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Buffer Strip Dynamics in the Western Oregon Cascades

by

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Although buffer strips have long been used as a protection tool when logging near streams, long-term studies investigating buffer strip dynamics are rare. Steinblums et al. (1984) inventoried 40 buffer strips 1 to 15 years old in the western Oregon Cascades beginning in the summer of 1975. Numerous site and stand characteristics were evaluated and regional regression equations were developed to predict survival of the buffer strips (Steinblums et al. 1984).

During the summer of 1990, 20 of the original buffer strips (Steinblums et al. 1984) were selected for reinventory to assess overstory conifer changes and density of conifer regeneration. Three sites had experienced severe windthrow followed by salvage logging, and a fourth could not be matched with original field notes. The 1990 comparison utilized the 16 remaining sites.

Four diameter classes (10-14 inches DBH, 15-29 inches DBH, 30-44 inches DBH, and ≥45 inches DBH) were used to

evaluate changes in overstory conifers since the original study. Density and basal area of each class were evaluated for each of the three common coniferous species (western hemlock, western redcedar, and Douglas-fir), and combined conifers. Average combined conifer densities of these late successional buffer strips increased from 54 to 59 trees per acre since the earlier study (Steinblums et al. 1984); average combined conifer basal area decreased from 299 to 263 ft^2 per acre since the original study.

Ingrowth was most common in the two smallest diameter classes, with the majority of buffer strips showing increases in density and basal area. Average combined conifer density increased from 32 to 41 trees per acre; average combined conifer basal area increased from 64 to 76 ft^2 per acre. Western hemlock was the major contributor to the increases. Western redcedar and Douglas-fir represented relatively minor components of the two smallest diameter classes in both samplings. While combined conifer basal area increases were small, density increased as much as 900%.

Decreases in density and basal area were common for conifers 30-44 inches DBH, with the majority of losses evident among western hemlock. However, Douglas-fir also exhibited some declines in this class. Western redcedar was relatively unchanged since the original study. Density losses ranged from 0 to 50% of the original buffer; basal area losses ranged from 0 to 72%.

Density and basal area losses typically occurred among conifers ≥45 inches DBH. Though trees of this size were not prevalent, basal area losses from this class ranged from 0 to 84% of the original sample value.

Conifer regeneration data indicate these buffer strips are sufficiently stocked to maintain conifers over time. Average densities of saplings (<8 inches DBH and >3 feet tall) ranged from nearly 200 to 3600 trees per acre.

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INTRODUCTION

"Buffer strips" have been extensively used as one of many stream protection measures while logging the forests of western Oregon. They help shade the stream, stabilize slopes, and provide important biologic and hydrologic complexity to stream systems (Adams et al. 1988). On public land, recent changes in riparian management philosophy have modified even the terminology associated with these areas. Buffer strips or "buffers", which once focused on the immediate streamside vicinity and allowed for commercial timber extraction, have been expanded to "Riparian Management Zones" (RMZs), which may extend far beyond the streamside zone in recognition of the processes and interactions occurring between the hillslope and the channel (Gregory and Ashkenas 1990).

Although thousands of buffer strips have been established over the past few decades, there is little documentation of their long-term dynamics. In fact, it is difficult to evaluate effectiveness of buffer strips because of a changing philosophy; those of "yesteryear" were not designed to serve the same purpose that riparian management zones created today are. Historically, buffers were left primarily for stream shade, but research over the past several decades has underscored their importance for streambank stabilization and coniferous woody debris inputs (Adams et al. 1988). Even though many historic buffers are configured quite differently than they would be under today's management philosophy, there is still much to be learned from revisiting them.

Steinblums (1978) inventoried 40 buffer strips in the western Oregon Cascades and developed regional regression equations to predict their survival, defined as the percentage of original stand volume remaining over time. Several site and topographic variables were measured or estimated, (Appendix A(1 - 2)) and a 100% inventory was obtained of standing conifers over eight inches diameter at breast height (DBH) in sample areas. Condition of these buffers had not been documented since 1977.

During the summer of 1990, 20 of the original buffer strips, all on the Willamette National Forest (WNF), were selected for reinventory and comparison with the original stand condition. During the previous 13 years, several regional storms, including the severe storm systems of 1990 affected the buffers, influencing their survival.

This study compares the 1990 overstory species composition and diameter distribution of the buffers with their condition as documented in 1977. For the 1990 study, difficulties relocating sample areas and different tree measurement techniques precluded direct comparison of timber volume remaining over time. Overall and species-specific density and basal area comparisons were used as a surrogate for volume. A steady recruitment of conifers is important both for shading and influencing the hydraulic features of mountain streams. Conifer regeneration studies are non-existent in Oregon Cascades buffer strips and have been included as an important component of this study.

Buffer strip survey information may reveal a shift in species composition or diameter distribution, or a lack of conifers for woody debris recruitment from the current or future stand. Regeneration transects may indicate potential for a continuous source of conifers over time, or it may signal an interruption of large wood sources that will last several decades. Linking current stand composition with regeneration potential in specific buffers may provide a conceptual framework for understanding the evolution of the buffer strips over time.

Buffer strips, (Riparian Management Zones) should be designed to meet identifiable, obtainable, long-term objectives. Revisiting previously inventoried buffers provides an opportunity to develop an understanding of buffer strip dynamics which can be used for future riparian area delineation and prescription.

LITERATURE REVIEW

Though replicated buffer strip studies are rare, much research has focused on specific roles of buffer strips as they relate to various resources: fish, commercial timber (including economics of riparian management, and constraint of timber sale layout), wildlife, and recreation. Buffer strips serve to enhance several resource components. They provide a linkage for Oregon's fish and wildlife with the timber resource, and may help to enhance recreational opportunities.

Fish

Oregon's important fisheries industry, both commercial and recreational, hinges on the maintenance of high quality fish habitat. Several species of anadromous and resident salmonids play a vital role to Oregon's economy; they are intimately dependent on streams of all orders (after Strahler 1957), from the headwaters to the Pacific Ocean. Important habitat features are: food, cover, water of the appropriate temperature and quality, and an adequate balance of spawning and rearing habitat. Buffer strips have been used to help maintain or enhance fish habitat through shading, nutrient inputs, (Beschta et al. 1987), and habitat diversity -- both structural and hydraulically (Bisson et al. 1987).

Shade -- Although salmonids require cool water, they are able to tolerate considerable fluctuations in temperature. In general, anadromous salmonid production begins to decline when water temperatures exceed 20°C (68°F). Mortality usually occurs if water temperatures exceed 25°C (77°F) for a few days (Everest and Harr 1982). Although numerous studies have documented increases in Pacific Northwest stream temperatures following the removal of riparian vegetation, the majority of temperature increases in harvested watersheds of the Pacific Northwest have not approached the tolerance thresholds of resident fish species (Beschta et al. 1987).

Buffer strips help to shade fish-bearing and cool water source streams and may allow for the removal of some commercial timber. Brazier and Brown (1973) identified those characteristics of buffer strips important for stream temperature regulation: type of vegetation, canopy density, canopy height, stream width, and stream discharge. Width of the buffer strip had a positive influence on stream shading until about 80 ft.; beyond this point the relationship with stream shade was asymptotic. Research focusing on levels of shading following disturbance indicates that on small coastal streams, adequate shade is often provided by quick regrowth of brush species after logging or wildfire (Andrus and Froehlich 1986a). In the Cascades, it may take several years for the understory vegetation to reshade the stream following logging (Summers 1982).

Macroinvertebrates -- Essential to healthy salmonid populations are not only cool waters, but an adequate supply of food and nutrients. Buffer strips should provide, maintain, or create a suitable environment for benthic macroinvertebrates, particularly those that are a salmonid food source, as well as providing organic inputs.

Though it is difficult to isolate variables in the field, Hawkins et al. (1983) found that opening the riparian canopy increased invertebrate abundance. Because various limiting factors can play an important role for salmonid populations, Hawkins et al. (1983) indicated that increased numbers of fish due to greater food production may be offset, for example, by loss of winter habitat.

Opening the riparian canopy can obviously increase the solar radiation load to a given stream reach. Clearcutting of adjacent hillslopes may also change nutrient inputs to the stream. The combined effect of these changes has been reflected in shifts in abundance and diversity of macroinvertebrates (Erman et al. 1977). Erman and Mahoney (1983), following up on the previous study, define recovery as "the extent to which the diversity index of macroinvertebrate communities in logged or narrow (<30 meters) buffered streams resemble unlogged streams now as compared to the past". After five years, they found recovery of benthic communities to have occurred in buffered streams compared to their condition one year after logging. However, recovery was often "incomplete", as indicated by having significantly lower macroinvertebrate diversity than control streams. Erman and Mahoney (1983) concluded that buffer strip effectiveness decreased with decreasing width, and that an average buffer width of 98 ft (30 m) represented a "threshold width" below which detrimental effects to the biological stream environment would result. However, these findings are complicated by the fact that several of the reinventoried streams and associated riparian zones had experienced moderate to severe disturbance, including road construction and additional harvesting, in the time between studies (Erman and Mahoney 1983). Also, other confounding factors, such as differences in geology, elevation, and discharge, may also have influenced the results. In contrast, Carlson et al. (1990) found no statistically significant differences in macroinvertebrate diversity of logged and undisturbed riparian forests in northeastern Oregon. Macroinvertebrate density was well correlated with elevation, a variable often overlooked in paired upstream/downstream studies.

Site specific variables limit generalizations, but it becomes obvious that changes in riparian vegetation affect light, temperature, and instream organisms, ranging from algae to salmonids. Though generalizations can be made, the importance of stream by stream assessment cannot be overstated.

Organic inputs -- The River Continuum Concept (Vannote et al. 1980) hypothesizes that overall health of a river or stream is largely dependant on processes occurring in the headwaters. First and second order streams are most closely linked with adjacent terrestrial environments because of their narrow channel width relative to canopy opening.

By providing organic inputs for aquatic invertebrates, buffers directly and indirectly enrich the stream nutritionally (Vannote et al. 1980; Gregory et al. 1987; Maser et al. 1988). They provide allocthonous organic inputs to stream systems in the form of needles, leaves, twigs, and branches. In headwater streams, these terrestrial inputs dominate over other nutrient sources. An important ramification of streamside logging is a shift in both quality and quantity of organic inputs to the stream. At extreme ends, streamside logging may result in a 3- to 4-fold decrease in allocthonous inputs, accompanied by a shift in riparian species composition (Gregory et al. 1987).

Summers (1982) surveyed revegetation of 40 riparian zones clearcut without buffers up to 29 years after timber harvest in the Coast and Cascade Ranges of Oregon. Within the timeframe of his study, harvested sites typically experienced a shift to hardwood, deciduous vegetation. Andrus and Froehlich (1986a) found that on some Oregon coast buffers, alder contributed 61% of the standing basal area 50 to 75 years following logging, while it accounted for only 27% of the basal area 80 to 140 years after wildfire. Although quality of deciduous litter is higher as a nutritional resource for microbial communities, rates of decomposition and spiraling are much faster (Gregory et al. 1987), possibly offsetting the nutritional gains. This shift to deciduous species is thought to last anywhere from 30 to 100 years (Gregory et al. 1987; Maser et al. 1988).

Hibbs (1987) warns of irreversible shifts from coniferous to deciduous vegetation in coastal Oregon buffer strips (no entry and partial cutting) without deliberate efforts to secure conifers. He indicates narrow buffers with no or partial entry experience greatly increased light levels causing a shift in species composition. To maintain conifers, he suggests either wider buffers (no specific width) or clearcutting (and planting?).

Andrus and Froehlich (1986a), in a study of 28 coastal Oregon streams that had been clearcut and burned 2 to 135 years prior to the study, found certain characteristics that support Hibbs' (1987) concerns. Though riparian sites were quickly revegetated, many areas experienced a shift to deciduous species. They hypothesize that conifer establishment on disturbed terraces is usually minimal due to moist soils and heavy competition by brush and alder.

Although buffer strips offer an opportunity to mediate the effects of streamside timber harvesting, the issue of riparian zone management has become increasingly complex. Instead of solely dealing with the shade provided to the stream, concerns have expanded to include organic inputs to the stream system, changes in species composition that may result from harvesting, and effects that last into or well beyond the next rotation. Documentation of management induced changes over time is critical to the advancement of riparian management.

Structure -- Perhaps the most complex aspect of fish habitat provided by buffer strips is structure, spatially and functionally. Recent inventories suggest that wood from downed trees in "old-growth" systems was a dominant feature of western Oregon Cascade streams. Harmon et al. (1986) found loadings ranging from 4 to 121 lb/yd^2 in unmanaged streams whose mean widths ranged from <1 ft to 33 ft flowing in the western Oregon Cascades. Froehlich (1973) found total woody debris loadings in undisturbed westslope Cascade channels ranging from 1 to 26 T per 100 ft of stream length.

Large woody debris (LWD) is thought to influence channel morphology, and therefore fish habitat, in the following ways (Sedell et al. 1984):

* longitudinal profile
* channel position
* formation of (major) channel features
* development of finer scale features

Geologic formations control the general longitudinal profile of most streams. However, on smaller streams, LWD can also have an important influence. It functions as an in-stream obstruction to produce and maintain high quality pools, provide surface turbulence, sort substrate materials, and form undercut banks (Everest et al. 1985). It influences the longitudinal profile by the creation of "steps" in the channel. Once a log is incorporated into the bed and creates a dam, sediment accumulates and partially fills the channel, reducing stream velocities. Sediment comprises the "tread" of the "step"; the "riser" is the obstruction itself (Sedell et al. 1984). Energy is dissipated as water runs over the LWD, and a step pool may be formed immediately below it (Sullivan et al. 1987).

Pool and riffle features resulting from LWD "steps" are extremely important to salmonid production, particularly for feeding and spawning sites. Pools, with low current velocities and deeper, often cooler water, provide feeding locations that require a minimum expenditure of energy. Depth and quality of the pools may be the limiting factor for salmonids during summer low flows. The sorting and settling of sediments by LWD also helps provide suitable spawning and rearing sites (Bisson et al. 1987). The creation and duration of these log steps is dependent on the source material provided by the adjacent riparian zone.

Although first order streams may not be inhabited by salmonids, they are of vital importance because they act as "viaducts" of water, sediments, nutrients, and woody debris. The role of LWD in these streams should be an important consideration in timber harvesting and buffer strip design. Winter floods and "sluice-outs" are part of the natural processes. With these events comes the addition of LWD inputs resulting from bank undercutting and flushing of small headwater streams loaded with wood (Everest et al. 1985).

Lower in the drainage basin (larger order reaches), or in areas that are not geologically constrained, LWD plays a role in lateral channel position. Logs extending partially across and into the channel deflect the current laterally, sometimes causing the streambed to widen. Debris accumulations along the streambanks cause meander cutoffs and create well developed secondary channels. These features are believed to increase salmonid survival, serving as refuge sites during floods and winter storms (Bisson et al. 1987).

Geomorphologists characterize LWD as "large roughness elements", capable of storing sediment and reducing stream energy, while fisheries biologists tend to identify it as an important habitat feature (Bisson et al. 1987). This helps illustrate the close linkage of stream hydraulics to salmonids. Sediment movement and storage, water aeration, water depth, and stream energy are all hydraulic functions of vital importance to fisheries management; each of these is ultimately linked to management of the riparian zone.

Species composition of a buffer strip greatly influences the future condition of the stream, physically, biologically, and hydraulically. For example, alder decomposes much more quickly than coniferous woody material. Although alder rarely reaches the size of conifers, it begins to enter the stream at a younger age and thus replenishes woody material more frequently than longer lived conifers (Maser et al. 1988). Alder tends to be shorter in length than mature conifers and will not readily be keyed into the channel for that reason. Deliberate efforts to secure future sources of LWD may be aided by a methodology recently developed to determine which trees are most likely to contribute LWD to a stream (Robison and Beschta 1990a).

The maintenance of Oregon's important salmonid fishery is biologically and economically important. Buffer strips help minimize potential effects of timber harvesting on this important resource. They influence both present and future channel characteristics, as affected by inputs of LWD. This relationship is so intimate, Potts and Anderson (1990) state: "...in effect, management of riparian vegetation and the supply of organic debris constitutes management of channel characteristics and behavior".

Perhaps intentional efforts must be made to provide the kinds of LWD inputs that best meet the perceived needs of the stream over the long term, thus maintaining or enhancing the integrity of the stream system.

Commercial Timber

Riparian areas have long been a concern for timber managers of the Pacific Northwest. Ephemeral, intermittent, and perennial streams typically traverse harvesting units. Over the last several decades, riparian management has become a major issue in the political arena. Recent federal and state legislation of buffer strip requirements have made timber management in the riparian zone much more challenging; it is now mandated that buffer strips be left, but the question of how to manage the buffer remains an important issue.

"Management" begins with broad scale forest planning and continues through the operational phase of timber harvesting and regeneration of the next stand. Garland (1987) has identified several analytical and operational considerations of streamside management. He stresses the importance of basin area planning in mixed ownerships and suggests that terrain features, rather than property boundaries be utilized in harvest scheduling. He suggests the utilization of computer assisted cable harvest planning in areas of steep terrain for optimal efficiency, incorporating streamside management constraints. He also supports the concept of utilizing work such as Steinblums' (1978) in the configuration of buffer strips to help achieve desired streamside results.

From an operational standpoint, Garland (1987) suggests that directional felling and designated skid trails, and pulling winch line to remove trees from the riparian zone should be considered as techniques to protect riparian areas. During the actual harvesting, he proposes better control of logs being removed from the riparian zone to minimize residual stand damage.

Each of these procedures requires an investment in time, money, and qualified personnel. Cost generalizations are impractical due to site specificity. True costs can only be measured when specific parcels of land, site conditions, logging options, and buffer options are considered (Garland 1987). Economic analyses using different buffer management scenarios have been completed (Olsen 1987), but they are complicated by the fact that many resource values cannot be directly compared monetarily.

Windthrow of buffer strips

Blowdown is a frequent event in buffer strips (Steinblums et al. 1984; Andrus and Froehlich 1986b). Blowdown may not be biologically detrimental to the stream or riparian area, but if the ownership objective is timber production, it will no doubt be viewed as a loss. Similarly, even if it doesn't blow down, commercial timber left on site may represent an economic loss to the landowner.

Loucks (1957) documented blowdown along an Ontario, Canada lakeshore 10 years following harvesting. He found wind damage to be about four times greater in the lakeshore reservations than in control uncut stands, over the 10-year period, but blowndown timber accounted for only 20% of the reservation basal area over the same timeframe. Wind damage was very localized; most of it was experienced on only five of the 30 sample areas. These sites had features (old pit and mound topography) indicating past episodic blowdown that could have been identified during sale layout. Those trees most susceptible to blowdown could have been removed with the adjacent harvest in anticipation of the blowdown losses, unless blowdown of these trees was the objective.

Steinblums (1978) identified various factors associated with blowdown on 40 sites in the western Oregon Cascades. He found slope distance to the cutting line, horizontal distance to, and change in elevation from the buffer strip to the nearest major ridge in the direction of damaging winds, and buffer strip overstory composition coupled with natural site stability to be the most influential factors.

Andrus and Froehlich (1986b) inventoried buffer strips up to six years old on 30 coastal Oregon streams (harvested on both sides of stream). Basal area of snapped or uprooted trees ranged from 0 to 72% (average = 22%) of the original stand and generally occurred in clumped patches; they hypothesized high winds were the most common cause. They found blowdown to be greater on boggy terraces, on sites with a higher percentage of stand basal area contributed by conifers, and where buffers were oriented perpendicular to prevailing storm winds. Harris (1989) studied blowdown in southeast Alaska and found uneven-aged stands in advanced stages of succession to be "high-risk" stands. Topography, species, stand condition, direction of prevailing winds, and soils were deemed the most significant elements.

Leaving a buffer strip for future recruitment of LWD usually assumes inputs will happen periodically, not as an episodic event. In order to ensure adequate future recruitment, regeneration of desired species must occur. Coniferous inputs decompose more slowly than alder, though alder would be added more frequently (Bisson et al. 1987).

Although hand planting conifers can augment natural seeding, it's important that provisions be made to assure conifer ingrowth to the buffer strip.

Loucks' (1957) survey of natural regeneration within lakeshore buffers found it to be comparable to natural stocking in control uncut stands. Summers (1982) found shifts from coniferous to deciduous vegetation on streamside logging sites in the Coast and Cascade Ranges of Oregon. Hibbs (1987) has warned of alder and salmonberry outcompeting conifers on harvested streamside sites in the Oregon Coast Range. Thus far, no one has investigated conifer regeneration in partially harvested western Oregon Cascade buffers.

Wildlife

Riparian areas provide continuity between hillslopes and streams, and are thought to be migration and dispersal routes for wildlife. Water is available for consumption and provides breeding sites for many amphibians. Prey species such as fish and insects, upon which many other species feed, are also intimately linked to the riparian area. Water is the medium through which many aquatic and semi-aquatic vertebrates travel. Water influences vegetative diversity in the riparian area, and sometimes moderates microclimatic conditions, compared to the upland areas (Rochelle 1987).

Of the 414 species of amphibians, reptiles, birds, and mammals that occur in western Oregon and Washington, 359 (87%) use riparian areas or wetlands during some season(s) or part(s) of their life cycles. The majority of these species is comprised of birds (64%), followed by mammals (26%), and amphibian and reptiles (10%). Eleven species of birds, and nine species each of mammals, amphibians and reptiles can be considered riparian obligates (Anthony et al. 1987).

Unfortunately, little information exists as to the riparian obligates species specific habitat requirements, particularly the influence of habitat alterations in riparian zones of western Oregon. Just as fish species have different habitat requirements, so too do different wildlife species. From studies outside the PNW, it appears that reducing plant diversity in the riparian area will decrease wildlife diversity (Anthony et al. 1987).

One reason habitat threshold limits remain largely unknown is because "wildlife" is an ambiguous term. Historically, managers have been primarily concerned only with big-game species, but that emphasis has begun to shift. Maser (1987) contends there are six major questions within which to frame a riparian area/wildlife objective, the first of which is: what species is desired?

Numerous complications exist relative to buffer strip/wildlife interactions. Long, narrow strips tend to complicate the sampling design of wildlife inventories. If this obstacle is overcome, an additional problem arises in data interpretation: which habitat is being utilized, and why? Is it the aquatic portion, the ecotype between the water and the upland, or the upland that a given species has selected (Anthony et al. 1987)?

Different silvicultural modifications of the riparian zone, (i.e., a buffer strip), affect wildlife species differently. The challenge is how to manage these areas until research can help to guide the way. Certainly, buffer strip studies are needed relative to species of interest in western Oregon forests.

Recreation

The importance of recreation on National Forest land has increased tremendously over the last decade, and is largely responsible for much of the current legislation relative to riparian management. Buffer strips on land dedicated to forest management are not usually sought for recreational activities. Because they are often on higher headwater streams, the range of recreational opportunities is limited. Recreational drives, hiking, berry and mushroom picking, fishing, and hunting are usually what draws the public within range of a buffer strip. On limited sites, rafting, boating, or canoeing may also offer people the opportunity to see a buffer. A buffer strip may then enhance the recreational experience by partially or completely obscuring a cutting unit, reducing noise--either from a harvesting area or noise on the river itself, or may enhance wildlife viewing opportunities for hunters, hikers, or river users.

Loucks (1957) concluded that clearcuts were effectively concealed by lakeshore buffers, but that where blowdown occurs, it may be just as offensive as the cutting unit. There has been no research on the degree to which buffer strips influence recreation.

Summary-literature review

This literature review on riparian buffer strips clearly indicates the need for long-term research related to their dynamics.

OBJECTIVE STATEMENT

Replicated buffer strip studies are almost nonexistent. In 1990, the buffers inventoried by Steinblums (1978) ranged from 15 to 29 years old. The current study builds on his data set and uses it as a basis for comparison. Numerous ecological processes could be investigated with the aide of the existing database. Two items of particular interest were chosen for this study.

Density and standing basal area of previously sampled buffer strips were compared and analyzed for changes by species and contribution to basal area by diameter class since Steinblums' (1978) study. Ingrowth to the buffer is of major interest, as is mortality (blowdown), in the aggregate and by diameter class. These dynamics are reflected by this analysis. Based on Steinblums' (1978) work, it was anticipated that the buffer strips would be found with varying conditions of survival. An interest in the interaction of site and topographic variables coupled with severe winds over a relatively long timespan prompted the current study.

Conifer regeneration in the western Oregon Cascades is an important component of buffer strip dynamics, influencing the potential for future coniferous recruitment from the streamside area. Investigations in the Coast Range indicated buffer strips had the potential to experience a substantial decline in their coniferous component. Cascade buffers had thus far not been inventoried for conifer regeneration. Baseline data on established conifer regeneration was collected and analyzed.

SITE DESCRIPTION

All buffer strips inventoried in the present study are located in the Willamette National Forest, Oregon. Ranger Districts included were Detroit, Sweet Home, Blue River, McKenzie Bridge, Lowell, and Oakridge at sites identified in Steinblums' original study.

Geologic types in the study area are comprised mainly of Oligocene and Miocene volcanic and pyroclastic formations, derived mostly from the Little Butte Volcanic Series and the Sardine Formation. Soils from the Little Butte Series tend to weather rapidly, forming deep, fine-textured soils prone to instability. The Sardine Formation doesn't weather as quickly and often produces coarse-textured, well drained soils (Hemstrom et al. 1987).

Western hemlock (*Tsuga heterophylla*) plant associations are most prevalent on the buffers, based on field reconnaissance at each site. Two buffers were exceptions to the western hemlock types, and were characterized by Pacific silver-fir (*Abies amabilis*) types. These plant associations reflect elevations ranging from roughly 1500 to 4000 feet. Temperatures drop below freezing in the winter; summers can be hot and dry, with daily maximum temperatures between 90° and 100° F. Annual precipitation on the Forest ranges from 50 inches on the southern portion up to 130 inches in the northern portion of the Forest and upper elevations (Hemstrom et al. 1987). Very little is known about the frequency and intensity of damaging wind in the region. Return interval estimates of the 1990 storms ranged from 30- to 100-year events (Dave Halemier (USFS-Detroit Ranger Station) and Arthur McKee (Oregon State University-Forest Science Dept.) personal communication 1990).

BUFFER STRIP SURVIVAL

Steinblums (1978) defined survival as the percentage of original stand volume remaining over time (VOLREM). He found it to be significantly correlated with several site and stand characteristics. The equation developed for the Willamette National Forest and the statistically correlated variables are listed below. Percent variation contributed by each parameter is listed in parenthesis.

VOLREM = 81.1 - 0.013 * (DISTWIND) - 0.0030 * (DISTRIDG) + 17.5 * (ORIENT) + 0.013 * (ELEVRIDG) - 0.03 * (WETVOL)

DISTWIND = slope distance (ft) from the upper edge of the buffer strip to the cutting line in the direction of damaging winds. (44%)

DISTRIDG = horizontal distance (ft) to the nearest major ridge in the direction of the damaging winds. (17%)

ORIENT = direction of streamflow. NW or SW equals 1; NE or SE streamflow equals 2. (14%)

ELEVRIDG = the change in elevation (ft) from the mid-point of the buffer strip to the top of the nearest major ridge in the direction of the damaging winds. (17%)

WETVOL = an interaction term (UNSPECIE * ORIGVOL). (7%)

UNSPECIE = a code for understory plant species moisture class, ranging from 1 for dry sites, to 4 for very wet sites.

ORIGVOL = original, after timber harvest, gross timber volume per acre (MBF).

Steinblums, beginning in 1975, sampled forty buffer strips of various ages ranging from 1 to 15 years. His field work was completed during the summer of 1976. Final conifer overstory data in his thesis (1978) reflected the condition of the buffers in 1977 (Steinblums, personal communication 1993). Using the 1977 data, regression equations were developed to predict buffer strip survival. The intent of the current study, using half of the original 40 sites, was to appraise survival on this subset of sites, which by 1990, ranged in age from 15 to 29 years old.

FIELD METHODS

Relocation and setup for measurement

Twenty of the original 40 sites were selected for reinventory during the summers of 1990 and 1991. All sites for the current study are on the Willamette National Forest; they were selected based on their administrative and geographic similarities. Of these sites, three were no longer usable because of extensive blowdown and salvage logging. Details of field notes on one site from the 1978 study could not be matched closely enough for comparison; this site was excluded from the current study. Thus, the final data set for this study is comprised of 16 sites (Figure 1). Schematics of individual buffer strip layout relative to the stream are illustrated in Appendix B. Note that five of the reinventoried sites (Canal, Hardy 2, Owl, Tidbits, and Winberry) had buffer strips on both sides of the channel for some portion of the inventoried reach.

For the 1990 study, road mileage logs to the harvest units of interest were recorded to assist future relocation attempts. Once on site, efforts were made to locate the original buffer sample areas using topographic maps, sale maps, and aerial photos. Steinblums identified stations with flagging and a three inch square aluminum tag every 100 ft (stream distance). Stations were reestablished using original monumentation if it could be found. Often

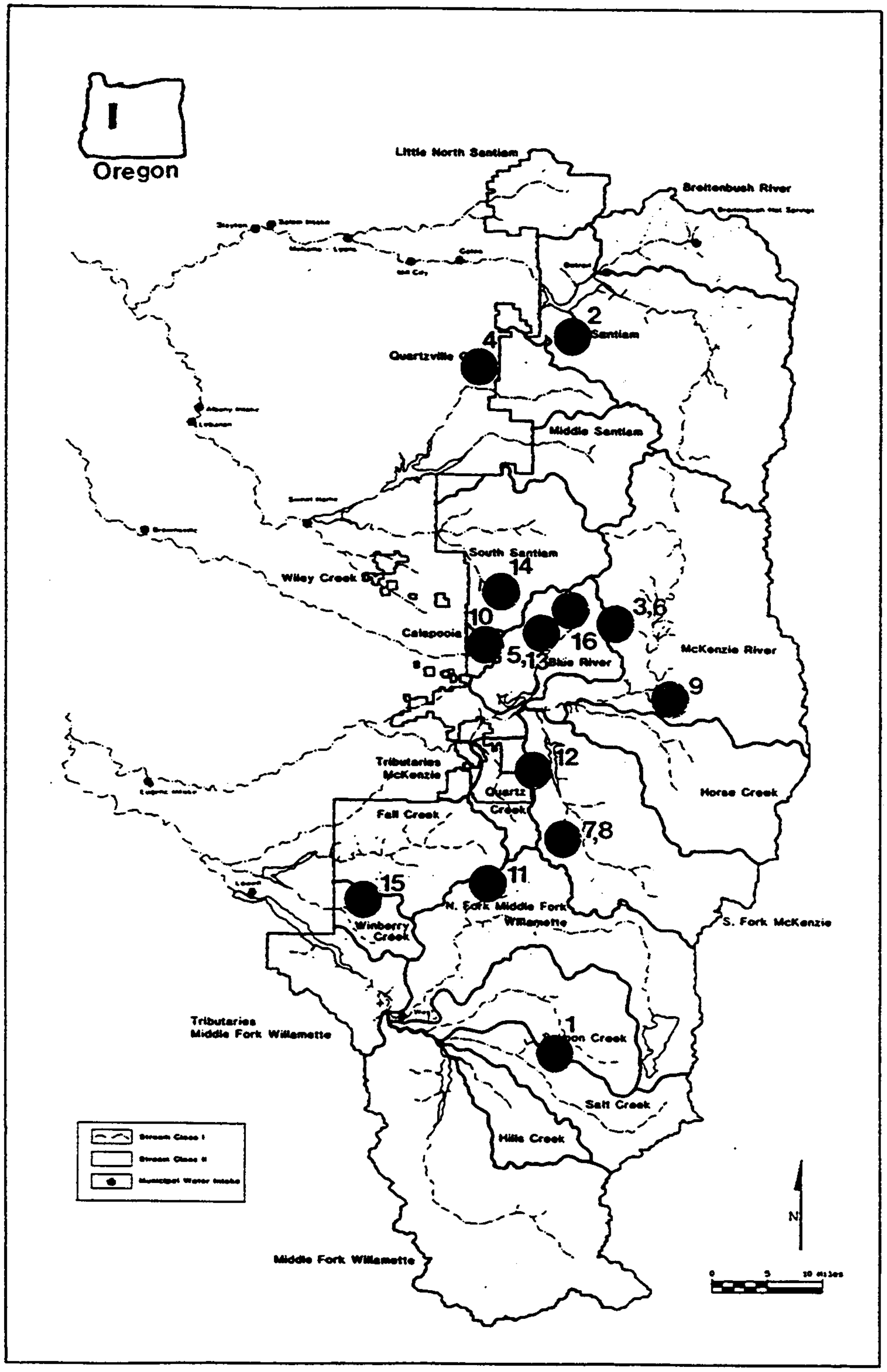


Figure 1. Location map of resampled Willamette National Forest buffer strips. Numerals (#) indicate approximate location of individual sites referred to in thesis text.

only one or some, but not all of the original tags could be located. On these sites, stations were established by measuring 100 foot stream distances and approximating the original locations. On those few sites where none of the tags could be located, stations were reestablished using Steinblums' field notes and photographs. All stations in the current study were numbered with yellow tree-marking paint and with new tags. Photographs were taken at most stations for future reference and for use in documenting stream channel and riparian vegetation changes.

At each station, transects perpendicular to the stream were installed to measure buffer strip width (Figure 2). Beginning at the edge of the bankfull channel, horizontal distances were recorded to the outer edge of the buffer. Changes in buffer strip width may have resulted from difficulty in locating boundaries of the original sample, blowdown of the original buffer, and from salvage logging. These temporary transects also served as a center line for regeneration plots.

Field measurements

Once the buffer strip sample area was partitioned by station, all standing conifers over eight inches DBH were recorded by species and diameter for comparison with Steinblums' work. Overstory species encountered were western hemlock, western redcedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziessii*), Pacific silver fir, Pacific

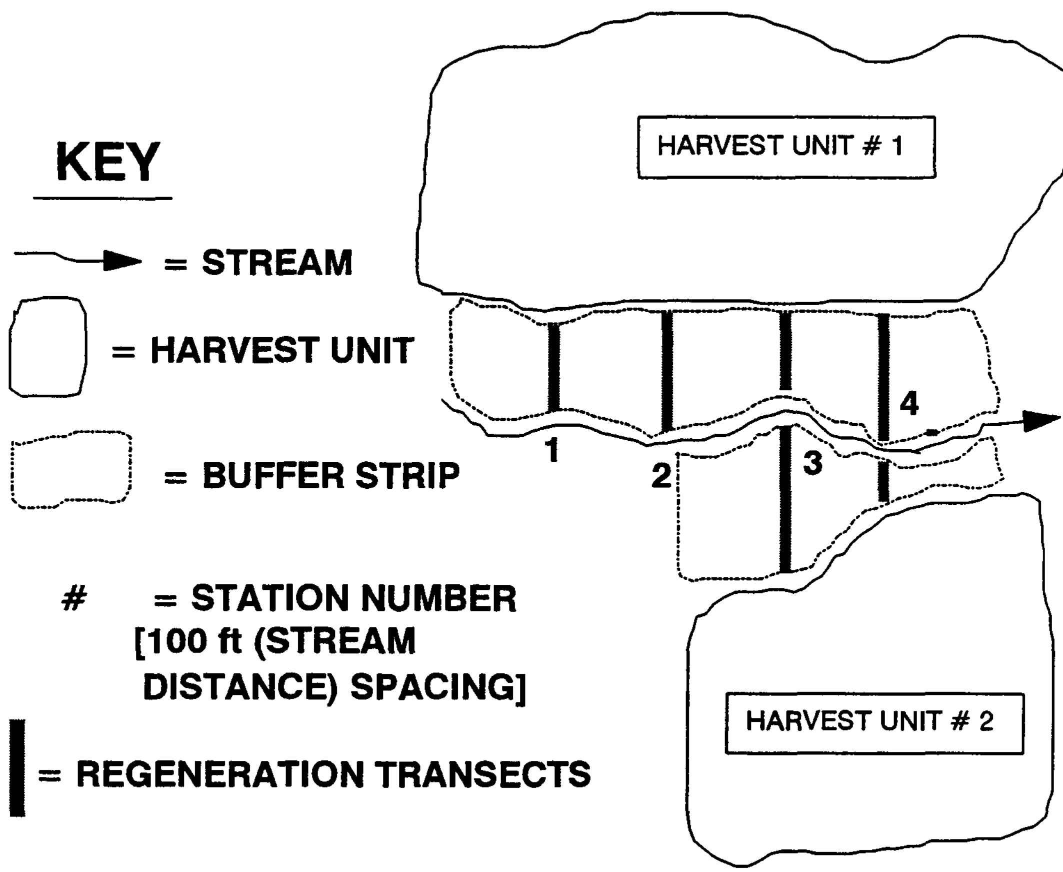


Figure 2. Planimetric schematic of buffer strip sampling layout.

yew (*Taxus brevifolia*), and Bigleaf Maple (*Acer macrophyllum*). Tree vigor (dead, dying, snag, broken snag, or broken top) was recorded for those trees where it was appropriate.

Several channel characteristics were recorded at each station. Active and bankfull widths, attributes such as substrate, average and largest particle sizes, woody debris loading, bank undercutting, and condition of riparian vegetation were estimated. Ocular estimates (by percent) of LWD volumes in each of four functional classes (Robison and Beschta, 1990b) were made at each station to characterize woody debris function. These estimates were further split into "new" contributions from the 1990 storms, and "old" wood, using extent of decay as the distinguishing criterion. Notes were recorded between stations documenting how LWD was influencing geomorphic changes to the stream. Cross sectional profiles were run from the edge of the bankfull channel width to the outer edge of the buffer at each station.

Established conifer regeneration was tallied by species and height class. It was sampled at each station, using plots six feet wide by ten feet long (horizontal distance), beginning at the bankfull channel edge and extending for the width of the buffer. Conifers sampled were those less than eight inches DBH and three feet or greater in height.

SOURCES OF ERROR BETWEEN STUDIES

Two potential sources of error should be acknowledged from the outset. Because so many sites had been sampled in the original study, exact sample boundaries were not permanently delineated on the ground. This created difficulties in trying to relocate the boundaries in 1990. Differences in sample areas of up to 0.40 acres in size made some of the areal comparisons questionable. To compensate for this discrepancy, average sample acreages (of both studies) were used for areal calculations, and a 20% margin of error was used to assess changes in the buffers.

