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Vegetation Characteristics of Alder-Dominated Riparian Buffer Strips in the Oregon Coast Range

Abstract

We examined the effects of harvesting the adjacent forest on tree regeneration, understory development, and overstory dynamics in riparian buffer strips, and compared them with undisturbed riparian communities in the western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] zone of the Oregon Coast Range. All sites were dominated by red alder (*Alnus rubra* Bong.). Salmonberry (*Rubus spectabilis* Pursh) was the dominant shrub in these riparian systems and the only shrub species to increase with buffer creation. Through the chronosequence of buffers aged 0 to 32 years, little further change in overstory composition or cover was observed. Tree regeneration (seedlings younger than the overstory) was scarce. The alder-dominated riparian community appeared largely resistant to environmental changes associated with becoming buffer strips. The scarcity of tree regeneration indicates that future tree cover may be limited after alder senescence.

Introduction

In the Pacific Northwest, the extremely diverse and dynamic riparian plant communities that form a transition between aquatic and upslope systems (Beschta 1991) are important in regulating habitat quality for small mammal and amphibian species (McComb et al. 1993). They also contribute to the complexity of stream channels by introducing woody debris into the system, thereby increasing aquatic invertebrate and vertebrate habitat (Gregory et al. 1991). Such communities are a major determinant of water quality for domestic use (Anthony et al. 1987) and provide raw material for commercial wood products. To protect water quality and fish and wildlife habitat during and following logging, the state of Oregon in 1972 began to require forested bufferstrips along streams. To provide protection over the short term, these forested strips must maintain their integrity; to provide protection over the long term, the forest community must regenerate itself.

In the Oregon Coast Range, where red alder (*Alnus rubra* Bong.) is the predominant tree species in riparian areas, there have been few attempts to examine the dynamics of buffer strips. Andrus and Froelich (1988) documented the role of topography and aspect in windthrow of near-ocean buffer strips. After studying succession of Coast Range alder stands, Hibbs (1987) suggested that alder-dominated buffer strips might have an accelerated or different successional pathway from that of riparian alder stands contiguous with the adjacent, unharvested forest. Even if the successional pathway were unchanged, forest characteristics desirable for water, fish, timber and wildlife could be lost if tree cover is lost.

Studies of succession in Coast Range alder stands (Henderson 1970, Carlton 1989) have indicated that shrub dominance, especially by salmonberry (*Rubus spectabilis* Pursh), increases with time, and that tree regeneration is generally lacking (Minore and Weatherly 1994). An accelerated succession, through mechanisms like windthrow or increased rates of tree senescence could lead more rapidly to the development of this shrub-dominated community. The predominance of red alder and concern that alder-dominated forest may undergo more rapid succession (Hibbs 1987) in buffer strips make study of alder-dominated riparian communities of special interest. Study of the present vegetation structure and composition of riparian buffer strips can provide evidence of the effects of past practices and long-term riparian processes.

This study was made within the western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] and Sitka spruce (*Picea sitchensis* [Bong.] Carr.) zones (Franklin and Dyrness 1973) of the Oregon Coast Range, a region in which red alder has always been a common riparian dominant (Harrington et al. 1981). Extensive logging in the early part of this century greatly increased the dominance of alder in riparian zones as well as on adjacent slopes (Hibbs et al. 1994). Our specific objective was to determine the effects on tree regeneration, understory development, and overstory harvesting of forests adjacent to alder-dominated riparian forests. We sampled a spectrum of buffer strips and alder-dominated riparian communities (called here "undisturbed" communities) that were next to unharvested forests. Our working hypothesis was that succession in alder-dominated buffer strips would differ from that observed in undisturbed alder communities. We used two approaches: examination of a chronosequence of buffer strips, and a comparison of buffer strips with undisturbed riparian forest.

Methods

Sampling-Site Selection

The western hemlock-Sitka spruce zones cover much of the Oregon Coast Range. Sampling sites were selected to represent the range of temperature and precipitation in these vegetation zones, and the range of geomorphology (unconstrained and constrained streams), disturbance type (undisturbed streamside vegetation; buffer strips), and buffer strip age (0 to 32 years since disturbance). General site characteristics are presented in Table 1. The overstory on all sites was composed only of red alder. A streamside terrace was present at most sites, ranging in width from 5 to 35 m, averaging 11.5 m. Stream width ranged from 1.8 to 22 m. Slopes ranged from 0° to 82°, averaging 19°. There was no significant linear relationship between stream width and buffer width.

