AN ABSTRACT OF THE THESIS OF

Cynthia A. Froyd for the degree of Master of Science in Forest Ecology presented on June 30, 1992.

Title: The Effect of Riparian Buffer Strips on Salmonberry (Rubus spectabilis) Community Structure in Alder Stands of the Oregon Coast Range

Abstract approved: Signature redacted for privacy.

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Salmonberry community structure was examined in alder-dominated riparian buffer strips in the Oregon Coast Range. Salmonberry growing on slopes was found to respond differently, to both characteristics of the buffer strips and to environmental factors, than salmonberry growing on terraces.

Salmonberry, as measured by total height, number of ramets or sprouting centers, cover, and estimated biomass, was found to increase with increasing light on the slopes. Salmonberry cover, height and number of ramets were all found to be greater on slopes within buffer strips, than on slopes in undisturbed riparian stands, where the adjacent stand had not been cut and no buffer created. The greater dominance of salmonberry within buffer strips was attributed to increased sidelight into the riparian area, due to the harvest of the adjacent stand. None of the four salmonberry characteristics were found to be related to light on the

terraces. Salmonberry height, cover, number of ramets, and biomass on terraces did, however, all increase with increasing age of the buffer strip.

There did not appear to be any clear edge effect on salmonberry within the buffer strips. An index of herbaceous vegetation was developed, through ordination, to examine the effects of unquantified environmental factors on salmonberry. Disturbance appeared to play a role in the variation seen in the salmonberry population.

Salmonberry's aerial stem diameter distribution, both within buffer strips and in undisturbed stands, resembled an uneven-aged distribution. Salmonberry stem distribution followed the same pattern whether on slopes or terraces. This suggests persistent, self-replacing salmonberry stands in these alder-dominated riparian communities.

Salmonberry was found to be negatively correlated with herb, vine maple, and swordfern cover, and also with herbaceous species abundance. There was no relationship between salmonberry and elderberry cover. Tree regeneration was found to be extremely sparse. Only one alder seedling per hectare was found in the undisturbed riparian stands. There were 29 seedlings per hectare found within the buffer strips, 22 of which were conifers.

The four salmonberry community variables increased in response to buffer strip creation when growing on both slopes and terraces. Salmonberry was shown to have a self-replacing canopy, and to dominate other shrubs and herbs in the riparian community. These factors, along with the lack of tree regeneration in these alder-dominated riparian areas, all suggest that without silvicultural intervention salmonberry could eventually dominate the riparian community.

The Effect of Riparian Buffer Strips
on Salmonberry (Rubus spectabilis) Community
Structure in Alder Stands of the Oregon Coast Range

by

Cynthia A. Froyd

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirement for the
degree of

Master of Science

Completed June 30, 1992

Commencement June 1993

ACKNOWLEDGEMENTS

I would like to thank the members of my committee for all of their help: Drs. Bill Emmingham, Dave Hibbs, Ed Jensen, Bruce McCune, John Tappeiner, and John Zasada. Special thanks to Bill Emmingham for taking over the duties of major professor, to John Tappeiner for always finding the time to help right away no matter how busy he was, and to John Zasada for helping out at the last minute. Thanks also to the C.O.P.E. (Coastal Oregon Productivity Enhancement) program for supporting this research.

I'd like to thank Glenn Ahrens, Klaus Puettman, Sam Chan, and Mary O'dea for all of their help and suggestions. Thanks also to Pete Giordano for crawling through the salmonberry with me all summer and for always putting up a good fight when it came to radio stations.

Special thanks to my roommate Cindy for feeding me and letting me live out in the country (allowing me to maintain my sanity). Thanks also to Glenn and all of the other Madras "ranchermentalists" for always helping me find something better to do than work on my thesis. I'd also like to express my gratitude to my grandparents for encouraging me throughout my education. Thanks also to Bozeman, the dog, for only eating the relatively unimportant sections of the final document.

Finally, I'd like to thank my parents, Stan and Ellen, for exposing me to the beauty of the natural environment from an early age and for making sure that I hiked every nature trail west of the Mississippi. They have supported me over

the years in whatever I wanted to do, no matter how strange they thought it was.

And thank-you Mom and Pa for paying the phone bill!

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INTRODUCTION

The riparian areas of the Oregon Coast Range are dynamic ecosystems, highly valued for a variety of resources including fish and wildlife, water, recreation and wood products. They support a very diverse population of both vegetation and wildlife. These areas are the subject of a great deal of regulation that has been designed for their protection. It has become increasingly clear that in order to maintain these riparian resource values, there must be some deliberate management of the vegetation (Hibbs 1987). In order to properly manage riparian areas, we must first understand the dynamic successional processes of the vegetation.

Coast Range

This study focused on riparian areas in the Oregon Coast Range. The Oregon Coast Range supports a very productive forest ecosystem (Fujimori 1971). It extends from the Columbia River, south to the middle fork of the Coquille River. The highest point in the range is Mary's Peak, at 4097 feet, although the general crestline altitude of the range is only about 1500 feet (Baldwin 1976).

Geology and Soil

The Oregon Coast Range consists primarily of uplifted marine sedimentary and volcanic rock. Soil parent materials are mainly marine shales, coastal plain sediments, Pleistocene dunes, and some basalt (Allen 1969). There is also recent alluvium on the plains along the major streams (Corliss and Dyrness 1963).

Climate

The maritime climate of the Oregon Coast Range favors forest development, with mild, wet winters and warm, relatively dry summers. Annual precipitation is approximately 2500 - 3000 mm, with about 50 percent of it occurring between December and February, and only about 8 percent in the summer months (Worthington 1979). Annual snowfall along the coast is 25 mm, increasing moderately with elevation.

Coastal temperatures range from an average winter minimum of -6 C to an average summer maximum of 31 C. Temperatures fluctuate slightly more inland, ranging from -7 to 35 C (Carlton 1989). Temperatures at low elevations drop below freezing less than 35 days per year. Prevailing winds are generally from the south or southwest, frequently as strong as 160 kph (Worthington 1979). Summer winds generally blow from the north or the northwest.

The microclimate in Coast Range riparian areas is also influenced by: a diurnal shift in upstream and downstream airflow, channeled wind in the stream bottoms, and temperature modification by the continual presence of water (Henderson 1970).

Vegetation

The Oregon Coast Range historically supported dense coniferous stands of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), Sitka spruce (Picea sitchensis (Bong.) Carr.), western hemlock (Tsuga heterophylla (Raf.) Sarg.), and western redcedar (Thuja plicata Donn ex D. Don). Disturbance by logging and fire over the last century has favored Douglas-fir regeneration on upslope sites, and has also led to an increase in red alder (Alnus rubra Bong), especially in the riparian areas.

The study area lies within the Tsuga heterophylla vegetation zone, with some of the more coastal plots bordering the Picea sitchensis zone (Franklin and Dyrness 1973). Franklin and Dyrness (1973) describe a variety of climax plant associations for the Coast Range, none of which seem to fit the seral, alder-salmonberry (Rubus spectabilis Pursh) dominated riparian communities of this study. Hemstrom (1986) described a Western Hemlock / Salmonberry association that consisted of a red alder overstory with a dominant salmonberry understory. This association was found in riparian areas and on toe slopes. Hemstrom (1986) did not believe that most of these stands would ever reach the western hemlock climax condition.

Carlton (1989) described both riparian and upslope red alder communities in the Coast Range, dividing them into five community types: Swordfern, Swordfern- Mixed Shrub, Swordfern- Salmonberry, Salmonberry, and Vine Maple. The riparian sites in Carlton's (1989) study were primarily included in the Alder / Salmonberry community type, although sites were not specifically categorized as riparian or upslope. Carlton's Alder / Salmonberry community is characterized by a high site index, a fairly continuous subcanopy of salmonberry, and an herbaceous layer of shade tolerant species, with relatively low species diversity (Carlton 1989).

Henderson (1970) described a river bottom community type, characterized by a red alder overstory and dominant salmonberry understory. Other common associates included: Polystichum munitum (Kaulf.) Presl., Sambucus racemosa (T.& G.) Gray, Rubus ursinus (C.& S.) Brown, Oxalis oregana Nutt. ex T.& G., and Galium triflorum Michx. (Henderson 1970). There are studies underway (Pabst pers. comm.) in the Oregon Coast Range to further define riparian plant associations, analyzing them separately from upslope communities.

Riparian Buffer Strips

Past logging practices, of clearcutting directly down to the stream, created the intense scarification which favors the establishment of dense red alder stands. These logging practices helped lead to the widespread dominance of alder now seen in the riparian areas of the Oregon Coast Range (Newton 1989). Regulations were established during the 1970's to limit cutting in riparian areas, and require the creation of buffer leave strips along waterways.

Riparian regulations were established primarily for the protection of fish habitat and water quality. Riparian vegetation was recognized as important to fish habitat for its control of water temperature, through shading, and also for organic debris input, the food base of the stream ecosystem (Minore and Weatherly 1990). Streamside vegetation is also important in maintaining the physical integrity of stream channels, by stabilizing stream banks and intercepting eroding sediments (Beschta 1989).

Riparian vegetation is also important as a source of woody debris. Recently, large woody debris in streams has been determined to be a "keystone" habitat feature for fish (McMahon and Reeves 1989). It controls the routing of sediment and water flow, creates pools and riffles, and is also a base of biological activity (Meehan et al. 1977).

Riparian zones are also important habitat for a large variety of wildlife.

The riparian zones of western Oregon have been recognized as extremely productive wildlife habitats, characterized by high faunal species diversity, density, and productivity (Anthony et al. 1987). Riparian areas are important for many species of amphibians and reptiles (Bury 1988), birds (Knopf and Samson 1988), small mammals and bats (Cross 1988), and large mammals (Raedeke et al. 1988). Many species of wildlife are considered dependent on riparian habitat (Raedeke et al. 1988). Brown (1985) has recognized 359 vertebrate species, excluding fish, which use the riparian areas of western Oregon and Washington for at least part of their life cycle.

There are many different boundary definitions of a riparian zone. In the past, only the vegetation directly adjacent to the stream's edge was considered to be within the riparian area. Researchers have recently taken a more functional view, focusing on riparian areas as the link between the terrestrial and aquatic environments (Summers 1982).

Meehan (1977) defined a riparian zone as the area containing all of the vegetation that directly influences the stream environment. Researchers have interpreted this in a variety of ways. Some identify the border of the riparian zone as the point at which shrubby vegetation no longer interacts with the stream (Campbell and Franklin 1979). Others have extended it to the height of the tallest tree in the stand (Cummins 1975). In this study, the definition was expanded even further, extending the riparian border inland until there was a definite change in the plant community from riparian to an upslope type.

The practice of leaving riparian buffer strips, to protect the fisheries resource and provide a continued supply of coarse woody debris input to the stream, has been shown to work in the short-term, but its effectiveness over the long-term has recently come into question (McMahon and Reeves 1989). It has been speculated that these alder-dominated communities in the Oregon Coast Range may eventually succeed to salmonberry brushfields (Newton et al. 1968, Henderson 1970, Carlton 1989). A review of the autecology of red alder and salmonberry is important in understanding the successional processes within Coast Range riparian buffer strips.

Red Alder

Red alder (Alnus rubra Bong.) is a rapidly growing, shade-intolerant pioneer species, which colonizes disturbed sites west of the Cascades in the Pacific Northwest. It is the most abundant hardwood in the Douglas-fir region of western Oregon and Washington, and is a particularly aggressive competitor in burned and logged-over lands in the Coast Range (Franklin et al. 1968). Long considered a "weed" by foresters, red alder is now noted for its importance in wildlife habitat, stream protection, nitrogen fixing ability, and value as a timber commodity.

Riparian areas in the Oregon Coast Range disturbed by logging or flooding provide red alder with ideal conditions for its germination, bare mineral soil and abundant moisture. The most productive red alder stands are found on deep, well-drained, moist alluvial soils (Fowells 1965). Red alder is also believed to tolerate restricted drainage better than the other tree species in the area (DeBell et al. 1983).

Red alder begins producing seed at about age ten (Carlton 1989). A substantial amount of the wind-dispersed seeds are eaten by rodents and soil invertebrates. Once successfully established, red alder stands develop with few problems, provided there is adequate light and moisture (Carlton 1989). The age at which alder senesces varies across the region, but is typically between 100-160 years (Henderson 1978). Mature stands are subject to Hypoxylon fuscum, a white heart rot of dead and dying trees (Rogers 1968), and Fomes igniarius, a heart rot in living trees.

Red alder is noted for its influence on soil properties. Reported rates of nitrogen fixation under red alder range from 35 to 320 kg per hectare per year (Luken and Fonda 1983). There is speculation that the high organic matter and increased nitrogen found in alder soils may lead to an increase in acid decomposition products (Franklin et al. 1968). This could lead to a lower soil pH, and therefore reduce the amount of exchangeable calcium and magnesium (Franklin et al. 1968, DeBell et al. 1983).

Red alder communities can quickly accumulate above-ground biomass, with a maximum annual productivity in 10 to 15 year-old stands of 240 metric tons (dry weight) per hectare (Zavitkovski and Stevens 1972). Red alder stands also produce large amounts of litter, up to 300 metric tons per acre (dry weight) in the first 50 years of growth. This can lead to the development of a substantial organic layer (Zavitkovski and Newton 1971).

Many authors have noted the absence of tree regeneration under pure red alder stands in the Oregon Coast Range. Newton (1968) observed the lack of tree regeneration in young alder stands. Carlton (1989) confirmed this, and noted the scarcity of regeneration in older red alder stands as well. Henderson (1970) and Minore and Weatherly (1990) noted the scarcity of tree regeneration in alder-dominated riparian areas in the Coast Range. Franklin and Pechanec (1968), on the other hand, did find suppressed Sitka spruce saplings growing in a 40-year-old upslope, alder stand. They predicted that the scattered seedlings might be released when the alder overstory deteriorated.

Alder logs are considered less effective than conifers for fish habitat, due to their faster rate of decomposition (McMahon and Reeves 1989). Their smaller size also makes them less desirable as large woody debris.

Salmonberry

Salmonberry (Rubus spectabilis Pursh) is a widespread shrub species of the Pacific Northwest, particularly in the Oregon Coast Range. It is commonly found in mesic locations, especially near streams. Salmonberry-dominated communities have become widespread in the Coast Range as a result of disturbance, competition, and successional patterns (Hemstrom 1986).

After disturbance in riparian areas, red alder and salmonberry often reestablish a site at the same time (Henderson 1970). Salmonberry can also regenerate from buried seed beneath a growing alder overstory. Dense shrub competition, the first few years after a disturbance, often prevents the establishment of conifers in these stands.

Salmonberry cover increases, in these disturbance-established stands, when the alder overstory begins to thin at about 25-30 years (Henderson 1970). Salmonberry perpetuates itself by both sexual and asexual reproduction. It can rapidly colonize a disturbed area by seedling reproduction, and then maintain its presence through vegetative reproduction. If a more shade tolerant overstory species were to eliminate salmonberry in the community, buried seed can still remain viable for up to a hundred years (Barber 1976). This flexibility is the key to salmonberry's success.

Salmonberry is able to play two successional roles, that of a colonizer following a disturbance, as well as a persistent understory species. Its small seeds, attractive fruits, seedling habits, and aggressive spread following a disturbance all suggest that it is an early successional species. Salmonberry also thrives, however, as a more tolerant understory species, forming a tall shrub layer in alder and mixed stands, and possibly playing a climax role following overstory senescence.

Salmonberry has been subjectively described in the literature both as tolerant (Henderson 1970, Ruth 1970) and as intolerant (Franklin and Pechanec 1968), tolerant because of its role as an understory dominant and intolerant because of its inability to survive in dense conifer stands. Most other Northwest species of Rubus are intolerant, growing best in exposed locations (Barber 1976). Salmonberry, however, is also able to thrive as an understory species, with established stands perpetuating indefinitely through vegetative reproduction.

Adequate light and water are sufficient growth requirements, leading to dense, rapidly forming stands of salmonberry (Barber 1976). There is abundant water in the riparian areas of the Oregon Coast Range, so the limiting factor for salmonberry growth in these areas appears to be light. Krygier and Ruth (1961) reported that salmonberry prefers partial shading, and that its best development is often along stand margins. When riparian buffer strips are left, a new stand margin has been created.

Salmonberry initiates growth early in the spring, approximately one month before the alder overstory canopy begins to develop (Barber 1976). This allows higher light intensities at a time of active salmonberry growth. Salmonberry apparently relies on food stored from the previous year, rather than heavy initial carbohydrate production, to initiate growth. These factors account for salmonberry's extended growing season (Barber 1976). Barber (1976) believes that this early spring precocity represents a "compromise" between the extremes of tolerance and intolerance, enabling salmonberry to avoid the unfavorable effects of shading on growth and reproduction.

It is salmonberry's ability to reproduce vegetatively, however, that is responsible for the persistence of colonies under the alder canopies within riparian buffer strips. Salmonberry may account for up to 75% of the understory biomass in bottom land red alder stands (Henderson 1970). Rhizome shoots are the most important form of vegetative reproduction, but tip layering and rooting of cane fragments also occurs (Barber 1976). Unlike some other species, salmonberry rhizome development is not restricted to the periphery of clones, and new aerial stems are produced throughout the clone (Tappeiner et al. 1990).

Salmonberry clones consist of ramets, which are made up of a tap root and 1-5 aerial stems, connected by a network of rhizomes (Tappeiner et al. 1990). Clonal colonies of up to 30 m^2 of connected ramets have been discovered. Actual clone size may be much larger, but the rhizome connections often rot (Zasada pers. comm.). Aerial stems can reach up to 4 meters in height. Rhizome density of salmonberry in alder stands is often greater than 5 miles/acre, with a preformed bud in every 2-3 cm of rhizome (Barber 1976).

On undisturbed sites, individual clones and populations of salmonberry replace aerial stems by sprouts from basal buds, rhizome extension, and production of new genets (Tappeiner et al. 1990). Frequent production of stems from these three sources allows salmonberry to persist on a site, and to maintain a dense network of rhizomes below-ground, and a continuous cover above-ground. The size distribution of salmonberry aerial stems has been found to resemble an uneven-age stand, in a variety of stand types in the Oregon Coast Range (Tappeiner et al. 1990). This implies a continuous cover of salmonberry, once it is established on a site.

The extensive thickets formed by salmonberry in these riparian areas often inhibit tree regeneration. Many studies have noted the absence of tree regeneration in understories dominated by salmonberry (Carlton 1989, Minore 1990, Newton 1968). If there is conifer regeneration, it often occurs on down logs in the stand. Salmonberry seedling regeneration itself is also inhibited by the low light levels and deep litter layer created by the mature salmonberry, but it is still able to reproduce vegetatively.

Once salmonberry is established on a site it can have a profound effect on succession. It has been cited as inhibiting the establishment not only of tree seedlings, but also of other tall shrubs such as vine maple (Acer circinatum Pursh) and elderberry (Sambucus racemosa (T.& G.) Gray (Franklin and Pechanec 1968). These shrubs might otherwise have replaced salmonberry in the understory. Salmonberry is also thought to inhibit the growth of herbaceous species on a site, although some species such as swordfern (Polystichum munitum

Kaulf) and Oregon oxalis (Oxalis oregana Nutt. ex T.& G.) may be abundant under salmonberry (Henderson 1978). Salmonberry communities appear to be stable for long periods of time, due to the continual replacement of dead aerial stems at a rate which allows salmonberry to inhibit taller or more competitive species (Tappeiner et al. 1990).

