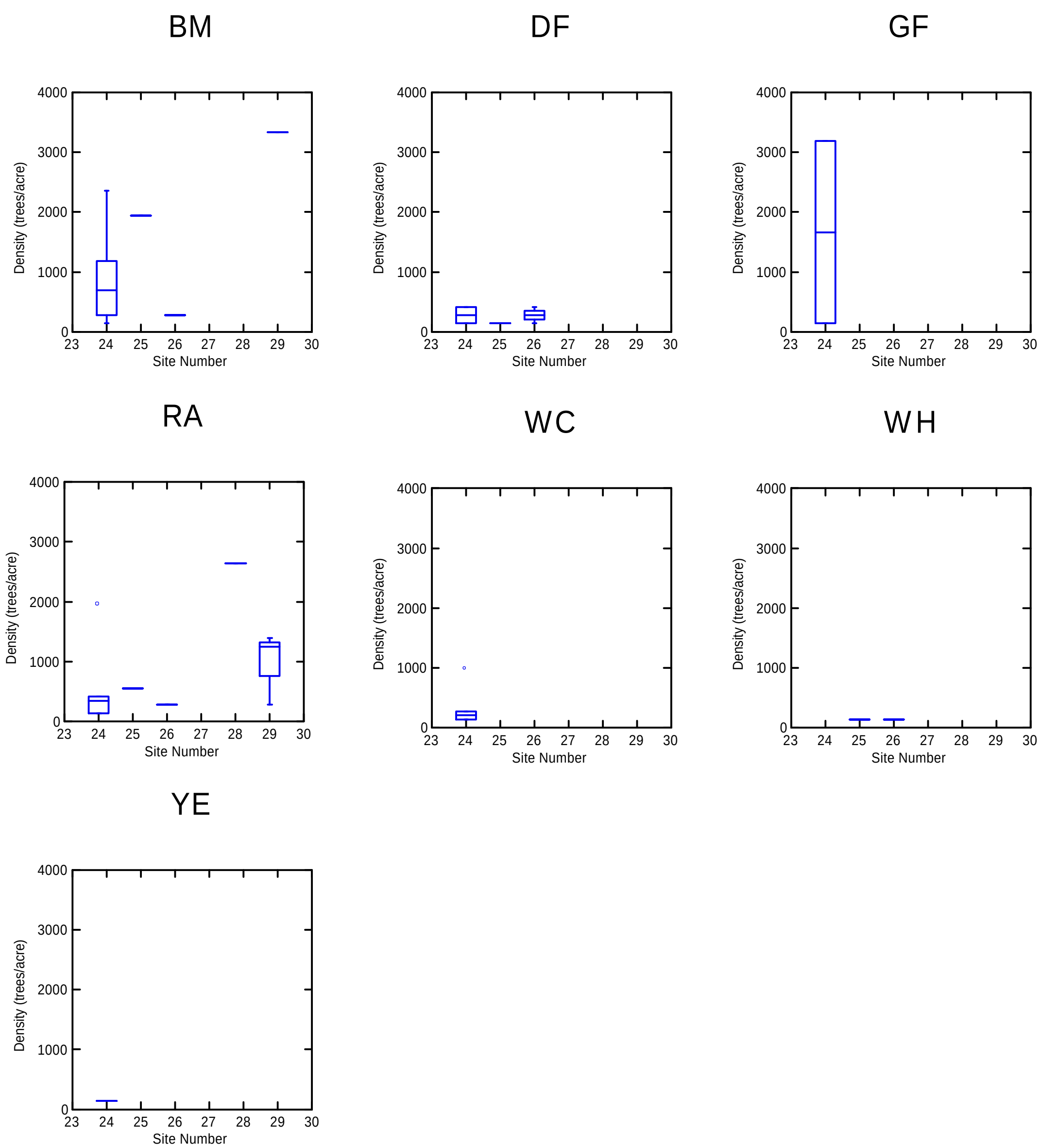

Figure 18. Interior Georegion: Seedling and sapling density (trees/acre) for each site by species. BM = bigleaf maple, DF = Douglas-fir, RA = red alder, SI = Sitka spruce, WC = western redcedar, WH = western hemlock, YE = Pacific yew.

Because of the variability in species composition between sites, one must be cautious about interpretation of data that combines sites. Therefore, only very general trends will be discussed.

The mix of species changed with distance from stream. In general, Douglas-fir seedlings and saplings increased with distance from stream in both georegions. In the Coast georegion, hardwood (bigleaf maple and alder) and western redcedar seedlings and saplings decreased with distance from stream, while in the Interior, hardwood regeneration was common throughout the near-stream area (Figures 19 and 20).

In the Coast georegion, conifers dominated regeneration at 20ft., 50ft., and 80ft. from the stream (69%, 66%, and 100% respectively). In the Interior, regeneration in all three zones (20ft., 50ft. and 80ft. from the stream) was predominantly hardwood (54%, 68%, and 72%, respectively).

In the Coast georegion, western redcedar and western hemlock were the dominant conifer species within 20 feet (34 and 42% of all regeneration, respectively) and Douglas-fir was the dominant conifer species at 80 feet from the stream (49% of all regeneration). In the Interior, grand fir accounted for 44% of the conifer regeneration within 20 feet of the stream. However, grand fir was only observed at one site. Were it not for the grand fir site, the 20ft. zone would be nearly absent of conifers (2% western redcedar). In the Interior, Douglas-fir was the dominant conifer species at 50 feet and 80 feet from the stream (29 and 27%, respectively).

Regeneration in both the Coast and Interior georegions was highly variable. However, when compared with data from unmanaged riparian forests, these data indicate relatively good conifer stocking in the Coast georegion. The most commonly observed conifer seedling and sapling species in the Coast georegion were western hemlock and Sitka spruce. Hardwood seedlings and saplings dominated regeneration in the Interior georegion. In the Interior georegion, Douglas-fir accounted for the most commonly observed conifer species, with the exception of one site with substantial grand fir regeneration. The higher incidence of conifer regeneration on these sites as compared with studies on unmanaged stands is most likely a result of reforestation efforts.