Streamside harvest units extended several hundred meters along a stream. Sampling areas selected within these lengths had undisturbed homogeneous vegetation of variable width running a minimum of 50 m parallel to the stream. Buffer strips had a minimum of one tree every 15 m of stream length. Information was collected from 54 streamside sites: 44 buffer strips and 10 undisturbed sites. A buffer strip was defined as a riparian forest community left after upslope logging, an undisturbed site as one in which riparian and adjacent forest trees were of the same age. The buffers were of the most simple kind — a strip of trees in which there was no harvesting between the stream and a clearcut. What we call here "undisturbed" sites are stretches of riparian forest that were continuous with and the same age as the upslope forest and were selected to include the range of tree age, stand conditions, and geographic distribution represented among the sample of buffer sites.

TABLE 1. General site characteristics.

	Buffer sites (n = 44)		Undisturbed sites (n = 10)	
Variables	Range	Mean	Range	Mean
Elevation (m)	120-1200	248	80-880	369
Stream gradient (%)	0-7	2.6	1-5	2.5
Stream width (m)	1.7-22	8.6	5.7-14	9.3
Transect length (m)	5-40	18.5	25-60	45.5
Buffer age (yr)	0-32	10.5	—	—
Overstory age (yr)	17-88	43	27-102	55

Plot Establishment and Data Collection

Transects 5- to 50-m long were established perpendicular to stream flow (Figure 1). Each transect extended upslope from the stream edge, ending at the buffer edge on buffer sites, and on undisturbed sites at 60-m distance or at the edge of the alder community, whichever came first. Plots of different size were established along each transect line for tallying overstory alder trees (5 m by 15 m), shrubs (5 m by 5 m), and herbs (1 m by 1 m). Overstory and shrub plots were centered on the transect line; herb plots were 2 m distant. Overstory plots were oriented with the 5-m axis along the transect line. The first plot was located immediately adjacent to the stream; successive plots were located continuously every 5 m to the buffer or terrace edge, or until the maximum transect length was reached. When the transect extended more than five plots, succeeding plots were spaced at 10-m intervals (every other 5-m interval).

Information collected for each transect area was time since buffer creation, elevation, stream gradient, stream width, and overstory age (derived from increment cores of dominant trees). Each plot was designated as terrace, transition, slope, or hilltop. Overstory, shrub, and herb cover was estimated visually as the percentage of plot ground-area covered by each.

The overstory information collected was light, cover, and tree diameter at breast height (dbh) by species. Light was measured at three equally spaced points along the center line of the overstory plot above the shrub cover. One reading was taken in the center of the plot, the other two readings at a distance of 3 m from the plot center. Light was measured with a handheld quantum sensor and calibrated against a continuously recording sensor placed in the open.