Succession

The predominance of alder stands in riparian areas of the Oregon Coast Range has led many to believe that it is the natural riparian vegetation, but the presence of large conifer stumps in many of these areas indicates a historically wider variety of vegetation (Bacon and McConnell 1989). The lack of conifers in many of these areas is thought to be the result of disturbance, rather than innate potential (Newton 1989). Past logging, along with periodic flooding, agricultural clearing, road construction, and fire have increased the presence of alder stands (Henderson 1978).

Maintenance and management of these communities requires that we look at their long-term behavior (Hibbs 1989). Preserving a buffer area along streams makes sense in the short-run, the plant community is maintained and all of the resources are protected, but management upslope may have altered the situation. Creating buffer strips in these alder-dominated communities could alter the successional path of many riparian areas. Sidelight may be increased into the riparian system when a buffer strip is left after harvest of the adjacent stand. This increased light could result in increased salmonberry growth within the leave strip. Senescence of the alder overstory and the lack of tree regeneration in these areas could lead to a salmonberry dominated community (Hibbs 1989). Once these changes have begun they may be difficult to alter, and could lead to long-term degradation of the riparian areas of the Oregon Coast Range.

Hemstrom (1986) states that the riparian alder-salmonberry communities (which he terms the Western Hemlock / Salmonberry Association) could be considered disturbance climax or seral communities, which may never complete succession to the projected hemlock climax (Hemstrom 1986). Hemstrom hypothesizes that these communities, in the absence of available hemlock seed, will succeed to a salmonberry brushfield.

Henderson (1970) searched for examples of the salmonberry brushfield stage of succession, but could not find any. He believed that this did not negate the hypothesis, however, that salmonberry replaces red alder as the community dominant. Henderson attributed the current lack of brushfields to the fact that the man-caused disturbances, which have led to the proliferation of the alder-salmonberry community type, are unprecedented in the natural environment.

Management

Management of riparian areas has become increasingly controversial. Coherent long-term management for the benefit of diverse riparian values is a necessity. We know very little about the successional processes in riparian forests, and even less about the effect of creating buffer strips on these processes. Riparian areas are currently managed based on our knowledge of upslope forests, even though plant community composition, distribution, regeneration, growth, and mortality may differ greatly (Gregory 1989). Some of the current riparian management regulations are largely the result of political compromise, and were written without a firm technical basis (Morman 1989).

Uniform regulations for riparian areas are attractive because they simplify the management of these areas (Hubbert et al. 1985), but such an approach inadequately addresses the complexity of streamside resources (Adams et al. 1988). Better scientific understanding, combined with active management that focuses on all of the resources in the riparian ecosystem, will result in the greatest benefit (Schnee 1989).

Many believe that the current practice of leaving buffer strips maintains the diversity of the riparian zone (Brown 1985). Riparian leave strips have been shown to effectively maintain fish habitat and populations, for example, over the short-term, but long-term planning requires management of riparian vegetation to provide a continued supply of the appropriate quantity and quality of large woody debris (McMahon and Reeves 1989). This protection of the riparian resource through preservation makes sense in the short-run, but we must understand long-term processes to best manage for all riparian resources, including fish, wildlife, water quality, recreation, and wood products. Active management requires a better understanding of successional patterns of vegetation, under existing conditions.

RESEARCH OBJECTIVES

This study was conducted to gain a better understanding of salmonberry's successional role in alder-dominated riparian buffer strips in the Oregon Coast Range. Specific objectives are as follows:

1. To examine the relationship between the salmonberry community and characteristics of both the alder buffer strips and the riparian environment.

(a). I hypothesized that the salmonberry community behaves differently when growing on slopes and terraces.

(b). I hypothesized that salmonberry would increase with time since buffer strip creation, due to increased side light into the riparian area.

(c). I hypothesized that there would be more salmonberry within buffer strips than in undisturbed riparian alder stands.

(d). I hypothesized that there would be an edge effect within the buffer strip, with an increase in salmonberry near the clearcut edge.

(e). I hypothesized that other environmental factors effecting salmonberry growth, which were not directly measured in this study, could be assessed through their effect on the herbaceous community.

2. To examine salmonberry's aerial stem diameter distribution pattern in alder-dominated riparian communities.

(a). I hypothesized that salmonberry's diameter distribution would resemble an uneven-aged stand, as has been found in other community types in the Oregon Coast Range.

3. To assess the effect of salmonberry on other components of the riparian plant community: herbs, shrubs, and tree regeneration.

(a). I hypothesized that herbaceous cover and species abundance would be inversely related to salmonberry height, cover, number of ramets, and biomass.

(b). I hypothesized that cover of the other dominant shrubs in the riparian community (vine maple, elderberry, and swordfern) would be inversely related to salmonberry height, cover, number of ramets, and biomass.

(c). I hypothesized that salmonberry's relationship with buffer age could be affected by increasing competition from vine maple.

(d). I hypothesized that tree regeneration would be sparse in these alder-salmonberry dominated riparian communities.

AREA OF STUDY

Fifty-four alder-dominated riparian stands were sampled on the western slope of the Oregon Coast Range. Plot locations ranged from just south of Waldport, north to Tillamook (see map, Figure 1). All stands were located along perennial streams, but not along the major rivers of the Coast Range. Study sites were located in riparian areas with homogenous vegetation and site conditions, parallel to the stream. Each stand extended at least 50 m along the stream without any major changes in vegetation or topography. More than one transect could be located along the same stream, as long as they were in different stands. This led to the establishment of transects along a total of 32 different streams (Table 1).

All sample sites were located within the Tsuga heterophylla vegetation zone (Franklin and Dyrness 1973). Elevation of sites ranged from 120 to 1200 feet. Ten transects were located in undisturbed riparian stands, where the adjacent stand had not been cut, and no buffer created. Forty-four were located in buffer strips of various ages, ranging from 0-28 years since the adjacent stand had been cut and the buffer strip created. This led to the establishment of a chronosequence on the buffer strip sites. The zero year buffer strips were in stands in which the buffer had been created the same year as the sampling.

Soils in the study area are derived primarily from uplifted marine sedimentary and volcanic rock. Soils in the riparian study sites are more variable

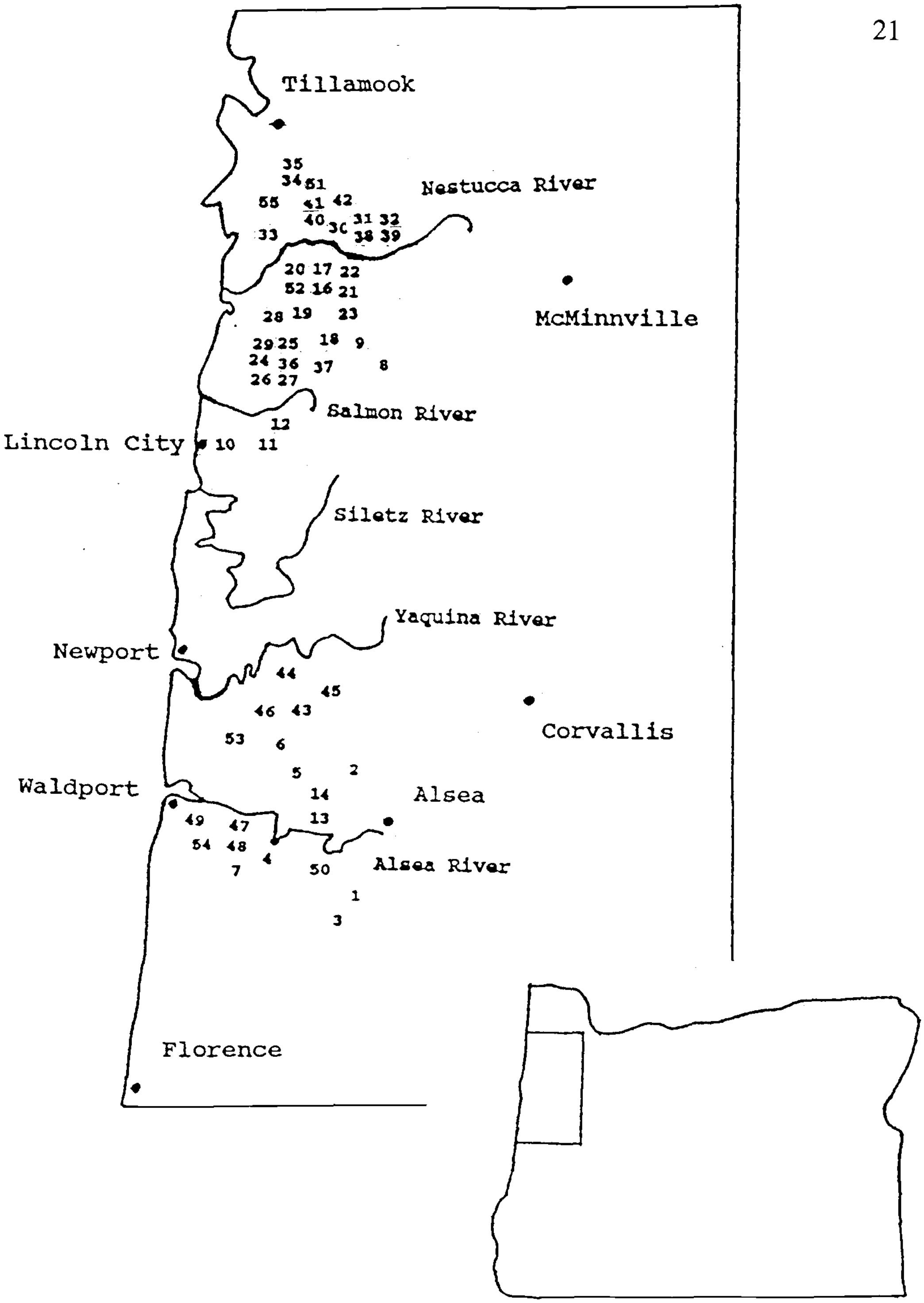

FIGURE 1. Location of transect lines.

TABLE 1. Buffer age, elevation, and stream name of sample sites. UN = undisturbed riparian stand, adjacent stand has not been cut and no buffer strip has been created.

TRANSECT #	BUFFER AGE	ELEVATION (FT)	STREAM NAME
1	4	320	PREACHER
2	18	800	FALL
3	5	320	PREACHER
4	12	240	CASCADE (N. fork)
5	11	640	BULL RUN
6	12	800	DRIFT (S. fork)
7	22	160	CANAL
8	11	480	AGENCY
9	UN	720	AGENCY
10	20	160	ROCK
11	12	400	TROUT
12	11	360	TREAT
13	8	200	FALL
14	20	280	FALL
16	14	400	TONY
17	UN	320	TONY
18	2	1200	THREE RIVERS
19	8	520	THREE RIVERS
20	17	400	FOLAND
21	9	640	TURPY
22	10	680	BOULDER

TABLE 1 (continued)

TRANSECT #	BUFFER AGE	ELEVATION (FT)	STREAM NAME
23	10	640	BOULDER
24	0	480	LOUIE
25	0	480	LOUIE
26	5	440	LITTLE NESTUCCA
27	5	440	LITTLE NESTUCCA
28	9	400	ALDER
29	7	480	LOUIE
30	4	280	MOON
31	12	1040	CLARENCE
32	12	960	CLARENCE
33	9	120	BEAVER
34	1	600	EAST BEAVER
35	1	640	EAST BEAVER
36	2	440	LOUIE
37	10	440	SOURGRASS
38	UN	880	CLARENCE
39	12	920	CLARENCE
40	12	240	BAYS
41	6	280	BAYS
42	11	480	EAST
43	UN	600	NETTLE
44	UN	120	BEAVER

TABLE 1 (continued)

TRANSECT #	BUFFER AGE	ELEVATION (FT)	STREAM NAME
45	4	120	BIG ELK
46	28	440	DRIFT
47	UN	80	CANAL
48	UN	120	CANAL
49	UN	200	ECKERMAN
50	UN	200	LOBSTER
51	UN	280	BAYS
52	18	520	FOLAND
53	18	320	DRIFT
54	16	200	BEAR
55	0	280	WILDCAT

than upland soils of the region, due to alluvial deposition. The study site locations can, however, be divided into two broad geographic areas of differing parent material, those north of Lincoln City and those south of Newport.

The parent material in the northern portion of the study area is dominated by volcanic rocks, intermixed with some related intrusive rocks and marine sedimentary rocks (Badura et al. 1974). The southern portion of the study area is dominated by the Tyee Formation (also referred to as the Flournoy Formation (Baldwin 1976)), which is composed of medium-grained sandstone (Badura et al. 1974).

Temperature in the study area is assumed to be fairly uniform. All sites are on the western slope of the Oregon Coast Range, where streams are located in draws. Temperature in the riparian areas is also moderated by the presence of water.

Moisture is abundant in the study area, both in the soil and from atmospheric humidity. There is little evaporative demand in the Coast Range, compared to other areas, especially in the sheltered, riparian environments.

METHODS

Data Collection

Transects were located perpendicular to the stream, beginning at full-bank width and extending the width of the buffer strip. The transects on undisturbed sites extended the width of the riparian community. The initial point of the transect was established 25 m in from the edge of the homogeneous riparian stand.

Five meter wide plots were established along the length of each transect. A total of 231 plots were sampled in the study. An herb, shrub, and overstory sampling unit was established for each 5m wide plot (see figure 2). Each herb plot was 1 m^2, each shrub plot was 25 m^2, and each overstory plot was 75 m^2. The shrub and overstory plots were centered on the transect line. Herb plots were offset one meter to the right to avoid trampling the herbaceous vegetation.

Chronosequence

A chronosequence is used to study plant succession through time, without the requirement of permanent plots. This method equates looking at equivalent stands of different ages, with following one stand over time. The basic assumption in the chronosequence approach is that the different study sites are the same, except for the time elapsed since a particular event (in this case, the

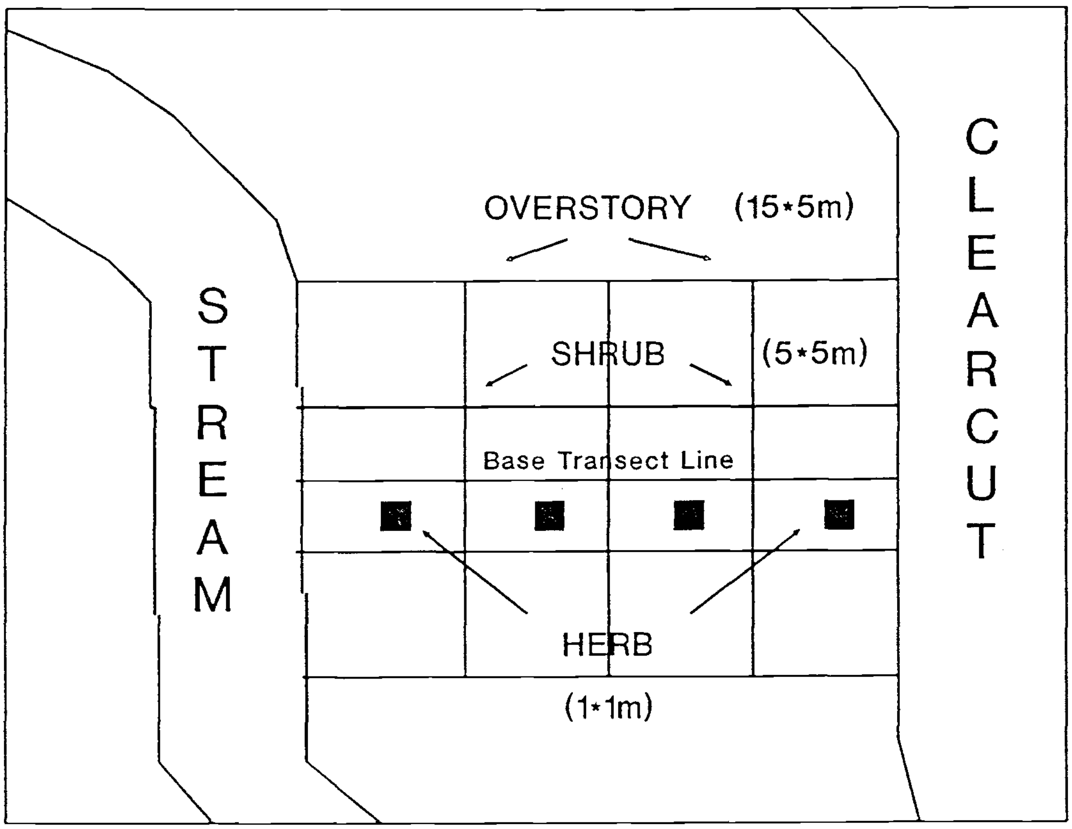

FIGURE 2. Sampling scheme.

creation of a buffer strip) (Oliver 1982). The differences between sites can therefore be attributed to successional development.

All of the study sites were established in alder-dominated riparian areas of the western Oregon Coast Range, within the Tsuga heterophylla vegetation zone (Franklin and Dyrness 1973), to minimize differences in initial stand conditions. Previous studies have used the chronosequence approach in riparian zones of the same geographic area (Andrus and Froehlich 1987).

Variables

The following variables were measured:

1. For each transect line:

Elevation (ft), stream gradient (% slope), stream width (average full-bank width in meters), secondary disturbance on the site (landslide, windthrow, wind breakage, erosion, deposition, beaver, other animals), buffer age (number of years since the adjacent stand was cut, thereby creating a buffer strip), alder overstory age (years), buffer width (m), latitude, distance from ocean (miles).

2. For each 5m wide plot:

Slope (%), physiographic position (5 slope position categories, see Bowersox and Ward 1972), height above stream (m), tree basal area (measured with a 10 BAF prism), distance of plot from stream (m), distance of plot from cut edge (m), plot edge position (directly adjacent to an edge, one plot away from an edge, or an interior plot), and aspect. Aspect was transformed using the following equation: aspect = cos(45-azimuth)+1. This converts aspect to a scale ranging from 0 (southwest) to 2.00 (northeast) (Beers et al. 1966).

3. For each herb plot (1*1m):

Percent cover of each herbaceous species, and calliper of salmonberry stems rooted in the plot (cm, measured 15 cm above the ground). Total above and below-ground biomass of salmonberry on each herb plot was calculated using the following equation: total salmonberry biomass (kg/m^2)= 0.206 + 0.189 * (salmonberry basal area) - 0.047 * (salmonberry stem number) (Tappeiner et al. 1991).

4. For each shrub plot (5*5m):

Percent cover of each shrub species, average maximum salmonberry height (measured every 1 m along the transect line, 5 per plot, and averaged), and number of salmonberry ramets.

Salmonberry ramets, or clumps, are the central points of the salmonberry clones from which the aerial stems originate. The ramets of a salmonberry clone are interconnected by the rhizomes. The rhizomes may often break, so the above-ground salmonberry clumps seen in an area may actually be separate individuals, but still be genetically identical (Tappeiner pers. comm.).

5. For each overstory plot (15*5m):

Diameter (cm) and species of all trees, overstory % cover (ocular estimate), presence of herb species not found in the herb plot (to get total herb species abundance), tree regeneration (species, abundance, and rooting substrate), and % full light.