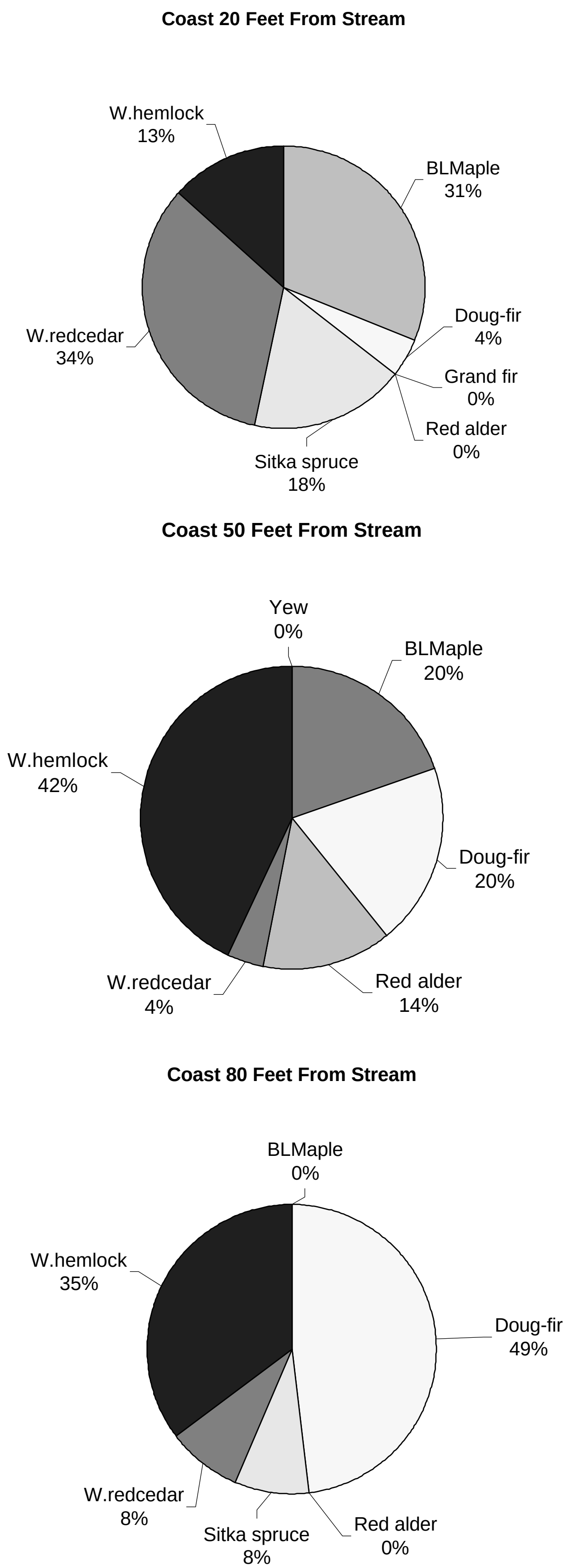

Figure 19. Relative seedling species abundance at 20 feet, 50 feet, and 80 feet from the stream for Coast streams (N = 5).

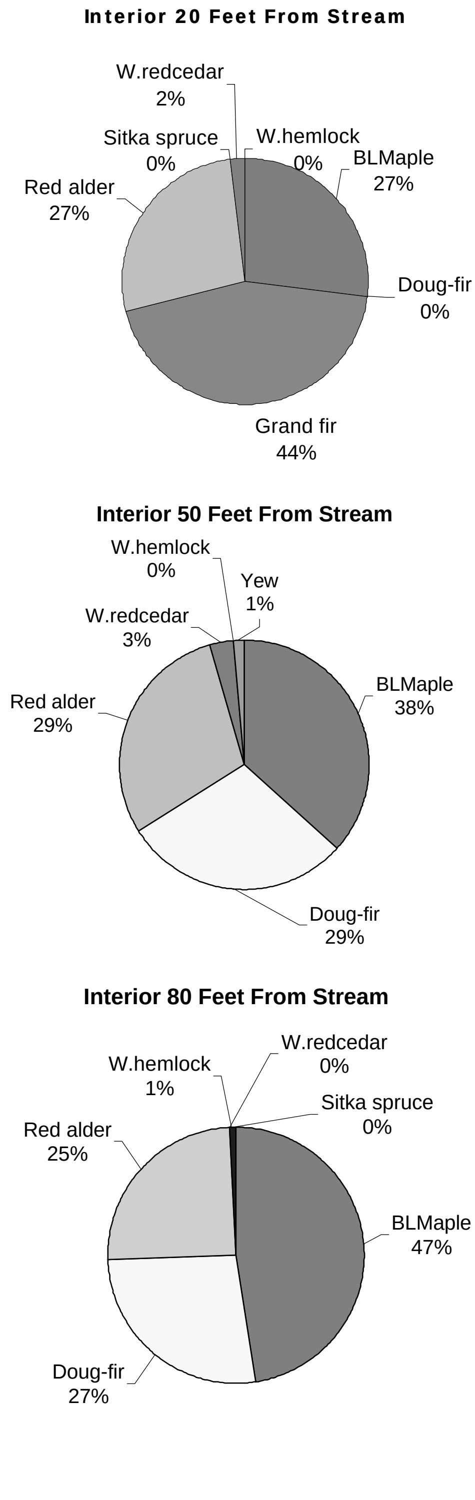

Figure 20. Relative seedling species abundance at 20 feet, 50 feet, and 80 feet from the stream for Interior streams (N = 5).

SUMMARY AND CONCLUSIONS

1. *Do estimates of average basal area that were used to craft the standard targets for basal area accurately represent mature riparian forests?*

The desired future condition for streamside areas along fish-bearing streams is to grow and retain vegetation so that, over time, average conditions across the landscape become similar to those of mature streamside stands. A comparison of mature forest conditions to the assumed basal area for 120-year-old managed stands indicates that the standard targets often underestimate average conifer stocking for West Cascade and Interior streams, and approximate average conifer stocking for Coastal, Northeast Oregon and Central Oregon areas.

2. *Do hardwoods dominate the near-stream area on all stream sizes?*

When crafting the basal area standard targets, an assumption was made that small and medium streams would have lower coniferous stocking in the first 20 feet from the stream due to presence of hardwoods. Hardwood domination was a good assumption for large and small coastal streams. In the cases of other georegions and for medium coastal streams, reducing the standard target to account for hardwood domination was not supported by these data. In addition, while hardwoods dominated the first 20 feet, conifer stocking was still greater than expected on small streams.