The second problem was that a Biltmore stick was used for the original diameter measurements. Though the Biltmore stick was adequate for the purpose intended, it may have lead to some discrepancies when comparing original measurements with those derived from the current study.

The current study was designed in part, to verify or improve Steinblums' (1978) predictive equations. Lack of tagged trees and clearly marked sample boundary locations made this particular objective impossible. Because these errors were inherent in the replication of Steinblums' study, statistical assumptions are violated and statistical comparisons are inappropriate. Replication of the original study essentially became sixteen observational studies.

DATA ANALYSIS

General discussion

Inventory data from both studies were compiled in a computer spreadsheet using Quattro Pro software. Overstory characteristics entered were creek name, station number, diameter and species of all conifers over eight inches DBH, and vigor class of tree.

Information about trees less than 10 inches DBH was incomplete for the earlier study. Therefore, although data were collected on all trees over eight inches DBH for the 1990 study, only those conifers ≥10 inches DBH were included and analyzed for comparison between studies.

Overstory density

Four diameter classes were developed to track dynamics of the buffers. Trees 10-14 inches DBH were investigated to track ingrowth. The next grouping was for trees 15-29 inches DBH (INTCLS 1). These trees reflect the lower end of the intermediate size diameter distribution. They were presumed to respond to canopy opening and stand dynamics differently than larger diameter trees. Trees 30-44 inches DBH (INTCLS 2) were also considered to be an intermediate size class, but field observations suggested their dynamics may be different from the previous class. The density and function of trees ≥45 inches DBH (LGCLS) led to establishment of the final class.

Because their density was relatively low, but their contribution to basal area was high, they were analyzed as a separate group.

Using a 20% margin of error, sites were assessed for shifts above or below 1977 levels. Twenty percent was chosen as a "reasonable" error estimate, given the difficulties involved in relocating exact sample boundaries. Trees per acre were calculated by dividing number of trees sampled by the sample area. Density was analyzed by buffer strip and diameter class for all conifers and for individual species at both sample dates in time.

Overstory basal area

Standing basal area comparisons were assumed to serve as a surrogate for the original dependant variable, "volume remaining" (VOLREM). The measurements taken in the field lend themselves directly to an assessment of standing basal area changes since Steinblums' study and were analyzed similarly to the number of trees per acre. Standing basal area was calculated by site, species, and diameter class in 1977 and 1990. Comparisons and trend analyses were performed using the same margin of error (20%) as for overstory density. Of particular interest relative to basal area information was the ingrowth of smaller diameter trees and the loss of large diameter conifers. Many state forest practice regulations are written in terms of basal area left on site. Conifer density and basal area on these sites may be useful for comparison with current or future state guidelines.

Regeneration

Regeneration survey information entered in the database includes stream name, station, and number of established conifers by species at 10-foot horizontal distances over the width of the buffer. From this data, the average number of established conifers per acre, by species was calculated for each site. Attempts were made to correlate conifer density with variables tallied by Steinblums (1978).

RESULTS AND DISCUSSION

Overstory composition-general density changes

To assess overstory change, the aggregate number of total overstory conifers per acre between studies was compared (Table 1). This presentation provides an initial assessment of buffer strip dynamics. However, it may be more useful to look at relative trends than to focus on absolute numbers.

Using a 20% margin of error, six of the sites (38%), have shown an overall increase in the number of trees per acre (TPA). Based on the field visits, most buffer strips appeared to have a substantial increase in the number of trees in the smaller diameter classes. Three sites show a decrease in the number of conifers per acre by more than 20%. One of these sites (Hardy 1) had obviously had additional harvesting of standing conifers since the time of the original study. The Owl Creek buffer experienced severe blowdown shortly after it was installed in 1975 and the Cadenza buffer experienced blowdown in 1990. In terms of conifer density only, the remaining seven buffers remained relatively stable.

Though the preceding summary indicates little about contribution by species or diameter, it does demonstrate that most buffers (81%) continue to have at least as many conifers per acre today as they did in 1977.

Table 1. Comparison of number of trees/acre (TPA) in 1977 and 1990 (conifers ≥10 inches DBH), and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 TPA (#/ac)	1990 TPA (#/ac)	REM (%)
1. Black	89	88	99
2. Blowout	59	88	149
3. Cadenza	47	36	77
4. Canal	39	35	90
5. Cook	68	84	124
6. Deer	74	80	108
7. Hardy 1	69	52	75
8. Hardy 2	43	62	144
9. Lost	42	44	105
10. Owl	56	28	50
11. Perdue	69	70	101
12. Rider	37	60	162
13. Tidbits	28	33	118
14. Two Girls	26	36	138
15. Winberry	36	60	167
16. Wolf	83	86	104
Average	54	59	113

Overstory composition-general basal area changes

Linking basal area per acre (BA/AC) with the previous information, it is possible to begin piecing together relationships between density and basal area (Table 2). None of the sites have less than 100 ft^2 of basal area per acre, which is ten times the current Forest Practices rule in Oregon. However, Oregon Department of Forestry regulations (1991) state that basal area of any tree over 20 inches DBH will only be calculated as a 20-inch tree. The most recent Willamette National Forest Riparian Management Guide (1990) does not incorporate a basal area requirement, largely because riparian management zone widths have been expanded and most harvesting has been curtailed in these areas.

While the number of trees per acre has been stable or increased above the 20% threshold on thirteen sites (81%), BA/AC has dropped below this level on seven sites (44%) (Table 3 and Figure 3). This indicates substantial ingrowth to these buffers. Basal area has decreased significantly while trees per acre remains relatively stable, probably indicating that the larger trees are more susceptible to blowdown in these stands. On the remaining sites, density and basal area have remained relatively stable, without drastic fluctuation in either parameter.

The fact that some sites indicate greater than 100% of original basal area may be attributable to a combination of

Table 2. Comparison of basal area/acre (BA/AC) in 1977 and 1990 (conifers ≥10 inches DBH), and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 BA/AC (ft^2/ac)	1990 BA/AC (ft^2/ac)	REM (%)
1. Black	355	346	97
2. Blowout	375	388	104
3. Cadenza	184	139	76
4. Canal	282	151	54
5. Cook	248	277	112
6. Deer	373	363	97
7. Hardy 1	353	279	79
8. Hardy 2	342	360	105
9. Lost	370	426	115
10. Owl	326	115	35
11. Perdue	522	416	80
12. Rider	185	241	130
13. Tidbits	259	205	79
14. Two Girls	206	171	83
15. Winberry	227	178	78
16. Wolf	162	147	91
Average	298	263	88

Table 3. Percentage of 1977 trees/acre (TPA) and basal area/acre (BA/AC) (conifers ≥10 inches DBH) remaining (REM) in resampled Willamette National Forest buffer strips in 1990.

SITE	1977 TPA (#/ac) REM (%)	1978 BA/AC (ft^2/ac) REM (%)
1. Black	99	97
2. Blowout	149	104
3. Cadenza	77	76
4. Canal	90	54
5. Cook	124	112
6. Deer	108	97
7. Hardy 1	75	79
8. Hardy 2	144	105
9. Lost	105	115
10. Owl	50	35
11. Perdue	101	80
12. Rider	162	130
13. Tidbits	118	79
14. Two Girls	138	83
15. Winberry	164	78
16. Wolf	104	91

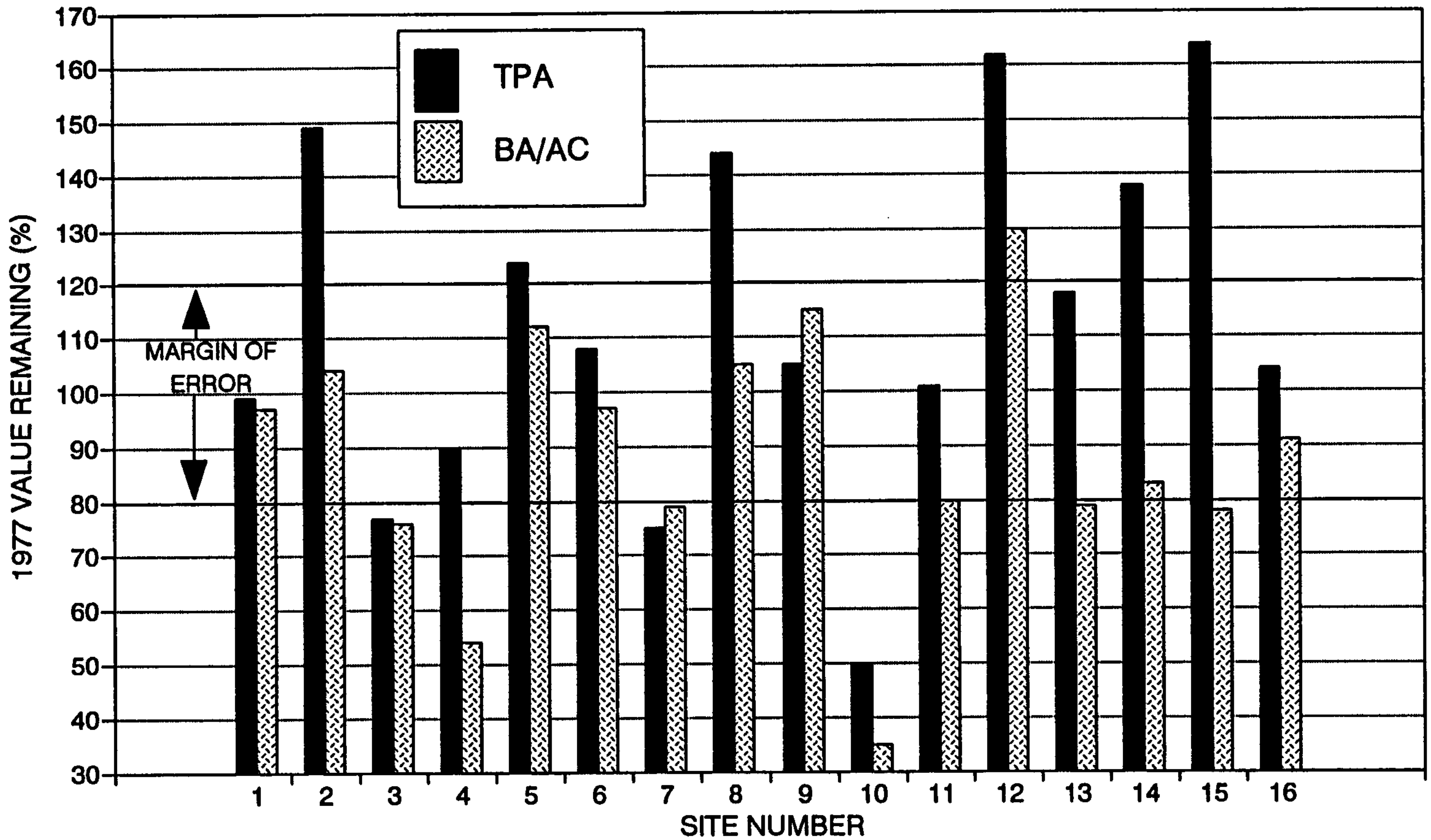


Figure 3. Percentage of 1977 trees per acre (TPA) and basal area per acre (BA/AC) (conifers ≥10 inches DBH) remaining in 1990 in resampled Willamette National Forest buffer strips.

factors. First, it is certainly possible that ingrowth to the buffer has occurred; this could explain small increases in basal area. Second, often it was difficult to ascertain the exact edge of the buffer. One has to bear in mind these buffers had been established 15 to 29 years prior to the current study. Due to difficulties in boundary delineation, it is possible that more (or less) trees were sampled in 1990 than in 1977. If those trees were of large diameter, they could contribute greatly to basal area on the site.

Only site 10 shows a drastic reduction in both density and basal area; the Owl Creek buffer experienced severe blowdown the first winter after being installed. Three other unsampled buffers suffered catastrophic blowdown as well; therefore there is some inherent bias in this sample. Only the buffers that withstood the twelve year interim could be resampled.

Density-trees ≥10 inches DBH

Density (trees per acre-TPA) of combined conifers (and the contribution by species) ≥10 inches DBH on these 16 sites in 1976 and 1990 is listed in Table 4 (plotted in Figure 4). Although diameters have been split into four classes, Figure 4 (a-d) serves as a reference when assessing the contribution of the diameter classes to the total values.

Table 4. Density (TPA) of conifers ≥10 inches DBH in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC TPA (#/ac) [a]	1990 CC TPA (#/ac)	REM (%) [e]	1977 WH TPA (#/ac) [b]	1990 WH TPA (#/ac)	REM (%)	1977 WC TPA (#/ac) [c]	1990 WC TPA (#/ac)	REM (%)	1977 DF TPA (#/ac) [d]	1990 DF TPA (#/ac)	REM (%)
1. Black	89	88	99	38	35	92	25	24	96	26	29	112
2. Blowout	59	88	149	34	58	171	19	24	126	6	6	100
3. Cadenza	47	36	77	37	26	70	0	0	NA [f]	6	8	133
4. Canal	39	35	90	26	22	85	1	1	100	12	12	100
5. Cook	68	84	124	28	32	114	17	28	165	23	24	104
6. Deer	74	80	108	42	43	102	10	14	140	22	23	105
7. Hardy 1	69	52	75	26	19	73	20	16	80	23	17	74
8. Hardy 2	43	62	144	22	21	95	0	0	NA	11	16	145
9. Lost	42	44	105	9	7	78	10	14	140	23	23	100
10. Owl	56	28	50	18	10	56	0	0	NA	38	18	47
11. Perdue	69	70	101	28	33	118	17	15	88	24	22	92
12. Rider	37	60	162	17	31	182	11	20	182	9	9	100
13. Tidbits	28	33	118	16	23	144	0	0	NA	12	10	83
14. Two Girls	26	36	138	20	30	150	0	3	NA	5	3	60
15. Winberry	36	60	167	26	49	188	2	2	100	8	9	113
16. Wolf	83	86	104	71	72	101	11	12	109	1	2	200
Average	54	59		29	32		9	11		16	14	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

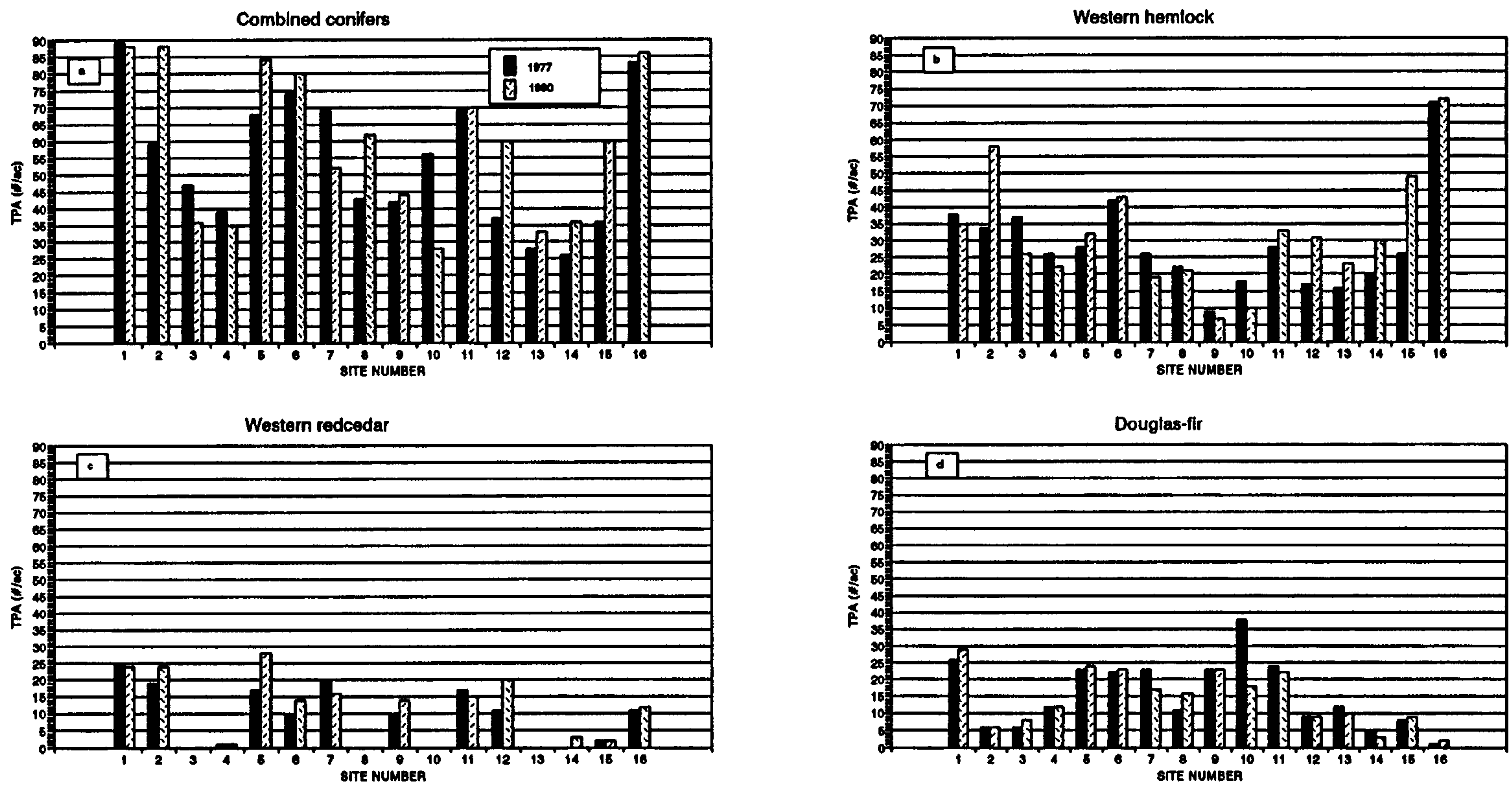


Figure 4. Density (TPA) of conifers ≥10 inches DBH in 1977 and 1990 in resampled Willamette National Forest buffer strips.

Density-trees 10-14 inches DBH

To assess buffer strip ingrowth, changes in trees 10-14 inches DBH were investigated. The relative amount of ingrowth can be determined by comparing the densities in 1977 and 1990 (Table 5 and Figure 5). Eleven sites indicate an increase of at least 20%. On two sites (3-Cadenza, 8-Hardy 2) totals for combined conifers in Figure 5 do not reflect the sum of the other graphs because there was a Pacific silver fir component which has not been illustrated graphically.

Of the 11 sites showing an increase in this diameter class, 10 (91%) increased by the threshold amount or greater as a result of western hemlock ingrowth (Figure 5(a and b)). This is not surprising as these sites are all late successional stands and hemlock would be expected to comprise a significant component of the smaller diameter classes. Site 7 (Hardy 1) actually shows less hemlock in 1990 than in 1977. This buffer had another harvest entry after the initial study and prior to the 1990 study, though there was no evidence of any trees in the 10-14 inch diameter class having been removed.

Figure 5(c) suggests interesting dynamics for western redcedar. The cedar component in this diameter class is not as prevalent as hemlock. Sites 7 and 16 (Hardy 1 and Wolf) show a decrease in the western redcedar component in this diameter class beyond the threshold 20%. A few sites

Table 5. Density (TPA) of conifers 10-14 inches DBH in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC TPA (#/ac) [a]	1990 CC TPA (#/ac)	REM (%) [e]	1977 WH TPA (#/ac) [b]	1990 WH TPA (#/ac)	REM (%)	1977 WC TPA (#/ac) [c]	1990 WC TPA (#/ac)	REM (%)	1977 DF TPA (#/ac) [d]	1990 DF TPA (#/ac)	REM (%)
1. Black	10	15	150	5	5	100	5	7	140	0	3	NA [f]
2. Blowout	8	22	275	7	17	243	1	4	400	0	1	NA
3. Cadenza	6	6	100	4	4	100	0	0	NA	0	0	NA
4. Canal	4	8	114	4	7	175	0	0	NA	0	1	NA
5. Cook	24	34	142	17	22	129	5	10	200	2	2	100
6. Deer	14	17	121	7	10	143	7	6	86	0	1	NA
7. Hardy 1	11	5	45	6	3	50	5	2	40	0	0	NA
8. Hardy 2	8	23	288	5	8	160	0	0	NA	0	0	NA
9. Lost	2	8	400	1	5	500	1	3	300	0	0	NA
10. Owl	8	5	63	8	4	50	0	0	NA	0	1	NA
11. Perdue	4	8	200	4	8	200	0	0	NA	0	0	NA
12. Rider	2	18	900	2	13	650	0	5	NA	0	0	NA
13. Tidbits	3	6	200	3	6	200	0	0	NA	0	0	NA
14. Two Girls	2	11	550	2	9	450	0	2	NA	0	0	NA
15. Winberry	9	26	289	9	25	278	0	0	NA	0	1	NA
16. Wolf	29	32	110	25	29	116	4	3	75	0	0	NA
Average	9	15		7	11		2	3		0	1	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

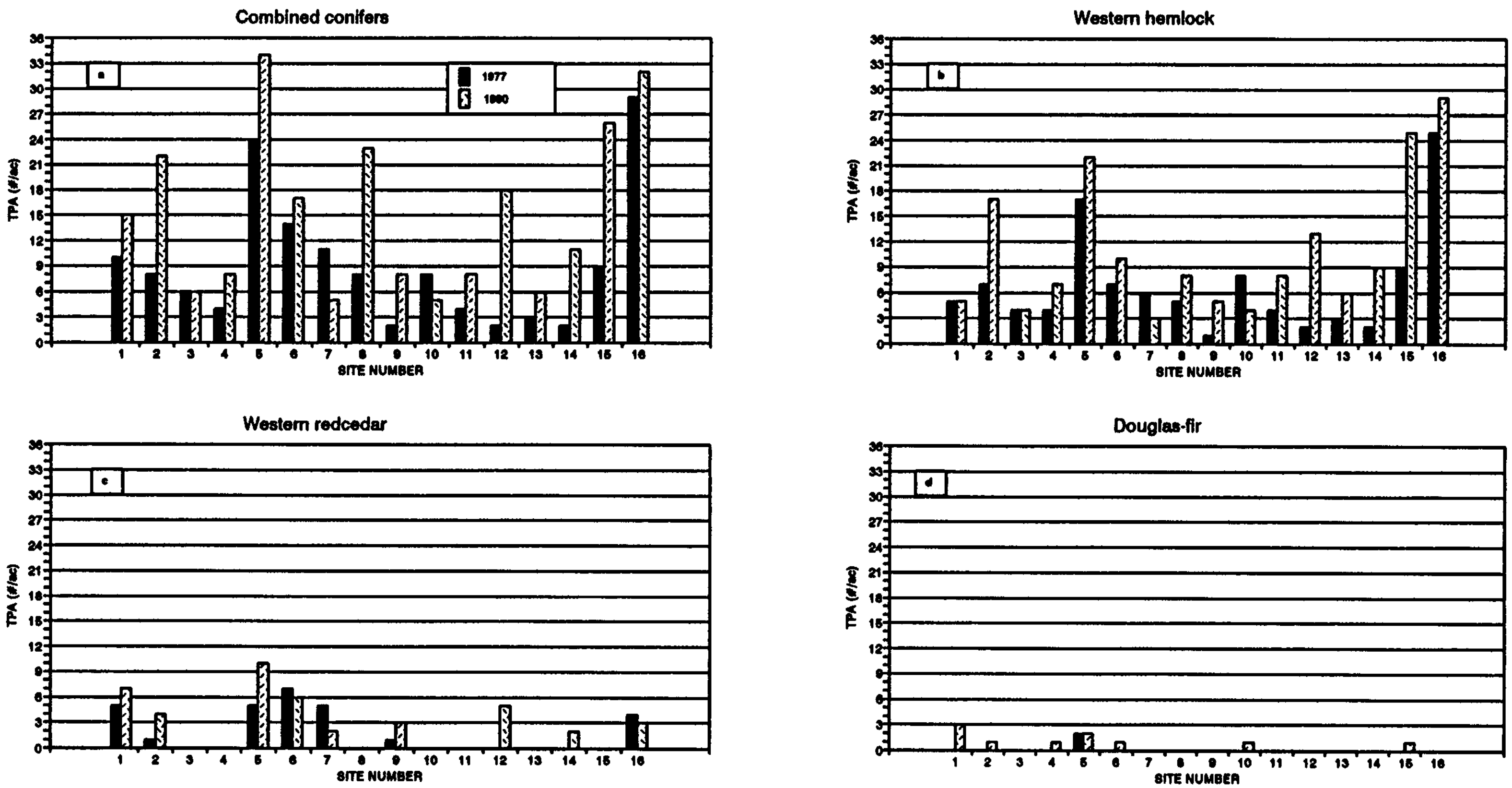


Figure 5. Density (TPA) of conifers 10-14 inches DBH in 1977 and 1990 in resampled Willamette National Forest buffer strips.

did have substantial decay which may have lead to mortality in this diameter class trees.

Thirty-six percent of those buffers showing an increase in the number of trees in the 10-14 inch diameter class had a cedar component. Of the seven sites that initially had cedar, four show an increase of at least 20%. In addition, sites 12 and 14 (Rider and Two Girls) now have a cedar component where they previously did not.

The last major species to be assessed is Douglas-fir. With the exception of site 5 (Cook), none of the sites had Douglas-fir in the 10-14 inch diameter class during the earlier study (Figure 5(d)). By 1990, seven sites had a Douglas-fir component. All of these buffers had partial entry during the time of harvest. This may have been sufficient impetus to release the smaller diameter trees, and the years since Steinblums' study has been long enough to give them a chance to grow into this diameter class.

Assuming the 10-14 inch DBH class can be used to track "development" of the riparian stand, these graphs indicate western hemlock is definitely the dominant component of these buffers in the western Oregon Cascades. The fact that there is substantial ingrowth suggests the buffers will have a supply of conifers into the next century, barring catastrophic events or periodic harvesting. That so much of this material is comprised of western hemlock signals this ingrowth is the result of natural stand regeneration; all of these trees were present during the earlier study. Some of it was measured earlier; the rest grew into measurable size. Disease was not usually a problem in the smaller diameter classes on most sites. Most of the trees in this class seemed relatively healthy and stable. Only two sites (7-Hardy 1 and 10-Owl) experienced substantial loss of smaller diameter trees.

Density-trees 15-29 inches DBH

With some understanding of what is happening in the lower end of the diameter classes, it is useful to examine the intermediate classes. Particularly on sites that were heavily stocked, or with wet soils, high initial volumes, little topographic protection, and had been opened considerably by partial removal, the potential for blowdown in the intermediate classes is much greater, based on Steinblums' (1978) work (Appendix A2). For purposes of this study, two intermediate classes have been developed: diameters 15-29 inches DBH (INTCLS 1), and 30-44 inches DBH (INTCLS 2).

Combined conifer densities in INTCLS I during 1977 ranged from 7 to 54 conifers per acre; in 1990 they ranged from 13 to 55 (Table 6 and Figure 6). This initial increase in the lower end of the range is thought to be mostly due to ingrowth from the previous size class during the thirteen years since Steinblums' inventory.

Percent change by species should be viewed with

Table 6. Density (TPA) of conifers 15-29 inches DBH (INTCLS 1) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC TPA (#/ac) [a]	1990 CC TPA (#/ac)	REM (%) [e]	1977 WH TPA (#/ac) [b]	1990 WH TPA (#/ac)	REM (%)	1977 WC TPA (#/ac) [c]	1990 WC TPA (#/ac)	REM (%)	1977 DF TPA (#/ac) [d]	1990 DF TPA (#/ac)	REM (%)
1. Black	54	55	102	22	25	114	15	13	87	17	17	100
2. Blowout	26	41	158	20	34	170	6	7	117	0	0	NA [f]
3. Cadenza	26	20	77	24	18	75	2	0	0	0	2	NA
4. Canal	19	17	89	17	14	82	1	1	100	1	2	200
5. Cook	26	35	135	10	10	100	9	16	178	7	9	129
6. Deer	23	30	130	17	22	129	3	5	167	3	3	100
7. Hardy 1	25	24	96	15	13	87	8	9	113	2	2	100
8. Hardy 2	13	16	123	9	7	78	0	0	NA	0	0	NA
9. Lost	16	10	63	4	1	25	7	7	100	5	2	40
10. Owl	17	15	88	10	6	60	0	0	NA	7	9	129
11. Perdue	26	26	100	16	17	106	9	9	100	1	0	0
12. Rider	17	20	118	9	10	111	8	10	125	0	0	NA
13. Tidbits	8	13	163	8	13	163	0	0	NA	0	0	NA
14. Two Girls	7	13	186	7	12	171	0	1	NA	0	0	NA
15. Winberry	13	22	169	12	21	175	1	0	0	0	1	NA
16. Wolf	51	52	102	45	42	93	6	8	133	0	2	NA
Average	23	26		15	17		5	5		3	3	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

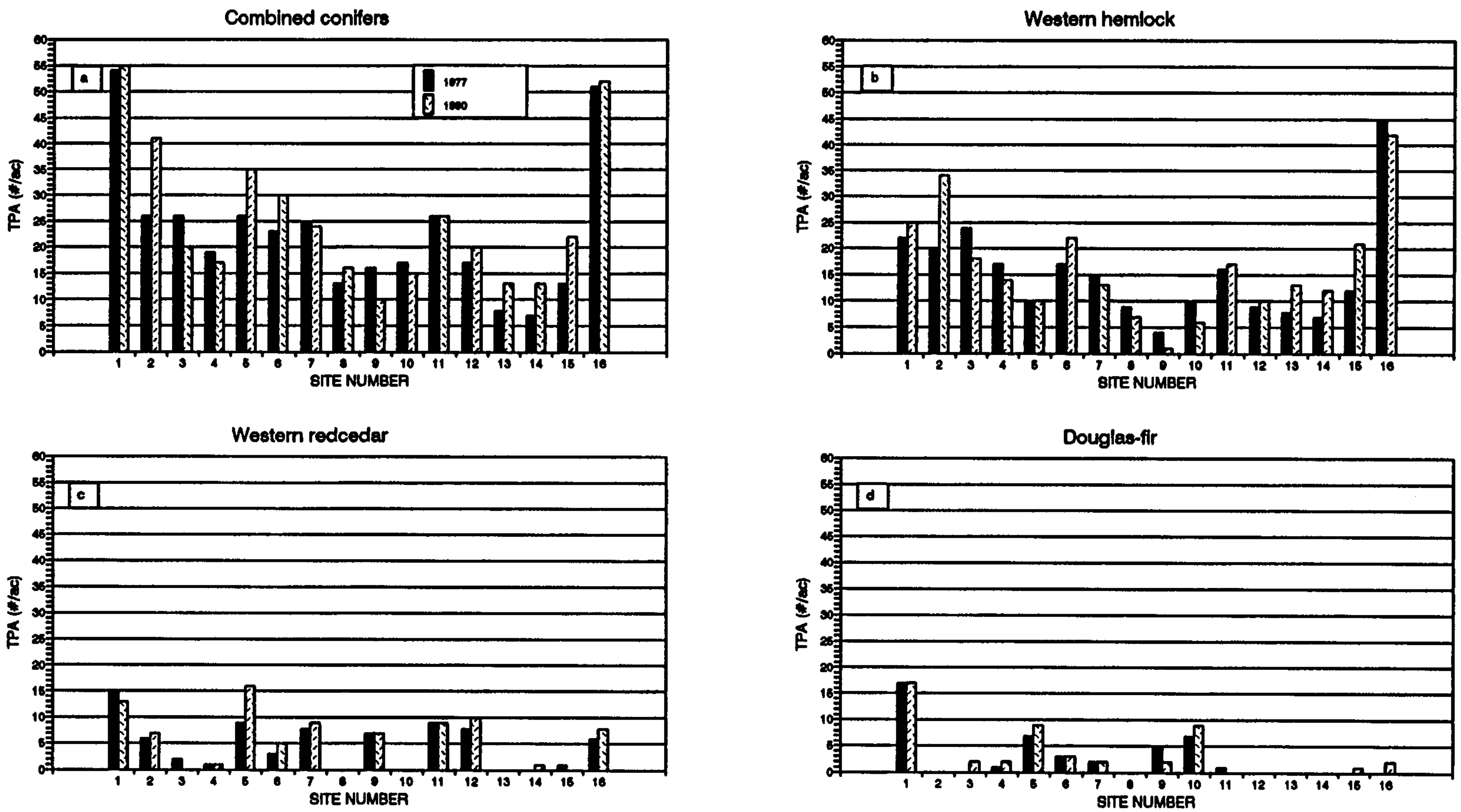


Figure 6. Density (TPA) of conifers 15-29 inches DBH (INTCLS 1) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

caution because of decreasing sample sizes. Though 20% will be used as a basis for change for all discussion of dynamics, the shifting (and small) sample sizes limits the importance of any relative change.

Two sites (3-Cadenza, 9-Lost) have decreased below the 20% threshold for combined conifers (Figure 6(a)). The Cadenza buffer had considerable blowdown as a result of the 1990 storm, particularly among hemlock (Figure 6(b)). The Lost Creek buffer had some loss along the boundary, although little blowdown occurred within the buffer. Changes in this buffer are reflected in the decrease of western hemlock and Douglas-fir (Figures 6(b) and (d)).

For INTCLS 1, seven sites (2-Blowout, 5-Cook, 6-Deer, 8-Hardy 2, 13-Tidbits, 14-Two Girls, and 15-Winberry) show an increase in number of conifers per acre ≥20%. With the exception of sites 5 and 8, increases to this diameter class came largely from western hemlock (Figure 6(a)), most with gains of more than 60% over 1977 values. Site 5 (Cook) showed increases in the number of western redcedar and Douglas-fir, both more than 20% of 1977 levels in INTCLS 1. This ingrowth may be a response to decreased competition resulting from the partial removal of riparian conifers during harvest of adjacent upslopes. Interestingly, there was no change in the number of western hemlock per acre in the Cook Creek buffer. Site 8 (Hardy 2) is unique among the sites sampled. It is an upper elevation site with a heavy Pacific silver fir component which was included in total conifer assessment, but was not utilized in the species breakdown (This explains why Figure 6(a) shows such an increase in the number of trees per acre on this site, but the increase isn't reflected in Figures 6(b - d)). The decrease in western hemlock has apparently been compensated for by the increase in Pacific silver fir.

Figure 6(c) shows the western redcedar component of this intermediate diameter class. Of the sites showing an overall density increase in INTCLS 1, sites 5 and 6 (Cook and Deer) show a relative increase in western redcedar ≥60% greater than background levels. Presumably, this increase is attributed mostly to ingrowth from the previous class, but some additional trees may also have been measured.

Of those sites with an overall 20% increase, only site 5 (Cook) showed an increase greater than the threshold value in the number of Douglas-fir per acre (Figure 6(d)). This species plays a minor role the 15-29 inch DBH class.

Seven sites (1-Black, 4-Canal, 7-Hardy 1, 10-Owl, 11-Perdue, 12-Rider, 16-Wolf) showed no difference in overall number of conifers per acre in INTCLS 1. This cannot be interpreted as absolutely no change, but rather that the decrease that occurred in one or more species has been offset by increases in the other species. It has already been indicated that the Black Creek buffer was stable; this is supported by the fact that there is no significant difference in INTCLS 1 for any given species. Figure 6(d) shows the Canal Creek (Site 3) buffer gaining 100% over background Douglas-fir levels; however this only amounts to one tree per acre. Hardy 1, like Black Creek, shows no change by species in excess of 20% in INTCLS 1. However this is complicated by the fact that there was some removal (four trees per acre) from the buffer. Based on the field reconnaissance in 1990, a single tree per acre each of western hemlock and western redcedar was removed as well as two Douglas-fir per acre as a result of harvesting within the riparian area since the time of Steinblums' study. Final numbers do not bear out this change; differences in sample areas (from 1.90 acres in 1977 to 1.60 acres in 1990) may be part of the problem. The Owl Creek buffer experienced a 40% loss of western hemlock (from ten to six trees per acre), but this was offset by nearly a 30% gain (from seven to nine trees per acre) in Douglas-fir, for a net change of minus 12%. These numbers illustrate the problems of reporting percentages; the smaller the sample size, the less it takes to make a larger relative difference. The Perdue Creek buffer gained a single western hemlock per acre, while losing one Douglas-fir per acre, for a net zero change. The Rider Creek buffer actually shows a positive change of 18% overall, stemming from an increase of one western hemlock per acre and two western redcedar per acre.

The previous discussion shows that by species these sites have fluctuated somewhat over background levels, but when taken together, have not changed significantly. Gross changes, those that would be apparent given the methodology, are not evident.

The majority of contributing trees in INTCLS 1 are western hemlock. Hemlock densities in 1977 ranged from 4 to 45 trees per acre; in 1990 they ranged from 1 to 42 trees per acre. The one tree per acre was on the Owl Creek buffer. Excluding this site from the study, the minimum number of hemlock on any site increased to seven trees per acre. The fact that several sites indicate more hemlock in this class than were previously measured suggests ingrowth from the previous class (10-14) since the original study. Although some loss of hemlock has occurred from a few buffers, it has not been substantial. Western redcedar was present on 12 sites during both studies, though not always the same sites. It contributes to the stand in generally smaller numbers than western hemlock. In 1977, Douglas-fir was present on eight sites. During the 1990 inventory, Douglas-fir was documented on ten sites. This species seems relatively persistent, with perhaps a little ingrowth, though not very prevalent on these sites.

In general, losses do not seem to be coming from this intermediate diameter class. The majority of sites are stable or have actually gained trees per acre. These late successional western Cascade buffers seem to be continuing their progression toward a western hemlock plant association. From the standpoint of future LWD, it seems that a steady supply exits on the majority of these sites.

Density-trees 30-44 inches DBH

Density dynamics of conifers 30-44 inches DBH (INTCLS 2) are quite different from the previous classes (Table 7 and Figure 7). By grouping trees 30-44 inches DBH together, it is possible to ascertain how the larger trees in the buffers have responded to climatic events and landscape changes over the years since Steinblums' (1978) study.

Combined conifer densities ranged from 1 to 33 trees per acre in 1977 and from 1 to 28 trees per acre in 1990 (Figure 7). The smallest of these values is substantially less than those of the previously discussed diameter class (INTCLS 2: 1 tree per acre vs INTCLS 1: 13 trees per acre), indicating considerably fewer trees overall in this diameter class. Although the maximum number of trees in INTCLS 2 has decreased over time, suggesting that some blowdown has occurred, the difference between maximum densities represents a decrease of only 15%.