Percent full light was obtained with a hand-held Licor 190S quantum sensor. Three measurements, above the shrub canopy, were taken on each plot and the time recorded. Values were compared to those measured at the same time in full sun, through the use of a quantum sensor attached to a data recorder. Percent of light reaching the understory was then determined. This allowed us to measure the percent of light reaching the understory, regardless of weather conditions. The data logger recorded the amount of light out in the open at a particular moment, which could then be compared to the understory measurement.

<u>Terraces and Slopes</u>

The transects were divided by landform, separating them into terrace and slope sampling units. Figure 3 shows how a single transect could contain both a terrace and a slope sampling unit. Some transects consisted of a terrace

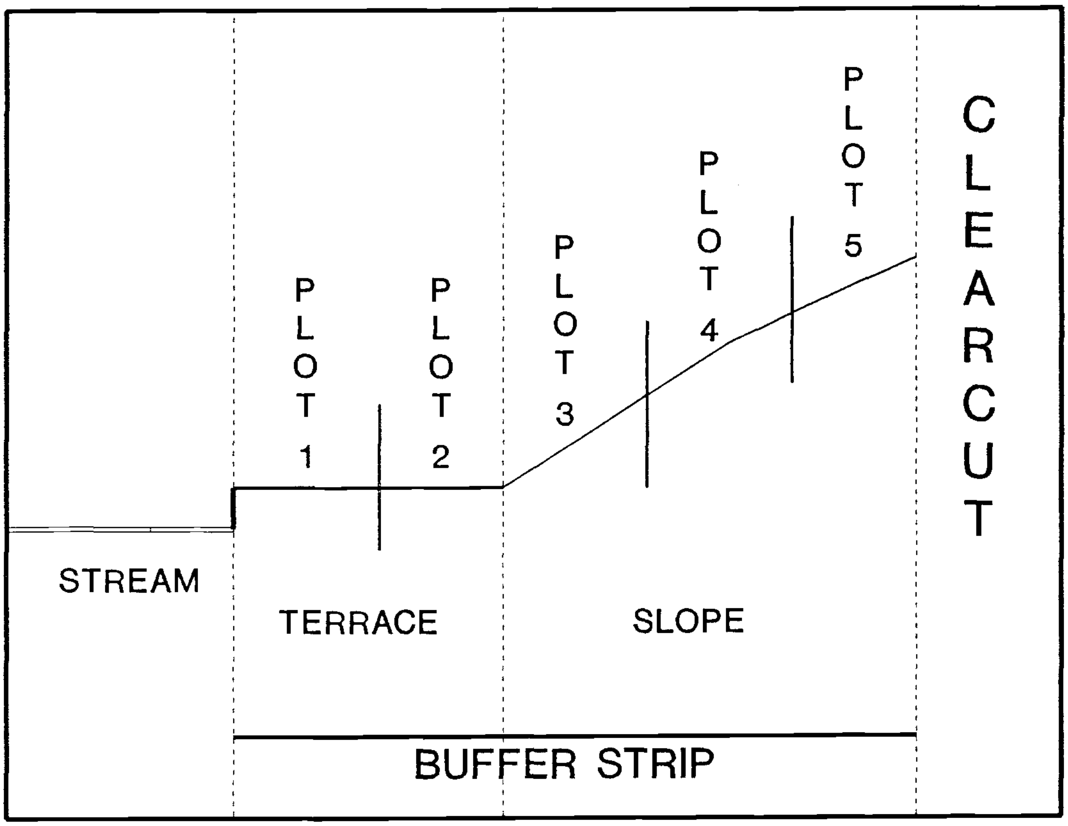

FIGURE 3. Side view, layout of a typical transect. This transect is divided into a terrace and a slope sampling unit.

section, adjacent to the stream, and a slope section, as in the diagram. Other transects were located entirely within terraces, while some consisted of a slope running directly down to the stream. Plots were established every five meters along a transect. The number of plots in each type of landform unit, therefore, varied with the width of the particular terrace or slope section of each buffer strip.

Landform designation was assessed visually. Plots of relatively flat topography adjacent to the stream were characterized as terrace plots, although no specific percent slope limitation was set. If the topographic break from terrace to slope occurred within a plot, the plot was classified according to whether it was predominantly terrace or slope.

There were a total of 26 terrace and 32 slope sampling units, within the 44 buffer strips. The 10 undisturbed plots were separated into 8 terrace and 8 slope sampling units. Terrace and slope sampling units varied in width and, therefore, in the number of 5 meter wide plots established within them. Eighty-two plots were taken on slopes within buffer strips, and 60 on terraces. There were 34 slope and 27 terrace plots surveyed in the undisturbed stands.

Plot measurements were averaged within each terrace and slope sampling unit. Table (2) presents the means and ranges of the buffer and environmental variables, on the buffer strip sites. Table (3) presents the means and ranges of

TABLE 2. Ranges and means of independent variables.
Terrace n=26, Slope n=32.

VARIABLES	TERRACE Mean	TERRACE Range	SLOPE Mean	SLOPE Range
Buffer Age (yrs)	9.8	0 - 28	9.5	0 - 20
Buffer Width (m)	18.7	5 - 40	19.4	10 - 40
Overstory Age (yrs)	41.1	17 - 61	45.8	17 - 82
Stream Width (m)	8.4	1.7 - 22.0	8.4	1.7 - 21.5
Stream Gradient (%)	2.6	1 - 7	2.6	.1 - 7
Elevation (ft)	492	120 - 1200	465	120 - 1200
Basal Area- Prism (m^2/ha)	25	5 - 60	16	2 - 49
Basal Area- Plot (m^2/ha)	49	0 - 110	27	0 - 65
Overstory % Cover	75	56 - 90	56	13 - 93
% Full Light	17	.3 - 100	19	.3 - 100
Height Above Stream (m)	.1	.2 - 2.3	3.8	.8 - 8.4
Aspect (trans.)	1.11	0 - 1.97	1.36	0 - 2.00
Slope (%)	15	2 - 40	65	14 - 117
Distance From Ocean (m)	11.6	.0 - 19.0	11.4	2.0 - 18.5

TABLE 3. Ranges and means of dependent variables.
Terrace n=26, Slope n=32.

VARIABLES	TERRACE		SLOPE	
	Mean	Range	Mean	Range
Salmonberry Height (m)	1.06	0 - 2.57	1.32	.09 - 2.82
# of Ramets / m^2	.72	.20 - 1.60	.71	.08 - 1.80
Salmonberry % Cover	49.6	5 - 100	49.9	0 - 100
Salmonberry Biomass (kg/m^2)	.439	0 - 1.32	.557	0 - 4.31

the four salmonberry community structure variables (average maximum height, number of ramets, percent cover, and estimated biomass) within the buffer strips.

Basal Area

Two measures of basal area were taken on each plot. The basal area on each 75 m^2 plot was calculated from the tree diameter measurements. This gave a local measure of basal area, of all the trees growing on the plot. A 10 BAF prism was used for the second determination of basal area. This stand level measure includes not only trees rooted in a plot, but also adjacent trees which can influence the vegetation on a plot. The stand level measure of basal area was smaller, on the average, than the plot measure. This is likely due to the fact that the plots were all located entirely within homogeneous, alder-dominated stands. The prism method could also include the influence of adjacent stands and openings, especially the stream itself, where there are no trees.

Statistical Analysis

Objective 1

A principle components analysis was performed to see if the four salmonberry community structure variables (average maximum height, percent cover, number of ramets, and estimated biomass) could be treated as one composite variable. The correlation method was used to calculate the cross-products matrix, because of the different units associated with the salmonberry variables (Johnson and Wichern 1988). The PCA was performed using the PC-ORD statistical program (McCune 1990).

Objectives 1 (a)

Simple linear regression was used to test for linear relationships between the salmonberry community variables and a variety of buffer strip characteristics and environmental factors. Terraces and slopes were analyzed separately. The analysis (using the statistical program SAS) was weighted by N (number of plots), to account for the differing number of plots within each terrace and slope sampling unit.

The dependent variables were: salmonberry height, number of ramets, salmonberry cover, and salmonberry biomass. Residual plots were examined, and biomass was transformed using a log+1 transformation.

The independent variables were: buffer age, overstory age, buffer width, basal area (using a 10 BAF prism and direct measurement on the 75 m^2 plot), overstory percent cover, percent full light, stream width, height above stream, aspect (transformed), stream gradient, elevation, distance from ocean, latitude, and percent slope.

The assumptions made in the linear regression analysis were:

1. The independent variables are measured without error and are assumed to be fixed values.

2. The residuals are normally distributed with a mean of zero and a constant variance.

3. The error terms are statistically independent.

T-tests were used to look for differences between the four salmonberry community structure variables on slopes and terraces. T-tests were also used to look for differences in the salmonberry variables, due to differing parent materials, between the plots north of Lincoln City and the plots located south of Newport.

The assumptions made in the t-tests were:

1. Both population distributions are normal.

2. The two population standard deviations are equal.

Multiple regressions were used to examine whether the relationships revealed by the simple linear regressions were independent or interrelated. The stepwise model selection method was used. The four salmonberry variables were the dependent variables. The independent variables examined on the terraces were (in order): buffer age, height above stream, aspect, latitude, stream gradient, slope, and stream width. The independent variables examined on the slopes were (in order): basal area (prism), basal area (plot count), overstory percent cover, percent full light, elevation, and height above stream.

The assumptions made in the multiple regression analysis were the same as in the simple linear regression analysis.

Objective 1 (b)

Buffer age was included as an independent variable in the analysis described above. Graphs of the four salmonberry variables were examined over five buffer age categories: 0, 1-5, 6-10, 11-15, >15 years. Transects were separated into terraces and slopes. Multiple regressions were performed, between the four salmonberry variables and buffer age on the slopes. An x^2 term was introduced to see if the salmonberry response was curvilinear.

Objective 1 (c)

T-tests were used to look for differences between the four salmonberry variables on the undisturbed and buffer strip sites. Terraces and slopes were analyzed separately.

Objective 1 (d)

Each 5 m wide plot was treated separately in this portion of the analysis, unlike the previous analyses, in which plots within terraces and slopes were averaged on each transect. There were a total of 161 individual plots within the buffer strips.

Simple linear regression was used to examine the relationships between the salmonberry variables and distance from the stream, and from the cut edge.

Each plot was also assigned to one of three edge categories: (1) directly adjacent to an edge, (2) one plot away from an edge, or (3) interior plot, at least two plots away from both edges. An analysis of variance was used to examine the relationships between the salmonberry community variables and plot edge position. The same assumptions were made as in the regression analysis.

Graphs of the four salmonberry variables, across three of the longest buffer strips, were also examined to see if there were any trends related to edge position.

Objective 1 (e)

Ordination of transects in herbaceous species space was used to develop a vegetation index. The Bray-Curtis ordination method was used, with the variance-regression method of endpoint selection (Beals 1984). The distance measure was euclidean. Frequency of herbaceous species was used in the analysis. The ordination was performed using the PC-ORD statistical program (McCune 1990).

Simple linear regression was used to examine the relationships between the four salmonberry variables and the vegetation index.

Objective 2

The distributions of salmonberry aerial stems within the buffer strip and undisturbed, alder-dominated riparian study sites were graphically compared to Tappeiner et al.'s (1991) results. Tappeiner et al. (1991) examined salmonberry stem distributions in riparian stands in the Oregon Coast Range. The overstory of these stands was primarily mixed alder-conifer.

The salmonberry aerial stems were divided into seven diameter classes. Frequency values for each diameter class were expressed as a percentage of the total number of stems. The salmonberry aerial stem diameter distributions on terraces and slopes were also examined graphically.

Objectives 3 (a) & (b)

A correlation analysis was used to test the relationships between the four salmonberry community variables and total herbaceous cover, herb species abundance, and vine maple, elderberry, and swordfern cover on an individual plot basis. The assumptions made in the correlation analysis were:

1. The Y's at each X are assumed to be normal.
2. The X values at each Y are assumed to have come at random from a normal population (assumption of bivariate normality).

Objective 3 (c)

Simple linear regression was used to examine the relationship between vine maple cover and buffer age, on both slopes and terraces.

Objective 3 (d)

Average amount of conifer and hardwood regeneration per hectare was calculated for both the buffer strip and undisturbed stands.

RESULTS

Objective 1

Salmonberry Variables

The first PCA (Principle Components Analysis) axis extracted only 38% of the variance (see Appendix A, for PCA). The four salmonberry community structure variables (height, percent cover, number of ramets, and estimated biomass) could, therefore, not be treated as a composite salmonberry variable and were treated individually throughout the rest of the analysis.

Objective 1 (a)

Terraces and Slopes

Relationships between the four salmonberry community structure variables and the various buffer strip and environmental characteristics were examined with simple linear regressions. This initial analysis was performed by averaging all of the plots on each transect. No clear relationships were revealed. Transects were then divided by landform, separating the terrace and slope segments of each transect in the regression analysis. This revealed clear differences in salmonberry behavior when growing on terraces and slopes.

T-test

T-test results (Table 4) indicate that there is no difference between the four salmonberry variables when growing on slopes and terraces. Although amount and distribution of salmonberry did not vary with landform, the relationships between the four salmonberry variables and the characteristics of the buffer strips and the riparian environment did.

All relationships presented in the following discussion are statistically significant at the .05 level. "Indication" of a relationship means that it is significant at the .10 level. The actual p-value is reported in these cases. Salmonberry biomass was transformed throughout the analysis, using a log+1 transformation.

Linear Regressions

Buffer Strip Characteristics

Terrace

The four salmonberry variables (height, percent cover, number of ramets, and biomass) were regressed on the three buffer strip characteristics: buffer age, buffer width, and age of the alder overstory (Table 5). None of the salmonberry characteristics on the terraces were related to alder overstory age or buffer width.

TABLE 4. T-test results comparing salmonberry variables on terraces and slopes. Biomass was transformed (log+1) in the t-tests, however, the means presented are actual values. ** = significant at the .05 level, ++ = significant at the .10 level.

SITE	N	MEAN	SE	p-VALUE
SALMONBERRY HEIGHT (m)				
TERRACE	25	1.06	.15	.23
SLOPE	30	1.32	.13	
# OF RAMETS / M^2				
TERRACE	25	.72	.08	.84
SLOPE	30	.71	.07	
SALMONBERRY % COVER				
TERRACE	26	49.6	5.36	.61
SLOPE	32	49.9	4.98	
SALMONBERRY BIOMASS (kg/m^2)				
TERRACE	20	.439	.089	.40
SLOPE	26	.557	.172	

TABLE 5. Results of simple linear regressions of salmonberry variables against buffer strip characteristics, separated according to landform. Salmonberry biomass has been transformed using a log+1 transformation. ** = significant at the .05 level, ++ = significant at the .10 level.

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	TERRACE			SLOPE		
		N	r^2	p	N	r^2	p
Salmonberry Height (m)	Buffer Age	25	.26	.009 **	30	.01	.60
# of Ramets / m^2	Buffer Age	25	.35	.002 **	30	.00	.93
Salmonberry % Cover	Buffer Age	26	.26	.008 **	32	.01	.53
Salmonberry Biomass (kg/m^2)	Buffer Age	20	.38	.004 **	26	.06	.24
Salmonberry Height (m)	Overstory Age	17	.14	.14	23	.07	.21
# of Ramets / m^2	Overstory Age	17	.11	.19	23	.00	.87
Salmonberry % Cover	Overstory Age	17	.11	.20	24	.06	.25
Salmonberry Biomass (kg/m^2)	Overstory Age	17	.01	.76	26	.00	.99
Salmonberry Height (m)	Buffer Width (m)	25	.01	.67	30	.00	.99
# of Ramets / m^2	Buffer Width (m)	25	.01	.56	30	.00	.86
Salmonberry % Cover	Buffer Width (m)	26	.03	.36	32	.00	.90
Salmonberry Biomass (kg/m^2)	Buffer Width (m)	20	.08	.24	26	.01	.72

All four salmonberry measures, however, were found to be positively related to buffer strip age on the terraces, increasing with increasing buffer age. Buffer age accounted for up to 38% of the variation in the salmonberry community when growing on terraces.

Slope

Salmonberry growing on slopes was not related to any of the buffer strip characteristics.

Light Measures

Terrace

Table (6) presents the results of regressing salmonberry variables on the four light measures: basal area (both prism and plot count method), overstory percent cover, and percent full light. Salmonberry growing on terraces was not found to be related to any of the light measures, except for salmonberry biomass which decreased with increasing overstory cover.

TABLE 6. Results of simple linear regressions of salmonberry variables against light measures, separated according to landform. Salmonberry biomass has been transformed using a log+1 transformation. ** = significant at the .05 level, ++ = significant at the .10 level.

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	TERRACE N	TERRACE r^2	TERRACE p	SLOPE N	SLOPE r^2	SLOPE p
Salmonberry Height (m)	Basal Area-Prism (ft^2/ac)	24	.00	.80	28	.13	.06 ++
# of Ramets / m^2	Basal Area-Prism (ft^2/ac)	24	.01	.71	28	.02	.46
Salmonberry % Cover	Basal Area-Prism (ft^2/ac)	24	.00	.97	29	.03	.38
Salmonberry Biomass (kg/m^2)	Basal Area-Prism (ft^2/ac)	20	.00	.86	26	.24	.01 **
Salmonberry Height (m)	Basal Area-Plot Count (m^2/ha)	25	.01	.60	30	.05	.26
# of Ramets / m^2	Basal Area-Plot Count (m^2/ha)	25	.00	.91	30	.09	.10 ++
Salmonberry % Cover	Basal Area-Plot Count (m^2/ha)	26	.00	.84	32	.03	.35
Salmonberry Biomass (kg/m^2)	Basal Area-Plot Count (m^2/ha)	20	.00	.97	26	.19	.03 **

TABLE 6 (continued)

DEPENDENT VARIABLES	INDEPENDENT VARIABLES	TERRACE N	TERRACE r^2	TERRACE p	SLOPE N	SLOPE r^2	SLOPE p
Salmonberry Height (m)	% Full Light	22	.00	.86	25	.03	.45
# of Ramets / m^2	% Full Light	22	.00	.90	25	.15	.05 **
Salmonberry % Cover	% Full Light	22	.06	.28	26	.21	.02 **
Salmonberry Biomass (kg/m^2)	% Full Light	17	.07	.30	21	.21	.04 **
Salmonberry Height (m)	Overstory % Cover	12	.01	.76	19	.13	.13
# of Ramets / m^2	Overstory % Cover	12	.07	.40	19	.08	.25
Salmonberry % Cover	Overstory % Cover	12	.01	.83	20	.23	.03 **
Salmonberry Biomass (kg/m^2)	Overstory % Cover	12	.51	.01 **	19	.29	.02 **

Slope

Contrastingly, all four salmonberry variables on the slopes were related to light. Salmonberry biomass increased with decreasing basal area (prism count) on the slopes. There was indication (p=.06) that salmonberry height also increased with decreasing stand basal area, as measured with the prism method. Salmonberry biomass on slopes was also inversely related to the plot count measure of basal area. There was indication (p=.10) of an inverse relationship between number of ramets and the plot count basal area.

Both salmonberry cover and biomass increased with decreasing percent cover of the alder overstory, when growing on slopes. Salmonberry cover, biomass, and number of ramets were all found to be related to the percent full light measure on slopes, increasing with greater amounts of light reaching the understory community. The light measures accounted for up to 29% of the variation in the salmonberry community on the slopes.