3. *How does the available basal area in riparian management areas compare to standard targets?*

Results indicate substantial variability in conifer stocking within and between georegions and stream sizes. However, the current basal area targets consistently underestimate the available basal area on small and medium streams. While targets are commonly met within 20 feet of the stream on small and medium streams, these data indicate that, in most instances, landowners are not exercising the option to clearcut harvest to within 20 feet of the stream.

These data indicate that portions of RMAs managed with an RCR prescription were actually well stocked with conifers. The RCR prescription should be evaluated on a larger scale and in greater detail to determine if the application adequately maintains existing patches of potential LWR.

4. *Are the 1994 forest practices riparian rules effective in maintaining potential sources of large wood recruitment for in-stream habitat as compared with pre-harvest condition?*

Reductions in potential large wood recruitment (LWR) were minimal on large streams under the current rules. However, statistically significant reductions in large wood recruitment were observed on small streams. Observed reductions in potential LWR on medium streams, while substantial in some cases, were not statistically significant on average. Furthermore, while the sample size is small, results also indicate a notable decrease in LWR potential with the application of the RCR rule.

The intention of the RCR rule is to provide for long term sources of large wood, even though there may be a short-term impact on stream temperature. The possibility that the application of RCRs may be contributing to a reduction in potential LWR is an unintended consequence of that alternative. This potential consequence needs to be evaluated in greater detail on both a larger scale and on a site-by-site basis as the rule is applied. If the findings from this study do accurately represent the larger population, it is clear that the success of the prescription heavily relies on achieving regeneration and retention goals in *both* "conversion" and "retention" blocks. If achieved, then the long-term LWR of such sites would be improved through this management strategy.

4. *Are the 1994 stream protection rules effective in maintaining stream shade?*

The current rules are effective at protecting cover on large streams. Although the actual cover levels were relatively high, shade retention results were mixed for medium and small streams, with the greatest impacts observed on RCR sites. The most consistent reductions in cover were observed along small streams.

5. *What are the trends in conifer regeneration within riparian areas?*

Regeneration in both the Coast and Interior georegions was highly variable. However, when compared with data from unmanaged riparian forests, these data indicate relatively high conifer stocking in the Coast georegion. The most commonly observed conifer seedling and sapling species in the Coast georegion were western hemlock and Sitka spruce. Hardwood seedlings and saplings dominated regeneration in the Interior georegion. In the Interior georegion, Douglas-fir accounted for the most commonly observed conifer species, with the exception of one site that had substantial grand fir regeneration. The higher incidence of conifer regeneration on these sites as compared with studies on unmanaged stands is most likely a result of reforestation efforts that follow harvesting. Further monitoring is needed to evaluate this trend with a statistically reliable study.

RECOMMENDATIONS

OVERALL FINDINGS

The great amount of variability observed in existing basal areas indicates that a single basal area target is problematic. In general, the rules are adequate at maintaining structure that is predicted to protect large wood recruitment and shade on large streams. The degree to which and the frequency with which pre-harvest basal area exceeded the standard target on small and medium streams indicates the existing targets are likely to be too low to achieve the desired future condition as described in OAR 629-640-110. This conclusion is supported by the findings of substantial reductions in LWR and cover on small streams and for riparian areas managed with an RCR prescription. Moderate reductions were also observed on medium streams. This conclusion is further supported by the finding that the standard targets underestimated average basal area for mature riparian forests in Interior and West Cascade streams.

The following recommendations are made:

The Board of Forestry should re-evaluate the standard targets for basal area to better address the range of conditions and better reflect the capabilities of riparian areas on medium and small streams, particularly in the Interior and West Cascade georegions.

The Board of Forestry should consider changes to vegetation retention rules to increase the maintenance and promotion of shade and potential LWR on small and medium streams.

The Board of Forestry should investigate the advantages and disadvantages of the RCR prescription with greater detail and on a larger scale. In the interim, riparian areas that are going to be managed under this prescription should undergo a detailed assessment to ensure that existing sources of future large wood are adequately maintained and that regeneration stocking standards are achieved.

The Board of Forestry should evaluate on a larger scale the trends in both conifer and hardwood regeneration within riparian areas. The goal should be to determine if the results from this study are reliable and if there are management strategies that will continue to improve regeneration within 100 feet of the stream.

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APPENDIX A

Characteristics of Unmanaged Riparian Stands in Oregon That Originated After Wildfire

Figure A-1: Characteristics of unmanaged riparian stands in Oregon that originated following wildfire.

Coast Range & Northeast Oregon

Study and Site Region	Site Number	Stream Size	Overstory Tree Age *	Basal Area Ft2/acre	
				Conifer	Hardwood
ODF Shade Study Coast Range DBH > 8"	53L	S	100	77	38
	53R	S	100	118	49
	58L	M	100	289	0
	58R	M	100	426	1
	61L	M	100	190	67
	61R	M	100	31	101
	64L	M	100	107	12
	64R	M	100	194	25
	55L	L	100	48	64
	55R	L	100	49	69
	65L	L	80	155	90
	65R	L	80	181	61
	Average		**97**	**155**	**48**
ODF Shade Study Blue Mountains DBH > 8"	67L	M	160	78	2
	67R	M	160	52	8
	72L	M	25	49	2
	72R	M	25	108	6
	80L	M	37	29	0
	80R	M	37	63	1
	35L	M	?	108	4
	35R	M	?	120	4
	76L	L	49	55	5
	76R	L	49	51	20
	77L	L	82	55	6
	77R	L	82	95	10
	Average		**76**	**72**	**6**

* Although some tree ages are quite young, the stands had not been managed. Trees in the riparian area are younger than the surrounding upland stand due to fluvial disturbances.

Coast Range

Study and Region	Site Number	Stream Size	Stand Age **	Basal Area (ft2/acre)	
				Conifer	Hardwood
Pabst & Spies (1999) * North Coast	Average	1st Order (S/M)	130 - 150	119	44
	Average	2nd Order (M/L)	130 - 150	40	75
	Average	3rd Order (L)	130 - 150	49	74
	Average			*69*	*64*
Central Coast	Average	1st Order (S/M)	130 - 150	130	27
	Average	2nd Order (M/L)	130 - 150	68	48
	Average	3rd Order (L)	130 - 150	66	53
	Average			*88*	*43*
South Coast	Average	1st Order (S/M)	130 - 150	108	19
	Average	2nd Order (M/L)	130 - 150	95	41
	Average	3rd Order (L)	130 - 150	48	59
	Average			*84*	*40*
Coast Range		Mix	> 150	139	19
All Coast Range	**Average**	**1st Order (S/M)**	**130 - 150**	**119**	**30**
	Average	**2nd Order (M/L)**	**130 - 150**	**67**	**55**
	Average	**3rd Order (L)**	**130 - 150**	**54**	**62**

*No data on stand density.