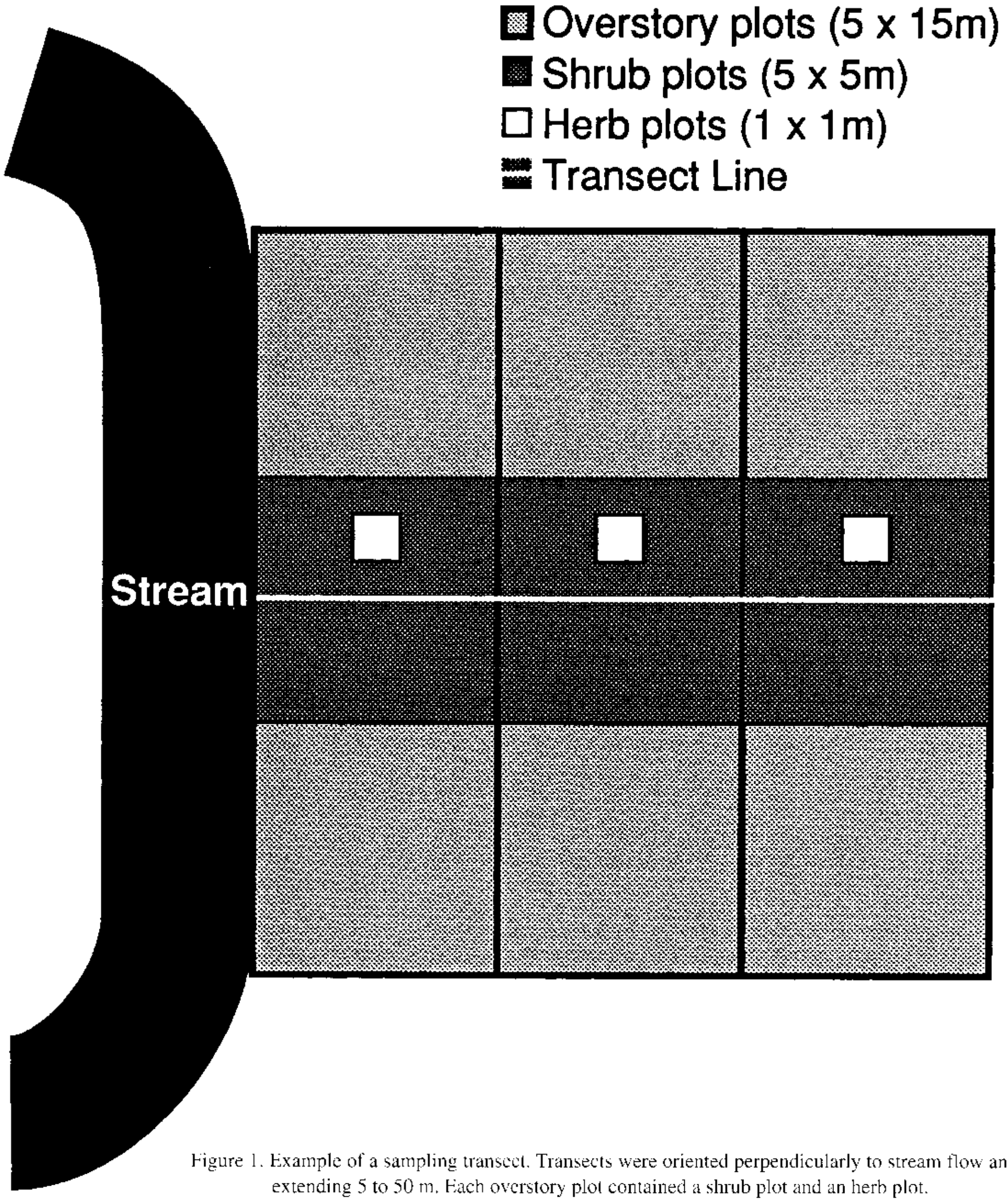

Figure 1. Example of a sampling transect. Transects were oriented perpendicularly to stream flow and extending 5 to 50 m. Each overstory plot contained a shrub plot and an herb plot.

Shrub species and cover were recorded in shrub plots and herb species and cover in herbaceous plots. Swordfern (*Polystichum munitum* [Kaulf.] Presl) cover was assessed in both shrub and herb plots because it is herbaceous but is perennially erect.

For analysis, data were partitioned into buffer and undisturbed sites, and into slope and terrace. Buffer and overstory age (in 5-year age classes) were related to vegetation characteristics. ANOVA and regression analyses were performed with SAS (SAS Institute Inc. 1987). ANOVA and means

TABLE 2. The general analysis-of-variance model for all tests and results for tree basal area, tree cover, and shrub cover. The degrees of freedom in some tests varied from the maximum shown because of missing data.

Effect	df	Basal area (m^2/ha)		Overstory cover (%)		Understory cover (%)	
		Mean square	P	Mean square	P	Mean square	P
Site type	1	216	0.63	4	0.90	6354	0.03
Replication (site type)	52	607	0.86	498	0.13	1300	0.42
Physiographic position	1	3691	0.06	1006	0.07	2717	0.14
Site type x physiographic position	1	385	0.52	1108	0.06	23	0.89
Error	18	887	—	241	—	1167	—

comparisons utilized a split-plot design (Table 2). Means comparisons were made with Fisher's Protected Test of least significant difference. Herbaceous species richness, Shannon diversity index, and species evenness were defined as in Pielou (1977) and calculated on a plot basis. Unless stated otherwise, the significance level is $p \leq 0.05$.