Investigating combined conifers in INTCLS 2, nine sites (1-Black, 3-Cadenza, 4-Canal, 5-Cook, 7-Hardy 1, 8-Hardy 2, 10-Owl, 13-Tidbits, and 14-Two Girls) have decreased by ≥20% over their 1977 densities. Some

Table 7. Density (TPA) of conifers 30-44 inches DBH (INTCLS 2) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC TPA (#/ac) [a]	1990 CC TPA (#/ac)	REM (%) [e]	1977 WH TPA (#/ac) [b]	1990 WH TPA (#/ac)	REM (%)	1977 WC TPA (#/ac) [c]	1990 WC TPA (#/ac)	REM (%)	1977 DF TPA (#/ac) [d]	1990 DF TPA (#/ac)	REM (%)
1. Black	21	13	62	11	5	45	4	2	50	6	6	100
2. Blowout	15	18	120	6	7	117	7	9	129	2	2	100
3. Cadenza	15	10	67	9	4	44	0	0	NA [f]	6	6	100
4. Canal	10	6	60	4	1	25	0	0	NA	6	5	83
5. Cook	15	12	80	1	0	0	3	2	67	11	10	91
6. Deer	33	28	85	17	11	65	2	3	150	14	14	100
7. Hardy 1	25	17	68	5	3	60	6	4	67	14	10	71
8. Hardy 2	12	9	75	6	4	67	0	0	NA	3	4	133
9. Lost	12	10	83	3	1	33	2	4	200	7	5	71
10. Owl	25	7	28	0	0	NA	0	0	NA	25	7	28
11. Perdue	22	21	95	8	8	100	7	5	71	7	8	114
12. Rider	14	17	121	6	8	133	3	5	167	5	4	80
13. Tidbits	7	5	71	5	3	60	0	0	NA	2	2	100
14. Two Girls	12	6	50	9	5	56	0	0	NA	2	1	50
15. Winberry	6	7	100	4	3	75	1	2	200	1	2	200
16. Wolf	1	1	100	0	0	NA	1	1	100	0	0	NA
Average	15	12		6	4		2	2		7	5	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

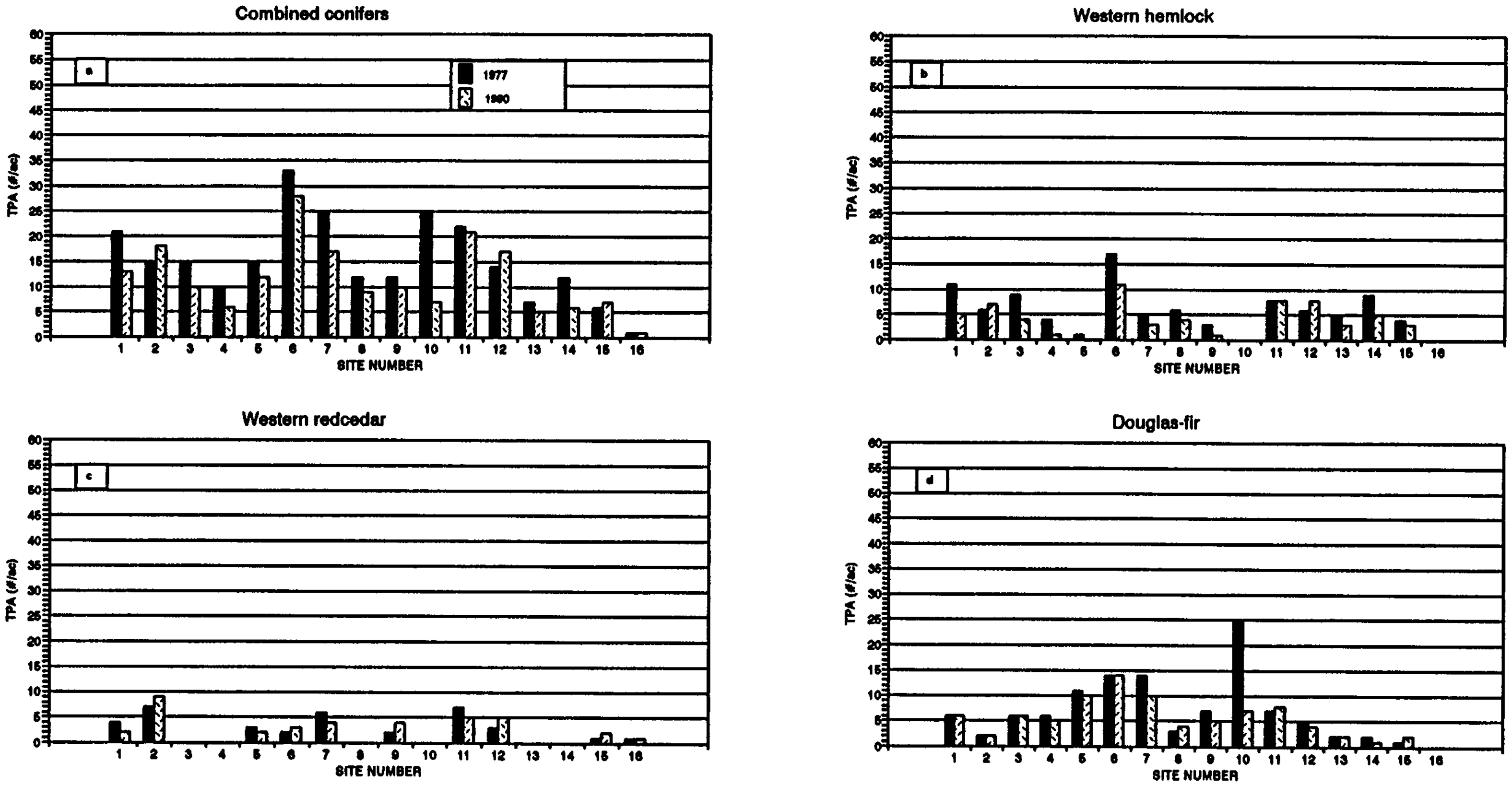


Figure 7. Density (TPA) of conifers 30-44 inches DBH (INTCLS 2) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

differences were readily substantiated; others suggest discrepancies in measurement were partially responsible.

Changes in the Black Creek buffer strip are thought to be due primarily to differences in measurement; this buffer seemed relatively stable over time. Specifically, from Figures 7(b - d), decreases occurred in both western hemlock and western redcedar. The loss of six western hemlock per acre is puzzling, particularly because the total percent remaining trees per acre and basal area per acre were 99 and 97, respectively (Figure 3). Douglas-fir densities were identical for the two studies.

As previously discussed, the Cadenza Creek buffer strip had blowdown resulting from the 1990 storms. Changes in INTCLS 2 were restricted to western hemlock, with a decrease of 46% over 1977 levels.

The Canal Creek buffer strip also had blowdown during the 1990 storms, but this was evidently not the first time. Older windfall in the buffer indicates a history of blowdown. Figures 7(b - d) show that most blowdown in INTCLS 2 occurring on Canal Creek was western hemlock, though there was a minor decrease of Douglas-fir (<20%). It should be noted that the Canal Creek buffer was the most difficult to relocate. No monumentation tags from the original study were found, presumably due to blowdown, adding to the difficulty discerning the buffer boundary.

Sample areas in 1990 had to be reestablished on the basis of original field notes and photographs.

The Cook Creek buffer strip experienced some blowdown prior to the 1990 events. All species were apparently equally susceptible to windthrow. Interestingly, on Cook Creek, several tree tops were snapped as a result of the 1990 storms, but blowdown did not occur. Trees with snapped tops were noted and included in this analysis, but not specifically evaluated.

The Hardy 1 buffer strip is located 1.75 miles downstream from the Hardy 2 buffer. Both of these sites show a decrease in INTCLS 2 density, but for different reasons. Hardy 1 did have some blowdown, but it also had additional harvesting since the initial study. Based on the 1990 field survey, one western hemlock per acre, one western redcedar per acre, and two Douglas-fir per acre were removed during this operation for a total decrease of four trees per acre. Therefore, half this decrease is a result of removal of standing trees, and not blowdown. This was confirmed by differences in the extent of stump decay on site. All of the species have been reduced from their original density, but Douglas-fir shows the greatest change (from 14 to 10 trees per acre).

The Hardy 2 buffer strip was the highest elevation site resampled (3800 feet). It experienced blowdown within a short time of establishment in 1975, and was salvage logged shortly thereafter. Unfortunately, official records cannot be traced and it becomes difficult to identify some of the salvaged blowdown stumps once they have uprighted themselves. Western hemlock was the species showing the most difference, but this was a loss of only two trees per acre. Figure 7(d) actually shows an increase in Douglas-fir by a single tree per acre, probably a function of differences in measurement. The extra trees per acre reflected in combined conifers are from Pacific silver fir which were not analyzed in the species assessment.

There was no western hemlock or western redcedar in this diameter class in the Owl Creek buffer strip; virtually all of the blowdown in INTCLS 2 was Douglas-fir. This change was substantial; from 25 trees per acre in 1977 to 7 in 1990. It is also conceivable that this heavy blowdown contributed to the loss of western hemlock in the 10-15 inch DBH range (Figure 5(a)).

The buffer strip on Tidbits Creek was one of the sparsest of those initially sampled (Figure 4(a)); a 20% decrease occurs with relatively little change. Western hemlock was the only species showing a decline, but only by two trees per acre. This buffer increased in INTCLS 1 density (Figure 6(a)); the two classes may be overlapping and differences in measurement may be the real culprit behind the apparent changes. Most trees left in the Tidbits buffer were cull trees left for shade. They were of inferior quality (this is not to say a buffer must be comprised of high-quality trees); this too could have contributed to the blowdown.

Finally, the Two Girls buffer strip lost half the conifers per acre in INTCLS 2 (from 12 trees per acre to 6 trees per acre). Most of those lost (67%) were western hemlock, but a couple Douglas-fir per acre also contributed to the decline. There was a single Pacific silver fir per acre present in 1977 that was gone in 1990.

Sites 2 and 12 (Blowout and Rider) both show threshold increases in the number of trees in this intermediate diameter class. The change on these sites is thought to be due to differences in area sampled.

Five sites (6-Deer, 9-Lost, 11-Perdue, 15-Winberry, 16-Wolf) show essentially no density change in INTCLS 2 conifers, indicating general stability among trees of this size. A more detailed summary can be found by investigating the species breakdown (Figures 7(b - d)). Deer Creek had six fewer western hemlock per acre (-35%), but gained a western redcedar per acre for a net loss of 15%. Lost Creek had decreases of western hemlock and Douglas-fir (-67% and -29%, respectively), but a gain of 100% in western redcedar. Though the buffer area differed only slightly, differences in actual sample location may be introducing some error. The Perdue buffer strip shows a loss of two western redcedar per acre (-29%), but a

Douglas-fir gain of 14% (1 trees per acre). The Winberry buffer lost one of four western hemlock per acre (-25%), but gained a Douglas-fir per acre (for a total of two per acre). Finally, the Wolf Creek buffer strip shows no change in its original composition in INTCLS 2, but this is only one Douglas-fir per acre.

In summary, the density of trees in INTCLS 2 during the 1990 study is considerably less than that of INTCLS 1, as might be expected. With respect to INTCLS 2 conifers per acre, nine sites (just over half) decreased below the 20% threshold. This contrasts dramatically with density dynamics of INTCLS 1. Only two sites showed a loss of total conifers per acre in INTCLS 1, with much fewer losses on a species by species breakdown as well. Changes in INTCLS 2 came mostly from western hemlock, though losses of Douglas-fir on Owl Creek were substantial. Eleven (69%) of the sites showed a decrease in the number of western hemlock per acre; apparently it is the most susceptible to blowdown in this diameter class. Of the ten sites (63%) having a component of western redcedar, five sites (50%) showed an increase, but these differences were not substantial--a maximum of two trees per acre. The other half showed a decrease in number of western redcedar per acre. Fifteen of the sites (94%) had Douglas-fir in INTCLS 2; four (27%) experienced a loss beyond the threshold. Only two sites (13%) showed a gain above background density levels. Obviously there are some complicating factors, but clearly there have been more changes in stand structure, notably losses, in INTCLS 2 than in the previous diameter groupings.

Density-trees ≥45 inches DBH

Density of trees 45 inches DBH and greater (LGCLS) are listed in Table 8 and plotted in Figure 8. These large trees remaining in the sampled western Cascade buffers will not likely be removed. Functionally, it probably doesn't matter exactly how big this material is. It will function in much the same way whether it's 45 or 70 inches DBH, though obviously longevity will vary. The largest tree measured for the 1978 study was an 88-inch DBH Douglas-fir in the Hardy 2 buffer. In 1990, the largest tree was a 76-inch DBH Douglas-fir found in the Cook Creek buffer.

The scale on the graphs (Figure 8) has been greatly reduced over the previous classes because of much smaller sample sizes. Density ranged from 0 to 17 trees per acre in 1977 and 0 to 16 trees per acre in 1990. Fluctuations in density in this size are to be expected due to several factors. Assuming a relationship between diameter and age, these are the oldest trees, prone to natural mortality. As these trees become senescent, they would be expected to blow down. In some buffers that may have been opened by harvesting, it's possible that the remaining trees become more susceptible to windthrow, as Steinblums (1978)

Table 8. Density (TPA) of conifers ≥45 inches DBH (LGCLS) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC TPA (#/ac) [a]	1990 CC TPA (#/ac)	REM (%) [e]	1977 WH TPA (#/ac) [b]	1990 WH TPA (#/ac)	REM (%)	1977 WC TPA (#/ac) [c]	1990 WC TPA (#/ac)	REM (%)	1977 DF TPA (#/ac) [d]	1990 DF TPA (#/ac)	REM (%)
1. Black	4	5	125	0	0	NA [f]	1	2	200	3	3	100
2. Blowout	10	7	70	1	0	0	5	4	80	4	3	75
3. Cadenza	0	0	NA	0	0	NA	0	0	NA	0	0	NA
4. Canal	6	4	67	1	0	0	0	0	NA	5	4	80
5. Cook	3	4	125	0	0	NA	0	1	NA	3	3	100
6. Deer	6	5	83	1	0	0	0	0	NA	5	5	100
7. Hardy 1	8	6	75	0	0	NA	1	1	100	7	5	71
8. Hardy 2	10	14	140	2	2	100	0	0	NA	8	12	150
9. Lost	12	16	133	1	0	0	0	0	NA	11	16	145
10. Owl	6	1	17	0	0	NA	0	0	NA	6	1	17
11. Perdue	17	15	88	0	0	NA	1	1	100	16	14	88
12. Rider	4	5	125	0	0	NA	0	0	NA	4	5	125
13. Tidbits	10	9	90	0	1	NA	0	0	NA	10	8	80
14. Two Girls	5	6	120	2	4	200	0	0	NA	3	2	67
15. Winberry	8	5	63	1	0	0	0	0	NA	7	5	71
16. Wolf	2	1	50	1	1	100	0	0	NA	1	0	0
Average	7	6		1	1		1	1		6	5	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

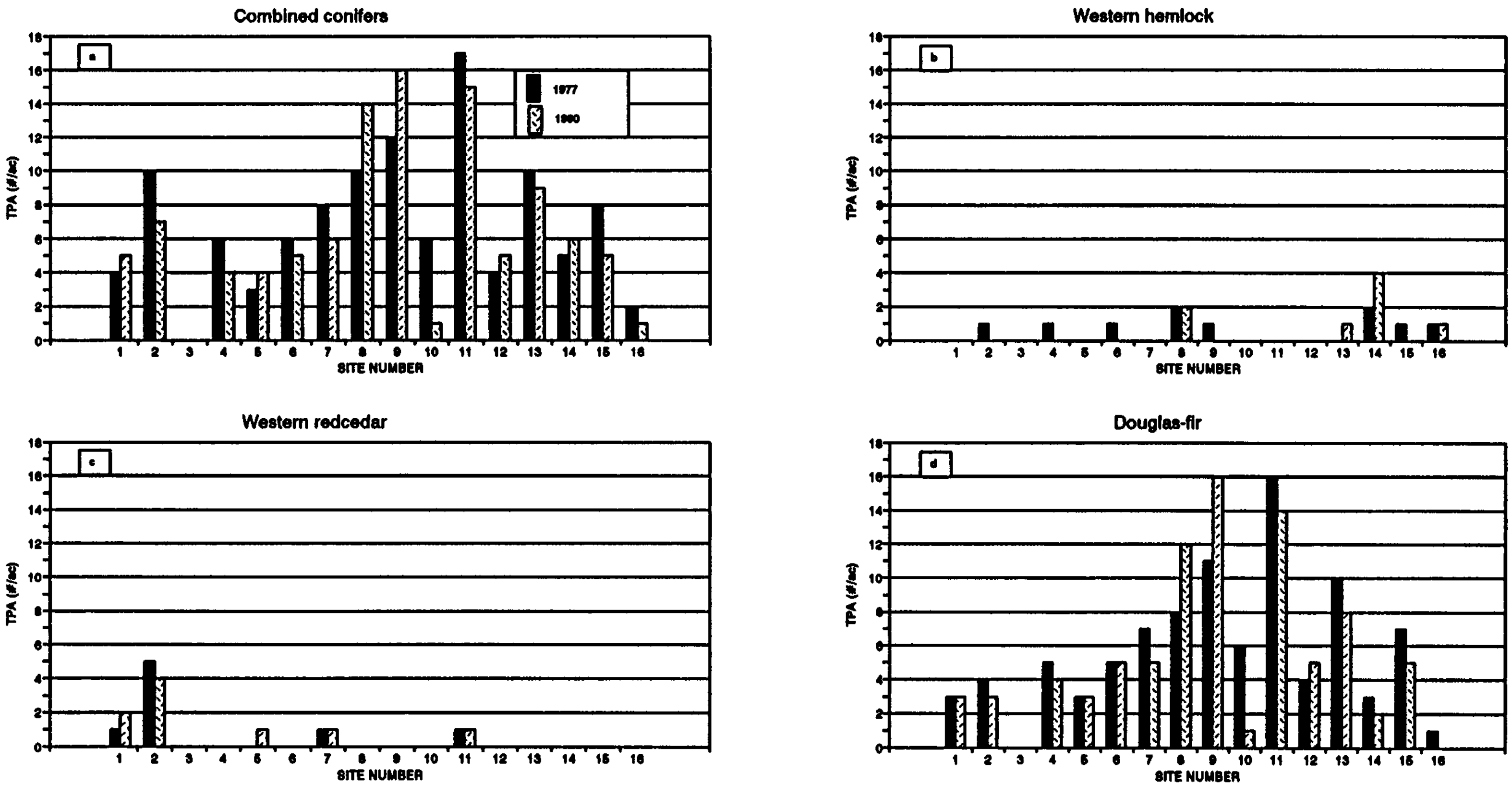


Figure 8. Density (TPA) of conifers ≥45 inches DBH (LGCLS) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

suggested. Finally, these large trees are most likely to reflect differences in measurement between a Biltmore stick and a diameter tape.

Figure 8(a) summarizes density of this DBH class for combined conifers. Immediately evident is the lack of trees in LGCLS on site 3, Cadenza Creek, at either point in time. However, the sampled Cadenza Creek buffer strip was only four hundred feet in length.

Another obvious change is the 83% decrease in conifer density on Site 10, (Owl), from six to one trees per acre. The Owl Creek buffer strip experienced episodic blowdown shortly after being established in the mid-1970s. All of the LGCLS decrease on this site was Douglas-fir (Figure 8(d)). The six sites indicating a density decrease ≥20% (2-Blowout, 3-Canal, 7-Hardy 1, 10-Owl, 15-Winberry, and 16-Wolf) must be viewed with caution. Total densities are small; it's easy to get a 20% change. Percent changes will only be discussed relative to combined conifers.

The Blowout Creek buffer strip decreased by one tree per acre from each species, leaving a total of seven trees per acre. The Canal Creek buffer strip decreased 33% (from six to four trees per acre), losing one western hemlock and one Douglas-fir per acre. The Hardy 1 buffer strip lost 29%, all Douglas-fir, (from seven to five trees per acre). The Winberry buffer strip lost 38%, one western hemlock and two Douglas-fir, leaving five trees per acre. Finally, Wolf Creek lost 50% of the trees in this diameter class (one Douglas-fir per acre), leaving only one western hemlock per acre remaining.

From Figures 8(b - d), it becomes obvious that western hemlock and western redcedar do not contribute greatly to LGCLS. Western hemlock numbers for the 1978 study did not exceed two trees per acre on any of the eight sites where it occurred; most buffers had only a single hemlock per acre. Site 13 (Tidbits) shows a western hemlock measured in 1990 that was not measured in the previous study. Site 14 (Two Girls) shows an increase in hemlock density over 1977 levels (four vs. two trees per acre). Western redcedar in this diameter class was found on 5 of the 16 sites (31%) in 1990. Site 1 (Black) shows an increase, while Site 2 (Blowout) shows a decrease, both only by a single tree per acre. Site 5 (Cook) shows a cedar measured in 1990 that was unaccounted for in the 1977 inventory. The other two sites (7-Hardy 1 and 11-Perdue) have remained the same with respect to LGCLS western redcedar density.

Figure 8(d) shows the LGCLS density dynamics of Douglas-fir. The majority of conifers in this diameter class are contributed by this species. In 1977, the number of Douglas-fir per acre ranged from 1 to 16, in 1990 the range was identical, but individual buffers showed fluctuation. Eight sites (50%) have decreased in the number of Douglas-fir per acre but three (19%) have shown an increase. Measurement differences are most likely the cause. Clearly, Douglas-fir is the most common species in this size class.

Basal area-trees ≥10 inches DBH

The problems interpreting actual numbers of trees, especially when sample sizes are small, may be remedied by an investigation of basal area per acre (BA/AC). If there were some discrepancies in the measurement of these trees, there could be some shifting between classes that would be difficult to detect by density alone. Overall, basal area per acre may be a more useful parameter to ascertain changes in the buffers.

It is useful to discuss changes in basal area while simultaneously reviewing stand density. By linking the two, a more realistic assessment of actual stand dynamics may be revealed. Utilizing the species composition grouped by previously defined diameter classes may reveal more about how these sites have actually changed over time. Several different scenarios are evident.

No discernable change in either density or basal area would indicate a site that has been relatively stable over time. Although this could be an acceptable result, it might indicate a sheltered (no blowdown), less productive (no ingrowth) site.

The other "extreme" might be that both parameters have decreased substantially. This may be typical of a wet, high elevation buffer with poor topographic protection. These sites often have shallow soils, and higher probability of damaging winds affecting the buffer. Due to these conditions, the buffer strip may be more prone to episodic blowdown. Larger trees may topple smaller trees, leading to a more chronic decrease of conifers over time. Again, an investigation of diameter distributions may help to identify gaps in the coniferous component of the buffer.

A site may show an increase in trees per acre, but a substantial decrease in basal area per acre. This buffer is probably one that has experienced some blowdown, of the larger trees, but is simultaneously gaining trees from ingrowth. Figures 4-8 will be useful in the following discussion.

Estimates of basal area in 1977 ranged from 162 to 522 ft^2 per acre (avg. = 299 ft^2 per acre) (Table 9 and Figure 9). In 1990, basal area varied between 115 and 426 ft^2 per acre (avg. = 263 ft^2 per acre).

Utilizing the 20% threshold, seven sites (3-Cadenza, 4-Canal, 7-Hardy 1, 10-Owl, 11-Perdue, 13-Tidbits, and 15-Winberry) have experienced a decrease in basal area per acre. On many sites, basal area dynamics mirror density changes.

The Cadenza Creek buffer strip had no western redcedar; the decrease in basal area came from western hemlock.

Table 9. Basal area (BA/AC) of conifers ≥10 inches DBH in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC BA/AC (ft^2/ac) [a]	1990 CC BA/AC (ft^2/ac)	REM (%) [e]	1977 WH BA/AC (ft^2/ac) [b]	1990 WH BA/AC (ft^2/ac)	REM (%)	1977 WC BA/AC (ft^2/ac) [c]	1990 WC BA/AC (ft^2/ac)	REM (%)	1977 DF BA/AC (ft^2/ac) [d]	1990 DF BA/AC (ft^2/ac)	REM (%)
1. Black	355	346	97	115	90	78	78	86	110	161	170	106
2. Blowout	374	388	104	121	152	126	166	165	99	87	71	82
3. Cadenza	184	139	76	126	80	63	0	0	NA [f]	51	56	110
4. Canal	282	151	54	96	55	57	3	2	67	183	95	52
5. Cook	248	277	112	35	34	97	45	68	151	168	175	104
6. Deer	373	363	97	159	140	88	25	33	132	189	190	101
7. Hardy 1	352	279	79	69	53	77	75	65	87	208	161	77
8. Hardy 2	351	360	103	98	93	95	0	0	NA	215	233	108
9. Lost	370	426	115	50	16	32	34	48	141	286	361	126
10. Owl	326	115	35	23	18	78	0	0	NA	303	97	32
11. Perdue	522	416	80	94	103	110	95	66	69	334	246	74
12. Rider	186	241	130	56	89	159	38	62	163	92	90	98
13. Tidbits	259	205	79	59	63	107	0	0	NA	200	142	71
14. Two Girls	206	171	83	111	125	113	0	3	NA	90	43	48
15. Winberry	228	178	78	74	80	108	7	9	129	147	89	61
16. Wolf	162	148	91	124	121	98	21	24	114	17	3	18
Average	299	263		88	82		37	39		171	139	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

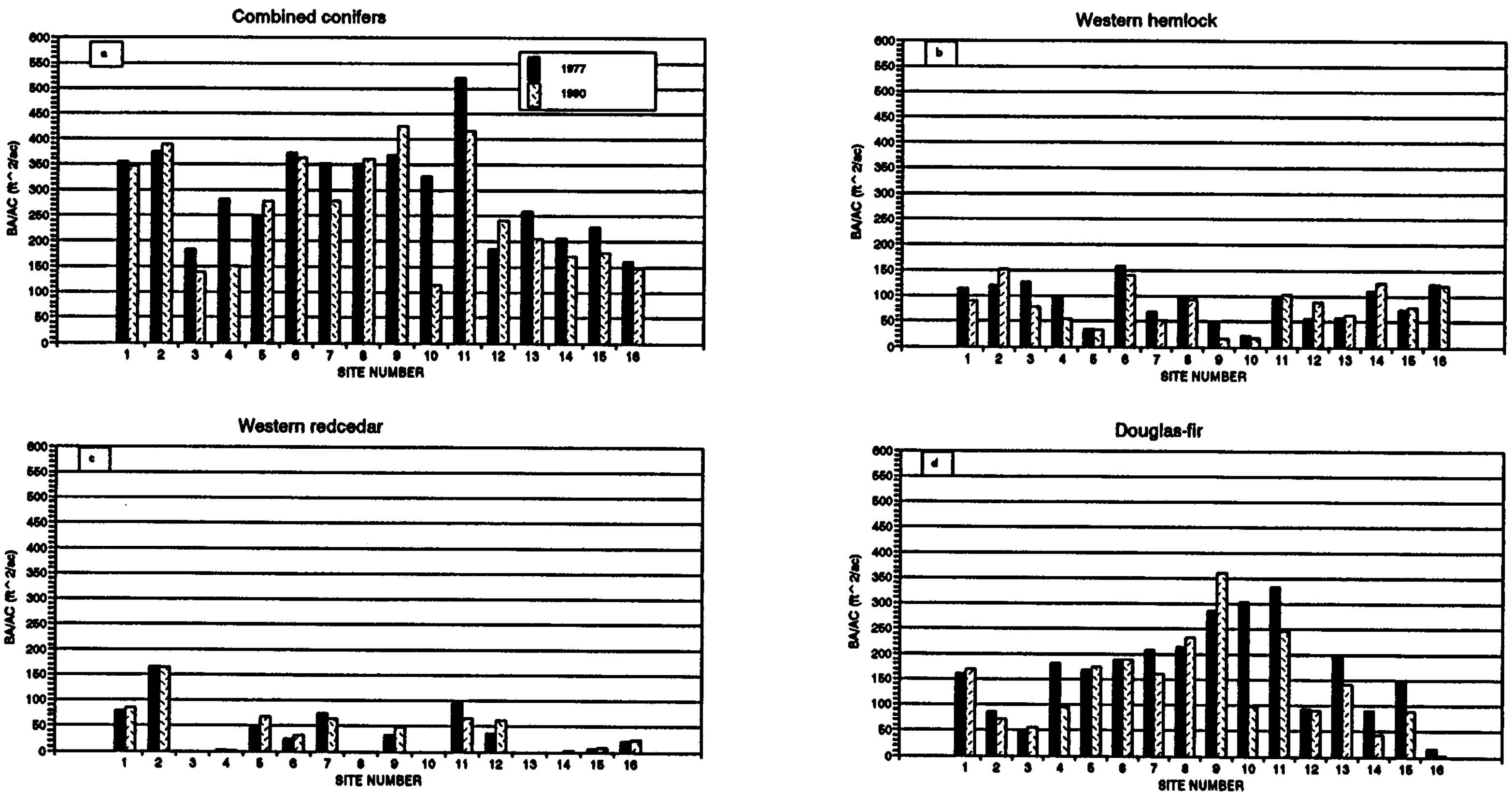


Figure 9. Basal area (BA/AC) of conifers ≥10 inches DBH in 1977 and 1990 in resampled Willamette National Forest buffer strips.

Figure 9(d) shows the Douglas-fir component actually increasing in 1990, but by less than 20%.

Basal area in the Canal Creek buffer strip has decreased by 46% (combined conifers). Western hemlock decreased by 43%; western redcedar by 33% (however this was only a loss of one tree per acre), and Douglas-fir by 48%.

Buffer strips on Cadenza and Canal Creeks appeared to have some previous blowdown, coming to some degree of stability, but then being influenced by the 1990 storms to a noticeable extent. Possible explanations for why 1990 storms had such impact are landscape level changes in the basin, (such as additional harvest units) and simply that the winds were strongest at these locations. No wind data was available for these sites. Most wind data stations are at lower elevation locations; they are probably unrepresentative of these upland sites.

Western hemlock and Douglas-fir showed the largest reduction in the Hardy 1 buffer strip. These species were removed during the subsequent harvest, reflected by a 23% decrease in basal area for each species. Though there was also a decrease in western redcedar, it was less than 20% of the 1977 levels.

The Owl Creek buffer strip shows the greatest decrease in basal area per acre losing 65% of the 1977 value. There was no western redcedar on this site; 78% of the western hemlock basal area per acre remained in 1990 but only 32% of the Douglas-fir basal area was still standing.

Though the Perdue Creek buffer strip did experience a 20% loss in basal area per acre, it still had exceptionally high basal area values for these buffer strips (from 522 to 416 ft^2 per acre). Western redcedar basal area decreased 31%, while Douglas-fir basal area decreased 26%.

The Tidbits buffer strip was sparse. Though there was an overall increase in density, combined conifer basal area per acre decreased by 21%. Most of the decline was attributed to Douglas-fir.

It should be noted that slight increases in western hemlock basal area per acre are to be expected, as described in the previous section. As expected, the natural progression of the buffer strips is toward a western hemlock overstory; these findings are consistent with this premise.

By investigating the basal area fluctuations within the diameter classes developed earlier, it's possible to identify where in the diameter distribution the changes are occurring. While the first class (10-14 inches DBH) is discrete, the remaining divisions (INTCLS 1, INTCLS 2, LGCLS) are quite broad. Only trees at or near the cutoff points are likely to grow into the next larger class. Because the relationship between diameter and basal area is curvilinear (particularly in the larger diameters), there is some value in investigating exactly where the changes in basal area occurred with respect to the diameter groupings used previously.

Basal area-trees 10-14 inches DBH

Exploring basal area fluctuations in this class allows some quantification of the contribution to overall BA/AC made from the smallest diameter trees. They are not expected to be contributing substantially at this point, but are very important because they will constitute the riparian stand into the next century.

Combined conifer basal area per acre for trees 10-14 inches in diameter averaged 7 ft^2 per acre in 1977 and 12 ft^2 per acre in 1990 (Table 10). The 20% threshold must be used cautiously; basal area per acre contributed by trees in this diameter class is not substantial. A 10-inch DBH tree equates to 0.54 ft^2 of basal area; a 14-inch DBH tree is only 1.07 ft^2; therefore percentages can be misleading.

Basal area contributed by trees 10-14 inches DBH ranged from 4 to 27 ft^2 per acre in 1990 (Figure 10). While this is a small contribution to the total, it indicates ingrowth when compared to 1977 estimates which ranged from 2 to 22 ft^2 per acre. This is not to say there has been no mortality in this class, only that on average, ingrowth is the dominant process.

Only two sites (7-Hardy 1 and 10-Owl) have decreased ≥20% of the 1977 levels. Both of these sites show

Table 10. Basal area (BA/AC) of conifers 10-14 inches DBH in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC BA/AC (ft^2/ac) [a]	1990 CC BA/AC (ft^2/ac)	REM (%) [e]	1977 WH BA/AC (ft^2/ac) [b]	1990 WH BA/AC (ft^2/ac)	REM (%)	1977 WC BA/AC (ft^2/ac) [c]	1990 WC BA/AC (ft^2/ac)	REM (%)	1977 DF BA/AC (ft^2/ac) [d]	1990 DF BA/AC (ft^2/ac)	REM (%)
1. Black	8	10	125	4	3	75	4	5	125	0	2	NA
2. Blowout	7	17	243	6	13	217	1	3	300	0	1	NA
3. Cadenza	5	6	120	4	4	100	0	0	NA	0	0	NA
4. Canal	3	6	200	3	6	200	0	0	NA	0	0	NA
5. Cook	18	26	144	12	16	133	4	8	200	2	2	100
6. Deer	8	13	163	4	8	200	4	5	125	0	0	NA
7. Hardy 1	8	5	63	4	3	75	4	2	50	0	0	NA
8. Hardy 2	6	16	267	4	6	150	0	0	NA	0	0	NA
9. Lost	2	6	300	1	4	400	1	2	200	0	0	NA
10. Owl	6	4	67	6	3	50	0	0	NA	0	1	NA
11. Perdue	3	7	233	3	7	233	0	0	NA	0	0	NA
12. Rider	2	14	700	2	10	500	0	4	NA	0	0	NA
13. Tidbits	2	4	200	2	4	200	0	0	NA	0	0	NA
14. Two Girls	2	8	400	1	7	700	0	1	NA	0	0	NA
15. Winberry	7	19	271	7	18	257	0	0	NA	0	1	NA
16. Wolf	22	27	123	19	24	126	3	3	100	0	0	NA
Average	7	12		5	9		1	2		0	0	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

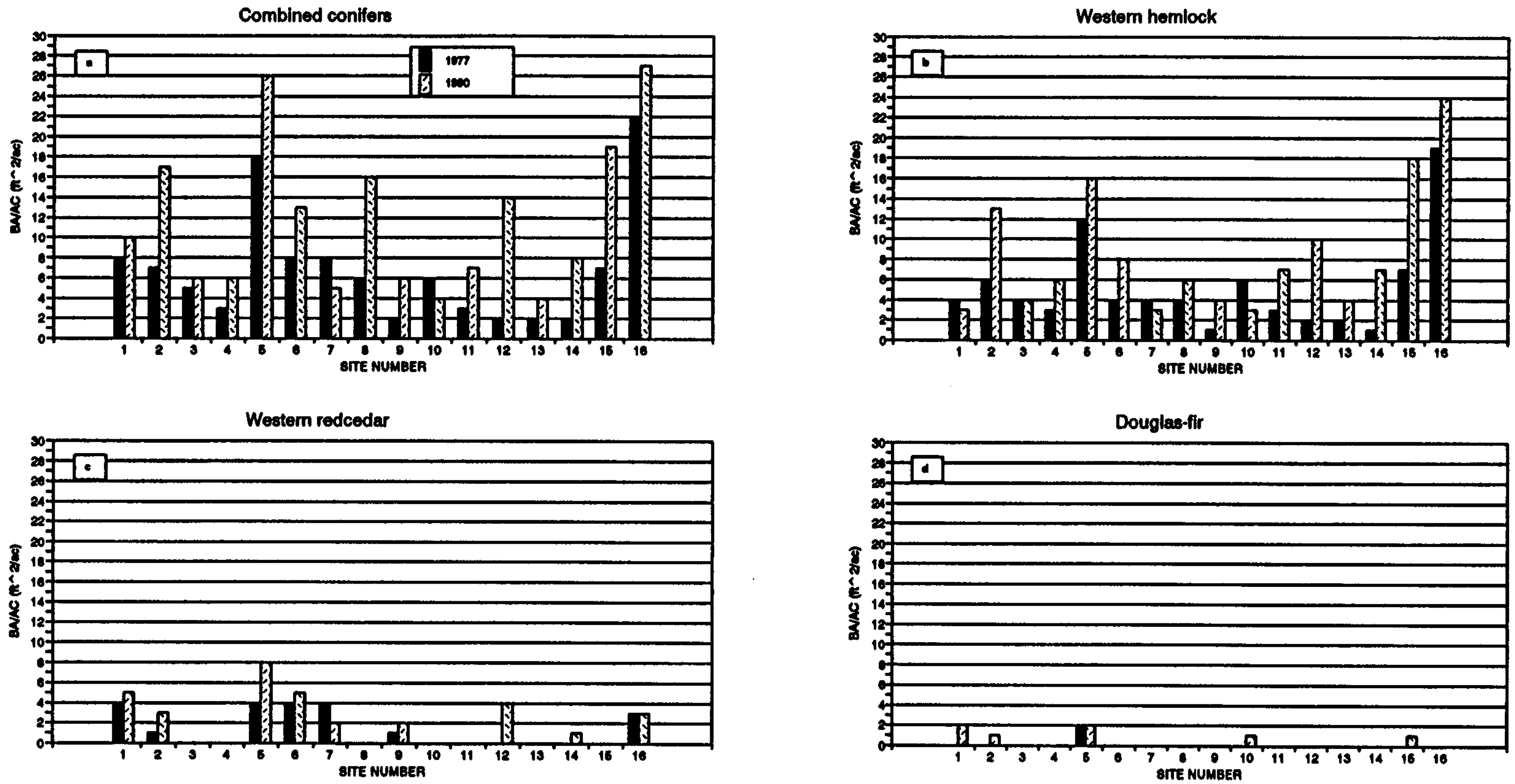


Figure 10. Basal area (BA/AC) of conifers 10-14 inches DBH in 1977 and 1990 in resampled Willamette National Forest buffer strips.

concurrent density decreases. There are two ways to interpret this phenomenon. These small diameter trees would be most likely to grow into the next larger class, particularly on a good site, leaving a "gap" in this class. This is quite possibly the case on Hardy 1. There was a decrease of six trees per acre from this class, and even accounting for the additional harvesting, only a loss of one tree per acre from INTCLS 1. The other explanation is that mortality has occurred. It might be direct or indirect. Direct mortality could be the result of sunscald, logging damage, or disease, i.e., the tree dies of "natural" causes. However on a site with a lot of blowdown, it is very likely that many smaller trees could be toppled by larger ones. This seems likely for the Owl Creek buffer strip where large-scale decreases also occurred in larger diameter trees.