** Stand age based on the upland stand. Trees within the riparian area may be younger.

Coast Range, Western Cascades, & the Interior

Study and Site Region	Site	Location	Stream Size	Overstory Tree Age	Stand Density (trees/acre)		Basal Area (ft²/acre)	
					Conifer	Hardwood	Conifer	Hardwood
ODFW Stream Surveys: Coast Range “reference sites” DBH > 6”	Drift	Coast	M/L	O.G.	151	139	126	77
	Franklin	Coast	M/L	O.G.	11	100	62	127
	Cummins	Coast	M/L	O.G.	113	47	174	29
	Average				**92**	**95**	**121**	**78**
ODFW Stream Surveys: West Cascades and Interior “reference sites” DBH > 6”	Elkhorn	Santiam	M/L	O.G.	181	57	281	37
	Opal	Santiam	M/L	O.G.	264	8	233	3
	L NF Santiam	Santiam	M/L	O.G.	178	8	264	3
	Limpy	Umpqua	M/L	O.G.	159	21	659	9
	Williams	Umpqua	M/L	O.G.	202	168	388	125
	Lost	Umpqua	M/L	O.G.	105	40	202	38
	Coffee	Umpqua	M/L	O.G.	69	17	217	13
	Shafer	McKenzie	M/L	O.G.	121	13	267	25
	Mack	McKenzie	M/L	O.G.	98	8	204	7
	Racks T1	Cascades	M/L	O.G.	87	4	174	2
	Anderson	Cascades	M/L	O.G.	260	11	433	5
	Average				**157**	**32**	**302**	**24**

Central Oregon

Study and Region	Site Number*	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer	Hardwood	Conifer	Hardwood
Knight (1990) Mature stands in central Oregon DBH >= 6"	1	80-150	116	0	155	0
	2	80-150	81	0	95	0
	3	80-150	50	0	94	0
	4	80-150	67	0	135	0
	5	80-150	94	0	69	0
	6	80-150	68	0	80	0
	7	80-150	100	0	157	0
	8	80-150	222	0	108	0
	9	80-150	68	0	93	0
	10	80-150	115	0	178	0
	11	80-150	72	0	85	0
	12	80-150	68	0	91	0
	Average	**80-150**	**93**	**0**	**112**	**0**

*Mixture of large and medium streams.

Northeast Oregon

Study and Region	Site Number*	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer	Hardwood	Conifer	Hardwood
Carlson et al. (1990) Mature stands in northeast Oregon DBH >=6"	1	80-150	72	0	105	0
	2	80-150	59	0	74	0
	3	80-150	97	0	135	0
	4	80-150	86	0	131	0
	5	80-150	91	0	122	0
	6	80-150	99	0	109	0
	7	80-150	85	0	118	0
	8	80-150	116	0	157	0
	9	80-150	249	0	192	0
	10	80-150	122	0	135	0
	11	80-150	26	0	74	0
	12	80-150	121	0	240	0
	13	80-150	82	0	161	0
	14	80-150	93	0	153	0
	15	80-150	81	0	105	0
	16	80-150	133	0	135	0
	Average	**80-150**	**101**	**0**	**134**	**0**

*Mixture of large and medium streams.

Coast Range

Study and Region	Site Number	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer	Hardwood	Conifer	Hardwood
Andrus and Froehlich (1987) Mature stands in the northern and central Coast Range, OR DBH >= 8"	15	140	40	23	209	27
	17	130	21	14	65	26
	19	110	27	14	109	23
	20	100	41	7	126	10
	21	130	27	0	95	0
	22	130	41	24	84	43
	23	115	30	25	78	39
	24	135	6	28	52	44
	25	135	40	7	187	13
	26	130	35	3	99	5
	29	110	29	7	93	12
	30	100	43	4	166	7
	Average	**120**	**32**	**13**	**114**	**20**
Heimann 1988 Mature stands in the central Coast Range, OR DBH >=6"	1	94	55	12	139	16
	2	110	48	6	214	4
	3	135	38	6	155	15
	4	135	28	41	162	20
	5	120	16	8	127	21
	Average	**125**	**37**	**15**	**159**	**16**

Mixture of large and medium streams.

Coast Range

Study and Region	Site Number	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer	Hardwood	Conifer	Hardwood
Ursitti (1990) Old-growth and mature stands in the south-central Coast Range, OR DBH >= 4"	1	> 250	16	57	170	61
	2	> 250	46	44	200	48
	3	> 250	60	52	248	57
	4	> 250	12	19	109	61
	5	> 250	54	1	392	4
	6	> 250	62	2	409	4
	Old-growth avg.	**> 250**	**42**	**29**	**255**	**39**
	7	80-150	11	93	65	87
	8	80-150	10	50	48	83
	9	80-150	9	50	48	83
	10	80-150	34	51	113	83
	11	80-150	76	0	213	9
	12	80-150	36	34	309	22
	13	80-150	28	70	87	100
	14	80-150	40	44	144	48
	15	80-150	16	49	61	57
	Mature avg.	**80-150**	**29**	**49**	**122**	**61**

Mixture of large and medium streams.

Western Cascades

Study and Region	Site Number	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer	Hardwood	Conifer*	Hardwood
Steinblums (1977) Old-growth stands in the Mt. Hood National Forest, OR DBH >?"	1	O.G.	58		518	
	2	O.G.	87		308	
	3	O.G.	69		559	
	4	O.G.	36		148	
	5	O.G.	112		809	
	6	O.G.	81		308	
	Average	**O.G.**	**74**		**442**	

* A small but unknown portion may be hardwoods.
Mixture of large and medium streams.

