THE GROWTH RESPONSE OF SECONDARY VEGETATION TO SILVICULTURAL TREATMENTS, SOIL AND SITE CONDITIONS IN THE CARNATION CREEK WATERSHED, VANCOUVER ISLAND

by

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ABSTRACT

A regenerating coastal watershed in the Pacific Northwest is examined to determine silvicultural treatment effects on the revegetation of nine sites characterized by combinations of burning, scarification and herbicide application. Biophysical site differences are summarized using site factors (including aspect, slope, elevation and moisture regime) and floristic diversity. Differences in site fertility are investigated using essential nutrients in soil and foliage; and vegetative cover of five competing species (Alnus rubra Bong., Rubus spectabilis Pursh, Gaultheria shallon Pursh, Vaccinium parvifolium Smith and Tsuga heterophylla (Raf.) Sarg.). Principal component analysis (PCA) and analysis of variance (ANOVA) are the principal methods of analysis.

Differences in sites and in floristic diversity are distinguished primarily with respect to elevation, slope and moisture. Scarified soils are associated more with mineral (clay) colloids and often have lower nutrient availability than unscarified soils. Unscarified soils are associated more with organic (humic) colloids, often have better horizonation, higher CEC's and generally contain more organic matter and total elements N, K, Ca, Mg and Na.

Differences in huckleberry cover are not explained by treatment. Although greater huckleberry cover occurs on mesic, south-facing slopes, it is <25% and probably not considered a threat to crop trees. Huckleberry cover is limited by low availability of rooting and canopy space (eg. interspecific competition with salmonberry, salal and alder).

Salmonberry cover is greater where available K and Ca are not limited by alder (eg. in scarified sites) and where high silt and clay contents do not reduce nutrient availability in general. A reduction in available P and Mn that is not induced by alder (eg. in unscarified sites treated with glyphosate) may also limit salmonberry growth.

Salal growth is limited by low light intensity (eg. in level or north-facing sites). Greater salal cover occurs in previously burned, south-, southwest- or west-facing sites with implicitly higher diurnal temperatures and minimal interspecific competition.

Greater alder cover is attributed to scarification (eg. production of a mineral seed bed), to the dispersal of clay colloids by high soil Na contents resulting in improved nutrient uptake, and to its inherent ability to fix N in nutrient deficient soils. Alder cover is limited by low availability of K and Ca in clay soils.

Low N availability does not limit hemlock growth but moisture and organic rooting media are fundamentally

important. Hemlock is more abundant in hygric, moisture-receiving, low elevation sites treated with glyphosate where salmonberry cover is consequently less abundant. Drier, west-facing, slash-covered sites previously broadcast burned and presently dominated by salal are the poorest growing sites for hemlock.

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1.0 STUDY INTRODUCTION

1.1 INTRODUCTION

This ecological study examines some vegetation-environment interactions following logging and reforestation activities in a coastal watershed of the Pacific Northwest. Secondary vegetation, silvicultural treatments, soil and site conditions are its primary foci.

Reforestation is a fundamental component of any silvicultural system. The primary objective is to create an environment that encourages the establishment and growth of commercially viable conifer seedlings. This can be achieved through harvesting methods, forest site preparation, natural and/or artificial regeneration, and stand tending (which includes brushing, weeding and conifer release). However, dense hardwood and shrub revegetation on some sites make it difficult for forest managers to effectively establish and maintain regeneration. Therefore, forest weed control is an essential component of the reforestation process, and basic knowledge concerning the growth of weed species in this context is important. The need for more information about the autecology of major species of competing vegetation in British Columbia was identified by Conard (1984) in a problem analysis of vegetation management research needs in this province.

Competing vegetation has a major impact on the establishment and growth of crop trees in B.C. (Haeussler & Coates, 1986). However, silviculturists have only recently begun examining alternative techniques of managing competing vegetation for successful regeneration of logged areas and unsatisfactorily restocked sites. Autecological information on plant species or complexes of species that compete with crop trees, and on their response to silvicultural treatments, is fundamental for successful forest management. Research which examines the effects of various silvicultural practices on revegetation and regeneration is clearly needed. This study was undertaken to examine the response of secondary vegetation to silvicultural treatments, soil and site conditions in the Carnation Creek Experimental Watershed, Vancouver Island.

The study site has been chosen primarily for the practical significance of information that could be obtained by conducting research in an operational forestry setting. Collaboration with the Canadian Forestry Service (CFS) and MacMillan Bloedel Ltd. (MB) has enabled access to ten years of post-harvest vegetation and site data, and provided an opportunity to examine the effects of various silvicultural treatments on revegetation in this coastal watershed. The study site is of interest to coastal forest managers because the watershed is similar to many other drainage systems on Vancouver Island.

1.2 PROBLEM DEFINITION

According to Canada's Forest Inventory for 1981 (Bonnor, 1982), 42.034 million ha of British Columbia's total land area (93.1 million ha) is stocked productive forest land area, and 2.994 million ha is considered insufficiently restocked (NSR) forest land. In 1986, current and backlog NSR forest lands in B.C. totalled 1.6535 million ha (Pearse et al., 1986a). Backlog NSR lands alone contributed to 1.3 million ha of which approximately 600 000 ha warranted rehabilitation for reforestation, occupying areas with good and medium site quality (Pearse et al., 1986a). NSR forest lands in B.C. are expected to increase at a rate of 11 800 ha per year (Pearse et al., 1986a). Refer to Table 1.0 for distribution of NSR forest land by forest region in B.C., and to Pearse et al. (1986a) for definition of forestry terminology. B.C.'s forest regions are shown in Figure 1.0.

Insufficient stocking levels are usually attributed to low natural or artificial regeneration. As a corollary, competition from fast-growing shrubs and trees of low commercial value ("brush" or "weeds") significantly reduces the availability of resources for seedling establishment and subsequent growth, regardless of seedling source. A recent study estimates that brush problems exist on 80% of good sites and 66% of medium sites of backlog NSR lands (Boateng,

TABLE 1.0 Inadequately stocked Crown forest land at the beginning of 1984[a], by forest region in B.C. (Pearse et al., 1986b).

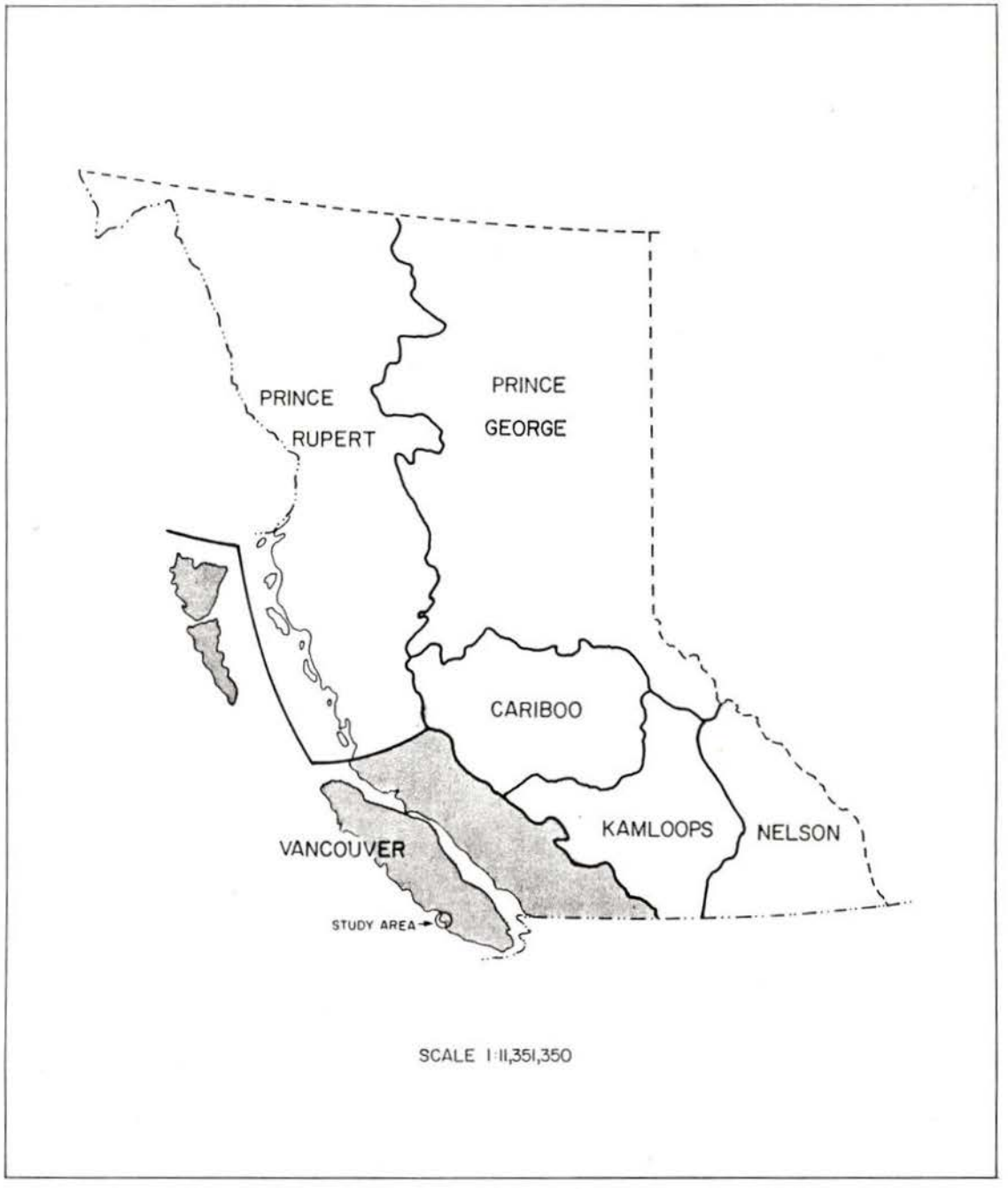
	Cariboo	Kamloops	Nelson	Prince George	Prince Rupert	Vancouver	Province
				(Thousand ha)			
Current NSR							
Good & medium sites	21.1	26.2	22.8	57.3	14.6	7.9	149.9
Poor & low sites	12.4	6.6	11.3	75.2	76.2	1.7	183.3
	33.5	32.8	34.1	132.4	90.8	9.6	333.2
Backlog NSR							
a) NCBr:							
Good & medium sites	1.4	4.3	31.8	348.4[b]	13.2	1.8	400.7
Poor & low sites	3.2	2.4	19.2	410.4	38.3	0.6	474.1
	4.5	6.6	51.0	758.8	51.4	2.4	874.8
b) Other backlog NSR:							
Good & medium sites	20.9	21.0	39.2	83.0	12.7	10.8	187.5
Poor & low sites	9.5	10.0	21.6	110.6	81.3	6.4	239.4
	30.3	31.0	60.8	193.6	94.0	17.2	426.8
c) Total Backlog NSR:	34.5	37.6	111.8	952.4	145.5	19.6	1301.6
(current and backlog)	68.3	70.3	145.8	1084.8	236.3	29.2	1634.8

[a] Including private lands within Tree Farm Licenses but excluding all other private lands. The gross areas of NSR land have been reduced by correction factors to allow for the proportion of lands in this category that is likely to be adequately reforested (see text).

[b] This includes the lands in the Peace and Fort Nelson districts reclassified by the Ministry from poor to good and medium site classes between its 1979 and 1984 Forest and Range Resource Analyses.

Source: Ministry of Forests, unpublished data.

FIGURE 1.0 Map showing B.C.'s forest regions.



1984). Thus, site preparation and stand tending must be performed to ensure seedling survival and brush control.

In 1985, stand tending in the coastal western hemlock (CWH) biogeoclimatic zone (for definition see Krajina, 1965) in the Vancouver forest region consisted mainly of brushing and weeding, and also juvenile spacing, conifer release and seed tree control and fertilization (Pearse et al., 1986a). In the highly productive CWH zone, major competing species targeted for brushing and weeding usually include alder (Alnus rubra Bong.), salmonberry (Rubus spectabilis Pursh) and salal (Gaultheria shallon Pursh) among others (Haeussler & Coates, 1986; Boyd et al., 1985; Lauterbach & Warren, 1982; Stewart, 1977, 1974a; Baber & McCall, 1974; Allan et al., 1972; Gratkowski, 1971).

1.3 PREVIOUS RESEARCH IN AUTECOLOGY OF COMPETING SHRUBS

Brief autecological descriptions of four brush species that compete with conifer seedlings in west coast, low-elevation forests are provided below to familiarize the reader with their characteristics. These species include red alder, salmonberry, salal and huckleberry (Plates 1-4, Appendix 1.0).

Red alder (Alnus rubra Bong.) is a major competitor of young conifers. It exhibits rapid juvenile growth

(Haeussler & Coates, 1986; Minore, 1972) and at ages of about 6 to 8 years produces seed from unisexual flowers (Hitchcock & Cronquist, 1973). Dissemination of seed is primarily by wind (Haeussler & Coates, 1986). Red alder does not sucker from the roots but can reproduce vegetatively if damaged (Haeussler & Coates, 1986).

Competition by alder becomes more pronounced with age, particularly for light, soil moisture and available nutrients (DeBell & Radwan, 1984; Radwan et al., 1984; Cole et al., 1983; Gessel et al., 1981; Kenady, 1978; Henderson, 1978). It rapidly invades sites with disturbed mineral exposures. Growth of red alder may be limited by low availability of phosphorus, calcium or magnesium in the soil (DeBell et al., 1984).

Salmonberry (Rubus spectabilis Pursh) is also considered a major competitor of young conifers especially on moist, productive, coastal or alluvial forest sites (Haeussler & Coates, 1986; Newton & White, 1983; Barber, 1976; Stewart, 1974a, 1974b, 1974c, 1972; Gratkowski, 1971). Nutrient relations of salmonberry are highly variable and relatively unknown. Effects of combined treatments on salmonberry regrowth have not yet been reported.

Its early development and shade tolerance enable dense, perennial thickets to develop from rhizomes. The success of removal of rhizomes by burning or scarification depends on treatment intensity. Often, increased rooting occurs as a result of insufficient depth of burn or mineral disturbance. Salmonberry stems continue to elongate as long as soil moisture is available and temperatures are not extreme. Consequently, conifer seedling establishment is retarded by low light levels and matting salmonberry litter.

In salal (Gaultheria shallon Pursh), continuous resprouting from rhizomes results in significant root competition, primarily for soil moisture and available nutrients (Price et al., 1986; Haeussler & Coates, 1986; Lauterbach & Warren, 1982; Long, 1977; Stewart, 1974a, 1974b, 1974c). Nutrient preferences of salal in coastal sites and its impact on the nutrient relations and microclimate of conifer seedlings in a regenerating setting are not well documented.

Although huckleberry (Vaccinium parvifolium Smith) is not usually considered a major competitor on coastal sites, its frequent distribution within coastal hemlock forest types has been reported (Haeussler & Coates, 1986). It is a rhizomatous shrub common in clearcut, unburned sites where light is not limited (Abrams & Dickman, 1984, 1983; Pritts & Hancock, 1984; Lauterbach & Warren, 1982). Nutrient relations of huckleberry are highly variable, and its

response to treatments other than burning are relatively unknown. Similarly, there is little information on its growth and development, reproductive strategies and habitat interactions, particularly with crop trees.

The nature of interactions between non-crop species and coniferous crop trees are not well documented. More information is needed on the mechanism and magnitude of competitive effects. Similarly, variability in many species' autecological characteristics and responses to disturbance are not well understood. Some studies examine the effects of a specific silvicultural application on vegetation and regeneration in a forest ecosystem (Beese, 1983; Pregitzer & Barnes, 1982; Heilman, 1982). However, information on the effects of combinations of cutting, prescribed burning, mechanical site preparation and chemical applications is lacking. Successful management of any species requires that this basic information be obtained and reported (Coates & Haeussler, 1985; Conard, 1984).

The Carnation Creek Watershed offers a unique opportunity to examine the effects of combined site preparation applications on brush and conifer species in a typical, regenerating west coast forest. To date, minimal vegetation research has been conducted in this operational logging setting.

1.4 OBJECTIVES

This study attempts to quantify the relationship between plant cover and soil fertility where nutritional differences may be related to silvicultural treatments. The nature of interactions between competing vegetation and environment, and the nature of individual species' growth following disturbance in the Coastal Western Hemlock b_1 biogeoclimatic variant (wetter, submontane, windward) may thus be better understood. The primary objective of this study is to examine the cover response of secondary vegetation (i.e. major competitors) to silvicultural treatments, soils and site conditions in the Carnation Creek Watershed. To achieve this goal, the study was designed to address two questions: (1) how are the treatment sites different with respect to vegetative cover, site conditions and soil fertility? and; (2) how does growth in the dominant competitors differ with respect to treatment, site conditions and relative fertility?

Treatment areas are delineated on the basis of silvicultural site history, and include sites that were previously slash- or broadcast burned, scarified (mechanically cleared using a D-6 Caterpillar tractor fitted with brush-blade) and/or aerially treated with glyphosate (2.0 kg active ingredient per ha).

Dominant plant species examined include red alder, salmonberry, salal, huckleberry and western hemlock (Tsuga heterophylla (Raf.) Sarg. Aboveground canopy cover (%) and foliar determinations of elements essential for plant growth (N, P, K, Ca, Mg, Mn, Fe, Cu and Zn) are used to measure plant growth.

To characterize the forest soils and reflect soil properties of significance (fertility) chiefly those nutrients essential for plant nutrition are analyzed. Soil pH is also examined because it can influence the relative availability of nutrient elements; and soil texture is examined because it is one of the more stable properties of a soil, little modified by disturbance over time (Armson, 1977). These properties are of primary importance to plant growth because they affect water movement, aeration and fertility in a soil.

Since measurements of fertility based on determination of amounts of nutrient elements in the soil, alone, may be questionable due to elemental variability, vertical and lateral horizon variability, variability in root distribution and variability in the extraction of a particular element (Lloyd & McKee, 1983; Courtin et al., 1983; Wang, 1982; Khan & Nortcliff, 1982; Mausbach et al., 1980; Bracewell et al., 1979; Blyth & Macleod, 1978; Drees & Wilding, 1973; Beckett & Webster, 1971; McCormack & Wilding, 1969), foliar nutrient comparisons are often more reliable

measures of fertility (Armson, 1977). Thus, foliar nutrient comparisons between individuals of the same species and similar ages, growing in the same location on similar soil materials are used to assess fertility.

The research aims to improve reforestation efforts by examining the relative effectiveness of site preparation techniques in minimizing noncrop forest vegetation for improved conifer succession. From this, more effective, efficient and less costly reforestation and stand tending in future applications could occur, increasing the potential for conifer seedling survival, quality and growth. The research will also provide a basic inventory of forest vegetation nutrient status, and soil and site characteristics influenced by various silvicultural practices. Since undesired hardwood and shrub growth affect other land uses, the research has application in areas other than forest management.

A list of abbreviations and symbols used in the following chapters is included for the reader's convenience (Appendix 2.0).

2.0 BACKGROUND INFORMATION

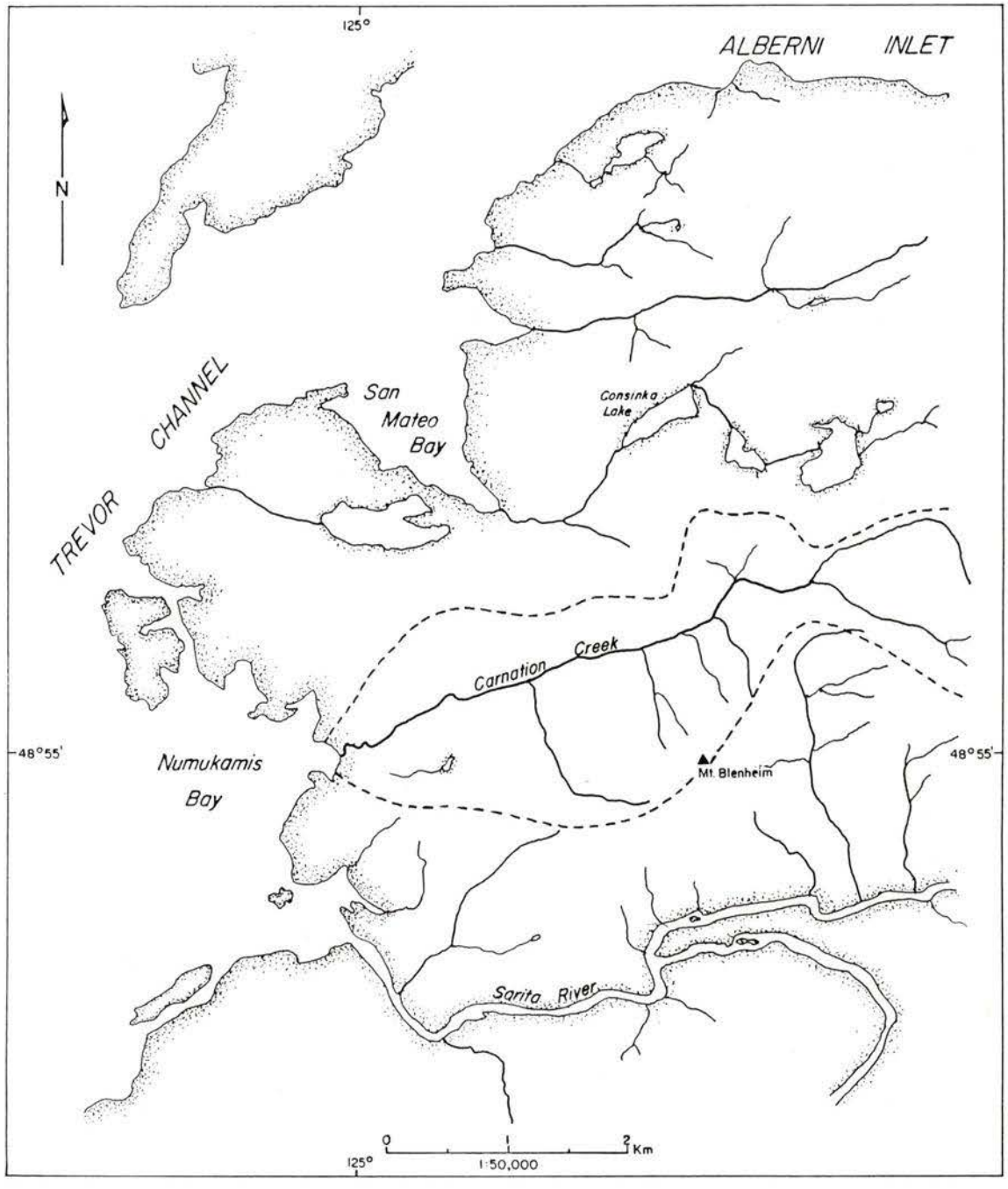
2.1 STUDY SETTING

Carnation Creek, located north of the Sarita River (Figure 2.0), drains a watershed approximately 1000 ha. The creek flows westward for about 6 km into Trevor Channel of Barkley Sound on the west coast of Vancouver Island. The watershed is characterized by heavy rainfall (260-350 cm/yr) and dense coniferous forest. It is situated in the CWH b_1 biogeoclimatic variant (wetter, submontane, windward) (Klinka et al., 1979).

2.1.1 Species Composition

Prior to logging, the watershed was characterized by old-growth western hemlock (Tsuga heterophylla (Raf.) Sarg.) - amabilis fir (Abies amabilis (Dougl.) Forbes) - western red cedar (Thuja plicata Donn.) forest on steep hills; some Douglas fir (Pseudotsuga menziesii (Mirbel) Franco.) on the drier south-facing slopes; scattered white pine (Pinus monticola Doug.) around Mt. Blenheim (Figure 2.0), and sitka spruce (Picea sitchensis (Bong.) Carr.) in the valley bottom. Red alder (Alnus rubra Bong.) and broadleaf maple (Acer macrophyllum Pursh) constituted a significant proportion of the tree species along the creek (Oswald, 1973). These five plant community types occur along a

FIGURE 2.0 Map showing location of Carnation Creek Watershed, Vancouver Island.



gradient of site moisture regimes resulting from variation in elevation and topography (Oswald, 1973). Preharvest vegetation research in the watershed was conducted exclusively by Oswald (1973).

2.1.2 Soil Characteristics

Soils in the Carnation Creek watershed were mapped by Oswald (1973) on the basis of topographic features that affect soil moisture and drainage. The mapping units were complexes of soil series, each complex possessing a similar aspect, landform, gross slope and position in relation to surrounding topography. In general, all the soils examined had medium to coarse texture, ranging from gravelly loam to loamy sand, although some had a silt loam or clay loam surface horizon. The soils along the valley bottom were underlain by small gravels and pure sand. Variability in soils was attributed to microtopography. No glacial till was found in the surveyed area, although it does occur in areas adjacent to the watershed (Oswald, 1973).

Soils were strongly acid, acidity generally decreasing slightly with depth. Most soils had a moderately high water holding capacity, the exceptions being those with low contents of both clay and organic matter. Most soils were considered to be Ferro-Humic Podzols; organic soils were classified as Lithic Mesisols; and soils associated with the creek channel were mostly Cumulic Regosols. Preharvest

soils research in the watershed was conducted exclusively by Oswald (1973).

2.1.3. Logging History

Logging and related road construction in the Carnation Creek Watershed were performed by MacMillan Bloedel Ltd (MB) under the tree farm license (TFL) system which is regulated by the B.C. Forest SErvice. A six-year logging operation began in 1975 according to a plan proposed by MB (Cameron Division), and approved by members of the task force engaged in studying the effects of forest harvesting on salmonid fish populations (MB, 1979). Logging settings are identified in Figure 3.0.

Prior to logging, to discourage regeneration of alder after logging, seed alders along the stream in two settings that had been clearcut to the streambank (sections RR8 and 640B) were killed by notching the base of the tree with an axe, followed by squirting the herbicide picloram into the cut ("hack and squirt" treatment). Treatment took place in the spring of 1975, six months prior to the start of logging, and extended about 16 m upstream and downstream past the limit of the opening. In 1978, the streambank in opening 864-4 was similarly treated (Figure 3.0).

In general, the logging plan and harvesting methods followed normal west coast practices for timber removal with the exception of two settings. In settings RR8 and 640B,

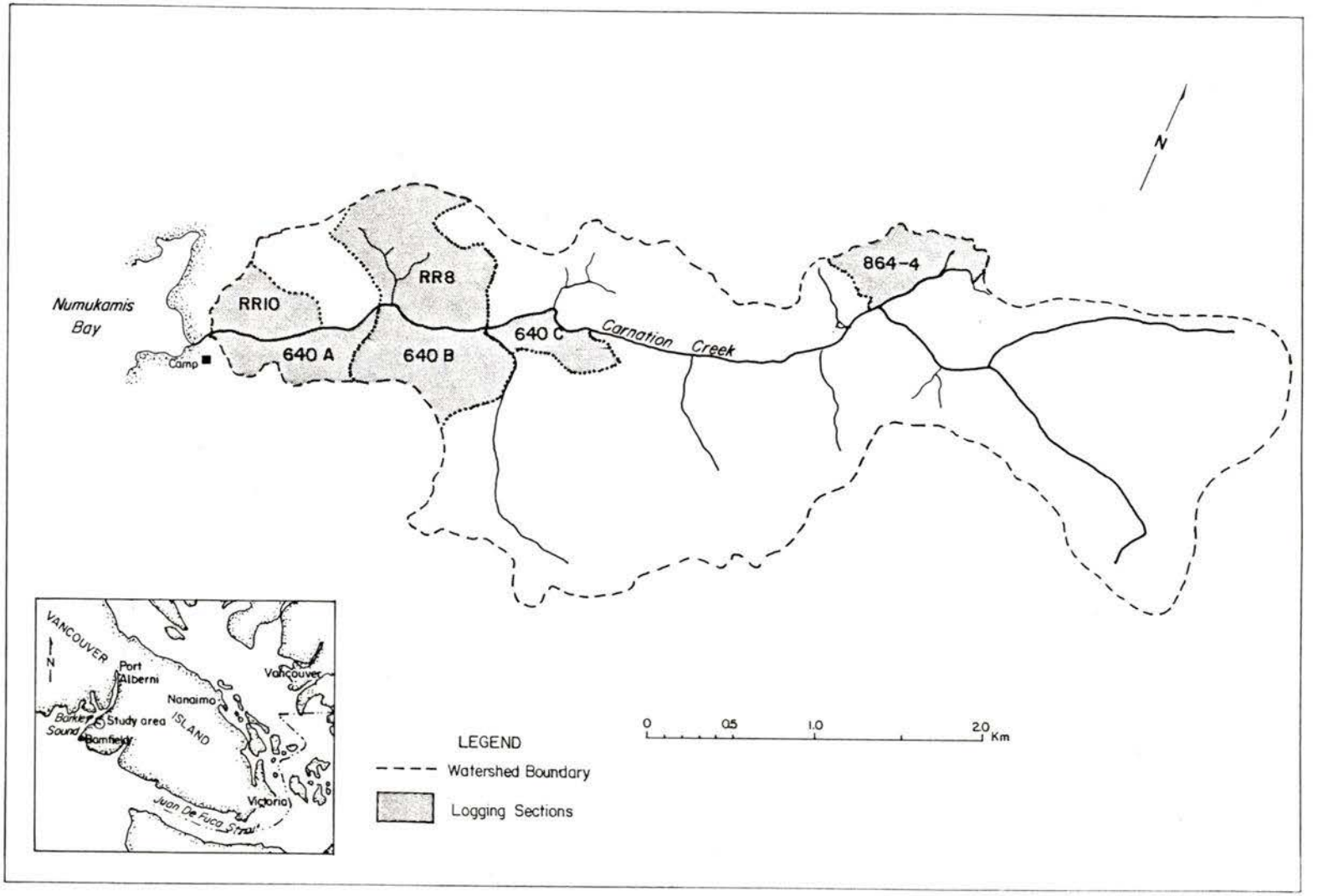


FIGURE 3.0 Map of Carnation Creek Watershed showing mainstem and tributaries and the location of logging settings; inset shows location of Carnation Creek on Vancouver Island.

all streamside trees were removed for a specifically requested "severer than normal" treatment (MB, 1979). By completion of the six-year operation, approximately 41% of the watershed had been logged (MB, 1979).

In recognition of the provincial standard that 750 trees/ha of acceptable species be established within three years of harvest on the coast (Pearse et al., 1986a), MB performed site preparation in the fall, according to recommendations made by their divisional forester. Harvested settings were normally left undisturbed through the summer.

To encourage growth of harvestable trees after logging, areas were scarified and/or burned to expose the mineral soil, to remove heavy slash, and to reduce competition and shading from fast-growing species of low commercial value (e.g. alder and salmonberry). For satisfactory conifer regeneration, brush control or fire protection, the sites were burned by hand, helicopter Aerial Ignition Dispenser (A.I.D.) or by drop torch in the fall. For broadcast burning, slopes were ignited starting from the top and usually burned well with the exception of north-facing slopes. The valley bottom was often too wet to burn satisfactorily. Scarification of these valley bottom sites and burning of piled debris was a more effective method under these conditions, resulting in exposed mineral soils also conducive to alder growth.