Environmental Factors

Terrace

Table (7) presents the regression results between the four salmonberry variables and the environmental factors measured in this study: stream width,

TABLE 7. Results of simple linear regressions of salmonberry variables against environmental factors, separated according to landform. Aspect has been transformed using an arcsin transformation. Salmonberry biomass has been transformed using a log+1 transformation. ** = significant at the .05 level, ++ = significant at the .10 level.

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	TERRACE			SLOPE		
		N	r^2	p	N	r^2	p
Salmonberry Height (m)	Stream Width (m)	25	.14	.07 ++	30	.01	.56
# of Ramets / m^2	Stream Width (m)	25	.03	.39	30	.01	.56
Salmonberry % Cover	Stream Width (m)	26	.08	.17	32	.02	.45
Salmonberry Biomass (kg/m^2)	Stream Width (m)	20	.18	.06 ++	26	.07	.19
Salmonberry Height (m)	Ht. Above Stream (m)	24	.19	.03 **	27	.01	.61
# of Ramets / m^2	Ht. Above Stream (m)	24	.18	.04 **	27	.01	.62
Salmonberry % Cover	Ht. Above Stream (m)	24	.15	.06 ++	28	.00	.99
Salmonberry Biomass (kg/m^2)	Ht. Above Stream (m)	19	.44	.002 **	24	.14	.07 ++

TABLE 7 (continued)

DEPENDENT VARIABLES	INDEPENDENT VARIABLES	TERRACE N	r^2	p	SLOPE N	r^2	p
Salmonberry Height (m)	Aspect	24	.19	.03 **	28	.00	.78
# of Ramets / m^2	Aspect	24	.17	.05 **	28	.00	.87
Salmonberry % Cover	Aspect	25	.23	.02 **	30	.02	.43
Salmonberry Biomass (kg/m^2)	Aspect	19	.13	.13	24	.01	.71
Salmonberry Height (m)	Stream Gradient (%)	25	.06	.23	30	.00	.94
# of Ramets / m^2	Stream Gradient (%)	25	.08	.17	30	.09	.11
Salmonberry % Cover	Stream Gradient (%)	26	.20	.02 **	32	.00	.75
Salmonberry Biomass (kg/m^2)	Stream Gradient (%)	20	.02	.60	26	.00	.90
Salmonberry Height (m)	Elevation (ft)	25	.08	.17	30	.06	.20
# of Ramets / m^2	Elevation (ft)	25	.11	.11	30	.11	.08 ++
Salmonberry % Cover	Elevation (ft)	26	.02	.46	32	.03	.31
Salmonberry Biomass (kg/m^2)	Elevation (ft)	20	.02	.52	26	.00	.95

TABLE 7 (continued)

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	TERRACE N	TERRACE r^2	TERRACE p	SLOPE N	SLOPE r^2	SLOPE p
Salmonberry Height (m)	Distance from ocean (miles)	25	.05	.30	30	.00	.87
# of Ramets / m^2	Distance from ocean (miles)	25	.03	.38	30	.00	.77
Salmonberry % Cover	Distance from ocean (miles)	26	.03	.44	32	.00	.89
Salmonberry Biomass (kg/m^2)	Distance from ocean (miles)	20	.02	.57	26	.00	.80
Salmonberry Height (m)	Latitude	25	.23	.02 **	30	.00	.91
# of Ramets / m^2	Latitude	25	.22	.02 **	30	.00	.91
Salmonberry % Cover	Latitude	26	.19	.03 **	32	.01	.60
Salmonberry Biomass (kg/m^2)	Latitude	20	.32	.01 **	26	.04	.34
Salmonberry Height (m)	% Slope	25	.04	.35	28	.00	.81
# of Ramets / m^2	% Slope	25	.11	.10 ++	28	.09	.12
Salmonberry % Cover	% Slope	25	.06	.24	30	.02	.50
Salmonberry Biomass (kg/m^2)	% Slope	20	.36	.01 **	25	.05	.26

height above stream, aspect (transformed), stream gradient, elevation, distance from ocean, latitude, and percent slope.

Height above stream, aspect, and latitude all showed clear relationships with the salmonberry community on terraces. Salmonberry height, number of ramets, biomass, and possibly ($p=.06$) salmonberry cover all increased with increasing height above stream. Salmonberry height, number of ramets, and percent cover were all related to aspect on the terraces. These three measures of salmonberry were all greatest on the northeastern aspects, and least on the southwestern.

All four salmonberry variables were related to latitude when growing on terraces, with salmonberry increasing as you go farther south. T-tests (Table 8) revealed differences in the four salmonberry variables on terraces between the northern half of the study area, dominated by volcanic parent material, and the southern half, which is dominated by sandstone.

There were some relationships discovered between salmonberry on the terraces and stream width, stream gradient, and percent slope, although there were no clear trends. There was indication that salmonberry height ($p=.07$) and biomass ($p=.06$) increased with increasing stream width. Salmonberry cover was found to increase with increasing stream gradient. Salmonberry biomass and possibly number of ramets ($p=.10$) were found to increase with increasing percent slope.

TABLE 8. T-test results comparing salmonberry variables, on terraces, between the northern and southern portions of the study area. Biomass was transformed (log+1) in the t-tests, however, the means presented are actual values.
** = significant at the .05 level, ++ = significant at the .10 level.

TERRACES

SITE	N	MEAN	SE	p-VALUE
SALMONBERRY HEIGHT (m)				
NORTH	17	.88	.20	.01**
SOUTH	8	1.44	.20	
# OF RAMETS / M^2				
NORTH	17	.65	.10	.01**
SOUTH	8	.86	.10	
SALMONBERRY % COVER				
NORTH	17	43.1	7.14	.02**
SOUTH	9	62.0	6.12	
SALMONBERRY BIOMASS (kg/m^2)				
NORTH	17	.368	.086	.001**
SOUTH	3	.842	.266	

Salmonberry growing on terraces was not related to either elevation or distance from the ocean.

Slope

None of the salmonberry variables were related to any of the eight environmental characteristics examined in this study, when growing on slopes. There was indication of a possible relationship ($p=.07$) between salmonberry biomass and height above stream, with biomass increasing with increasing height above stream. There was also indication ($p=.08$) of a positive relationship between number of ramets and elevation.

Multiple Regressions

Multiple regressions were performed to see if the relationships revealed in the simple linear regressions were independent or interrelated. Table (9) presents the multiple regression results and the "best" models, using the stepwise selection method.

The variables tested on the terraces were (in order): buffer age, height above stream, aspect, latitude, stream gradient, percent slope, and stream width. The adjusted r^2 for the best models ranged from 42% for salmonberry height to

TABLE 9. Results of multiple regressions, using the stepwise selection method, of salmonberry variables regressed on the independent variables indicated in the linear regression analysis. Salmonberry biomass has been transformed using a log+1 transformation. Independent variables: Terrace: buffer age, height above stream, aspect, latitude, stream gradient, slope, stream width; Slope: basal area (prism), basal area (plot count), overstory % cover, % full light, elevation, height above stream.

TERRACE

DEPENDENT VARIABLE	"BEST" MODEL	ADJ. r^2
Salmonberry Height (m)	Latitude, Stream gradient, Height above stream	.42
# of Ramets / m^2	Buffer age, Stream gradient, Latitude	.49
Salmonberry % Cover	Stream gradient, Latitude, Height above stream	.56
Salmonberry Biomass (kg/m^2)	Height above stream, Stream gradient, Buffer age	.59

SLOPE

DEPENDENT VARIABLE	"BEST" MODEL	ADJ. r^2
Salmonberry Height (m)	Basal area (prism)	.19
# of Ramets / m^2	% Full light	.11
Salmonberry % Cover	% Full light, Basal area (plot count)	.41
Salmonberry Biomass (kg/m^2)	Overstory % cover, Height above stream	.55

59% for salmonberry biomass. This indicates that the relationships seen in the linear regression analysis on the terraces were independent of each other.

The results on the slopes were not as clear. The variables indicated by the simple linear regression analysis were: basal area (prism), basal area (plot count), overstory percent cover, percent full light, elevation and height above stream. The basal area and light measurements are obviously interrelated. The "best" models for salmonberry height, number of ramets, and salmonberry cover included only these variables. The best model for salmonberry biomass, however, included percent overstory cover and height above stream. This model accounted for 55% of the variation. The sample size for the multiple regressions on the slopes was greatly reduced, from 32 to 13, due to the fact that values for all of the selected variables were only available on 13 of the transects. This is the result of the theft of our quantum sensor, and the decision to begin collecting ocular estimates of percent cover once the study was already underway.

Objective 1 (b)

Figures (4-7) demonstrate the relationship between salmonberry community structure and buffer age. Salmonberry on the terraces increases with buffer age, as was seen in the regression analysis. The salmonberry variables on

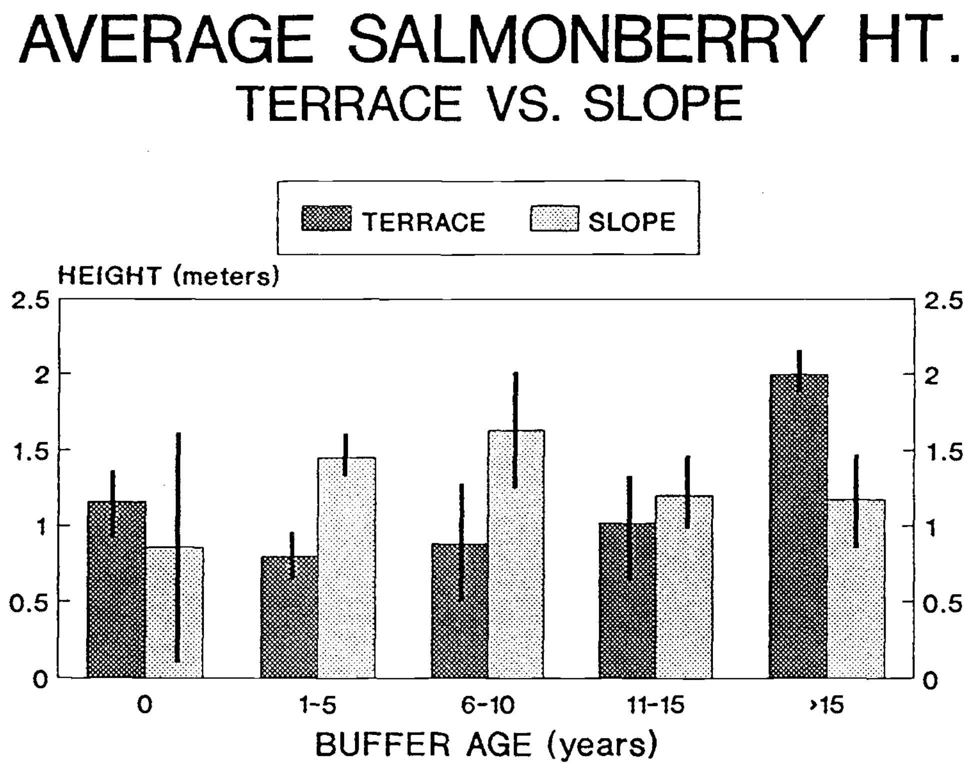

FIGURE 4. Average maximum salmonberry height by buffer age class. Data are means +/- 1 standard error. Terrace: N=2,6,7,7,3 Slope: N=2,8,6,9,5.

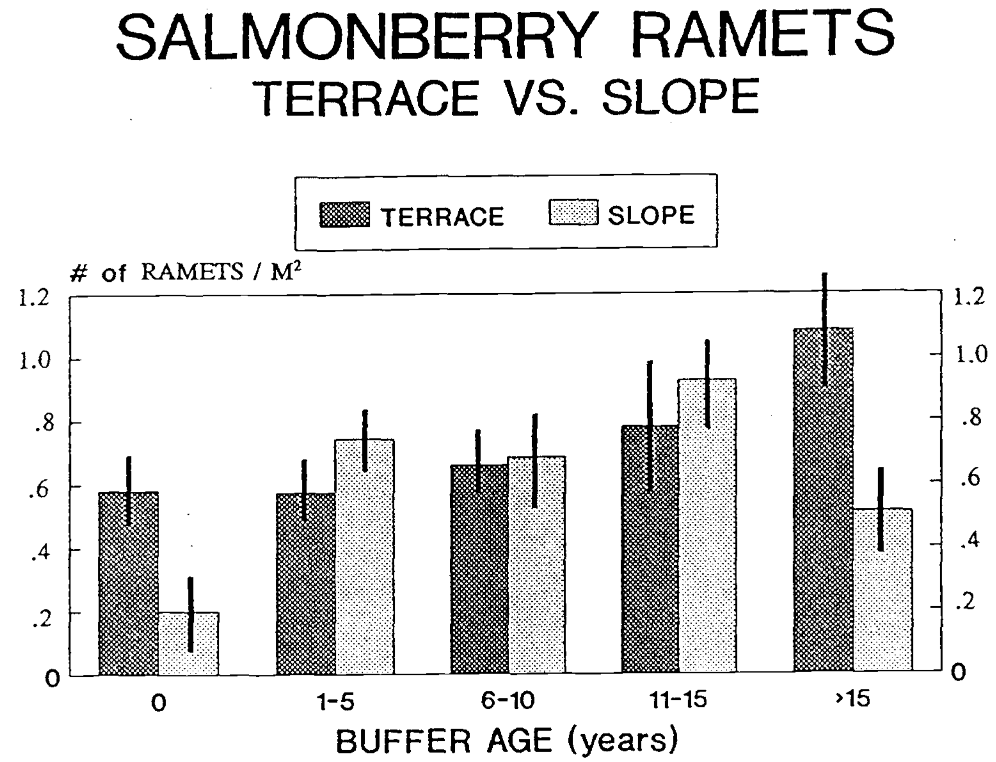

FIGURE 5. Number of salmonberry ramets per square meter by buffer age class. Data are means +/- 1 standard error. Terrace: N=2,6,7,7,3 Slope: N=2,8,6,9,5.

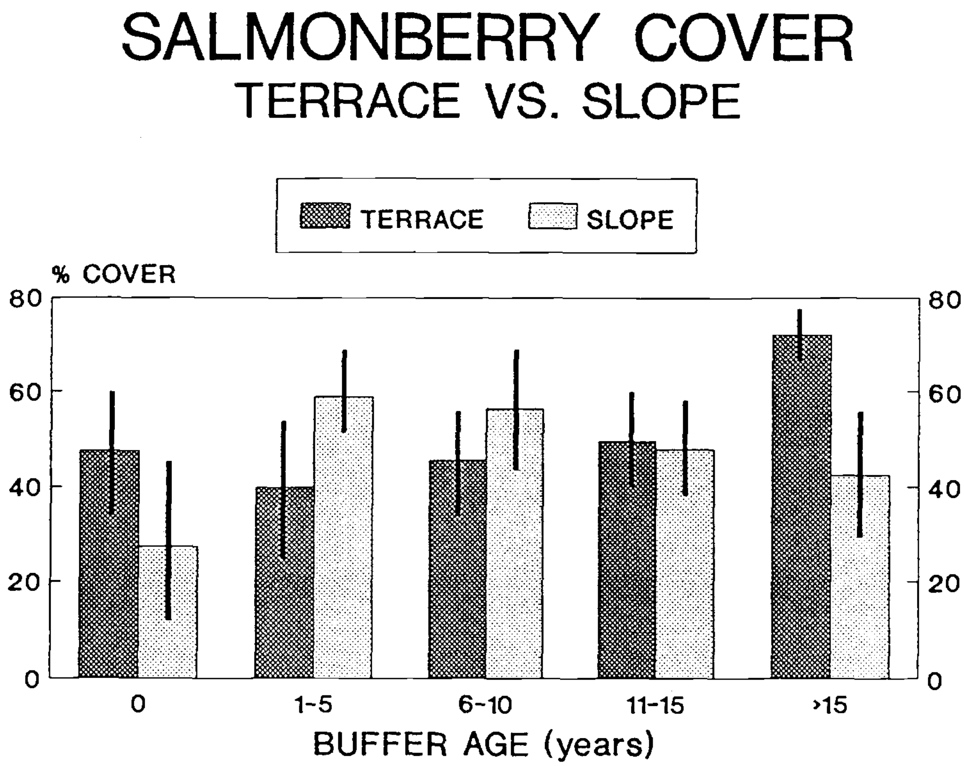

FIGURE 6. Salmonberry cover by buffer age class. Data are means +/- 1 standard error. Terrace: N=2,6,7,7,4 Slope: N=2,8,6,10,6.

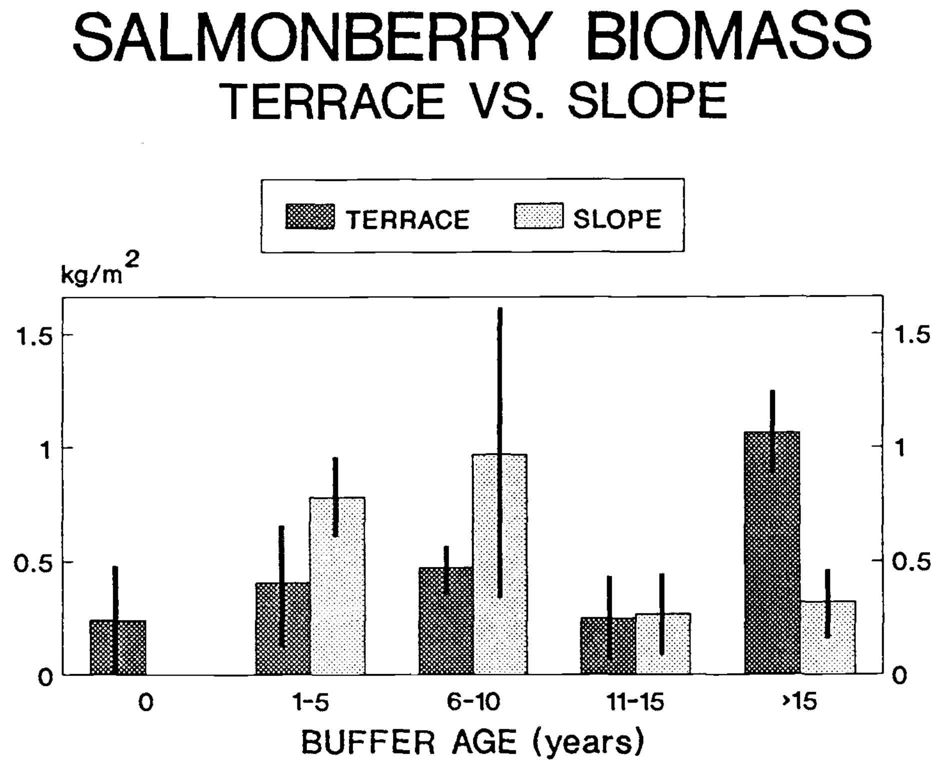

FIGURE 7. Salmonberry biomass, both above and below-ground, by buffer age class. Data are means +/- 1 standard error. Figure presents actual (untransformed) values. Terrace: N=2,4,7,5,2 Slope: N=2,7,6,6,5.

the slopes appeared to peak in the middle age classes, and then decline. Curvilinear regression results were not significant, so the decline in salmonberry growth in the older buffer age classes could not be verified statistically.

Objective 1 (c)

Buffer vs. Undisturbed

Table (10) presents the t-test results comparing the four salmonberry community structure variables on terraces, between buffer and undisturbed sites. There were no differences found. T-tests, however, did reveal differences on the slopes (Table 11). Salmonberry cover, number of ramets, and possibly salmonberry height ($p=.07$) on slopes were greater in the buffer strips, than on undisturbed sites.