Western Cascades

Study and Region	Site Number	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer*	Hardwood	Conifer*	Hardwood
Steinblums (1977) Old-growth stands in the Willamette National Forest , OR DBH >?"	1	O.G.	98		409	
	2	O.G.	77		482	
	3	O.G.	44		187	
	4	O.G.	41		311	
	5	O.G.	67		262	
	6	O.G.	79		386	
	7	O.G.	56		326	
	8	O.G.	56		452	
	9	O.G.	59		362	
	10	O.G.	39		368	
	11	O.G.	39		378	
	12	O.G.	100		526	
	13	O.G.	71		605	
	14	O.G.	50		269	
	15	O.G.	23		215	
	16	O.G.	25		272	
	17	O.G.	28		246	
	18	O.G.	66		144	
	19	O.G.	57		177	
	20	O.G.	56		429	
	Average	**O.G.**	**57**		**340**	

* A small but unknown portion may be hardwoods.
Mixture of large and medium streams.

Interior

Study and Region	Site Number	Stand Age (years)	Stand Density (# trees/acre)		Basal Area (sq.ft./acre)	
			Conifer*	Hardwood	Conifer*	Hardwood
Steinblums (1977) Old-growth stands in the northern part of the Umpqua National Forest , OR DBH >?"	1	O.G.	40		205	
	2	O.G.	21		81	
	3	O.G.	39		117	
	4	O.G.	58		143	
	5	O.G.	51		151	
	6	O.G.	30		110	
	7	O.G.	23		58	
	8	O.G.	49		304	
	9	O.G.	43		118	
	10	O.G.	38		100	
	11	O.G.	23		220	
	12	O.G.	27		37	
	13	O.G.	66		50	
	Average	**O.G.**	**39**		**130**	

* A small but unknown portion may be hardwoods.
Mixture of large and medium streams.

APPENDIX B:

PRE-HARVEST BASAL AREA FOR ALL SITES

Table B-1. Pre-harvest basal area within 20 feet of the stream and within the entire RMA, post-harvest measured buffer width, and RMA width for each site.

Stream Size	Site Code	Within 20 Feet		Within Entire RMA				
		Conifer Basal Area (ft2/1000 ft)	Hardwood Basal Area (ft2/1000 ft)	Conifer Basal Area (ft2/1000 ft)	Hardwood Basal Area (ft2/1000 ft)	Standard Target (ft2/1000 ft)	Post-Harvest Buffer Width (ft)	RMA Width (ft)
L*	14	1	100	48	502	230	105	100
L*	19	0	59	65	198	230	ND	100
L	19.2	23	ND	97	ND	230	NA	100
L	19.3	114	ND	539	ND	230	NA	100
L	21	3	97	94	144	270	137	100
L	23	101	27	384	47	270	20	100
L	27	54	32	420	170	270	103	100
L	30	0	34	0	360	270	102	100
L	31	0	26	308	185	270	113	100
L	32	105	40	927	50	270	102	100
L	50	56	7	248	13	220	100	100
M	11	48	48	392	70	120	100	70
M	13	170	115	209	299	120	80	70
M	22	94	18	250	49	140	53	70
M	24	78	89	174	104	140	33	70
M	25	16	68	149	122	140	70	70
M	26	19	38	210	44	140	50	70
M	29.2	8	50	111	125	140	ND	70
M	33	17	37	42	44	140	ND	70
M	40	197	0	352	0	90	123	70
M	60	17	0	154	0	120	NA	70
M*	63	24	ND	150	ND	120	NA	70
S	10	0	37	4	57	40	133	50
S	12	41	168	160	168	40	47	50
S	15	39	60	180	145	40	103	50
S	16	15	51	49	67	40	30	50
S	17	29	57	114	90	40	32	50
S	18	7	33	123	55	40	70	50
S	19.1	0	52	0	55	40	93	50
S*	19.4	16	ND	75	ND	40	NA	50
S	20	30	88	30	184	40	93	50
S	28	73	56	166	70	40	13	50
S	29	12	110	116	164	40	35	50
S	29.1	71	3	131	27	40	40	50
S	41	40	15	97	22	40	ND	50
S	51	20	45	127	70	40	83	50
S	61	21	4	24	4	50	121	50
S	62	10	0	57	0	50	ND	50
S*	64	20	ND	46	ND	50	NA	50
S*	65	41	ND	81	ND	50	NA	50

*Data from 6 sites came from a separate ODF 1999 Shade Study (63,64,65,19.2,19.3,&19.4) and only contain pre-harvest measures.

ND = No Data. Hardwood data are available for these sites, although they were not included in this report. Buffer width data are not available for sites that were not harvested

APPENDIX C

STATISTICAL COMPARISONS OF PRE- AND POST-HARVEST AVERAGE DIAMETERS

Statistical Results of Diameter Distribution Analysis

Table C-1. Small Streams: No significant change in diameter distribution.

Two-sample t-test on DIAM grouped by HARVEST$

Group	N	Mean	SD
POST	68	16.441	8.034
PRE	112	16.857	8.133

Separate Variance t = -0.335 df = 142.9 Prob = 0.738
Difference in Means = -0.416 95.00% CI = -2.869 to 2.037

Pooled Variance t = -0.334 df = 178 Prob = 0.739
Difference in Means = -0.416 95.00% CI = -2.872 to 2.040

Table C-2. Medium Streams: No significant change in diameter distribution.

Two-sample t-test on DIAM grouped by HARVEST$

Group	N	Mean	SD
POST	216	14.889	7.861
PRE	247	15.429	8.708

Separate Variance t = -0.701 df = 460.5 Prob = 0.483
Difference in Means = -0.540 95.00% CI = -2.054 to 0.973

Pooled Variance t = -0.697 df = 461 Prob = 0.486
Difference in Means = -0.540 95.00% CI = -2.064 to 0.984

Table C-3. Large Streams: No significant change in diameter distribution.

Two-sample t-test on DIAM grouped by HARVEST$

Group	N	Mean	SD
POST	164	14.585	7.771
PRE	175	16.029	11.515

Separate Variance t = -1.360 df = 306.9 Prob = 0.175
Difference in Means = -1.443 95.00% CI = -3.531 to 0.645

Pooled Variance t = -1.344 df = 337 Prob = 0.180
Difference in Means = -1.443 95.00% CI = -3.556 to 0.670

APPENDIX D:

COEFFICIENTS FOR TREE HEIGHT PREDICTION EQUATIONS

Table D-1. Coefficients for tree height prediction equations. Taken from Hanus, Marshall, & *Hann, and Hanus, Hann & Marshall 1999.