Reforestation was the responsibility of the forest company either through hand-planting or by natural means, as governed by the B.C. Forest Service. Species selection for planting followed guidelines suggested by Klinka (1977). When necessary for satisfactory regeneration, selected bottomlands and sidehills were planted with conifers in the following spring, to get trees well established before brush became a serious problem. In setting RR10, 100% of the area was planted with sitka spruce, western red cedar and western hemlock. In RR8, 24% of the area, mostly on the creek floodplain, was planted with western red cedar, Douglas fir, western hemlock, grand fir and sitka spruce. In 640B, 13% of the area, exclusively on the floodplain, was planted with sitka spruce and western red cedar. The upper slopes of RR8 were planted with Douglas fir. Logging and reforestation activities in the watershed are summarized in Table 2.0.

In September of 1984, the herbicide glyphosate was aerially applied (2 kg active ingredient/ha) to lower sections of the watershed as part of an efficacy study using glyphosate and the Microfoil boom applicator. Results of that study are forthcoming (Reynolds, pers.comm.[1]). Glyphosate control and treated plots are delineated in each setting (Figure 4.0). Herbicide treatment in the watershed was intended as a means of brush control to improve crop tree survival and in some cases, to allow crop tree release.

[1]Reynolds, P. 1987. Project leader, Weed Control Program, CFS, Forest Pest Management Institute, Saulte Ste.Marie,Ont.

TABLE 2.0 Inventory of clearcuts and reforestation in Carnation Creek Watershed (MB, 1979).

Setting	Size (ha)	Date Cut	Treatment	Planted
RR10	23.5	10/75-03/76	09/76 H.B.	02/77-4.9 ha spruce & cedar
				Spring 78 - 21 ha (incl. 1.2 ha replant of 1977 plantation) spruce, cedar, D.fir, hemlock
				03/79 - replant 5.7 ha hemlock
RR8	61.0	10/76-01/77	09/77 H.B. (70% burn)	Spring 78 - 14.6 ha cedar, D.fir, grand fir, hemlock, spruce
				Spring 79 - 46.4 ha D.fir
640-A	19.4	10/78-03/79	04/79 B.S.	
640-B	34.4	10/76-01/77	09/77 H.B. (Failure)	Spring 77 - 4.9 ha(floodplain) spruce & cedar
			09/78 burn	Spring 78 - 3.2 ha (Landings) replant with spruce
640-C	13.0	10/78	04/79 B.S.	
864-4	48.2 (+ 8.5 ha outside of watershed)	11/77-04/78	04/79 M.B. (60% burn)	03/79 - 2.4 ha (bottomland) cedar, amabilis fir

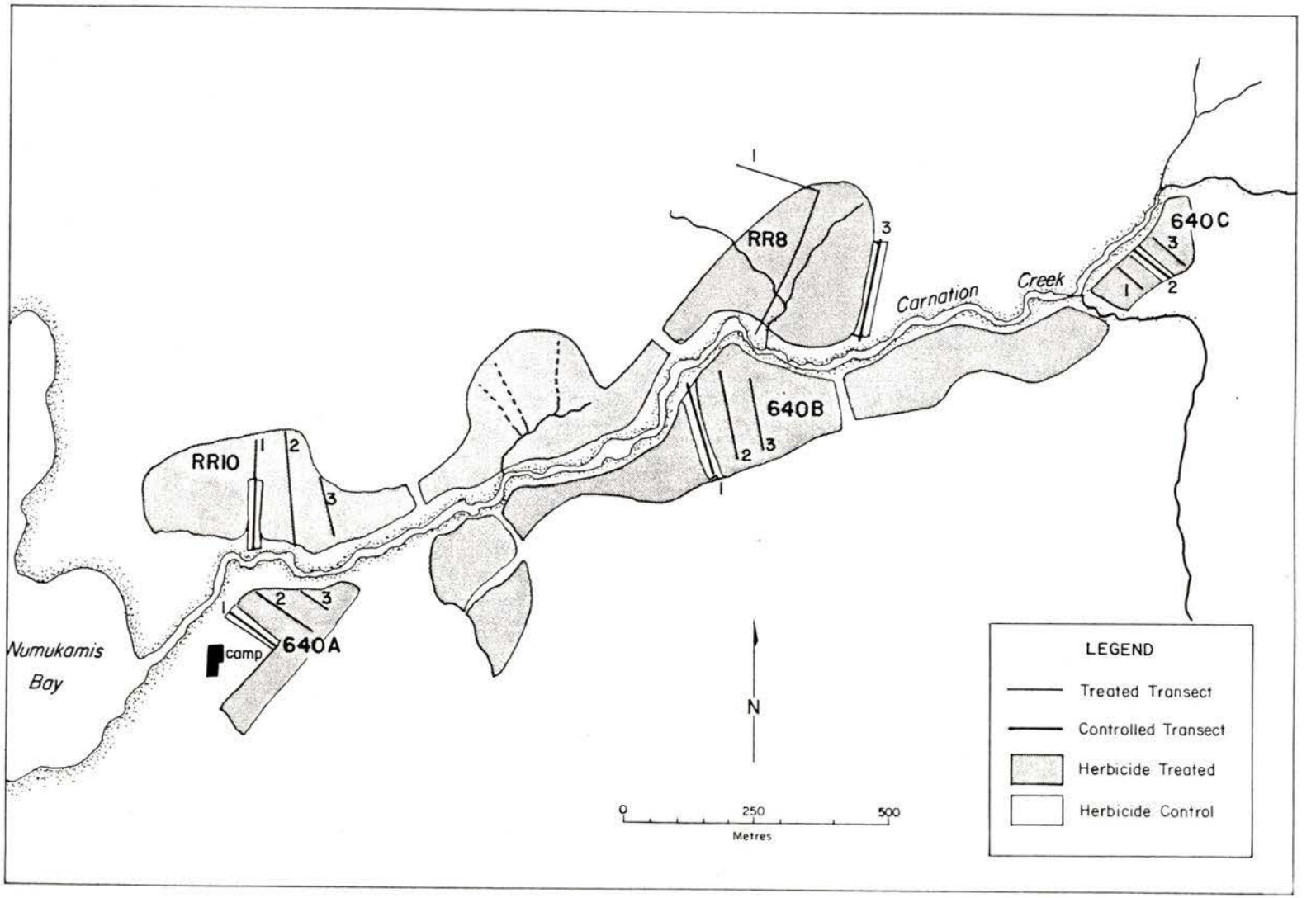


FIGURE 4.0 Map showing glyphosate control and treated transects in five logging settings, Carnation Creek Watershed.

2.2 WORK DONE TO DATE BY THE CANADIAN FORESTRY SERVICE

In 1972, the CFS at the Pacific Forestry Center in Victoria implemented a study to monitor recolonization by vegetation following logging, scarification and burning activities in the Carnation Creek Watershed. To date, a total of 260 permanent plots have been established along preselected cross-sectional transects in 11 settings that were logged and burned for slash removal (King & Oswald, 1983). The number, length and arrangement of transects that were established was dependent on the size, shape and topography of each setting. The overall objective was to establish sufficient transects to cover the range of conditions present, and to provide a sufficient number of plots in each setting for statistical analysis.

Most logging settings have one dominant aspect, but topographical variations occur in each setting (King & Oswald, 1983). Consequently, the extent and intensity of burning were not uniform, but depended on the amount and size of slash, moisture conditions, presence of living vegetation and various conditions that were not evenly distributed (King & Oswald, 1983).

Depending on the setting size, variability and length of each transect, the plot centers were located at either 30 or 50 m intervals. A sample plot design was adopted which occupies 16 m^2 around each center point (King & Oswald, 1983). Each plot was divided into 4 m^2 quadrats. For sampling herbaceous vegetation, subplots of 1 m^2 were located in the outer corner of each quadrat. Metal posts were used as permanent markers and were painted and flagged to facilitate relocation in subsequent years.

Vegetation assessments were scheduled to occur in years 1, 2, 3, 5, 10 and 15 following the last disturbance. For example, plots established in 1978 have been sampled in 1978, 1979, 1980 and 1982; their tenth year of assessment occurred in 1987. Monitoring vegetation is expected to continue through 1990 as follows:

Year	Setting	Sampling Years
1978	RR10*	1978, 1979, 1980, 1982, 1987, 1992
	RR8*	1978, 1979, 1980, 1982, 1987, 1992
1979	864-4	1979, 1980, 1981, 1983, 1988, 1993
1980	640A*	1980, 1981, 1982, 1984, 1989, 1994
	640B*	1980, 1981, 1982, 1984, 1989, 1994
	640C*	1980, 1981, 1982, 1984, 1989, 1994

* Preherbicide sampling conducted before September, 1984. Foliar glyphosate application - September, 1984. Post-glyphosate sampling to be conducted in the years indicated, in addition to the regular vegetation assessments: 1985, 1986, 1987, 1989, 1994 and 1999.

The CFS has assessed regeneration and general vegetation for species abundance. In addition, regeneration species have been identified, counted, measured for height (cm) if eligible. Total vegetative cover and cover for each of the four canopy types (tree, shrub, forb and moss) have been estimated for each 2 m^2 quadrat as well. In each quadrat, individual species have been assessed for cover (%), vigor (0 = dead, 1 = moribund, 2 = poor, 3 = moderate, 4 = good) and height (cm) where height is recorded in a corresponding height class (Table 3.0). The Carnation Creek species list appears in Appendix 3.0.

Site conditions were inventoried by quadrat at the time of plot establishment. Characteristics that were sampled include aspect, slope(%), elevation (m), burn season (if burned), burn extent and intensity, moisture regime, surface shape of local terrain, slope position (e.g. upper slope, valley floor), slope position moisture (e.g. shedding, receiving) and placement (e.g. skid road, swamp) (Table 4.0). Thus, with the exception of elevation and slope, site conditions have been measured on a nominal scale. Subsequent site assessments referring to a particular quadrat have been recorded in the vegetation field assessment form under "Comments", complementing the vegetation record for that sample (Table 3.0).

TABLE 3.0

CARNATION CREEK VEGETATION AND REGENERATION DATA

UNIT NUMBER:_____ TRANSECT:____ PLOT:____ QUADRANT:____

NAME:_____ DATE:__ /__ /__

COMMENTS: (QUAD 4 ONLY)

_____

_____

_____

REGENERATION	count	avg.hgt	avg.diam.	shortest	tallest
HEMLOCK	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
CEDAR, RED	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
FIR (AMABILIS	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
FIR (DOUGLAS)	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
OTHER	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
OTHER	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _
SEEDLINGS	_ _ _ _	_ _._ _	_ _._	_._ _	_ _._ _

% TOTAL COVER:_____TREES:____SHRUBS:____FORBS:____MOSS:_____

		HEIGHT (CM)						
SPECIES	COVER	0-8	9-15	16-30	31-60	61-120	121-200	200+
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7
_ _	_ _	1	2	3	4	5	6	7

TABLE 4.0

CARNATION CREEK PRE-SAMPLING PLOT, QUADRANT SITE CONDITION DATA ENTRY FORM

UNIT NUMBER:_ _ _ _ _ TRANSECT:__ PLOT:_ _ QUADRANT:__

DATE:__ /__ /__ ASPECT:_ _ SLOPE%:_ _ ELEVATION:_ _ _ _

LOGGED:__ /__

QUADRANT TREATMENT: BURNED 1 SPRING 1 FALL 2
UNBURNED 2

FIRE INTENSITY: LOW 1 MEDIUM 2 HIGH 3

SLOPE POSITION MOISTURE:
1 SHEDDING 2 NORMAL 3 RECEIVING 4 COLLECTING 5 SEEPAGE

MOISTURE REGIME:
1 HYDRIC 2 HYGRIC 3 MESIC 4 XERIC

SLOPE POSITION:
1 APEX 3 UPPER SLOP 5 LOWER SLOPE
2 FACE 4 MIDDLE SLOP 6 VALLEY FLOOR 7 PLAIN

SURFACE SHAPE:
1 SMOOTH CONVEX 4 IRREGULAR STRAIGHT 7 SMOOTH FLAT
2 IRREGULAR CONVEX 5 SMOOTH CONCAVE 8 IRREGULAR FLAT
3 SMOOTH STRAIGHT 6 IRREGULAR CONCAVE

PLACEMENT:
1 SKID ROAD 3 SLASH 5 MINERAL 7 ORGANIC
2 SWAMP 4 ROCK 6 DUFF 8 OTHER

COMMENTS:

The study has limited utility in that preharvest vegetation was not inventoried at the plot or quadrat level; the intensity and extent of burning and scarification were either not documented or were classified as opposed to being quantified more specifically; the extent and efficacy of preharvest alder seed tree control were not recorded; and subsequent glyphosate treatment did not accommodate previous treatment delineations since the initial study objectives were not intended to assess glyphosate efficacy on regeneration and noncrop species.

3.0 MATERIALS AND METHODS

3.1 INTRODUCTION

Methods of investigation employed in this study are organized by job description with subsections detailing specific components of each job and materials used. Sampling strategies, data collection and methodologies involving laboratory and statistical analyses are reported. Data collection and laboratory analyses have been done cooperatively with the CFS and MB, respectively.

3.2 SAMPLING STRATEGY

For this study, six of the eleven logging settings were selected for examination on the basis of comparable treatment combinations and collective site histories, and minimal apparent variability in biotic and abiotic attributes. Each setting contains three transects and a variable number of plots (Figure 3.0).

Sampling employed a stratified-random design nested within the CFS's stratified-systematic plot layout. The latter stratification is based on logging settings; the former stratification is based on silvicultural treatment, dominant and codominant vegetation, and site characteristics. Using this complex design, nine different treatment areas containing essentially homogeneous plot groupings were obtained. Treatment groups with a minimum of

5 plots (20 quadrats) per group are designated in Table 5.0. Since treatment intensity was not measured quantitatively at the time of application, only treatment type could be used to differentiate the areas.

Three plots per treatment were randomly selected for soil sampling. This process was repeated for foliar sampling.

3.3 DATA COLLECTION STRATEGY

I carried out field sampling from June through November (1984-1986) in collaboration with the CFS. Vegetation data collection followed the revegetation sampling schedule described by King & Oswald (1983) (refer to Section 2.2). Foliage collection employed Ballard's (1980) guidelines. Soils were sampled using standard extraction methods that had been demonstrated by Dr. E.T. Oswald and Mr. J. Senyk (CFS - PFC), and Mr. W. Beese (Woodlands Services, MB) during a presampling reconnaissance of the watershed.

The number and type of laboratory analyses being conducted limited the number of samples that were collected for analysis. In 1985, soil sampling was emphasized over foliar sampling. In 1986, foliar sampling was conducted exclusively.

TABLE 5.0. LIST OF SAMPLING UNITS BY TREATMENT GROUP

TREATMENT SITE	UNIT	TRANSECT	PLOT	QUADS (No.)	YRS SAMPLED	CASES (No.)
(BH)						
Burn	RR8	1	6,7,8,9	16	4	64
& Herbicide		3	7,8	8	4	32
			n = 6	24		96
(C2)						
Control 2	RR10	1	1,2,3	12	4	48
		2	1,2,3	12	4	48
		3	1,5,6,7	16	4	64
			n = 10	40		160
(BS)						
Burn	640A	1	1,2,4	12	3	36
& Scarify	640B	1	1,5	8	3	24
	640C	2	2	4	3	12
			n = 6	24		72
(S)						
Scarify	640B	1	2,3,4,6,7	20	3	60
	640C	2	1,3,4,5	16	3	48
			n = 9	36		108
(HS)						
Herbicide	640A	3	3	4	3	12
& Scarify	640B	2	1,2,6,7	16	3	48
		3	1,3,6,7	16	3	48
	640C	3	1,4	8	3	24
			n = 11	44		132
(H)						
Herbicide	RR8	1	1,2,3,4,5	20	4	80
			n = 5	20		80

TABLE 5.0 cont'd

TREATMENT SITE	UNIT	TRANSECT	PLOT	QUADS (No.)	YRS SAMPLED	CASES (No.)
(BHS)						
Burn	640A	1	6	4	3	12
Herbicide		2	1,2,3,4,5	20	3	60
& Scarify		3	1,2,4	12	3	36
	640B	2	3,4,5	12	3	36
		3	2,4,5	12	3	36
	640C	1	1,2,3,4	16	3	48
		1	5,6,7	12	3	36
		3	2,3	8	3	24
			n = 24	96		288
(B)						
Burn	RR10	2	4,5	8	4	32
		3	2,3,4	12	4	48
			n = 5	20		80
(C1)						
Control 1	C864	1	1,2,3	12	4	48
		2	1,2,3	12	4	48
		3	1,2,3,4	16	4	64
			n = 10	40		160

Minimum Age = 5 years for all units sampled

RR10 & RR8 sampled: '82, '84, '85' '86 (Age = 5,7,8,9)
C864 sampled: '83, '84, '85, '86 (Age = 5,6,7,8)
640's sampled: '84, '85, '86 (Age = 5,6,7)

3.3.1 Soil Data

Soils were analyzed in the field for physical characteristics to a maximum depth of 1 m, to and including the C-horizon, to bedrock, or to the watertable. Soil pits were described by horizon for physical attributes such as structure, texture and organic content (Walmsley et al., 1980). For laboratory analyses, samples were extracted from at least three different faces of each horizon and composited by equal volume. Samples were air dried prior to further compositing by horizon for each treatment group.

Measures of coarse fragments were obtained from each air-dried sample prior to being ground to < 2 mm particle size using a Wiley-Mill (Standard No. 3). For each treatment site, soil samples (e.g. 3 sample sites per treatment) were subsequently composited by horizon on an equal weight basis. Use of compositing to reduce the inherent elemental variability in soils is supported by Courtin et al. (1983) and Lloyd & McKee (1983). Bulk density samples were also obtained from each sampling site using a soil auger. Three representative cores were extracted per sampling site, and their mean values were calculated per treatment site.

Thus, the number of samples representing each treatment site was dependent on the degree of soil zonation and soil depth.

3.3.2 Foliage Data

Foliage samples were collected over two field seasons- 1985 and 1986. In 1985, foliar sampling was intended to supplement the more intensive soil sampling, particularly in riparian areas where soil zonation was less developed. Alder, salmonberry and huckleberry were sampled in early to mid August, prior to leaf senescence. Hemlock was sampled in late November, during its dormant phase when seedlings are resistant to environmental stresses (Nelson & Lavender, 1976). Newly elongated shoots were randomly collected from the upper one-third of each plant. Foliage from three individuals per site in three randomly selected plots per treatment formed a composite sample, respectively.

Preliminary indication of nutrient variability in 1985 foliage led to greater emphasis being placed on foliar sampling in the subsequent season. In August (1986), alder, salmonberry, huckleberry and salal were sampled. Four replicate samples of three individuals per site were taken.

Foliage was oven dried (70° C) for approximately 18 hours. Samples from each site were ground to 20-mesh using a Wiley-Mill (Standard No.3) and then composited by equal weight for each respective species. Thus, four composite replicate samples per treatment site of each species' foliar nutrients were obtained.

Hemlock was not sampled in 1986 for several reasons:

1. Hemlock occurs irregularly within the treatment areas and would have required a separate sampling design to accommodate more intensive sampling;

2. planted and natural hemlock regeneration were not easily distinguishable; and

3. destructive sampling was not feasible on some hemlock seedlings due to size and/or form limitations.

Because salal is considered a major competitor of conifer seedlings in the Carnation Creek Watershed, investigation of this species was deemed more important.

Due to cost limitations in laboratory analysis, each species was not sampled from all nine treatment sites for 1986 nutrient determinations. Selection for nutrient determinations was based on each species' relative presence/absence in each site. Species were sampled from treatment sites as follows:

Species	Treatment Site	
	Reference	Description
Salal & Huckleberry	BH	Burn & Herbicide
	C2	Control 2
	H	Herbicide
	B	Burn
	C1	Control 1
Salmonberry	C2	Control 2
	BS	Burn & Scarify
	S	Scarify
	HS	Herbicide & Scarify
	H	Herbicide
	BHS	Burn, Herbicide & Scarify
	C1	Control 1
Alder	BS	Burn & Scarify
	S	Scarify
	HS	Herbicide & Scarify
	BHS	Burn, Herbicide & Scarify

3.4 METHODOLOGY

3.4.1 Laboratory Analyses

3.4.1.1 Soils

Soil analyses were conducted at MB's Woodlands Services laboratory in Nanaimo.

Laboratory analyses on the < 2 mm portion of soil samples included pH, nitrogen and organic matter content, cation exchange capacity (CEC), exchangeable cations and texture. The pH of samples was determined in both a 1:1 soil:water suspension and in a 1:2 soil:0.01 M $CaCl_2$ suspension (Black, 1982). Total N was determined colorimetrically by a Technicon Autoanalyzer II after 60-mesh samples were digested in H_2SO_4 and catalysts K_2SO_4, $CuSO_4$ and Se (Black, 1982). Organic carbon was determined using the Walkley-Black wet oxidation method (Black, 1982). Percent organic matter was calculated by multiplying % carbon by a correction factor of 1.724 (Black, 1982). Exchangeable cations were determined by atomic absorption spectrophotometry after extraction with CH_3COONH_4. Total exchange capacity was assessed by Autoanalyzer after extraction with KCl. Soil texture was determined on the mineral samples by hydrometer and wet sieving after the organic matter was destroyed by hydrogen peroxide, and oven-dry weights were assessed. All results on mineral samples are reported on air-dried weights (Appendix 4.0).

3.4.1.2 Foliage

Foliar analyses were conducted at MB's Woodlands Services laboratory in Nanaimo. Total nitrogen content was determined on foliage samples collected in 1985; total macro- and micronutrients (except boron and sulfur) were determined on samples collected in 1986. Foliage samples underwent a wet digestion in sulphuric acid and hydrogen peroxide. Nitrogen and phosphorus were determined on the Autoanalyzer II. Total elements K, Ca, Mg, Mn, Fe, Cu and Zn were determined by atomic absorption spectrophotometer (Ballard, 1981). Other results are reported on oven-dried weights (Appendix 5.0).

3.5 FLORISTIC DIVERSITY

While early community development is characterized by limitless diversity, later development is characterized by increasing competition expressed as a reduction in the number of plants in the stand (Harper, 1977). The vegetation itself affects and gradually changes the physiochemical factors of the habitat and favours the development of certain competitors at the expense of their neighbors (Whittaker, 1978).

Changes in a habitat's floristic diversity may be indicative of an alteration in its stability (Wilson & Bossert, 1971), or of environmental/physiological stress (Smith, 1980). The degree of floristic diversity is related

to habitat size and to the frequency of disturbance (Begon & Mortimer, 1981). The greater the number of species in a community, the smaller the role of dominant species (Whittaker, 1978). Conversely, the total number of species in a community may be low due to the restriction of invading plants by the strong competitive capacity of various dominant species (Whittaker, 1978).

Given these basic relationships between floristic diversity and habitat, the following equation is used to generate an index of floristic diversity based on site attributes that will enable an examination of floristic variability among the sites (Chapter 4.0):

$$FD_{ij} = \sum_{k=1}^{s} \frac{(OCC_k)_{ij}}{QUADS_{ij}} \qquad \text{where}$$

FD_{ij} = the floristic diversity index for the jth category of the ith site attribute;
i = the ith site attribute ($i = 1, \ldots, 8$);
j = the jth category of an attribute ($j = 1, \ldots, m$);
m = the number of categories;
s = the number of possible species (see species list, Appendix 3.0);
OCC_k = the number of occurrences of kth species, and;
$QUADS_{ij}$ = the number of plots that have the jth category of the ith site attribute.

The resulting value is an expression of how successful a particular class of a site attribute (e.g. mesic moisture regime) is in supporting a diverse plant community. Higher values indicate greater floristic diversity (Wilson & Bossert, 1971; Oosting, 1956).

The floristic diversity measure also reflects the scale of each site attribute. Macrosite factors include aspect and elevation; mesosite factors include slope position, slope position moisture, moisture regime and slope angle; and microsite factors include surface shape and placement. This means that larger-scale attributes (e.g. aspect) will tend to yield higher diversities than smaller-scale attributes (e.g. placement). Similarly, poor sites with few species result in low floristic diversity values.

Mean floristic diversity based on each site attribute is plotted (Chapter 4.0) for each treatment site; cross tabulations are used (Chapter 4.0) to show predominant site attributes among the treatment sites. In this way, the nature of variability in site conditions and floristic diversity can be illustrated for the treatment areas.

3.6 STATISTICAL ANALYSES

Descriptive statistics, correlation, principal component analysis (PCA) and analysis of variance (ANOVA) are employed to reveal compositional patterns and variability within the data, and to examine treatment effect on vegetation and soils. It is assumed that samples have been collected randomly and consistently using the stratified-systematic / stratified-random complex sampling design. A large sample size and sample replication are assumed to approximate a multivariate normal sample

distribution with random error terms, homoscedasticity, minimal multicollinearity and minimal autocorrelation. Sample statistics are also assumed to be representative, precise, efficient and reliable measures (Zar, 1984).

3.6.1 Ordination

To address the first objective, namely identification and description of compositional patterns and variability in groups of plots, PCA is used. For a general discussion of ordination techniques, see Pielou (1984); Gauch (1982); Maarel (1979); and Whittaker & Gauch (1978).

PCA was chosen over other ordination techniques because it is a straightforward eigenanalysis exercise that is able to define complex relationships in simpler terms with the least possible distortion. Weighting, as in weighted averages, and endpoint selection, as in polar ordination, are not required, thus making PCA an objective ordination procedure. Also, PCA produces simultaneous species and sample ordination scores in one integrated analysis (Pielou, 1982). This permits the real pattern of the data (e.g. the related responses of groups of species to persistent features of the environment) to be visualized while suppressing noise (e.g. the unrelated sporadic responses of a few individual members of a few species to the environment with local and temporary effects) (Pielou, 1982).

Although PCA is considered to be the simplest of all ordination techniques (Pielou, 1984), the data ought to meet several assumptions. Principal components must have normal distributions and be uncorrelated. Specifically, the eigenvectors must be orthogonal, so that the components represent jointly perpendicular directions through the space of the original variables, and the principal component scores (direction cosines) are jointly uncorrelated. The first principal component has the largest variance of any unit-length linear combination of the observed variables; subsequent components show decreasing variances (Pielou, 1984).

For applications involving statistical testing of hypotheses, these assumptions should be met; for descriptive purposes, larger departures from ideal data structure are tolerable (Grieg-Smith, 1980). Field data rarely meet all of the requirements. Possible violations of the requirements in the data utilized here do not represent a problem since application of PCA is predominantly exploratory and descriptive in nature.

In this study, R-mode PCA (e.g. ordination by quadrats) is used to identify combinations of variables that account for the greatest variation in treatment sites and in floristic diversity. Principal components are computed from a Sums of Squares and Cross Products (SSCP) matrix with principal component scores standardized to unit variance.

In an evaluation of ordination techniques, Gauch (1982) indicates that centered and standardized PCA's are commonly used. Correlation matrices are also used to show if/where interactions occur between variables.

The Statistical Analysis System (SAS) Institute recommends that eigenvalues accounting for at least 5 % of the standardized variance be retained as significant. However, this criterion for retaining an eigenvalue and its corresponding eigenvector for detailed analysis is ignored. Instead, since a substantially larger proportion of variance is often explained by the first three eigenvalues and is therefore more practically significant, only the first, second and/or third principal components are plotted to simplify interpretation of the relationships quantified by their corresponding eigenvectors, and to illustrate the relative variability explained by their corresponding eigenvalues. Plotted components illustrate similarities and dissimilarities among treatment sites.

3.6.2 Analysis of Variance

To address the second objective, namely to examine treatment effect on the growth (e.g. % cover) of dominant competitors in relation to environmental conditions, factorial analysis of variance (ANOVA) with unequal replication is employed using a general linear model

procedure (Zar, 1984). Apparent differences in site and/or vegetation characteristics within a treatment site are accommodated by more intensive sampling (Table 5.0). Thus, a fixed model is employed on data in an unbalanced, randomized design. Primarily main effects are examined. ANOVA is used rather than the t-test because statistical inferences are to be made about multiple means (Zar, 1984).

In this study, ANOVA is used to determine if treatment, site age and site factors explain significant differences in foliar, soil and vegetation characteristics. For a general discussion of ANOVA applications refer to Tabachnick & Fidell (1983); Zar (1984); and Neter et al. (1983).

When ANOVA does not yield significant results and consistent intercorrelation of certain variables occurs, analysis of covariance (ANOCOVA) is employed to reduce the variance of the error terms and to increase the model's precision (SAS Inst., 1985; Zar, 1984; Neter et al., 1983). In addition, Tukey's studentized range test is used to detect which main-effect means are significantly different (Zar, 1984). This multiple range test was selected on the basis of its power and robustness, and for its recognition in the statistical community for multiple means comparison (Zar, 1984).

4.0 RESULTS

4.1 INTRODUCTION

Results are presented in three sections. The first section summarizes the variability in site attributes and in floristic diversity based on each site attribute, in the vegetative cover and foliar nutrients of each species, and in soil nutrients. Cross tabulations of site attributes, plots of mean floristic diversity and correlations between vegetative cover and nutrients are used for this purpose.

In the second section, results of R-mode PCA of site attributes and floristic diversity are reported. Plots of the first two components are used to graphically portray these results.

The third section describes ANOVA results (e.g. treatment effect) on soil and foliar nutrients, floristic diversity and vegetative cover. ANOVA tables appear in Appendices 7.1 to 14.5. Treatment site references are listed in Appendix 2.0.

4.2 DESCRIPTIVE STATISTICS

4.2.1 Site Conditions

Although aspect in treatment site BH is predominantly south-facing and in site B it is mostly west-facing, both sites have some quadrats facing southwest. In site C1,

aspect is mostly north- to northeast-facing although some quadrats occur on level ground. Like site C1, some quadrats in site HS have north aspect although most quadrats occur on level ground. In sites C2, BS, S, H and BHS the predominant aspect is level (Table 6.1).

The predominant slope among sites (excluding site BH) ranges from 0 - 15 % . In site BH, most quadrats occur on slopes ranging from 15 - 30 % (Table 6.1).

The predominant elevation among sites (excluding sites BH and C1) ranges from 0 - 40 m above sea level (ASL). In site BH, elevation ranges from 40-80 m (ASL) and in site C1, most quadrats occur at elevations ranging from 160 - 200 m (ASL) (Table 6.2).

Sites C2, BS, S, HS, H and BHS are situated in the valley floor. Sites BH, B and C1 occur in a lower slope position (Table 6.2).

Most sites have normal moisture conditions for their slope position. However, site H occupies a moisture-receiving position and site C1 tends toward a moisture-shedding position (Table 6.3).

With the exception of site H which has a hygric moisture regime, the predominant moisture regime among sites is mesic (Table 6.3).

Surface shape in sites BS, S, HS, H and BHS is irregular-flat. In sites BH, C2, B and C1, most surfaces have an irregular-straight shape (Table 6.4).