Results

Trees and Shrubs

Overstory cover did not differ between site types, averaging 66.9% on buffer sites and 67.9% on undisturbed sites; total basal area was also similar for both site types (35.3 and 37.5 m^2/ha, respectively). However, on buffer sites, terrace basal area and overstory cover differed from that on slopes (Table 3). We noted no more incidence of sun scald, windthrow, or stem rots in buffer than in undisturbed sites.

Total shrub cover was high on all sites and differed between buffer and undisturbed sites. Shrub cover averaged 112% on buffer strips (range 42%-236%) and 92% on undisturbed sites (range 72%-140%). In total, 22 shrub species were found on buffer sites, 17 on undisturbed sites (Table 4). On undisturbed sites, approximately 87% of the total shrub cover was salmonberry, vine maple (*Acer circinatum* Pursh), swordfern, and red elderberry (*Sambucus racemosa* L.) (Vine maple occasionally grew over 8 m tall but was always considered to be an understory species.). On buffer sites, the same four shrub species accounted for approximately 91% of total shrub cover. Salmonberry and swordfern were the most constant

TABLE 3. Differences in basal area, overstory cover, and shrub cover among site types and physiographic positions. Means in each column followed by the same letter are not significantly different ($p \geq 0.05$).

Site and position	Overstory Basal area (m^2/ha)	Overstory Cover (%)	Shrub Cover (%)
Buffer terrace	52.6a	82.6a	102.1ab
Buffer slope	24.9b	54.7b	121.7a
Undisturbed terrace	41.4ab	67.6ab	79.8b
Undisturbed slope	27.2ab	68.3ab	96.2ab

TABLE 4. Mean percentage of shrub cover on undisturbed and buffer transects (± SE). The symbol "S" indicates species that were found only on slopes within the site type. No shrub species were unique to terraces.

Species	Undisturbed sites	Buffer sites
Rubus spectabilis	35.3 (7.3)	47.3 (3.6)
Polystichum munitum	22.7 (4.2)	19.8 (2.8)
Acer circinatum	18.6 (4.0)	11.8 (3.3)
Sambucus racemosa	10.5 (2.9)	12.5 (2.5)
Corylus cornuta	3.6 (1.4)	2.8 (1.5) S
Rubus ursinus	2.3 (1.5)	1.9 (0.6)
Rubus parviflorus	1.1 (0.7)	6.2 (1.2)
Ribes bracteosum	1.0 (0.8)	2.4 (0.9)
Gaultheria shallon	< 1 S	1.1 (1.0) S
Holodiscus discolor	< 1 S	< 1 S
Physocarpus capitatus	< 1	< 1
Rhamnus purshiana	< 1 S	3.2 (2.0)
Rubus laciniatus	< 1	< 1
Vaccinium alaskaense	< 1	< 1
Vaccinium ovatum	< 1 S	< 1
Vaccinium parvifolium	< 1	2.1 (0.8)
Not identified	< 1	< 1
Ilex aquifolium	0	< 1
Menziesia ferruginea	0	< 1
Ribes lacustre	0	1.7 (1.4)
Rubus procerus	0	< 1
Salix sp.	0	< 1

species, appearing on 100% and 91% of sites, respectively. Vine maple cover was not significantly lower on buffer sites than on undisturbed sites, but it was present on only 48% of them and was present on 90% of undisturbed sites.

Salmonberry had the highest cover of any shrub species, and only salmonberry was present on all 10 undisturbed sites. In addition, salmonberry cover was significantly higher on buffer sites, (47.3%) than on undisturbed sites (35.3%, p = 0.08) (Table 4).

A comparison of slopes and terraces within buffers and undisturbed sites showed that the slopes had similar shrub cover and lower overstory cover and basal area (Table 3). On buffer sites, only cover by swordfern was significantly greater on slopes (27.5%) than on terraces (10.1%). On buffer sites, 14% of shrub species were found only on slopes; on undisturbed sites, 25% (Table 4).