Clearly, there has been an overall increase, albeit small, in the contribution of basal area from the smallest diameter class. Fourteen sites (1-Black, 2-Blowout, 3-Cadenza, 4-Canal, 5-Cook, 6-Deer, 8-Hardy 2, 9-Lost, 11-Perdue, 12-Rider, 13-Tidbits, 14-Two Girls, 15-Winberry, and 16-Wolf) have increased basal area per acre by ≥20%. Two sites (Cook and Wolf) had unusually high basal area estimates for this diameter class evident in both studies. Opportunities for ingrowth in these buffer strips seems especially good in light of this situation. Only two sites

(Black and Cadenza), of those showing an increase in basal area per acre (combined conifers) in the ≥10-15 inch diameter class do not show a comparable increase in western hemlock density. In this range of diameters, there is almost a linear relationship between diameter and basal area, therefore, it's not surprising that Figures 5(a - c) look so much like Figures 10(a - c).

Five sites (1-Black, 2-Blowout, 5-Cook, 6-Deer, 9-Lost) have increased western redcedar basal area per acre ≥20% over 1977 levels (Figure 10(c)). Two sites (11-Rider and 14-Two Girls) had a cedar component in 1990, but previously did not. This seems typical of sites at this successional stage, and in keeping with the density dynamics shown in Figure 5(c). Obviously this ingrowth can't be expressed as a percent increase, but it is an important component of the buffer strip dynamics.

Figure 5(d) shows that only one site (5-Cook) had a Douglas-fir component during the previous study. By 1990 several other sites (1-Black, 2-Blowout, 10-Owl, and 15-Winberry) had Douglas-fir in this diameter class as a buffer strip component.

Sites 6 and 16 (Deer and Wolf) had fewer trees per acre in 1990 than 1977 (Figure 5(a)), yet they had more basal area per acre in 1990 (Figure 10(a)). Because this is the lowest end of the diameter range, growth increases would be expected to be maximized, especially with release.

Therefore there could easily be an increase in basal area without a corresponding increase in density.

The preceding discussion indicates that on most of these sites, there is a healthy contribution of smaller diameter trees. Conifers have apparently not only grown into this class from below, but the trees that were measured in the 1977 study have grown radially as well. Although this information helps to describe current stand conditions, it's real utility may be to hypothesize future buffer composition. A "current state" assessment of these buffers today might be better accomplished by comparing basal area of intermediate classes.

Basal area-trees 15-29 inches DBH

Table 11 lists basal area contributions of INTCLS 1 for the two studies. In this range, the relationship between basal area and diameter is essentially linear; basal area dynamics closely parallel the density dynamics but some slight differences are evident. Average basal area values for INTCLS 1 are 57 and 64 ft^2 per acre in 1977 and 1990 respectively, a gain of 12%.

While many sites show an increase in combined conifer basal area (Figure 11), two buffer strips (3-Cadenza and 4-Canal) have decreased below the threshold. INTCLS 1 basal area per acre decreased by 30% in the Cadenza Creek buffer (from 71 to 50 ft^2 per acre). This change occurred mostly in western hemlock, which decreased by 32% (from 66 to 45

Table 11. Basal area (BA/AC) of conifers 15-29 inches DBH (INTCLS 1) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC BA/AC (ft^2/ac) [a]	1990 CC BA/AC (ft^2/ac)	REM (%) [e]	1977 WH BA/AC (ft^2/ac) [b]	1990 WH BA/AC (ft^2/ac)	REM (%)	1977 WC BA/AC (ft^2/ac) [c]	1990 WC BA/AC (ft^2/ac)	REM (%)	1977 DF BA/AC (ft^2/ac) [d]	1990 DF BA/AC (ft^2/ac)	REM (%)
1. Black	146	149	102	55	63	115	38	32	84	53	54	102
2. Blowout	75	106	140	58	86	148	17	20	118	0	0	NA
3. Cadenza	71	50	70	66	45	68	0	0	NA [f]	0	5	NA
4. Canal	49	38	78	44	30	68	3	2	67	2	6	300
5. Cook	60	83	138	19	19	100	21	35	167	20	29	145
6. Deer	59	85	144	46	62	135	7	12	171	6	11	183
7. Hardy 1	68	67	99	37	34	92	25	26	104	6	7	117
8. Hardy 2	30	39	130	22	20	91	0	0	NA	0	0	NA
9. Lost	36	33	92	2	3	150	17	21	124	17	10	59
10. Owl	36	45	125	17	15	88	0	0	NA	19	30	158
11. Perdue	72	74	103	43	50	116	27	24	89	3	0	0
12. Rider	38	50	132	19	28	147	19	22	116	0	0	NA
13. Tidbits	16	27	169	16	27	169	0	0	NA	0	0	NA
14. Two Girls	15	30	200	15	28	187	0	2	NA	0	0	NA
15. Winberry	28	47	168	25	45	180	3	0	0	0	2	NA
16. Wolf	106	104	98	92	85	92	14	16	114	0	3	NA
Average	57	64		36	40		12	13		8	10	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

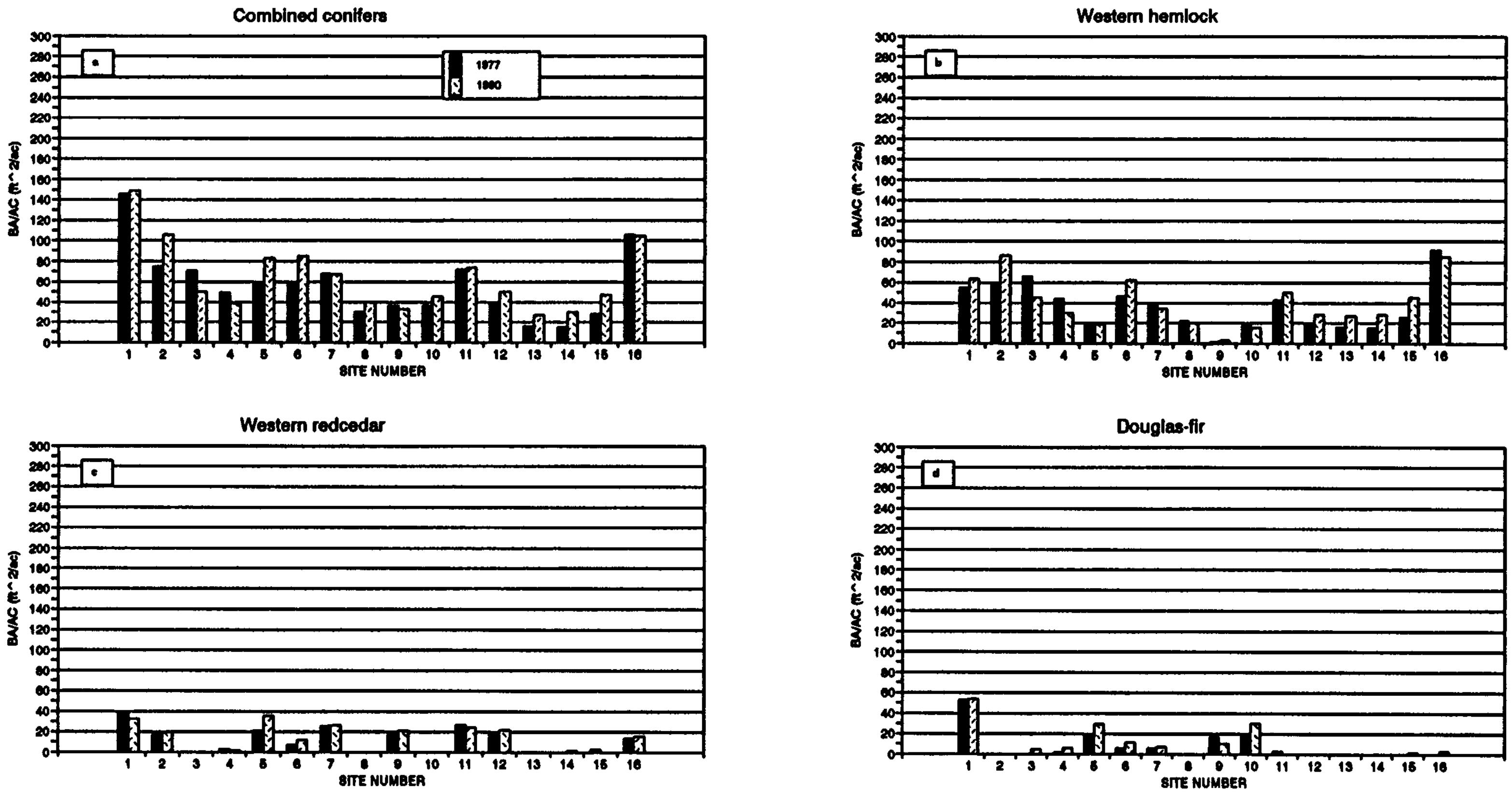


Figure 11. Basal area (BA/AC) of conifers 15-29 inches DBH (INTCLS 1) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

ft^2 per acre). Some Douglas-fir (five ft^2 per acre) added to the basal area estimate in 1990 where there previously was none.

The Canal Creek buffer strip exhibited similar dynamics. Western hemlock showed the greatest change in basal area, from 44 to 30 ft^2 per acre (-32%); density of hemlock in this class did not show a discernable change. Basal area of western redcedar was reduced from three to two ft^2 per acre, while densities at both points in time held steady at one tree per acre. The Canal Creek buffer is one of the few sites with a Douglas-fir component in this class. A density increase of one tree per acre (one vs. two trees per acre) in 1990 was reflected by a simultaneous increase in basal area of four ft^2 per acre (from two to six). These two sites are unique among this data set. The fact that they are the ones most influenced by the 1990 storms may help to explain their dynamics. Of the variables Steinblums' measured, there were no similarities of these two sites except overstory density. In 1977, Cadenza had 44 trees per acre and Canal had 41 trees per acre. Attempts to develop a statistical relationship between 1990 basal area and the variables in Appendix A1 were unsuccessful.

Nine sites (2-Blowout, 5-Cook, 6-Deer, 8-Hardy 2, 10-Owl, 12-Rider, 13-Tidbits, 14-Two Girls, and 15-Winberry) have increased basal area over 1977 levels by ≥20%.

Increases range from 25 to 100% greater than 1977 levels. Most of these sites (all except Owl and Rider) had a corresponding increase in density.

The Blowout Creek buffer strip had a combined conifer INTCLS 1 basal area per acre increase of 40% (from 75 to 106 ft^2 per acre). The most substantial increase (48%) is attributed to shifts in western hemlock (Figure 11(a)). Western redcedar did not fluctuate within the range of tolerance, and there was no Douglas-fir in this diameter class at either point in time.

The Cook Creek buffer strip showed a 38% increase in basal area per acre, (from 60 to 83 ft^2 per acre). Rather than basal area increasing as a result of western hemlock, the change has come from both western redcedar and Douglas-fir (Figures 11(b and d)). Interestingly, on the Cook Creek buffer, basal area per acre for western hemlock has not changed.

INTCLS 1 basal area has increased 44% in the Deer Creek buffer strip (from 59 to 85 ft^2 per acre). This site in particular may have been influenced by differences in sample area. That problem aside, all three species contributed to the overall change in basal area per acre on this site. Increases in western hemlock, western redcedar, and Douglas-fir were 35, 71, and 83%, respectively. Changes in density by species for this buffer weren't consistent with fluctuations in basal area. Hemlock, cedar, and Douglas-fir densities increased by 29, 67, and 0%, respectively. However, this too has to be interpreted with caution; hemlock density increased (from 17 to 22 trees per acre), while cedar went from three to five trees per acre. Nonetheless, it is probably safe to say some ingrowth is occurring on this site, though the numbers discussed here may be somewhat imprecise.

Comparing Figure 11(a) with the changes evident from Figures 11(b - d) for the Hardy 2 buffer strip, basal area shifts in this diameter class obviously came from species other than those discussed here. This site was dominated by Pacific silver fir, particularly in the smaller diameter classes. Though Figure 11(a) shows an combined conifer increase in basal area per acre for this site from 30 to 39 ft^2 per acre, among the three species examined, basal area per acre in 1977 and 1990 was 22 and 20 ft^2 per acre. All of it resulted from western hemlock.

It comes as somewhat of a surprise that the Owl Creek buffer strip shows an increase in basal area per acre for INTCLS 1, particularly because it experienced a decrease in density (from 17 to 15 trees per acre). The Owl Creek buffer was very sparse and difficult to delineate, particularly by the time of the 1990 study. Only one of the original identification tags could be found, and it was on a downed tree. Basal area increases of 25% (from 36 to 45 ft^2 per acre) came exclusively from Douglas-fir. The western hemlock in INTCLS 1 actually decreased slightly (< 20%); there was no western redcedar present at either point in time.

The Rider Creek buffer strip combined conifer basal area increased 32% (from 38 to 50 ft^2 per acre). This change came largely from western hemlock, which gained 47% more basal area per acre, though a slight increase in western redcedar (<20%) also occurred. Density increases occurred only in western redcedar, suggesting a combination of ingrowth and mortality. As is frequently the case, there were no INTCLS 1 Douglas-fir on this site.

Western hemlock was the only INTCLS 1 species present in the Tidbits Creek buffer strip, and it increased by 69% over 1977 basal area values (from 16 to 27 ft^2 per acre). The corresponding increase in conifer density (from 8 to 13 trees per acre) suggests more trees may have been measured for the current study than for Steinblums' (1978) study.

Basal area per acre increased by 100% in the Two Girls buffer strip (from 15 to 30 ft^2 per acre). This resulted primarily from increases in western hemlock, which showed a corresponding increase in density (Figure 6(b)). There was, however two ft^2 per acre contributed by western redcedar in the 1990 study where there previously had been no cedar tallied.

Basal area in the Winberry Creek buffer strip increased 68% (from 28 to 47 ft^2 per acre). While western hemlock showed unusually high gains, increasing by 80% of the 1977 value, (from 25 to 45 ft^2 per acre), the cedar present (three ft^2 per acre) from the 1978 study was gone by 1990. However, there was a Douglas-fir component (two ft^2 per acre) in 1990 where there previously had been none.

Five sites (1-Black, 7-Hardy 1, 9-Lost, 11-Perdue, and 16-Wolf) showed no discernible differences in INTCLS 1 basal area reflected in combined conifers. Density dynamics are consistent for all but one site.

The Lost Creek buffer strip shows a 40% decrease in density (from 16 to 10 trees per acre). This confounding revelation is difficult to explain. A possible theory is that there were differences resulting from the two measurement techniques. Combined conifer density on Lost Creek (trees ≥10 inches DBH) did not show a discernible increase (42 vs 44 trees per acre), so it does seem possible that these trees were "absorbed" by the previous and subsequent diameter classes.

Black Creek is thought to be relatively unchanged from the earlier investigation. Hardy 1 did have some removal, but densities at both points in time were fairly similar; it seems likely basal area would follow suit. The Perdue buffer strip density for this class was unchanged from the 1978 study (26 trees per acre); basal area characteristics would be expected to be similar. Wolf Creek densities were

51 and 52 trees per acre in 1977 and 1990; basal area was 106 and 104 ft^2 per acre, respectively.

Basal area per acre in 1990 of INTCLS 1 on these sites range from 30 to nearly 150 ft^2 per acre. In the aggregate, the general trend is for hemlock basal area per acre to have increased and to be the greatest contributor to the combined conifer values. Western redcedar in INTCLS 1 is a relatively minor component, and Douglas-fir even less so. These results are to be anticipated; ingrowth would be expected to be maximized in the smaller trees as a result of release.

Basal area-trees 30-44 inches DBH

From the investigation of density dynamics, trees in INTCLS 2 (and larger) seemed most prone to blowdown. Because trees of this size are likely to reflect differences in measurement techniques, an investigation of basal area dynamics may reveal whether fluctuations in density are "real".

INTCLS 2 combined conifer basal area per acre in 1976 ranged from 4 to 213 ft^2 per acre, (avg. = 107 ft^2 per acre). In 1990 the estimates were from 5 to 190 ft^2 per acre, (avg. = 83 ft^2 per acre) (Table 12 and Figure 12).

Nine sites (1-Black, 3-Cadenza, 4-Canal, 7-Hardy 1, 8-Hardy 2, 10-Owl, 11-Perdue, 13-Tidbits, and 14-Two Girls) showed a basal area decrease ≥20% compared to 1977 levels.

Table 12. Basal area (BA/AC) of conifers 30-44 inches DBH (INTCLS 2) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC BA/AC (ft^2/ac) [a]	1990 CC BA/AC (ft^2/ac)	REM (%) [e]	1977 WH BA/AC (ft^2/ac) [b]	1990 WH BA/AC (ft^2/ac)	REM (%)	1977 WC BA/AC (ft^2/ac) [c]	1990 WC BA/AC (ft^2/ac)	REM (%)	1977 DF BA/AC (ft^2/ac) [d]	1990 DF BA/AC (ft^2/ac)	REM (%)
1. Black	107	63	59	57	24	42	19	7	37	31	32	103
2. Blowout	119	150	126	36	53	147	69	76	110	14	21	150
3. Cadenza	107	83	78	56	32	57	0	0	NA [f]	51	51	100
4. Canal	85	44	52	29	4	14	0	0	NA	56	40	71
5. Cook	101	98	97	4	0	0	20	19	95	77	79	103
6. Deer	213	190	89	99	69	70	14	16	114	100	105	105
7. Hardy 1	166	121	73	28	16	57	39	21	54	99	84	85
8. Hardy 2	93	63	68	45	30	67	0	0	NA	30	29	97
9. Lost	87	79	91	15	10	67	16	25	156	56	43	77
10. Owl	187	50	27	0	0	NA	0	0	NA	187	50	27
11. Perdue	178	137	77	47	46	98	54	30	56	66	60	91
12. Rider	93	117	126	35	51	146	19	36	189	39	30	77
13. Tidbits	52	36	69	40	23	58	0	0	NA	12	13	108
14. Two Girls	90	42	47	69	35	51	0	0	NA	15	7	47
15. Winberry	34	38	112	23	16	70	4	9	225	7	13	186
16. Wolf	4	5	125	0	0	NA	4	5	125	0	0	NA
Average	107	82		36	26		16	15		52	41	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

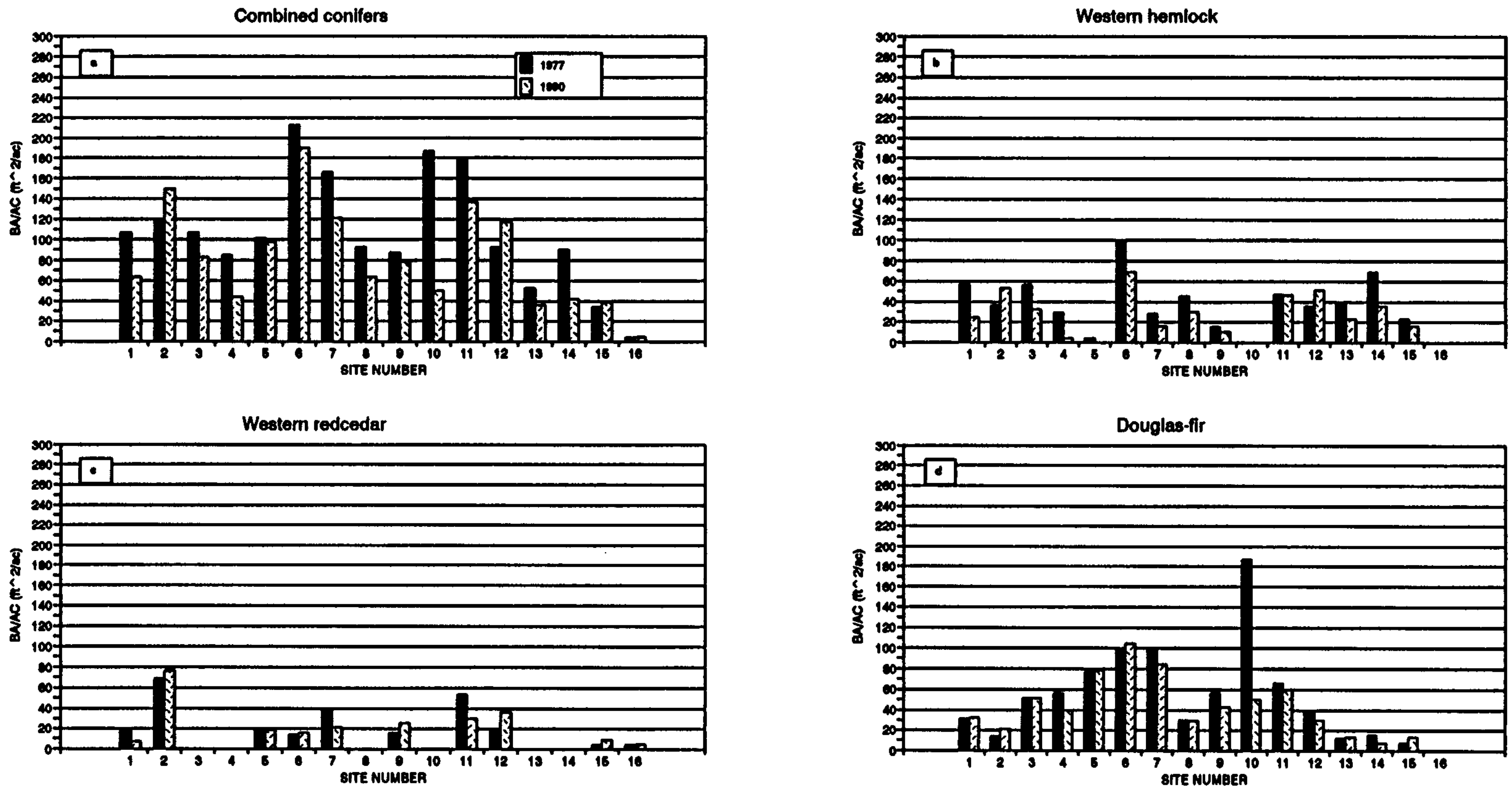


Figure 12. Basal area (BA/AC) of conifers 30-44 inches DBH (INTCLS 2) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

This closely parallels the density trends (Figure 7), with two exceptions.

Site 5 (Cook) showed a density decrease without a detectible decline in basal area. Conversely, Site 11 (Perdue) showed a decrease in basal area without a perceptible change in density.

The Black Creek buffer strip lost 41% of the basal area in this class (from 107 to 63 ft^2 per acre). The majority of the decline resulted from western hemlock (Figure 12 (b - d)), which decreased 58% (from 57 to 24 ft^2 per acre). There was also a 63% decline in western redcedar (from 19 to 7 ft^2 per acre). This was one of the only sites showing a notable decrease in INTCLS 2 western redcedar basal area per acre.

INTCLS 2 combined conifer basal area per acre in the Cadenza Creek buffer strip decreased 22% since 1977 (from 107 to 83 ft^2 per acre). Western hemlock alone was responsible for the decline, showing a basal area reduction of 43% (from 56 to 32 ft^2 per acre). Douglas-fir basal area remained constant at 51 ft^2 per acre for both studies. Pacific silver fir was not a component in INTCLS 2.

Basal area of the Canal Creek buffer strip decreased 48% (from 85 to 44 ft^2 per acre). Western hemlock has decreased 86% (from 29 to 4 ft^2 per acre). There was also a change in Douglas-fir, which lost 29% of the original estimate (from 56 to 40 ft^2 per acre), but only lost one tree per acre. Western redcedar was not present on the site at either point in time.

Combined conifer basal area in the Hardy 1 buffer strip decreased by 27% (from 166 to 121 ft^2 per acre) since Steinblums' (1978) study. Western hemlock basal area decreased by 43% (from 28 to 16 ft^2 per acre); western redcedar decreased 46% (from 39 to 21 ft^2 per acre). Although the basal area decrease in Douglas fir was within the tolerance threshold, density of Douglas-fir decreased more than 20% (from 25 to 17 trees per acre).

In the Hardy 2 buffer strip, combined conifer basal area per acre was reduced 32% (from 93 to 63 ft^2 per acre). There was no western redcedar present at either point in time and Douglas-fir basal area barely decreased. However, western hemlock basal area per acre was reduced by 33% (from 45 to 30 ft^2 per acre).

It comes as no surprise that INTCLS 2 basal area in the Owl Creek buffer strip has decreased in the time between the two studies. The combined conifer basal area was 187 ft^2 per acre in 1977; by 1990 it had been reduced to 50 ft^2 per acre, (-73%). These changes have resulted from dynamics of Douglas-fir alone.

The Perdue Creek buffer strip had a reduction in basal area per acre without a corresponding decrease in density (Figure 7). However, Figure 7(d) shows Douglas-fir density slightly greater than 1977 levels, distorting the combined conifer picture somewhat. Basal area for combined conifers decreased 23% (from 178 to 137 ft^2 per acre). Primarily, the decrease came from western redcedar which was reduced 44% (from 54 to 30 ft^2 per acre). Basal area for the other two species did not change beyond the threshold value.

INTCLS 2 combined conifer basal area in the Tidbits Creek buffer strip was reduced 36% (from 52 to 36 ft^2 per acre). Western hemlock basal area decreased 42% (from 40 to 23 ft^2 per acre). Douglas-fir did not readily change relative to 1977 levels (it actually increased slightly); western redcedar was absent from the site.

In the Two Girls buffer strip, the 1977 combined conifers basal area was reduced 53% (from 90 to 42 ft^2 per acre) by 1990. Western hemlock basal area declined by 49% (from 69 to 35 ft^2 per acre), and Douglas-fir basal area was also reduced by 53% (from 15 to 7 ft^2 per acre).

These nine buffer strips, which represent just over half the data set, have shown INTCLS 2 basal area declines mostly in the western hemlock, and to some extent, Douglas-fir. Though the other species have shown some fluctuation, hemlock is by far the species experiencing the most change, a premise which is supported by the density analysis. It is possible there has been some growth or measurement differences, however it also appears that hemlock in this diameter class, under these topographic and stand conditions is most susceptible to blowdown. The sites previously described represent an array of environmental, site, and topographic characteristics (Appendix A2). Attempts to statistically correlate variables with basal area remaining were unsuccessful.

Three buffer strips (2-Blowout, 12-Rider, and 16-Wolf) actually showed an INTCLS 2 basal area increase. The Blowout and Rider Creek buffers showed a corresponding increase in density (Figure 7(a)).

INTCLS 2 basal area increased 26% (from 119 to 150 ft^2 per acre) in the Blowout Creek buffer strip. This change was facilitated by a 47% increase in western hemlock (from 36 to 53 ft^2 per acre) and a 50% increase in Douglas-fir (from 14 to 21 ft^2 per acre). Western hemlock densities increased from 15 to 18 trees per acre, while there was no change in the number of Douglas-fir per acre.

Similar dynamics may well have occurred in the Rider Creek buffer strip where combined conifer basal area per acre increased 26% (from 93 to 117 ft^2 per acre). Hemlock increased 46% (from 35 to 51 ft^2 per acre); cedar increased 89% (from 19 to 36 ft^2 per acre). Douglas-fir basal area per acre actually decreased beyond the threshold 20%.

Combined conifer basal area on the Wolf Creek buffer strip increased by 25%, but this was only from four to five ft^2 per acre, the lowest of any site for INTCLS 2. Only western redcedar was present.

Four sites (5-Cook, 6-Deer, 9-Lost, and 15-Winberry) have not experienced INTCLS 2 combined conifer basal area per acre changes ≥20% since the time of Steinblums' (1978) study. Density dynamics illustrated in Figure 7 support this finding.

Combined conifer basal area per acre in the Cook Creek buffer strip decreased by only three percent of the 1977 value (from 101 to 98 ft^2 per acre). One tree per acre from each of the three species was missing in the 1990 study; with the exception of western hemlock, basal area values were within two ft^2 per acre of their previous value. Douglas-fir basal area in 1977 and 1990 (77 and 79 ft^2 per acre) contributed most to INTCLS 2 combined conifer basal area.

In the Deer Creek buffer strip, 1977 INTCLS 2 combined conifer basal area decreased 11% (from 213 to 190 ft^2 per acre). The western hemlock contribution decreased 30% (from 99 to 69 ft^2 per acre). Western redcedar basal area actually increased 14% (from 14 to 16 ft^2 per acre). Douglas-fir basal area increased five percent (from 100 to 105 ft^2 per acre).

The Lost Creek buffer decreased combined conifer basal area per acre nine percent (from 87 to 79 ft^2 per acre) by 1990. While western hemlock and Douglas-fir both diminished in their contribution since the 1977 tally, western redcedar basal area per acre increased. However, the density values (Figure 7) show two more western redcedar per acre being tallied in 1990 than in 1977.

The additional tree per acre measured in the Winberry Creek buffer translated into 12 additional ft^2 per acre of basal area in 1990 than 1977. Basal area increases were evident in both western redcedar (from four to nine ft^2 per acre) and Douglas-fir (from 7 to 13 ft^2 per acre). Western hemlock basal area decreased since the earlier study (from 23 to 16 ft^2 per acre). All totaled, combined conifer basal area increased 12% (from 34 to 38 ft^2 per acre) in 1990.

Dynamics of INTCLS 2 can be used to assess current, and to some degree, future condition of a buffer strip and associated stream channel. The basal area shifts in INTCLS 2 differ greatly from the previous two classes.

Overall losses in density and basal area are more prevalent in INTCLS 2, occurring on 56% of the sites. Trees in this class tend to be the tallest in the buffers, based on Steinblums' (1978) study. Although INTCLS 2 is dominated from a basal area standpoint by Douglas-fir, western hemlock seems more susceptible to blowdown.

Basal area-trees ≥45 inches DBH

The basal area of LGCLS combined conifers (Table 13 and Figure 13) is stunning; basal area is more than for any other class even though densities are the lowest (Figure 8(a)). Average basal area per acre in 1977 was 128 ft^2 per

Table 13. Basal area (BA/AC) of conifers ≥45 inches DBH (LGCLS) in 1977 and 1990, and percent of 1977 value remaining (REM) in resampled Willamette National Forest buffer strips.

SITE	1977 CC BA/AC (ft^2/ac) [a]	1990 CC BA/AC (ft^2/ac)	REM (%) [e]	1977 WH BA/AC (ft^2/ac) [b]	1990 WH BA/AC (ft^2/ac)	REM (%)	1977 WC BA/AC (ft^2/ac) [c]	1990 WC BA/AC (ft^2/ac)	REM (%)	1977 DF BA/AC (ft^2/ac) [d]	1990 DF BA/AC (ft^2/ac)	REM (%)
1. Black	94	124	132	0	0	NA [f]	17	42	247	77	82	106
2. Blowout	173	115	66	21	0	0	79	66	84	73	49	67
3. Cadenza	0	0	NA	0	0	NA	0	0	NA	0	0	NA
4. Canal	146	64	44	21	15	71	0	0	NA	125	49	39
5. Cook	68	72	106	0	0	NA	0	6	NA	68	66	97
6. Deer	93	74	80	10	0	0	0	0	NA	83	74	89
7. Hardy 1	111	85	77	0	0	NA	7	16	229	104	69	66
8. Hardy 2	222	242	109	28	37	132	0	0	NA	185	205	111
9. Lost	244	308	126	32	0	0	0	0	NA	212	308	145
10. Owl	97	16	16	0	0	NA	0	0	NA	97	16	16
11. Perdue	279	199	71	0	0	NA	14	12	86	265	187	71
12. Rider	52	59	113	0	0	NA	0	0	NA	52	59	113
13. Tidbits	188	138	73	0	10	NA	0	0	NA	188	128	68
14. Two Girls	99	91	92	25	55	220	0	0	NA	74	36	49
15. Winberry	158	74	47	18	0	0	0	0	NA	140	74	53
16. Wolf	30	12	40	13	12	92	0	0	NA	17	0	0
Average	128	104		11	8		7	9		110	87	

[a] CC = Combined conifers
[b] WH = western hemlock
[c] WC = western redcedar
[d] DF = Douglas-fir
[e] REM = percent of 1978 value remaining
[f] NA = Not appropriate

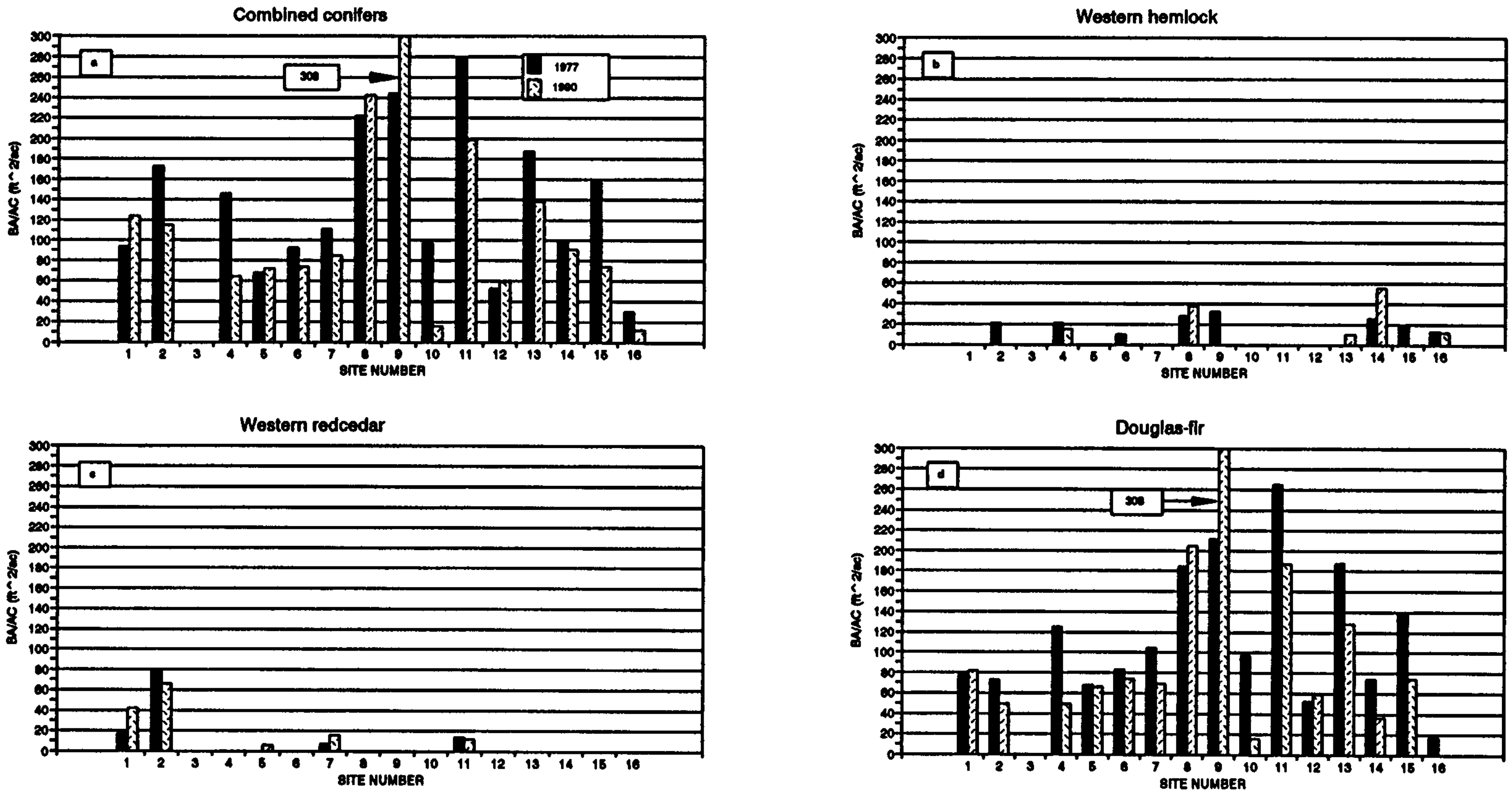


Figure 13. Basal area (BA/AC) of conifers ≥45 inches DBH (LGCLS) in 1977 and 1990 in resampled Willamette National Forest buffer strips.

acre, while in 1990 it had been reduced to 104 ft^2 per acre (-19%).

Even though these trees obviously contribute the most to basal area; they are also most likely to be mismeasured due to their size. One of these trees can translate into quite a discrepancy in basal area; the problem is magnified if several trees have been measured imprecisely.

Figure 13(a) reveals nine sites (2-Blowout, 4-Canal, 6-Deer, 7-Hardy 1, 10-Owl, 11-Perdue, 13-Tidbits, 15-Winberry, and 16-Wolf) that have shown a decrease in basal area per acre by ≥20% of the 1977 levels. Douglas-fir is the largest contributor to basal area, but perhaps also most prone to blowdown (Figure 13(d)). Most of these (all but Blowout, Winberry, and Wolf) also had decreased basal area in INTCLS 2. Of the nine showing reductions in LGCLS basal area, three (Perdue, Tidbits, and Wolf) did not show a corresponding decrease in density (Figure 8(a)), suggesting differences in measurement or measurement of different trees.

The Blowout Creek buffer strip lost 34% of the original LGCLS basal area (from 173 to 115 ft^2 per acre). All the hemlock previously on site (21 ft^2 per acre) was downed by 1990. Western redcedar basal area per acre was reduced somewhat (<20%) and Douglas-fir basal area decreased by 33% (from 73 to 49 ft^2 per acre), but by only one tree per acre. This buffer still has a total of 115

ft^2 per acre contributed by the seven trees per acre ≥45 inches DBH still standing.