(1)

TABLE OF ASPECT BY TREATMENT SITE

ASPECT / TREATMENT SITE FREQUENCY	BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
LEVEL	0	20	20	28	24	16	96	4	12	220
NORTH	0	0	4	8	16	0	0	0	12	40
NORTHEAST	0	0	0	0	0	0	0	0	16	16
SOUTH	16	8	0	0	0	4	0	4	0	32
SOUTHWEST	8	8	0	0	0	0	0	4	0	20
WEST	0	5	0	0	0	0	0	9	0	12
TOTAL	24	40	24	36	40	20	96	20	40	340

(2)

TABLE OF SLOPE BY TREATMENT SITE

SLOPE (%) / TREATMENT SITE FREQUENCY	BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
0 - 14.9	4	24	20	28	24	20	96	16	12	244
15 - 29.9	12	12	4	0	4	0	0	4	8	44
30 - 44.9	8	4	0	0	8	0	0	0	8	28
45 - 59.9	0	0	0	8	4	0	0	0	4	16
75 - 89.9	0	0	0	0	0	0	0	0	8	8
TOTAL	24	40	24	36	40	20	96	20	40	340

TABLE 6.1 Cross tabulations of quadrat frequency for each category of site attribute (1) aspect and (2) slope among treatment sites.

(1)

TABLE OF ELEVATION BY TREATMENT SITE

ELEVATION (M) FREQUENCY	TREATMENT SITE BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
0 - 39.9	8	40	24	36	36	20	96	20	0	280
40 - 79.9	16	0	0	0	4	0	0	0	0	20
120-159.9	0	0	0	0	0	0	0	0	8	8
160-199.9	0	0	0	0	0	0	0	0	32	32
TOTAL	24	40	24	36	40	20	96	20	40	340

(2)

TABLE OF SLOPE POSITION BY TREATMENT SITE

SLOPE POSITION FREQUENCY	TREATMENT SITE BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
MIDDLE	0	16	0	0	0	0	0	4	12	32
LOWER	24	4	4	8	12	0	0	12	28	92
VALLEY	0	20	20	28	28	20	96	4	0	216
TOTAL	24	40	24	36	40	20	96	20	40	340

TABLE 6.2 Cross tabulations of quadrat frequency for each category of site attribute (1) elevation and (2) slope position among treatment sites.

(1) TABLE OF SLOPE POSITION MOISTURE BY TREATMENT SITE

SLOPE POSITION MOISTURE FREQUENCY	TREATMENT SITE BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
SHEDDING	0	0	0	0	0	0	0	0	17	17
NORMAL	20	22	24	29	40	2	96	15	16	264
RECEIVING	2	10	0	0	0	12	0	1	6	31
COLLECTING	0	8	0	7	0	6	0	3	1	25
SEEPAGE	2	0	0	0	0	0	0	1	0	3
TOTAL	24	40	24	36	40	20	96	20	40	340

(2) TABLE OF MOISTURE REGIME BY TREATMENT SITE

MOISTURE REGIME FREQUENCY	TREATMENT SITE BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
HYDRIC	0	0	0	4	0	0	0	0	1	5
HYGRIC	2	7	0	4	0	18	1	4	3	39
MESIC	22	33	24	28	40	2	95	14	32	290
XERIC	0	0	0	0	0	0	0	2	4	6
TOTAL	24	40	24	36	40	20	96	20	40	340

TABLE 6.3 Cross tabulations of quadrat frequency for each category of site attribute (1) slope position moisture and (2) moisture regime among treatment sites.

(1)

TABLE OF SURFACE SHAPE BY TREATMENT SITE

SURFACE SHAPE / TREATMENT SITE FREQUENCY	BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
IRREG. CONVEX	1	1	0	1	2	4	3	1	0	13
IRREG.STRAIGHT	18	16	4	5	9	0	6	11	29	98
SMOOTH CONCAVE	0	0	0	4	0	0	0	0	0	4
IRREG. CONCAVE	4	12	1	3	10	3	12	4	9	58
IRREG. FLAT	1	11	19	23	19	13	75	4	2	167
TOTAL	24	40	24	36	40	20	96	20	40	340

(2)

TABLE OF PLACEMENT BY TREATMENT SITE

PLACEMENT / TREATMENT SITE FREQUENCY	BH	C2	BS	S	HS	H	BHS	B	C1	TOTAL
SKID ROAD	0	0	0	0	0	0	0	1	0	1
SWAMP	0	0	0	0	0	9	1	3	1	14
SLASH	4	28	3	6	10	3	3	8	12	77
ROCK	0	0	1	4	0	0	0	0	5	10
MINERAL	4	0	15	12	22	1	43	1	1	99
DUFF	0	1	5	6	4	0	21	6	20	63
ORGANIC	16	8	0	8	3	7	26	1	1	70
OTHER	0	3	0	0	1	0	2	0	0	6
TOTAL	24	40	24	36	40	20	96	20	40	340

TABLE 6.4 Cross tabulations of quadrat frequency for each category of site attribute (1) surface shape and (2) placement among treatment sites.

Quadrats in sites BS, S, HS and BHS predominantly occur in mineral substrate. Sites C2 and B are slash-covered. Quadrats in site H have swampy/organic substrate. Like site H, some quadrats in site BH are covered with organic material. Site C1 is duff-covered (Table 6.4).

4.2.2 Floristic Diversity

Plots of mean floristic diversity are used to show differences in floristic diversity among treatment sites. Each plot represents the floristic diversity derived from each site attribute; the mean number of species ± 1 standard deviation are indicated (Figures 5.1 - 5.8).

Mean floristic diversity (FD) based on aspect is greatest in sites BS, S, HS and BHS (exceeding 12 species), followed by sites H, C2, B, BH and C1 (less than 6 species). It is least variable in site BH and most variable in site C2. Sites BS, S, HS and BHS show less variation in FD than sites C2, H, B and C1 (Figure 5.1).

Mean floristic diversity based on slope is greatest in sites S and HS (exceeding 13 species), followed by sites H, BHS, B, BS, C2, BH and C1 (approximately 7 species). It is most variable in sites S and HS and least variable in sites H and BHS (Figure 5.2).

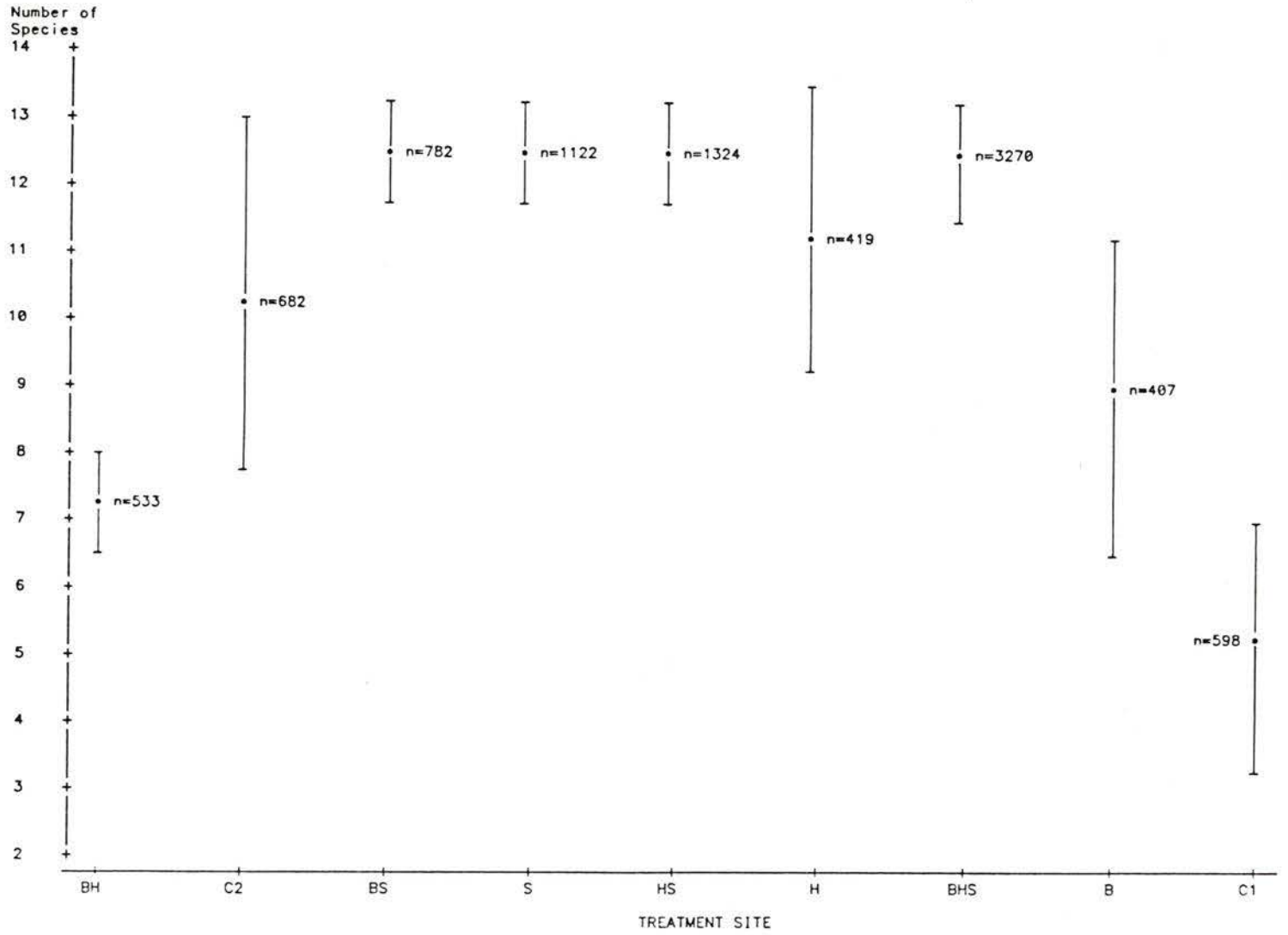


FIGURE 5.1 Plot of mean (*) floristic diversity based on aspect (± 1 standard deviation) among treatment sites. The number of species sampled (n) is indicated for each site.

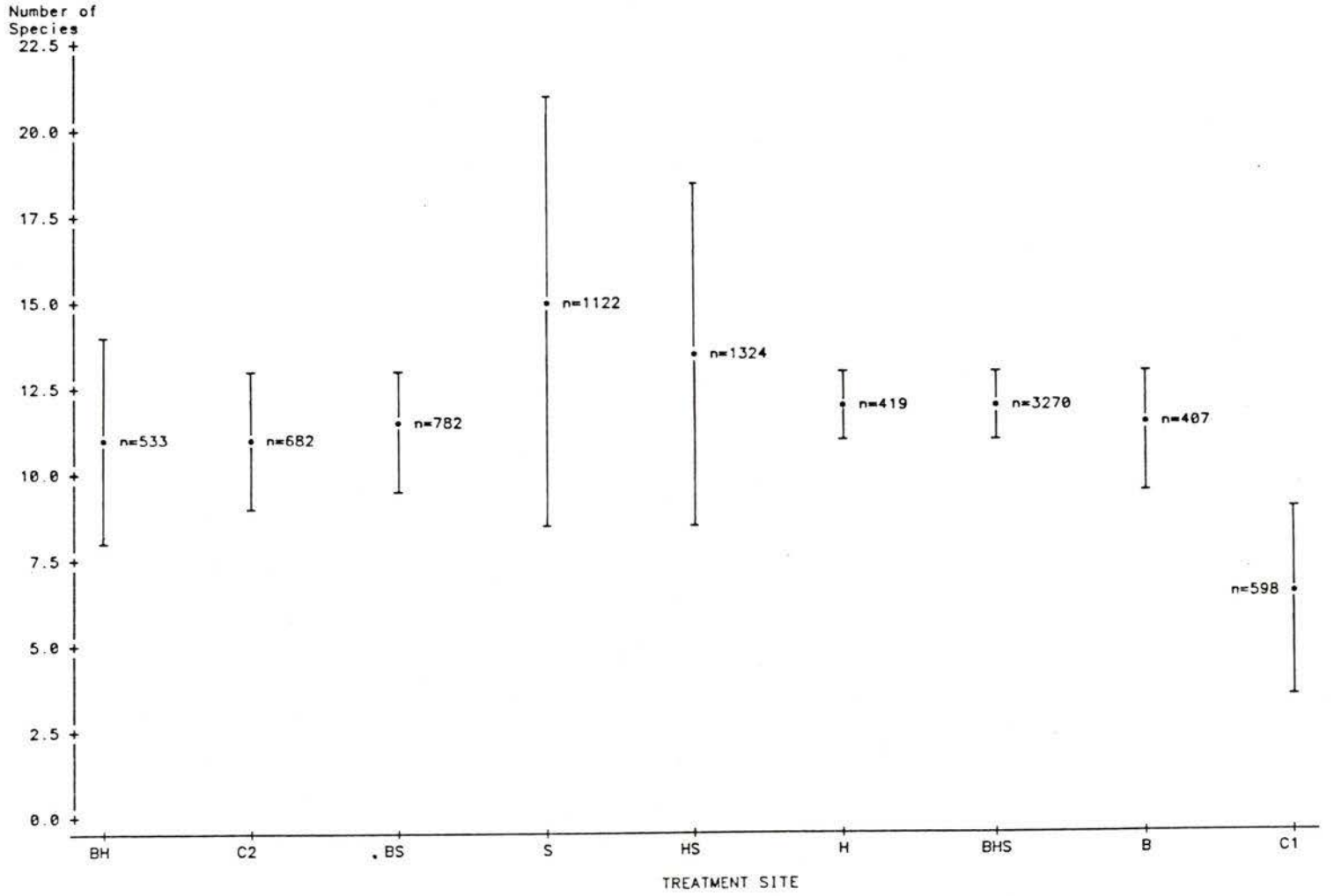


FIGURE 5.2 Plot of mean (*) floristic diversity based on slope (± 1 standard deviation) among treatment sites. The number of species sampled (n) is indicated for each site.

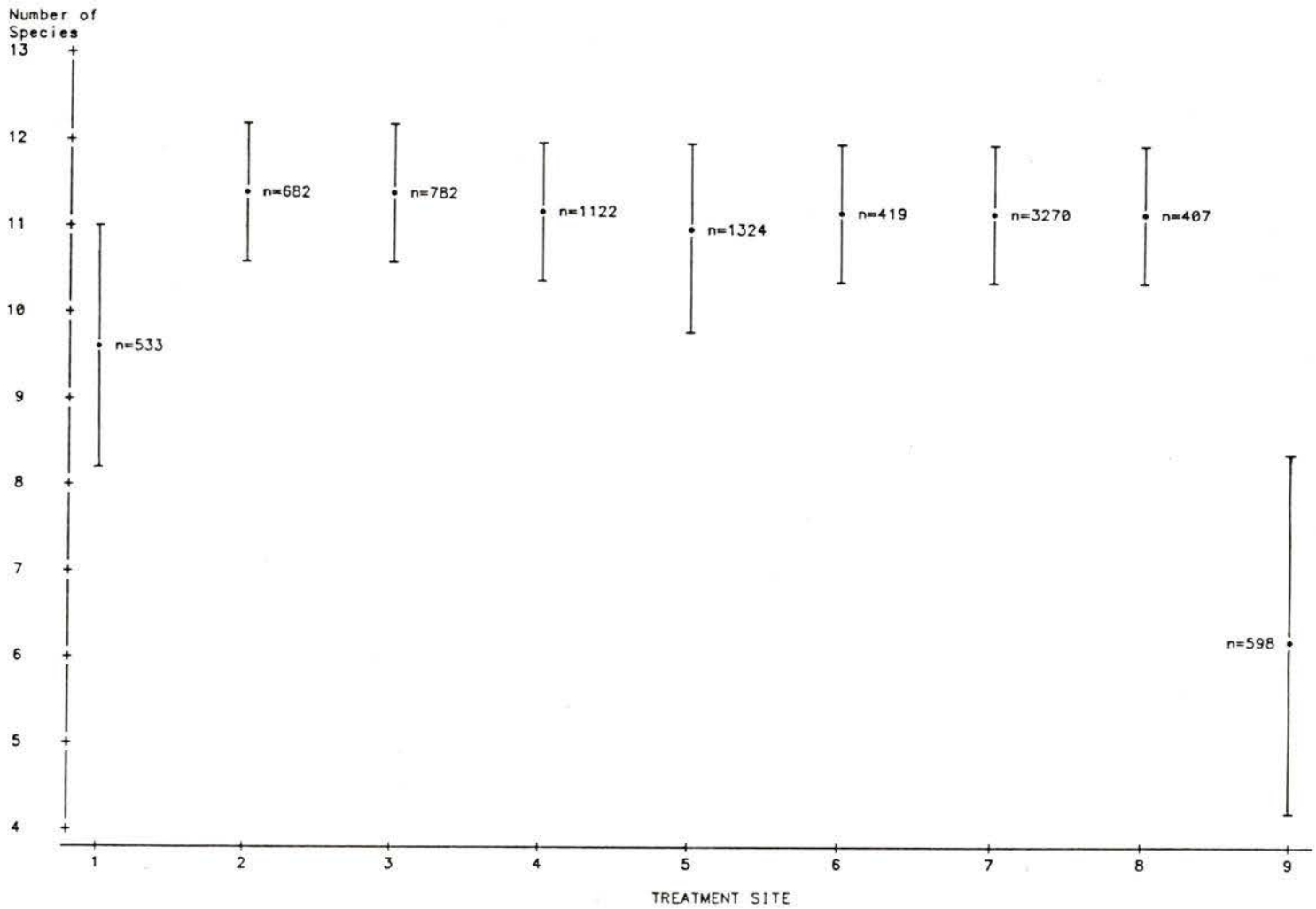


FIGURE 5.3 Plot of mean (*) floristic diversity based on elevation (± 1 standard deviation) among treatment sites. The number of species sampled (n) is indicated for each site.

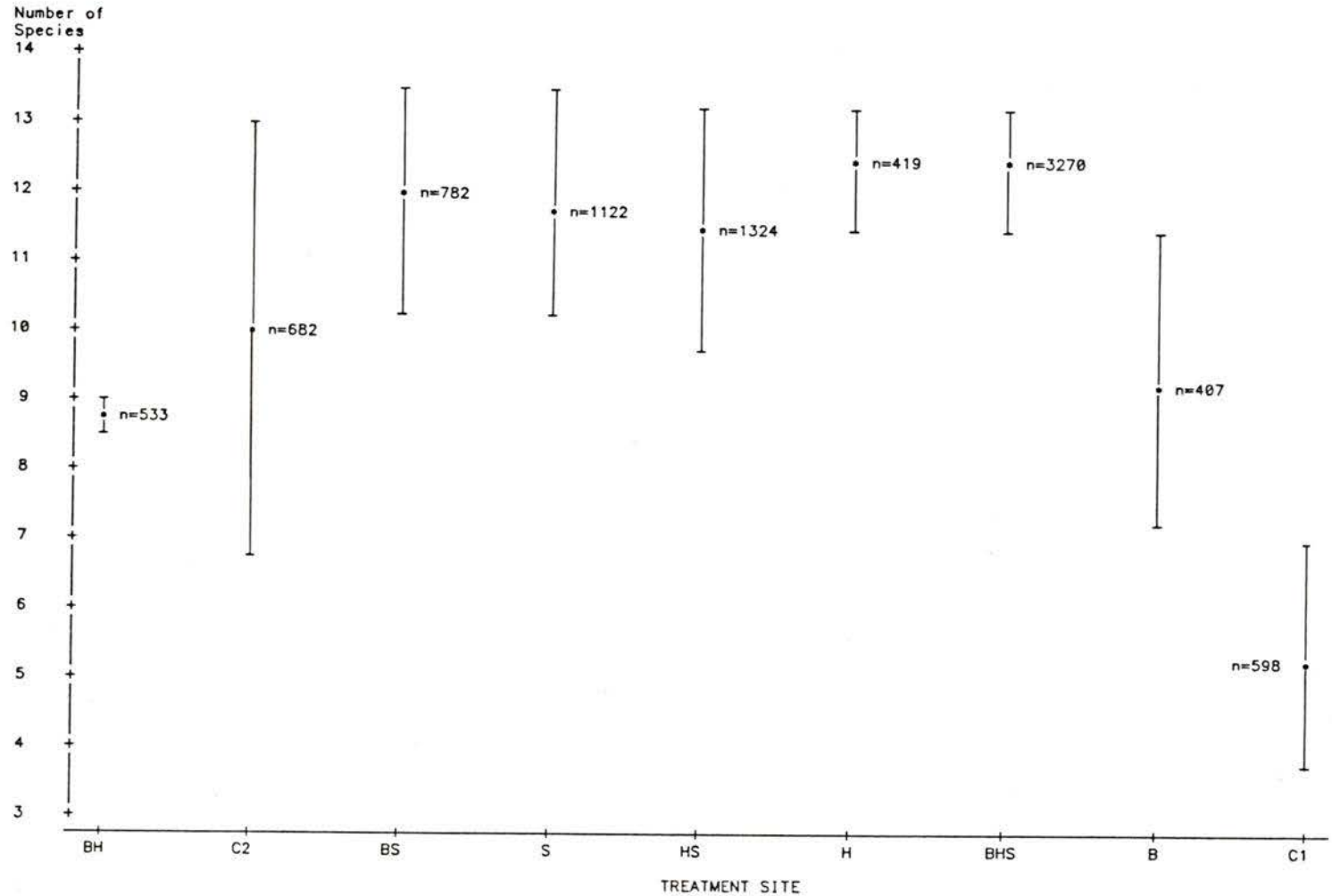


FIGURE 5.4 Plot of mean (*) floristic diversity based on slope position (± 1 standard deviation) among treatment sites. The number of species sampled (n) is also indicated for each site.

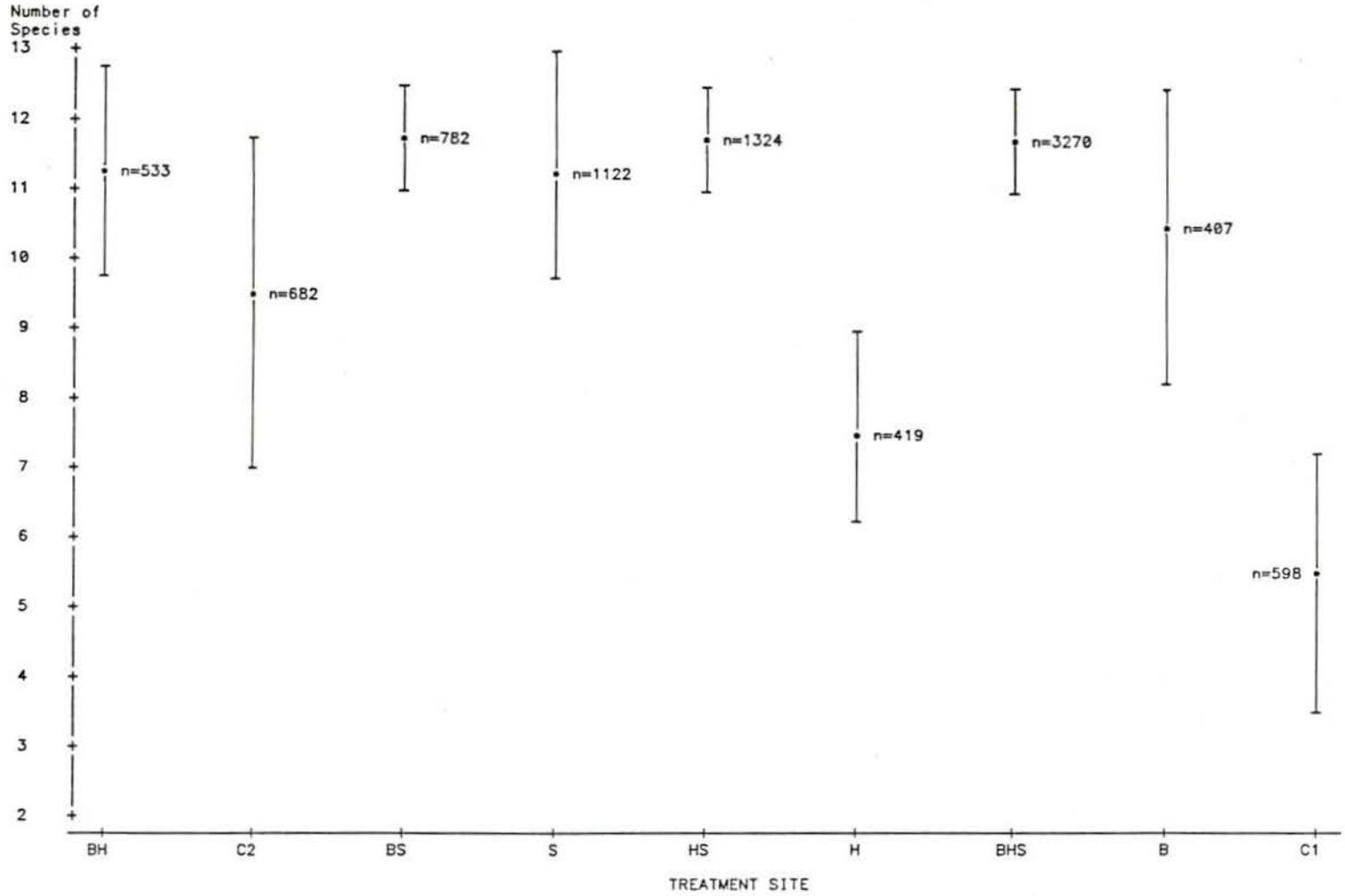


FIGURE 5.5 Plot of mean (*) floristic diversity based on slope position moisture (± 1 standard deviation) among treatment sites. The number of species sampled (n) is also indicated for each site.

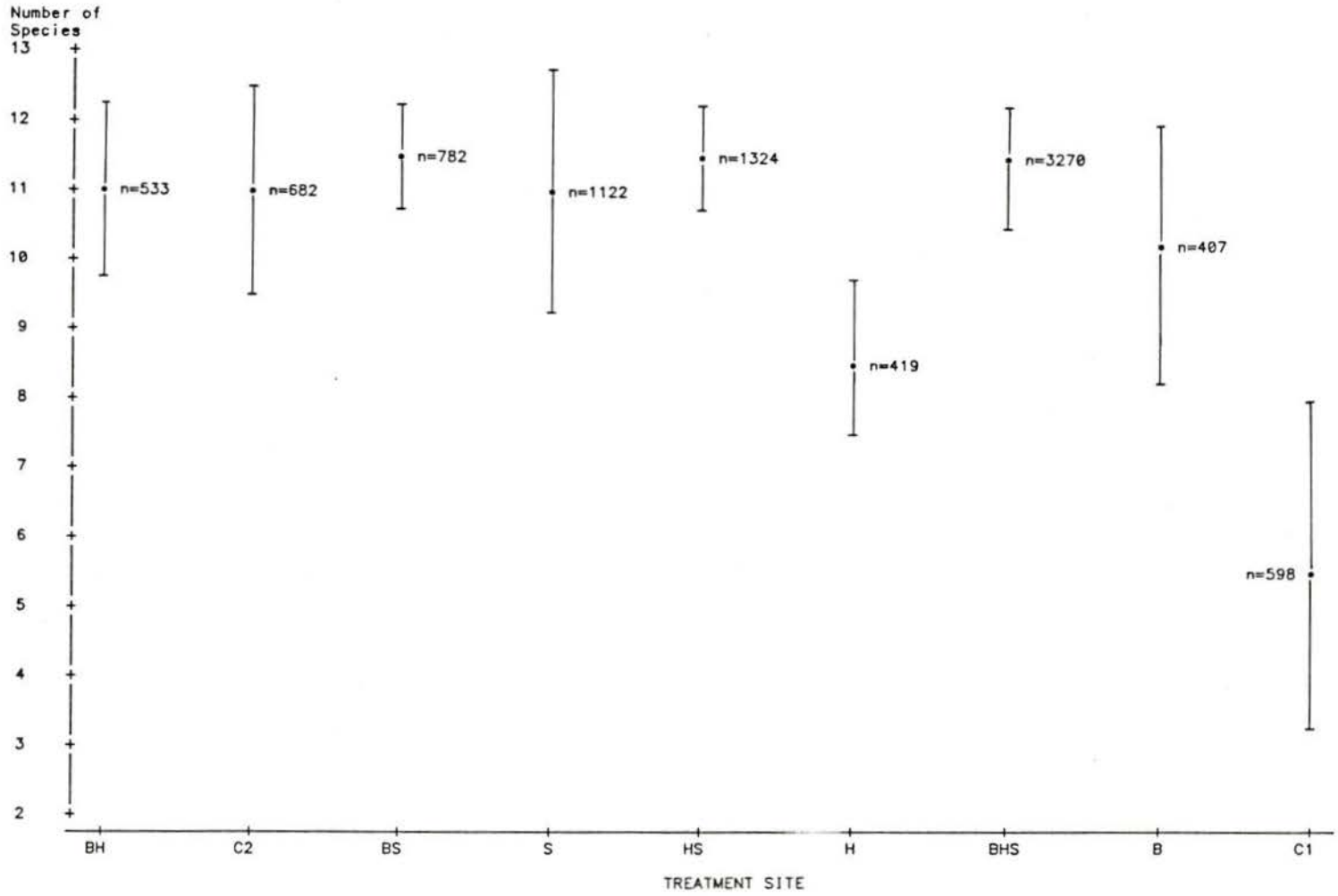


FIGURE 5.6 Plot of mean (*) floristic diversity based on moisture regime (± 1 standard deviation) among treatment sites. The number of species sampled (n) is also indicated for each site.