Overstory cover was unrelated to buffer width. Total shrub cover decreased with increasing buffer width (p = 0.06) and width of the undisturbed area (p = 0.08). Total shrub cover increased significantly with proximity to the upslope buffer edge, although the R^2 value was low (0.05). In contrast, total shrub cover had little relationship to distance from the stream edge on either buffer or undisturbed sites. Cover of individual shrub species was not significantly related to distance from the buffer edge or stream edge on buffer sites, nor was it significantly related to distance from the stream edge on undisturbed sites.

Herbaceous Diversity

Over all transects, there were 52 herbaceous species (including ferns) found on undisturbed sites and 97 on buffer sites. Twenty-two of the species found were unique to buffer sites. Species richness, evenness, and diversity did not differ between undisturbed and buffer sites (Table 5). Between terraces and slopes, no differences were found on undisturbed sites; however, evenness and diversity on buffer sites differed significantly (Table 5). In buffer strips, diversity and evenness were significantly higher on terraces than on slopes. Undisturbed sites had 12 herbaceous species found only on slopes, none found only on terraces. Buffer sites had 15 species unique to slopes and 9 unique to terraces. On individual plots, species evenness and diversity increased significantly with increasing distance from the buffer edge (p = 0.01 and 0.06, respectively), although the R^2 value for both was low (0.04); species richness showed no significant relationships.

Dynamics

Overstory cover was not significantly related to overstory age on either undisturbed or buffer sites, although there appeared to be developing a decreasing trend in overstory cover on undisturbed sites as overstory age increased. Total shrub cover was not significantly related to overstory tree age on either undisturbed or buffer sites. However, on buffer sites, salmonberry and hazel (*Corylus cornuta* Marsh) cover increased slightly with increasing overstory age (not to be confused with time since buffer creation; p = 0.03 and 0.08, respectively), and, on undisturbed sites, vine maple had a positive relationship with overstory age (p = 0.08).

Neither overstory cover nor basal area showed a significant linear relationship to buffer age; however, light reaching the understory decreased significantly as buffer age increased (light = 14.6 - 0.46 (age); $r^2 = 0.12$). Expressed as a percentage of open light, it decreased from 13% in new buffer strips to 6% in 20-year-old buffers.

In spite of the decrease in understory light with buffer age, buffer age seemed to have little relationship with shrub cover, which remained relatively constant over a span of 30+ years (Figure 2). Cover of individual shrub species (e.g., salmonberry)

TABLE 5. Herb indices (transect basis) for terraces and slopes on undisturbed sites and buffer sites, and the probability (P) that the two means are significantly different.

	Undisturbed sites			Buffer sites			Total plots		
Index	Terrace	Slope	P	Terrace	Slope	P	Undisturbed	Buffer	P
Richness	7.8	7.6	0.67	8.3	8.0	0.44	7.7	8.1	0.36
Evenness	0.43	0.40	0.61	0.45	0.34	0.00	0.41	0.39	0.53
Diversity	0.89	0.81	0.52	1.99	0.69	0.00	1.80	0.84	0.60