LGCLS basal area in the Canal Creek buffer strip was reduced 56% (from 146 to 64 ft^2 per acre). Hemlock decreased by 29% (from 21 to 15 ft^2 per acre) and Douglas-fir decreased 61%, (from 125 to 49 ft^2 per acre). There was no western redcedar in this size class. While the change in western hemlock is believable, the decrease in Douglas-fir is questionable. Figure 8(d) shows that only one tree per acre has been lost, yet the basal area per acre has decreased by 76 ft^2 per acre. Obviously, some discrepancies have occurred.

LGCLS basal area in the Deer Creek buffer strip was reduced 20% (from 93 to 74 ft^2 per acre). Ten ft^2 per acre of western hemlock tallied in 1977 were gone by 1990. There was no western redcedar present for either study. Douglas fir basal area per acre decreased by 11%, (from 83 to 74 ft^2 per acre).

The Hardy 1 buffer strip did have some blowdown in this size class, with basal area decreasing 23% (from 111 to 85 ft^2 per acre). There was no hemlock in this diameter class. LGCLS basal area resulting from western redcedar actually shows an increase of 129% (from 7 to 16 ft^2 per acre), though the density (one tree per acre) did not change, making this result suspect. Douglas-fir has been reduced 34%, (from 104 to 69 ft^2 per acre).

This decline resulted from a loss of only two trees per acre.

Decreases in LGCLS basal area in the Owl Creek buffer strip are the most dramatic of any site. Only 16% of the original buffer basal area per acre was standing by 1990 (from 97 to 16 ft^2 per acre). This tremendous reduction occurred exclusively in Douglas-fir. No western hemlock or western redcedar was present on the site at either point in time.

The Perdue Creek buffer strip, which had a slight LGCLS density reduction shows a combined conifer basal area per acre decrease of 29% (from 279 to 199 ft^2 per acre), resulting from a decrease of only two trees per acre (from 17 to 15). Douglas-fir basal area per acre was reduced 29% (from 265 to 187 ft^2 per acre). Western hemlock wasn't present in this size class, and the reduction in western redcedar basal area was within the tolerance threshold.

Site 13 (Tidbits) shows a LGCLS basal area decrease of 27%, (from 188 to 138 ft^2 per acre). Ten ft^2 per acre of western hemlock in this diameter class tallied in the current study that was unaccounted for in 1977. Western redcedar was not a component at either point in time. Douglas-fir was reduced 32% (from 188 to 128 ft^2 per acre) by 1990. This loss resulted from two fewer trees per acre (from ten to eight trees).

LGCLS basal area in the Winberry Creek buffer strip decreased 53% (from 158 to 74 ft^2 per acre). Eighteen ft^2 per acre of western hemlock present in 1977 was gone by 1990. There was no western redcedar on this site. Douglas-fir basal area per acre decreased 47% (from 140 to 74 ft^2 per acre) by 1990.

Two sites (1-Black and 9-Lost) showed more LGCLS basal area per acre in 1990 than in 1977. Basal area on Black Creek has increased 32% (from 94 to 124 ft^2 per acre). The Lost Creek buffer strip showed a 26% increase in basal area per acre (from 244 to 308 ft^2 per acre), resulting from an additional five Douglas-fir per acre (from 11 to 16 trees per acre). Obviously, more trees were measured for the current study.

Four sites (5-Cook, 8-Hardy 2, 12-Rider, and 14-Two Girls) have not changed LGCLS basal area within the threshold tolerance, indicating some degree of stability for these sites between the two studies. However, overstory density on all these sites has increased over the 1977 value, making the results difficult to interpret.

LGCLS basal area in the Cook Creek buffer strip was relatively stable not only in LGCLS, but also in INTCLS 2 (Figure 12(a)). In LGCLS, there was six ft^2 per acre (one trees per acre) of western redcedar that was measured in 1990 which was unaccounted for in 1977. Basal area for Douglas-fir, the only other species in this size class, barely changed between the two studies (from 68 to 66 ft^2 per acre).

The Hardy 2 buffer strip had four additional trees per acre (from 10 to 14 trees per acre) in 1990. Assuming diameter measurements differed on several trees, it's not unbelievable that even with additional trees being tallied, the basal area estimate has not significantly changed. Density changes on this site resulted solely from differences in Douglas-fir (from 8 to 12 trees per acre). There was no western redcedar in this size class. The basal area summary reveals western hemlock basal area increased 32%, (from 28 to 37 ft^2 per acre), while Douglas-fir increased <20% (from 185 to 205 ft^2 per acre). The additional basal area for combined conifers includes a snag that had no species designation in the earlier study; thus the sum of totals by species is 213 ft^2 per acre.

Basal area on the Rider Creek buffer strip did increase, but only slightly (from 52 to 59 ft^2 per acre). Density increased from four to five trees per acre, all Douglas-fir.

Though LGCLS combined conifer basal area per acre in the Two Girls buffer strip has not significantly changed (from 99 vs 91 ft^2 per acre) since the original study, individual species have undergone drastic shifts. Western hemlock basal area per acre increased 120% (from 25 to 55 ft^2 per acre). Density changes for this species increased

100% (from two to four trees per acre). Conversely, Douglas-fir basal area was reduced 51% (from 74 to 36 ft^2 per acre). This could be a case of mistaken identity; in 1977 there were two hemlock and three Douglas-fir per acre. In 1990 this was almost reversed; there were four hemlock and two Douglas-fir per acre.

In summary, LGCLS is dominated by late successional Douglas-fir. Western hemlock is a minor component on several sites, as is western redcedar. Average 1990 basal area per acre by species is 8 ft^2 per acre (western hemlock), 9 ft^2 per acre (western redcedar), and 87 ft^2 per acre (Douglas-fir). The dynamics of this class indicate a substantial difference from the previous class. Undoubtedly, Douglas-fir is the dominant contributor, both in prevalence and magnitude. It also was the species with the most frequent decrease in basal area, suggesting it, and not western hemlock (as in LGCLS 2), is most prone to windthrow. Basal area reductions ranged from the threshold 21% to 100% of the original value. However, because these trees are probably the oldest, their dynamics might be a combination of natural mortality and stand configuration coupled with topographic exposure and site characteristics that makes them more susceptible to windthrow. With the exception of two sites (Cadenza and Wolf), there is still one Douglas-fir per acre in this size class on all sites (Figure 8(d)).

Trees in LGCLS that were windthrown tended to be shallow-rooted, but were not limited to streamside terraces, based on field observation. Figure 13(a) and Appendix A2 indicates that losses were common throughout the study area, and not restricted to the higher elevation or wetter locations. A more thorough investigation of individual sites may reveal unique attributes and conditions that have lead to these dynamics.

Density and basal area have now been assessed on all sites, for the four diameter classes, showing aggregate composition and a summary by species, at two points in time. This investigation provides a conceptual framework for analyzing dynamics of these late successional buffers. Problems inherent in the study precluded rigorous statistical comparisons, but some general trends have become apparent in these four diameter classes.

Vigor dynamics

The previous discussion of these western Cascades buffer strips has helped to describe their overstory dynamics since Steinblums' (1978) study. Stand vigor is an additional characteristic that relates to overall changes in these buffers.

Overstory vigor was summarized for the field inventory of both studies (Table 14). For the 1977 inventory, categories evaluated were dying (DY), dead (DD), and snags (SN). Dead trees were those with most branches, including

Table 14. Density (TPA) of conifer vigor classes in 1977 and 1990: [dying (DY), dead (DD), snags (SN) and broken tops (BT)] using trees ≥10 inches DBH in Willamette National Forest buffer strips.

SITE	1977 TPA (#/ac)	1990 TPA (#/ac)	SITE	1977 TPA (#/ac)	1990 TPA (#/ac)
1. Black			9. Lost		
DY	1	2	DY	0	0
DD	2	1	DD	1	0
SN	1	3	SN	1	4
BT	-	1	BT	-	1
2. Blowout			10. Owl		
DY	0	2	DY	3	1
DD	0	0	DD	1	0
SN	1	4	SN	4	5
BT	-	2	BT	-	0
3. Cadenza			11. Perdue		
DY	2	6	DY	4	3
DD	0	2	DD	0	0
SN	0	0	SN	4	10
BT	-	0	BT	-	7
4. Canal			12. Rider		
DY	1	0	DY	0	0
DD	1	0	DD	1	0
SN	4	6	SN	0	5
BT	-	1	BT	-	0
5. Cook			13. Tidbits		
DY	9	6	DY	3	0
DD	1	0	DD	1	0
SN	0	5	SN	2	5
BT	-	2	BT	-	2
6. Deer			14. Two Girls		
DY	3	1	DY	1	0
DD	1	0	DD	1	0
SN	0	1	SN	0	2
BT	-	2	BT	-	2
7. Hardy 1			15. Winberry		
DY	3	0	DY	0	1
DD	1	0	DD	0	1
SN	0	1	SN	3	2
BT	-	0	BT	-	0
8. Hardy 2			16. Wolf		
DY	2	2	DY	14	0
DD	0	0	DD	2	0
SN	2	11	SN	1	11
BT	-	1	BT	-	3

DY = Dying SN = Snag
DD = Dead BT = Broken top

Fluctuations in density of dead trees follow expected trends. Sixty three percent of the sites showed decreases in the number of standing dead trees since the earlier study. Only 13% of the sites showed increases in dead trees; 24% of the sites showed no change.

The most likely explanation for decreases in the number of standing dead trees is blowdown, though it is inappropriate to suggest these trees would necessarily blow down prior to live trees. The live trees, having functioning root systems should be more likely to remain upright during extreme events than their standing dead counterparts, though windfirmness may be jeoprodized by the live crown. Obviously, site characteristics, tree species, and the root mass function interactively. Without a more complete system of tracking dynamics, firm conclusions cannot be made.

Increases in the number of dead trees occurred on only two sites, both of which showed increases in the number of dying trees. These trees could be likely candidates for blowdown in the near future, continuing to add large woody debris to the riparian management zone.

Twenty-five percent of the sites showed no change in the number of standing dead trees over time. Half of these had not changed in the number of dying trees either.

Density-snags (whole and broken) -- Snag dynamics show the most changes since Steinblums' study. Fourteen sites have shown increased numbers of snags; while one has decreased and one has remained unchanged. Attempts to correlate logging damage with number of snags using linear regression was unsuccessful.

It was actually somewhat surprising that there were not more widespread decreases in snags. These trees would presumably be most likely to be windthrown. From the few studies investigating rates of snag fall, Harmon et al. (1986) estimate the lag time for snags to begin falling at less than 20 years. However, it's possible that some of the decreases revealed in the dead tree data have translated to increases in the number of snags, masking dynamics to some extent.

Density-broken tops -- Live green trees with broken tops were not recorded on all sites for the 1978 study, but were included for the current study. These trees are obviously unique in their function over time. Having exposed tops, they are more likely to succumb to rot and other decay problems. Clearly, trees with broken tops lose their commercial value, but may become nesting sites for birds, and with the passage of time, presumably will more quickly become incorporated into the large woody debris on site. Of the 16 sites inventoried, 11 had at least one tree per acre in this category.

Summary-vigor classes -- In summary, half the sites have shown a decrease in the number of dying trees, while the remaining sites are equally split between increases in dying trees or no change. These trees could conceivably have moved into either the dead or snag categories since the earlier study. Overlaying new mortality with this movement could increase numbers of dying trees on some sites. The gains and losses may balance each other out and reveal no change in the density of dying trees on some of the other sites.

Dead tree densities are consistently on the decline on most of these buffers. Assuming windthrow is most likely to affect trees without functioning root systems, it is plausible that some of the dead trees initially inventoried have been windthrown since Steinblums' (1978) study. The increases in dead trees that have occurred on a couple of sites are not anomalies; natural mortality is still occurring in these late successional stands.

Numbers of snags per acre have increased on almost all sites. Perhaps a more detailed analysis of snag dynamics would be helpful to ascertain exactly why there has been such widespread increase in snags on these sites. Assuming trees without functioning root systems will begin to fall within 20 years (Harmon et al. 1986), many sites have potential for large woody debris recruitment in the relatively near future.

Information collected on trees with broken tops does not reflect changes *per se*, but is a stand dynamic that should be considered when designing riparian management areas. Over time, the trees will be incorporated into the other vigor classes so they must be accounted for in any stand level prescription designed with long-term objectives in mind.

Large woody debris

The discussion thus far has centered on standing trees. There has been considerable speculation, based on these dynamics, about mortality and windthrow. An additional item of importance on these sites is the dynamics of large woody debris (LWD).

The function of LWD has been researched extensively over the past several years. For decades, the big question was whether trees were standing or downed. As a means of assessing LWD position and function, Robison and Beschta (1990b) developed a simple model for depicting where in the channel wood is located (Figure 14).

Although it was outside the scope of this study to quantify stream debris loadings, an ocular estimate of the percentage of LWD volume in each of the four functional zones (Robison and Beschta 1990b) was made. This was further subdivided into "old" (before the 1990 storms) and "new", (that which was a result of the 1990 storms) (Table 15).

Estimates of LWD in Zone 1 range from 5 to 20%. The majority of these streams are first or second order

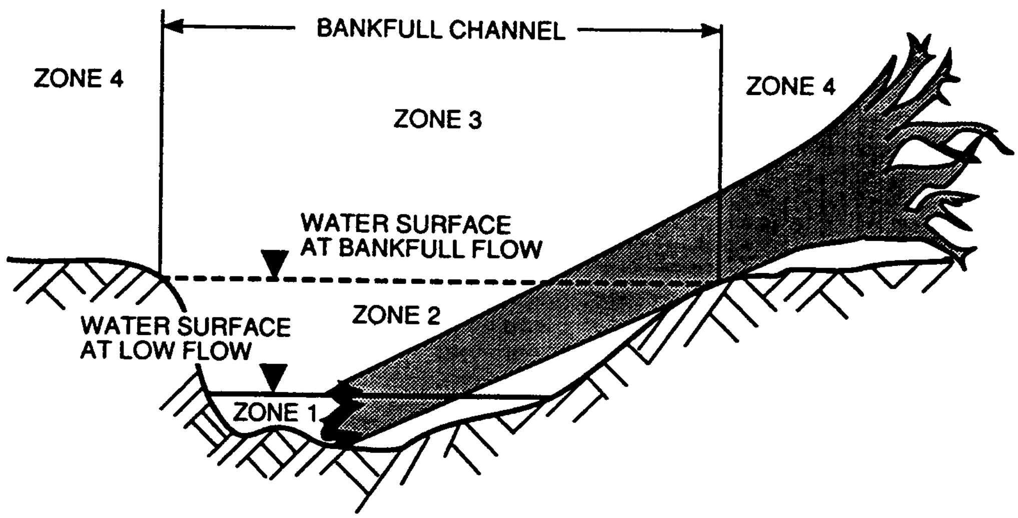


Figure 14. Functional zones (from Robison and Beschta 1990b) used in describing large woody debris (LWD) distribution in Willamette National Forest buffer strips.

Table 15. Summary of woody debris volume percentages (VOLUME) occupying influence zones (Robison and Beschta, 1990b), and percent resulting from 1990 storms (NEW) in Willamette National Forest buffer strips.

SITE (ZONE #)	VOLUME (%)	NEW (%)	SITE (ZONE #)	VOLUME (%)	NEW (%)
1. Black			9. Lost		
1	15	<5	1	20	0
2	20	<5	2	15	0
3	15	<5	3	5	0
4	50	<5	4	60	10
2. Blowout			10. Owl		
1	5	0	1	15	<5
2	10	<5	2	20	<5
3	0	-	3	20	5
4	85	10	4	45	10
3. Cadenza			11. Perdue		
1	10	<5	1	10	10
2	10	5	2	10	20
3	35	70	3	30	40
4	45	70	4	50	50
4. Canal			12. Rider		
1	5	10	1	20	10
2	10	15	2	25	25
3	25	15	3	20	50
4	60	40	4	35	40
5. Cook			13. Tidbits		
1	5	5	1	15	10
2	20	10	2	20	15
3	10	5	3	10	0
4	65	20	4	55	10
6. Deer			14. Two Girls		
1	20	10	1	5	10
2	20	5	2	10	15
3	5	5	3	5	15
4	55	15	4	80	15
7. Hardy 1			15. Winberry		
1	15	10	1	5	5
2	10	10	2	20	5
3	10	75	3	15	0
4	65	10	4	60	10
8. Hardy 2			16. Wolf		
1	10	<5	1	5	<5
2	20	<5	2	10	<5
3	0	-	3	5	0
4	70	<5	4	80	20

1 = Low flow zone
2 = High flow zone
3 = Spanning channel
4 = All other locations

channels at the buffer location. For woody debris to be in this zone it would either have to be anchored with part of it extended into the low flow zone, or it would have to be small enough to fit into the channel. Not surprisingly, percent contributed by the 1990 storms was minimal, ranging from zero to ten percent.

New LWD contributions were more often found in regions of high flow, Zone 2. The percent of LWD volume in this zone ranged from 10 to 25. Estimates of percentage contributed by the 1990 storms varied from <5 to 25%. Much of this wood was located on floodplains and point or channel bars; the rest of it resulted from trees anchored on the streambank and extending diagonally into the stream.

Often times trees falling in the riparian zone span the channel (Zone 3). Though they will eventually be incorporated in the channel, they often are initially out of the path of water flow. Some stems anchored on the streambank may also have a portion of the wood in this area. On these Cascade sites, estimates of the percent of the LWD volume in this zone ranged from 0 to 35%. Recent additions were estimated between 0 and 75%.

For this project, the definition of Zone 4 was expanded to include all LWD in locations other than those previously discussed (not only material with a portion in Zones 1, 2, or 3). This is wood that is unlikely to enter the stream without modifications to the buffer. The vast majority of downed wood was in this area, with percent of LWD volumes ranging from 35 to 85%. The 1990 storms were responsible for <5 to 70% of the wood in this zone.

Estimates of the percentage of LWD volume in each of the four influence zones are somewhat limited without quantification of actual volumes. However, general trends of spatial orientation are evident from these numbers. The percentage of LWD in Zones 1 and 2 averaged 27%, but this is relative to the total downed wood. However, it is this wood in these zones that is also responsible for reducing stream power and influencing geomorphic channel features. On average, approximately 13% of the LWD volume was poised over the channel (Zone 3). Over the next century, this wood will become incorporated with the stream and serve to replace some of the wood currently in Zones 1 and 2, as it decays and is moved through the system. On average, 60% of the downed wood in these buffers is in Zone 4, outside any of the zones influencing the channel directly. These are not typically landslide-prone sites; the possibility of this wood interacting with the channel is minimal.

It follows intuitively that dynamics of LWD in these sites is cyclic in nature. By tracking downed wood in the four influence zones, the importance of riparian conifers is highlighted. It would also be advisable to look at source distances (McDade et al. 1990) for LWD on these sites. A "continuous" supply of conifers within range of the channel is necessary to ensure periodic inputs of LWD that will actually interact with these systems.

Conifer regeneration

Research in the Coast Range indicates that many sites are either losing their coniferous component, or that they historically had a very sparse conifer component (Hibbs 1987; Andrus and Froehlich 1990a). In an effort to collect preliminary data about Cascade buffer strips, established conifer regeneration (<8 inches DBH and ≥3 feet tall) was sampled on all revisited sites.

Established conifer regeneration will help to ensure that these buffer strips have a coniferous component over time. The characteristics and functions of buffers outlined in the literature review to some extent depend on an ongoing supply of conifers.

Although two classes (trees between three and five feet tall, and trees over five feet tall, both under eight inches DBH) were utilized when collecting the data, they were combined for this discussion. Saplings over three feet tall are well established and can be considered a viable source of future conifers in these buffers.

Average density data suggest that these western Cascade buffer strips are not lacking in conifer regeneration, and are typically "well stocked" (Table 16). Values reflect densities of western hemlock, western redcedar, and Douglas-fir only. It should be noted that on

Table 16. Average established conifer regeneration density (TPA) in 1990 by site and species in Willamette National Forest buffer strips.

Site (Area sampled-ac)	Hemlock TPA (#/ac)	Cedar TPA (#/ac)	Douglas-fir TPA (#/ac)	Total TPA (#/ac)
1. Black (0.086)	325	93	58	476
2. Blowout (0.082)	902	86	171	1159
3. Cadenza (0.017)	177	0	0	177
4. Canal (0.113)	332	0	89	421
5. Cook (0.083)	325	132	229	686
6. Deer (0.066)	409	45	30	484
7. Hardy 1 (0.085)	1565	1035	1000	3600
8. Hardy 2 (0.062)	537	0	67	604
9. Lost (0.035)	257	143	400	800
10. Owl (0.045)	66	0	292	358
11. Perdue (0.057)	772	123	439	1334
12. Rider (0.049)	612	122	143	877
13. Tidbits (0.068)	755	0	147	902
14. Two Girls (0.072)	1236	166	500	1902
15. Winberry (0.080)	1311	276	302	1889
16. Wolf (0.051)	255	138	20	413
Average	615	147	243	1005

sites 3 and 8 (Cadenza and Hardy 2), Pacific silver fir regeneration also contributed to the stand. In addition, even though it was not used in the analysis, Pacific yew regeneration was tallied. Area sampled is the sum of the sampled (6 ft X 10 ft) plots, rounded to the nearest 1/1000 of an acre.

Several sites (4-Canal, 8-Hardy 2, 10-Owl, 13-Tidbits, and 15-Winberry) had buffers on both sides of the stream, at least for some portion of the inventoried reach. On these sites, the average value reflects the average of the two sides.

The contribution of each of the three coniferous species is indicated by different fill patterns (Figure 15). Numbers above the bars signify the percentage of conifers per acre ≤80 feet (horizontal distance) of the bankfull stream channel. These trees have the greatest opportunity as shade-bearing conifers (Brazier and Brown 1973; Steinblums 1978), and for large woody debris recruitment to the channel (McDade et al. 1990).

Total average conifers per acre in the buffers range from 177 to 3600 (average = 1005) trees per acre. Site 7 (Hardy 1) was especially well stocked with 3600 trees per acre. If this site is considered an outlier, the mean average conifers per acre is reduced to 832 trees per acre. The graph indicates that western hemlock is the predominant regeneration species in the buffers, suggesting

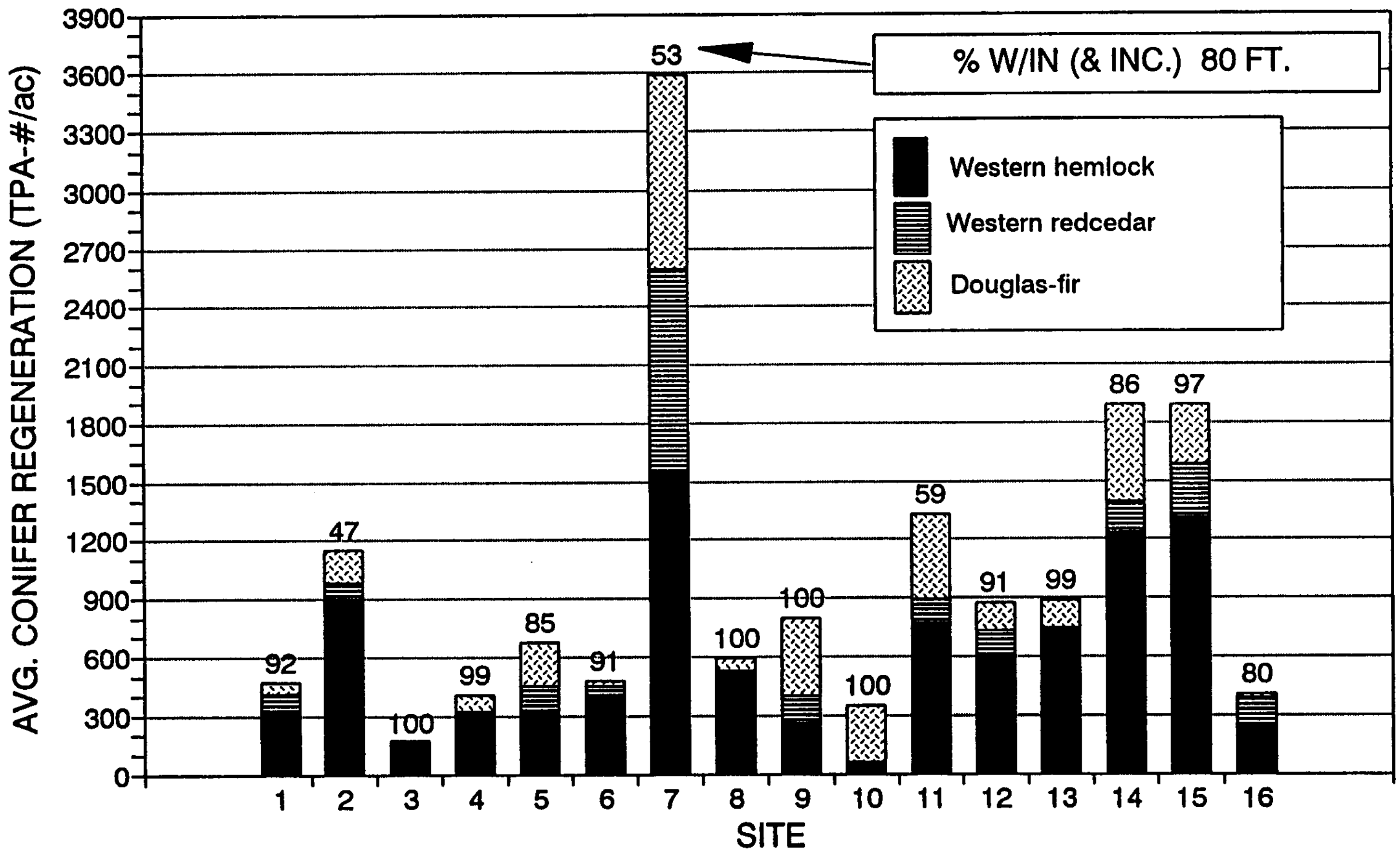


Figure 15. Average established conifer regeneration density (TPA) by site, and percentage of value within 80 ft (HD) of bankfull channel width in Willamette National Forest buffer strips.

regeneration is from natural sources rather than planted stock. Average number of western hemlock is 615 trees per acre. Average density of western redcedar is 147 trees per acre, while Douglas-fir averaged 243 trees per acre.

Regression analysis, used to investigate relationships between stocking and distance from the stream was only somewhat successful. A statistical correlation ($\alpha = 0.10$) was evident on only six (1-Black, 5-Cook, 6-Deer, 14-Two Girls, 15-Winberry, and 16-Wolf) buffer strips. Mean average stocking on these sites ranged from 476 to 1889 trees per acre (Table 16). The fit of the regression equations varied considerably; the coefficient of determination (r^2) ranged from 0.16 to 0.61. In all cases, the slope of the regression line was negative, indicating that density was greatest closer to the stream and decreased across the width of the buffer. It should be noted that for these analyses, densities are weighted by number of samples at a given distance (Figure 16). Because the cumulative area sampled further away from the stream was typically smaller, areal densities may be somewhat inflated.

Possible explanations for why density may be correlated with horizontal distance from the stream include a soil water relationship that varies with distance from stream, different geomorphic surfaces, competition from

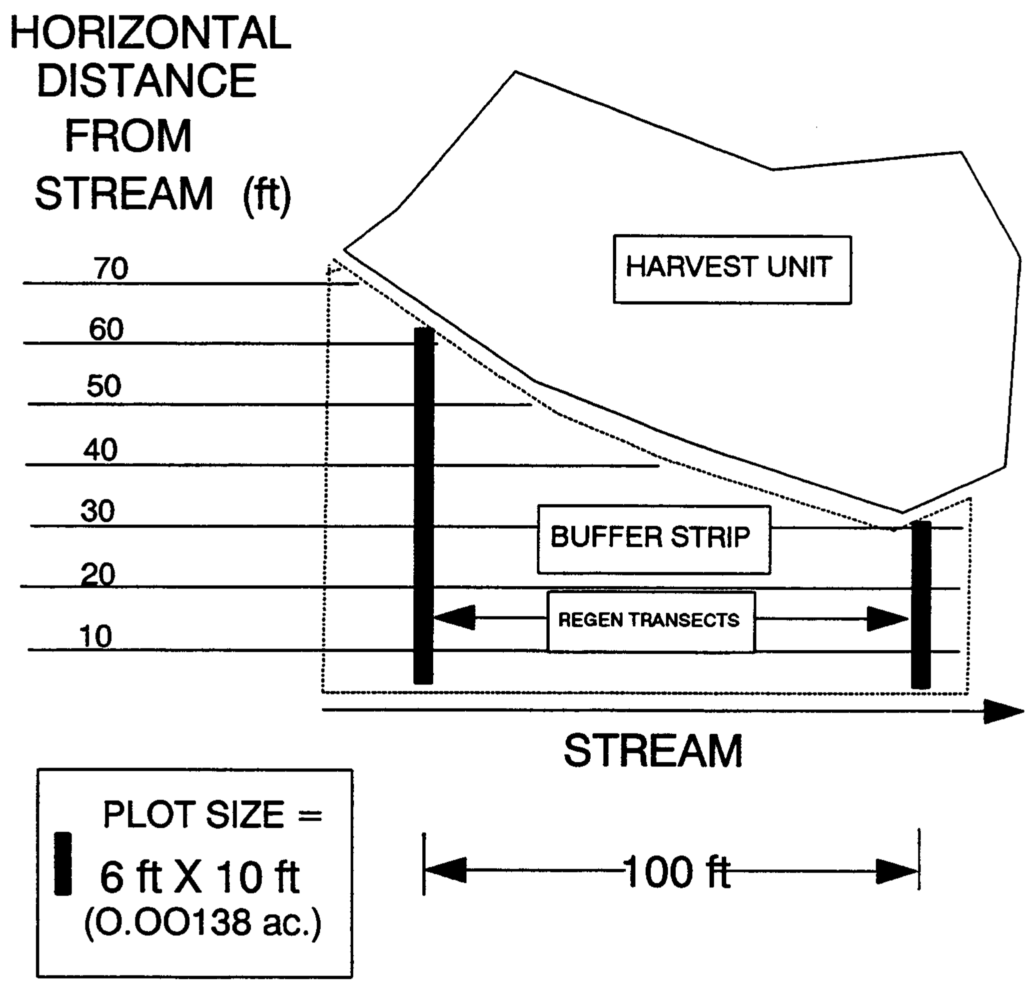


Figure 16. Planimetric schematic of buffer strip regeneration sampling. Note two sampling points for distances within 30 ft of the stream and only one sample point for distances beyond 30 ft.

understory vegetation, blowdown patterns, slope and aspect, and overstory composition.

Although terrain profiles were recorded for the regeneration tallies, geomorphic (ie. terraces vs hillslopes) surfaces were not analyzed for differences in regeneration. Percent of understory vegetation was not formally quantified. If there has been an increase in understory vegetation as a result of harvesting the adjacent hillslopes, presumably increases in understory cover would be found closest to the unit, where increased light levels would be greatest. Hibbs (1987) has documented this in the Coast Range, but it has not been investigated in the Cascades.

Blowdown, a natural disturbance mechanism in the Oregon Cascades, was not specifically investigated relative to its affect on regeneration. Though they were not tallied for this study, seedlings often were found in old blowdown sites where a seedbed had been prepared by the fallen tree.

Although the effect of slope was normalized to evaluate the effect of distance from the stream, it may play an important role in conifer establishment. Many of these streams had narrow floodplains at the base of steep slopes. On sites with poor soils or steep slopes, nurse logs often harbored much of the conifer (particularly hemlock) regeneration.

Regression analysis was used to determine a relationship between overstory variables and regeneration. No clear relationships emerged. Regeneration in these western Cascade buffers was not uniformly distributed. The patchy nature of the saplings seems to be an interactive function of overstory density and tree vigor. Some sites (2-Blowout, 4-Canal, 9-Lost, 11-Perdue, 13-Tidbits, 14-Two Girls, and 15-Winberry) contained substantial amounts of red alder and other hardwoods; much of this tended to parallel the stream. This too is likely to influence regeneration potential.

Average established conifer regeneration density values indicate these Cascade buffers have had a very different response to logging than their Coast Range counterparts. Hibbs (1987) warned of the potential for losing conifers altogether in logged buffers of the Coast Range. Riparian conifer densities of similar size saplings in unmanaged Coast Range stands revealed densities ranging from 8 trees per acre (valley floor) to 31 trees per acre (slopes) (Pabst, personal communication 1993). Giordano (personal communication 1993), inventoried Coast Range buffer strips and calculated average conifer regeneration densities of 43 trees per acre (conifer dominated sites). In alder dominated buffer strips, conifer densities averaged eight trees per acre.

A summary of individual plot data (Table 17) reveals

Table 17. Summary statistics of established conifer regeneration density (TPA)[(median (MED.), average (AVG.), standard deviation (STD. DEV.), and coefficient of variation (C.V.)] with horizontal distance (H.D.) from the stream.

NUMBER OF PLOTS		SUMMARY STATISTICS TPA (#/ac)			
H.D.(ft)	# PLOTS	MED.	AVG.	STD. DEV.	C.V.
0	118	0	1200	2800	2.3
10	118	0	1200	2700	2.3
20	112	0	1300	2900	2.2
30	96	0	1200	3000	2.5
40	91	0	1100	1900	1.7
50	81	0	800	1600	2.0
60	75	0	1000	1600	1.6
70	60	0	1100	1800	1.6
80	52	0	1200	2700	2.3
90	46	1000	1700	3100	1.8
100	42	0	1200	2600	2.2
110	34	0	800	1700	2.1
120	30	0	1900	4500	2.4
130	22	0	2000	5700	2.9
140	18	0	300	700	2.3
150	15	0	100	300	3.0
160	12	0	900	1700	1.9
170	4	0	300	400	1.3
180	4	1000	2000	2900	1.5
190	2	NA	1000	1000	1.0
200	2	NA	0	0	NA
TOTAL PLOTS 1,034					

the variation inherent in the discussion of average densities. Median values of zero and coefficients of variation (C.V.s) greater than one for nearly all distances underscore the variation evident on these sites. Differing sample sizes with distance from the stream also influence the validity and importance of average values. From these statistics, it becomes clear these buffer strips should more intensively sampled in the future.

The generally accepted belief that conifers will be lost from riparian buffer strips may not be universally applicable. While it would be advisable to further investigate these initial results from the Cascades, these data suggest these late successional buffers will have a source of conifers to benefit the stream and riparian zone well into the future.

Individual stream comparisons

The natural variation on these sites coupled with some of the measurement difficulties encountered may "dilute" the results previously discussed. While it is useful and interesting to try to identify trends in all buffers combined, variation between sites seems to preclude this in other than a general sense.

There is some utility in examining buffers on a stream by stream basis to identify changes and make projections about future stand conditions. Linking the components of the inventory (overstory, vigor, LWD, and conifer regeneration) with specific site characteristics would be the next step for researchers or land managers investigating linkages and mechanisms responsible for buffer strip dynamics.

Conifer density (trees per acre-TPA) in the Black Creek buffer strip (Figure 17) appears relatively stable over time. There has been some increase in the 10-14 inch DBH class, but little change in INTCLS 1. This dynamic suggests some ingrowth, but maybe a poorer quality site since few changes are reflected in INTCLS 1. Density has declined somewhat in INTCLS 2 conifers but there has been a subsequent increase in LGCLS. Higher than average densities in the two smaller DBH classes will provide a steady supply of conifers over time. Average stocking of established conifer regeneration in the Black Creek buffer strip was 475 trees per acre, seemingly sufficient to assure riparian conifers well into the next century. Black Creek has three trees per acre or less in each of the four vigor classes (DY, DD, SN, and BT). The LWD distribution (Table 15) indicates that each of the first three functional zones are occupied, but the majority of LWD is in Zone 4. The potential for future LWD on this site is tremendous due to unusually high densities of INTCLS 1 trees.

There has been a net gain of conifers resulting from changes in the smaller diameter classes in the Blowout

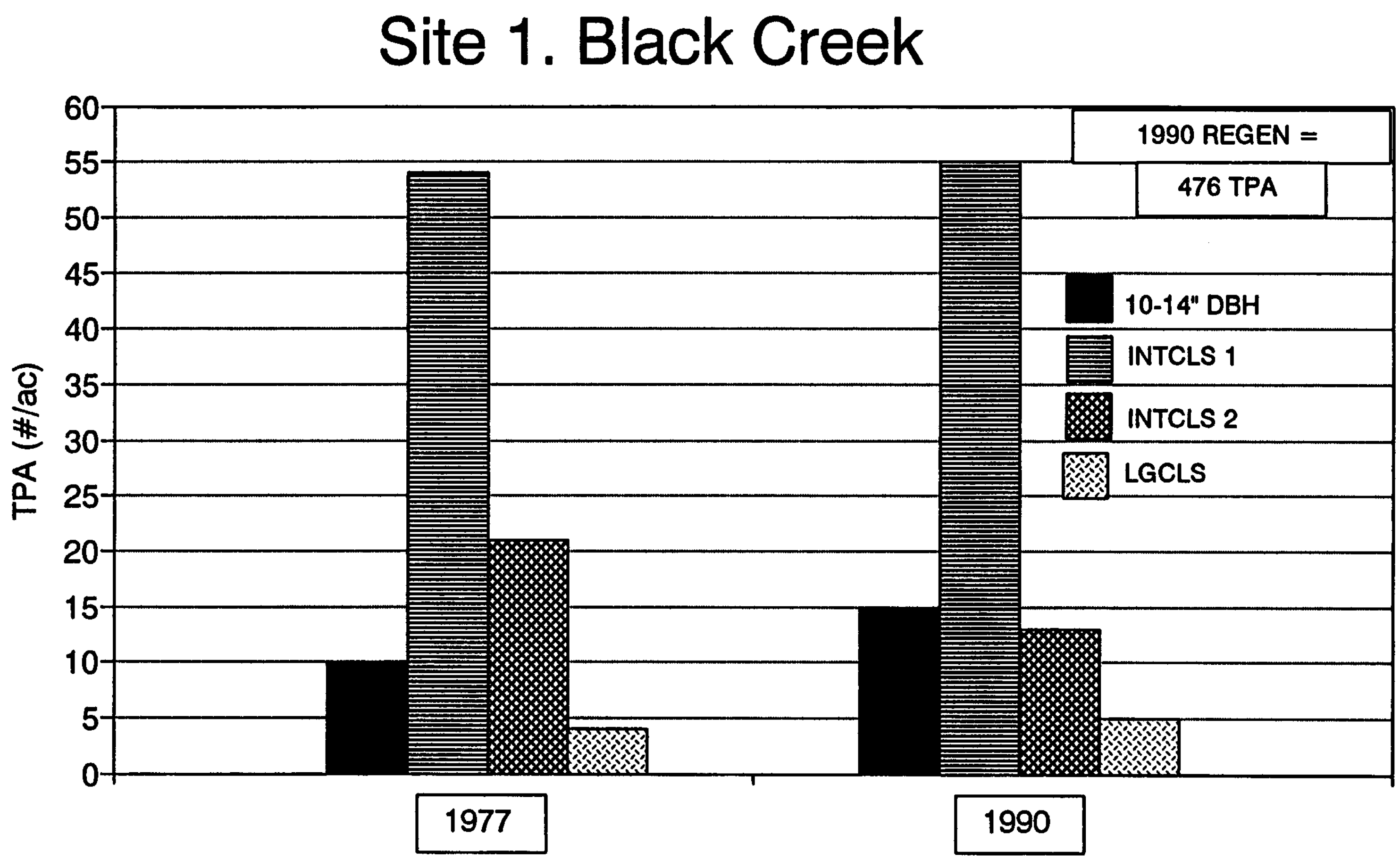


Figure 17. Density comparison of conifers (TPA) in Site 1 (Black Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

Creek buffer strip (Figure 18). All diameter classes are well represented; densities of the first three classes are above average. Even though there is an alder corridor paralleling the stream, the potential for regeneration seems adequate, averaging over 1150 trees per acre. Though there are not currently any dead trees in the sample area (Table 15), densities of dying trees and snags has increased since the 1978 study. There is relatively little LWD interacting with this channel (Table 16). However, at the buffer location, Blowout Creek is a third order stream, not as prone to the influence of LWD.