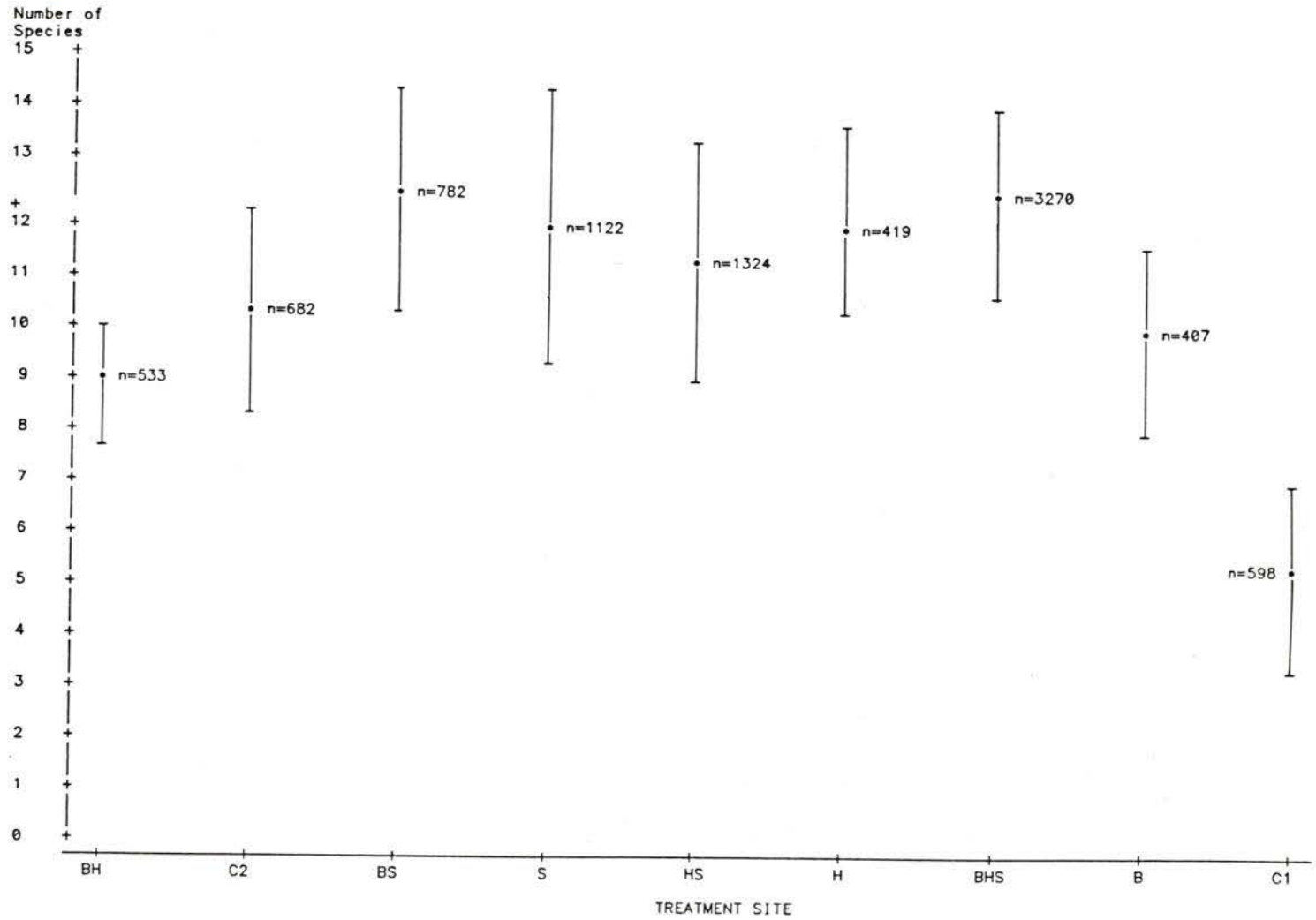


FIGURE 5.7 Plot of mean (*) floristic diversity based on surface shape (± 1 standard deviation) among treatment sites. The number of species sampled (n) is also indicated for each site.

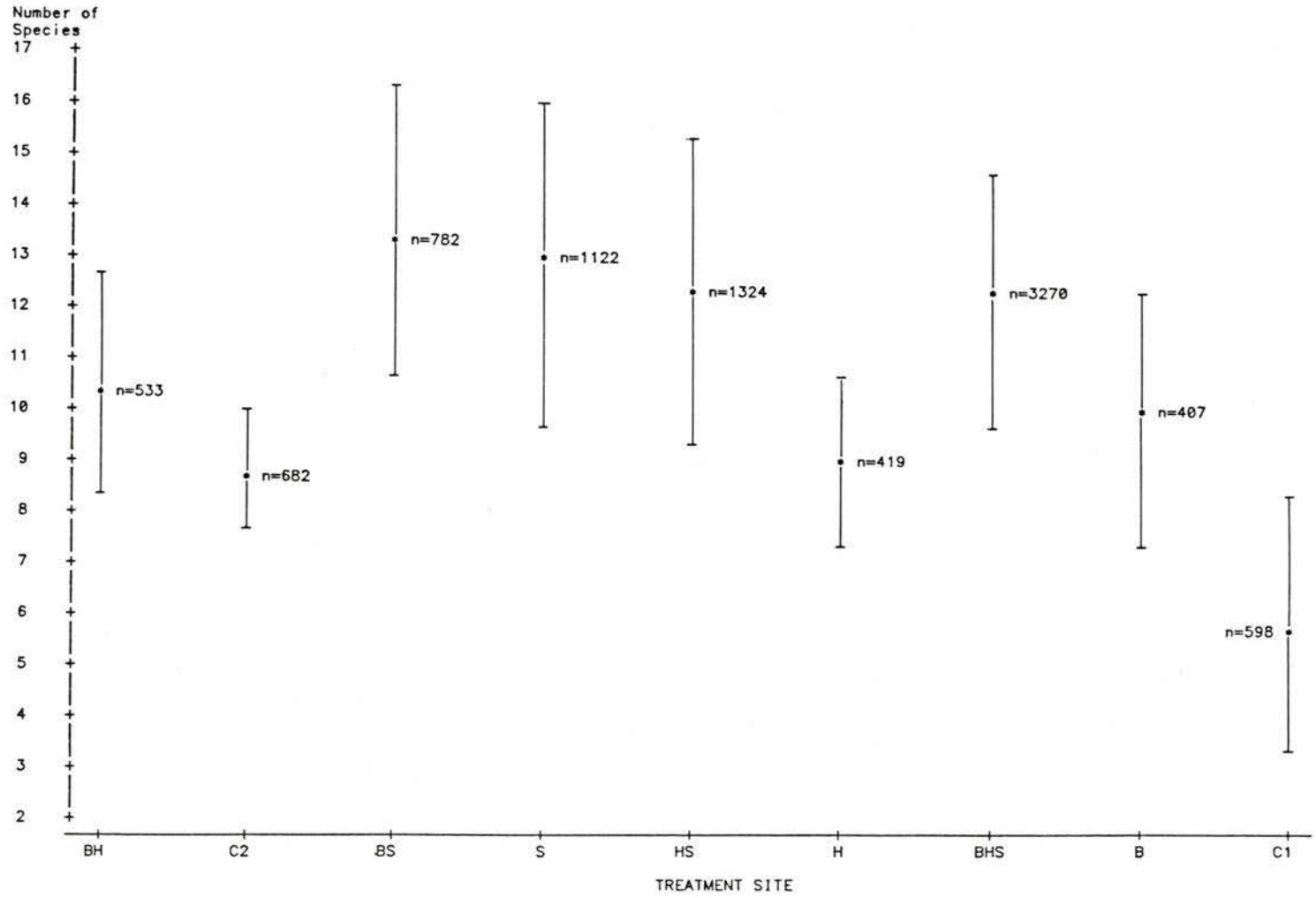


FIGURE 5.8 Plot of mean (*) floristic diversity based on placement (± 1 standard deviation) among treatment sites. The number of species sampled (n) is also indicated for each site.

Mean floristic diversity based on elevation is lowest and most variable in site C1 (less than 7 species). It is highest and generally less variable in sites C2, BS, S, HS, H, BHS and B (over 11 species) (Figure 5.3).

Mean floristic diversity based on slope position is higher and less variable in sites H and BHS (over 12 species), followed by sites BS, S and HS. Sites C2 and B have the greatest variation in FD in contrast to the least variation in site BH. Again, site C1 has the lowest mean FD (less than 6 species) (Figure 5.4).

Mean floristic diversity based on slope position moisture is greater and generally less variable in scarified sites (about 12 species), followed by sites BH and B (about 11 species), C2, H and C1 (less than 10 species). Greater variation in FD is found in site C2 (Figure 5.5).

Mean floristic diversity based on moisture regime is marginally higher and less variable in sites BS, HS and BHS (exceeding 11 species) than in sites BH, C2, S and B (with approximately 11 species). FD is lowest and most variable in site C1 (less than 6 species) (Figure 5.6).

Mean floristic diversity based on surface shape is higher in sites BS, S, HS, H and BHS (over 11 species) than in sites BH, C2, B and C1 in particular (less than 11 species). Variation in FD within these groups is similar (Figure 5.7).

Mean floristic diversity based on placement is similar to that based on surface shape. However, slightly less variation in FD occurs in sites BH, C2 and H (Figure 5.8).

Several conclusions can be drawn from an examination of the plots of floristic diversity and the cross tabulations of site attributes among treatment sites.

Sites with level aspect support a greater floristic diversity than sites with south, west and northeast aspect. Gently sloping sites (0-15%) tend to have greater floristic diversity than steep sites (75-90%), and sites occurring at elevations from 0-40 m have greater floristic diversity than those at higher elevations.

Sites occupying a valley floor position also tend to have greater floristic diversity than sites in lower and middle slope positions. Sites with normal slope position moisture tend to have greater numbers of species than sites with moisture-receiving or moisture-shedding conditions. With the exception of site C1, mesic sites have greater floristic diversity than hygric sites. Although considerable overlap in floristic diversity occurs between sites with irregular-straight surfaces and sites with irregular-flat surfaces, sites having the latter surface shape tend to also have greater floristic diversity. Sites having mineral placement tend to have greater numbers of species than swampy sites or sites covered with organic, slash or duff material (Figures 5.1-5.8 & Tables 6.1-6.4).

4.2.3 Vegetative Cover

Descriptive statistics are used to summarize the differences in vegetative cover of each species among treatment sites (Tables 7.1 - 7.5).

An examination of the summary statistics (Tables 7.1-7.5) shows that under conditions of extreme variability in cover, the standard deviation exceeds the mean. This occurs when a small portion of the sample attains 99% cover while most of the sample shows less than 10% cover. It can be verified by an examination of the range in cover and mean cover values for each treatment site.

To remedy this problem and reduce the variability in cover, only those sites which yield standard deviations lower than the mean are examined in subsequent analyses. These are listed for each species as follows (* indicates standard deviation < mean):

Treatment Site	Salmonberry	Alder	Salal	Huckleberry	Hemlock
BH	*	*	*	*	*
C2	*	*	*		*
BS	*	*	*		*
S	*	*	*	*	
HS			*		
H	*	*	*	*	*
BHS		*	*		
B			*	*	*
C1			*		

VARIABLE	Number of Observations	MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION
		SITE BH			
COVER (%)	44	14.06818182	1.00000000	35.00000000	10.07275332
		SITE C2			
COVER (%)	49	13.00000000	1.00000000	70.00000000	14.84362939
		SITE BS			
COVER (%)	16	5.31250000	1.00000000	20.00000000	5.37548447
		SITE S			
COVER (%)	13	5.84615385	1.00000000	10.00000000	3.80451823
		SITE HS			
COVER (%)	28	6.32142857	1.00000000	35.00000000	8.13339513
		SITE H			
COVER (%)	10	7.30000000	1.00000000	15.00000000	5.31350481
		SITE BHS			
COVER (%)	86	5.74418605	1.00000000	25.00000000	6.93530787
		SITE B			
COVER (%)	24	7.95833333	1.00000000	25.00000000	7.75426484
		SITE C1			
COVER (%)	35	10.42857143	1.00000000	40.00000000	10.41572825

TABLE 7.1 Summary statistics of huckleberry cover by treatment site.

VARIABLE	Number of Observations	MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION
			SITE BH		
COVER (%)	72	25.63888889	1.00000000	90.00000000	16.75448694
			SITE C2		
COVER (%)	79	48.05063291	1.00000000	99.00000000	42.78026706
			SITE BS		
COVER (%)	72	31.86111111	1.00000000	99.00000000	21.96495644
			SITE S		
COVER (%)	92	25.22826087	1.00000000	85.00000000	16.93562683
			SITE HS		
COVER (%)	146	16.22602740	1.00000000	99.00000000	19.30258891
			SITE H		
COVER (%)	64	40.43750000	1.00000000	99.00000000	33.56154025
			SITE BHS		
COVER (%)	338	12.97041420	1.00000000	85.00000000	14.22891528
			SITE B		
COVER (%)	75	12.05333333	1.00000000	85.00000000	18.15391651
			SITE C1		
COVER (%)	82	20.07317073	1.00000000	90.00000000	24.09230218

TABLE 7.2 Summary statistics of salmonberry cover by treatment site.

VARIABLE	Number of Observations	MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION
		SITE BH			
COVER (%)	57	32.49122807	1.00000000	85.00000000	20.93793789
		SITE C2			
COVER (%)	92	34.95652174	1.00000000	95.00000000	19.85104589
		SITE BS			
COVER (%)	21	12.80952381	1.00000000	35.00000000	10.00309476
		SITE S			
COVER (%)	5	6.20000000	1.00000000	10.00000000	4.38178046
		SITE HS			
COVER (%)	56	15.14285714	1.00000000	55.00000000	10.95350267
		SITE H			
COVER (%)	5	3.40000000	1.00000000	8.00000000	3.04959014
		SITE BHS			
COVER (%)	68	16.66176471	1.00000000	75.00000000	16.36579095
		SITE B			
COVER (%)	58	43.86206897	10.00000000	99.00000000	23.48381173
		SITE C1			
COVER (%)	6	4.16666667	1.00000000	10.00000000	3.86867764

TABLE 7.3 Summary statistics of salal cover by treatment site.

VARIABLE	Number of Observations	MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION
			SITE BH		
COVER (%)	3	2.66666667	1.00000000	5.00000000	2.08166600
			SITE C2		
COVER (%)	9	15.33333333	5.00000000	35.00000000	9.00000000
			SITE BS		
COVER (%)	65	47.47692308	1.00000000	99.00000000	32.47119285
			SITE S		
COVER (%)	63	44.28571429	1.00000000	99.00000000	35.64313650
			SITE HS		
COVER (%)	77	24.19480519	1.00000000	99.00000000	29.25839464
			SITE H		
COVER (%)	19	28.10526316	5.00000000	70.00000000	19.62678084
			SITE BHS		
COVER (%)	176	29.00000000	1.00000000	99.00000000	24.49466414
			SITE B		
COVER (%)	20	30.55000000	1.00000000	99.00000000	32.82725921

TABLE 7.4 Summary statistics of alder cover by treatment site.

VARIABLE	Number of Observations	MEAN	MINIMUM VALUE	MAXIMUM VALUE	STANDARD DEVIATION
			SITE BH		
COVER (%)	46	12.80434783	1.00000000	40.00000000	10.38079330
			SITE C2		
COVER (%)	43	12.41860465	1.00000000	45.00000000	10.36301243
			SITE BS		
COVER (%)	44	11.75000000	1.00000000	35.00000000	10.82659301
			SITE S		
COVER (%)	59	5.79661017	1.00000000	25.00000000	6.70763759
			SITE HS		
COVER (%)	76	5.68421053	1.00000000	35.00000000	7.38324324
			SITE H		
COVER (%)	4	19.75000000	1.00000000	35.00000000	14.31491064
			SITE BHS		
COVER (%)	238	13.42436975	1.00000000	95.00000000	15.02770138
			SITE B		
COVER (%)	24	5.37500000	1.00000000	15.00000000	4.81675066
			SITE C1		
COVER (%)	23	10.78260870	1.00000000	45.00000000	12.61657107

TABLE 7.5 Summary statistics of hemlock cover by treatment site.

4.2.3.1 Huckleberry

Mean huckleberry cover is highest (10-14%) in treatment sites BH, C2 and C1, respectively decreasing in cover; sites H and B, with approximately 8 % cover, have more huckleberry cover than sites S, BS, HS and BHS, with approximately 6% cover. Huckleberry cover is less variable in site S and highly variable in treatment sites HS, BS and BHS (Table 7.1).

4.2.3.2 Salmonberry

Mean salmonberry cover is highest in treatment site C2 (cover>40%), followed by site H (40%), BS (approximately 30%), BH and S (both with about 25%), C1 (approximately 20%) and HS (approximately 15%). Sites B and BHS are lowest in mean salmonberry cover (approximately 10%). Salmonberry cover is less variable in treatment site BH and highly variable in sites C1, B, HS and BHS (Table 7.2).

4.2.3.3 Salal

Mean salal cover exceeds 40% in treatment site B. It is followed by sites BH and C2 with 30-35% cover. Treatment sites BS, HS and BHS have about 15% cover, and sites C1, S and H have about 5% mean cover. Salal cover is less variable in treatment site B and more variable in treatments C1 and BHS (Table 7.3).

4.2.3.4 Alder

Mean alder cover is at least 45% in treatment sites BS and S; in site BH it is less than 5%; and in treatment site C1 is it absent. Treatment C2 has 15% mean cover, and in sites H, HS, B and BHS it increases respectively, from 25-30%. Alder cover is less variable in site C2 and highly variable in sites B and HS (Table 7.4).

4.2.3.5 Hemlock

Mean hemlock cover reaches 20% in treatment site H. However, this may be a result of the small sample size representing this site. In sites BHS, BH, C2, BS and C1, hemlock cover decreases respectively, within a range of 10-13% cover; and in treatment sites B, S and HS, mean cover does not exceed 6%. Hemlock cover is less variable in sites H and highly variable in treatment sites C1, S, HS and BHS in particular, where it attains 95% cover (Table 7.5).

4.2.4 Soils

Descriptive statistics of the soil data summarize the variation in soil characteristics among treatment sites (Tables 8.1, 8.2 and 8.3).

PROPERTY	Number of Samples	MEAN	STANDARD DEVIATION	STD ERROR OF MEAN	MINIMUM VALUE	MAXIMUM VALUE	C.V.
			SITE BH				
PH_H20	2	4.25000000	0.63639610	0.45000000	3.80000000	4.70000000	14.974
PHCACL	2	3.70000000	0.70710678	0.50000000	3.20000000	4.20000000	19.111
O_M_	2	43.50000000	47.80041841	33.80000000	9.70000000	77.30000000	109.886
N	2	0.72000000	0.69296465	0.49000000	0.23000000	1.21000000	96.245
CA	2	7.36000000	8.98025612	6.35000000	1.01000000	13.71000000	122.014
MG	2	5.54000000	7.36805266	5.21000000	0.33000000	10.75000000	132.997
K	2	0.82500000	0.94045202	0.66500000	0.16000000	1.49000000	113.994
NA	2	0.34000000	0.33941125	0.24000000	0.10000000	0.58000000	99.827
			SITE C2				
PH_H20	3	4.60000000	0.45825757	0.26457513	4.10000000	5.00000000	9.962
PHCACL	3	4.13333333	0.45092498	0.26034166	3.70000000	4.60000000	10.909
O_M_	3	26.60000000	20.32805943	11.73641058	3.20000000	39.90000000	76.421
N	3	0.35000000	0.30265492	0.17473790	0.11000000	0.60000000	86.473
CA	3	6.48000000	4.89968366	2.82883368	0.95000000	10.28000000	75.612
MG	3	1.95333333	1.52529779	0.88063109	0.36000000	3.40000000	78.087
K	3	0.22333333	0.21197484	0.12238373	0.03000000	0.45000000	94.914
NA	3	0.21333333	0.16165808	0.09333333	0.04000000	0.36000000	75.777
			SITE BS				
PH_H20	4	4.42500000	0.61846584	0.30923292	3.60000000	4.90000000	13.977
PHCACL	4	4.00000000	0.69761498	0.34880749	3.10000000	4.60000000	17.440
O_M_	4	29.20000000	35.54490118	17.77245059	2.60000000	81.20000000	121.729
N	4	0.57250000	0.55132416	0.27566208	0.06000000	1.31000000	96.301
CA	4	6.10000000	5.58566618	2.79283309	0.04000000	11.43000000	91.568
MG	4	2.69500000	3.36181003	1.68090501	0.05000000	7.60000000	124.742
K	4	0.23775000	0.25586504	0.12793252	0.00100000	0.60000000	107.619
NA	4	0.13000000	0.09486833	0.04743416	0.05000000	0.26000000	72.976

LEGEND: PH_H20 = pH determined in water ; PHCACL = pH determined in calcium chloride ; O_M_ = organic matter ; N = nitrogen ; CA = calcium ; MG = magnesium ; K = potassium ; NA = sodium.

TABLE 8.1 Summary statistics of soil properties by treatment site.

PROPERTY	Number of Samples	MEAN	STANDARD DEVIATION	STD ERROR OF MEAN	MINIMUM VALUE	MAXIMUM VALUE	C.V.
			SITE S				
PH_H20	3	4.80000000	0.50000000	0.28867513	4.30000000	5.30000000	10.417
PHCACL	3	4.30000000	0.36055513	0.20816660	3.90000000	4.60000000	8.385
O_M_	3	17.70000000	16.05988792	9.27218061	6.50000000	36.10000000	90.734
N	3	0.32666667	0.29091809	0.16796164	0.05000000	0.63000000	89.057
CA	3	4.01666667	2.94051583	1.69770760	1.46000000	7.23000000	73.208
MG	3	1.19333333	1.30293259	0.75224848	0.25000000	2.68000000	109.184
K	3	0.22666667	0.15534907	0.08969083	0.10000000	0.40000000	68.536
NA	3	0.42000000	0.59101607	0.34122329	0.03000000	1.10000000	140.718
			SITE HS				
PH_H20	1	4.40000000	.	.	4.40000000	4.40000000	.
PHCACL	1	4.30000000	.	.	4.30000000	4.30000000	.
O_M_	1	11.40000000	.	.	11.40000000	11.40000000	.
N	1	0.31000000	.	.	0.31000000	0.31000000	.
CA	1	0.36000000	.	.	0.36000000	0.36000000	.
MG	1	0.13000000	.	.	0.13000000	0.13000000	.
K	1	0.05000000	.	.	0.05000000	0.05000000	.
NA	1	0.08000000	.	.	0.08000000	0.08000000	.
			SITE H				
PH_H20	2	4.75000000	0.35355339	0.25000000	4.50000000	5.00000000	7.443
PHCACL	2	4.55000000	0.07071068	0.05000000	4.50000000	4.60000000	1.554
O_M_	2	29.20000000	13.43502884	9.50000000	19.70000000	38.70000000	46.010
N	2	0.79500000	0.28991378	0.20500000	0.59000000	1.00000000	36.467
CA	2	10.55500000	9.68029183	6.84500000	3.71000000	17.40000000	91.713
MG	2	2.20000000	1.90918831	1.35000000	0.85000000	3.55000000	86.781
K	2	0.25500000	0.17677670	0.12500000	0.13000000	0.38000000	69.324
NA	2	0.15000000	0.04242641	0.03000000	0.12000000	0.18000000	28.284

LEGEND: PH_H20 = pH determined in water ; PHCACL = pH determined in calcium chloride ; O_M_ = organic matter ; N = nitrogen ; CA = calcium ; MG = magnesium ; K = potassium ; NA = sodium.

TABLE 8.2 Summary statistics of soil properties by treatment site (cont'd).

PROPERTY	Number of Samples	MEAN	STANDARD DEVIATION	STD ERROR OF MEAN	MINIMUM VALUE	MAXIMUM VALUE	C.V.
			SITE BHS				
PH_H20	2	4.50000000	0.14142136	0.10000000	4.40000000	4.60000000	3.143
PHCACL	2	4.20000000	0.14142136	0.10000000	4.10000000	4.30000000	3.367
O_M_	2	14.20000000	9.75807358	6.90000000	7.30000000	21.10000000	68.719
N	2	0.38000000	0.24041631	0.17000000	0.21000000	0.55000000	63.267
CA	2	3.42500000	3.30218867	2.33500000	1.09000000	5.76000000	96.414
MG	2	0.70500000	0.67175144	0.47500000	0.23000000	1.18000000	95.284
K	2	0.13500000	0.14849242	0.10500000	0.03000000	0.24000000	109.994
NA	2	0.13000000	0.08485281	0.06000000	0.07000000	0.19000000	65.271
			SITE B				
PH_H20	2	4.65000000	0.49497475	0.35000000	4.30000000	5.00000000	10.645
PHCACL	2	4.25000000	0.49497475	0.35000000	3.90000000	4.60000000	11.646
O_M_	2	62.10000000	28.56711396	20.20000000	41.90000000	82.30000000	46.002
N	2	0.60000000	0.29698485	0.21000000	0.39000000	0.81000000	49.497
CA	2	3.96000000	4.27092496	3.02000000	0.94000000	6.98000000	107.852
MG	2	1.33000000	1.41421356	1.00000000	0.33000000	2.33000000	106.332
K	2	0.12500000	0.10606602	0.07500000	0.05000000	0.20000000	84.853
NA	2	0.19000000	0.12727922	0.09000000	0.10000000	0.28000000	66.989
			SITE C1				
PH_H20	2	4.55000000	0.49497475	0.35000000	4.20000000	4.90000000	10.879
PHCACL	2	4.05000000	0.49497475	0.35000000	3.70000000	4.40000000	12.222
O_M_	2	38.75000000	20.85965005	14.75000000	24.00000000	53.50000000	53.831
N	2	0.56500000	0.44547727	0.31500000	0.25000000	0.88000000	78.846
CA	2	3.57000000	3.01227489	2.13000000	1.44000000	5.70000000	84.377
MG	2	2.99500000	3.83958982	2.71500000	0.28000000	5.71000000	128.200
K	2	1.28000000	1.76776695	1.25000000	0.03000000	2.53000000	138.107
NA	2	0.23500000	0.19091883	0.13500000	0.10000000	0.37000000	81.242

LEGEND: PH_H20 = pH determined in water ; PHCACL = pH determined in calcium chloride ; O_M_ = organic matter ; N = nitrogen ; CA = calcium ; MG = magnesium ; K = potassium ; NA = sodium.

TABLE 8.3 Summary statistics of soil properties by treatment site (cont'd).

4.2.4.1 pH (H_2O)

Although mean pH (H_2O) is higher in treatment sites S and H (pH>4.5), and lower in sites BH, BS, HS and BHS (pH<4.5), it does not vary greatly. It is more variable in sites BS (coefficient of variation (C.V.) >12.0) and less variable in site BHS (C.V.<3.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.2 pH ($CaCl_2$)

Mean pH ($CaCl_2$) shows similar results. It is higher in site H (pH>4.5) and lower in sites BH and BS (pH<4.0). Other sites are comparable in pH ($CaCl_2$). It is less variable in sites H and BHS (C.V.<4.5) and more variable in site BS (C.V.>15.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.3 Organic matter

Mean organic matter (O.M.) content in site B (62.1%) particularly, and in sites BH and C1 (O.M.>35%) is substantially greater than that in sites S, HS and BHS (O.M.<20%). Sites BS, H and C2 are comparable in organic matter content (approximately 28%). It is less variable in site B (C.V.<35.0) and more variable in site BS (C.V.>110.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.4 N

Treatment sites BH and H in particular, and also sites BS, B and C1 have substantially high mean N content (N>.50)

than sites C2, S, HS and BHS (N<.40). N content is less variable in site H (C.V.<30.0) and more variable in site BS (C.V.>85.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.5 CEC

Mean CEC is greater in site BH (95.3 me/100g). Sites C2, BS, H, B and C1 have higher mean CEC (CEC>65 me/100g) than sites S, HS and BHS (CEC<50 me/100g). Like N, CEC is less variable in site H (C.V.<22.0) and more variable in site BS (C.V.>80.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.6 Ca

Treatment site H contains substantially more Ca than other sites (10.55 me/100g), particularly site HS with minimal Ca (0.36 me/100g). Sites S, BHS, B and C1 contain somewhat lower quantities of Ca (Ca<4 me/100g) than sites BH, C2 and BS (Ca>6 me/100g). Ca content is more variable in site BH (C.V.>90.0) and less variable in site C1 (C.V.<65.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.7 Mg

Mean Mg content in site BH is substantially greater than in other treatment sites (5.54 me/100g). Sites C2, BS, H and C1, nevertheless, have somewhat higher Mg contents (Mg>1.9 me/100g) than sites BHS, B and HS, is particular (Mg<1.5 me/100g). Mg content is more variable in site BS

(C.V.>115.0) and less variable in sites C2 and H (C.V.<75.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.8 K

Mean K content in site C1 in particular (1.28 me/100g) and in site BH (0.825 me/100g) is substantially greater than that in other treatment sites, especially site HS (0.05 me/100g). K content is more variable in site C1 (C.V.>100.0) and less variable in site H (C.V.<57.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.9 Na

Mean Na content is substantially higher in site S (0.42 me/100g) and also in site BH (0.34 me/100g), particularly over site HS (0.08 me/100g). Sites C2, B and C1 have slightly greater mean Na content (Na>0.19 me/100g) than sites BS, H and BHS (Na<0.15 me/100g). Na content is less variable in site H (C.V.<25.0) and more variable in site S (C.V.>125.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.10 Sand

Mean sand content is greatest in sites S (34.88%) and BHS (45.55%), and lowest in site H (8.25%). It is absent from site B. Sites BH, C2, BS and HS contain more sand (sand>20%) than site C1 (17.95%). Sand content is less

variable in site BHS (C.V.<35.0) and more variable in site C2 (C.V.>150.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.11 Silt

Mean silt content is higher in sites HS, H and BHS (silt>35%). It is absent from site B. Treatment sites C2 and S contain less silt (silt<12%) than sites BH, BS and C1 (silt>18%). Like sand, silt content is less variable in site BHS (C.V.<42.0) and more variable in site C2 (C.V.>150.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.12 Clay

The highest mean clay content is found in site HS (26.1%) in particular, and also in site BS (11.95%). It is absent from site B. Treatment sites C2, S and H contain less clay (clay<8%) than sites BH, BS and C1 (clay>9%). Like sand and silt, clay content is more variable in site C2 (C.V.>150.0) and less variable in site BHS (C.V.<5.0) (Tables 8.1, 8.2 and 8.3).

4.2.4.13 Soil Profile Variability

The mean standard errors for respective soil characteristics among treatment sites (Tables 8.1, 8.2 and 8.3) indicate that soils in site BS are generally more variable in soil pH, CEC, organic matter and soil elements than soils in site H. Soils in treatment site C2 are more

variable in texture (% sand, silt, clay) than those in site BHS.

Each observation in the soil data matrix (Appendix 4.0) is a composite sample of a soil horizon; and at least two horizons are recorded for each treatment area. This implies that where variability in soil properties is greatest (e.g. soils in sites BS and C2), there is a greater distinction in horizons. Also, in soils from BS and C2 sites at least three horizons are identified whereas only two horizons are shown for H and BHS soils, and one for HS soils.

Horizons identified in the soil data matrix (Appendix 4.0) indicate the within-profile variation of soil characteristics by treatment site. To enable interpretation of these horizons by the reader, soil horizons and horizon 'modifiers' recognized by the Canadian System of Soil Classification are defined (Table 9.0). By referring to the range in soil properties for each treatment site (Tables 8.1, 8.2 and 8.3), it can be shown that in C2 soils, contents of sand, silt and clay are highest in the B_m - B_t horizon and lowest in the highly organic A_h horizon. In BS soils, soil pH is lowest in the A_h horizon and highest in the B - B_h horizon. Also, soil organic matter, N, Mg and CEC are lowest in the B_f horizon and highest in the A_h horizon of BS soils.

TABLE 9.0 A description of horizons and horizon modifiers used in the Canadian System of Soil Classification (Canada Soil Survey Committee,1978)

Organic Horizons

L, F, H horizons - Well aerated areas where leaves, needles,twigs and branches fall and decompose.