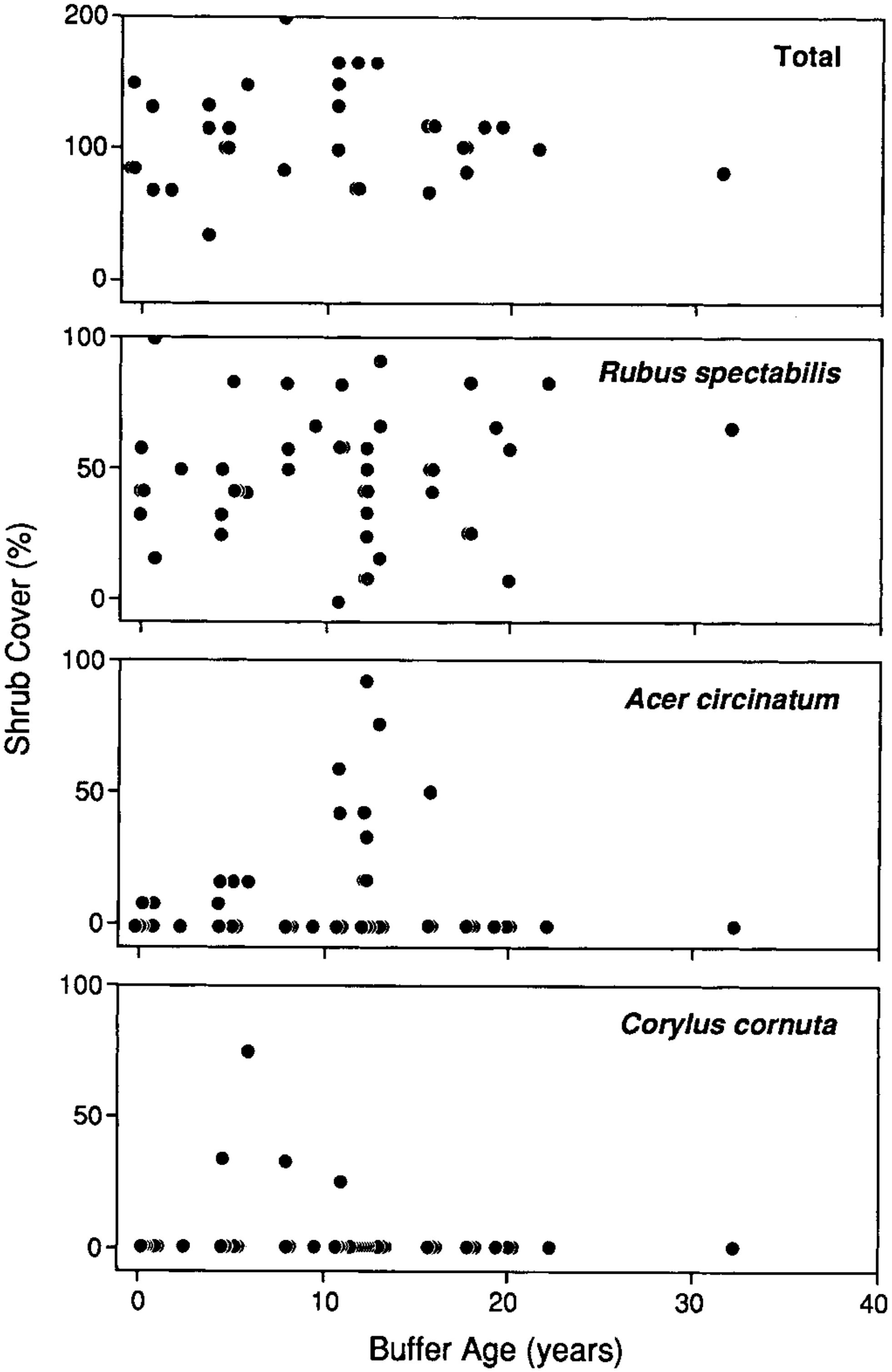

Figure 2. Change in shrub cover with buffer-strip age: a) Total shrub cover, b) salmonberry, c) vine maple, d) hazelnut.

also showed no linear relationship with buffer age, although vine maple and hazel on a small subset of transects had high values at specific times in the chronosequence (Figure 2).

Species richness, evenness, and diversity showed no significant relationship to buffer or overstory age.

Tree Regeneration

Only a small amount of tree regeneration (seedlings or trees younger than the overstory) was found. Of the 28 individuals in 1.73 ha of sample area on undisturbed and buffer sites combined, 9 were hardwood and 19 were conifer seedlings. Of the hardwood regeneration, 89% had established on mineral soil. Only 42% of conifer seedlings were found on mineral soil; others had established on rotting conifer logs (Figure 3).

Discussion

In field studies, site selection has the potential to bias results. We deliberately distributed our sites over the geographic and environmental range of the study area. Ultimately, however, selection was limited to those locations, and thus to those environmental conditions in which our sampling criteria were met: alder-dominated buffer strips or riparian areas in which there had been no partial harvesting. Did older buffer strips have a different history, (e.g., greater or lesser numbers of conifers in the now-harvested adjacent stand) than younger buffer strips? We do not know. We do