Of all reinventoried buffer strips, Owl Creek (Figure 19) showed the most density changes. All diameter classes show density decreases, signaling the potential for an overall decline of conifers in the buffer. The reduction in conifers of all diameters suggests no class is immune to blowdown. This is a high elevation (3800 ft), apparently unstable site. Average established conifer regeneration density was 358 trees per acre; compared to the overstory density of 28 trees per acre, it seems sufficient to supply conifers to this stand over time. Additional harvest units (visible in the 1990 Forest air photos) and wind eddies over the leading ridge may influence wind dynamics, making it difficult for this stand to establish itself as it once was, even at the time of Steinblums' inventory. Changes in the overstory composition of the Owl Creek buffer strip

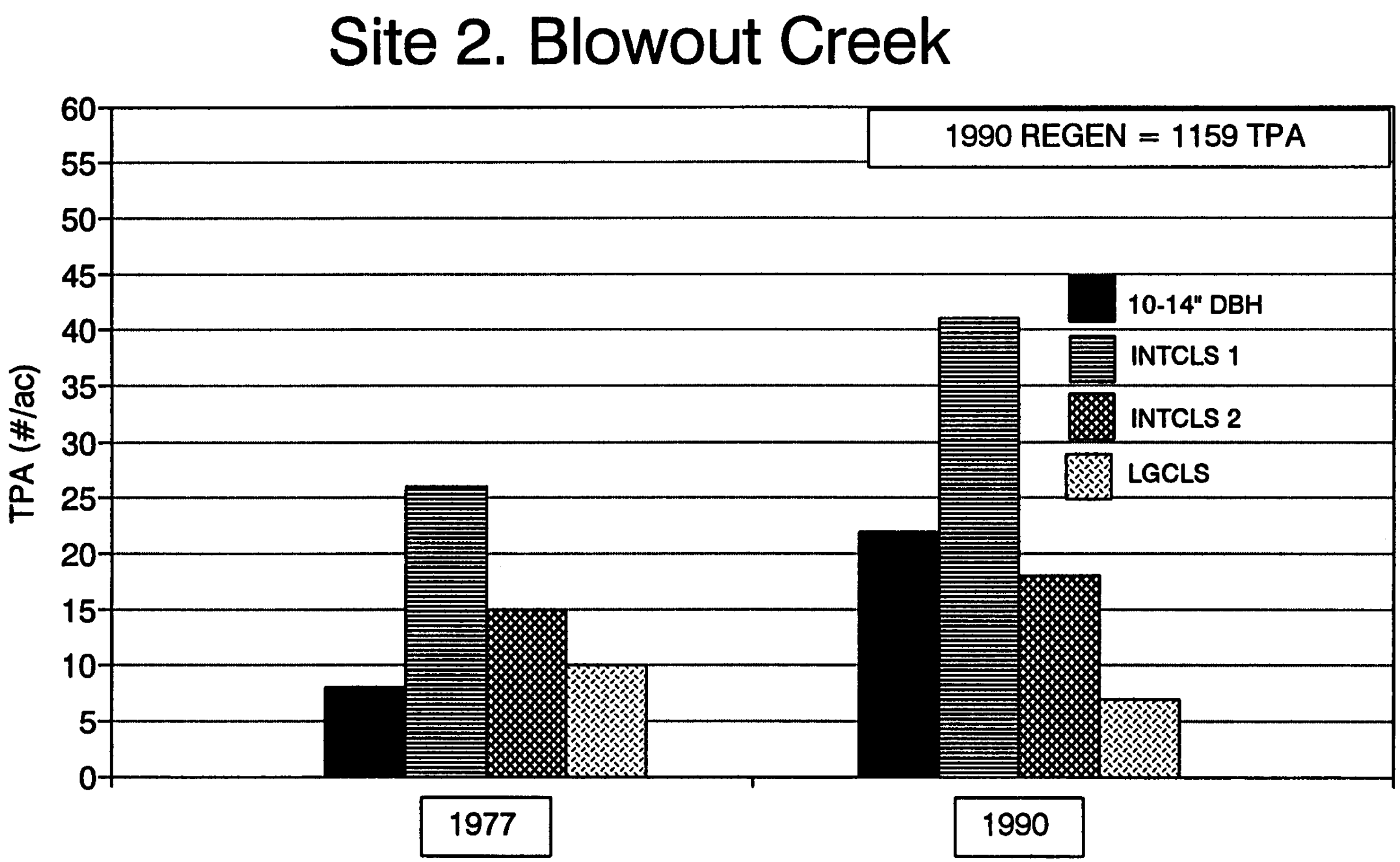


Figure 18. Density comparison of conifers (TPA) in Site 2 (Blowout Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

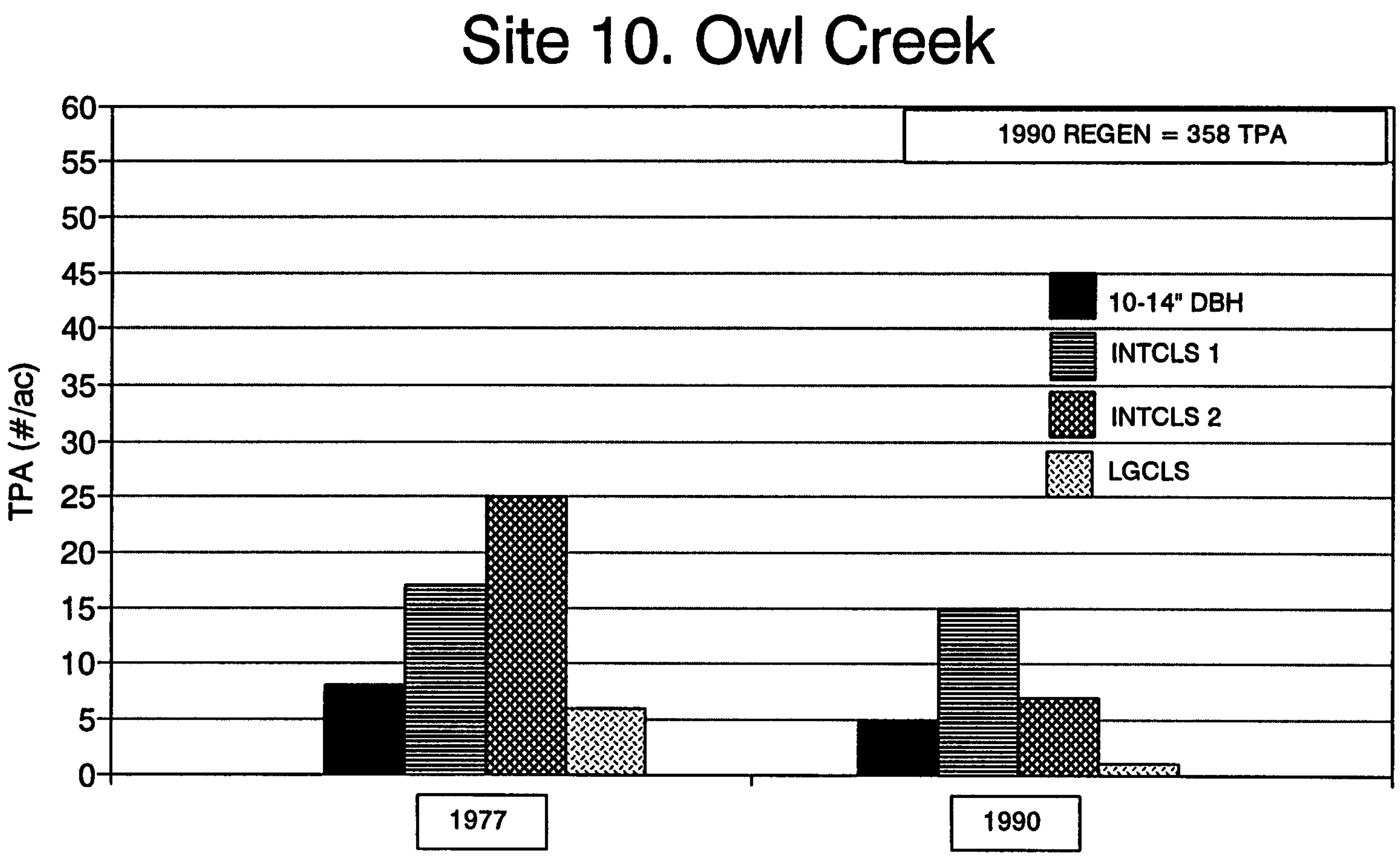
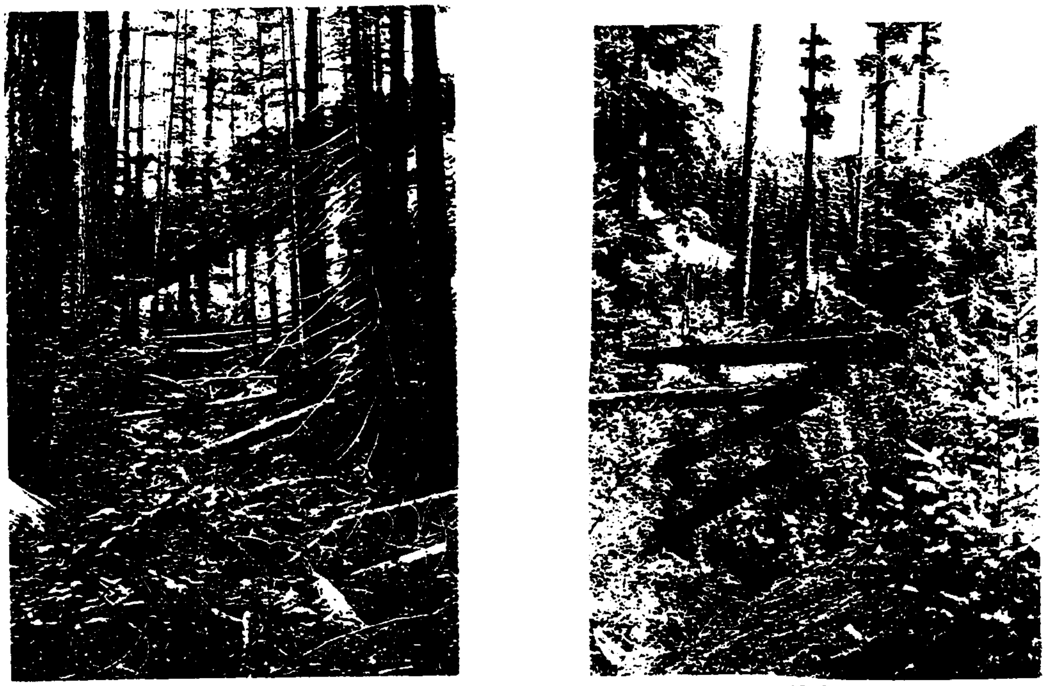


Figure 19. Density comparison of conifers (TPA) in Site 10 (Owl Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

between 1975 and 1990 are evident in Figure 20 (a and b, respectively). Vigor dynamics (Table 14) indicate a decrease in dying trees per acre (from three to one), and dead trees (from one to zero). Snags have increased since Steinblums' study, from four to five trees per acre. There were no trees with broken tops. Because this site had substantial blowdown shortly after establishment, there was almost no new material added to the LWD functional zones as a result of the 1990 storms (Table 15). The distribution shows more material in Zones 1 and 2 than most sites, probably a result of the episodic blowdown (and breakage) without salvage after the buffer was installed.

Investigating buffer strip dynamics on a stream by stream basis, changes over time are more easily recognizable. Perhaps more important are the inferences that can be hypothesized about dynamics of a given buffer strip when the overstory information is linked with the regeneration potential, snag dynamics, and LWD distribution. Utilizing this information in unison allows for speculation of how these buffers might look over the next century. With data from the two studies compared and presented side by side, much can be learned about the overall dynamics. Detailed comparisons for the remainder of the sites are presented in Appendix C.

Natural variation is reduced when investigating dynamics on any given site, but still provides a sizeable



(a) (b)

Figure 20. (a) Owl Creek buffer strip in 1975.
(b) Owl Creek buffer strip in 1990.

obstruction when trying to establish cause and effect mechanisms relative to buffer strip dynamics. Without detailed analysis of site conditions and landscape disturbance, it is difficult to know with certainty how these buffers have responded to the test of time.

Comparison with current WNF Riparian Guidelines

Table 18 lists all sites with their average buffer strip widths in 1977 and 1990, the 1990 USFS stream classification, and the corresponding Riparian Management Zone (RMZ) average width that would be used if these sites were laid out today. A full summary of the 1990 Guidelines is listed in Appendix D. 1990 USFS stream classification is known to be in error for site 2 (Blowout). Based on 1990 values, nine of the sites (1-Black, 3-Cadenza, 4-Canal, 8-Hardy 2, 9-Lost, 10-Owl, 12-Rider, 13-Tidbits, 15-Winberry) would have RMZ widths increased based on the current guidelines. On six sites (5-Cook, 6-Deer, 7-Hardy 1, 11-Perdue, 14-Two Girls, and 16-Wolf), widths would have decreased. Under the current guidelines, no trees would have been removed from these riparian stands. All sites would have required directional felling along the RMZ and full suspension over streambanks. Yarding and line corridors would be required; woody material would be left on site or used to "enhance" the channel if deemed necessary. Windthrown trees in these buffers, were they managed under the current guidelines, would not be salvaged

Table 18. Stream order, 1977 and 1990 buffer strip widths, 1990 USFS Stream Classification, and corresponding buffer strip width for resampled Willamette National Forest buffer strips.

Site	Stream Order [a]	1977 Width (ft) [b]	1990 Width (ft) [c]	1990 Stream Class [d]	1990 Width (ft) [e]
1. Black	3	144	110	1	200
2. Blowout	3	115	158	4*	30
3. Cadenza	1	50	35	3	75
4. Canal	2	73	80	2	100
5. Cook	2	140	141	3	100
6. Deer	2	165	122	3	100
7. Hardy 1	1	155	125	2	100
8. Hardy 2	1	58	60	2	100
9. Lost	3	65	54	1	200
10. Owl	1	40	35	3	75
11. Perdue	2	110	108	2	100
12. Rider	1	70	60	3	100
13. Tidbits	2	58	54	3	100
14. Two Girls	2	80	122	2	100
15. Winberry	1	55	62	2	100
16. Wolf	1	135	97	3	75
Average		95	89		108

[a] after Strahler (1957)
[b] average buffer strip width
[c] average buffer strip width
[d] 1990 USFS Stream Classification
[e] average buffer strip width, based on 1990 USFS Stream Classification, (Average value excludes Site 2)
* known error in USFS Stream Classification

unless it served to "restore degraded habitat and benefit riparian dependent resources". Stream cleanout would be permitted only immediately upstream of culverts.

The shift in riparian management philosophy on the WNF is clearly evident in the new guidelines. These prescriptions differ greatly from the way the sites were treated historically. However, without a system for tracking dynamics of newly established RMZs on the forest, it will be difficult or impossible to ascertain whether these prescriptions are appropriate over time.

CONCLUSIONS

The stand dynamics of twenty Cascade buffer strips are difficult to characterize in anything other than a general sense, yet it is important to glean as much information as possible from this work. Separating conifer diameters into four DBH classes has allowed a more detailed investigation of overstory dynamics.

In general, most sites have shown the largest overstory density increases in the smallest diameter class (10-14 inches DBH), with western hemlock showing the greatest gains over 1977 levels. Western redcedar is a minor component in this class, while Douglas-fir is largely absent. The basal area contribution of this diameter class is minimal; most sites have shown small increases that correspond to density changes. Ingrowth into this class suggests that most sites will have a coniferous component over the next several decades or longer, based on current stand conditions. Caution must be used with this statement because landscape level changes coupled with moderate or extreme climatic events may prove sufficient to cause minor or extensive blowdown. Current Forest Service perspective is now focused on a watershed level which should help to facilitate recognition of future activities in a basin.

Ingrowth is also the dominant condition exemplified in the 15-29 inch DBH class (INTCLS 1), expressed in both density and basal area. Again, the majority of increases resulted from western hemlock. While it is the prevalent species, both western redcedar and Douglas-fir contributions have increased over the 10-14 inch DBH class. Growth in INTCLS 1 is not surprising; trees of this diameter, assuming they are healthy, would show the greatest proportion of growth as a result of release. Overall, trees in this diameter range seem in good vigor, and will assist in supplying the buffer and the stream with conifers in years to come.

Conditions are quite different for trees 30-44 inches DBH (INTCLS 2). Density and basal area are simultaneously decreasing over time in this diameter class. Western hemlock and Douglas-fir share similar densities, though the basal area contributed by Douglas-fir is typically greater. Analysis of both density and basal area indicate western hemlock is more prone to losses in this diameter range than Douglas-fir. It is possible this decrease will be offset by ingrowth of hemlock from the previous two classes, but on some sites, there may some disruption in hemlock over the long term. Though it is a minor component, western redcedar appears fairly stable in this class.

Data for trees ≥45 inches DBH (LGCLS) indicate a slight density decline, but a substantial decrease in basal area. With relatively small densities in this class, every change carries considerable weight. Douglas-fir is by far the species with the greatest density and basal area contribution. Changes documented suggest that in this class, Douglas-fir is prone to blowdown.

It is tempting to use regionally developed growth and yield estimates or models to predict future buffer stand dynamics, particularly growth rates, in the four diameter classes. However there is justification not to apply this information to these riparian stands. Projected yields are based on even aged stands with densities of ≥100 trees per acre, neither of which typify the inventoried buffers. Had sampled trees been tagged initially, it would have been feasible to compare average diameters in each of the four classes and make some assessment and projection of growth rates on these sites. However, because of ingrowth and differences in measurement technique, statistical comparisons did not reveal any significant differences in average diameter (except for trees ≥45 inches DBH, which were apparently smaller in 1990). Researchers looking specifically at productivity of unmanaged western Oregon Cascades riparian valley floors have found considerable variation within stands for measures affected by stocking such as basal area, volume, and mean annual increment (Means et al., in press). With the exception of this study, there has been no documentation specifically addressing growth of western Cascade streamside zones.

Although Andrus and Froehlich (1986a) have investigated growth of riparian stands in the Coast Range, evidence suggests differences in the Cascades would make application of this information inappropriate. Certainly growth dynamics in riparian stands is an important consideration for future research.

Natural conifer regeneration has seemingly occurred in sufficient numbers to retain conifers over the next century. These initial findings contrast with Coast Range research which indicates understory competition has seemingly precluded establishment of naturally occurring conifers. This disparity may have important ramifications from operational and regularity standpoints. Site-specific field observations indicate that density and overall vigor of the overstory influence the degree to which natural regeneration is successful. Other potential parameters include percent of understory cover, soil conditions, slope, aspect, windthrow, and on some sites, distance from the stream. A more intensive investigation of conifer regeneration would augment these initial findings and perhaps statistically correlate these or other parameters to successful conifer regeneration.

On a stream by stream basis, these buffers exhibit a broad spectrum of dynamics. The fact that four sites could not be reinventoried has biased this sample to some extent. Of those buffers revisited, two showed evidence of widespread blowdown shortly after installation. One of these, and one additional site seemed heavily affected by the storms of 1990. The remaining buffers seem to be functioning as current thinking would prescribe, with periodic recruitment of large woody debris into channels.

It is important to distinguish between function and configuration. At the time these buffers were established, the main concern was stream temperatures. Documented contributions of buffer strips to the stream system would likely affect configuration (i.e. width and prescription) on many of these sites if the buffers were installed today.

Since Steinblums' study, much research has been done regarding the function of large wood in streams, and the differences between conifers and softwoods in meeting those goals. Due to the evolving knowledge, many of the inventoried buffer strips would probably be reconfigured were they to be installed today. Preliminary investigation of LWD distribution in these sites shows most often this material will not be interacting with the stream without modification to the buffers. This raises concern about density of conifers within range of the stream. Additionally other concerns, such as utilization of buffers by birds and wildlife might imply a reconfiguration of the buffers.

The importance of Steinblums' work should not be overlooked. Though landscape level changes can throw a wild card in any predictive equation, the variables he identified as influencing buffer strip dynamics are of tremendous utility to land managers. Difficulties encountered in the current study have precluded direct or statistical comparison to Steinblums' results. However, utilizing the two data sets has helped gain an understanding of buffer strip dynamics.

Results of this study are limited in application. They are thought to be representative of the Willamette National Forest and adjacent ownerships in stands of similar characteristics (i.e., late successional western hemlock stands). The degree to which the other buffers initially inventoried would correspond with these could only be confirmed by a similar contemporary investigation. These results should not be generalized to characterize buffers in other geographic regions or those having dissimilar stand characteristics.

The methodology employed in this study is not complex or expensive, but it does require forethought and "institutional memory". A more direct comparison could easily be achieved by survey and maintenance of sample boundaries. Recent advances in survey technology (i.e., Global Positioning Systems (GPS)) could be very beneficial for permanently marking boundaries of these Cascade buffer strips. Tagging of individual trees and accurate measurement using a diameter tape for each replication would greatly increase the reliability and interpretation of the results. These measures would help ensure that as people leave an agency, another person could complete the inventory with no question as to which trees were measured.

Current Willamette National Forest Riparian Guidelines (1990) would have left these sites in a very different condition had they been established in recent times. Due to high initial timber volumes and tall trees on some sites, it is possible that episodic blowdown would have been much more prevalent in many of these buffers had 1990 guidelines been utilized for prescription of these riparian stands. As objectives and desired future condition of buffer strips or RMZs evolve, it becomes obvious prescriptions developed in one era may be ill-suited in the next. As new RMZ configurations are adopted on the Forest (i.e., the 1990 Riparian Guidelines), the methodology used in the current study could be useful to assess dynamics of these sites and "success" of alternative or new riparian management area prescriptions.

There are still many unanswered questions relative to streamside management. For example, woody debris input rates and source distances, in-channel sediment storage, geomorphic changes over time and in response to management, hardwood and snag dynamics, regeneration dynamics, and utilization of these areas by fish and wildlife are some of the questions that could be researched, utilizing these sites, and tracking them over time. The initial results of the conifer regeneration survey indicate a very different story on these sites than for Coast Range counterparts.

This documentation of buffer strips over time could easily be adapted for any owner seeking to gain a better understanding of leave area dynamics. Replicated studies of stand conditions can add significantly to the knowledge base of these sites. Obtaining such information periodically and in an interdisciplinary fashion would assist in answering challenging land management questions.

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APPENDIX A1

BUFFER STRIP VARIABLES (from Steinblums 1978)

Variable Unit Summary

Variable	(Column)	Units
ELEV	(2)	feet
Estimated acreage	(3)	acres
WIDTH	(4)	feet
Estimated length	(5)	feet
Sample length	(6)	feet
SLPCRK	(7)	percent
SLPCC	(8)	percent
SOILDPT	(9)	feet
STABRATE	(11)	no units
UNSPECIE	(12)	no units
Dir. wind	(13)	NW, NE, SW, SE
DISTWIND	(14)	feet
SLPWIND	(15)	percent
DISTRIDG	(16)	feet
ELEVRIDG	(17)	feet
VERTHOR	(18)	percent
ORIENT	(19)	no units
EXPCODE	(20)	no units
NOSIDES	(21)	no units
OVSPECIE	(22)	no units
NETGROSS	(23)	percent
ORIGVOL	(24)	MBF/ACRE (gross)
ORIGBA	(25)	ft^2/acre (gross)
VOLTREE	(26)	MBF (gross)
NOSTEMS	(27)	trees/acre
LOGDAM	(28)	trees/acre
TOTVOL	(33)	MBF
VOLREM	(34)	percent
VOLREM*	(35)	percent
Vol. down	(36)	percent
Vol. dead	(37)	percent
Vol dyn. (dying)	(38)	percent
ACD	(39)	percent
Buff. shade	(40)	yes=buffer strip shade no=uncut stand shade
AVHTALL	(41)	feet
AVHTTALL	(42)	feet
NOTALL	(43)	trees/acre
NOSMALL	(44)	trees/acre
No. of winters	(45)	years (as of 1976)

APPENDIX A2

BUFFER STRIP VARIABLES, BY SITE (from Steinblums 1978)

Variable Measurements and Estimates

Buffer Name	(1) Legal desc.	(2) ELEV	(3) Estimated Acr.	(4) WIDTH	(5) Estimated length	(6) Sample length	(7) SLPCRK
Black Creek	S22,T21S,R5E	2900	5.0	144	1500	500	70
Blowout Creek	S35,T10S,R5E	1600	2.2	115	760	400	68
Cadenza Creek	S29,T14S,R6E	3400	0.6	50	500	400	32
Canal Creek	S11,T11S,R4E	1990	2.4	73	800	500	73
Cook Creek	S17,T15S,R5E	1840	2.9	140	900	500	67
Davey Creek	S29,T25S,R4E	4000	2.0	70	1250	600	46
Deer Creek	S04,T15S,R5E	2550	2.5	165	700	400	85
Elk Creek	S16,T19S,R6E	3100	2.9	186	720	400	65
Hardy Creek 1	S09,T18S,R5E	2800	3.8	155	1050	500	22
Hardy Creek 2	S20,T18S,R5E	3800	1.6	58	600	500	38
Lost Creek	S13,T16S,R6E	1780	2.0	65	1300	500	17
Owl Creek	S08,T15S,R4E	3000	1.9	40	1200	500	67
Perdue Creek	S18,T19S,R4E	2700	1.0	110	470	400	56
Rider Creek	S19,T17S,R5E	2960	1.3	70	800	700	47
Tidbits Creek	S22,T15S,R4E	2600	1.7	58	700	500	80
Two Girls Creek	S14,T14S,R4E	2450	2.4	80	1000	500	47
Winberry Creek	S22,T15S,R4E	2160	2.0	55	760	500	51
Wolf Creek 1	S01,T15S,R5E	3000	3.5	135	1100	400	50
Wolf Creek 2	S01,T15S,R5E	3050	3.6	70	1100	400	57
Wolf Creek 3	S01,T15S,R5E	3200	0.4	30	600	500	79

APPENDIX A2 (Continued)

BUFFER STRIP VARIABLES, BY SITE (from Steinblums 1978)

Variable Measurements and Estimates

Buffer Name	(8) SLPCC	(9) SOIL DPT.	(10) Soil type	(11) STABRATE	(12) UNSPECIE	(13) Dir. Wind
Black Creek	20	11.0	gravelly cobbly loam	1	3.0	SW
Blowout Creek	61	3.5	gravelly sandy loam	2	3.0	SW
Cadenza Creek	30	9.0	gravelly loam	1	2.0	--
Canal Creek	63	2.0	gravelly loam	2	4.0	SW
Cook Creek	80	4.5	gravelly loam	1	2.0	SW
Davey Creek	33	8.0	gravelly loam	3	2.0	E
Deer Creek	40	7.5	gravelly cobbly loam	3	4.0	E
Elk Creek	30	10.0	gravelly sandy loam	1	2.0	SW
Hardy Creek 1	25	8.5	gravelly sandy loam	1	4.0	SW
Hardy Creek 2	25	8.5	gravelly sandy loam	3	4.0	SW
Lost Creek	13	12.0	gravelly cobbly sandy loam	2	2.0	E
Owl Creek	70	6.0	gravelly cobbly loam	1	4.0	E
Perdue Creek	56	4.0	gravelly loam	1	3.0	SW
Rider Creek	32	6.0	gravelly sandy loam	2	3.0	SW
Tidbits Creek	84	3.0	gravelly loam	2	2.0	E
Two Girls Creek	70	3.0	gravelly loam	1	3.5	--
Winberry Creek	25	6.0	gravelly sandy clay loam	3	3.0	E
Wolf Creek 1	41	4.0	gravelly loam	1	2.5	--
Wolf Creek 2	43	6.0	gravelly loam	2	3.5	E
Wolf Creek 3	66	5.0	gravelly loam	1	2.5	--

APPENDIX A2 (Continued)

BUFFER STRIP VARIABLES, BY SITE (from Steinblums 1978)

Variable Measurements and Estimates

Buffer Name	(14) DIST WIND	(15) SLP WIND	(16) DIST RIDG	(17) ELEV. RIDG	(18) VERT. HOR.	(19) ORIENT	(20) EXP. CODE	(21) NO. SIDES	(22) OVSPECIE
Black Creek	735	21	4900	2499	51	NW,1	2	1	6
Blowout Creek	590	89	4900	2352	48	NW,1	2	2	6
Cadenza Creek	0	20	6600	1782	27	NW,1	1	1	6
Canal Creek	790	43	1214	813	67	NW,1	2	2	2
Cook Creek	610	80	1300	975	75	SE,2	2	2	2
Davey Creek	3140	33	4860	1652	34	NW,1	3	1	5
Deer Creek	770	30	2640	1135	43	SE,2	3	1	4
Elk Creek	3000	5	6000	960	16	SW,1	2	2	2
Hardy Creek 1	1478	14	9700	2425	25	NE,2	2	1	4
Hardy Creek 2	1429	29	2376	1045	44	NE,2	4	2	2
Lost Creek	990	21	3660	1648	46	NW,1	3	1	2
Owl Creek	633	16	6230	1558	25	NW,1	4	2	2
Perdue Creek	530	50	1848	407	22	SE,2	2	1	4
Rider Creek	3000	11	5491	275	5	SE,2	2	1	4
Tidbits Creek	750	100	1900	1159	61	SW,1	4	2	2
Two Girls Creek	0	7	3200	192	6	SW,1	1	1	6
Winberry Creek	400	20	15048	1806	12	SW,1	3	2	2
Wolf Creek 1	0	20	5350	696	13	SW,1	1	1	8
Wolf Creek 2	920	24	5200	676	13	SW,1	4	2	4
Wolf Creek 3	0	20	4800	624	13	SW,1	1	1	8

APPENDIX A2 (Continued)

BUFFER STRIP VARIABLES, BY SITE (from Steinblums 1978)

Variable Measurements and Estimates

Buffer Name	(23) NET GROSS	(24) ORIG. VOL.	(25) ORIG. BA.	(26) VOL. TREE	(27) NO. STEMS	(28) LOGDAM	(33) TOT. VOL.	(34) VOL. REM.	(35) VOL.* REM.
Black Creek	64	125	409	1.27	98	3	634M	100.0	94.0
Blowout Creek	68	132	482	1.71	77	5	295M	96.5	96.5
Cadenza Creek	71	56	187	1.26	44	3	31M	97.0	96.0
Canal Creek	63	104	311	2.54	41	11	253M	89.0	87.0
Cook Creek	85	82	262	1.23	67	11	241M	100.0	97.0
Davey Creek	85	121	386	1.24	79	1	248M	53.0	53.0
Deer Creek	75	108	326	1.94	56	9	285M	95.0	92.0
Elk Creek	73	162	452	2.86	56	2	474M	47.4	42.0
Hardy Creek 1	79	118	362	2.00	59	2	447M	91.4	89.3
Hardy Creek 2	79	132	368	3.41	39	3	204M	86.0	84.0
Lost Creek	78	129	378	3.34	39	4	116M	98.0	94.0
Owl Creek	78	206	526	2.06	100	8	393M	58.7	57.0
Perdue Creek	78	221	605	3.13	71	3	256M	100.0	93.0
Rider Creek	76	94	269	1.88	50	0	120M	57.0	57.0
Tidbits Creek	85	80	215	3.54	23	17	139M	91.0	81.0
Two Girls Creek	75	80	272	3.17	25	4	193M	91.0	79.0
Winberry Creek	72	82	246	2.89	28	1	166M	64.0	64.0
Wolf Creek 1	73	41	144	0.62	66	4	144M	94.2	79.0
Wolf Creek 2	80	145	429	2.60	56	2	517M	50.3	50.1
Wolf Creek 3	69	35	177	0.61	57	5	14M	86.0	82.0

APPENDIX A2 (Continued)

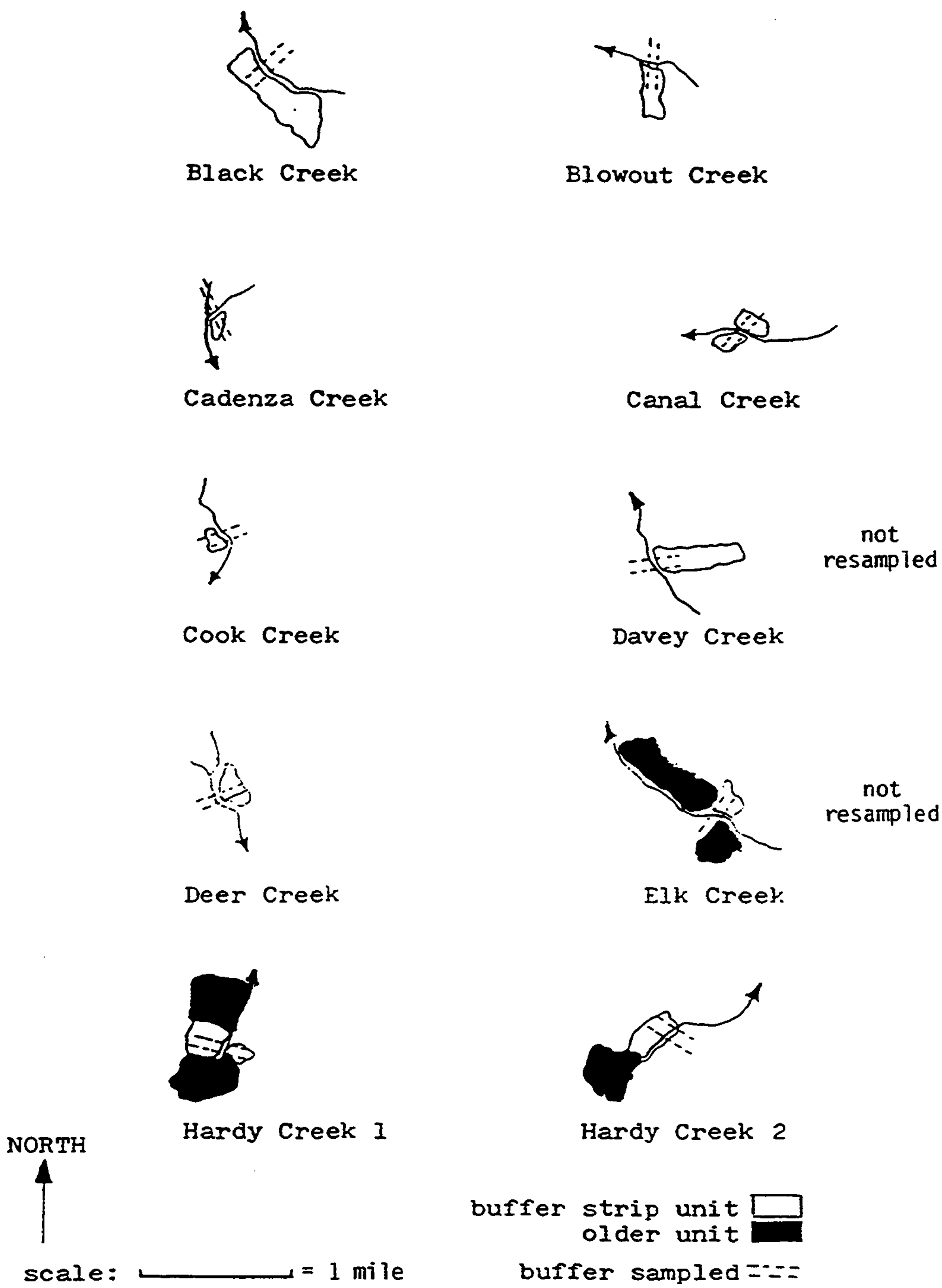
BUFFER STRIP VARIABLES, BY SITE (from Steinblums 1978)

Variable Measurements and Estimates

Buffer name	(36) Vol. down	(37) Vol. dead	(38) Vol. dyn	(39) ACD	(40) Buff. shade	(41) AVHT ALL	(42) AVHT TALL	(43) NO. TALL	(44) NO. SMALL	(45) No. of winters
Black Creek	0.0	6.0	0.0	87	yes	129	147	27	22	7
Blowout Creek	3.5	0.0	0.0	67	yes	130	148	22	24	3
Cadenza Creek	3.0	1.0	0.0	29	yes	119	129	9	9	2
Canal Creek	11.0	0.0	2.0	62	yes	130	158	14	14	2
Cook Creek	0.0	0.0	3.0	33	yes	107	153	16	33	3
Davey Creek	47.0	0.0	0.0	83	no	112	130	6	42	3
Deer Creek	5.0	2.0	1.0	26	no	135	146	19	13	15
Elk Creek	52.6	5.1	0.3	--	no	137	162	22	18	3
Hardy Creek 1	8.6	1.1	1.0	70	no	136	152	19	12	11
Hardy Creek 2	14.0	0.0	2.0	58	yes	145	166	17	10	3
Lost Creek	2.0	4.4	0.0	60	no	141	162	16	8	9
Owl Creek	41.3	0.0	1.7	38	yes	149	179	48	34	3
Perdue Creek	0.0	3.0	4.0	71	yes	150	165	34	9	4
Rider Creek	43.0	0.0	0.0	52	yes	140	162	19	11	4
Tidbits Creek	9.0	0.0	10.0	30	yes	146	166	11	10	3
Two Girls Creek	9.0	4.0	8.0	75	no	144	158	14	4	3
Winberry Creek	36.0	0.0	0.0	37	yes	126	163	11	11	4
Wolf Creek 1	5.8	2.0	13.2	62	no	99	120	3	31	4
Wolf Creek 2	49.7	0.0	0.2	43	yes	135	161	21	17	1
Wolf Creek 3	82.0	14.0	3.0	44	no	90	114	0	29	4

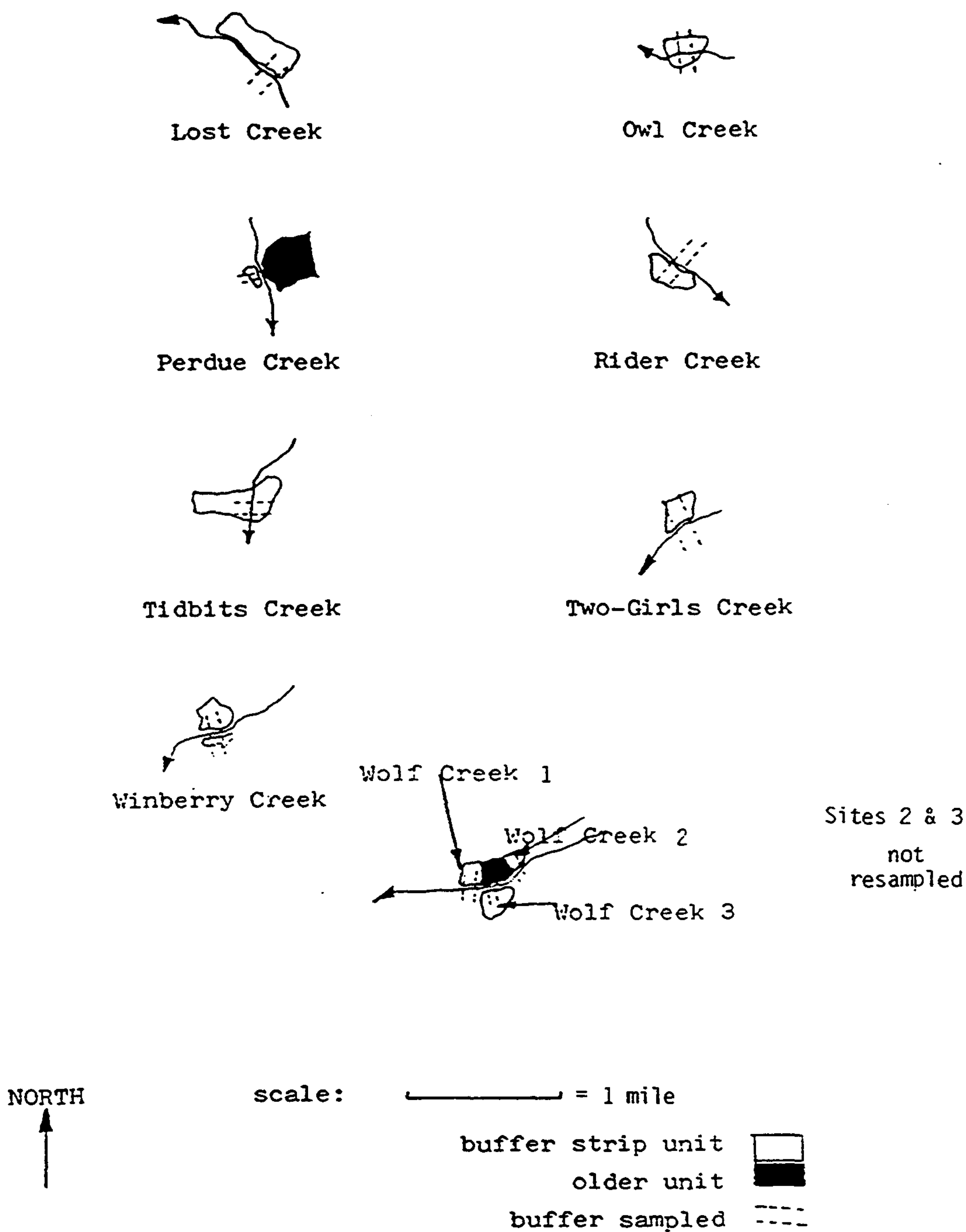
APPENDIX B

Schematic drawings of Willamette National Forest buffer strips (from Steinblums 1978).