Objective 1 (d)

Edge Effects

Edge effects within buffer strips were assessed by examining individual plots, instead of averaging by landform unit within a transect, as was done in the preceding analysis. Table (12) presents the results of regressing the four salmonberry variables on distance from the cut edge, and distance from the

TABLE 10. T-test results comparing salmonberry variables on terraces within buffer strips, with undisturbed terraces. Biomass was transformed (log+1) in the t-tests, however, the means presented are actual values. ** = significant at the .05 level, ++ = significant at the .10 level.

TERRACES

SITE	N	MEAN	SE	p-VALUE
SALMONBERRY HEIGHT (m)				
BUFFER	25	1.06	.15	.32
UNDIS.	8	1.06	.30	
# OF RAMETS / M^2				
BUFFER	25	.72	.08	.47
UNDIS.	8	.66	.13	
SALMONBERRY % COVER				
BUFFER	26	49.6	5.36	.15
UNDIS.	8	40.2	10.20	
SALMONBERRY BIOMASS (kg/m^2)				
BUFFER	20	.439	.089	.81
UNDIS.	8	.460	.129	

TABLE 11. T-test results comparing salmonberry variables on slopes within buffer strips, with undisturbed slopes. Biomass was transformed (log+1) in the t-tests, however, the means presented are actual values. ** = significant at the .05 level, ++ = significant at the .10 level.

SLOPES

SITE	N	MEAN	SE	p-VALUE

SALMONBERRY HEIGHT (m)

BUFFER	30	1.32	.13	.07++
UNDIS.	8	0.97	.25	

OF RAMETS / M^2

BUFFER	30	.71	.07	.01**
UNDIS.	8	.47	.10	

SALMONBERRY % COVER

BUFFER	32	49.9	4.98	.01**
UNDIS.	8	32.3	8.71	

SALMONBERRY BIOMASS (kg/m^2)

BUFFER	26	.557	.172	.18
UNDIS.	7	.308	.110	

TABLE 12. Results of simple linear regressions of salmonberry variables against distance from cut edge and distance from stream, on an individual plot basis (n=161). Salmonberry biomass has been transformed using a log+1 transformation. ** = significant at the .05 level, ++ = significant at the .10 level.

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	r^2	p
Salmonberry Height (m)	Distance From Cut Edge	.01	.24
# of Ramets / m^2	Distance From Cut Edge	.03	.02**
Salmonberry % Cover	Distance From Cut Edge	.01	.20
Salmonberry Biomass (kg/m^2)	Distance From Cut Edge	.01	.19
Salmonberry Height (m)	Distance From Stream	.00	.57
# of Ramets / m^2	Distance From Stream	.02	.08++
Salmonberry % Cover	Distance From Stream	.01	.08++
Salmonberry Biomass (kg/m^2)	Distance From Stream	.00	.79

stream edge. Number of ramets was the only variable related to distance from the cut edge, decreasing with increasing distance from the cut. There was indication that number of ramets ($p=.08$) and salmonberry cover ($p=.08$) may be related to distance from the stream. Number of ramets tended to increase with distance from the stream, while salmonberry cover decreased. None of the above relationships accounted for more than 3% of the variation.

An analysis of variance was also used to examine the edge effects within buffer strips. Plots were divided into three ANOVA classes of edge proximity: directly adjacent to an edge, one plot away from an edge, or an interior plot. There were no differences in any of the salmonberry variables among the three ANOVA classes.

Three of the longest buffer strip transects were displayed graphically, to get a more descriptive assessment of salmonberry's response to the stream and cut edges (see Appendix B, for graphs of edge effects). All of the salmonberry variables varied greatly across the transects. As in the regression analysis, there were no clear edge effects, except in the case of number of ramets which increased near the cut edge. The graphs also indicate a peak in the number of ramets in the middle of the transects.

Objective 1 (e)

Vegetation Index

An ordination of transects in herbaceous species space was performed, in order to develop a synthetic vegetation index. I hypothesized that the herbaceous species on the site would be integrating complex environmental factors that we could not measure directly. The influence of these factors on the salmonberry community was then examined through linear regression analysis.

The initial ordination did not reveal much structure in the data, and had many outliers. The analysis was then repeated, using only those herbaceous species which were present on at least four transects, to eliminate the influence of rare species. This greatly improved the structure of the data, reducing the number of herbaceous species used in the analysis from 60 to 33. The first three ordination axes accounted respectively for 18, 13, and 12 percent of the variation (see Appendix C, for ordinations).

Transect scores from the first three ordination axes were then regressed against transect averages of the four salmonberry variables. The regression results (Table 13) show that the number of ramets and salmonberry cover are inversely related to the first ordination axis. There is also the possibility of an inverse relationship between salmonberry height and the first axis ($p=.07$). Biomass is not related to the first ordination axis, but is positively related to the

TABLE 13. Results of simple linear regressions of salmonberry variables and buffer age regressed on the first three ordination axes. Salmonberry biomass has been transformed using a log+1 transformation. ** = significant at the .05 level, ++ = significant at the .05 level.

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	R^2	P-VALUE
Salmonberry Height (m)	Ordination Axis #1	.06	.07++
# of Ramets / m^2	Ordination Axis #1	.12	.01**
Salmonberry % Cover	Ordination Axis #1	.07	.05**
Salmonberry Biomass (kg/m^2)	Ordination Axis #2	.11	.03**
Buffer Age (years)	Ordination Axis #1	.13	.02**

second axis. The other three salmonberry variables are not related to the second axis, and none are to the third.

Three linear regressions were performed to see if buffer age was related to any of the ordination axes. Ordination axis #1 was found to be inversely related to buffer age. None of these regressions had an r^2 greater than 13%, so there is still a great deal of unexplained variation in the system.

Objective 2

Aerial Stem Distribution

Figure (8) shows the salmonberry aerial stem distribution in the buffer and undisturbed alder-dominated riparian stands, in comparison with that found by Tappeiner et al. (1991) in riparian stands of the Oregon Coast Range. Tappeiner et al.'s stands were primarily mixed alder-conifer overstories. Figure (9) presents the distribution within the buffer strips, when separated into terraces and slopes. All of the distributions resemble that of an uneven-aged stand.

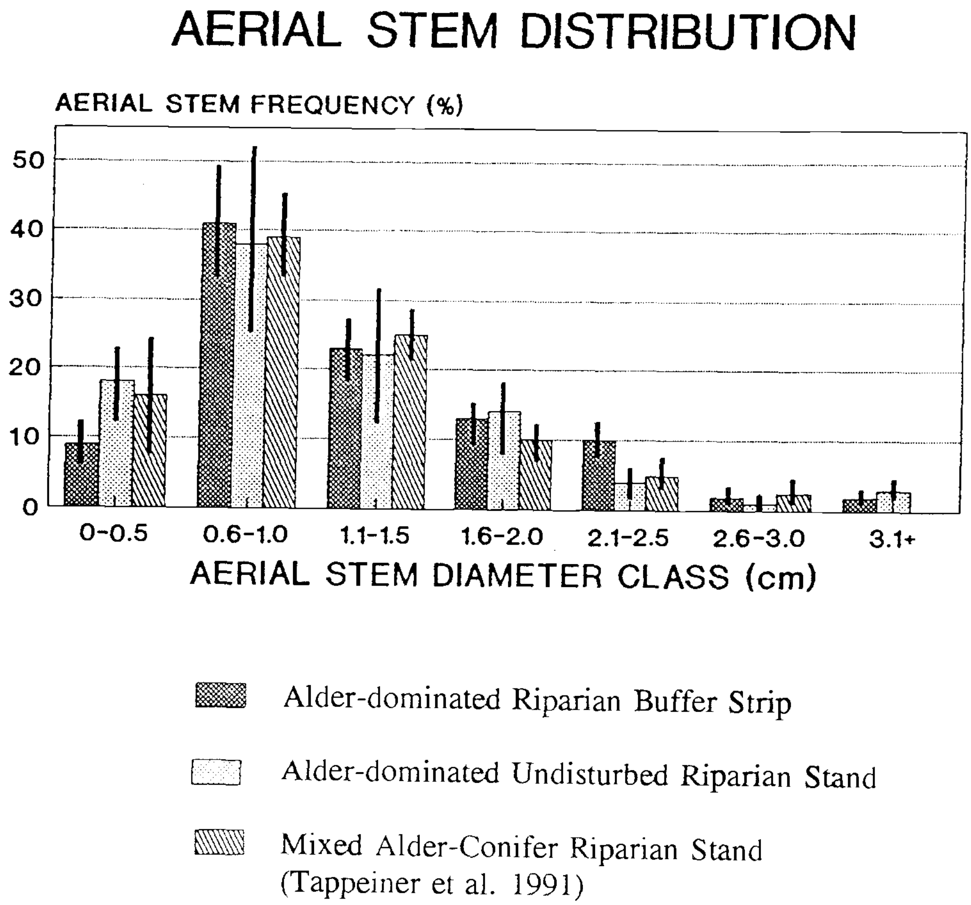

FIGURE 8. Salmonberry aerial stem population frequency by diameter class and stand type. Data are means +/- 1 standard error.

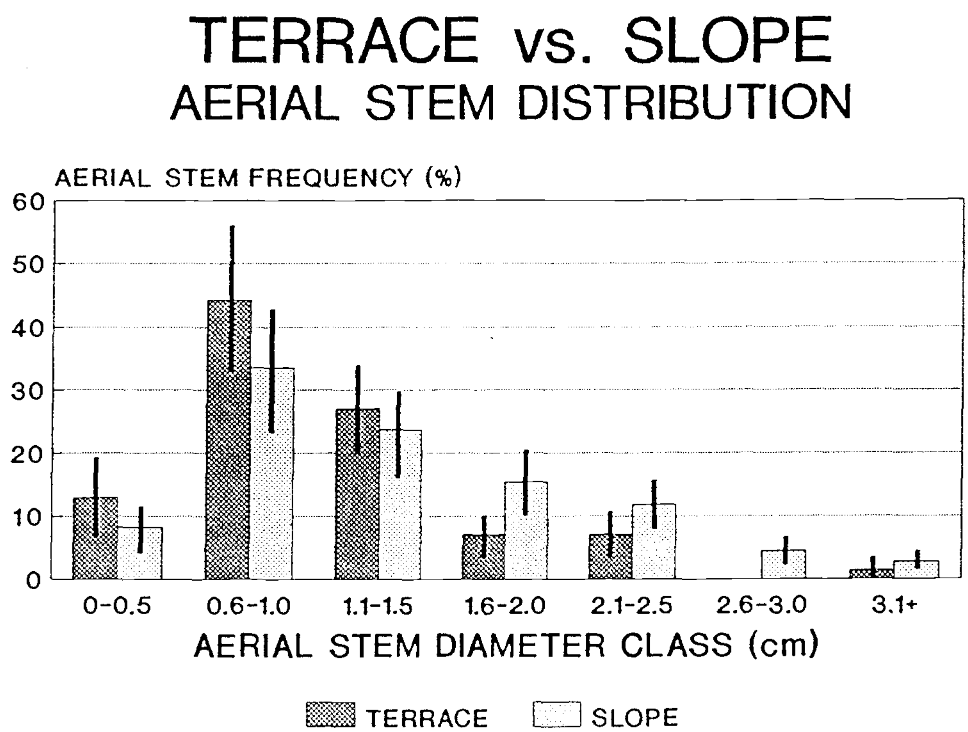

FIGURE 9. Salmonberry aerial stem population frequency by diameter class and landform. Terrace and slope are the topographic sampling units within riparian buffer strips. Data are means +/- 1 standard error.

Objectives 3 (a) & (b)

Salmonberry's Influence on the Understory Community

Table (14) presents the correlation results between the four salmonberry community variables (height, percent cover, number of ramets, and biomass) and total herbaceous cover, herb species abundance, vine maple, elderberry, and swordfern cover. The results indicate that herbaceous cover and species abundance decrease in the presence of salmonberry. Total herb cover is negatively correlated with salmonberry height, cover, and number of ramets, but not with biomass. Herb species abundance, on the other hand, is negatively correlated only with salmonberry biomass.

Salmonberry height, cover, and number of ramets were all negatively correlated with vine maple cover. Vine maple did not appear to be related to salmonberry biomass. Swordfern cover was negatively correlated with number of ramets and salmonberry cover. There was no correlation between elderberry cover and any of the salmonberry measurements.

The correlation coefficient is not always a good measure of species association, because it includes joint absences as being correlated. Salmonberry, however, was very rarely absent on a plot, so the correlation coefficient is a valid measure in this case. Frequency distributions were examined, and cover of all of the species was well distributed.

Table 14. Correlations of salmonberry variables with herbs and shrubs. Top number is the Pearson Correlation Coefficient, bottom number is the p-value. Salmonberry biomass has been transformed using a log+1 transformation.
** = significant at the .05 level.

	S.BERRY HEIGHT (m)	S.BERRY # OF RAMETS	S.BERRY % COVER	S.BERRY BIOMASS (kg/m^2)
TOTAL HERB COVER	-.19 .005**	-.19 .004**	-.22 .0008**	-.10 .151
HERB SPECIES ABUNDANCE	-.04 .574	-.01 .834	-.10 .141	-.16 .025**
VINE MAPLE COVER	-.17 .009**	-.20 .003**	-.23 .0004**	-.06 .386
ELDER-BERRY COVER	.03 .671	.01 .874	-.04 .511	-.09 .234
SWORD-FERN COVER	-.07 .288	-.23 .0005**	-.16 .015**	-.06 .434

Objective 3 (c)

Vine Maple

Vine maple cover was not found to be linearly related to buffer age on either the slopes or the terraces. Scatter plots indicate a peak in vine maple cover in the middle buffer ages.

Objective 3 (d)

Regeneration

Table (15) summarizes the tree regeneration found in both the buffer strips and the undisturbed stands. I found that regeneration was more frequently found within buffer strips (on 34% of the transects) than on undisturbed sites (on 20% of the transects). Conifer regeneration was found only in the buffer strip sites, both on down logs and rooted in the soil. There were approximately 29 seedlings per hectare found within the buffer strips, 22 conifers and 7 hardwoods. There was approximately one seedling per hectare found in the undisturbed riparian stands, and no conifer regeneration at all. All of the seedlings found on the undisturbed sites were red alder, rooted in the soil.

Table 15. Tree regeneration. ACMA= Acer macrophyllum, ALRU= Alnus rubra, PISI= Picea sitchensis, PSME= Pseudotsuga menziesii, THPL= Thuja plicata, TSHE= Tsuga heterophylla.

	BUFFER	UNDISTURBED
TOTAL # OF TRANSECTS SAMPLED	44	10
# OF TRANSECTS WITH REGENERATION	15	2
TOTAL # OF SEEDLINGS BY SUBSTRATE	LOG SOIL 10 14	LOG SOIL 0 2
# OF SEEDLINGS BY SPECIES	ACMA ALRU 5 1 PISI THPL 5 1 PSME TSHE 7 5	ACMA ALRU 2 PISI THPL PSME TSHE
HARDWOOD/ HECTARE CONIFER/ HECTARE	7 22	1 0

DISCUSSION

Terraces and Slope

Salmonberry was found to behave differently when growing on slopes and terraces. When analyzed on a whole transect basis, few significant relationships were revealed between the salmonberry community and characteristics of the buffer strip and the riparian environment. The factors examined included: buffer age, overstory age, buffer width, overstory basal area, overstory cover, percent of full light penetrating the canopy, stream width, height above stream, aspect, stream gradient, elevation, distance from the ocean, latitude, and percent slope. The four measures of the salmonberry community were: average maximum height, number of ramets (or rooting clumps) per square meter, salmonberry percent cover, and total estimated biomass (both above and below-ground).

Once the transects were divided by landform, into terrace and slope units, significant relationships were revealed. Salmonberry characteristics were not statistically different between slopes and terraces. Salmonberry did, however, clearly respond differently to the factors examined according to landform. The inconclusive results seen at the whole transect level were attributed to the averaging of responses on the slope and terrace plots.

Andrus and Froehlich (1988) also found vegetative differences between terraces and slopes in riparian stands of the Oregon Coast Range. They did not limit their study, as this one, to alder-dominated stands, but looked at a range of overstory conditions. They found differences in the overstory vegetation between terraces and adjoining slopes, with alder dominating the terraces and conifers becoming more prevalent on the slopes.

Salmonberry amount and distribution, as measured by height, number of ramets, cover, and biomass, increased with increasing buffer age on the terraces. Salmonberry on the terraces did not appear to be related to light. It was, however, related to a number of environmental characteristics: height above stream, aspect, latitude and possibly stream width, stream gradient, and percent slope.

Salmonberry growing on slopes, on the other hand, was not related to buffer age or any of the environmental characteristics. Salmonberry amount and distribution did increase with increasing light to the understory. Light was measured by four different methods: a direct plot count measure, a 10 BAF prism, an ocular percent cover estimate, and a quantum sensor measure of light reaching the understory. Salmonberry biomass was the variable most consistently related to light, no matter which light measure was used.

A possible explanation, for the difference in salmonberry response on slopes and terraces, is that site conditions on the terraces may be better than on the slopes. Terraces are also different from slopes on these sites because of the continual presence of disturbance. Flooding and beaver damage are the major disturbances on these riparian sites, and they primarily affect only the terraces.

Browsing is another factor which probably accounts for some of the variation seen in the salmonberry community. The plots adjacent to the stream on some of the larger terraces were often very open, with a shorter, less dense cover of salmonberry. There was visible evidence of browsing on these sites, some of which was quite severe.

Browse damage from both wildlife and cattle was noted. Beaver use was abundant on the study sites, and could account for some of the browsing adjacent to the stream. Salmonberry leaves and shoots are moderately important winter and spring browse for elk, year-round forage for deer, and a favorite summer food of mountain beaver (Singleton 1976, Leslie et al. 1984).

Another possible explanation, for the differences in salmonberry response on slopes and terraces, is water conditions. The terraces can have more variable water tables, leading to variation in growing conditions. Frequently, on the terraces, there are also depressions with standing water. The slopes, on the other hand, are better drained with more consistent conditions within a transect. The terrace areas closest to the streams also have a more rocky substrate. Tappeiner (pers. comm.) has observed that salmonberry growth is affected when the roots hit rocks in the soil.

The relationships, between the salmonberry community variables on the terraces and latitude, were most likely due to the differing parent materials in the northern and southern regions of the study area. T-tests revealed that all four salmonberry variables were greater in the southern, sandstone dominated, half of the study area. The northern half, contrastingly, is dominated by volcanic rocks, intermixed with some related intrusive rocks and marine sediments.

The nutrient content in the northern half is most likely higher than in the southern half, due to the widespread presence of basalt. The higher nutrient content in the north may favor competitors of salmonberry, leading to less salmonberry than in the southern region.

Aspect is another environmental factor that was related to the salmonberry community on terraces. Salmonberry was greatest on northeastern aspects and least on southwestern. It could be that because southwest aspects are drier, salmonberry growth was reduced. It is also possible that, although the statistical analysis showed salmonberry to be related to aspect on the terraces, this relationship might not be ecologically real. The terraces are, by definition, relatively flat and, although aspect was recorded on every plot with a slope greater than zero, it seems unlikely that aspect would influence salmonberry growth much on the terraces.