L horizons consist of undecomposed litter
F horizons are partly decomposed
H horizons are well decomposed

O horizons - Poorly aerated organic accumulations associated with wet areas (e.g., bogs, fens, swamps)

Mineral Horizons

A horizon Surface horizon where maximum accumulation of organic mater (i.e. Ah) and/or maximum removal of materials occurs (i.e., Ae) by solution or suspension

B horizon Subsurface horizon where materials accumulate from A horizon, or where soil structure exists, or where soil colour changes occur

C horizon Relatively unmodified parent material

Horizon Modifiers (commonly used suffixes)

b - Buried horizon
c - Cemented soil horizon (i.e., pans)
e - Greyish horizon characterized by eluviation (removal) of Fe, Al, clay and/or organic material
f - Reddish horizon enriched with Fe and Al
g - Gleyed horizon indicative of poor drainage
h - Darkened horizon enriched with organic matter
m - Brownish horizon showing structure with properties different than underlying horizon (affected by hydrolysis, oxidation, and/or solution)
n - Horizon with prismatic structure and significant level of exchangeable Na
t - Horizon enriched with clay
z - Frozen horizon

As soil pH decreases, soil nutrient availability also decreases. This implies that since the B_f horizon has a higher pH and lower nutrient levels than the A_h horizon, the B_f horizon offers greater nutrient availability and represents the effective rooting zone. Similarly, low Ca and K contents are reported for the B_f horizon in BH and C1 treatment areas. Higher contents of Ca and K occur in the A_h horizon where greater input of these elements from weathering of soil minerals likely occurs; they are probably closely associated with organic (humic) colloids in this horizon as well.

Conversely, soil Na content is greater in the B_f (B_{fn}) horizon of S soils. Na is not essential for plant growth. However, it is an important factor in nutrient availability since Na disperses clay colloids. The higher Na content in the clayey (18.2%) B_{fn} horizon should promote nutrient availability in this horizon and perhaps (from eluviation) the underlying BC horizon as well, which is low in overall nutrients, sandy (86%) and probably rapidly drained. However, in S soils, nutrient availability appears to decrease with depth, indicated by a decreasing CEC (Appendix 4.0).

In unscarified soils, the amount of coarse fragments generally increases with depth. However, in soils from treatment sites BS and BHS, the surface horizon has more coarse fragment material; in site S, the BC horizon has more

coarse fragments (e.g. the underlying gravels are more evident) (Appendix 4.0). Differences in the amount of coarse fragments occurring within the horizons of scarified soils may consequently reflect differences in the intensity (or depth) of and degree of soil churning by scarification. Intensity of scarification has not been previously assessed.

4.2.5 Foliage

For each species, descriptive statistics are used to summarize the differences in foliar nutrients among the treatment sites respectively concerned. The foliar data matrix is shown in Appendix 5.0.

4.2.5.1 Huckleberry

Examination of the mean standard errors (Table 10.1) indicates that foliar nutrients are somewhat less variable in site C2 and more variable in site B. Specifically, N, Fe and Cu are more variable in site B; P, Ca and Mn are more variable in site H; Mg is more variable in site BH; and K and Zn are more variable in site C1. N, Mg and Fe are less variable in site H; P, Mn and Cu are less variable in site C2; K and Zn are less variable in site B; and Ca is less variable in site BH (Table 10.1).

Table 10.1 Summary statistics of huckleberry foliar data by treatment site.

NUTRIENT	Number of Samples	MEAN	STD ERROR OF MEAN
	SITE BH		
N	4	1.42250000	0.04150803
P	4	0.10000000	0.00577350
K	4	0.68500000	0.03378856
CA	4	1.25500000	0.03427827
MG	4	0.21500000	0.02217356
MN	4	2257.50000000	168.98594616
FE	4	79.50000000	5.26782688
CU	4	5.50000000	0.86602540
ZN	4	13.00000000	1.22474487
	SITE C2		
N	4	1.37250000	0.02750000
P	4	0.11000000	0.00000000
K	4	0.68500000	0.00866025
CA	4	1.33500000	0.04645787
MG	4	0.22000000	0.00707107
MN	4	2130.00000000	114.23659659
FE	4	99.75000000	2.56173769
CU	4	5.25000000	0.47871355
ZN	4	19.50000000	1.55456318
	SITE H		
N	4	1.35750000	0.01250000
P	4	0.13000000	0.02041241
K	4	0.84250000	0.02657536
CA	4	1.27000000	0.14759178
MG	4	0.20000000	0.00408248
MN	4	2325.00000000	575.56493986
FE	4	99.75000000	1.88745861
CU	4	3.25000000	0.47871355
ZN	4	18.50000000	1.50000000
	SITE B		
N	4	1.33750000	0.06523994
P	4	0.09250000	0.00250000
K	4	0.78000000	0.00707107
CA	4	0.87750000	0.07284401
MG	4	0.17500000	0.01707825
MN	4	1192.50000000	123.31362455
FE	4	34.50000000	10.57118726
CU	4	7.50000000	2.59807621
ZN	4	23.25000000	1.43614066
	SITE C1		
N	4	1.38250000	0.01931105
P	4	0.10000000	0.00408248
K	4	0.79000000	0.07884584
CA	4	1.16750000	0.04767512
MG	4	0.21500000	0.01190238
MN	4	2197.50000000	327.11809794
FE	4	58.50000000	9.91211380
CU	4	8.25000000	0.75000000
ZN	4	21.00000000	2.12132034

4.2.5.2 Salmonberry

The mean standard errors (Table 10.2) show that foliar nutrients are generally more variable in site H and less variable in sites BS and C2. Specifically, N and Zn are more variable in site C1; P is more variable in site C2; K, Mg and Mn are more variable in site H; Ca is more variable in site HS; and Mg and Mn are more variable in site H. N, Fe, Cu and Zn are less variable in site C2; P, K and Mn are less variable in site BS; Ca is less variable in site S; and Mg is less variable in site HS (Table 10.2).

4.2.5.3 Salal

Examination of the mean standard errors (Table 10.3) show that foliar nutrients are generally more variable in site B and less variable in site BH. Specifically, N and Zn are more variable in site C1. P, Ca and Fe are more variable in site B; K and Mn are more variable in site C2; Mg and Cu are more variable in site BH and H, respectively. N, P, K, Ca and Cu are less variable in site BH; Mg and Fe are less variable in site C2; Mn and Zn are less variable in sites B and H, respectively (Table 10.3).

Table 10.2 Summary statistics of salmonberry foliar data by treatment site.

NUTRIENT	Number of Samples	MEAN	STD ERROR OF MEAN
	SITE C2		
N	4	1.78000000	0.01224745
P	4	0.16750000	0.01108678
K	4	0.95000000	0.05082650
CA	4	0.80000000	0.03719319
MG	4	0.54250000	0.01493039
MN	4	667.50000000	76.85213074
FE	4	98.25000000	2.25000000
CU	4	4.50000000	0.28867513
ZN	4	13.00000000	0.40824829
	SITE BS		
N	4	1.99250000	0.05022864
P	4	0.16750000	0.00250000
K	4	0.99500000	0.03201562
CA	4	0.68000000	0.02549510
MG	4	0.50750000	0.01652019
MN	4	1395.00000000	69.82120022
FE	4	63.50000000	6.06217783
CU	4	7.50000000	0.86602540
ZN	4	17.25000000	0.75000000
	SITE S		
N	4	2.24250000	0.04836924
P	4	0.16750000	0.00750000
K	4	1.07750000	0.06762334
CA	4	0.85750000	0.00853913
MG	4	0.49500000	0.01258306
MN	4	1032.00000000	65.22269544
FE	4	104.75000000	23.47472045
CU	4	15.00000000	1.73205081
ZN	4	21.00000000	1.22474487
	SITE HS		
N	4	2.07250000	0.08239893
P	4	0.13750000	0.00853913
K	4	1.17750000	0.04939214
CA	4	0.68750000	0.06169481
MG	4	0.55250000	0.00853913
MN	4	470.25000000	33.14456969
FE	4	99.50000000	12.81600562
CU	4	14.25000000	2.56173769
ZN	4	21.00000000	1.22474487

Table 10.2 (Cont'd)

NUTRIENT	Number of Samples	MEAN	STD ERROR OF MEAN
	SITE H		
N	4	2.11250000	0.08844725
P	4	0.13500000	0.00288675
K	4	1.03000000	0.07359801
CA	4	0.80750000	0.02015564
MG	4	0.49750000	0.03350995
MN	4	327.00000000	80.08745220
FE	4	86.00000000	19.44222210
CU	4	18.00000000	3.67423461
ZN	4	19.50000000	0.86602540
	SITE BHS		
N	4	2.43750000	0.07375353
P	4	0.22750000	0.00478714
K	4	1.25500000	0.05377422
CA	4	0.71000000	0.01080123
MG	4	0.55250000	0.02015564
MN	4	652.50000000	53.90964663
FE	4	66.00000000	19.01315334
CU	4	12.00000000	3.00000000
ZN	4	24.00000000	1.22474487
	SITE C1		
N	4	1.61750000	0.07814250
P	4	0.10500000	0.00288675
K	4	1.20750000	0.05893146
CA	4	0.81500000	0.02661453
MG	4	0.49500000	0.01040833
MN	4	802.50000000	211.55672998
FE	4	60.00000000	7.64852927
CU	4	9.00000000	1.22474487
ZN	4	18.00000000	1.22474487

Table 10.3 Summary statistics of salal foliar data by treatment site.

NUTRIENT	Number of Samples	MEAN	STD ERROR OF MEAN
	SITE BH		
N	4	0.90000000	0.01000000
P	4	0.09000000	0.00000000
K	4	0.73500000	0.01322876
CA	4	0.99750000	0.03750000
MG	4	0.27250000	0.05764475
MN	4	1230.00000000	112.91589791
FE	4	93.00000000	6.12372436
CU	4	3.75000000	0.25000000
ZN	4	18.75000000	1.25000000
	SITE C2		
N	4	1.02000000	0.04203173
P	4	0.10000000	0.00408248
K	4	0.72000000	0.04434712
CA	4	1.32750000	0.06562202
MG	4	0.33500000	0.01190238
MN	4	1477.50000000	423.44568719
FE	4	93.00000000	1.73205081
CU	4	2.75000000	0.47871355
ZN	4	38.75000000	2.56173769
	SITE H		
N	4	0.99250000	0.01376893
P	4	0.09000000	0.00408248
K	4	0.68000000	0.05049752
CA	4	1.32500000	0.06512808
MG	4	0.38500000	0.02901149
MN	4	1927.50000000	182.22582144
FE	4	92.00000000	6.74536878
CU	4	6.75000000	3.75000000
ZN	4	34.25000000	1.54784797
	SITE B		
N	4	1.01000000	0.02121320
P	4	0.08250000	0.00478714
K	4	0.67250000	0.02561738
CA	4	0.93500000	0.04974937
MG	4	0.30500000	0.01322876
MN	4	1305.00000000	39.68626967
FE	4	58.50000000	29.22755549
CU	4	4.50000000	0.86602540
ZN	4	27.00000000	2.12132034
	SITE C1		
N	4	0.76750000	0.22746337
P	4	0.08250000	0.00250000
K	4	0.58750000	0.01652019
CA	4	1.18750000	0.05498106
MG	4	0.36500000	0.02397916
MN	4	2427.50000000	260.01201895
FE	4	77.25000000	28.99245592
CU	4	8.50000000	2.87228132
ZN	4	30.75000000	4.80234318

4.2.5.4 Alder

The mean standard errors (Table 10.4) indicate that foliar nutrients are generally more variable in site S and less variable in site BHS. Specifically, N, Ca, Mg and Zn are more variable in site S; P and Fe are more variable in site HS; and Mn and Cu are more variable in site BS. N and Zn are less variable in sites BS and BHS; P, Mn and Fe are also less variable in site BHS; K and Ca are less variable in site BS; Mg and Ca are less variable in site HS; and Cu is less variable in site S (Table 10.4).

4.2.5.5 Hemlock

Examination of the mean standard errors (Table 10.5) shows that foliar N is more variable in treatment site B, and less variable in treatment site C1 (Table 10.5). Other nutrients are not reported since only total N was determined on hemlock samples collected in 1985.

Table 10.4 Summary statistics of alder foliar data by treatment site.

NUTRIENT	Number of Samples	MEAN	STD ERROR OF MEAN
	SITE BS		
N	4	2.44500000	0.02533114
P	4	0.14750000	0.00629153
K	4	0.61500000	0.01707825
CA	4	0.67250000	0.02561738
MG	4	0.18750000	0.01030776
MN	4	412.50000000	64.08002809
FE	4	27.00000000	3.67423461
CU	4	7.50000000	2.59807621
ZN	4	21.75000000	0.75000000
	SITE S		
N	4	2.13500000	0.31808018
P	4	0.13250000	0.00750000
K	4	0.77500000	0.02723356
CA	4	0.74250000	0.04767512
MG	4	0.19000000	0.02738613
MN	4	427.50000000	60.33034063
FE	4	75.50000000	6.76387463
CU	4	17.25000000	1.88745861
ZN	4	30.00000000	2.12132034
	SITE HS		
N	4	2.50750000	0.05170026
P	4	0.15000000	0.01080123
K	4	0.54250000	0.02561738
CA	4	0.48250000	0.01887459
MG	4	0.17500000	0.00645497
MN	4	187.50000000	29.86218344
FE	4	68.00000000	16.65833125
CU	4	12.75000000	2.25000000
ZN	4	23.25000000	1.43614066
	SITE BHS		
N	4	2.72500000	0.03593976
P	4	0.16500000	0.00288675
K	4	0.73750000	0.04784959
CA	4	0.70500000	0.04213075
MG	4	0.21250000	0.01436141
MN	4	307.50000000	30.92329219
FE	4	30.75000000	1.43614066
CU	4	7.50000000	0.86602540
ZN	4	28.50000000	0.86602540

Table 10.5 Summary statistics of hemlock foliar data by treatment site.

NUTRIENT	Number of samples	MEAN	STD ERROR OF MEAN
	SITE BH		
N	3	1.04666667	0.08838049
	SITE B		
N	3	1.32000000	0.23515952
	SITE C1		
N	3	1.07666667	0.05547772

4.2.6 Correlation

Since this study is exploratory in nature, correlations between each competitor's abundance (% cover) and foliar nutrient contents, and also between each species' vegetative cover and the soil nutrients characterizing the sites in which each species occurs are used to indicate if/where relationships occur between vegetative growth (e.g. cover) and nutrients essential for plant growth.

No relationships are found among each species' cover and soil nutrients (Appendix 6.1). Similarly, no relationships are found among each species' cover and their foliar nutrients (Appendix 6.2).

4.3 PRINCIPAL COMPONENT ANALYSIS

R-mode PCA is employed descriptively to summarize the variation in both site and floristic diversity data. Plots of the first two components are used to simplify interpretation of the eigenanalysis. Treatment classifications are superimposed on ordination plots to allow examination of treatment site distribution. Correlations, eigenvalues and principal components are incorporated in table form.

4.3.1 Site Attributes

Substantial correlation occurs between the site variables (Table 11.1), particularly between surface shape and slope position (r=+.91), slope and elevation (r=+.87) and between moisture regime and slope position moisture (r=-.84).

The eigenvalues indicate that two components explain over 75% of the standardized variance. The first component shows high positive loadings on slope and elevation, in particular, and also on aspect. The second component shows high positive loadings on moisture regime and placement; surface shape, slope and slope position have moderate loadings (Table 11.1).

A plot of component 1 (slope and elevation) and 2 (moisture regime and placement) shows that sites BH and C1 are highest in elevation and slope followed by sites B and C2, about average in these respects. Lower elevation and slope are shown by sites BS, S, HS and BHS (representing level, valley floor sites). Site H is lowest along the first component axis. With the exception of site H, these latter sites are highest along the second component axis; sites BH and C1 are about average; sites C2 and B are below average; and site H is lowest. Unscarified treatment sites tend to be hygric to mesic in moisture regime with rocky to mineral (and duff) placement (Figure 6.1).

(1) CORRELATIONS (* r > 0.60)

	ASPECT	SLOPE	ELEV_N	SPM	SL_POS	MREGIM	SHAPE	PLACMT
ASPECT	1.0000	0.1568	-0.0247	0.3590	-0.6373	-0.0062	-0.7718	-0.1042
SLOPE	0.1568	1.0000	0.8717	-0.4261	-0.7643	0.2141	-0.6898	0.1933
ELEV_N	-0.0247	0.8717 *	1.0000	-0.3463	-0.6962	0.0390	-0.5659	-0.0206
SPM	0.3590	-0.4261	-0.3463	1.0000	0.0952	-0.8377	-0.1601	-0.5669
SL_POS	-0.6373 *	-0.7643 *	-0.6962 *	0.0952	1.0000	-0.1951	0.9120	0.1426
MREGIM	-0.0062	0.2141	0.0390	-0.8377 *	-0.1951	1.0000	0.0698	0.4677
SHAPE	-0.7718 *	-0.6898 *	-0.5659	-0.1601	0.9120 *	0.0698	1.0000	0.1213
PLACMT	-0.1042	0.1933	-0.0206	-0.5669	0.1426	0.4677	0.1213	1.0000

(2)

	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
PRIN1	3.55328	1.03520	0.444159	0.44416
PRIN2	2.51808	1.34792	0.314760	0.75892
PRIN3	1.17016	0.55060	0.146270	0.90519
PRIN4	0.61956	0.53700	0.077445	0.98263
PRIN5	0.08256	0.03991	0.010320	0.99295
PRIN6	0.04264	0.02894	0.005330	0.99828
PRIN7	0.01371	0.01369	0.001713	1.00000
PRIN8	0.00002	.	0.000002	1.00000

(3) PRINCIPAL COMPONENTS

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6	PRIN7	PRIN8
ASPECT	0.276593	-.326435	0.618829	0.023652	0.162510	-.414255	0.369869	0.314018
SLOPE	0.475968	0.152243	-.248981	0.187341	-.705226	0.021465	0.306997	0.247258
ELEV_N	0.423568	0.097231	-.511977	0.040616	0.609714	-.068657	-.067937	0.407782
SPM	-.130665	-.596444	0.008654	0.204832	-.035718	0.636193	-.080765	0.415464
SL_POS	-.509658	0.103352	-.081098	0.211348	-.200820	-.484114	-.323621	0.546714
MREGIM	0.118375	0.488809	0.406351	-.491129	-.045487	0.337833	-.249315	0.402946
SHAPE	-.475672	0.243383	-.145616	-.132915	0.153915	0.156872	0.768714	0.190818
PLACMT	0.020976	0.442958	0.316167	0.785618	0.192698	0.213004	0.001483	-.060714

LEGEND : Aspect = aspect ; slope = slope ; elev_n = elevation ; spm = slope position moisture ; sl_pos = slope position ; mregim = moisture regime ; shape = surface shape = placmt = placement ; prin (n) = principal component (n).

TABLE 11.1 Results of R-mode principal component analysis of site attributes, showing (1) correlation (SSCP/n) matrix; (2) eigenvalues; and (3) transformed SSCP matrix of component scores.

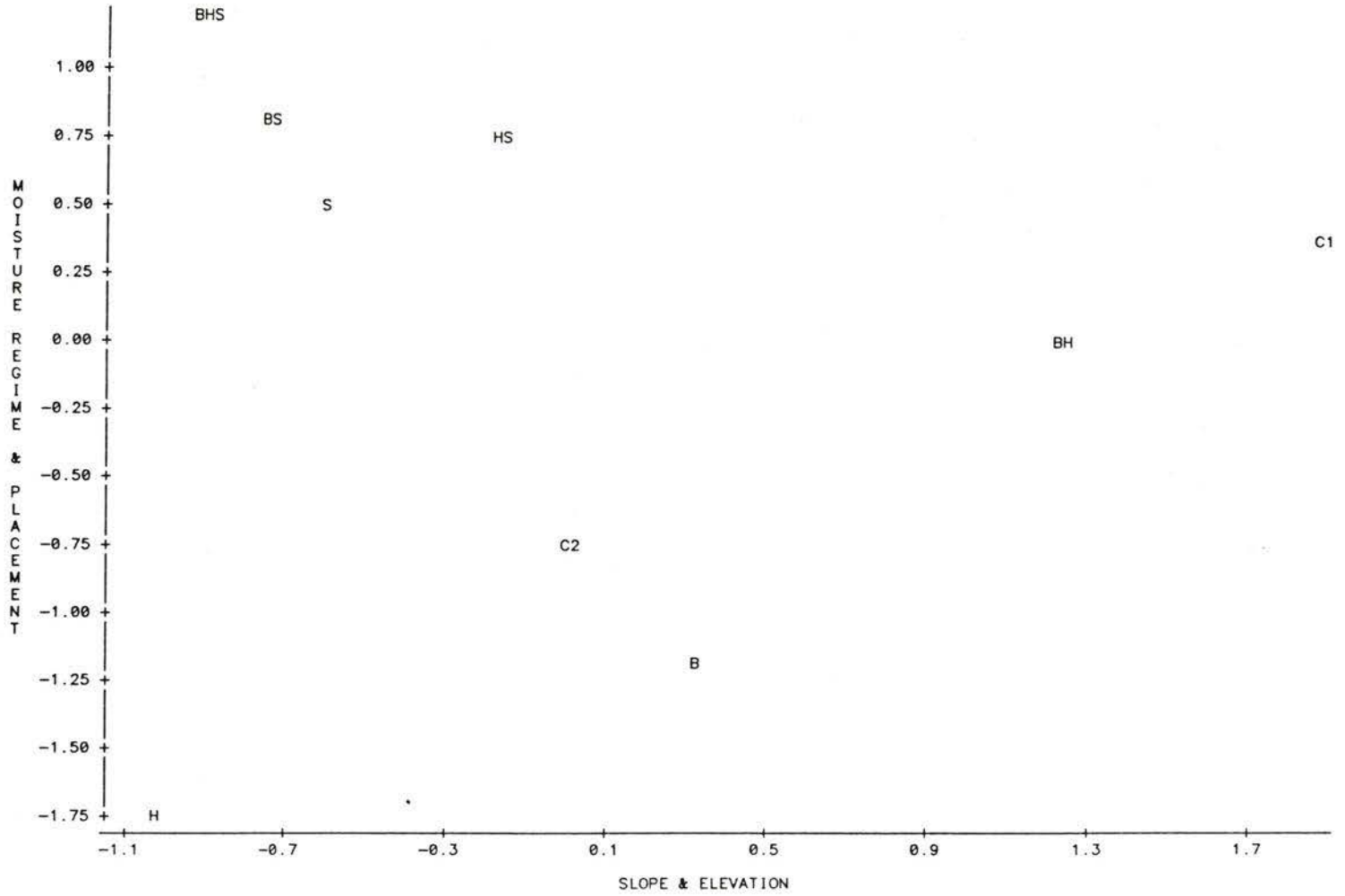


FIGURE 6.1 Plot showing distribution of treatment sites along component 1 (slope and elevation) and 2 (moisture regime and placement) produced from R-mode principal component analysis of site attributes.

4.3.2 Floristic Diversity

Substantial intercorrelation of variables occurs (Table 11.2). The weakest correlation is between floristic diversity (FD) based on slope position moisture and FD based on slope position (r=+.63) (Table 11.2).

The eigenvalues indicate that one component explains over 83% of the standardized variance. The first component measures FD based on overall site attributes.

A plot of components 1 (FD of overall site attributes) and 2 (FD based on slope position moisture and moisture regime) shows that with the exception of site C1 which is substantially lower in FD, the treatment sites are average along the first component axis. Sites in the valley floor (BS, S, HS and BHS) have marginally higher FD than those occupying the lower slopes (BH, C2, H and B). Floristic diversity based on moisture is highest in site BH, lowest in site H and approximately average in the remaining sites (Figure 6.2).

(1) CORRELATIONS (* r > 0.60)

	FD_ASP	FD_SLP	FD_ELV	FD_SPM	FD_MRG	FD_POS	FD_SRF	FD_PLC
FD_ASP	1.0000	0.8320	0.8397	0.6526	0.6966	0.9507	0.9489	0.8146
FD_SLP	0.8320 *	1.0000	0.8256	0.7413	0.7650	0.8313	0.8309	0.8027
FD_ELV	0.8397 *	0.8256 *	1.0000	0.7008	0.8088	0.8785	0.9233	0.7093
FD_SPM	0.6526 *	0.7413 *	0.7008 *	1.0000	0.9565	0.6375	0.6880	0.9251
FD_MRG	0.6966 *	0.7650 *	0.8088 *	0.9565 *	1.0000	0.7003	0.7547	0.8592
FD_POS	0.9507 *	0.8313 *	0.8785 *	0.6375 *	0.7003 *	1.0000	0.9897	0.7809
FD_SRF	0.9489 *	0.8309 *	0.9233 *	0.6880 *	0.7547 *	0.9897 *	1.0000	0.8078
FD_PLC	0.8146 *	0.8027 *	0.7093 *	0.9251 *	0.8592 *	0.7809 *	0.8078 *	1.0000

(2)

	EIGENVALUE	DIFFERENCE	PROPORTION	CUMULATIVE
PRIN1	6.66809	5.90352	0.833511	0.83351
PRIN2	0.76457	0.49901	0.095571	0.92908
PRIN3	0.26556	0.06308	0.033195	0.96228
PRIN4	0.20247	0.15086	0.025309	0.98759
PRIN5	0.05161	0.01246	0.006452	0.99404
PRIN6	0.03916	0.03148	0.004894	0.99893
PRIN7	0.00768	0.00682	0.000960	0.99989
PRIN8	0.00086	.	0.000108	1.00000

(3) PRINCIPAL COMPONENTS

	PRIN1	PRIN2	PRIN3	PRIN4	PRIN5	PRIN6	PRIN7	PRIN8
FD_ASP	0.358196	−.324730	−.333157	−.103957	0.786647	0.033450	0.154283	−.026645
FD_SLP	0.351638	−.053799	−.008331	0.923732	−.062881	0.084165	−.037919	−.087351
FD_ELV	0.355086	−.190982	0.665451	−.060049	0.062843	−.571224	0.016043	0.245977
FD_SPM	0.332676	0.578800	−.027151	−.078972	−.076739	−.073470	0.711166	−.174068
FD_MRG	0.345700	0.439965	0.363203	−.149028	0.220993	0.545641	−.427057	0.062103
FD_POS	0.360141	−.376668	−.117836	−.168724	−.438113	0.411813	0.236929	0.518071
FD_SRF	0.369191	−.306011	0.016008	−.259384	−.314755	0.011968	−.170071	−.757879
FD_PLC	0.354647	0.301798	−.547098	−.090066	−.165963	−.438913	−.448672	0.232851

LEGEND : FD = floristic diversity ; FD_ASP = FD based on aspect ; FD_SLP = FD based on slope ; FD_ELV = FD based on elevation ; FD_SPM = FD based on slope position moisture ; FD_MRG = FD based on moisture regime ; FD_POS = FD based on slope position ; FD_SRF = FD based on surface shape ; FD_PLC = FD based on placement ; PRIN (n) = principal component (n).

TABLE 11.2 Results of R-mode principal component analysis of floristic diversity based on site attributes, showing (1) correlation (SSCP/n) matrix; (2) eigenvalues; and (3) transformed SSCP matrix of component scores.

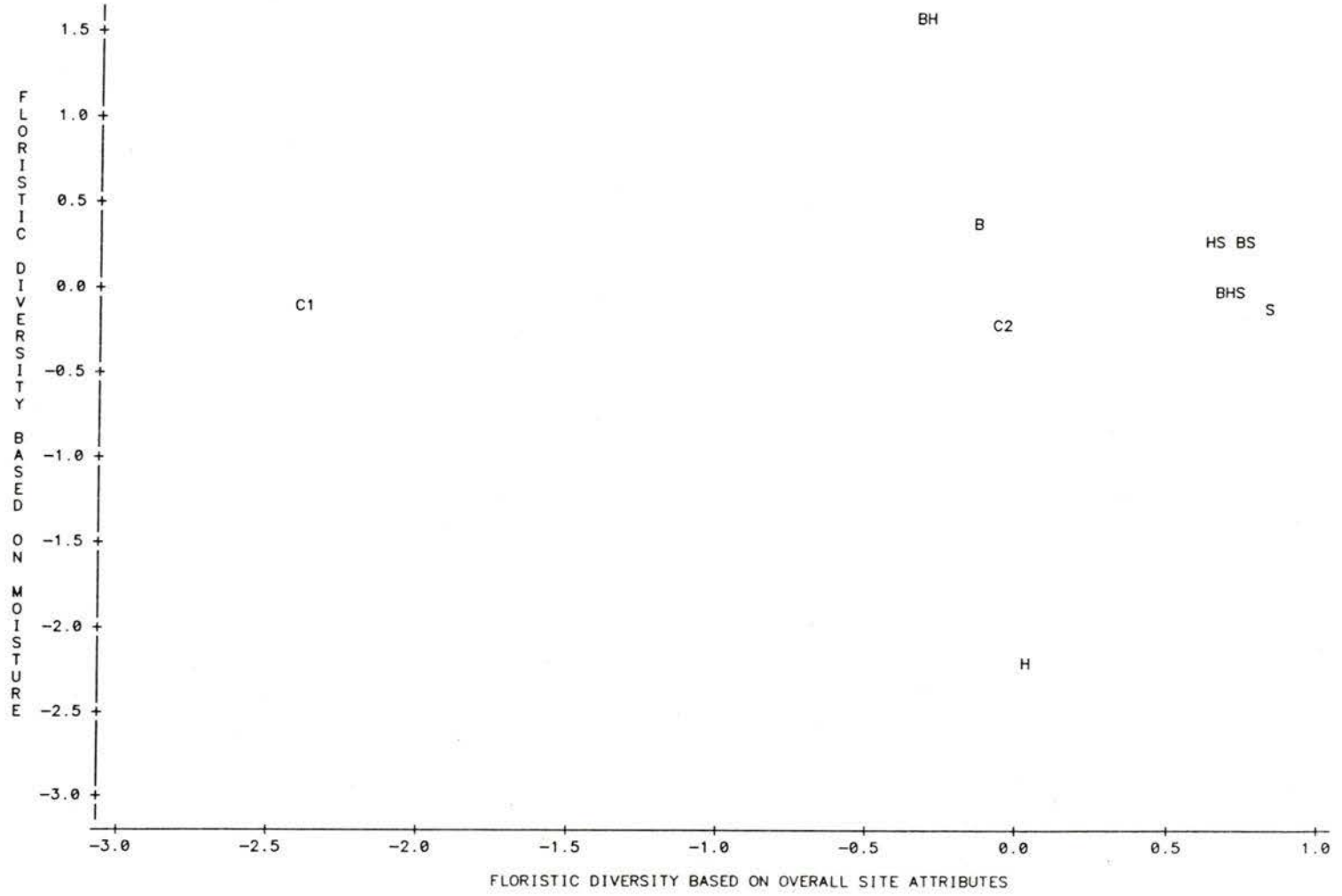


FIGURE 6.2 Plot showing distribution of treatment sites along component 1 (floristic diversity based on overall site attributes) and 2 (floristic diversity based on moisture) produced from R-mode principal component analysis of floristic diversity.

4.4 ANALYSIS OF VARIANCE

ANOVA is employed to determine if treatment, site age and site factors explain significant differences in soil and foliar nutrients, floristic diversity and vegetation characteristics. When ANOVA is not significant and consistent intercorrelations of certain variables occur, ANOCOVA is employed to reduce the variance of the error terms and to increase the model's precision. Comparisons are significant at alpha = 0.05. This means that p values $\leq$ 0.05 are significant. For each analysis, Tukey's studentized range test is used to identify which treatment sites are significantly different from others.