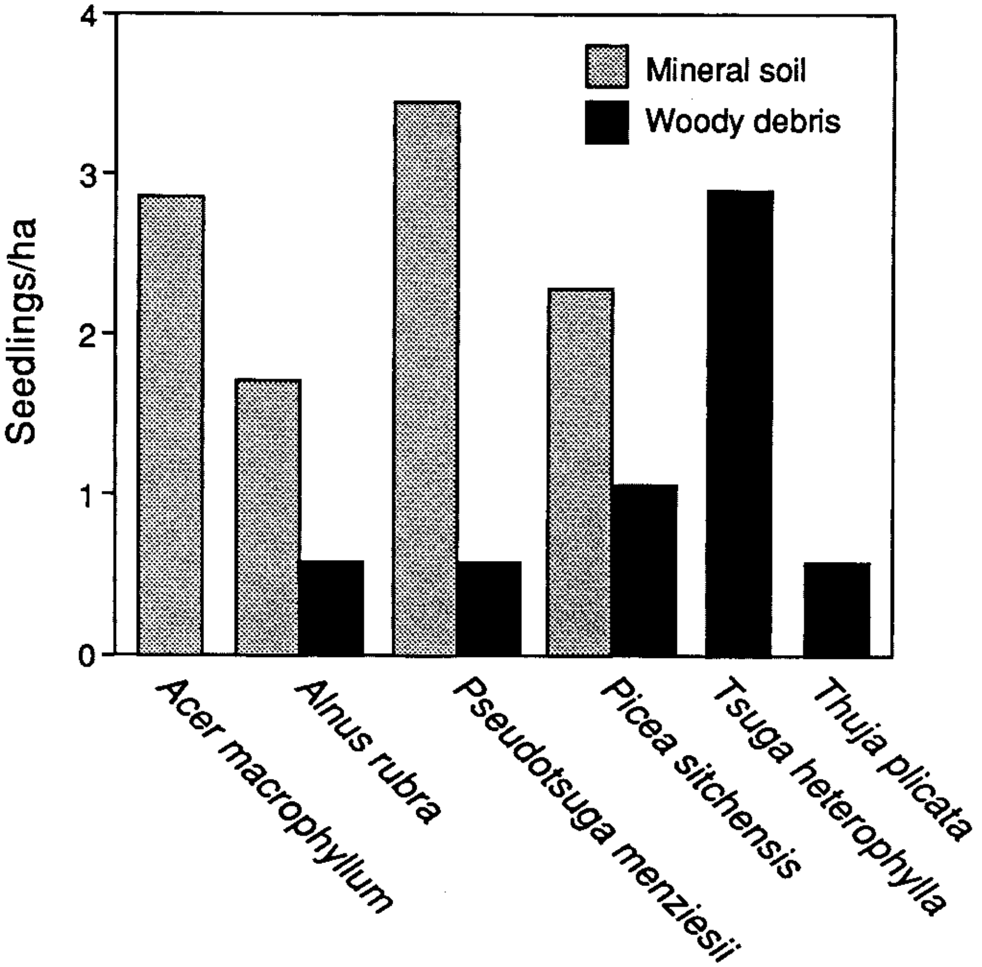

Figure 3. Tree regeneration in buffer stirps on mineral soil and woody debris.

know that all had similar post-harvest histories. Were undisturbed sites different in important ways from buffer sites? Again, there is not a definite answer. Table 1 indicates that there is a reasonable match for a number of characteristics, but one still must interpret results with caution.

We had expected to find more developmental trends in the buffer strips, inasmuch as these small pieces of forest community were suddenly placed in new environments characterized by increased side light and air movement, reduced humidity, and, perhaps, a higher water table. Such changes might be expected to affect plant growth and to change community dynamics, yet we found little evidence of this. In the overstory, we saw no more evidence of stem rot, sunscald, or windthrow than in the undisturbed sites. Overstory cover and basal area were stable through time. It seems unlikely that the similarities of buffer and undisturbed sites are due to our site-selection procedure; we simply looked for the presence of an alder overstory. We did not look at its health.

The comparison of total shrub cover on buffer and undisturbed sites showed that the creation of a buffer increased cover, which may indicate a small increase in the rate of understory development over that of undisturbed communities (Henderson 1970, Carlton 1989). There was little evidence of edge effect, only a small increase in shrub cover near buffer edges, probably lasting only until new, adjacent forest attains a height of 10 to 15 m. Although some individual species may have shown a temporary response, total understory cover was stable in buffers. Some differences in herb diversity and evenness appeared in buffers, but the differences were not great and may reflect responses to change in the shrub layer or some unmeasured site factors. The alder-dominated riparian community appears surprisingly resistant to floristic change. The general rate and pathway of succession in these communities appears fundamentally unchanged from succession on undisturbed sites.