Some of the four salmonberry community variables on the terraces increased with increasing height above stream, percent slope, and stream gradient. These are all variables that are related to slope. It could be that the terrace plots bordering the transition area between terraces and slopes influenced these results. These plots would be higher above the stream and steeper than the other terrace plots. Steeper stream gradients could be associated with more constrained streams and narrower terraces. It is also possible that, as in the case of aspect, these relationships are not ecologically significant. The ranges of slopes and heights above stream were much more narrow on the relatively flat terraces, than on the slope plots.

The hypothesis of salmonberry increasing in buffer strips over time, due to increased sidelight into the riparian area, is an over-generalization. Salmonberry was found to increase with buffer age on the terraces, but not on the slopes. It was on the slopes, however, that salmonberry was found to increase with more available light, not on the terraces.

Salmonberry amount and distribution on the slopes was greater in the buffer strips than on the undisturbed sites. Salmonberry characteristics were not different between buffer and undisturbed stands on the terraces. This supports the hypothesis that, on the slopes at least, salmonberry increases with the creation of a buffer strip, as the result of increased light into the system. The salmonberry growing on slopes, which was shown to respond to increasing light, was greater in the stands where buffer strips had been created.

Salmonberry on slope plots appears sensitive to increasing amounts of light and decreasing overstory basal area. Yet it is not on the slopes, but on the terraces, where salmonberry was found to increase with the age of the buffer strip. Logically, it would seem that, after the creation of a buffer strip, salmonberry on slopes would steadily increase in response to the increased light. This, however, was not the case. The range of overstory densities sampled in this study was similar on the slopes and terraces, but average overstory density was greater on the terraces. Graphs indicate that salmonberry variables tend to peak in the middle buffer ages on the slopes, and then appear to decrease. This decrease, however, could not be shown statistically, so it is possible that salmonberry growth just levels out.

I hypothesized that the possible decline in salmonberry, in older buffer strips on slopes, might be due to increasing competition from vine maple. Vine maple on the slopes might be able to grow over the salmonberry and root by layering. Regression analysis of vine maple cover, however, shows that there is no linear relationship between vine maple and buffer age on either the terraces or slopes. Scatter plots indicate a tendency for vine maple cover to reach a peak in the middle buffer ages, as did the salmonberry variables when growing on slopes. The decline in the four salmonberry characteristics on slopes in older buffer strips cannot, therefore, be attributed to increased competition from vine maple.

Another possible explanation for the leveling off of salmonberry growth, in older buffers on slopes, is that it may reach its maximum leaf area within buffers early, due to the increased light. After that it would remain at a fairly constant level, depending on disturbance in the stand. Another possibility is that salmonberry growth levels out as the adjacent stand of trees grows up. When the adjacent stand is clearcut, and the buffer created, there is a lot of sidelight into the riparian buffer strip. As the adjacent stand grows up, its influence on the buffer strip increasingly resembles that of the undisturbed stand condition.

Comparison with Other Studies

Minore and Weatherly (1991) found that salmonberry cover in riparian areas of the Oregon Coast Range varied with distance from the ocean, distance from the stream, latitude, and elevation. It was not found to be related to stream gradient, stream width, or percent slope. Minore and Weatherly's study was not limited, as this one was, to pure alder stands.

Unlike Minore and Weatherly, I did not find any relationship between salmonberry and distance from the ocean. I did find that salmonberry was related to latitude, but only on the terraces. This relationship was attributed to differences in soil parent material. Minore and Weatherly's results could also have been influenced by this, in addition to the true latitude effect. Their study extended much further south than this study, down to Gold Beach. Unlike

Minore and Weatherly, I did not find a relationship between the salmonberry community and elevation. I did find indication ($p=.08$) that salmonberry cover decreased with distance from the stream, which supports their findings.

There are other differences between the results in this study and Minore and Weatherly's. I found that salmonberry cover was related to stream gradient, although only on the terraces. As in their study, I found no relationship between salmonberry cover and stream width. I did, however, find indication of a relationship between stream width, on the terraces, and salmonberry height and biomass. Although unrelated to salmonberry cover, as was the case in Minore and Weatherly's study, salmonberry biomass and possibly number of ramets were found to be related to percent slope, but only on the terraces.

The differences in the results seen between the two studies could possibly be due to averaging between landforms in Minore and Weatherly's study. This study has shown that landform does influence salmonberry behavior. There is also the problem of comparing this study to Minore and Weatherly's, which included not only alder-dominated riparian areas, but also mixed alder-conifer and pure conifer stands. Salmonberry under these canopy types may behave quite differently.

Vegetation Index

The first three ordination axes accounted respectively for 18, 13, and 12 percent of the variation in the herbaceous community among transects. Ordination results were used to develop synthetic vegetation indices, which were believed to integrate complex environmental factors that could not be measured directly in this study. Linear regression revealed that salmonberry height, number of ramets, and cover were all related to the first ordination axis, and thus to the environmental factors that it represents.

I speculated that the first ordination axis was related to differences in herbaceous vegetation due to landform. This proved not to be the case. Percentage of terrace plots within each transect were examined in terms of each transect's location along the ordination axis. Transects located entirely on slopes or terraces were intermixed with the other transects, with no apparent pattern. I concluded that the first ordination axis was not related to landform.

I speculated that the first axis could be related to disturbance. The axis was strongly positively correlated with grasses, wild parsley (Oenanthe sarmentosa Presl.), buttercup (Ranunculus uncinatus D. Donn), piggyback plant (Tolmiea menziesii (Pursh) T.& G.), stinging nettles (Urtica dioica L.), and waterleaf (Hydrophyllum tenuipes Heller). The first ordination axis was strongly negatively correlated with bleeding heart (Dicentra formosa (Andr.) Walpers), miner's lettuce (Montia sibirica (L.) How.), and stream violet (Viola glabella Nutt.).

The only measure of disturbance taken in this study was the presence or absence of secondary disturbances. Disturbance from landslides, erosion, deposition, windthrow, wind break, fire, beaver, mountain beaver, and livestock and wildlife grazing were all noted for each transect. There was, however, no measure of degree of disturbance. There did appear to be a trend for the transects with no secondary disturbances to be at the lower end of the first ordination axis.

This interpretation of the axis would have salmonberry cover, height, and number of ramets decreasing with disturbance. More information is needed on degree of disturbance to validate this interpretation. It is possible that the ordination axis is dependent on one particular type of disturbance on the site, such as flooding.

It is also possible that the herbaceous species are responding to the disturbance of creating the buffer strip and the increased light that follows. This interpretation of the axis would mean that the stands at the lower end of the ordination axis would be older buffers with more salmonberry, which are no longer directly affected by the disturbance of creating the buffer strip. At the other, disturbed end of the axis, would be younger buffer strips with less salmonberry. Regression results reveal that buffer age is related to the first ordination axis, with the older stands located at what has been interpreted to be the least disturbed end of the axis.

A potential problem with this portion of the analysis is that salmonberry not only responds to environmental factors which are integrated by the herbaceous species, it also directly influences the herbaceous community.

Salmonberry Aerial Stem Distribution

Salmonberry aerial stem diameter distribution in both the buffer and undisturbed sites (see Figure 8) was found to be very similar to that found by Tappeiner et al. (1991) in a variety of stand types. Similar distributions were also found when the buffer strips were divided into slopes and terraces (see Figure 9). I had speculated that the salmonberry stem diameter distribution on the terraces may have been concentrated in the smaller size classes, due to more frequent disturbances than on the slopes. This was not the case. Although there was a slightly larger percentage in the smaller size classes, salmonberry stems on the terraces still followed the same uneven-sized distribution.

Salmonberry stems cannot be accurately aged because of ill-defined annual rings (Barber 1976), but the stem size distribution resembles that of trees in uneven-aged stands. These findings lend further support to Tappeiner et al.'s hypothesis of continual recruitment of new salmonberry stems (Tappeiner et al. 1991), suggesting persistent, self-replacing salmonberry stands.

Salmonberry's Influence on the Understory Community

Total herb cover was found to decrease with increasing salmonberry height, cover, and number of ramets, although it appeared unrelated to biomass. Herb species abundance decreased with increasing salmonberry biomass, although it appeared unrelated to the other three salmonberry variables. This indicates that as salmonberry increases over time, there will be a corresponding decline in herb cover and diversity below the salmonberry. This is most likely due to the reduction of light under the salmonberry canopy, and the dense litter layer which develops.

Other members of the shrub community are influenced by salmonberry, as well. Swordfern was treated as a member of the shrub community, as well as an herb. Although technically an herbaceous species, swordfern often functions as a shrub in these communities, in terms of its size and exclusion of other herbaceous species on the site. Both vine maple and swordfern were found to decrease with increasing salmonberry. The other shrub commonly found in these riparian communities, elderberry, appeared unaffected by the presence of salmonberry.

An explanation for vine maple's displacement by salmonberry in these areas could be their similarity in life form. Both species' primary method of reproduction in these areas is through sprouting and layering. The lower growing swordfern, also inhibited by salmonberry, is unable to grow above the salmonberry canopy. Swordfern is often able to persist under dense salmonberry cover, but its magnitude is reduced.

Regeneration

Many authors have noted the absence of tree regeneration under red alder stands in the Oregon Coast Range (Carlton 1989, Henderson 1970, Minore and Weatherly 1990, Newton 1968). Minore and Weatherly (1990) observed that tree regeneration in dense salmonberry areas occurs primarily on down logs, where the seedlings can get above the salmonberry. I found that tree regeneration was more frequent in buffer strips than on undisturbed sites. Conifer regeneration was found only within the buffer strips, and conifer seedlings were found both on down logs and rooted in the soil. There were approximately 29 seedlings per hectare found within the buffer strips. The presence of these seedlings, however, does not imply an ability to grow above the shrub layer and survive to maturity.

No conifer regeneration at all was found on the undisturbed sites. There were only a total of two tree seedlings found on the ten undisturbed sites, or approximately one seedling per hectare, and both of these were red alder rooted in the soil.

While more regeneration was found in this study than has been found in other surveys of Coast Range riparian areas (Carlton 1989, Henderson 1970, Minore and Weatherly 1990, Newton 1968), it is still a very small amount. Giordano (pers. comm.) has found a great deal more regeneration in mixed and conifer-dominated riparian stands in the same study area. It does not appear that there will be enough tree regeneration in these stands to replace the alder, once the overstory senesces. A small percentage of the seedlings could reach maturity, and natural disturbances will allow successful tree establishment in other areas, but many of these riparian stands could potentially succeed to salmonberry brushfields.

The lack of regeneration and salmonberry's influence on the other shrubs and herbs suggest that salmonberry will eventually dominate the riparian community, without silvicultural intervention. The intense man-made disturbances of the past have created these alder-dominated riparian stands where salmonberry flourishes. Natural disturbances, such as flooding and fire, historically had more of a patchy pattern. This allowed conifers to remain in the riparian canopy, shading the salmonberry and providing a seed source for conifer regeneration. Today's reduced conifer seed source, lack of a suitable seed bed, and intense competition from salmonberry in these alder-dominated stands will continue to exclude conifers from areas which they once inhabited.

Chronosequence

A potential problem with this study is the use of the chronosequence approach. This method assumes that all of the stands sampled began in the same initial condition, and that the only difference between stands is due to the changes that take place over time. While this is the most practical approach for following succession in these areas, it is obviously not as reliable as following permanent study plots over time.

There is an additional problem with this approach in examining the effect of buffer age. The stands were at different initial ages when the buffer strips were created. Although we did examine the effect of overstory age in the analysis, this still complicates the interpretation of the effect of time since creation of the buffer strip.

Another potential problem with this study is the use of the equations to estimate salmonberry biomass from stem calliper. These equations were developed on sites which were dominated by salmonberry, so they might not be as accurate on some of the study sites which had only a few stems of salmonberry in the biomass plot (Tappeiner pers. comm.).

Management Implications

This study indicates that while salmonberry responds differently on slopes and terraces, there are potential problems due to the creation of riparian buffer strips on both. The creation of a buffer strip will lead to increased sidelight into the riparian system, and salmonberry has been shown to increase with increasing light on the slope plots. Salmonberry has also been shown to increase on the terrace plots with buffer age. Little tree regeneration was found on any of the transects. This all supports the hypothesis that these areas could eventually succeed to salmonberry brushfields, unless there is some direct silvicultural manipulation of the vegetation.

Salmonberry has been difficult to eradicate both manually and by fire, due to its extensive rhizome system and ability to sprout from branches and rootstocks. Salmonberry, growing under alder, has been shown to resprout to its initial stem density within 3-4 months after cutting of the aerial stems (Zasada and Tappeiner 1989). Manual cutting has been shown to increase the total leaf area of salmonberry, as has fire, unless the burn is extremely intense (Haeussler and Coates 1985). Tappeiner (pers. comm.) has shown that cutting salmonberry growing under alder in two consecutive years will reduce the salmonberry vigor.

Salmonberry can be readily controlled by glyphosate. Barber (1976) recommended that herbicides be applied in mid-June or July, when salmonberry root food reserves are lowest. Late summer and fall applications have been shown to cause mortality, while earlier applications cause only moderate injury (Conard and Emmingham 1984). The use of herbicides, however, is not always a viable alternative, especially along streams, due to public pressure against their use. Indirect control by manipulation of the overstory may be more desirable in these streamside areas.

A possible silvicultural solution, to avoid the eventual conversion of riparian leave strips to salmonberry brushfields and to reintroduce conifers to many streamside areas, is to manage for western hemlock. It has been shown that when hemlock and salmonberry are established at the same time, the steady growing hemlock will eventually be able to overtop the salmonberry. It has also been demonstrated that salmonberry will eventually be eliminated in adequately stocked conifer areas, apparently as a response to reduced levels of light in these stands (Barber 1976).

Historically, conifers were much more widespread in many of these riparian areas, as can be seen from the remnant stumps. Conifers are also more desirable than red alder for down woody debris input to the stream for fish habitat, due to their greater longevity (Swanson and Lienkaemper 1978). Management for hemlock could also lead to the development of larger snags in these riparian areas for wildlife use.

Establishment of hemlock seedlings will require a reduction in competition for light, and possibly protection from animal damage to achieve successful regeneration (Hibbs 1989). Chan (pers. comm.) has studies underway to examine the establishment of a variety of coniferous species in Coast Range riparian areas under different understory and overstory treatments. Small patch cuts are a possibility for management in these areas, due to a natural structuring of many riparian communities in small patches (Hibbs 1989).

There has been very little active management of red alder in riparian areas. Thinning of the alder overstory and underplanting with western hemlock, however, has shown some promising results. Emmingham et al. (1989) found that underplanted hemlock had a 52-78% survival rate. Seedling height after 5 years averaged 15-20 inches on plots where the overstory was thinned, while heights on unthinned plots averaged only 3.5 inches (Emmingham et al. 1989). Both chemical, individual trunk injection, and manual overstory thinning are feasible under this system. This silvicultural technique provides continuous shade to the stream, while at the same time adding diversity to the riparian community.

A possible problem with thinning the alder overstory to facilitate the establishment of hemlock is that salmonberry growth is increased under openings in the canopy (Krygier and Ruth, 1961; Viereck and Little, 1972). Direct control of the salmonberry, although helpful for western hemlock growth, is not a necessity (Emmingham et al. 1989). Emmingham et al. (1989) found that seedling growth, on thinned plots with no treatment of the salmonberry understory, was reduced during the first three years. By the fifth year, however, seedling growth was similar on all of the thinned plots, whether or not the salmonberry had been treated (Emmingham et al. 1989). Newton (1978), on the other hand, did find a retardation of hemlock growth due to shrub competition in brushfields of the Oregon Coast Range. The key appears to be to initially plant larger hemlock seedlings (Emmingham et al. 1989).

Another potential problem with this system could be shock to the hemlock when the alder overstory is eventually removed, if this was desired to accelerate the species conversion. This could be ameliorated by removing the alder overstory during the dormant season, giving the hemlock a chance to produce sun-adapted leaves during the next growing season (Emmingham et al. 1989).

These silvicultural treatments in the riparian zone could be tied in with adjacent upslope treatments, to minimize entries into the stand. A partial overstory removal coupled with underplanting could be used to restore Coast Range riparian areas to their more natural condition (Bacon and McConnell 1989; Newton 1989). It would also assure long-term coarse woody debris input to the streams and continued protection of riparian resources.

SUMMARY AND CONCLUSIONS

Salmonberry was shown to be extremely prevalent in alder-dominated riparian stands in the central portion of the Oregon Coast Range. The responses of the salmonberry population to a variety of buffer strip, light, and environmental factors were found to vary with landform.

Salmonberry height, number of ramets, percent cover, and estimated biomass were found to increase with light, but only on the slopes. All four salmonberry variables increased with buffer age, but only on the terraces. Height above stream, aspect, and latitude were all related to the salmonberry characteristics on the terraces. The salmonberry characteristics were not different between the slopes and terraces, but they did respond differently to the factors described above.

On the slopes, there was significantly more salmonberry within buffer strips than on undisturbed sites, where the adjacent stands had not been cut and no buffer strips created. There was no difference, on the terraces, between buffer and undisturbed sites. The increase in salmonberry, in the buffer strips on slopes, is probably due to increased sidelight into the riparian stand. It was shown that the four salmonberry variables were all related to light on the slopes.

Salmonberry growing on terraces was not related to light, and was not significantly different between buffer strips and undisturbed stands. All four salmonberry characteristics were found, however, to increase with time since the creation of a buffer strip.

An ordination of transects by herbaceous species abundance was used to develop a synthetic vegetation index, where the effects of unquantified environmental factors are integrated by the responses of the herbaceous species. Each transect's score along the first three ordination axes was used in simple linear regression analysis against the four salmonberry community structure variables (height, number of ramets, percent cover, and estimated biomass) and buffer age. Three of the four salmonberry variables and buffer age were related to the first ordination axis. Interpretation of this axis revealed that disturbance may be responsible for many of the changes in salmonberry community structure in these alder-dominated areas.

The size distribution of salmonberry aerial stems in the study area was found to be similar to that found by Tappeiner et al. (1991) for other stand types in the Oregon Coast Range. The diameter distribution resembles that found for trees in uneven-aged stands. Salmonberry in both buffer strips and undisturbed stands was found to follow this distribution. When the buffer strips were separated by landform, both terraces and slopes were also found to follow the same uneven-sized distribution. This indicates permanent, self-replacing stands of salmonberry in riparian areas now dominated by an alder overstory.

Salmonberry was found to be correlated both with the other tall shrubs, and the herbaceous community. As salmonberry increased, herb cover and diversity decreased. Two prominent members of the shrub community, vine maple and swordfern, also decreased in the presence of salmonberry. Salmonberry's effect on the herbaceous community is most likely due to the reduction in light under the salmonberry canopy, and the dense litter layer which develops. The low growing swordfern is also unable to grow above the salmonberry canopy, in order to successfully compete for light. Vine maple's displacement by salmonberry is probably due to their similarity in life form. Both species have a spreading growth form, and their primary method of reproduction in these areas is through sprouting and layering. Elderberry, on the other hand, appears unaffected by salmonberry.

Very little tree regeneration was found in any of the alder-dominated study sites. Approximately 29 seedlings per hectare were found within riparian buffer strips, and only one per hectare in the undisturbed stands. Undisturbed sites contained only alder regeneration, while 75% of the regeneration in the buffer strips were conifers. All of the hardwood and 44% of the conifer regeneration occurred in bare soil, the rest was found on down logs.