Analyses conducted on floristic diversity, soil and foliar nutrients and cover of each species are respectively reported in the following sections of this chapter. ANOVA tables (Appendices 7.1 - 14.5) appear in the format output by SAS using the general linear model (GLM) procedure for unbalanced data. Tukey's test results have not been included due to the large number of comparisons made. Nevertheless, all significant comparisons have been carefully documented within the text.

4.4.1 Floristic Diversity

On the pretense that different categories of a site attribute support different numbers of species, 2-factor ANOVA is used to determine if significant differences in floristic diversity are explained by treatment and age factors. Results show that in all cases, floristic diversity significantly decreases with increasing site age.

4.4.1.1 Floristic Diversity based on Aspect

ANOVA shows that treatment and age explain a significant proportion of variation in floristic diversity (r^2=.84, P<0.01). Both factors are significant according to both Type I (Sequential) and Type III (Adjusted) Sums of Squares (SS) (P<0.01) (Appendix 7.1). Treatment sites BS, S, HS and BHS show significantly greater species numbers than sites BH, C2, H, B and C1.

4.4.1.2 Floristic Diversity based on Slope

Treatment and site age account for significant differences in floristic diversity based on slope (P<0.01), accounting for 30% of its total variation (Appendix 7.1). Significantly greater numbers of species are found in treatment site S, followed by site HS. Site C1 has significantly lower floristic diversity than the other sites.

4.4.1.3 Floristic Diversity based on Elevation

ANOVA indicates that both treatment and site age explain a significant proportion of variation in floristic diversity (r^2=.87, P<0.01). Both factors are highly significant in both Type I and Type III SS (P<0.01) (Appendix 7.2). Species numbers decrease in sites HS, BH and C1, respectively (P<0.05), although significantly higher floristic diversity is found in other treatments.

4.4.1.4 Floristic Diversity based on Slope Position Moisture

Treatment and site age explain a significant proportion of variation in floristic diversity based on slope position moisture (r^2=.78, P<0.01). Both factors are highly significant in Sequential and Adjusted Sums of Squares (P<0.01) (Appendix 7.2). Treatment sites BS, HS and BHS, similar in floristic diversity, show significantly higher species numbers than sites BH and S, and sites B, C2, H and C1 decreasing significantly in species numbers, respectively.

4.4.1.5 Floristic Diversity based on Slope Position

A significant proportion of variation in floristic diversity is explained (r^2=.71, P<0.01) by treatment and age, both highly significant in Types I and III SS (P<0.01) (Appendix 7.3). Sites H and BHS are significantly higher in floristic diversity than sites BS and S, and also sites HS,

C2, B, BH and C1 decreasing significantly in species numbers.

4.4.1.6 Floristic Diversity based on Moisture Regime

A large proportion of the total variation in floristic diversity is explained by treatment and age (r^2=.74, P<0.01). Both factors are highly significant according to Type I and III SS (P<0.01)(Appendix 7.3). Treatment sites BS, HS and BHS have significantly greater floristic diversity than sites BH, C2 and S, and also sites B, H and C1 significantly decreasing in species numbers. Site C1 is again lowest in floristic diversity.

4.4.1.7 Floristic Diversity based on Surface Shape

ANOVA significantly explains 60% of the total variation in floristic diversity (p<0.01) using treatment and age as factors. Both factors are highly significant in Sequential and Adjusted Sums of Squares (p<0.01) (Appendix 7.4). Treatment sites BS and BHS are significantly greater in floristic diversity than sites S and H, and also sites HS, C2, B, BH and C1 decreasing significantly in species numbers.

4.4.1.8 Floristic Diversity based on Placement

Treatment and site age explain 51% of the total variation in floristic diversity (P<0.01). Both factors are

highly significant in Type I and III SS ($P<0.01$) (Appendix 7.4). Site BS shows the highest number of species followed by site S, HS and BHS, BH and B, C2 and H, and C1 respectively.

4.4.2 Soil Variables

Treatment and site age are used as factors with covariates sand, silt and clay in an ANOCOVA. In conjunction with ANOVA of foliar data, this analysis is used to primarily to assess fertility among the treatment sites. It is also used to reduce error variance in each of the dependent variables that results in an ANOVA. Results indicate that age does not account for any significant differences in the soil properties of concern.

4.4.2.1 pH (H_2O)

ANOCOVA significantly explains 52% of the variation in pH (H_2O) ($P<0.01$). Sequential Sums of Squares indicate that sand and silt significantly explain differences in pH ($P<0.05$), while Adjusted Sums of Squares support the significance of treatment only ($P<0.01$). However, treatment sites are not significantly different in pH in multiple range analysis.

4.4.2.2 pH ($CaCl_2$)

ANOCOVA is highly significant (P<0.01), with 61% of the total variation in pH ($CaCl_2$) explained (an improvement over the previous method). Treatment and clay are significant in both Types I and III SS (P<0.01). Sand and silt are highly significant in Type III SS (P<0.01).

Treatment site BH is significantly lower in mean pH ($CaCl_2$) than treatment sites S, H and B. No other comparisons are significant.

4.4.2.3 Organic Matter

ANOCOVA explains approximately 80% of the total variation in organic matter (P<0.01). Sequential SS show that all variables are important in the analysis (P<0.05). Adjusted SS indicate that treatment, sand and clay (marginally) are significant (P<0.05) (Appendix 8.1).

Treatment site comparison shows that site B is significantly greater in organic matter than all other treatment sites except site BH. However, site BH is significantly greater in mean organic matter than sites S and BHS only. Treatment sites C2, BS, S, HS, H, BHS and C1 are not significantly different in organic matter.

4.4.2.4 Total N

ANOCOVA explains over 75% of the total variation in total N (P<0.01). Treatment, sand and silt are important in

the analysis according to both Type I and III SS ($P<0.01$) (Appendix 8.1).

Treatment sites H and BH are significantly higher in mean total N than sites C2 and S. All other sites are similar in total N content.

4.4.2.5 CEC

ANOCOVA is significant ($P<0.01$), explaining over 83% of the total variation in CEC. Treatment, sand, silt and clay are important according to both Type I and III SS ($P<0.01$) (Appendix 8.2).

Sites BH, H, B and C1 are significantly higher in CEC than sites S and BHS. No other comparisons are significant.

4.4.2.6 Ca

ANOCOVA explains over 71% of the total variation in Ca ($P<0.01$). Treatment, sand and silt are significant in both Sequential and Adjusted SS ($P<0.05$) (Appendix 8.2).

Treatment site HS is significantly higher in mean Ca than treatment sites S, HS, BHS, B and C1. No other comparisons are significant.

4.4.2.7 Mg

A significant ANOCOVA results ($P<0.01$), explaining over 84% of the total variation in soil Mg. Sequential SS show that all variables except age are important in the analysis

($P<0.01$) while Adjusted SS do not support the importance of silt (Appendix 8.3).

Site BH is significantly greater in mean soil Mg than other treatment sites. No other comparisons are significant.

4.4.2.8 K

ANOCOVA explains over 82% of the total variation in soil K ($P<0.01$). All variables except age are important in the analysis according to Type I SS ($P<0.01$). However, Type III SS support the significance of treatment and clay only ($P<0.01$) (Appendix 8.3).

Treatment site C1 is significantly greater in soil K than the other sites except site BH. Treatment site BH is also similar to sites HS and H. Treatment sites C2, BS, S, HS, H, BHS and B are not significantly different in soil K.

4.4.2.9 Na

A significant ANOCOVA results ($P<0.05$) although only 34% of the total variation in Na is explained. Sequential Sums of Squares indicate that sand is the only important variable in the analysis ($P<0.01$) while Adjusted SS show that treatment and sand are significant ($P<0.05$). No comparisons are significant.

4.4.3 Foliar Variables

4.4.3.1 1985 Data

Treatment and species are used as classification variables in a 2-factor ANOVA. The species are huckleberry, salmonberry, alder and hemlock. Since only total N is examined in 1985 foliage, this analysis is used to determine if significant differences in total foliar N can be attributed to treatment and species (and indirectly, to soil fertility).

Over 93% of the total variation in total N is explained by treatment and species differences ($P<0.01$). Although Sequential Sums of Squares and their associated F tests indicate that both treatment and species are highly significant ($P<0.01$), Adjusted SS and partial F tests show that treatment is not significant ($P>0.05$) (Appendix 9.1).

Alder and salmonberry are not significantly different in mean total N content, although they contain significantly more total N than hemlock and huckleberry. The latter two species are also not significantly different in total foliar N.

4.4.3.2 1986 Data

Treatment and species (huckleberry, salmonberry, salal and alder) are used as classification variables in a 2-factor ANOVA. Since hemlock foliage was not sampled in 1986 (as previously explained in Chapter 3.0), analyses of macro- and micronutrients (1986) do not include this species. Two-factor ANOVA is used to determine if significant differences in nutrients (N, P, K, Ca, Mg, Mn, Fe, Cu, Zn) can be attributed to treatment and species (and indirectly to soil fertility). Nutrients are discussed in order of decreasing variation explained by ANOVA. All analyses are highly significant nevertheless ($P<0.01$).

Ninety-two percent of the total variation in Mg is explained. However, Adjusted SS and partial F tests indicate that treatment is not significant ($P>0.05$), while species is highly significant ($P<0.01$) (Appendix 9.2).

Salmonberry shows significantly higher mean Mg than salal, huckleberry and alder, respectively. Salal is also significantly different from the latter two species which are not significantly different in mean Mg and show the lowest Mg content among species.

Over 80% of the total variation in N, P and Ca is explained by treatment and species, highly significant in each analysis ($P<0.01$) (Appendices 9.2 and 9.3, respectively).

Treatment site BHS contains significantly more total N than other treatment sites except site HS. Sites BH, C2, H, B and C1 show significantly lower N than sites BS, S, HS and BHS. Treatment sites BH and B also contain significantly less mean N than treatment site H.

All species contain significantly different mean N. Alder exhibits the highest N content, followed by salmonberry, huckleberry and salal, respectively.

Treatment site BHS is also significantly higher in mean P than other treatment sites. It is followed by sites C2, BS, S and HS, and also sites BH, B and C1, showing significantly decreasing mean P contents. Treatment site H is significantly lower in mean P content than sites BS, S and BHS, but significantly higher in P than treatment site B.

Salmonberry and alder are significantly higher in mean P content than huckleberry and salal. Salal is significantly lower in mean P content than other species.

Sites BH, C2 and H are significantly higher in foliar Ca than sites BS, S, HS, BHS and B. Treatment site C1 is higher in mean Ca than sites BS, S, HS and BHS as well. Site B is significantly higher in Ca than sites BS, HS and BHS; and site S is significantly higher than site HS, showing the lowest mean Ca content.

Huckleberry and salal contain significantly more foliar Ca than salmonberry and alder. Alder is significantly lower than the other species in foliar Ca.

Over 75% of the variation in K and Mn is explained by treatment and species factors ($P<0.01$) (Appendix 9.4).

Site BHS contains the highest mean K content among sites, followed by site S. Both treatment sites are significantly higher than sites BH and B which show the lowest mean K contents. Site BHS is also significantly higher than sites C2 and BS. Salmonberry contains significantly more foliar K than huckleberry, salal and alder which show decreasing mean K contents, respectively.

Treatment sites BH, C2, H and C1 contain significantly more Mn than sites S, HS and BHS, while only sites BH and C1 are significantly higher in mean Mn content than site BS. Site B is also significantly higher than sites HS and BHS which represent the lowest mean Mn contents.

Huckleberry and salal contain significantly more mean foliar Mn than salmonberry and alder. Alder shows significantly lower foliar Mn than the other species.

Treatment and species factors explain only about 69% of the total variation in foliar Fe, and less than 50% of the total variation in foliar Cu and Zn. Both variables are significant nevertheless ($P<0.05$).

Treatment site BH contains significantly less Fe than sites C2, S, H, BHS, B and C1 which are not significantly different in Fe content. However, sites BS and HS are not significantly different from site BH in Fe content.

Salal contains significantly more Fe than the other species. It is followed by alder which is also significantly higher in mean Fe content than salmonberry and huckleberry. The latter two species show no significant difference in mean Fe content.

Treatment sites C2, S and H contain significantly more Cu than sites BS, BHS and B. No other comparisons are significant. Alder contains significantly less mean Cu than the other species. No other comparisons are significant.

Site S contains significantly more foliar Zn than sites BH, C2, BS, H, B and C1. Sites BH, C2 and B are also significantly lower in mean foliar Zn than site HS. Salmonberry and alder contain significantly more mean Zn than huckleberry and salal.

Similar patterns of significant differences in several mean nutrient contents occur in the four species. For example, alder and salmonberry show significantly greater mean contents of total N (1985), N, P and Zn than huckleberry and salal (or hemlock for 1985 data). Huckleberry also contains greater quantities of these nutrients than salal. However, huckleberry and salal show

significantly greater mean Ca and Mn contents than salmonberry and alder. Salmonberry, huckleberry and salal show higher mean Cu contents than alder; and alder, huckleberry and salal contain less K and Mg than salmonberry. With salmonberry, salal shows significantly higher mean Mg than alder and huckleberry. With alder, salal also contains significantly more Fe than salmonberry or huckleberry.

4.4.3.3 Foliar Nutrients by Species

ANOVA using treatment and species as factors indicates that variation in foliar nutrients is both species-specific and treatment-specific. To identify the treatment-specific differences in each species' foliar nutrients, 1-way ANOVA is employed using treatment as the factor. In conjunction with ANOCOVA, this analysis provides a more complete picture of treatment effect on nutrient availability and soil fertility.

4.4.3.3.1 Huckleberry

A highly significant ANOVA of the micronutrient Fe explains a reasonable proportion of its total variation (r^2=.70, P<0.01) (Appendix 10.0). ANOVA's involving N, P, Mg, Mn and Cu are not significant (P>0.05).

Sites B and C1 yield significantly greater mean Fe than site BH. Foliar Fe from sites C2 and H is similar to that from sites B, C1 and BH.

4.4.3.3.2 Salmonberry

Highly significant ANOVA's ($P<0.01$) involving the nutrients N, P, Mn and Fe each explain a reasonable proportion of total variation in the respective nutrient ($r^2>.70$). Although less than 60% of the total variation in the other nutrients is explained, these ANOVA's are also highly significant ($P<0.01$); ANOVA's involving Mg and Cu are not significant ($P>0.05$). Therefore, only ANOVA's involving N, P, Mn and Fe are reported.

Over 82% of the total variation in N is explained by treatment differences ($P<0.01$) (Appendix 11.1). Foliar N from sites BHS and S has the highest mean foliar N contents, significantly different from that in sites C2 and C1 representing the lowest mean N contents. Sites H, HS and BS are significantly different in foliar N from both sites BHS and C1. Treatment site H is also significantly higher than site C2 in foliar N.

Over 90% of the variation in foliar P is explained by treatment differences ($P<0.01$) (Appendix 11.1). Foliar P in site BHS is significantly higher than that in other sites, while sites HS, H and C1 are significantly lower in foliar P

than the other sites. No significant comparisons are found between foliar P levels in sites HS and H, or between sites C2, BS and S.

Over 78% of the total variation in foliar Mn is explained by treatment differences ($P<0.01$) (Appendix 11.2). Foliar Mn from site BS is significantly higher than that in most other sites except site S. Site H, which represents the lowest mean foliar Mn content, is significantly different from sites S and C1. Site HS is also significantly lower in mean Mn than site S. Decreasing mean foliar Mn contents occur in sites C1, C2, BHS and HS respectively.

Over 76% of the total variation in foliar Fe is explained by treatment differences ($P<0.01$) (Appendix 11.2). Foliar Fe from site C2, which represents the lowest mean foliar Fe content, is significantly different from that in most other sites except site BS. Treatment site BHS, which represents the highest mean foliar Fe content, is significantly different in foliar Fe from sites C1, BS and C2, respectively decreasing in mean Fe content. Decreasing mean foliar Fe contents are also found in sites HS, S and H respectively.

The highest mean foliar N, P and Fe contents are found in site BHS; and the highest mean Mn contents occur in sites

BS and S. The lowest mean foliar N and Fe contents are found in sites C2 and C1; sites HS, H and C1 contain the lowest mean P contents; and site H yields the lowest mean foliar Mn content.

4.4.3.3.3 Salal

A highly significant ANOVA ($P<0.01$) involving the macronutrient Ca explains a reasonable proportion of its total variation ($r^2=.74$) (Appendix 12.0). ANOVA's involving nutrients N, Mg, Fe and Cu are not significant ($P>0.05$).

In sites BH and B, salal yields significantly lower mean Ca contents than in sites C2 and H. Site C1 is also significantly higher in foliar Ca than site B.

4.4.3.3.4 Alder

Highly significant ANOVA's ($P<0.01$) involving the macronutrients K and Ca explain a reasonable proportion of the total variation in the nutrients concerned ($r^2>.70$). Although less than 67% of the variation in outstanding nutrients is explained by treatment differences, ANOVA's are also significant for Mn, Fe and Cu ($P<0.01$). Analyses involving macronutrients N, P and Mg are not significant ($P>0.05$). Therefore, only ANOVA's involving K and Ca are reported.

Over 74% of the total variation in foliar K is explained by treatment differences ($P<0.01$) (Appendix 13.0).

Treatment site S contains significantly more foliar K than sites BS and HS. Site BHS is also significantly higher in mean K than site HS which represents the lowest mean foliar K content among sites.

Over 72% of the total variation in foliar Ca is explained by treatment differences ($P<0.01$) (Appendix 13.0). Site HS contains significantly less foliar Ca than sites BS, S and BHS. Sites S and BHS tend to show higher mean foliar Ca contents.

Sites S and BHS contain generally higher mean foliar Ca and K than treatment sites BS and HS. Site HS contains consistently less of these nutrients than sites BS, S and BHS.

4.4.4 Vegetative Cover

Multi-factor ANOVA is employed to determine if variation in each species' vegetative cover is explained by differences in treatment, site age and site attributes.

4.4.4.1 Huckleberry

ANOVA is employed to determine if variation in huckleberry cover is significantly explained by treatment, site age and site attributes. Approximately 64% of the total variation in huckleberry cover is explained ($P<0.01$);

Adjusted SS indicate that aspect ($P<0.01$), slope ($P<0.01$), slope position moisture ($P<0.05$) and moisture regime ($P<0.05$) significantly explain this variation. Placement ($P=0.0515$) is not significant (Appendix 14.1).

Multiple range analysis indicates that south aspects yield higher huckleberry cover than level, north or west aspects. South and south-west aspects are not significantly different. Slopes that are 45-60% yield significantly lower huckleberry cover than slopes that are less than 45%. Slope position moisture classes do not yield significantly different huckleberry cover. Mesic moisture regimes yield significantly higher cover than hygric regimes. Slash-covered sites yield significantly greater cover than mineral or duff-covered sites. Sites covered with organic matter also yield significantly more cover than duff-covered sites.

4.4.4.2 Salmonberry

ANOVA is employed to determine if variation in salmonberry cover is significantly explained by treatment, site age and site attributes. Over 51% of the total variation in cover is explained ($P<0.01$). Adjusted SS indicate that treatment ($P<0.01$), age ($P<0.01$), slope position ($P<0.01$) and placement ($P<0.05$) are significant. Slope ($P=0.0577$) is not significant (Appendix 14.2).

Treatment site C2 yields significantly greater salmonberry cover than sites BS, S and BH; and site H yields significantly greater cover than sites S and BH. Sites aged 7 years also yield significantly more cover.

Multiple range analysis also indicates that valley floor sites yield significantly greater salmonberry cover than either lower or middle slope positions, the least cover being found in middle slopes. Irregular-flat surface shapes yield significantly greater salmonberry cover than irregular-straight, irregular-concave and irregular-convex surface shapes, the least cover being found in the latter surface types. Placement in swamps, duff and organic material yields significantly greater salmonberry cover than placement in mineral, rock and slash material.

Treatment sites C2 and H occupy moisture-receiving, lower slope to valley floor positions with mineral or rock substrate over an irregular-concave surface. The lower slope moisture-receiving position of site C2, with its rock and mineral substrate, permits relatively continuous through-flow of nutrient-rich soil solution. Poorly drained substrates (e.g. clay) or a lower gravitational potential (e.g. valley floor position) do not favour salmonberry cover as significantly (e.g. sites BS, S and BH).

4.4.4.3 Salal

ANOVA is employed to determine if variation in salal cover is significantly explained by treatment, site age and site attributes. Over 54% of the total variation in salal cover is explained ($P<0.01$); Adjusted SS indicate that treatment ($P<0.01$), aspect ($P<0.01$), slope ($P<0.01$), elevation ($P<0.01$) and slope position ($P<0.01$) are highly significant (Appendix 14.3).

Treatment site B yields significantly more salal cover than the other sites, followed by sites C2 and BH (both similar in salal cover). Significantly less salal cover is found in sites HS, BHS, BS, S, C1 and H, decreasing in salal cover respectively.

Multiple range analysis also indicates that south-west aspects yield significantly greater salal cover than west, south, level and north aspects, respectively decreasing in salal cover. Slopes ranging from 15-30% yield significantly more salal cover than slopes 0-15%, 30-45% and 45-60%, decreasing in salal cover respectively. Elevations ranging from 40-80m yields significantly more salal than those ranging from 0-40 m and those exceeding 160 m. Middle slope positions yield significantly more salal cover than lower slope or valley floor positions, significantly decreasing in cover respectively. Rocky substrates also yield significantly more salal cover than other material.

Like site BH, treatment site B has a south-west aspect although its slope angle is lower at about 20%, more like that in site C2. Elevation differences between these three sites are not marked; moisture characteristics are similar. However, sites BH and C2 are more irregular in surface shape than site B, and site B has relatively more slash and rock than either site C2 and particularly site BH. Thus, site B is characterized by gently sloping, south-west facing, mesic, flat ground covered with slash and rock, and greater salal cover.

4.4.4.4 Alder

ANOVA is employed to determine if variation in alder cover is significantly explained by treatment, site age and site attributes. Over 46% of the total variation in cover is explained ($P<0.01$). Adjusted SS indicate that treatment ($P<0.01$), age ($P<0.01$), slope ($P<0.05$), moisture regime ($P<0.01$) and surface shape ($P<0.01$) are significant (Appendix 14.4).

Treatment sites BS and S yield significantly greater alder cover than sites BHS and C2. Decreasing alder cover is shown in sites H, C2 and BH respectively. A site aged 7 years also yields significantly more alder cover.

Multiple range analysis also indicates that slopes from 0-15% yield significantly greater alder cover than slopes 15-30% and 45-60%, significantly decreasing in cover respectively. Mesic moisture conditions also yield significantly greater alder cover than hygric conditions. Irregular-flat surfaces yield significantly more alder cover than irregular-concave and irregular-straight configurations, significantly decreasing in cover respectively.

Treatment sites BS, S, H and BHS occupy the valley floor whereas sites BH and C2 occur on the lower slopes. Although the moisture conditions and surficial materials in site H are substantially different from those in the other sites, sites in the valley floor share the same predominant slope angle (0-15%), moisture regime (mesic) and surface shape (smooth-flat to irregular-flat). Site BHS is duff-covered whereas sites C2, BS and S are mineral covered.

The evidence indicates that in the valley floor, scarified sites (BS, S, BHS) yield more alder cover than unscarified sites on the lower slopes (H, C2, BH). Alder cover in site BHS is significantly lower than that in sites BS and S, likely because of greater duff cover in site BHS in contrast to mineral placement in sites BS and S. This difference in placement is apparently not due to scarification since sites BS, S, HS and BHS have all been scarified.

Of the four sites significantly lower in alder cover than sites BS and S, three involve glyphosate treatment and the fourth is a control site (C2). Recall that sites C2 and BH occupy a moisture-receiving, lower slope position; site H is hygric; and site BHS is duff-covered. Thus, moisture conditions and placement are less favorable for alder growth in these sites.

Identification of treatment effect, separate from site effect, is often made difficult by the variation in site attributes among treatment sites. Nevertheless, it can be stated with reasonable certainty that scarification is the main causal factor of the high alder cover found in treatment sites BS and S. A variable glyphosate application may also explain differences in the alder cover of other similar sites. Burning of these sites has had little or no impact on alder growth.

4.4.4.5 Hemlock

ANOVA is employed to determine if variation in hemlock cover is significantly explained by treatment, site age and site attributes. Over 40% of the total variation in hemlock cover is explained ($P<0.01$); Adjusted SS indicate that treatment ($P<0.05$), aspect ($P<0.05$), elevation ($P<0.05$), slope position moisture ($P<0.01$), moisture regime ($P<0.01$)

and placement ($P<0.01$) are significant. Surface shape ($P=0.0526$) is not significant (Appendix 14.5).

Treatment site B yields significantly less hemlock cover than sites H, BS, BH and C2, decreasing in cover, respectively. Although ANOVA indicates that certain site attributes significantly explain variation in hemlock cover, no significant differences are detected using multiple range tests ($P=0.05$). Thus, significantly less hemlock cover in site B, and decreasing hemlock cover in sites H, BS and BH respectively, strongly suggest that burning adversely affects hemlock cover.

5.0 CONCLUSIONS

5.1 INTRODUCTION

Reforestation in productive second growth sites is made difficult by competing forest vegetation such as alder, salmonberry and salal. Site preparation techniques that include scarification, burning and herbicide application are commonly practiced to reduce this brush competition and to provide a desirable seed bed for both natural and artificial regeneration. To investigate the growth response of secondary vegetation (e.g. major competitors) to these treatments (i.e. their relative effectiveness in weed control), two research questions were posed: (1) how are the treatment sites different with respect to vegetative cover, site conditions and soil and foliar nutrients? and (2) in what way do the treatments affect growth in the competing species? Having addressed these two research objectives, it is now possible to discuss the nature of vegetative growth response (% cover) to treatments and site attributes.

5.2 DESCRIPTIVE SUMMARY

Cross tabulations between treatment sites and categories of each site attribute indicate that the predominant aspect is level although sites BH, B and C1 face south, west and northeast respectively. With the exception

of site BH (15-30%), slopes are minimal (0-15%). Similarly, elevation is minimal (0-40 m) except for sites BH (40-80 m) and C1 (160-200 m). Most sites occupy a valley floor position except sites BH, B and C1 which occur on the lower slopes. Site H is hygric, occupying a moisture-receiving slope position although the predominant moisture regime among treatment sites is mesic with normal slope position moisture. Site C1 tends toward a moisture-shedding position. Most surface shapes are irregular-flat except in sites Bh, C2, B and C1 which have irregular-straight surfaces. Placement is varied among the sites: Scarified sites have exposed mineral material; sites C2 and B are slash-covered; site H is somewhat swampy and organic; site BH is also covered with organic material; and site C1 is duff-covered.

Any change in habitat or disturbance (e.g. site preparation) that creates environmental and/or physiological stress results in a change in floristic diversity (Wilson & Bossert, 1971). Therefore, differences in floristic diversity (based on each site attribute) that are significantly explained by treatment are indicative of environmental and/or physiological stress. However, treatment effect cannot be claimed with complete certainty since adequate pre- and post-treatment assessments have not been conducted. Some site attributes are treatment-specific as well, suggesting that differences in floristic diversity

merely reflect these inherent site differences. Differences in floristic diversity based on aspect and elevation are best defined: Level, low elevation sites have greater floristic diversity than northeast-facing, higher elevation sites in particular.

In all cases, floristic diversity significantly decreases with site age. This reflects the scale of measurement unit that is used to sample revegetation (e.g. 2 m^2 quadrat). For assessing herbaceous species or plants with prostrate form the quadrat is suitable. It is less suitable for measuring larger vegetation increasing in size with age.

5.3 PCA

Results of R-mode PCA on site and floristic data are consistent with previously reported descriptions of these data. By relatively grouping the treatment sites along the major component axes, PCA demonstrates that sites C2, BS, S, HS, H and BHS are collectively more similar in site characteristics than sites BH, B and C1 that are also similar.

Treatment sites BH and C1 are higher in elevation and slope followed by sites B and C2. PCA also shows that treatment site C1 has much lower floristic diversity than the other sites, supported by plots of mean floristic diversity among sites. With the exception of site C1,

floristic diversity based on moisture is slightly higher in sites occupying the valley floor (BS, S, HS, BHS) and about average in other sites (BH, C2, H, B).

Thus, differences in treatment sites and floristic diversity are distinguished primarily with respect to elevation, slope and moisture, and also aspect. Based on these findings, use of site C1 as a control is questionable, particularly in comparison with valley floor sites.

5.4 SITE FERTILITY

5.4.1 Soils

In forest management, nutrient cycling within the forest-soil system is a primary concern since it is by manipulation of both forests and soils that the major nutrient changes occur (Armson, 1977). As forest vegetation increases in dimensions, the plant biomass and nutrient pool within it will also increase, particularly the less mobile nutrients such as Ca. However, the growth response to changing fertility is species-specific and relates to species density and to the density of roots and canopy (Armson, 1977). This implies that soil nutrient availability to plants not only depends on soil nutrient contents but is influenced by rooting depth, root configuration, soil moisture physics (including pH), and temperature regime (Armson, 1977). If a nutrient occurs in a plant, then it

must have been available in the soil (and also in the atmosphere in the case of N).

Although the fertility of a soil is ultimately shown by the growth of plants it supports, measurement of total soil nutrients forms the basis of fertility comparisons among treatment sites. Soil nutrients are generally less variable in treatment sites H and BHS and more variable in treatment sites BS and C2. Soils in sites H, B and BH are associated more with organic (humic) colloids. Scarified soils in treatment sites S, BS, HS and BHS are associated more with mineral (clay) colloids (i.e. a product of scarification).

Soils exhibiting higher total nutrient contents (e.g. in treatment sites BH, H, B and C1) may not necessarily indicate significantly higher nutrient availability to plants. The fact that soil pH increases and total nutrients decrease from the A to the B horizon suggests that higher nutrient availability (from eluviation) occurs in the silty B horizon.

Based on this pretense, scarified soils tend to have lower nutrient availability. Although these occur in the valley floor, they are low in organic matter and consist largely of clay and sand. Some scarified soils (e.g. in site BS) have relatively good horizonation with effective rooting in the B_f horizon, while others (e.g. in sites S and BHS) have poor horizonation with decreasing CEC. This is probably

the result of a clayey B horizon underlain by porous, sandy material.

Soils in the lower slope sites have highly organic A horizons with subsurface sandy or silty loams. These soils, and generally soils disturbed less by mechanical site preparation, have higher contents of organic matter (e.g. in B, BH and C1 soils); Na (e.g. in C2, B and C1 soils); N (e.g. in BH and H soils); Ca (e.g. in H soils); Mg (e.g. in BH soils); and K (e.g. in C1 and BH soils) than scarified soils. CEC is also lower in scarified soils than in unscarified soils. The low CEC found in sites BHS and S particularly, may be attributed to low organic matter content and poorly drained clay soils in the effective rooting zone underlain by sandy soil, and implies a more intensive scarification of these sites.