Damaged and Undamaged trees

Species	a_0	a_1	a_2
*Douglas-Fir	7.153156143	-5.36900835	-0.25832512
*Grand/White firs	6.638003799	-5.44399465	-0.33929196
*Incense-cedar	8.776627288	-74383668	-0.16906224
*Pacific yew	6.402691396	-4.79802411	-0.16317997
*Ponderosa pine	7.181264435	-5.90709219	-0.27533719
Sitka spruce	5.404491308	-6.570862442	-0.819705048
Western hemlock	6.58804	-5.35325461	-0.31897786
*Western redcedar	7.232880669	-5.746899904	-0.271564741

* = coefficients from Hanus, Hann and Marshall. The analysis in this paper was based on data and prediction equations which grouped damaged and undamaged trees.

APPENDIX E

STATISTICAL RESULTS OF PRE- AND POST-HARVEST PREDICTED LARGE WOOD RECRUITMENT POTENTIAL

Table E-1: Small Streams: Statistical results of predicted pre- and post-harvest large wood recruitment potential by probability class.

Small Streams:

10% probability of falling in the stream: no significant change.

Paired samples t-test on POST10 vs PRE10 with 10 cases

Mean POST10 =	1.000				
Mean PRE10 =	2.000				
Mean Difference =	-1.000	95.00% CI =	-5.061 to	3.061	
SD Difference =	5.676	t =	-0.557		
	df = 9	Prob =	0.591		

20% probability of falling in the stream: no significant change.

Paired samples t-test on POST20 vs PRE20 with 10 cases

Mean POST20 =	1.000				
Mean PRE20 =	2.000				
Mean Difference =	-1.000	95.00% CI =	-5.061 to	3.061	
SD Difference =	5.676	t =	-0.557		
	df = 9	Prob =	0.591		

30% probability of falling in the stream: no significant change.

Paired samples t-test on POST30 vs PRE30 with 10 cases

Mean POST30 =	4.000				
Mean PRE30 =	9.000				
Mean Difference =	-5.000	95.00% CI =	-14.080 to	4.080	
SD Difference =	12.693	t =	-1.246		
	df = 9	Prob =	0.244		

40% probability of falling in the stream: no significant change.

Paired samples t-test on POST40 vs PRE40 with 10 cases

Mean POST40 =	8.000				
Mean PRE40 =	21.000				
Mean Difference =	-13.000	95.00% CI =	-34.606 to	8.606	
SD Difference =	30.203	t =	-1.361		
	df = 9	Prob =	0.207		

50% probability of falling in the stream: significant change.

Paired samples t-test on POST50 vs PRE50 with 10 cases

Mean POST50 =	4.200				
Mean PRE50 =	10.600				
Mean Difference =	-6.400	95.00% CI =	-12.574 to	-0.226	
SD Difference =	8.631	t =	-2.345		
	df = 9	Prob =	0.044		

Table E-2: Medium Streams: Statistical results of predicted pre- and post-harvest large wood recruitment potential by probability class.

Medium Streams:

10% probability of falling in the stream: no significant change.

Paired samples t-test on POST10 vs PRE10 with 7 cases

Mean POST10 =	1.429				
Mean PRE10 =	0.000				
Mean Difference =	1.429	95.00% CI =	-2.067 to	4.924	
SD Difference =	3.780	t =	1.000		
	df = 6	Prob =	0.356		

20% probability of falling in the stream: no significant change.

Paired samples t-test on POST20 vs PRE20 with 7 cases

Mean POST20 =	1.429				
Mean PRE20 =	2.857				
Mean Difference =	-1.429	95.00% CI =	-7.811 to	4.953	
SD Difference =	6.901	t =	-0.548		
	df = 6	Prob =	0.604		

30% probability of falling in the stream: no significant change.

Paired samples t-test on POST30 vs PRE30 with 7 cases

Mean POST30 =	4.286				
Mean PRE30 =	14.286				
Mean Difference =	-10.000	95.00% CI =	-24.127 to	4.127	
SD Difference =	15.275	t =	-1.732		
	df = 6	Prob =	0.134		

40% probability of falling in the stream: no significant change.

Paired samples t-test on POST40 vs PRE40 with 7 cases

Mean POST40 =	15.714				
Mean PRE40 =	24.286				
Mean Difference =	-8.571	95.00% CI =	-47.234 to	30.091	
SD Difference =	41.805	t =	-0.542		
	df = 6	Prob =	0.607		

50% probability of falling in the stream: no significant change.

Paired samples t-test on POST50 vs PRE50 with 7 cases

Mean POST50 =	15.143				
Mean PRE50 =	14.571				
Mean Difference =	0.571	95.00% CI =	-5.629 to	6.772	
SD Difference =	6.705	t =	0.225		
	df = 6	Prob =	0.829		

***Table E-3*: Large Streams: Statistical results of predicted pre- and post-harvest large wood recruitment potential by probability class.**

Large Streams:
10% probability of falling in the stream: no significant change.
Paired samples t-test on POST10 vs PRE10 with 7 cases

Mean POST10 =	1.429				
Mean PRE10 =	0.000				
Mean Difference =	1.429	95.00% CI =	-2.067 to	4.924	
SD Difference =	3.780		t =	1.000	
	df = 6	Prob =	0.356		

20% probability of falling in the stream: no significant change.
Paired samples t-test on POST20 vs PRE20 with 7 cases

Mean POST20 =	2.857				
Mean PRE20 =	5.714				
Mean Difference =	-2.857	95.00% CI =	-9.848 to	4.134	
SD Difference =	7.559		t =	-1.000	
	df = 6	Prob =	0.356		

30% probability of falling in the stream: no significant change.
Paired samples t-test on POST30 vs PRE30 with 7 cases

Mean POST30 =	5.714				
Mean PRE30 =	10.000				
Mean Difference =	-4.286	95.00% CI =	-11.562 to	2.991	
SD Difference =	7.868		t =	-1.441	
	df = 6	Prob =	0.200		

40% probability of falling in the stream: no significant change.
Paired samples t-test on POST40 vs PRE40 with 7 cases

Mean POST40 =	7.143				
Mean PRE40 =	5.714				
Mean Difference =	1.429	95.00% CI =	-8.458 to	11.316	
SD Difference =	10.690		t =	0.354	
	df = 6	Prob =	0.736		

50% probability of falling in the stream: no significant change.
Paired samples t-test on POST50 vs PRE50 with 7 cases

Mean POST50 =	8.571				
Mean PRE50 =	10.000				
Mean Difference =	-1.429	95.00% CI =	-6.289 to	3.432	
SD Difference =	5.255		t =	-0.719	
	df = 6	Prob =	0.499		

APPENDIX F

STATISTICAL RESULTS: PRE- AND POST-HARVEST COMPARISONS OF COVER

Table F-1: Statistical Results: Pre- and post-harvest comparisons of cover by stream size.