Salmonberry has received considerable attention in recent studies of Oregon Coast Range vegetation communities (Tappeiner et al. 1991, Zasada et al. 1991). It is the most abundant shrub in the Coast Range and was the most abundant shrub in this study. Its rhizomatous regeneration habit as well as its ability to sprout vigorously after top damage allow it to colonize recently disturbed areas quickly, regenerate beneath its own cover, or re-establish itself where disturbance may have removed most salmonberry (Tappeiner et al. 1991, Zasada et al. 1991). Thickets of salmonberry often form beneath full alder canopies, greatly reducing available light in the understory. It has been speculated that total shrub cover and salmonberry cover increase in alder-dominated riparian areas as the alder canopy senesces (Newton et al. 1968, Henderson 1970, Carlton 1989). Although total shrub cover appeared to be fairly constant over time in this study, salmonberry cover in buffers increased as the overstory aged. This could indicate that total shrub cover has reached a maximum for this community type and that further successional changes will be a shift in species composition, a trend supported in undisturbed communities by the decrease in vine maple cover with overstory age.

The high shrub cover in buffer strips and the increase in salmonberry dominance may explain, in part, the scarcity of tree regeneration. Neither Henderson (1970) nor Carlton (1989) found many tree seedlings in their chronosequence studies of riparian and upslope alder stands. In alder-dominated Coast Range riparian zones, the combination of limited large woody debris (Ursitti 1991), an important regeneration substrate (Harmon and Franklin 1989, Minore and Weatherly 1994), and high shrub cover clearly limit the opportunity for natural regeneration of trees, conifer or otherwise. As these stands senesce, only a significant natural or man-made disturbance will allow reestablishment of a tree overstory.

Total shrub cover on the buffer strips (42%-236%) and undisturbed sites (72%-140%) was high compared to that in other community types in the Oregon Coast Range, where it generally ranges from 22% to 106% (Henderson 1970, Hemstrom and Logan 1986, McComb et al. 1993). The highest cover tends to be found in upslope communities. Total shrub cover in plant communities with a high salmonberry component is typically between 55% and 85% (Henderson 1970, Hemstrom and Logan 1986, McComb et al. 1993). In this study, shrub cover was similar (115%) to that in some Oregon Cascade Range communities dominated by rhododendron and salal (Hemstrom et al. 1987). These communities are generally on drier upslope sites where total shrub cover is between 54% and 118% (Hemstrom et al. 1987). Communities at higher elevations in the Cascade Mountains [Pacific silver fir (*Abies* *amabilis* Dougl.) associations] can have shrub cover >150% (Hemstrom et al. 1987).

Protection of riparian ecosystem integrity from adjacent harvest activities has typically involved establishment of buffer strips. While this study shows that the overstory vegetation structure of buffer strips is similar to that of undisturbed hardwood communities, some changes appear in understory composition and cover. The initial increase in salmonberry cover after buffer creation (from 99% to 115%) and the stability of total shrub cover over time have implications for the future structure and composition of these systems. In the short term, they may be quite stable. In the future, however, diminished conifer regeneration due to present-day shrub competition and lack of woody debris could further reduce the large-wood source for stream structure and, perhaps more important, could lead to a negative cycle in which conifer regeneration is further limited by the diminishing supply of woody debris.

Artificial regeneration (planting) of conifers would require a reduction in both shrub and tree cover. Light levels above the shrub canopy were low, generally less than 10% of full sun. Shrub cover, averaging nearly 100%, would reduce ground-level light even further. Riparian regeneration studies underway in the Oregon Coast Range (Chan and Hibbs, unpublished data) are clearly showing that light levels above about 25% are needed for basic survival and minimal growth of most native conifers. In a 24-year-old alder stand, cutting 75% of the trees (69% of basal area) and 100% of the shrub cover increased light from 4% to 15% of full sun (Chan and Hibbs, unpublished data). To be successful, tree regeneration efforts in the Coast Range will require, at minimum, intensive overstory thinning or creation of moderate-size or larger canopy openings.

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