APPENDIX B (Continued)

Schematic drawings of
Willamette National Forest
buffer strips (from Steinblums 1978).



APPENDIX C

Discussion of individual stream comparisons.

The situation depicted for the Cadenza Creek buffer strip (Figure C1) raises some cause for concern. Ingrowth is practically nonexistent in the 10-14 inch class; one of the few sites in this condition. Both INTCLS 1 and INTCLS 2 show a density decrease since the time of Steinblums' (1978) study. There were no LGCLS trees. These conditions suggest a potential conifer decline in the buffer over the next century. By 1990, shade had been restored on this stream largely due to regrowth of understory vegetation since 1975 (Figure C2, (a) and (b)). This was one of two sites obviously affected by the 1990 storms; the loss of conifers was more episodic than the periodic inputs usually desired. However, the Cadenza Creek buffer had reached some threshold of stability until the 1990 storms, raising questions about the mechanisms and linkages (besides the obvious, wind) responsible for blowdown in 1990. Windthrown trees indicated these winds came from the south, though fallen trees outside the sample area suggested winds from the north were also present. None of the site characteristics recorded by Steinblums (1978) offered an obvious explanation for these dynamics. Additional harvest units and an overstory removal visible in 1990 Forest Service aerial photography may have contributed to the

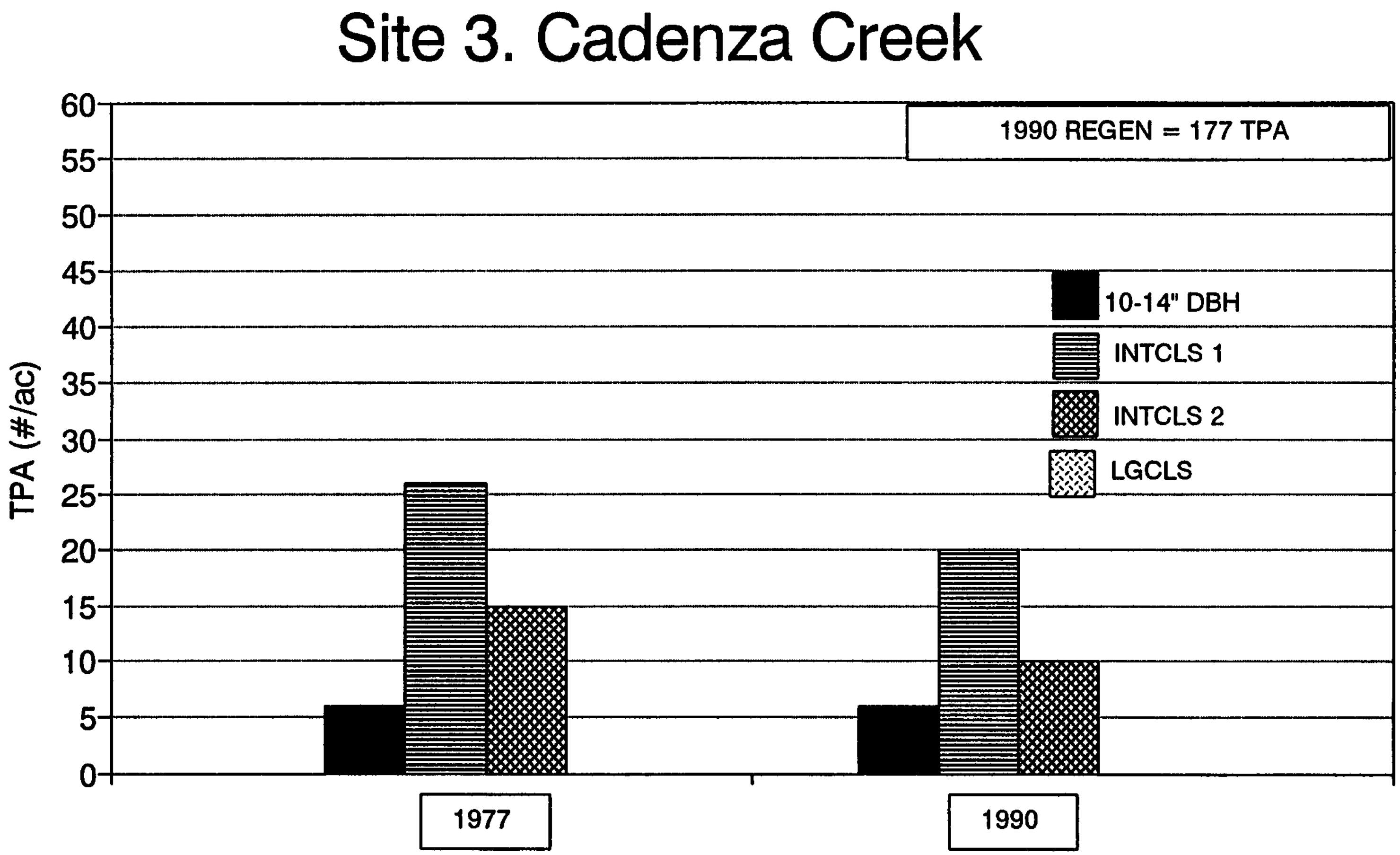


Figure C1. Density comparison of conifers (TPA) in Site 3 (Cadenza Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

(a)

(b)

Figure C2. (a) Cadenza Creek buffer strip in 1975.
(b) Cadenza Creek buffer strip in 1990.

dynamics on this site. Average established conifer regeneration densities on this site were the sparsest of any buffer sampled at 177 trees per acre. Vigor class data (Table 14) indicate an increase in the number of dying trees (from two to six trees per acre), and dead trees (from zero to two trees per acre), but no snags or broken top trees at either point in time. Because of the contribution of LWD from the 1990 storms, much large wood currently spans the channel, in Zone 3 (Table 15).

The other buffer strip directly affected by the 1990 storms was Canal Creek (Figure C3). By 1990, the densities of most diameter classes were below average. Ingrowth seems a minor component of the buffer, with the 10-14 inch DBH class increasing only slightly, and still totaling less than ten trees per acre. Canal Creek was one of the few sites to show a decline in INTCLS 1, signaling the potential for a conifer decrease over time. Both larger diameter classes show density decreases. Except for the slight ingrowth, the dynamics look very similar to Cadenza Creek (Figure C3). However, specific site factors offer better clues as to the mechanisms for these dynamics. DISTRIDG (the distance to the nearest major ridge in the direction of the damaging winds) was the shortest of any buffer measured, at 1,214 feet (Appendix A2). ELEVRIDG (the change in elevation from the mid-point of the buffer to the top of the nearest major ridge in the direction of

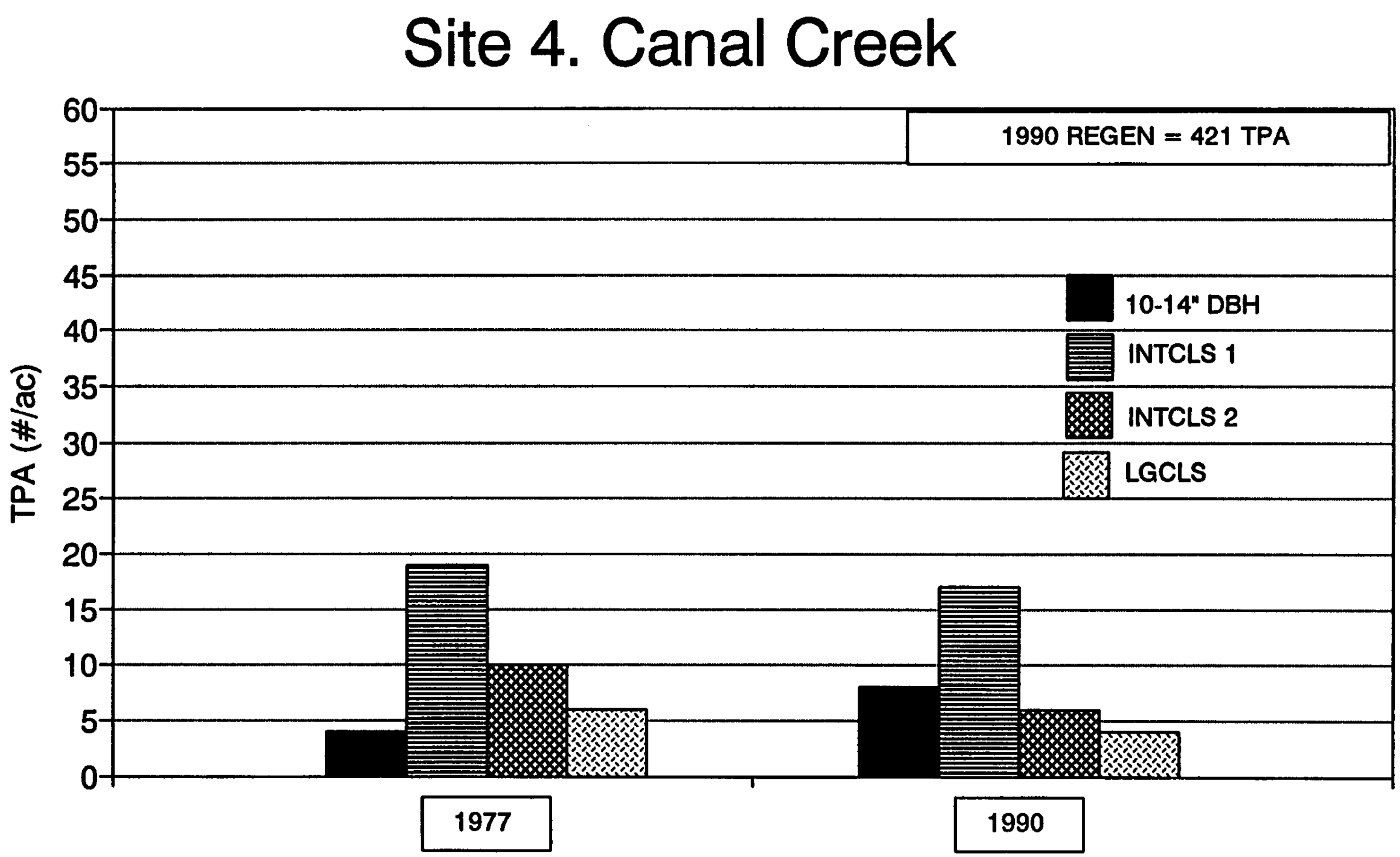


Figure C3. Density comparison of conifers (TPA) in Site 4 (Canal Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

damaging winds) was moderate for these buffers (813 feet). Though Steinblums (1978) documented the direction of damaging winds coming from the southwest, 1990 downfall indicated winds from the northeast. A recent harvest unit (northeast of the buffer) visible in 1990 WNF aerial photography may have contributed to changes in wind patterns. Steinblums also noted an unusually high occurrence of logging damage in the buffer (11 trees per acre); this too may have adversely influenced buffer strip survival. Average conifer regeneration density for the Canal Creek buffer strip was 421 trees per acre, despite a ribbon of alder paralleling the stream. Regeneration is limited to the south side of the stream; north side soils were shallow and side slopes were steep. Much of the north side regeneration was found on nurse logs. This seems to be a harsh site, somewhat topographically unprotected, with some limitations in the coniferous component evident over time. Tree vigor (Table 14) shows no dying or dead trees in 1990, but snags per acre have increased since Steinblums' study (from four to six trees per acre). The 1990 inventory revealed a single broken top tree per acre. On Canal Creek, as on Cadenza Creek, there was a fair amount of LWD in Zone 3 (Table 15), and some in Zones 1 and 2. The majority of material however, is in Zone 4.

Density data for the Cook Creek buffer strip (Figure C4) shows strong ingrowth, reflected in the two smaller

Site 5. Cook Creek

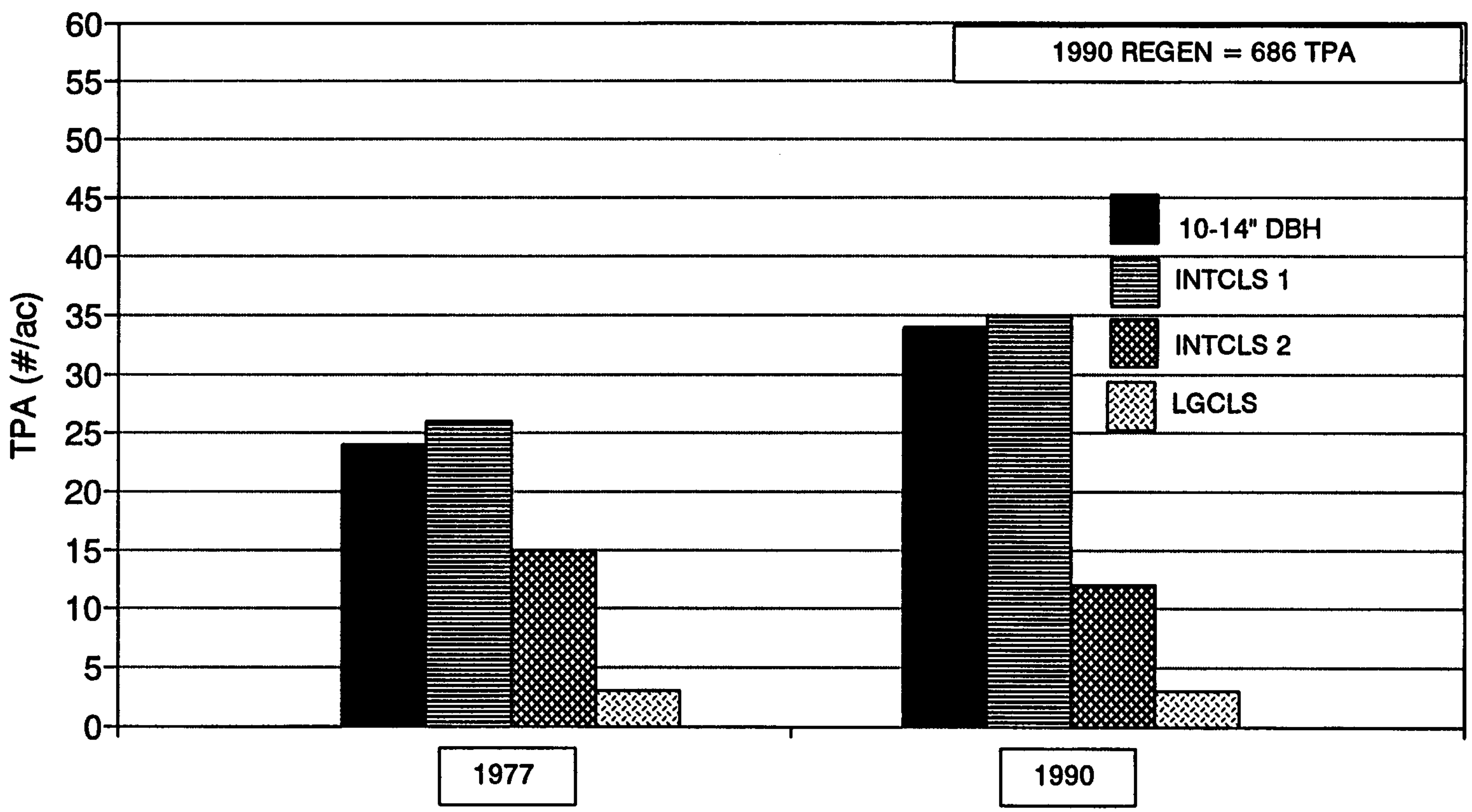


Figure C4. Density comparison of conifers (TPA) in Site 5 (Cook Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

diameter classes. Moderate decreases have occurred in INTCLS 2. LGCLS density shows little fluctuation over the 1978 level. Although alder is prevalent immediately adjacent to the stream, average established conifer regeneration in the Cook Creek buffer is strong with 686 trees per acre. Coupled with trees in the first two diameter classes, there should be an ample supply of conifers well into the future. The Cook Creek buffer has shown a decrease in the number of dying trees (Table 14), but still has six dying trees per acre on site. There are currently no dead trees. The number of snags has increased (from zero to five trees per acre) since Steinblums' study. There are two broken top trees per acre. Large woody debris distribution data (Table 15) shows a moderate percentage in the first three zones, but the majority of material in Zone 4.

The Deer Creek buffer strip (Figure C5) remained relatively stable since the time of the original study. Ingrowth has contributed to above average stocking in the first three DBH classes. Densities in LGCLS are essentially unchanged. In this case, additional harvest units in the basin visible in the USFS 1990 air photos do not appear to have adversely influenced windthrow. Average established regeneration density was 484 trees per acre. Vigor dynamics (Table 14) indicate a decrease in dying trees (from three to one trees per acre), no dead trees,

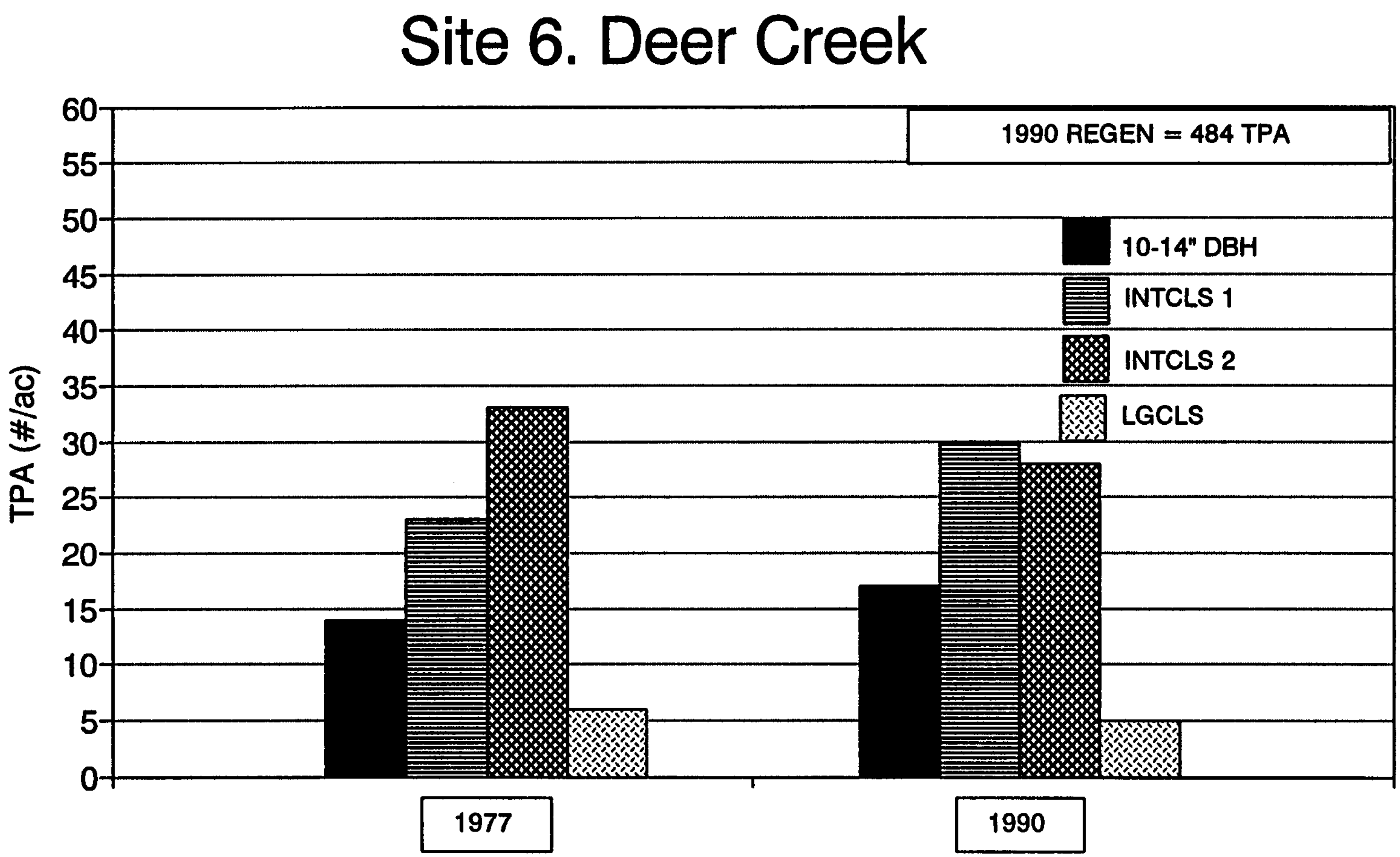


Figure C5. Density comparison of conifers (TPA) in Site 6 (Deer Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

and a slight "increase" in the number of snags per acre (from zero to one) by 1990. There were two broken top trees per acre in 1990. The Deer Creek buffer had more LWD in Zone 1 than most sites, but relatively little in Zone 3. Most LWD however, was in Zone 4 (Table 15).

As in the Canal Creek buffer strip, conifer density of 10-14 inch DBH trees has actually decreased in the Hardy Creek 1 buffer strip since the original study (Figure C6). INTCLS 1 density has decreased slightly over the 1978 levels; this is inconsistent with most buffers. There was some overstory removal from this buffer since the time of Steinblums' (1978) study; it is possible there had been ingrowth, and the subsequent removal restored densities to the previous level. Density of INTCLS 2 shows some decrease over the earlier value, presumably due to removal. Blowdown has reduced the density of the largest class slightly. This site was rated as one of the most stable by Steinblums. DISTRIDG and ELEVRIDG each had the second highest value of the revisited buffers (9700 ft and 2425 ft, respectively). Stream orientation is northeast, theoretically adding to the stability of the site. Regeneration potential for this site is the greatest of all sites inventoried; average density was 3600 trees per acre. The lack of ingrowth on this site might be offset by established regeneration growing into the buffer, however, there may be a time lag in the conifer component. Tree

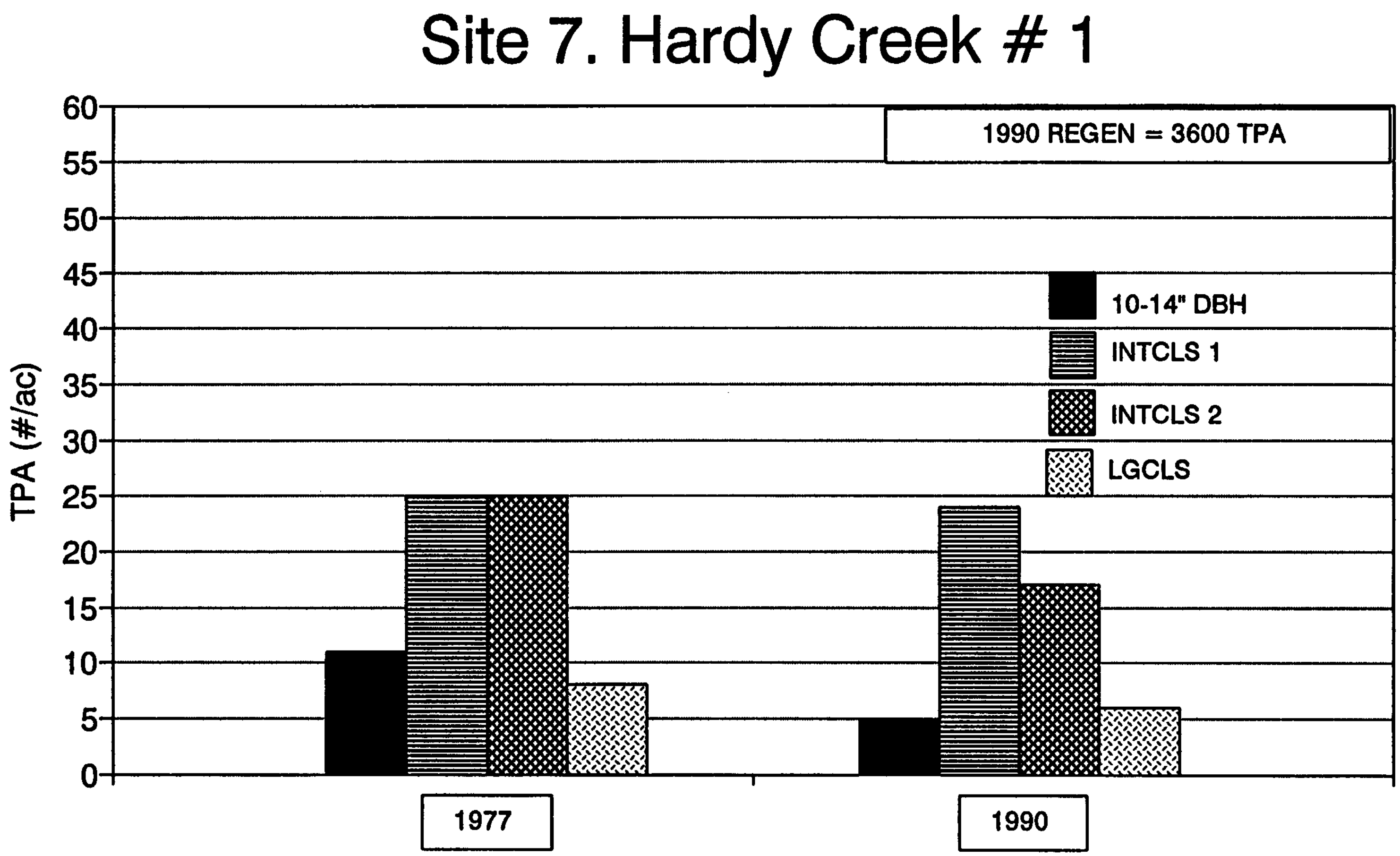


Figure C6. Density comparison of conifers (TPA) in Site 7 (Hardy 1 Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

vigor dynamics (Table 14) indicate a decline (to zero trees per acre) of both dying and dead trees. There was only a single snag per acre, and no broken top trees at the time of the 1990 study. Downed woody debris in 1990 (Table 15) shows the common situation, with most material being in Zone 4. This site is somewhat unique however, in that the majority of material in Zone 3 was contributed recently.

Density dynamics in the Hardy 2 buffer strip (Figure C7) show plentiful ingrowth in the smallest diameter class, and to a lessor extent, in INTCLS 1. This phenomenon is evident in photographs taken in 1975 and 1990 (Figure C8, (a) and (b)). Dynamics of the latter two diameter classes may indicate measurement discrepancies. This high elevation buffer (3800 ft) was rated as unstable by Steinblums (1978). Though he noted an exposure to southwest and east winds, direction of fall indicated by several boles in 1990 suggest other factors contributed to the instability. Because the windthrown trees were oriented in various directions, and because this is a high elevation site, it's possible that subsurface water in the rooting zone may have increased the susceptibility of the trees to windthrow. Because of the blowdown and subsequent salvage; it's a little surprising that INTCLS 2 and LGCLS don't show more of an overall density decline. There seems to be a continual source of conifers for this buffer strip. The average regeneration density on Hardy Creek 2

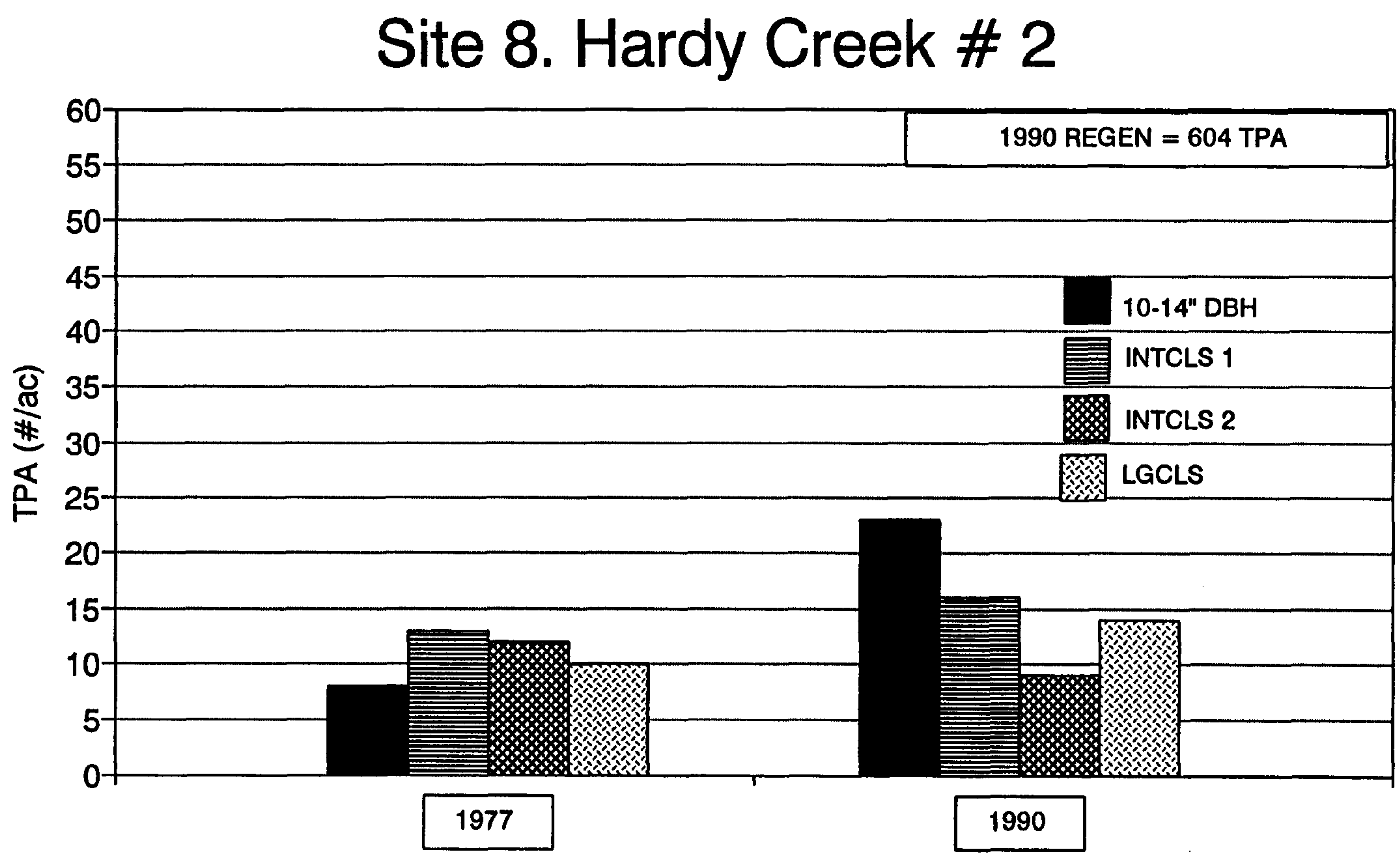
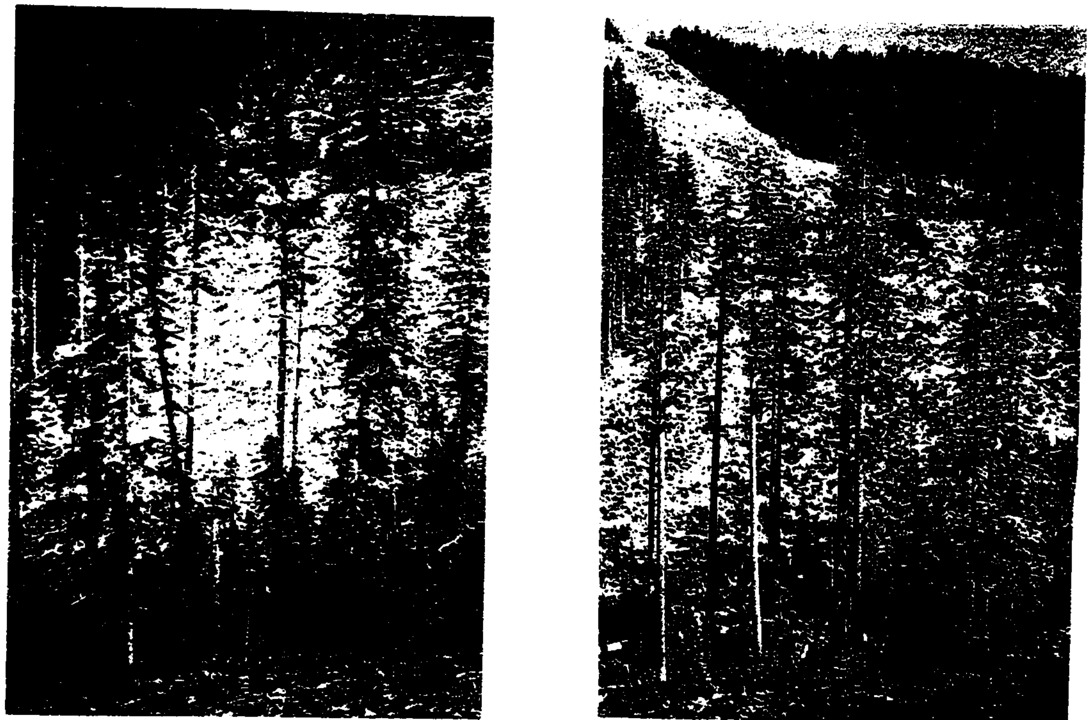


Figure C7. Density comparison of conifers (TPA) in Site 8 (Hardy 2 Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.



(a) (b)

Figure C8. (a) Hardy Creek # 2 buffer strip in 1975.
(b) Hardy Creek # 2 buffer strip in 1990.