Large Streams: No significant change in cover

Paired samples t-test on PRESHADE vs POSTSHADE with 8 cases

Mean PRESHADE =	83.750			
Mean POSTSHADE =	82.500			
Mean Difference =	1.250	95.00% CI =	-3.995 to	6.495
SD Difference =	6.274	t =	0.564	
	df = 7	Prob =	0.591	

Medium Streams: No significant change in cover

Paired samples t-test on PRESHADE vs POSTSHADE with 7 cases

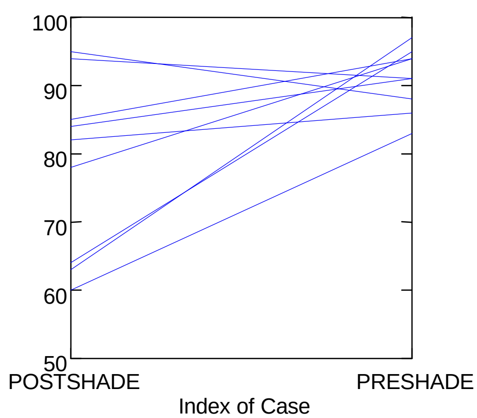
Mean PRESHADE =	88.000			
Mean POSTSHADE =	81.000			
Mean Difference =	7.000	95.00% CI =	-6.801 to	20.801
SD Difference =	14.922	t =	1.241	
	df = 6	Prob =	0.261	

Small Streams: Significant change in cover

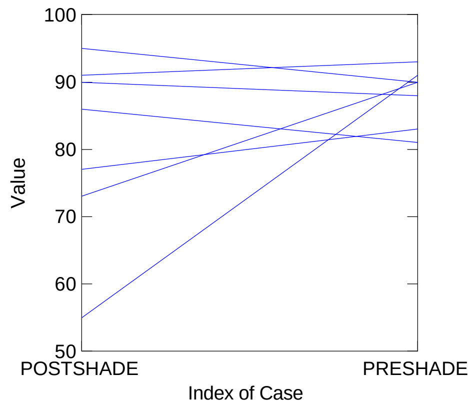
Paired samples t-test on PRESHADE vs POSTSHADE with 9 cases

Mean PRESHADE =	91.000			
Mean POSTSHADE =	78.333			
Mean Difference =	12.667	95.00% CI =	1.587 to	23.746
SD Difference =	14.414	t =	2.636	
	df = 8	Prob =	0.030	

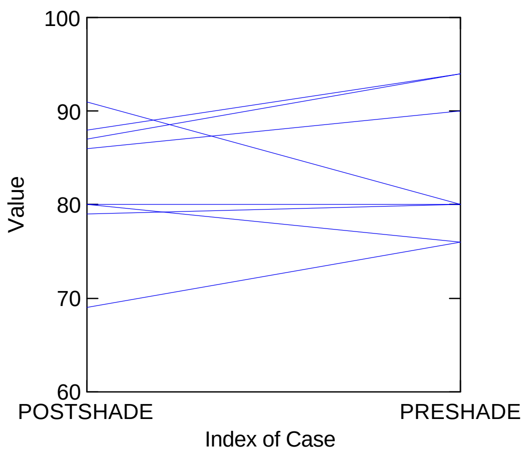
Small



Medium



Large



APPENDIX G

SUMMARY STATISTICS FOR REGENERATION ON INDIVIDUAL SITES

Table G-1. Coastal regeneration summary statistics by site number.

Site Number 11	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of Plots	30	30
Minimum	0.000	0.000
Maximum	3.000	416.000
Median	0.000	0.000
Mean	0.167	23.133
Standard Deviation	0.592	82.136

Site Number 12	Seedlings and Saplings(trees/plot)	Seedlings and Saplings (trees/acre)
N of Plots	30	30
Minimum	0.000	0.000
Maximum	3.000	416.000
Median	0.000	0.000
Mean	0.267	37.000
Standard Deviation	0.785	108.863

Site Number 13	Seedlings and Saplings(trees/plot)	Seedlings and Saplings (trees/acre)
N of Plots	33	33
Minimum	0.000	0.000
Maximum	5.000	693.000
Median	1.000	139.000
Mean	1.303	180.667
Standard Deviation	1.237	171.434

Site Number 16	Seedlings and Saplings(trees/plot)	Seedlings and Saplings (trees/acre)
N of Plots	34	34
Minimum	0.000	0.000
Maximum	14.000	1941.000
Median	1.500	208.000
Mean	2.059	285.500
Standard Deviation	2.795	387.598

Site Number 17	Seedlings and Saplings(trees/plot)	Seedlings and Saplings (trees/acre)
N of Plots	38	38
Minimum	0.000	0.000
Maximum	5.000	693.000
Median	1.000	139.000
Mean	1.500	208.026
Standard Deviation	1.466	203.197

Table G-2. Interior regeneration summary statistics by site number.

Site Number 24	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	48	48
Minimum	0.000	0.000
Maximum	23.000	3189.000
Median	2.000	277.000
Mean	3.396	470.875
Standard Deviation	4.602	638.052

Site Number 25	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	32	32
Minimum	0.000	0.000
Maximum	14.000	1941.000
Median	0.000	0.000
Mean	0.656	91.031
Standard Deviation	2.548	353.247

Site Number 26	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	31	31
Minimum	0.000	0.000
Maximum	3.000	416.000
Median	1.000	139.000
Mean	1.129	156.516
Standard Deviation	1.118	154.917

Site Number 28	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	30	30
Minimum	0.000	0.000
Maximum	19.000	2634.000
Median	0.000	0.000
Mean	0.633	87.800
Standard Deviation	3.469	480.900

	Seedlings and Saplings (trees/plot)	Seedlings and Saplings (trees/acre)
N of cases	30	30
Minimum	0.000	0.000
Maximum	24.000	3328.000
Median	0.000	0.000
Mean	1.500	208.000
Standard Deviation	4.890	678.123