Salmonberry's persistent stand structure, deleterious effects on the herbaceous and shrub communities, and the minimal tree regeneration found in the study area support the hypothesis of an eventual conversion of many of these riparian areas to salmonberry brushfields, once the alder overstory senesces. The leaving of riparian buffer strips may accelerate this conversion. Salmonberry has been shown to increase within buffer strips in these areas. It increases on slopes with the increased light, and on terraces with increasing age of the buffer. Although conifer regeneration was found within the buffer strips, it is probably not enough to counteract the effects of increased salmonberry growth on these sites.

Most of these alder-salmonberry dominated riparian areas are the result of man-made disturbances within the past century. Historically, conifers were much more widespread in these areas, as can be seen from the remnant stumps. Logging, agricultural clearing, and road construction have created bare mineral soil in areas of abundant moisture, ideal conditions for the establishment of alder. The salmonberry thrives under these alder-dominated canopies, probably due to its ability to initiate growth early in the spring, before the alder canopy begins to develop. Natural disturbances in the area, such as flooding and fire, had more of a patchy pattern. This allowed conifers to remain in the riparian canopy, shading the salmonberry and providing a seed source for conifer regeneration.

Silvicultural intervention appears necessary to restore these areas to their more natural condition. A potential solution is to manage for western hemlock. Thinning of the alder overstory and under-planting with hemlock will add diversity to the riparian community, while still providing continuous shade to the stream. The steady growing hemlock will be able to overtop, and should eventually shade out, much of the salmonberry. Other conifer species, such as western redcedar, should be considered as well. This solution would not only avoid the eventual conversion to salmonberry brushfields, it would also provide a continued source of more desirable material for down woody debris and wildlife snags.

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APPENDIX A

Principal Components Analysis

PRINCIPAL COMPONENTS ANALYSIS
Salmonberry Variables

PRINCIPAL COMPONENTS ANALYSIS -- STANDS IN SALMONBERRY SPACE

Cross-products matrix contains CORRELATION COEFFICIENTS among SALMONBERRY

FIRST 4 EIGENVECTORS

SALMON.	Vector 1	Vector 2	Vector 3	Vector 4
HEIGHT	-.6944	.2342	.1285	.6682
COVER	.3492	.5076	-.7183	.3231
CLUMPS	.0232	.8274	.4384	-.3502
BIOMASS (log+1)	-.6288	.0538	-.5246	-.5714

VARIANCE EXTRACTED, FIRST 4 AXES

AXIS	EIGENVALUE	% OF VARIANCE	CUM. % OF VAR.
1	1.519	37.984	37.984
2	1.121	28.029	66.013
3	.933	23.319	89.332
4	.427	10.668	100.000

COORDINATES OF STANDS

STANDS		AXIS 1	AXIS 2	AXIS 3	AXIS 4
1	ST01	.1413	.0415	.0514	.0490
2	ST02	.2086	-.2650	-.0706	.0581
3	ST03	-.0253	.0913	.1600	.1373
4	ST04	.0953	-.1831	.1352	.0016
5	ST05	.0093	.0965	.2840	-.0141
6.	ST06	-.0700	-.0856	.1879	.1442
7	ST07	-.0692	.1166	.1736	.1755
8	ST08	.2307	-.0218	.0582	-.0616
9	ST09	-.0142	.0926	.2238	.0666
10	ST10	.1453	-.1583	.1481	-.0630
11	ST11	.2025	.1255	.1282	-.0809
12	ST12	.0059	-.0652	.1982	.0532
13	ST13	-.0443	.0376	-.0579	-.0135
14	ST14	.0812	-.1853	-.1606	.1254
15	ST16	-.1995	-.0148	.1743	.1430
16	ST17	-.1458	.0512	-.1576	.1584
17	ST18	-.0331	-.0612	-.1364	-.0445
18	ST19	-.0157	-.2804	-.0220	-.0757
19	ST20	-.0343	-.2668	.0113	-.0025
20	ST21	.1682	.0563	-.0357	-.0703
21	ST22	-.0218	-.1744	-.0410	-.2775
22	ST23	-.0425	-.1590	-.2004	.1294
23	ST24	.0496	.1744	.0822	.1341
24	ST25	.0945	-.2612	.0244	.0968
25	ST26	.0492	.2841	-.0875	-.0334
26	ST27	-.1991	-.1859	-.0615	-.1135
27	ST28	-.5204	.1450	.0017	-.1453
28	ST29	-.2967	-.2620	-.1325	-.0459
29	ST30	-.0038	.0972	-.0978	.0657
30	ST31	-.0422	-.0660	.1281	-.0496
31	ST32	.0135	-.1998	.0698	-.0292
32	ST33	-.0917	.1063	.0879	.0253
33	ST34	-.2047	.1375	-.2375	.0113
34	ST35	.1798	.1020	.0015	-.0722
35	ST36	-.1365	-.0454	-.0466	.0127
36	ST37	.2271	.1732	-.0240	-.0371
37	ST38	.1645	.0060	-.2747	.0914
38	ST39	.2788	-.0337	-.0538	-.0127
39	ST40	.3007	.1234	-.0436	-.0315
40	ST41	-.1827	-.0415	.0616	-.0843
41	ST42	-.1964	.0828	-.1750	-.0277
42	ST43	.2596	.0555	-.1094	-.0056
43	ST44	.1994	-.0663	.0367	-.0116
44	ST45	.1844	.1951	-.0354	-.0509
45	ST46	-.1962	.1176	-.2129	-.0143
46	ST47	.0167	-.2014	.0073	.0489
47	ST48	.0095	.0787	.1795	-.1971
48	ST49	-.1671	.0082	-.0128	.0367
49	ST50	.2219	.0810	-.1346	-.0608
50	ST51	-.0766	.0852	-.2187	.0683
51	ST52	-.1530	.1748	.0584	.0449
52	ST53	-.2815	.1015	.1328	-.0438
53	ST54	.0511	.2371	-.1027	-.0504
54	ST55	-.1244	.0084	.1370	-.0581

COORDINATES CORRECTED FOR % VARIANCE IN EACH AXIS

	STANDS	AXIS 1	AXIS 2	AXIS 3	AXIS 4
1	ST01	.5365	.1162	.1200	.0523
2	ST02	.7922	-.7427	-.1646	.0620
3	ST03	-.0960	.2558	.3731	.1465
4	ST04	.3620	-.5133	.3152	.0017
5	ST05	.0353	.2706	.6623	-.0150
6	ST06	-.2657	-.2400	.4382	.1538
7	ST07	-.2629	.3268	.4048	.1873
8	ST08	.8765	-.0610	.1358	-.0657
9	ST09	-.0538	.2594	.5218	.0711
10	ST10	.5518	-.4436	.3454	-.0672
11	ST11	.7691	.3517	.2989	-.0863
12	ST12	.0224	-.1829	.4623	.0567
13	ST13	-.1682	.1055	-.1350	-.0144
14	ST14	.3086	-.5193	-.3744	.1338
15	ST16	-.7579	-.0416	.4064	.1525
16	ST17	-.5537	.1435	-.3676	.1690
17	ST18	-.1257	-.1716	-.3180	-.0475
18	ST19	-.0598	-.7858	-.0514	-.0802
19	ST20	-.1305	-.7477	.0263	-.0027
20	ST21	.6388	.1578	-.0832	-.0750
21	ST22	-.0829	-.4888	-.0955	-.2960
22	ST23	-.1613	-.4456	-.4673	.1381
23	ST24	.1884	.4888	.1917	.1431
24	ST25	.3590	-.7322	.0568	.1033
25	ST26	.1869	.7963	-.2040	-.0356
26	ST27	-.7561	-.5210	-.1435	-.1211
27	ST28	-1.9767	.4064	.0039	-.1550
28	ST29	-1.1271	-.7344	-.3089	-.0489
29	ST30	-.0146	.2724	-.2280	.0701
30	ST31	-.1604	-.1850	.2987	-.0529
31	ST32	.0513	-.5599	.1628	-.0312
32	ST33	-.3482	.2978	.2051	.0270
33	ST34	-.7776	.3854	-.5537	.0121
34	ST35	.6829	.2858	.0035	-.0770
35	ST36	-.5184	-.1271	-.1087	.0136
36	ST37	.8626	.4854	-.0560	-.0396
37	ST38	.6249	.0169	-.6406	.0975
38	ST39	1.0590	-.0946	-.1255	-.0136
39	ST40	1.1423	.3458	-.1016	-.0336
40	ST41	-.6939	-.1163	.1436	-.0899
41	ST42	-.7460	.2320	-.4080	-.0296
42	ST43	.9862	.1556	-.2551	-.0059
43	ST44	.7573	-.1859	.0857	-.0123
44	ST45	.7005	.5470	-.0827	-.0543
45	ST46	-.7453	.3297	-.4965	-.0152
46	ST47	.0634	-.5644	.0170	.0522
47	ST48	.0360	.2205	.4186	-.2103
48	ST49	-.6346	.0230	-.0299	.0392
49	ST50	.8429	.2270	-.3138	-.0648
50	ST51	-.2909	.2388	-.5101	.0728
51	ST52	-.5812	.4900	.1363	.0479
52	ST53	-1.0691	.2844	.3097	-.0468
53	ST54	.1943	.6646	-.2395	-.0538
54	ST55	-.4725	.0236	.3194	-.0620

APPENDIX B

Edge Effects

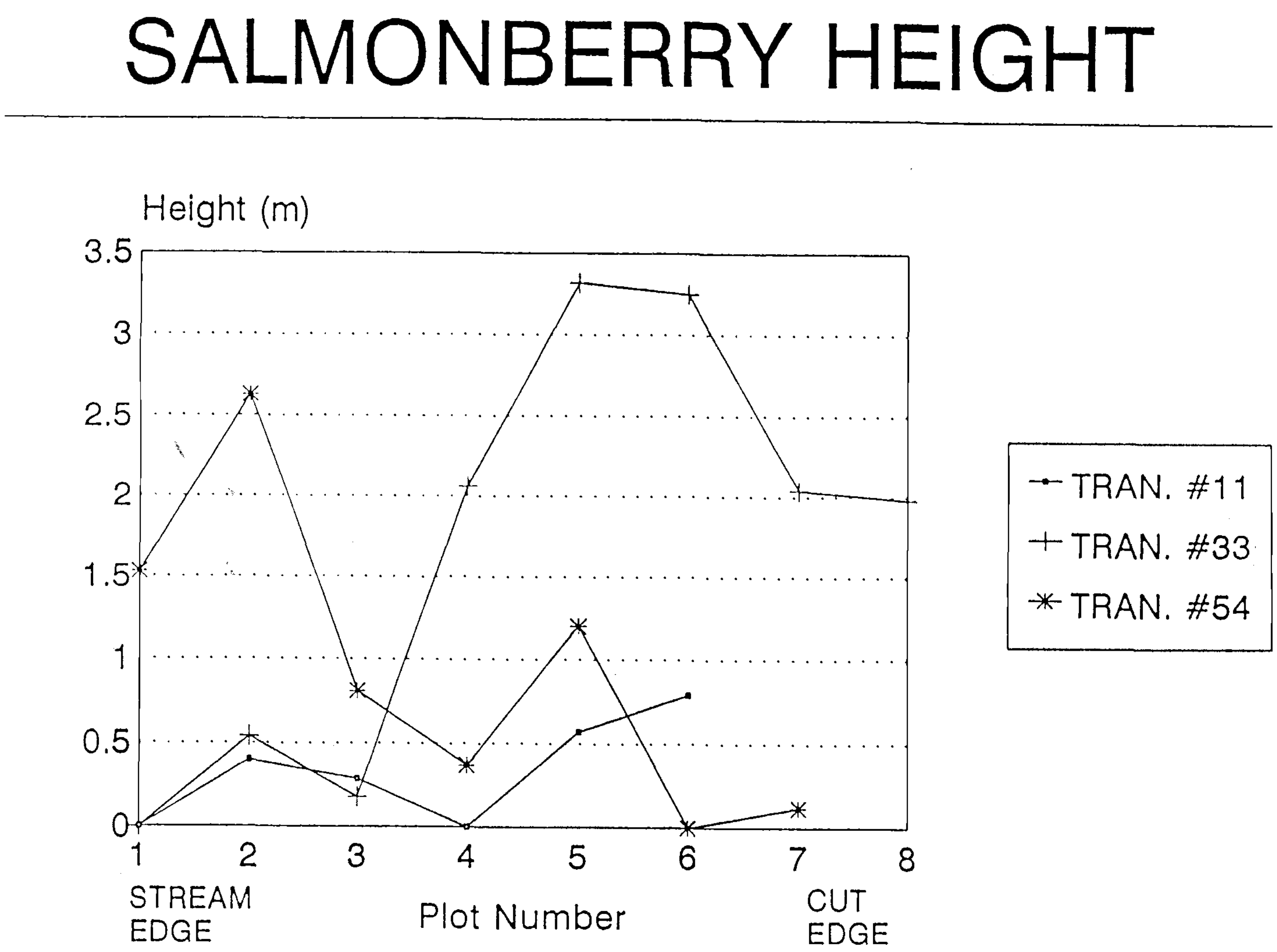


FIGURE 10. Average maximum salmonberry height across three of the widest buffer strips.

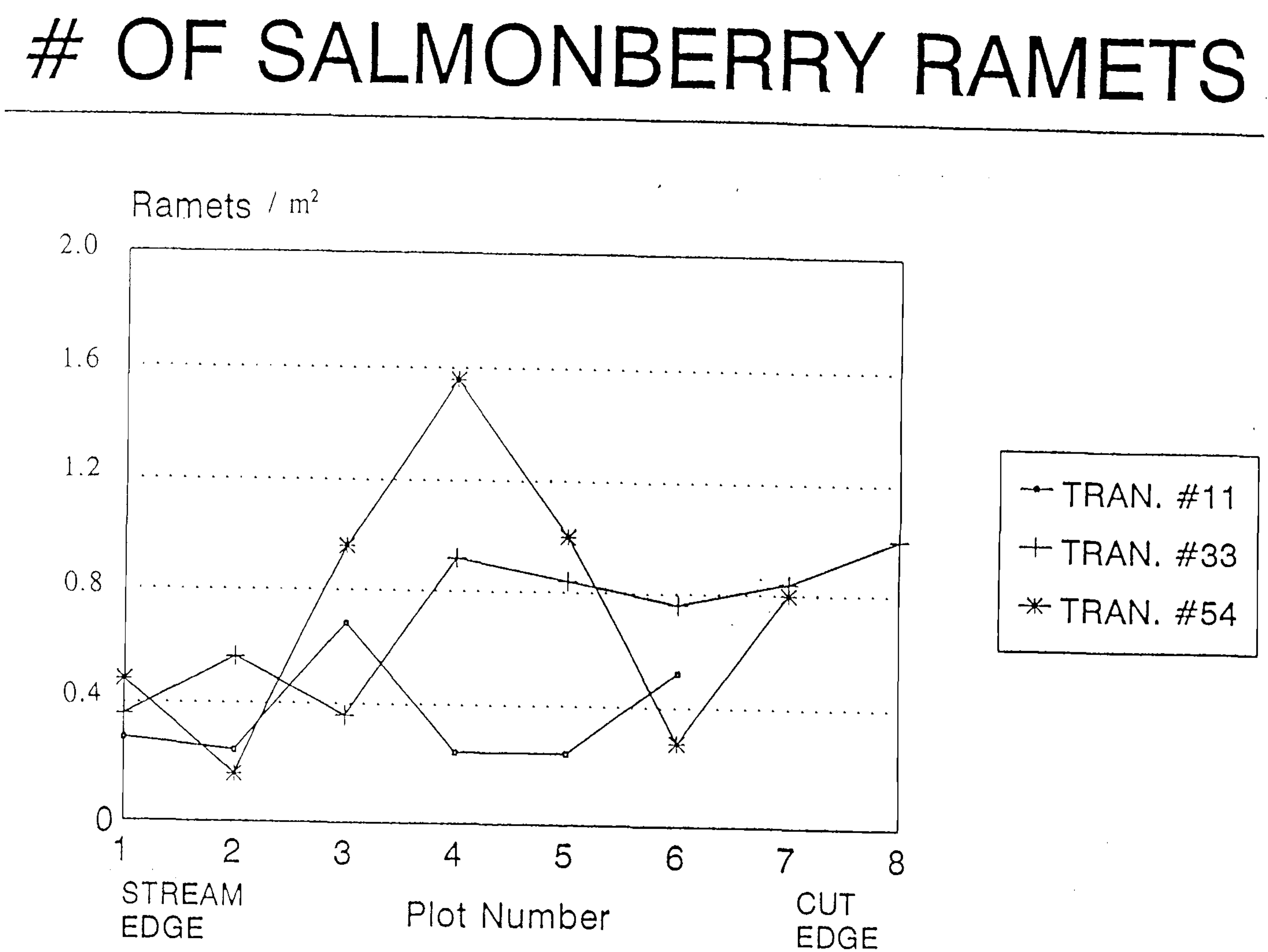


FIGURE 11. Number of salmonberry ramets, per square meter, across three of the widest buffer strips.

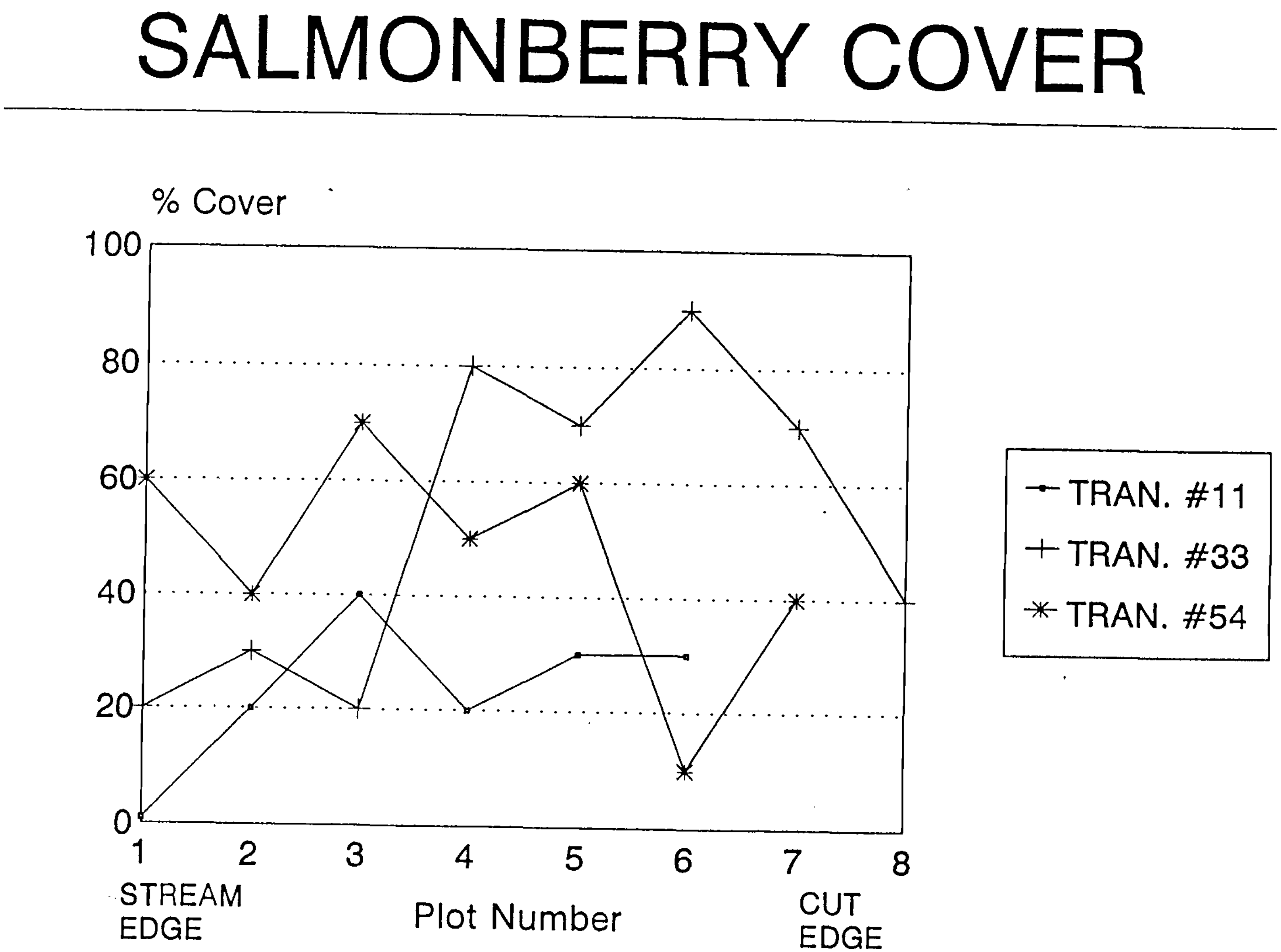


FIGURE 12. Salmonberry cover across three of the widest buffer strips.