(604 trees per acre) is surprisingly strong, considering streamside conifers have to compete with thickets of salmonberry and alder. This is the only site where understory competition rivals coastal buffers. Density of dying and dead trees per acre are identical to 1978 values (two and zero trees per acre, respectively, Table 14). In 1990, the Hardy 2 buffer had the greatest density of snags (11 trees per acre). On this windy site, it is quite likely these will contribute in relatively recent times to the LWD loading. Almost all the blowdown on this site occurred shortly after the buffer was established; values for new contributions were less than 5% in all zones (Table 15). In the inventoried reach, there was no wood in Zone 3. Perhaps much of the material spanning the channel had been salvaged.

The Lost Creek buffer strip (Figure C9) is understocked by comparison with the other sites. At the buffer location, Lost Creek is a third order stream (one of three inventoried). It shows evidence of past flooding, with a heavy alder component on a wide floodplain. The identical density increases of the two smallest DBH classes is a little suspect, but not totally unreasonable. However, densities of both small classes are well below average. LGCLS density values suggest more trees were measured in 1990 than in 1977. Average regeneration density was 800 trees per acre. The low overall stocking

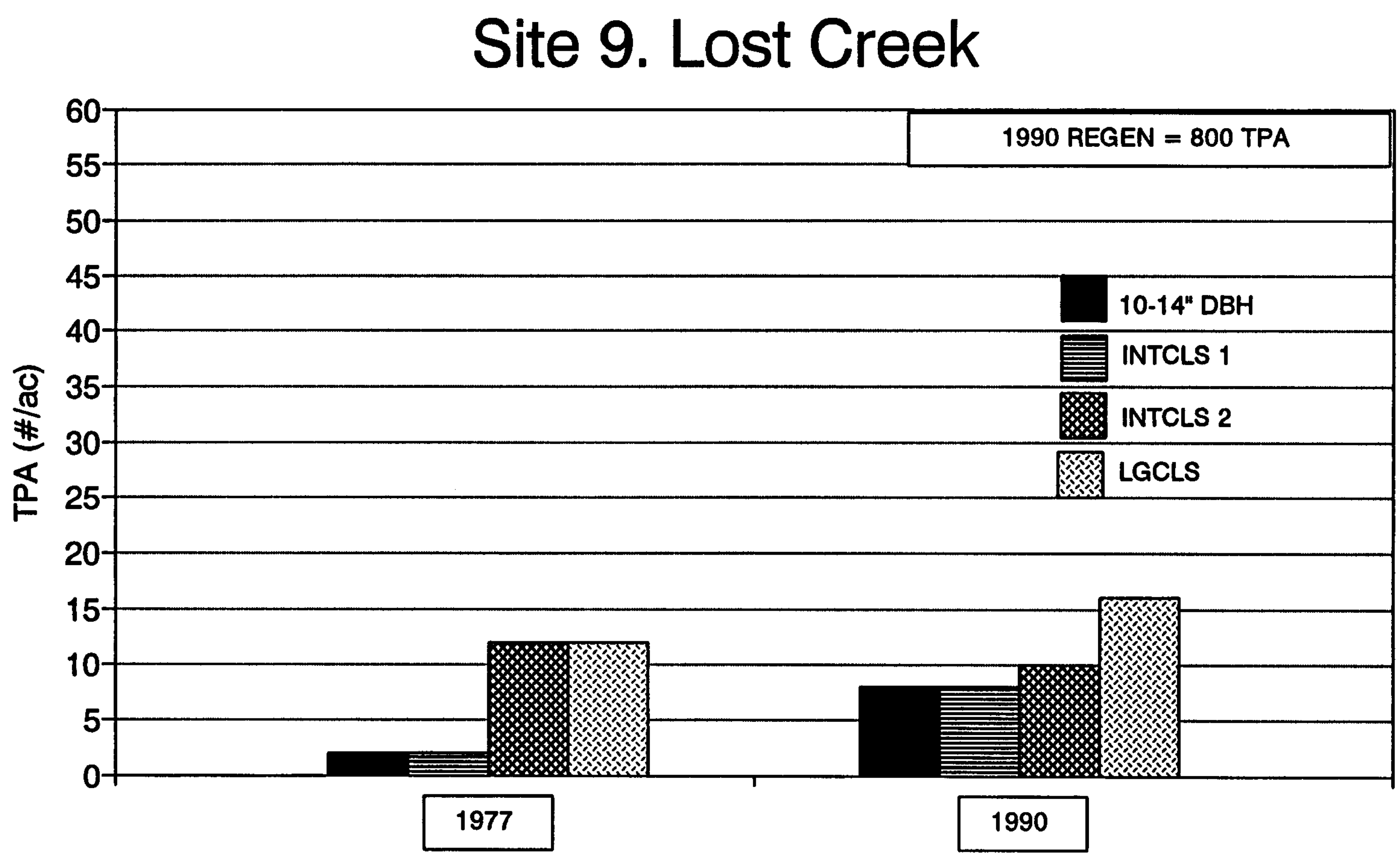


Figure C9. Density comparison of conifers (TPA) in Site 9 (Lost Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

and the fact that ingrowth seems limited may raise some cause for concern. However, because this buffer occurs on a higher order stream, the system dynamics are not as heavily influenced by conifers at this downstream location. Over time, regeneration seems sufficient to bring conifers back into the system. While there were no dead or dying trees in 1990 (Table 14); there were four snags and one broken top tree per acre. Thirty-five percent of the LWD volume is in Zones 1 and 2 (Table 15). The remainder is in Zone 4.

The Perdue Creek buffer strip (Figure C10) seems to be a well protected site, though not terribly dynamic in the timeframe since Steinblums' study. Slight ingrowth is evident in the 10-14 inch DBH class; changes in the other classes are almost nonexistent. Some decreases in the largest diameter class are evident, but they are minimal. Newer harvest units upslope of this site do not seem to have accelerated large scale blowdown of the buffer. Older blowdown tended to be clumped in seep areas, indicated by wet soils and the presence of skunk cabbage (*Lysicticum americanum*). In spite of a riparian alder corridor, average regeneration density (1334 trees per acre) suggests a conifer supply over time. Substantial increases in the number of snags (from four to ten trees per acre) have occurred since the 1977 tally (Table 14). This site also had the greatest number of broken top trees (seven trees

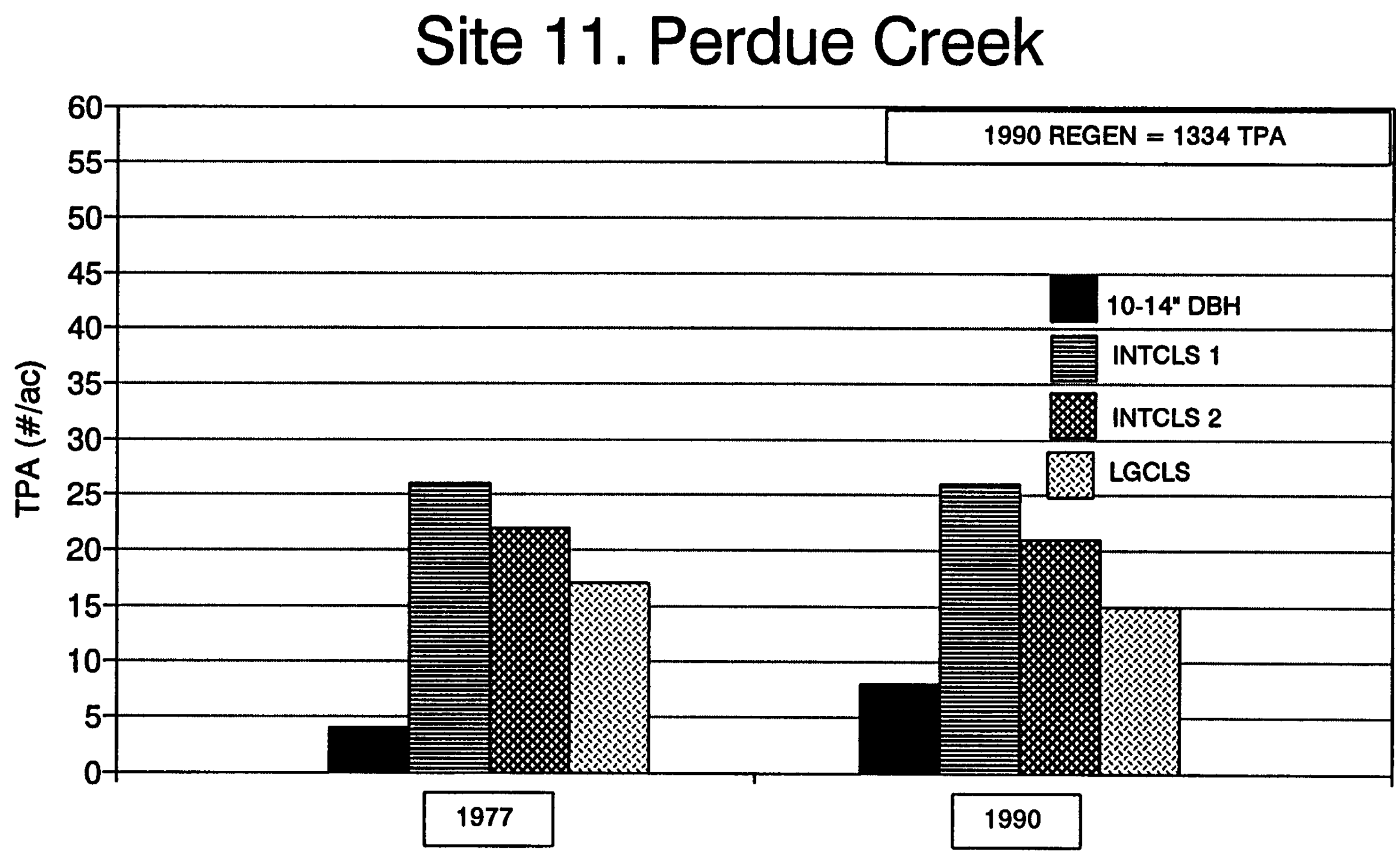


Figure C10. Density comparison of conifers (TPA) in Site 11 (Perdue Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

per acre). Broken tops made up much of this downed woody debris on this site. Conditions in these two vigor classes suggest LWD contributions will be forthcoming, perhaps in recent time. A fair amount of LWD in Zones 3 and 4 (40% and 50%, respectively) resulted from the 1990 storms (Table 15).

The Rider Creek buffer strip (Figure C11) shows tremendous ingrowth in the smallest DBH class; it has more than doubled. Current stocking for this class is above average (>15 trees per acre). Densities in INTCLS 1 and INTCLS 2 have increased slightly. LGCLS density is relatively unchanged. Blowdown in this area was widespread, in the buffer and the adjacent uncut stand, but most occurred prior to being tallied by Steinblums in 1977. ELEVRIDG had the lowest value of any site (275 ft), while DISTWIND was the greatest value recorded (3000 ft) for these sites. DISTRIDG was also one of the largest (5491 ft.). This combination of characteristics may have been influential in the dynamics of this area. Regeneration in this buffer (average density = 877 trees per acre) will help to maintain conifer stocks over time. The Rider Creek buffer was lacking in all vigor classes but snags by 1990 (Table 14). Much of the material in Zones 3 and 4 (50% and 40%, respectively) was from recent contributions (Table 15). This may seem contradictory to data in Table 14, however most material in these zones was broken limbs and

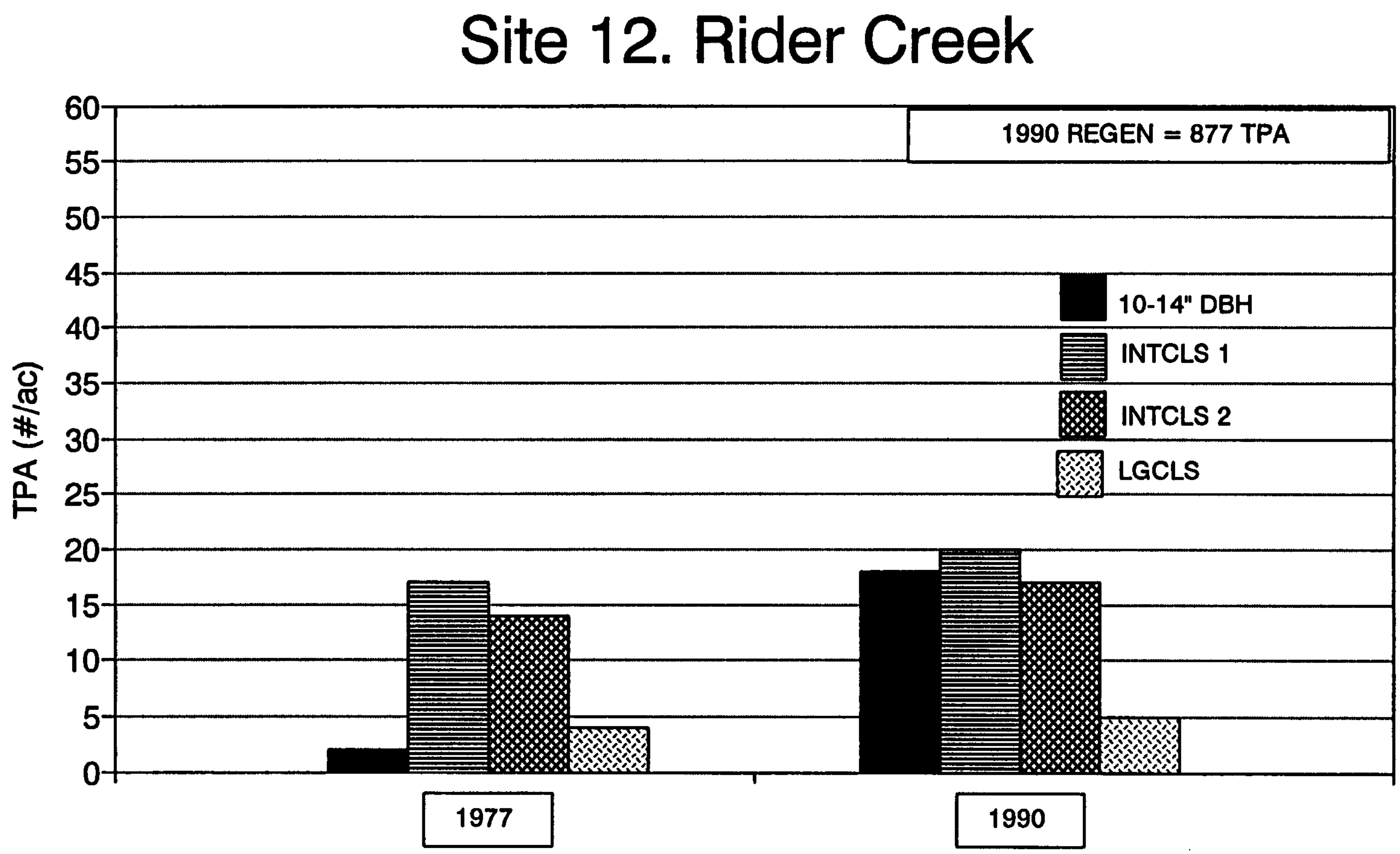


Figure C11. Density comparison of conifers (TPA) in Site 12 (Rider Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

branches. These smaller pieces tended to occupy Zones 1 and 2.

Stocking in the Tidbits Creek buffer strip (Figure C12) is relatively sparse (1990 combined conifers = 33 trees per acre). Logging damage recorded by Steinblums (1978) was the greatest of any site (17 trees per acre). Although there has been some increase in densities of trees in the two smallest DBH classes, conifer numbers in both larger classes have decreased. "Adequate stocking" is a relative term depending on the objective, but compared to other buffers, this one is definitely not showing strong signs of ingrowth. Stocking is less than average for all but LGCLS. Steinblums (1978) noted that southwest winds were responsible for most windthrow. New downfall (1990) just outside the sample area substantiated this, despite a relatively recent harvest unit southeast of the sample area. Established conifer regeneration is promising, with average stocking of 902 conifers per acre. All dying and dead trees present during the time of Steinblums' study are gone (or absorbed into other classes); density of snags has increased (from two to five trees per acre) and there are two broken top trees per acre (Table 14). Snags may offer the best potential for LWD recruitment in the near future. Loadings of LWD (Table 15) show an unusually high loading in Zone 2 (20%). Most remaining volume is in Zone 4.

The diameter distribution in the Two Girls buffer

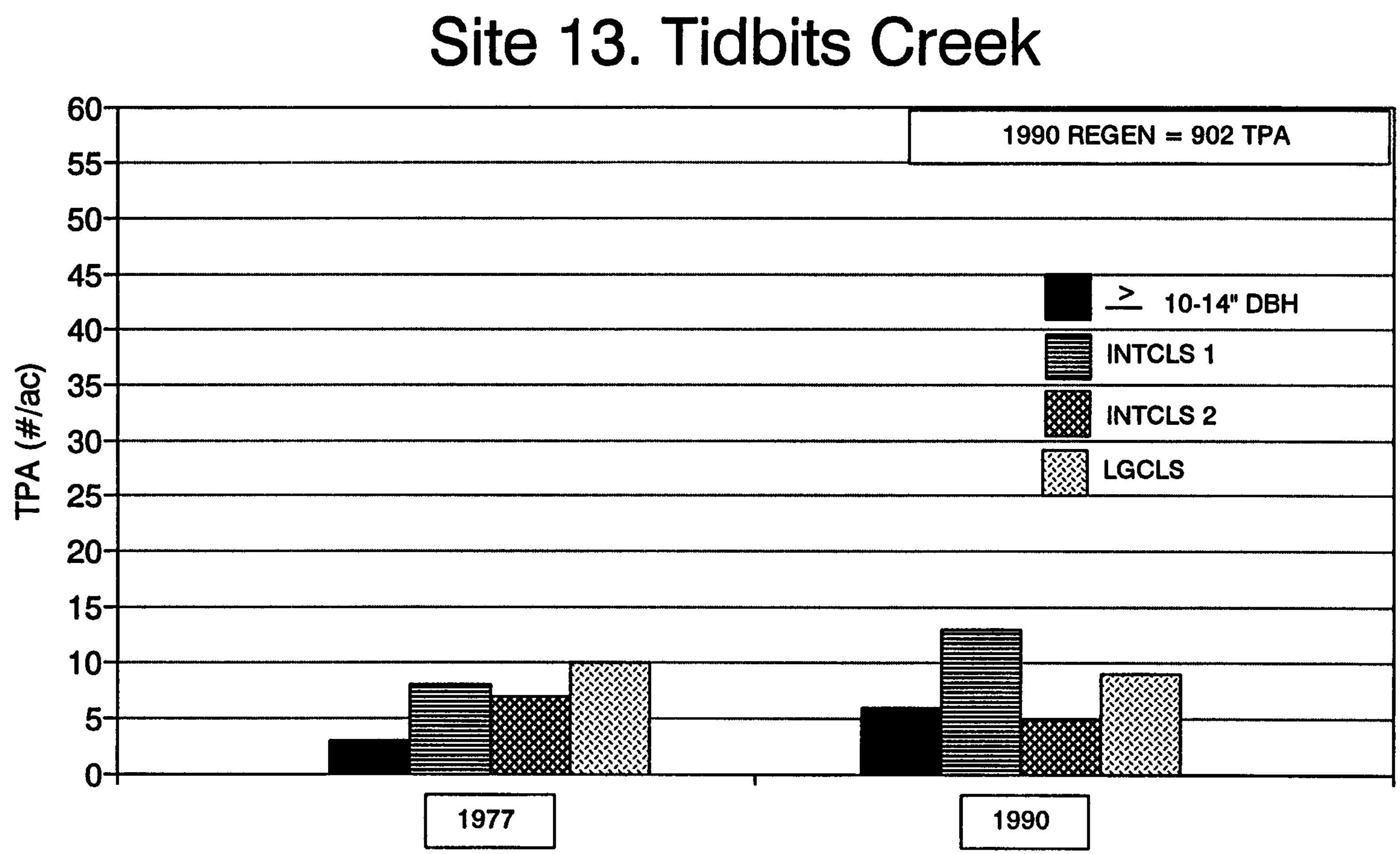


Figure C12. Density comparison of conifers (TPA) in Site 13 (Tidbits Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

strip (Figure C13) show the effects of ingrowth in the two smallest DBH classes, though by 1990, both had below average densities. There has been some loss of INTCLS 2 trees since the 1978 study. LGCLS conifers show a small increase, maybe the result of different measurement techniques. Total conifer density is 36 trees per acre, well below average. Steinblums documented minimal occurrence of susceptibility to wind, but gave this site a relatively unstable rating, apparently because of the shallow soils (three ft deep) and high initial timber volumes. A relatively new harvest unit southeast of the buffer may have influenced some of the windthrow opposite the sample area. Even though much of the site is dominated by red alder, average conifer regeneration stocking is strong at just over 1900 trees per acre. By 1990, the single dying and dead tree per acre from 1978 are either downed or shifted to another vigor class. In 1990, there were two trees per acre each in the snag and broken top classes (Table 14). Large woody debris distribution followed the usual pattern; most material was in Zone 4 (Table 15).

Ingrowth in the Winberry Creek buffer strip (Figure C14) has been substantial since the original study. Density of the first two classes have increased, both practically doubling in stems per acre since 1978. INTCLS 2 density has been relatively stable, while LGCLS has

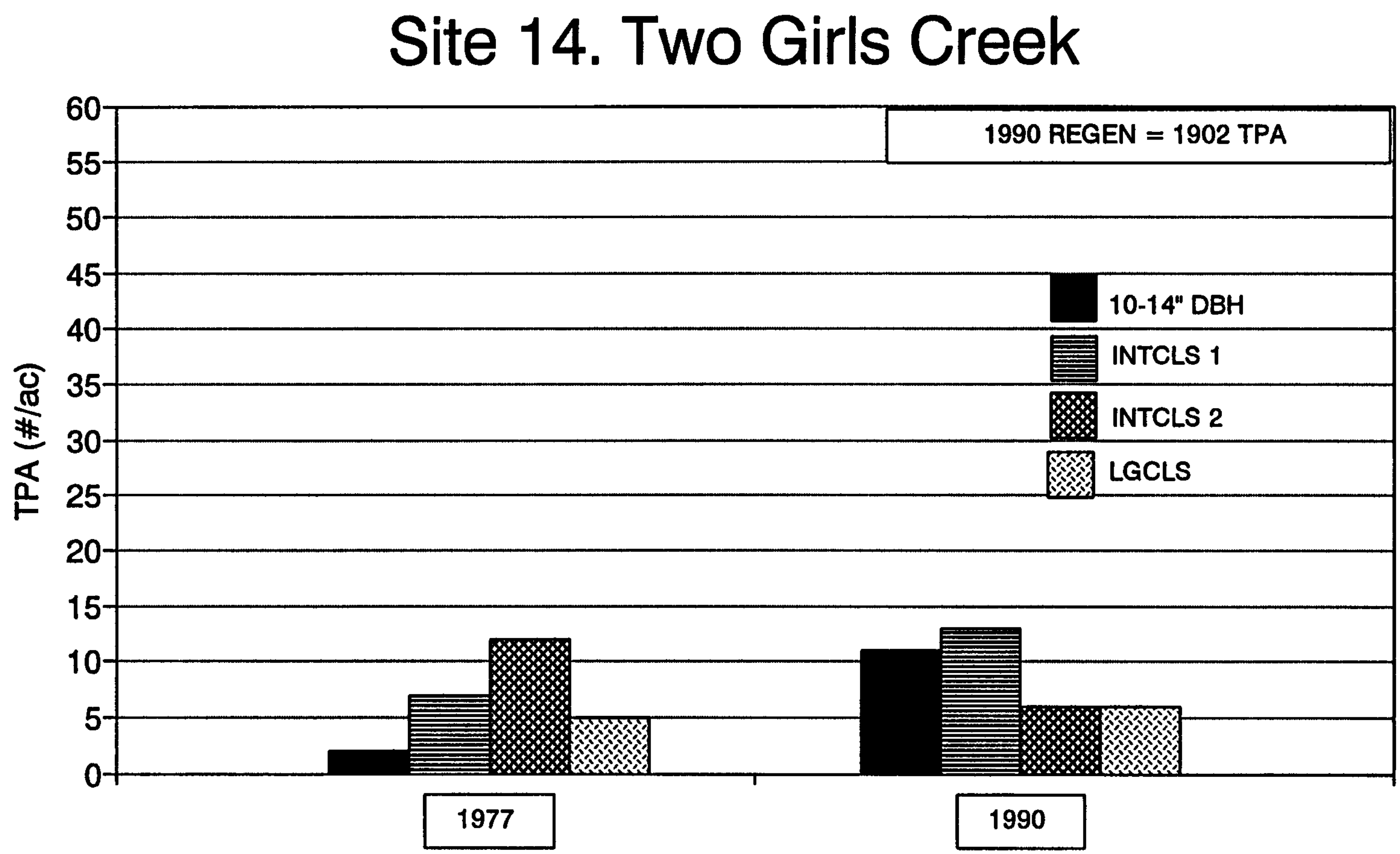


Figure C13. Density comparison of conifers (TPA) in Site 14 (Two Girls Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

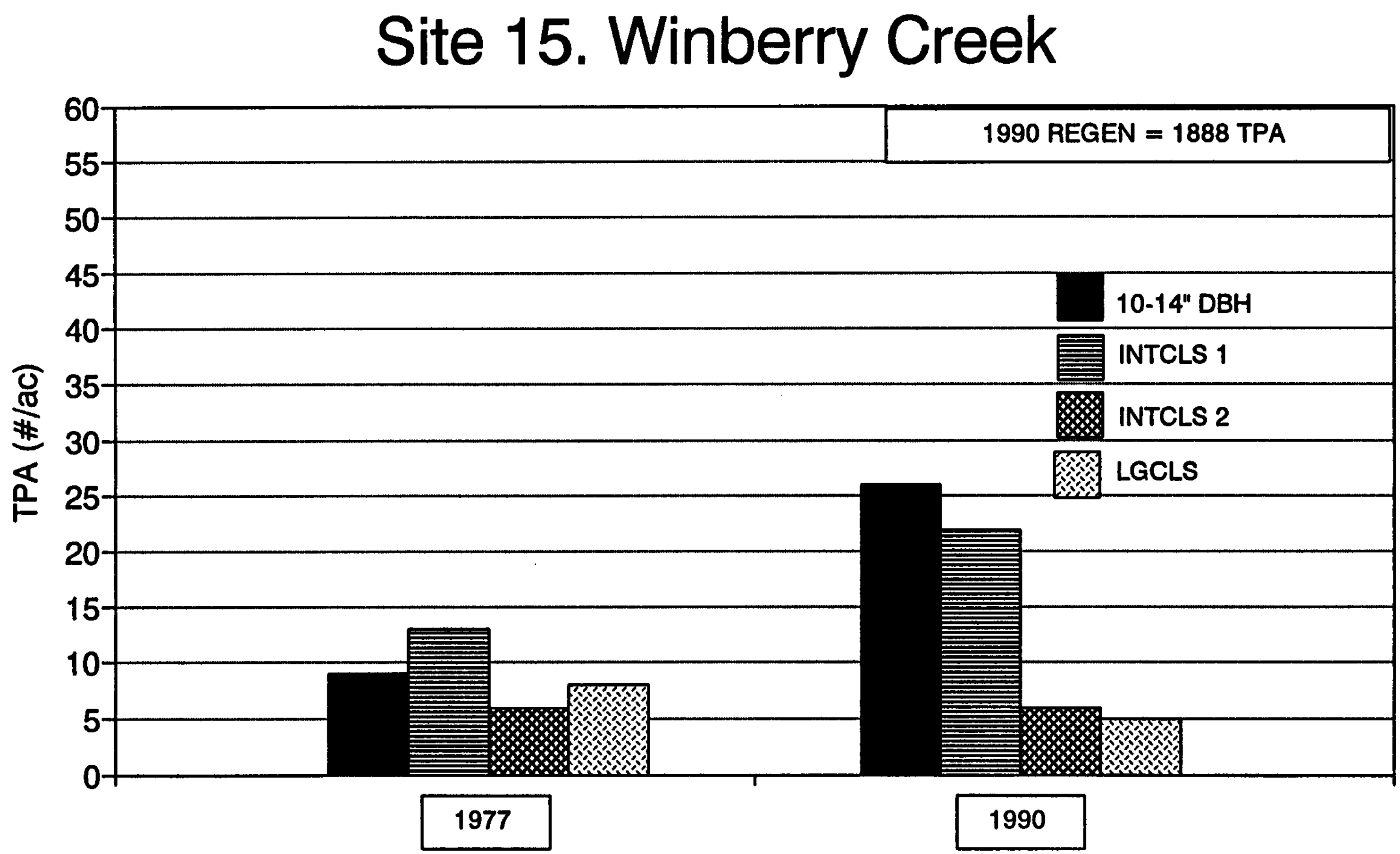


Figure C14. Density comparison of conifers (TPA) in Site 15 (Winberry Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

decreased. The only unusual site characteristic for Winberry Creek is a DISTRIDG of 15,048 feet, the greatest of any site. Since blowdown does not seem to be reflected in the larger trees, and density in the smaller classes is increasing, this buffer should have a steady supply of conifers over time. The fact that average regeneration is greater than 1800 trees per acre speaks strongly of the potential for conifers on this site over the long run. The current distribution in vigor classes shows one tree per acre each in the dying and dead classes, where there previously were none (Table 14). Snags have decreased by a single tree per acre, (from three to two). In 1990, there were no trees with broken tops. Low densities of trees in these vigor classes suggest they will not be contributing substantial volumes to LWD in the near future. Percentages of LWD in the four functional zones (Table 15) are consistent with most sites; most is located in Zone 4.

The Wolf Creek buffer strip, is also atypical of these sites (Figure C15). The distribution of overstory trees is heavily skewed by the prevalence of stems in the smaller diameter classes (10-14 = 32 trees per acre; INTCLS 1 = 52 trees per acre). In contrast, the two larger diameter classes had only a single tree per acre each by 1990. While there may be an "interruption" between size classes of trees (and then downed wood), there is certainly plenty of material on site for contribution of conifers over time.

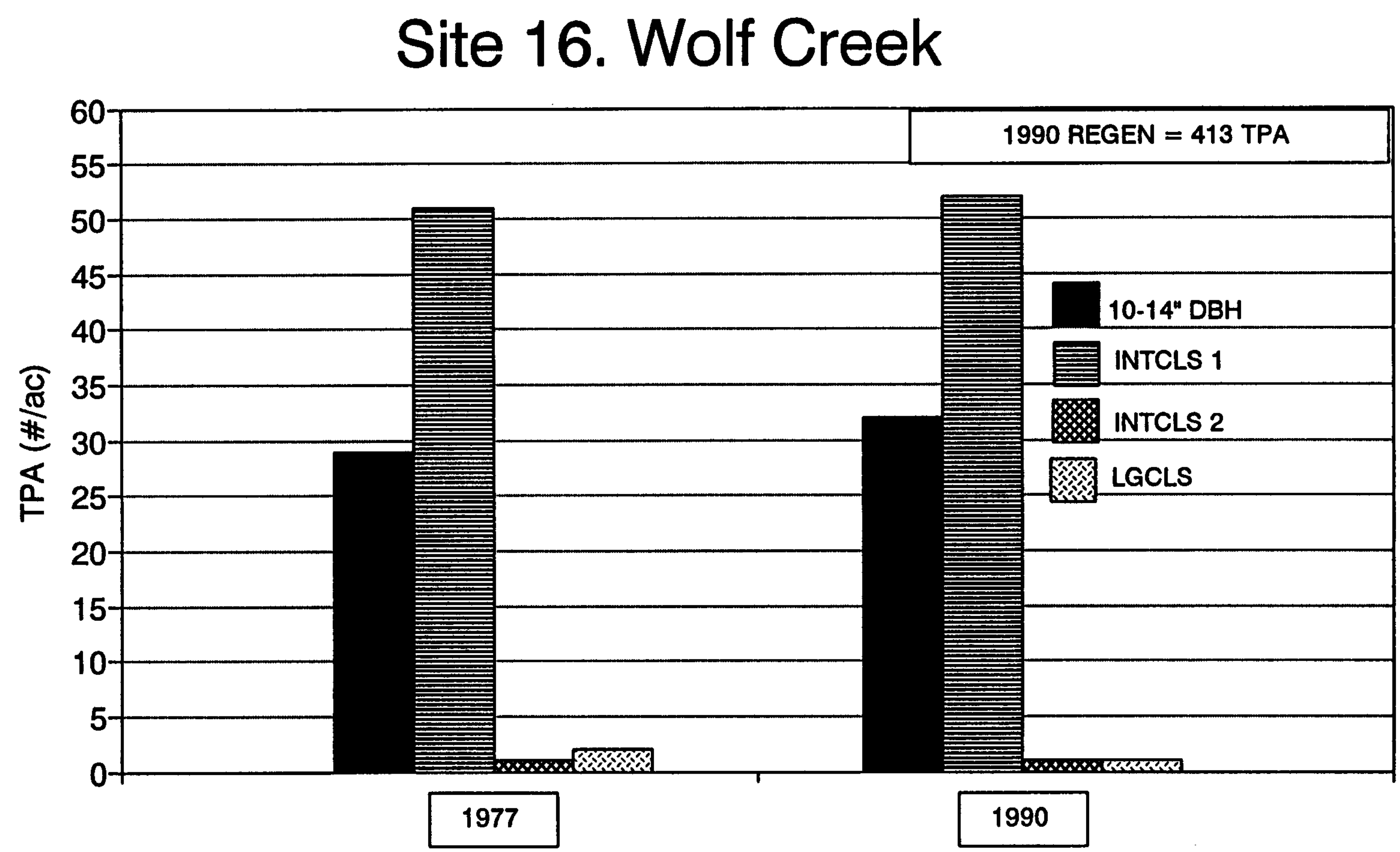


Figure C15. Density comparison of conifers (TPA) in Site 16 (Wolf Creek) buffer strip (1977 and 1990) by DBH class, and average established conifer regeneration density as of 1990.

Based on the analysis of all streams, trees in INTCLS 2 tended to be blown down most often. As some of the trees in INTCLS 1 move into the next size class, they will likely contribute to the LWD on site. Regeneration on the Wolf Creek buffer is sparse compared to many sites (average = 413 trees per acre), but does suggest a supply of conifers for the future. Vigor dynamics are some of the most interesting for these sites (Table 14). This buffer had the greatest density of dying trees in 1978 (14 trees per acre). There were two dead trees per acre and one snag per acre at the time of the earlier study. By 1990, it appears the trees previously in the dying tree class had shifted to the other classes. In 1990, there were no dying trees, two dead trees per acre, nine snags per acre and three trees per acre with broken tops. An unusually high (20%) amount of the material in Zone 4 was from recent contributions; much of this was older broken tops and limbs (Table 15).

APPENDIX D

Summary of Riparian Management Guidelines: Willamette National Forest (from Gregory and Ashkenas 1990).

Riparian Management Guidelines	Class I	Class II	Class III	
			Stable[1]	Moderate[1] & Unstable
Location				
Range of width from active channel[2]	150-400 ft	100-200 ft	50-100 ft	75-125 ft
Average width[3]	200 ft	100 ft	75 ft	100 ft
Objectives				
Extent of 100-yr floodplain within RMZ[4]	100%	100%	100%	100%
Temperature[5]	M & E	M & E	M & E	M & E
Input of woody debris	100%	90%	75%	90%
Input of terrestrial food resources	100%	100%	100%	100%
Bank stability	100%	100%	100%	100%
Operations				
Overstory vegetation remaining within RMZ	100%	100%	100%	100%
Understory vegetation remaining within RMZ	100%	100%	100%	100%
Directional falling along RMZ	Yes	Yes	Yes	Yes
Yarding suspension over banks	Full	Full	Full	Full
Yarding and line corridors	Yes	Yes	Yes	Yes
Stream cleanout[6]	No	No	No	No
Salvage within RMZ[7]	No	No	No	No

1 Stability ratings.
2 These riparian widths represent the horizontal distances commonly required to meet management objectives.
3 These widths represent the expected averages and were used in the FORPLAN model for the Forest and Resource Management Plan.
4 100-yr floodplains are assumed to be less than 400 ft wide on a single bank. Where floodplains extend beyond 400 ft, specific site conditions will be evaluated relative to the Executive Order on Floodplain Development.
5 Objectives for shade are to maintain or enhance water temperatures. At a minimum, 80% of the existing shade will be maintained.
6 Stream cleanout is permitted immediately upstream of culverts.
7 Salvage within an RMZ after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian-dependent resources. Evaluate specific site conditions.

APPENDIX D (Continued)

Summary of Riparian Management Guidelines: Willamette National Forest (from Gregory and Ashkenas 1990).

Riparian Management Guidelines	Class IV				
	Intermittent			Ephemeral	
	Stable[1]	Moderate[1]	Unstable[1]	Stable[1] & Moderate	Unstable[1]
Location					
Range of width from active channel[2]	0 ft	25-50 ft	25-100 ft	0 ft	25-100 ft
Average width[3]	0 ft	30 ft	50 ft	0 ft	50 ft
Objectives					
Provide floodplain functions[4]	No	No	No	No	No
Temperature[5]	M & E	M & E	M & E	No	No
Input of woody debris	0%	20-40%	30-50%	0%	0%
Input of terrestrial food resources	None	Partial	Partial	None	Partial
Bank stability	Locally Reduced	100%	100%	Locally Reduced	100%
Operations					
Overstory vegetation remaining within RMZ	None	Partial	All	None	Partial
Understory vegetation remaining within RMZ	Partial	Partial	All	Partial	Partial
Directional falling along RMZ	Yes	Yes	Yes	No	Yes
Yarding suspension over banks	Full-Partial	Full-Partial	Full	Partial	Partial
Yarding and line corridors	Yes	Yes	Yes	Yes	Yes
Stream cleanout[6]	No	No	No	No	No
Salvage within RMZ[7]	No	No	No	No	No

1 Stability ratings. See Appendix II for soil types and slope stability analysis
2 These riparian widths represent the horizontal distances commonly required to meet management objectives
3 These widths represent the expected averages and were used in the FORPLAN model for the Forest and Resource Management Plan.
4 Intermittent and ephemeral channels are assumed to have no floodplains.
5 Intermittent channels may flow during summer when stream temperatures are critical. Consider retention of vegetation for shade.
6 Stream cleanout is permitted immediately upstream of culverts.
7 Salvage within an RMZ after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian-dependent resources. Evaluate specific site conditions.