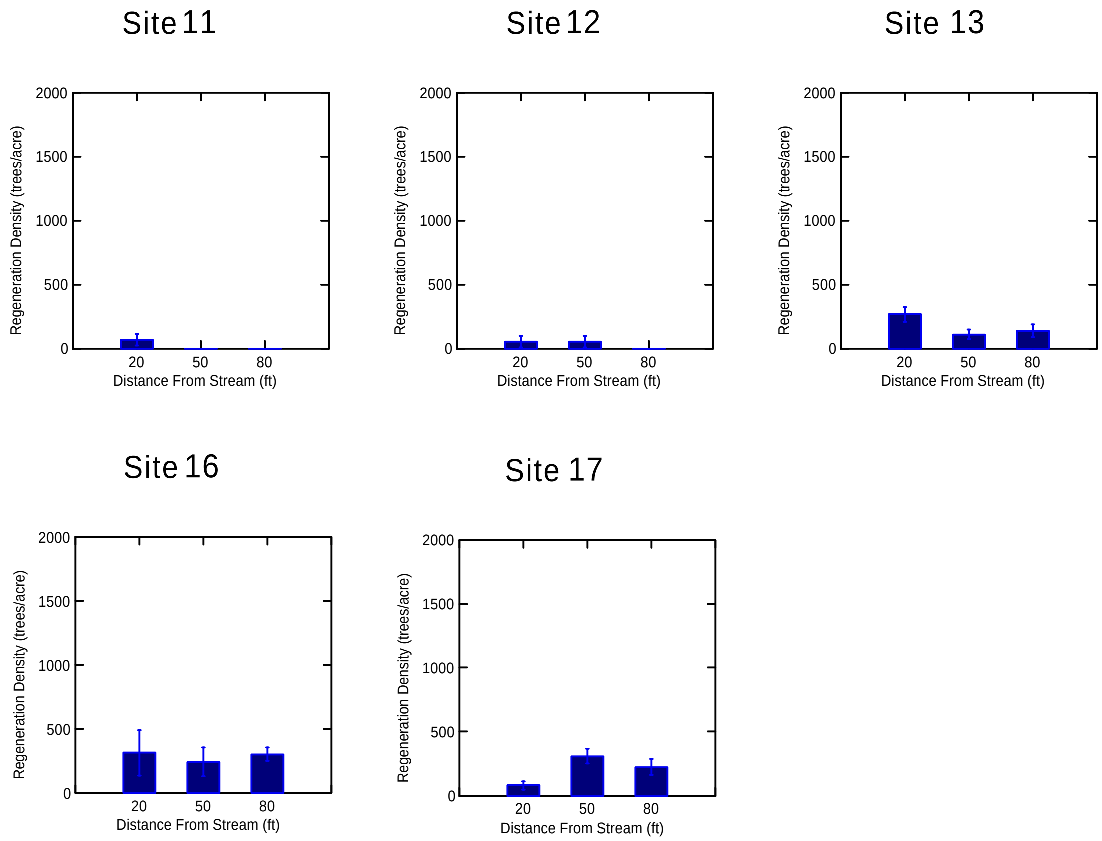


Figure G-1: Coast Range: Average seedling and sapling density and standard error versus distance from stream for each site.

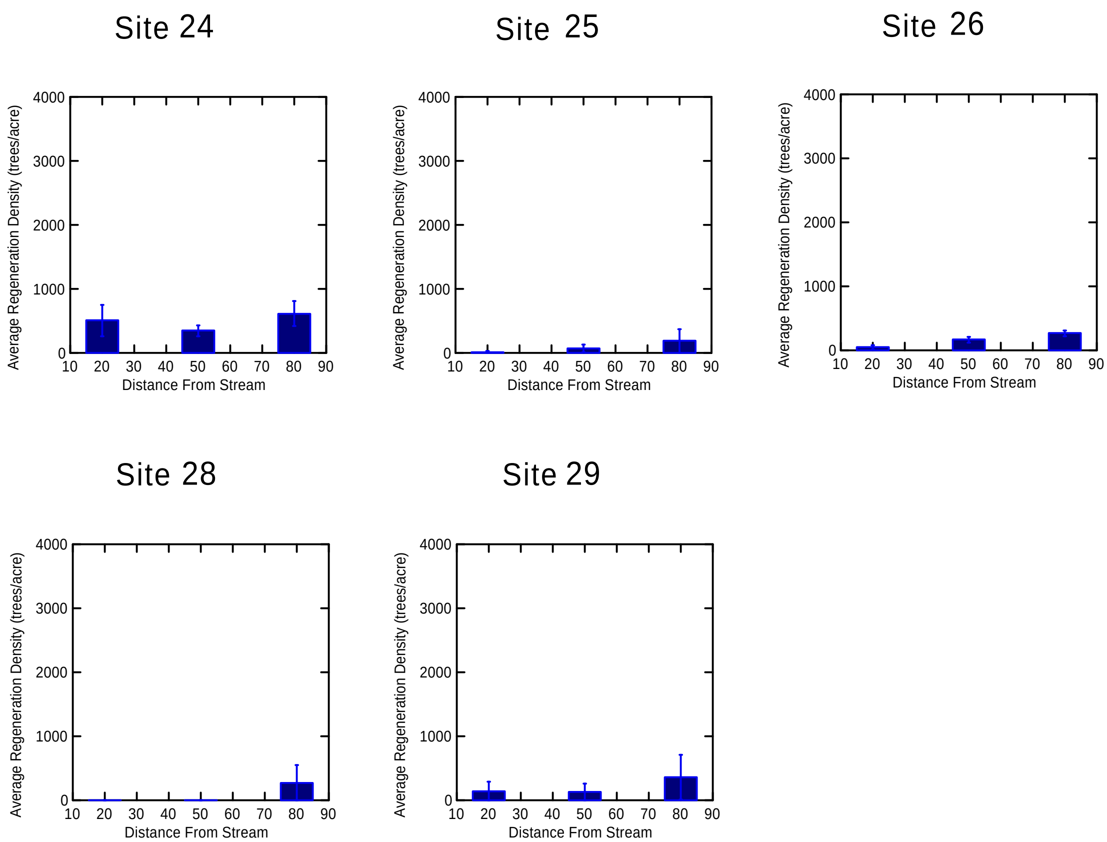


Figure G-2: Interior: Average seedling and sapling density and standard error versus distance from stream for each site.