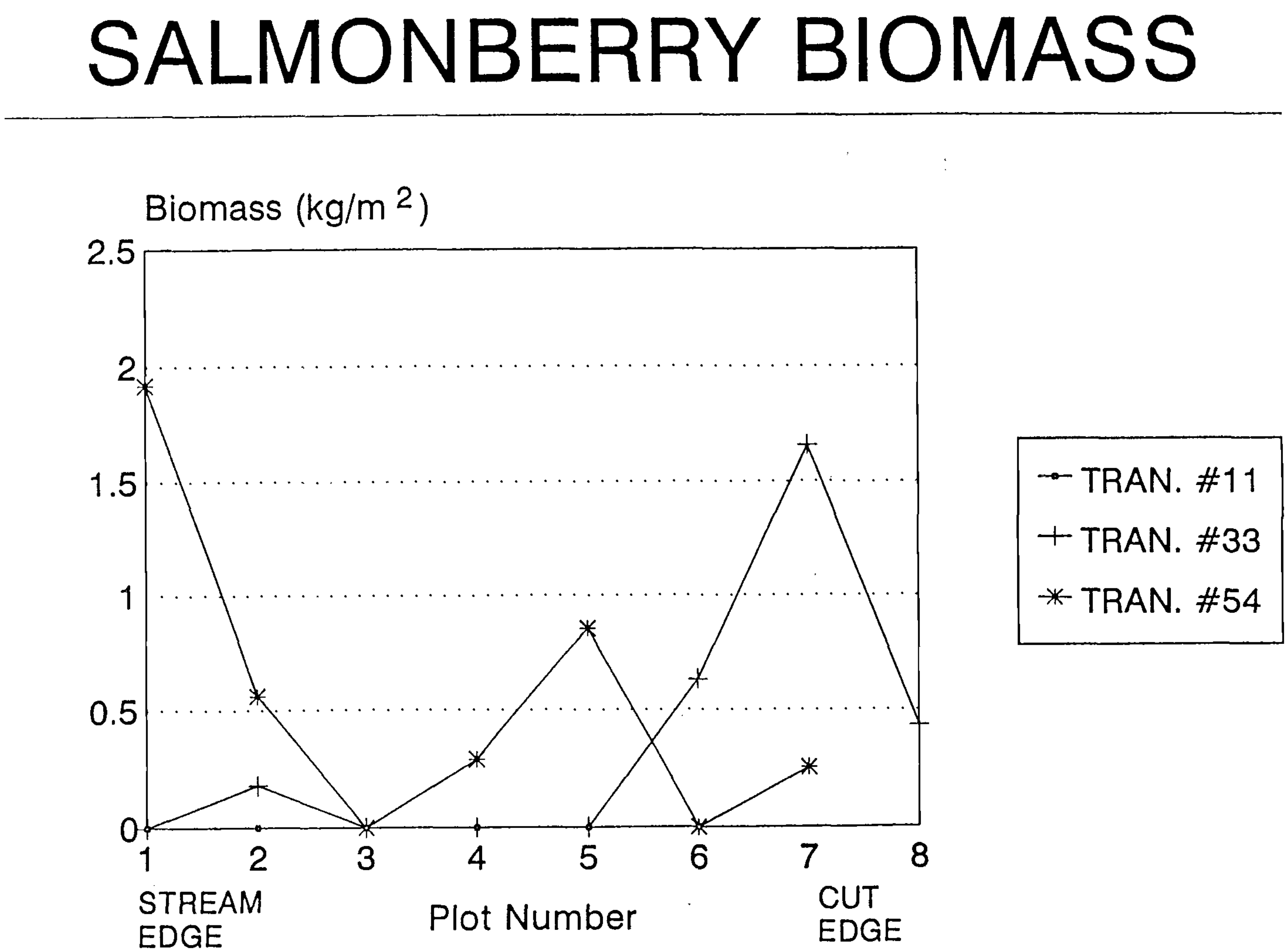


FIGURE 13. Salmonberry biomass across three of the widest buffer strips.

APPENDIX C

Ordination

BRAY-CURTIS ORDINATION
Herbaceous species with at least four occurrences

ORDINATION OF STANDS IN SPECIES SPACE.
54 STANDS 33 SPECIES

THE FOLLOWING OPTIONS WERE SELECTED

DISTANCE MEASURE = 1-2W/A+B
ENDPOINT SELECTION = VAR.-REGRESSION
PROJECTION GEOMETRY = EUCLIDEAN
CALCULATION OF RESIDUALS = EUCLIDEAN

ENDPOINTS FOR AXIS 1 STAN07 STAN40
DISTANCES ARE FROM STAN07

REGRESSION COEFICIENT FOR THIS AXIS = -25.14
VARIANCE OF THE FIRST END POINT = .89

THIS AXIS EXTRACTED 18.27 % OF THE INFORMATION IN THE DATA MATRIX.

.56	STAN01	1	.36	STAN02	2	.08	STAN03	3
.25	STAN04	4	.10	STAN05	5	.06	STAN06	6
.00	STAN07	7	.18	STAN08	8	.11	STAN09	9
.12	STAN10	10	.27	STAN11	11	.15	STAN12	12
.29	STAN13	13	.18	STAN14	14	.23	STAN16	15
.34	STAN17	16	.25	STAN18	17	.24	STAN19	18
.26	STAN20	19	.24	STAN21	20	.61	STAN22	21
.43	STAN23	22	.24	STAN24	23	.48	STAN25	24
.35	STAN26	25	.47	STAN27	26	.34	STAN28	27
.24	STAN29	28	.47	STAN30	29	.25	STAN31	30
.30	STAN32	31	.34	STAN33	32	.54	STAN34	33
.68	STAN35	34	.34	STAN36	35	.34	STAN37	36
.41	STAN38	37	.38	STAN39	38	.76	STAN40	39
.45	STAN41	40	.38	STAN42	41	.27	STAN43	42
.37	STAN44	43	.36	STAN45	44	.26	STAN46	45
.43	STAN47	46	.24	STAN48	47	.12	STAN49	48
.32	STAN50	49	.52	STAN51	50	.35	STAN52	51
.42	STAN53	52	.14	STAN54	53	.23	STAN55	54

BRAY-CURTIS ORDINATION
Herbaceous species with at least four occurrences

ENDPOINTS FOR AXIS 2 STAN01 STAN36
DISTANCES ARE FROM STAN01

REGRESSION COEFICIENT FOR THIS AXIS = -20.25
VARIANCE OF THE FIRST END POINT = .84

THIS AXIS EXTRACTED 13.02 % OF THE INFORMATION IN THE DATA MATRIX.

.00	STAN01	1	.40	STAN02	2	.24	STAN03	3
.25	STAN04	4	.43	STAN05	5	.30	STAN06	6
.31	STAN07	7	.37	STAN08	8	.44	STAN09	9
.29	STAN10	10	.30	STAN11	11	.02	STAN12	12
.26	STAN13	13	.33	STAN14	14	.17	STAN16	15
.24	STAN17	16	.39	STAN18	17	.43	STAN19	18
.22	STAN20	19	.16	STAN21	20	.48	STAN22	21
.07	STAN23	22	.34	STAN24	23	.29	STAN25	24
.36	STAN26	25	.41	STAN27	26	.32	STAN28	27
.41	STAN29	28	.42	STAN30	29	.32	STAN31	30
.26	STAN32	31	.34	STAN33	32	.31	STAN34	33
.28	STAN35	34	.76	STAN36	35	.53	STAN37	36
.42	STAN38	37	.37	STAN39	38	.31	STAN40	39
.41	STAN41	40	.50	STAN42	41	.18	STAN43	42
.25	STAN44	43	.44	STAN45	44	.37	STAN46	45
.34	STAN47	46	.47	STAN48	47	.36	STAN49	48
.48	STAN50	49	.33	STAN51	50	.36	STAN52	51
.62	STAN53	52	.43	STAN54	53	.37	STAN55	54

BRAY-CURTIS ORDINATION
Herbaceous species with at least four occurrences

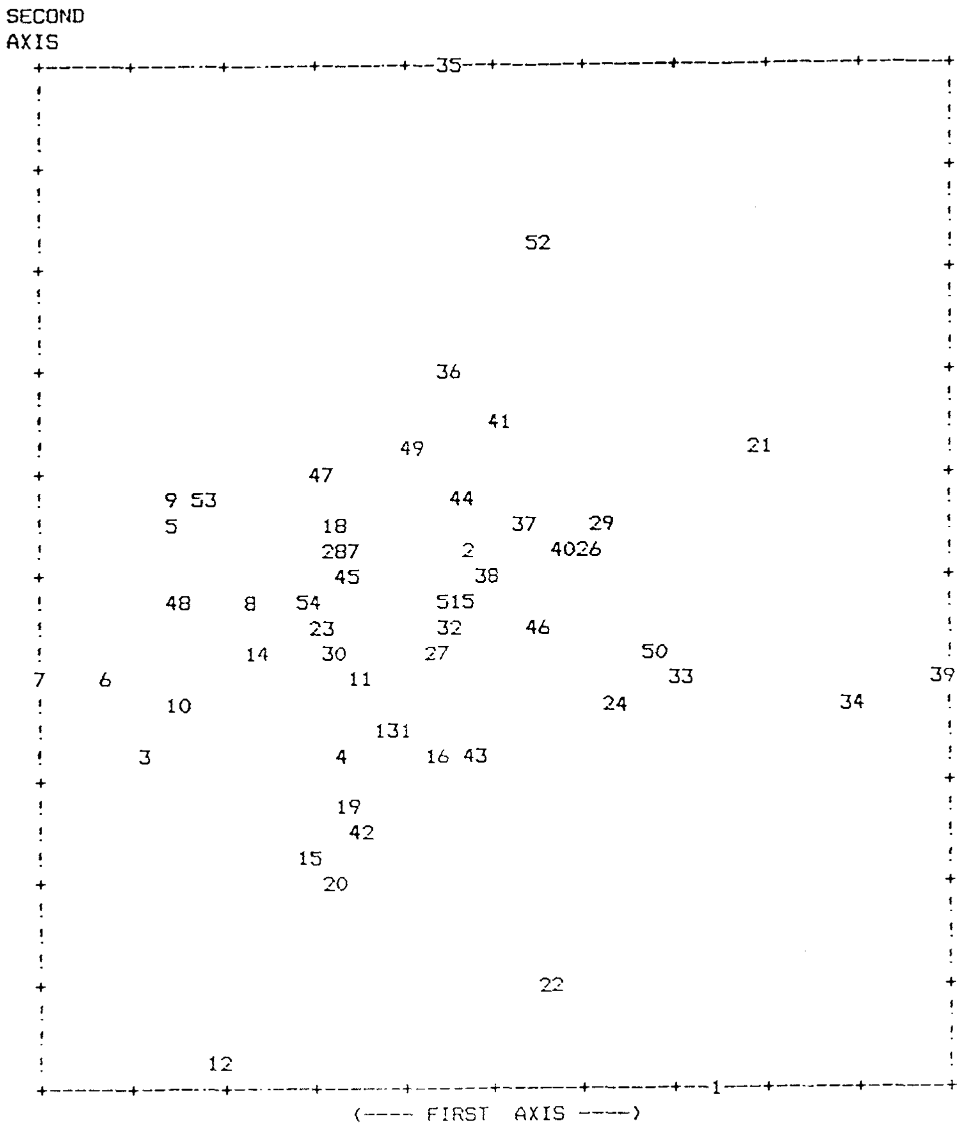
ENDPOINTS FOR AXIS 3 STAN04 STAN18
DISTANCES ARE FROM STAN04

REGRESSION COEFICIENT FOR THIS AXIS = -16.55
VARIANCE OF THE FIRST END POINT = .91

THIS AXIS EXTRACTED 11.54 % OF THE INFORMATION IN THE DATA MATRIX.

.21	STAN01	1	.12	STAN02	2	.08	STAN03	3
.00	STAN04	4	.20	STAN05	5	.21	STAN06	6
.26	STAN07	7	.29	STAN08	8	.47	STAN09	9
.42	STAN10	10	.25	STAN11	11	.26	STAN12	12
.34	STAN13	13	.27	STAN14	14	.28	STAN16	15
.21	STAN17	16	.73	STAN18	17	.37	STAN19	18
.22	STAN20	19	.36	STAN21	20	.20	STAN22	21
.42	STAN23	22	.35	STAN24	23	.18	STAN25	24
.28	STAN26	25	.25	STAN27	26	.20	STAN28	27
.22	STAN29	28	.14	STAN30	29	.19	STAN31	30
.41	STAN32	31	.19	STAN33	32	.26	STAN34	33
.12	STAN35	34	.21	STAN36	35	.18	STAN37	36
.24	STAN38	37	.12	STAN39	38	.26	STAN40	39
.08	STAN41	40	.02	STAN42	41	.23	STAN43	42
.31	STAN44	43	.38	STAN45	44	.23	STAN46	45
.19	STAN47	46	.41	STAN48	47	.30	STAN49	48
.42	STAN50	49	.28	STAN51	50	.14	STAN52	51
.43	STAN53	52	.29	STAN54	53	.21	STAN55	54

BRAY-CURTIS ORDINATION---Species with at least four occurrences



BRAY-CURTIS ORDINATION
Herbaceous species with at least four occurrences

PEARSON AND KENDALL CORRELATIONS WITH ORDINATION AXES
N= 54

AXIS:	1			2			3		
	r	r-sq	tau	r	r-sq	tau	r	r-sq	tau
ATFI	-.385	.148	-.265	-.404	.163	-.314	.015	.000	.018
DIFO	-.503	.253	-.357	-.095	.009	-.071	-.084	.007	-.026
GAAPE	-.155	.024	-.065	-.183	.034	-.250	-.237	.056	-.167
GRASS	.471	.222	.325	.327	.107	.200	-.045	.002	-.048
MOSI	-.677	.458	-.549	-.214	.046	-.192	.304	.092	.208
OESA	.474	.225	.338	-.315	.099	-.202	-.076	.006	-.073
OXOR	-.345	.119	-.211	.290	.084	.192	-.427	.183	-.330
POMU	-.188	.035	-.090	.499	.249	.374	.129	.017	.092
RAUNP	.478	.228	.352	-.085	.007	-.068	-.062	.004	-.068
STRI	-.254	.065	-.142	-.457	.209	-.343	-.259	.067	-.115
TOME	.456	.208	.311	-.512	.262	-.337	-.429	.184	-.280
URDI	.538	.289	.353	-.363	.132	-.271	-.300	.090	-.220
DIPU	.047	.002	-.029	.180	.032	.089	-.323	.105	-.261
MADI2	-.204	.042	-.173	-.009	.000	.070	.571	.326	.452
MAOR	.085	.007	.099	.176	.031	.091	-.352	.124	-.280
MOSS	-.230	.053	-.128	.327	.107	.243	-.363	.131	-.232
OSCH	-.134	.018	-.031	-.041	.002	-.024	-.313	.098	-.268
POGL4	.171	.029	.151	.275	.076	.274	-.095	.009	-.019
TROV	-.092	.009	-.014	.147	.022	.117	.184	.034	.115
VIGL	-.490	.241	-.375	-.361	.130	-.299	.159	.025	.176
ADPE	.063	.004	.016	.196	.039	.184	-.312	.097	-.285
DIHO	-.290	.084	-.213	.395	.156	.260	.340	.116	.240
TIUN	-.113	.013	-.068	.105	.011	.124	-.012	.000	.017
EQAR	-.093	.009	.018	-.149	.022	-.104	-.003	.000	-.025
HYSP	.458	.210	.325	.084	.007	.077	-.206	.043	-.106
GATR	.138	.019	.098	.160	.026	.200	-.180	.032	-.098
STME2	-.142	.020	-.120	.026	.001	-.029	.341	.116	.227
STCR	.166	.027	.158	.144	.021	.127	.073	.005	.041
LYAM	.044	.002	-.021	-.265	.070	-.146	.130	.017	.078
MIDE	-.031	.001	.040	-.032	.001	-.047	-.056	.003	-.023
BLSP	.021	.000	.085	.056	.003	.105	-.013	.000	.023
PEFR2	.271	.073	.250	-.026	.001	-.040	-.081	.007	-.077
DRAU2	-.149	.022	-.092	.078	.006	.054	.414	.171	.244

HERBACEOUS SPECIES CODES

Code	Species
ATFI	Athyrium filix-femina L.
DIFO	Dicentra formosa (Andr.) Walpers
GAAPE	Galium aparine L.
MOSI	Montia sibirica (L.) How.
OESA	Oenanthe sarmentosa Presl.
OXOR	Oxalis oregana Nutt. ex T.& G.
POMU	Polystichum munitum (Kaulf.) Presl.
RAUN	Ranunculus uncinatus D. Donn
STRI	Stachys rigida Nutt.
TOME	Tolmiea menziesii (Pursh) T.& G.
URDI	Urtica dioica L.
DIPU	Digitalis purpurea L.
MADI2	Maianthemum dilatatum (Wood) Nels.& Macbr.
MAOR	Marah oreganus (T.& G.) Howell
OSCH	Osmorhiza chilensis H.& A.
POGL4	Polypodium glycyrrhiza D.C. Eat.
TROV	Trillium ovatum Pursh
VIGL	Viola glabella Nutt.
ADPE	Adiantum pedatum L.
DIHO	Disporum hookeri (Torr.) Nicholson
TIUN	Tiarella trifoliata var. unifoliata (Hook.) Kurtz
EQAR	Equisetum arvense L.
HYTE	Hydrophyllum tenuipes Heller
GATR	Galium triflorum Michx.
STME2	Stachys mexicana Benth.
STCR	Stellaria crispa Cham. & Schlecht.
LYAM	Lysichitum americanum Hulten & St. John
MIDE	Mimulus dentatus Nutt.
BLSP	Blechnum spicant (L.) Roth.
PEFR2	Petasites frigidus (L.) Fries
DRAU2	Dryopteris austriaca (Jacq.) Woynar