Treatments significantly account for differences in soil nutrients and also in the foliar nutrients of each species, as confirmed by ANOVA. However, correlations between the foliar nutrients and cover of each species and also between soil nutrients and each species' cover indicate that nutrient levels are not related to vegetative abundance. Although foliar nutrients may be a useful measure of soil fertility (Armson, 1977), and they may indicate differences in the vigor and health of a site resulting from a specific treatment (supported by ANOVA), their utility to

foresters for the explicit purpose of estimating biomass is questionable. Significant differences in a species' cover does not require a concomitant change in available nutrients but can occur in response to changing canopy structure and/or composition.

5.4.2 Vegetative Cover

Summary statistics indicate that each species responds differently in cover to different treatments. Although mean huckleberry cover is highest in treatment site BH (14%), most huckleberry cover varies from about 4-24 % in the quadrats sampled. Mean salmonberry cover is highest in treatment site C2 (48%) although most salmonberry cover varies from about 6% to 90% in the quadrats sampled. Mean salal cover is highest in treatment site B (44%) although most salal cover varies from about 20% to 66% in the quadrats sampled. Mean alder cover is highest is treatment site B (47%) although most alder cover varies from about 15% to 80% in the quadrats sampled. Mean hemlock is greatest in treatment site H (20%) although most hemlock cover varies from about 5 to 34% in the quadrats sampled. Some quadrats in sites C1 and C2 attain 45% hemlock cover and in site BHS it reaches up to 95% in some quadrats. These results are consistent with the literature on autecological preferences of these species in similarly managed sites (Haeussler & Coates, 1986).

5.4.2.1 Huckleberry

Substantial differences in huckleberry cover are explained by aspect, slope, moisture regime and placement, though not by treatment. Greater huckleberry cover occurs on predominantly south-facing, mesic, organic-covered sites sloping 15-30%, often with salal and salmonberry.

Since foliar Fe in huckleberry is significantly lower in treatment site BH than in sites B and C1, and BH soils contain more sand than either C1 or B soils, Fe availability to huckleberry is lower in BH sites. Treatment with glyphosate appears to have resulted in lower Fe mobility in BH sites compared to that in B and C1 sites since less organic matter occurs in BH soils and Fe^{3+} requires chelation (e.g. from organic compounds) for uptake in the more soluble Fe^{2+} form. BH soils also have more abundant soil Mg and Ca cations than B and C1 soils that likely compete for chelating agents in BH soils and reduce the net amount of Fe available for huckleberry uptake. These differences in Fe availability are important since greater mean huckleberry cover occurs in treatment site BH (about 14%). Thus, the use of glyphosate may have decreased Fe and increased Mg and Ca availability to huckleberry resulting in greater growth in this species (e.g. Fe may have a toxic effect). Differences in nutrient availability from burning have not been detected.

The abundance of huckleberry in site BH (varying from about 4 to 24%) would probably not be considered a threat to crop tree growth. Instead, it may be considered valuable as a wildlife browse species. Differences in salmonberry and salal cover affecting growth in huckleberry are not apparent.

5.4.2.2 Salmonberry

Treatment, site age, slope position, surface shape and placement account for significant differences in salmonberry cover. Treatment sites C2 and H, significantly higher in mean salmonberry cover, occupy a moisture-receiving, lower slope to valley floor position with swampy/organic or slash material. This combination of site factors is unique to these two treatment sites and implies continuous nutrient enrichment from upslope facilitated by a high gravitational potential and well-drained substrate.

Since salmonberry cover is similar in these treatment sites (C2 and H), direct glyphosate impact on salmonberry cover appears to have been minimal. Less salmonberry cover (about 15%) is found in site BH which occurs in predominantly drier, submesotrophic conditions, and implies that less salmonberry occurs on burned, unscarified sites.

Although foliar N, P, Mn and Fe are more often higher in scarified treatment sites BHS and S than in site C2, their soil CEC and Ca and K contents are low. Less silt and

clay occur in C2 soils, suggesting that in scarified soils, Ca and K are less available to salmonberry than in undisturbed C2 soils. Alder has apparently outcompeted salmonberry for Ca and K in BHS, S and BS soils, where CEC's are generally lower. This has resulted in a lower mean salmonberry cover occurring in scarified sites (cover<32%) than in unscarified sites C2 and H (cover>40%). In addition, low nutrient availability in some scarified soils is attributed to significantly higher silt and clay contents even though their total nutrient contents are high (e.g. Ca in HS soils).

Thus, scarification has resulted in lower salmonberry cover due to the low nutrient availability in soils associated with this mechanical disturbance (e.g. mineral, silt & clay, colloids) and also due to the superior ability of alder to secure Ca and K under these conditions. In unscarified sites (e.g. H), salmonberry foliage contains significantly less P and Mn than that in site C2. Since mean cover is lower in site H, this implies that salmonberry growth may be limited by low availability of these nutrients in unscarified sites treated with glyphosate where Ca and K are not limited by alder.

The abundance of salmonberry in unscarified sites (e.g. C2) where most variation occurs from 5 to 90% makes management prescriptions very difficult. Even in scarified sites, the amount of salmonberry cover (from 5-40%) depends

more on nutrient availability since no differences in cover from burning and/or glyphosate are evident.

Any form of subsequent site preparation must avoid soil disturbance since this will likely cause vigorous resprouting from salmonberry rhizomes (Haeussler & Coates, 1986). Burning and scarification are therefore not recommended. Use of herbicide to reduce salmonberry cover directly or indirectly by decreasing the availability of nutrients to salmonberry (particularly P and Mn) might be an advantage over indiscriminant use of brush saws that may be a danger to salmonberry-suppressed and often hidden conifer seedlings.

5.4.2.3 Salal

Significant differences in salal cover are accounted for by treatment, aspect, slope, elevation and slope position. For example, treatment site B, which occupies a predominantly west-facing, slash-covered, lower slope position approximately 0-40 m in elevation, has significantly more salal cover (over 40%) than the other treatment sites. The hygric treatment site H has the least amount of salal cover (approximately 10%). However, substantial site-treatment interaction makes it difficult to separate their respective effects. Even so, three main points are made: (1) the direct effect of glyphosate on salal cover is minimal but can affect salal biomass

indirectly through structural canopy alteration; (2) on hygric sites, salal growth is not a concern; and (3) burning of south- or west-facing slopes with slash-covered, shallow, rocky soils should be avoided.

Foliar Ca is significantly lower in treatment sites BH and B than in sites C2 and H. In sites C2 and H, mean salmonberry cover exceeds 40% whereas mean salal cover decreases significantly in sites B (about 44%), C2 and BH (about 33%) and H (about 3%). This implies that salmonberry outcompetes salal for available Ca in site H, but competition for available Ca is likely more intense in site C2. Even so, in sites B in particular, BH and C2, the abundance of salal is apparently not limited by low Ca availability. However, with few competitors and available light, Ca (essential for normal cellular membrane functions) may offer an important advantage to salal growth in moister sites.

Differences in the abundance of salal are best explained by differences in light intensity: implicitly higher light intensity in sites facing south, southwest and west (e.g. sites B, BH and C2, in part) is directly related to greater salal cover than that in level sites (e.g. site H). However, differences in the abundance of salal in south- or west-facing sites where most variation can occur from 10 to 70% makes management prescriptions difficult.

Since burning tends to increase the diurnal temperature at soil surfaces, its effect is compounded with implicitly higher temperatures associated with southerly aspects and increasing slope. These environments may be suitable only to a few species capable of avoiding relatively severe evapotranspirative stress (e.g. salal). Burning of south- or west-facing slopes is therefore not recommended.

Any form of soil disturbance that causes mechanical damage to salal but does not eradicate it from the site (e.g. low impact burn, use of brush saws or mulching) will likely stimulate resprouting (Haeussler & Coates, 1986). In addition, several studies support the inverse relationship of salal biomass to overstory cover (Stanek et al., 1979; Long, 1977; Long & Turner, 1975). This also implies that the drier, nutrient poor sites are more suited to salal since they require a physiology capable of withstanding severe evapotranspirative stress and tolerant of oligotrophic conditions; and fewer competing species occur in these sites that limit increasing salal biomass.

In sites where salal is considered a threat to crop tree growth, it should be eliminated from the site with minimal soil disturbance. This might involve the use of herbicide and subsequent mulching of dead foliage and/or use of organic mill wastes to increase moisture and nutrients in these drier sites, and thus increase the potential for crop tree establishment and suppression of unwanted revegetation.

5.4.2.4 Alder

Significant differences in alder cover are accounted for by treatment, site age, slope, moisture regime and surface shape. Significantly more alder cover in treatment sites BS and S (about 60%) is attributed to the mineral seed bed produced by scarification, to the ability of alder to fix N when available N and CEC are low, and to a high soil Na content that disperses clay colloids for improved nutrient uptake in alder. Alder cover is not as prominent in hygric or duff-covered valley bottom sites similarly treated, or in moisture-receiving lower slope sites. Burning has apparently has little or no impact.

Minor differences in the substrate and moisture conditions of BHS, H and BH treatment sites confound the effects of herbicide treatment. Its efficacy in significantly reducing alder cover in these treatment sites from that in the control site (C2) is not supported. Substantial site-treatment interaction makes it difficult to separate their respective effects. Like salmonberry, less alder occurs in treatment site BH (about 15%) which is situated predominantly in drier, submesotrophic conditions.

Foliar K and Ca are generally lower in treatment site HS than in sites BHS, BS and S. Mean alder cover is also significantly lower in site HS (about 24%) than that in other scarified sites (exceeding 25%). Differences in cover apparently reflect availability of these nutrients to alder

since HS soils contain significantly higher amounts of silt and clay than soils in BS, S and BHS sites. Consequently, differences in the properties of scarified soils may reflect the depth and intensity of scarification used in each site. However, this was not previously assessed.

Among the scarified sites, alder cover my range from 1 to 99%, although it is most variable in site HS. Since scarified sites also treated with glyphosate have lower mean alder cover (e.g. sites BHS and HS < 30%) than scarified sites not treated with herbicide (e.g. BS and S > 45%) some herbicide effect may have occurred. Also in site H, herbicide treatment without scarification has resulted in a mean alder cover (28%) comparable to that in site BHS (i.e. burned, herbicided, scarified). This implies that some glyphosate impact has occurred. Comparison of scarified and burned treatment sites indicates that burning has had a minimal effect on alder cover in these sites.

A Microfoil boom was used to apply glyphosate, minimizing drift by providing a larger drop size. However, some droplets of glyphosate may not have impacted some of the foliage in the desired dispersion (e.g. some of the active ingredient may have "run off" branches and meristems with minimal leaf contact). Field observations of burned alder leaders and vigorous lateral growth support this hypothesis (sites BHS and H). The coastal topography may also have contributed to variation in the flight path and

aerial application and resulting herbicide effect among those treatments involving glyphosate.

Although mean alder cover is higher in scarified sites (BS, S, HS and BHS) than in unscarified sites (BH, C2, H and B), most cover varies from 1 to 80%. In unscarified sites, alder cover varies from 0 to 65%. Alder is absent from the quadrats sampled in site C1, characterized by northeast-facing, higher elevation sites (160-200 m), with irregular-straight, duff covered surfaces, in contrast to the level, low elevation scarified sites (0-40 m) with irregular-flat, mineral covered surfaces.

The abundance of alder is highly variable in both scarified and unscarified sites, making management of this species difficult. Since alder provides N and organic matter to nutrient poor soils, it is beneficial to crop tree growth. However, its rapid juvenile growth tends to suppress conifer seedlings (Haeussler & Coates, 1986). This implies that subsequent site preparation for control of unwanted revegetation is essential. Even so, subsequent site preparation to selectively remove alder may result in a change in the dominant species occupying scarified sites (e.g. in scarified sites, removal of alder that outcompetes salmonberry for available Ca and K may promote salmonberry growth).

Since soil disturbance may promote establishment of alder and resprouting from rhizomatous species (e.g.

salmonberry), and selective removal of alder may promote growth in salmonberry, subsequent site preparation must not discriminate between these major competitors; it must have minimal soil disturbance; and it must maintain N and organic inputs into the forest-soil system. This might involve the use of herbicide applied in a mosaic pattern (e.g. with alder leave-strips or islands). Minimal soil disturbance would thus occur; N and organic matter inputs from alder would still be available; and available canopy and rooting space in herbicide treated openings would increase the potential for conifer seedling establishment and growth.

5.4.2.5 Hemlock

Significant differences in hemlock cover are explained by treatment: burning significantly decreases hemlock cover. Greater mean hemlock cover occurs in treatment site H (approximately 20%) where salal cover is lower (about 3%). Although natural hemlock regeneration tends to be overdense where it occurs, greater cover may be found in moist sites with irregular-convex surfaces located in the valley floor. Seed bed preferences of hemlock, particularly in localized depressions where there is ample moisture but no flooding (Long, 1977; Newton, 1976) often result in an irregular seedling distribution such as occurs in site BHS.

Although significant differences in vegetative cover may be explained by treatment, it is difficult to state with

complete certainty that these are the causal factors of growth differences. It is often difficult to separate site and treatment effects due to some apparent treatment-site interactions and insufficient use of pretreatment controls.

Mean foliar N is greater in treatment site B (1.32%) than in sites BH (1.05%) and C1 (1.08%), although it is most variable in site B and least variable in site C1. Since mean hemlock cover is lowest in site B (cover<6%) and cover decreases in sites H, BS and BH, burning apparently results in less hemlock growth. Thus, lower N availability does not appear to limit hemlock growth. However, soil moisture and organic rooting media are fundamentally important in this respect (e.g. hygric site H has 15% greater mean cover than the drier, west-facing site B). Sites treated with herbicide (sites H and BH) also have greater hemlock cover (20% and 13% respectively) than treatments without herbicide (e.g. sites C2, BS, C1 and B $\leq$ 12%). This implies that glyphosate has had an indirect, beneficial effect on hemlock cover by reducing the abundance of one or more neighboring canopy species (e.g. salmonberry in sites H and BHS). This relationship can also be seen among burned treatment sites with and without herbicide, respectively: Mean hemlock cover is 12.8% in site BH; 11.8% in site BS; and 5.4% in site B.

Well aerated and well drained but moist mineral soil with dark organic matter or duff on the surface may promote hemlock growth (e.g. sites BHS and H). Thus, site

preparation for hemlock regeneration must avoid soil damage and preserve or improve soils moisture physics, surface organic matter and associated soil mycorrhizae. This would explain the apparent relative success of hemlock growth in subhygric, moisture-receiving, low elevation sites with minimal slope treated with glyphosate (e.g. sites H and BHS) in contrast to the drier, west-facing slash-covered sites, broadcast burned in the fall.

Fall burning of south- or west-facing slopes may lead to higher diurnal temperature fluxes and consequently lead to excessive moisture stress in this species. These dry and often nutrient poor sites are better tolerated by salal with minimal interspecific competition.

Although mean hemlock cover in site H is substantially higher than that in other sites, it may vary from 5 to 35%. In sites BH, C2 and C1, it ranges from 1 to 40^{+}% and up to 95% in site BHS. This substantiates the fact that natural hemlock regeneration tends to be overdense where it occurs, and implies that future thinning and intensive stand tending are necessary. This may be more costly in the long-term than managing for artificial hemlock regeneration. As previously indicated (Chapter 2.0), differences in the success of natural and artificial regeneration were not addressed in the initial CFS study objectives, and therefore have not been examined in this study.

5.5 RECOMMENDATIONS

The implications of this research are that there is a critical need for better understanding of site-treatment interactions and species-site interactions which are fundamental to an understanding of species-treatment interactions in any context. Research in an operational setting such as Carnation Creek Watershed must emphasize the use of sufficient pretreatment sampling and adequate controls for each treatment that is conducted, particularly when combined treatments are concerned.

As a priority, more information is needed on the autecology of selected species (e.g. alder, salmonberry and salal), particularly on their phenology. Such information will aid in the application of silvicultural treatments to achieve management objectives.

In productive coastal sites, reforestation is retarded by competition from forest vegetation, particularly alder, salmonberry and salal. Their occurrence represents an ecological response to environmental change resulting from forest canopy removal and subsequent site preparation (i.e. to an earlier successional phase).

This study demonstrates the value of an interdisciplinary research approach. Future research into vegetation/treatment relationships may also benefit from examination of some of the ecological conditions that define them.

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APPENDIX 1.0

PHOTOGRAPHIC PLATES

Plate 1: *Alnus rubra* Bong.

APPENDIX 1.0 (Cont'd)

Plate 2: Rubus spectabilis Pursh

APPENDIX 1.0 (Cont'd)

Plate 3: Gaultheria shallon Pursh

APPENDIX 1.0 (Cont'd)

Plate 4: Vaccinium parvifolium Smith

APPENDIX 1.0 (Cont'd)

Plate 5: Tsuga heterophylla (Raf.) Sarg.

APPENDIX 2.0

LIST OF ABBREVIATIONS AND SYMBOLS USED

General Text

CFS	Canadian Forestry Service
MB	MacMillan Bloedel Ltd.
TFL	Tree Farm License
NSR	Not satisfactorily restocked
CWH	Coastal western hemlock biogeoclimatic zone
$CWHb_1$	CWH variant: wetter, submontane, windward

Treatments

M.B.	Manual broadcast burn
H.B.	Helicopter broadcast burn
A.I.D.	Aerial ignition dispenser
B	Burned
BH	Burned + herbicided
BHS	Burned + herbicided + scarified
H	Herbicided
HS	Herbicided + scarified
S	Scarified
C1	Control 1
C2	Control 2
FD	Floristic diversity (refer to Chapter 3.0, section 3.6)

Site Attributes (refer also to Table 4.0)

Aspect	Aspect (N = north, E = east, S = south, W = west, NE = northeast, SE = southeast, SW = south-west, NW = northwest, L = level)
Slope	Slope angle (expressed as a percent)
Elev'n	Elevation (m)
Mreg	Moisture regime (Hydric, hygric, mesic, xeric)
Spos	Slope position (Valley floor, lower-, middle-slope)
Shape	Surface shape (e.g. Irregular concave)
Placmt	Placement (e.g. skid road, slash)

Numerical Analyses

ANOVA	Analysis of variance (factorial)
ANOCOVA	Analysis of covariance
GLM	General linear model
PCA	Principal component analysis
Prin(n)	Principal component (n) = 1, ... , n

APPENDIX 2.0 (cont'd)

Chemical Analyses

M	Molar (molarity: moles of solute/liter of final solution)
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
Mn	Manganese
Fe	Iron
Cu	Copper
Zn	Zinc
B	Boron
S	Sulfur
Na	Sodium
Se	Selenium
$CaCl_2$	Calcium chloride
KCl	Potassium chloride
H_2SO_4	Hydrogen sulfate
K_2SO_4	Potassium sulfate
$CuSO_4$	Copper sulfate
CH_3COONH_4	Ammonium oxaloacetate

Soil Variables

CEC	Cation exchange capacity
Orgmatr	Organic matter
O.M.	Organic matter
$pH(H_20)$	Soil reaction determined in water
$pH(CaCl_2)$	Soil reaction determined in $CaCl_2$

APPENDIX 3.0

CARNATION CREEK VEGETATION LISTING AND SPECIES CODES

Code	Common Name	Latin Name
1	Evergreen huckleberry	Vaccinium ovatum Pursh
2	Tall (blue) huckleberry	V. ovalifolium Smith
3	Red huckleberry	V. parvifolium Smith
4	Thimbleberry	Rubus parviflorus Nutt.
5	Salmonberry	R. spectabilis Pursh
6	Red elderberry	Sambucus racemosa L.
7	Black raspberry	Rubus leucodermis Dougl.
8	Trailing blackberry	R. ursinus Cham.& Schlecht.
9	Willow	Salix glauca L.
10	Salal	Gaultheria shallon Pursh
11	Devils club	Oplopanax horridum (Smith)Miq.
12	Twinberry	Lonicera involucrata (Rich.) Banks
13	Stink currant	Ribes bracteosum Dougl.
14	False azalea	Menziesia ferruginea Smith.
15	Willow sp.	Salix sp.
16	Ocean spray	Holodiscus discolor (Pursh) Maxim.
17	Rose sp.	Rosa sp.
18	Goatsbeard	Aruncus sylvester Kostel.
19	Spirea	Spirea douglasii Hook.
20	Bitter cherry	Prunus emarginata(Dougl.)Walp.
21	Myrica gale	Myrica gale L.
22	Alum root	Heuchera parvifolia Nutt.
23	Enchanter's nightshade	Circea alpina L.
24	Violet	Viola sp.
25	Hedge nettle	Stachys palustris L.
26	Pearly everlasting	Anaphalis margaritacea(L.)B.&H.
27	Galium	Galium boreale L.
28	Mitus	Mitella pentandra Hook.
29	American brooklime	Veronica americana Schwein.
30	Tolmia	Tolmiea menziesii (Pursh)T.&G.
31	Deer fern	Blechnum spicant (L.)Roth.
32	Sword fern	Polystichum munitum (Kaulf.) Presl
33	Oak fern	Gymnocarpium dryopteris (L.) Newm.
34	Bracken fern	Pteridium aquilinum (L.)Kuhn.
35	Maidenhair fern	Adiantum pedatum L.
36	Lady fern	Athyrium filix-femina (L.)Roth.
37	Foam flower(unifoliate)	Tiarella trifoliata L.
38	Foam flower(trifoliate)	T. trifoliata L.
39	Fireweed	Epilobium watsonii Barbey
40	Fireweed	E. angustifolium L.
41	Trillium	Trillium ovatum Pursh

APPENDIX 3.0 (Cont'd)

Code	Common Name	Latin Name
42	Skunk cabbage	Lysichitum americanum Hulten & St.John
43	Lily of the Valley	Maianthemum dilatatum (Wood) Nels.& Macbr.
44	Twisted stalk	Streptopus amplexifolius(L.)DC.
45	Saxifrage sp.	Saxifrage sp.
46	Coltsfoot	Petasites frigidus (L.)Fries
47	Miners lettuce	Montia sibirica (L.)Howell
48	Cornus	Cornus canadensis L.
49	Bleeding heart	Dicentra formosa (Andr.)Walp.
50	Bulrush (large)	Scirpus sp.
51	Thistle	Cirsium vulgare (Savil)Tenore
52	Dandelion	Taraxacum officinale Weber
53	Juncus	Juncus effusus L.
54	Hairy cats ear	Hypochaeris radicata L.
55	Lactuca sp.	Lactuca muralis (L.)Fresen.
56	Senecio sp.	Senecio vulgaris L.
57	Water starwort	Stellaria sp.
58	Equisetum sp.	Equisetum sp.
59	Silver green	Adenocaulon bicolor Hook.
60	Wild carrot	Daucus carota L.
61	Sedge sp.	Carex sp.
62	Carex acquatilis	Carex acquatilis Wahl.
63	Carex rostrata	Carex rostrata Stokes
64	Grass sp.	Poa sp.
65	Luzula	Luzula parviflora (Ehrh.)Desv.
66	Small fruited bulrush	Scirpus microcarpus Presl
67	Moss sp.	
68	Liverwort sp.	
69	Sphagnum sp.	Sphagnum sp.
70	Pogonatum	Pogonatum sp.
71	Dicranum	Dicranum sp.
72	Dicranella	Dicranella sp.
73	Feathermoss	Hylocomium splendens (Hedw.) B.S.G.
74	Polytrichum	Polytrichum sp.
75	Rhytidiadelphus	Rhytidiadelphus sp.
76	Isothecium (stolons)	Isothecium sp.
77	Isothecium (spicules)	Isothecium spiculiferum(Brid.) Ren.& Card.
78	Sphagnum squarrosum	Sphagnum squarrosum Crome
79	Plagiothecium	Plagiothecium sp.
80	Douglas fir	Pseudotsuga menziesia (Mirbel) Franco
81	Coastal western hemlock	Tsuga heterophylla (Raf.)Sarg.
82	Western red cedar	Thuja plicata Donn.

APPENDIX 3.0 (Cont'd)

Code	Common Name	Latin Name
83	Yellow cedar	Chamaecyparis nootkatensis (D.Don)
84	Amabilis fir	Abies amabilis (Dougl.)Forbes
85	Sitka spruce	Picea sitchensis (Bong.)Carr.
86	White pine	Pinus monticola Dougl.
87	Western yew	Taxus brevifolia Nutt.
88	Blackthorn	Prunus spinosa L.
89	Red alder	Alnus rubra Bong.
90	---------	
91	---------	
92	---------	
93	Seedlings (all species)	
94	Douglas fir - planted	
95	Hemlock - planted	
96	Red cedar - planted	
97	Sitka spruce - planted	
98	Grand / Amabilis fir - planted	
99	---------	
100	---------	

SITE REF.	AGE (YR)	PH H20	PH CACL	O.M. (%)	N (%)	CEC (me / 100 g)	CA	MG (me	K / 100g)	NA	SAND (%)	SILT (%)	CLAY (%)	COARSE FRG(%)	HORIZON NAME	DEPTH (CM)
BH	8	4.7	4.2	9.7	0.23	39.9	1.01	0.33	0.160	0.10	43.7	36.4	19.9	43.29	BF	0-20
BH	8	3.8	3.2	77.3	1.21	150.7	13.71	10.75	1.490	0.58	0.0	0.0	0.0	37.67	AH	20-53
C2	8	5.0	4.6	39.9	0.25	106.4	8.21	2.10	0.190	0.36	0.0	0.0	0.0	11.68	AH-BH	0-10
C2	8	4.7	4.1	3.2	0.11	14.1	0.95	0.36	0.030	0.04	82.7	10.2	7.1	75.94	BM-BT	10-40
C2	8	4.1	3.7	36.7	0.69	86.3	10.28	3.40	0.450	0.24	0.0	0.0	0.0	45.09	AH	0-29
BS	6	4.3	3.8	11.2	0.26	34.1	2.71	1.18	0.150	0.07	67.2	16.3	16.5	76.54	AE-BE	25-30
BS	6	4.9	4.6	21.8	0.66	63.2	11.43	1.95	0.200	0.14	47.1	34.6	18.3	35.35	B-BH	0-10
BS	6	3.6	3.1	81.2	1.31	162.5	10.22	7.60	0.600	0.26	0.0	0.0	0.0	11.29	AH	0-25
BS	6	4.9	4.5	2.6	0.06	25.4	0.04	0.05	0.001	0.05	25.2	61.8	13.0	17.43	BF	10-41
S	6	5.3	4.6	6.5	0.05	8.3	1.46	0.25	0.180	0.03	88.6	7.6	3.8	74.34	BC	30-51
S	6	4.3	3.9	36.1	0.63	68.9	7.23	2.68	0.400	0.13	0.0	0.0	0.0	38.45	AH	0-10
S	6	4.8	4.4	10.5	0.30	39.6	3.36	0.65	0.100	1.10	53.8	28.0	18.2	33.08	B-BFN	10-30
HS	6	4.4	4.3	11.4	0.31	50.7	0.36	0.13	0.050	0.08	31.4	42.5	26.1	38.13	BF	10-55
H	8	5.0	4.6	38.7	1.00	96.4	17.40	3.55	0.380	0.18	0.0	0.0	0.0	34.94	A-AH	0-13
H	8	4.5	4.5	19.7	0.59	66.4	3.71	0.85	0.130	0.12	16.5	75.2	8.3	54.76	BH-BF	13-39
BHS	6	4.4	4.1	21.1	0.55	56.4	5.76	1.18	0.240	0.19	32.4	51.3	16.3	31.83	A	0-5
BHS	6	4.6	4.3	7.3	0.21	14.1	1.09	0.23	0.030	0.07	58.7	24.0	17.3	24.48	B-BGF	0-34
B	8	4.3	3.9	41.9	0.81	93.6	6.98	2.33	0.200	0.28	0.0	0.0	0.0	46.57	AH	0-40
B	8	5.0	4.6	82.3	0.39	56.6	0.94	0.33	0.050	0.10	0.0	0.0	0.0	64.95	BFH	40-88
C1	7	4.9	4.4	24.0	0.25	44.3	1.44	0.28	0.030	0.10	35.9	43.4	20.7	61.62	BF	17-65
C1	7	4.2	3.7	53.5	0.88	116.8	5.70	5.71	2.530	0.37	0.0	0.0	0.0	49.92	AH	0-17

APPENDIX 4.0 Soil data matrix showing field descriptions and results of laboratory analyses.

SITE	AGE (YR)	SPECIES NAME	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (PPM)	Fe (PPM)	Cu (PPM)	Zn (PPM)
C2	9	SALMONBERRY	1.75	0.14	0.91	0.91	0.55	600	96	5	12
C2	9	SALMONBERRY	1.78	0.18	1.08	0.78	0.53	510	105	5	13
C2	9	SALMONBERRY	1.78	0.16	0.84	0.76	0.51	870	96	4	13
C2	9	SALMONBERRY	1.81	0.19	0.97	0.75	0.58	690	96	4	14
BS	7	SALMONBERRY	1.94	0.17	0.90	0.73	0.49	1440	74	9	18
BS	7	SALMONBERRY	2.05	0.16	1.04	0.68	0.54	1560	74	9	18
BS	7	SALMONBERRY	2.10	0.17	1.02	0.70	0.53	1230	53	6	15
BS	7	SALMONBERRY	1.88	0.17	1.02	0.61	0.47	1350	53	6	18
S	7	SALMONBERRY	2.24	0.16	1.01	0.85	0.50	1200	98	18	24
S	7	SALMONBERRY	2.38	0.18	1.18	0.88	0.50	990	71	12	21
S	7	SALMONBERRY	2.17	0.15	1.20	0.84	0.46	1050	77	12	21
S	7	SALMONBERRY	2.18	0.18	0.92	0.86	0.52	888	173	18	18
HS	7	SALMONBERRY	1.88	0.12	1.03	0.87	0.55	567	83	9	24
HS	7	SALMONBERRY	2.09	0.14	1.22	0.65	0.56	444	95	12	21
HS	7	SALMONBERRY	2.28	0.16	1.24	0.63	0.53	453	137	21	21
HS	7	SALMONBERRY	2.04	0.13	1.22	0.60	0.57	417	83	15	18
H	9	SALMONBERRY	2.02	0.14	1.03	0.83	0.55	267	50	12	18
H	9	SALMONBERRY	2.24	0.13	0.88	0.81	0.40	369	110	21	21
H	9	SALMONBERRY	2.28	0.14	0.98	0.84	0.53	525	56	12	21
H	9	SALMONBERRY	1.91	0.13	1.23	0.75	0.51	147	128	27	18
BHS	7	SALMONBERRY	2.24	0.22	1.14	0.72	0.61	810	123	21	24
BHS	7	SALMONBERRY	2.54	0.24	1.40	0.68	0.52	630	48	9	21
BHS	7	SALMONBERRY	2.56	0.22	1.24	0.71	0.55	600	48	9	24
BHS	7	SALMONBERRY	2.41	0.23	1.24	0.73	0.53	570	45	9	27
C1	8	SALMONBERRY	1.39	0.10	1.07	0.81	0.50	600	39	12	21
C1	8	SALMONBERRY	1.72	0.11	1.15	0.82	0.52	750	75	9	18
C1	8	SALMONBERRY	1.64	0.10	1.32	0.75	0.49	1410	66	6	15
C1	8	SALMONBERRY	1.72	0.11	1.29	0.88	0.47	450	60	9	18
BS	7	ALDER	2.43	0.13	0.63	0.64	0.16	450	27	15	24
BS	7	ALDER	2.41	0.15	0.61	0.70	0.19	360	27	3	21
BS	7	ALDER	2.52	0.16	0.57	0.62	0.21	270	36	6	21
BS	7	ALDER	2.42	0.15	0.65	0.73	0.19	570	18	6	21
S	7	ALDER	2.42	0.14	0.71	0.86	0.20	420	92	18	36
S	7	ALDER	2.57	0.15	0.76	0.66	0.26	459	59	12	27
S	7	ALDER	1.19	0.12	0.79	0.78	0.17	561	77	18	27
S	7	ALDER	2.36	0.12	0.84	0.67	0.13	270	74	21	30
HS	7	ALDER	2.53	0.18	0.57	0.44	0.16	132	44	9	24
HS	7	ALDER	2.37	0.13	0.51	0.49	0.18	198	65	15	21
HS	7	ALDER	2.51	0.14	0.49	0.47	0.17	153	47	9	21
HS	7	ALDER	2.62	0.15	0.60	0.53	0.19	267	116	18	27
BHS	7	ALDER	2.71	0.17	0.87	0.73	0.22	360	33	6	30
BHS	7	ALDER	2.83	0.17	0.69	0.58	0.19	270	30	9	27
BHS	7	ALDER	2.69	0.16	0.74	0.76	0.25	360	33	9	30
BHS	7	ALDER	2.67	0.16	0.65	0.75	0.19	240	27	6	27

APPENDIX 5.0 Results of foliar laboratory analyses.

SITE	AGE (YR)	SPECIES NAME	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn (PPM)	Fe (PPM)	Cu (PPM)	Zn (PPM)
BH	9	HUCKLEBERRY	1.48	0.11	0.66	1.23	0.19	2730	90	6	16
BH	9	HUCKLEBERRY	1.41	0.09	0.77	1.17	0.23	1950	87	7	13
BH	9	HUCKLEBERRY	1.31	0.09	0.70	1.32	0.17	2250	69	3	10
BH	9	HUCKLEBERRY	1.49	0.11	0.61	1.30	0.27	2100	72	6	13
C2	9	HUCKLEBERRY	1.41	0.11	0.71	1.40	0.23	1830	99	6	19
C2	9	HUCKLEBERRY	1.36	0.11	0.67	1.42	0.22	2100	102	4	17
C2	9	HUCKLEBERRY	1.30	0.11	0.68	1.22	0.20	2370	105	6	18
C2	9	HUCKLEBERRY	1.42	0.11	0.68	1.30	0.23	2220	93	5	24
H	9	HUCKLEBERRY	1.37	0.19	0.82	1.04	0.19	1800	96	4	17
H	9	HUCKLEBERRY	1.37	0.10	0.83	1.68	0.21	1680	99	4	17
H	9	HUCKLEBERRY	1.32	0.11	0.92	1.07	0.20	1770	99	2	17
H	9	HUCKLEBERRY	1.37	0.12	0.80	1.29	0.20	4050	105	3	23
B	9	HUCKLEBERRY	1.29	0.09	0.78	1.02	0.21	1470	24	6	27
B	9	HUCKLEBERRY	1.35	0.10	0.77	0.97	0.19	1050	21	6	24
B	9	HUCKLEBERRY	1.20	0.09	0.77	0.82	0.17	1320	27	3	21
B	9	HUCKLEBERRY	1.51	0.09	0.80	0.70	0.13	930	66	15	21
C1	8	HUCKLEBERRY	1.36	0.09	0.64	1.19	0.23	2100	87	9	24
C1	8	HUCKLEBERRY	1.44	0.10	0.67	1.29	0.24	3150	57	9	24
C1	8	HUCKLEBERRY	1.36	0.10	0.95	1.12	0.20	1740	45	9	21
C1	8	HUCKLEBERRY	1.37	0.11	0.90	1.07	0.19	1800	45	6	15
BH	9	SALAL	0.93	0.09	0.71	0.98	0.33	1170	75	3	16
BH	9	SALAL	0.89	0.09	0.77	0.99	0.32	1290	99	4	19
BH	9	SALAL	0.89	0.09	0.74	1.10	0.34	1500	96	4	22
BH	9	SALAL	0.89	0.09	0.72	0.92	0.10	960	102	4	18
C2	9	SALAL	1.11	0.11	0.83	1.26	0.30	1260	96	4	34
C2	9	SALAL	1.05	0.10	0.63	1.49	0.34	2730	90	2	37
C2	9	SALAL	1.01	0.10	0.75	1.19	0.35	960	96	3	38
C2	9	SALAL	0.91	0.09	0.67	1.37	0.35	960	90	2	46
H	9	SALAL	0.96	0.08	0.63	1.14	0.31	2370	74	18	30
H	9	SALAL	1.02	0.10	0.80	1.40	0.44	1560	90	3	37
H	9	SALAL	0.98	0.09	0.72	1.43	0.42	2070	105	3	34
H	9	SALAL	1.01	0.09	0.57	1.33	0.37	1710	99	3	36
B	9	SALAL	0.95	0.07	0.60	1.06	0.31	1410	24	6	33
B	9	SALAL	1.05	0.08	0.68	0.85	0.29	1230	48	6	24
B	9	SALAL	1.02	0.09	0.69	0.97	0.34	1320	144	3	24
B	9	SALAL	1.02	0.09	0.72	0.86	0.28	1260	18	3	27
C1	8	SALAL	0.92	0.08	0.55	1.15	0.34	2810	54	9	27
C1	8	SALAL	1.01	0.09	0.62	1.06	0.31	2310	72	9	24
C1	8	SALAL	0.09	0.08	0.61	1.22	0.41	2850	24	1	27
C1	8	SALAL	1.05	0.08	0.57	1.32	0.40	1740	159	15	45

APPENDIX 5.0 (Cont'd)

PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0

		pHW	pHC	O.M.	CEC	Ca	Mg	K	Na	SAND	SILT	CLAY
HUCKLEBERRY (n = 91)	COVER	-0.36129 0.0004	-0.37383 0.0003	0.24519 0.0192	0.38602 0.0002	0.36832 0.0003	0.38055 0.0002	0.38033 0.0002	0.04737 0.6557	-0.24961 0.0170	-0.21093 0.0448	-0.25985 0.0129
SALMONBERRY (n = 379)	COVER	-0.06996 0.1741	-0.00666 0.8972	-0.02094 0.6845	-0.00387 0.9402	0.03932 0.4454	-0.06486 0.2077	-0.06872 0.1818	-0.20367 0.0001	-0.16858 0.0010	0.00211 0.9674	-0.15498 0.0025
SALAL (n = 368)	COVER	-0.04310 0.4098	-0.13256 0.0109	0.44730 0.0001	0.25143 0.0001	0.23918 0.0001	0.16881 0.0012	0.09158 0.0793	0.09764 0.0613	-0.41915 0.0001	-0.45567 0.0001	-0.44557 0.0001
ALDER (n = 335)	COVER	0.30760 0.0001	0.24003 0.0001	-0.16288 0.0028	-0.02961 0.5892	-0.08696 0.1121	-0.12851 0.0186	-0.12887 0.0183	0.13084 0.0166	-0.05152 0.3471	0.17123 0.0017	0.07123 0.1934
HEMLOCK (n = 161)	COVER	-0.15055 0.0566	-0.12970 0.1011	-0.09825 0.2150	0.08714 0.2717	0.12639 0.1101	0.10515 0.1843	0.10356 0.1911	0.10038 0.2052	0.04550 0.5666	0.06834 0.3890	0.04503 0.5705

Legend: pHW = pH determined in water ; pHC = pH determined in calcium chloride ; O.M. = organic matter ; CEC = cation exchange capacity ; Ca = calcium ; Mg = magnesium ; K = potassium ; Na = sodium .

APPENDIX 6.1 Pearson product moment correlations between soil nutrients and vegetative cover of five competing plant species.

		PEARSON CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0								
		N	P	K	Ca	Mg	Mn	Fe	Cu	Zn
HUCKLEBERRY	COVER	-0.17558	-0.04373	0.05672	0.04666	-0.22085	0.22093	0.23215	-0.14384	-0.25704
(n = 103)		0.0761	0.6609	0.5693	0.6398	0.0250	0.0249	0.0183	0.1472	0.0088
SALMONBERRY	COVER	-0.18404	-0.16936	-0.23429	0.29266	0.19849	0.16696	0.04972	-0.20526	0.28941
(n = 389)		0.0003	0.0008	0.0001	0.0001	0.0001	0.0009	0.3280	0.0001	0.0001
SALAL	COVER	-0.40247	-0.38754	0.33563	0.24037	0.15882	0.25748	-0.08900	-0.35268	0.11709
(n = 386)		0.0001	0.0001	0.0001	0.0001	0.0017	0.0001	0.0808	0.0001	0.0214
ALDER	COVER	0.06970	-0.01605	0.13203	-0.14792	-0.14774	-0.03413	-0.03692	0.15354	-0.13748
(n = 343)		0.1978	0.7672	0.0144	0.0061	0.0061	0.5287	0.4956	0.0044	0.0108
HEMLOCK	COVER	-0.31599								
(n = 75)		0.0057								

APPENDIX 6.2 Pearson product moment correlations between foliar nutrients and vegetative cover of five competing plant species.

(1)
DEPENDENT VARIABLE: FD – BASED ON ASPECT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	48880.37755828	4073.36479652	4141.98	0.0	0.844903	8.7748
ERROR	9124	8972.84777584	0.98343356		ROOT MSE		FD – MEAN
CORRECTED TOTAL	9136	57853.22533411			0.99168219		11.30141621

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	42638.56690879	5419.60	0.0	8	26547.19873572	3374.30	0.0
AGE	4	6241.81064949	1586.74	0.0	4	6241.81064949	1586.74	0.0

(2)
DEPENDENT VARIABLE: FD – BASED ON SLOPE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	39682.10016288	3306.84168024	339.53	0.0	0.308704	26.0972
ERROR	9124	88862.26781946	9.73939805		ROOT MSE		FD – MEAN
CORRECTED TOTAL	9136	128544.36798234			3.12080087		11.95839430

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	32011.72104508	410.85	0.0	8	28112.83059160	360.81	0.0
AGE	4	7670.37911780	196.89	0.0	4	7670.37911780	196.89	0.0

APPENDIX 7.1 Results of 2-factor ANOVA on floristic diversity data based on (1) aspect and (2) slope.

(1)
DEPENDENT VARIABLE: FD - BASED ON ELEVATION

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	21463.33861514	1788.61155126	5456.69	0.0	0.877701	5.2984
ERROR	9124	2990.69242140	0.32778304		ROOT MSE		FD - MEAN
CORRECTED TOTAL	9136	24454.03103654			0.57252339		10.80560211

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	14748.19355189	5624.22	0.0	8	15743.41039855	6003.75	0.0
AGE	4	6715.14506325	5121.64	0.0	4	6715.14506325	5121.64	0.0

(2)
DEPENDENT VARIABLE: FD - BASED ON SLOPE POSITION

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	38655.49802278	3221.29150190	1902.19	0.0	0.714431	11.6721
ERROR	9124	15451.18246053	1.69346585		ROOT MSE		FD - MEAN
CORRECTED TOTAL	9136	54106.68048331			1.30133234		11.14906788

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	32224.78734838	2378.61	0.0	8	24593.31417808	1815.31	0.0
AGE	4	6430.71067440	949.34	0.0	4	6430.71067440	949.34	0.0

APPENDIX 7.2 Results of 2-factor ANOVA on floristic diversity data based on (1) elevation and (2) slope position.

(1)
DEPENDENT VARIABLE: FD - BASED ON SLOPE POSITION MOISTURE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	34510.28064020	2875.85672002	2767.44	0.0	0.784472	9.4190
ERROR	9124	9481.44653656	1.03917652		ROOT MSE		FD - MEAN
CORRECTED TOTAL	9136	43991.72717676			1.01940008		10.82283263

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	28039.26425514	3372.77	0.0	8	20753.61679043	2496.40	0.0
AGE	4	6471.01638506	1556.77	0.0	4	6471.01638506	1556.77	0.0

(2)
DEPENDENT VARIABLE: FD - BASED ON MOISTURE REGIME

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	26761.30331889	2230.10860991	2248.32	0.0	0.747284	9.2593
ERROR	9124	9050.09716155	0.99190017		ROOT MSE		FD - MEAN
CORRECTED TOTAL	9136	35811.40048044			0.99594185		10.75615249

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	21209.77594819	2672.87	0.0	8	19136.61492423	2411.61	0.0
AGE	4	5551.52737070	1399.22	0.0	4	5551.52737070	1399.22	0.0

APPENDIX 7.3 Results of 2-factor ANOVA on floristic diversity data based on (1) slope position moisture and (2) moisture regime.

(1)
DEPENDENT VARIABLE: FD – BASED ON SURFACE SHAPE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	39981.99819777	3331.83318315	1133.06	0.0	0.598429	15.3107
ERROR	9124	26829.61318366	2.94055383		ROOT MSE		FD – MEAN
CORRECTED TOTAL	9136	66811.61138143			1.71480431		11.20007420

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	32447.78296371	1379.32	0.0	8	25743.82240228	1094.34	0.0
AGE	4	7534.21523407	640.54	0.0	4	7534.21523407	640.54	0.0

(2)
DEPENDENT VARIABLE: FD – BASED ON PLACEMENT

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	12	49865.84806513	4155.48733876	791.52	0.0	0.510050	20.1268
ERROR	9124	47900.82433451	5.24998075		ROOT MSE		FD – MEAN
CORRECTED TOTAL	9136	97766.67239963			2.29128365		11.38421711

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	36850.06588527	877.39	0.0	8	22272.12908521	530.29	0.0
AGE	4	13015.78217986	619.80	0.0	4	13015.78217986	619.80	0.0

APPENDIX 7.4 Results of 2-factor ANOVA on floristic diversity data based on (1) surface shape and (2) placement.

(1)
DEPENDENT VARIABLE : ORGANIC MATTER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	31261.18034728	2841.92548612	15.60	0.0001	0.795955	38.2701
ERROR	44	8013.86822415	182.13336873		ROOT MSE		MEAN
CORRECTED TOTAL	55	39275.04857143			13.49567963		35.26428571

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	13497.94857143	9.26	0.0001	6	3175.48474662	2.91	0.0179
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	13293.88567807	72.99	0.0001	1	2020.56919700	11.09	0.0018
SILT	1	3788.15247926	20.80	0.0001	1	543.19305857	2.98	0.0912
CLAY	1	681.19361852	3.74	0.0596	1	681.19361852	3.74	0.0596

(2)
DEPENDENT VARIABLE : TOTAL N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	5.46576180	0.49688744	12.36	0.0001	0.755503	37.1299
ERROR	44	1.76883820	0.04020087		ROOT MSE		MEAN
CORRECTED TOTAL	55	7.23460000			0.20050154		0.54000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	1.26661667	3.94	0.0014	6	1.60978348	6.67	0.0001
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	3.00989325	74.87	0.0001	1	0.49435340	12.30	0.0011
SILT	1	1.10802428	27.56	0.0001	1	0.26613130	6.62	0.0135
CLAY	1	0.08122760	2.02	0.1622	1	0.08122760	2.02	0.1622

APPENDIX 8.1 Results of ANOVA on soil data using (1) organic matter and (2) total nitrogen as dependent variables.

(1)
DEPENDENT VARIABLE : CEC

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	80368.60205266	7306.23655024	20.32	0.0001	0.835515	26.9290
ERROR	44	15821.86009020	359.58772932		ROOT MSE		CEC MEAN
CORRECTED TOTAL	55	96190.46214286			18.96279856		70.41785714

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	18167.70547619	6.32	0.0001	6	18102.25291875	8.39	0.0001
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	51628.61192195	143.58	0.0001	1	11243.66909799	31.27	0.0001
SILT	1	9221.93680452	25.65	0.0001	1	1540.82771775	4.28	0.0444
CLAY	1	1350.34785000	3.76	0.0591	1	1350.34785000	3.76	0.0591

(2)
DEPENDENT VARIABLE : CALCIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	896.22025315	81.47456847	10.14	0.0001	0.717195	53.7149
ERROR	44	353.39788257	8.03177006		ROOT MSE		MEAN
CORRECTED TOTAL	55	1249.61813571			2.83403777		5.27607143

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	272.50180238	4.24	0.0008	6	439.88113573	9.13	0.0001
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	406.82439192	50.65	0.0001	1	139.05368313	17.31	0.0001
SILT	1	204.64835192	25.48	0.0001	1	152.99961691	19.05	0.0001
CLAY	1	12.24570693	1.52	0.2235	1	12.24570693	1.52	0.2235

APPENDIX 8.2 Results of ANOVA on soil data using (1) cation exchange capacity and (2) calcium as dependent variables.

(1)
DEPENDENT VARIABLE : MAGNESIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	423.98326562	38.54393324	21.20	0.0001	0.841298	56.3861
ERROR	44	79.98007010	1.81772887		ROOT MSE		MEAN
CORRECTED TOTAL	55	503.96333571			1.34823176		2.39107143

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	125.74096905	8.65	0.0001	6	228.61095714	20.96	0.0001
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	174.36156367	95.92	0.0001	1	7.08509371	3.90	0.0546
SILT	1	92.32714087	50.79	0.0001	1	6.33719720	3.49	0.0685
CLAY	1	31.55359203	17.36	0.0001	1	31.55359203	17.36	0.0001

(2)
DEPENDENT VARIABLE : POTASSIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	21.76946950	1.97904268	18.86	0.0001	0.825030	74.4899
ERROR	44	4.61679136	0.10492708		ROOT MSE		MEAN
CORRECTED TOTAL	55	26.38626086			0.32392449		0.43485714

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	9.51654269	11.34	0.0001	6	8.13773713	12.93	0.0001
AGE	0	0.00000000	.	.	0	0.00000000	.	.
SAND	1	5.07215284	48.34	0.0001	1	0.02981322	0.28	0.5967
SILT	1	4.10619774	39.13	0.0001	1	0.01380078	0.13	0.7186
CLAY	1	3.07457623	29.30	0.0001	1	3.07457623	29.30	0.0001

APPENDIX 8.3 Results of ANOVA on soil data using (1) magnesium and (2) potassium as dependent variables.

DEPENDENT VARIABLE : TOTAL N

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	10.92003374	0.99273034	16.67	0.0001	0.933785	12.6876
ERROR	13	0.77434226	0.05956479		ROOT MSE		MEAN
CORRECTED TOTAL	24	11.69437600			0.24405899		1.92360000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMENT	8	8.99735100	18.88	0.0001	8	0.82632758	1.73	0.1814
SPECIES	3	1.92268274	10.76	0.0008	3	1.92268274	10.76	0.0008

APPENDIX 9.1 Results of 2-factor ANOVA on 1985 foliar data using total nitrogen as the dependent variable.

(1)
DEPENDENT VARIABLE : MAGNESIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	1.65915491	0.15083226	75.28	0.0001	0.920008	13.2487
ERROR	72	0.14425938	0.00200360		ROOT MSE		MEAN
CORRECTED TOTAL	83	1.80341429			0.04476162		0.33785714

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	0.19043929	11.88	0.0001	8	0.02908705	1.81	0.0882
SPECIES	3	1.46871563	244.35	0.0001	3	1.46871563	244.35	0.0001

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(2)
DEPENDENT VARIABLE : NITROGEN

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	27.91525618	2.53775056	57.71	0.0001	0.898132	12.3597
ERROR	72	3.16621049	0.04397515		ROOT MSE		MEAN
CORRECTED TOTAL	83	31.08146667			0.20970252		1.69666667

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	21.65432083	61.55	0.0001	8	1.93999112	5.51	0.0001
SPECIES	3	6.26093535	47.46	0.0001	3	6.26093535	47.46	0.0001

APPENDIX 9.2 Results of 2-factor ANOVA on 1986 foliar data using (1) magnesium and (2) nitrogen as dependent variables.

(1)
DEPENDENT VARIABLE : PHOSPHORUS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	0.10318631	0.00938057	28.94	0.0001	0.815549	14.1073
ERROR	72	0.02333750	0.00032413		ROOT MSE		MEAN
CORRECTED TOTAL	83	0.12652381			0.01800366		0.12761905

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	0.08549881	32.97	0.0001	8	0.03108321	11.99	0.0001
SPECIES	3	0.01768750	18.19	0.0001	3	0.01768750	18.19	0.0001

(2)
DEPENDENT VARIABLE : CALCIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	5.36904943	0.48809540	36.61	0.0001	0.848312	12.3485
ERROR	72	0.96004937	0.01333402		ROOT MSE		MEAN
CORRECTED TOTAL	83	6.32909881			0.11547302		0.93511905

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	3.60473631	33.79	0.0001	8	1.09541580	10.27	0.0001
SPECIES	3	1.76431312	44.11	0.0001	3	1.76431312	44.11	0.0001

APPENDIX 9.3 Results of 2-factor ANOVA on 1986 foliar data using (1) phosphorus and (2) calcium as dependent variables.

(1)
DEPENDENT VARIABLE : POTASSIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	3.24384940	0.29489540	25.30	0.0001	0.794458	12.9261
ERROR	72	0.83924583	0.01165619		ROOT MSE		MEAN
CORRECTED TOTAL	83	4.08309524			0.10796385		0.83523810

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	0.54797440	5.88	0.0001	8	0.23455702	2.52	0.0180
SPECIES	3	2.69587500	77.09	0.0001	3	2.69587500	77.09	0.0001

(2)
DEPENDENT VARIABLE : MANGANESE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	11	42636169.02132937	3876015.36557540	20.17	0.0001	0.755018	36.5985
ERROR	72	13834266.53819444	192142.59080826		ROOT MSE		MEAN
CORRECTED TOTAL	83	56470435.55952381			438.34072456		1197.70238095

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	8	21412880.01785714	13.93	0.0001	8	7354888.56894841	4.78	0.0001
SPECIES	3	21223289.00347222	36.82	0.0001	3	21223289.00347222	36.82	0.0001

APPENDIX 9.4 Results of 2-factor ANOVA on 1986 foliar data using (1) potassium and (2) manganese as dependent variables.

DEPENDENT VARIABLE : IRON

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	4	12624.30000000	3156.07500000	15.92	0.0001	0.809312	18.9273
ERROR	15	2974.50000000	198.30000000		ROOT MSE		MEAN
CORRECTED TOTAL	19	15598.80000000			14.08190328		74.40000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	4	12624.30000000	15.92	0.0001	4	12624.30000000	15.92	0.0001

APPENDIX 10.0 Results of ANOVA on 1986 huckleberry foliar data using iron as the dependent variable.

(1)
DEPENDENT VARIABLE : NITROGEN

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	6	1.81439286	0.30239881	16.98	0.0001	0.829079	6.5537
ERROR	21	0.37405000	0.01781190		ROOT MSE		MEAN
CORRECTED TOTAL	27	2.18844286			0.13346125		2.03642857

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	6	1.81439286	16.98	0.0001	6	1.81439286	16.98	0.0001

(2)
DEPENDENT VARIABLE : PHOSPHORUS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	6	0.03543571	0.00590595	34.69	0.0001	0.908359	8.2467
ERROR	21	0.00357500	0.00017024		ROOT MSE		MEAN
CORRECTED TOTAL	27	0.03901071			0.01304753		0.15821429

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	6	0.03543571	34.69	0.0001	6	0.03543571	34.69	0.0001

APPENDIX 11.1 Results of ANOVA on 1986 salmonberry foliar data using (1) nitrogen and (2) phosphorus as dependent variables.

(1)
DEPENDENT VARIABLE : MANGANESE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	6	3081878.35714286	513646.39285714	12.80	0.0001	0.785312	26.2234
ERROR	21	842523.75000000	40120.17857143		ROOT MSE		MEAN
CORRECTED TOTAL	27	3924402.10714286			200.30022110		763.82142857

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	6	3081878.35714286	12.80	0.0001	6	3081878.35714286	12.80	0.0001

(2)
DEPENDENT VARIABLE : IRON

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	6	8735.35714286	1455.89285714	1.64	0.1861	0.318845	36.1022
ERROR	21	18661.50000000	888.64285714		ROOT MSE		MEAN
CORRECTED TOTAL	27	27396.85714286			29.81011334		82.57142857

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	6	8735.35714286	1.64	0.1861	6	8735.35714286	1.64	0.1861

APPENDIX 11.2 Results of ANOVA on 1986 salmonberry foliar data using (1) manganese and (2) iron as dependent variables.

DEPENDENT VARIABLE : CALCIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	4	0.53167000	0.13291750	10.75	0.0003	0.741422	9.6304
ERROR	15	0.18542500	0.01236167		ROOT MSE		CA MEAN
CORRECTED TOTAL	19	0.71709500			0.11118303		1.15450000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	4	0.53167000	10.75	0.0003	4	0.53167000	10.75	0.0003

APPENDIX 12.0 Results of ANOVA on 1986 salal foliar data using calcium as the dependent variable.

(1)
DEPENDENT VARIABLE : POTASSIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.13935000	0.04645000	11.67	0.0007	0.744789	9.4503
ERROR	12	0.04775000	0.00397917		ROOT MSE		MEAN
CORRECTED TOTAL	15	0.18710000			0.06308064		0.66750000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	3	0.13935000	11.67	0.0007	3	0.13935000	11.67	0.0007

(2)
DEPENDENT VARIABLE : CALCIUM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	0.16056875	0.05352292	10.58	0.0011	0.725591	10.9336
ERROR	12	0.06072500	0.00506042		ROOT MSE		MEAN
CORRECTED TOTAL	15	0.22129375			0.07113661		0.65062500

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TREATMT	3	0.16056875	10.58	0.0011	3	0.16056875	10.58	0.0011

APPENDIX 13.0 Results of ANOVA on 1986 alder foliar data using (1) potassium and (2) calcium as dependent variables.

DEPENDENT VARIABLE: COVER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	28	4483.09795402	160.11064122	3.61	0.0001	0.639414	61.0605
ERROR	57	2528.15785993	44.35364667		ROOT MSE		COVER MEAN
CORRECTED TOTAL	85	7011.25581395			6.65985335		10.90697674

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	3	1293.85252657	9.72	0.0001	2	135.14493332	1.52	0.2267
AGE	4	92.43790965	0.52	0.7206	4	121.42488050	0.68	0.6057
ASP	4	233.06140454	1.31	0.2759	3	585.28767101	4.40	0.0075
SLOPE	2	472.92941933	5.33	0.0075	2	453.20338648	5.11	0.0091
ELEV	1	1.20662069	0.03	0.8696	1	160.84739014	3.63	0.0619
SPM	3	386.98165663	2.91	0.0423	3	498.79376858	3.75	0.0158
MREG	2	1020.69674215	11.51	0.0001	2	433.44883476	4.89	0.0110
SPOS	1	188.90302941	4.26	0.0436	1	19.18047649	0.43	0.5134
SURF	3	269.85761385	2.03	0.1201	3	304.60170876	2.29	0.0881
PLCMT	5	523.17103119	2.36	0.0515	5	523.17103119	2.36	0.0515

Legend: Trtmt = Treatment ; Age = Site age ; Asp = Aspect ; Slope = slope ; Elev = Elevation ;
Spm = Slope position moisture ; Mreg = Moisture regime ; Spos = Slope position ; Surf = Surface shape ;
Plcmt = Placement.

APPENDIX 14.1 Results of multi-factor ANOVA on huckleberry cover using treatment, site age and site attributes as factors.

DEPENDENT VARIABLE: COVER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	31	162716.11765311	5248.90702107	10.90	0.0001	0.516818	63.0876
ERROR	316	152125.84499056	481.41090187		ROOT MSE		COVER MEAN
CORRECTED TOTAL	347	314841.96264368			21.94107796		34.77873563

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	4	26953.88666314	14.00	0.0001	4	32477.39977335	16.87	0.0001
AGE	4	7607.22075001	3.95	0.0038	4	10783.08179789	5.60	0.0002
ASP	4	30669.64507369	15.93	0.0001	4	2739.13085764	1.42	0.2263
SLOPE	3	16915.21913459	11.71	0.0001	3	3646.19162544	2.52	0.0577
ELEV	1	140.24657288	0.29	0.5898	1	5.58830663	0.01	0.9143
SPM	3	35659.53432760	24.69	0.0001	3	1517.37187294	1.05	0.3704
MREG	1	148.94128271	0.31	0.5785	1	204.24669521	0.42	0.5153
SPOS	2	7397.19963560	7.68	0.0006	2	17466.39949180	18.14	0.0001
SURF	3	29021.73552722	20.09	0.0001	3	15302.11693759	10.60	0.0001
PLCMT	6	8202.48868568	2.84	0.0105	6	8202.48868568	2.84	0.0105

Legend: Trtmt = Treatment ; Age = Site age ; Asp = Aspect ; Slope = slope ; Elev = Elevation ;
Spm = Slope position moisture ; Mreg = Moisture regime ; Spos = Slope position ; Surf = Surface shape ;
Plcmt = Placement.

APPENDIX 14.2 Results of multi-factor ANOVA on salmonberry cover using treatment, site age and site attributes as factors.

DEPENDENT VARIABLE: COVER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F-VALUE	PR > F	R-SQUARE	C.V.
MODEL	37	86585.33308237	2340.14413736	9.69	0.0001	0.540460	56.3856
ERROR	305	73621.41910422	241.38170198		ROOT MSE		COVER MEAN
CORRECTED TOTAL	342	160206.75218659			15.53646363		27.55393586

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	8	48758.39685945	25.25	0.0001	7	18314.37222273	10.84	0.0001
AGE	4	2839.75738436	2.94	0.0208	4	1943.50220649	2.01	0.0926
ASP	4	8882.03453478	9.20	0.0001	4	4811.27869108	4.98	0.0007
SLOPE	3	8829.69501203	12.19	0.0001	3	9852.19521845	13.61	0.0001
ELEV	1	2824.09350814	11.70	0.0007	1	1799.92269592	7.46	0.0067
SPM	4	3494.29725759	3.62	0.0067	4	1340.06844169	1.39	0.2380
MREG	2	729.60552004	1.51	0.2223	2	774.96304472	1.61	0.2025
SPOS	2	5326.01281132	11.03	0.0001	2	4375.21060358	9.06	0.0002
SURF	3	2274.92485676	3.14	0.0256	3	3115.38329951	4.30	0.0054
PLCMT	6	2626.51533792	1.81	0.0960	6	2626.51533792	1.81	0.0960

Legend: Trtmt = Treatment ; Age = Site age ; Asp = Aspect ; Slope = slope ; Elev = Elevation ; Spm = Slope position moisture ; Mreg = Moisture regime ; Spos = Slope position ; Surf = Surface shape ; Plcmt = Placement.

APPENDIX 14.3 Results of multi-factor ANOVA on salal cover using treatment, site age and site attributes as factors.

DEPENDENT VARIABLE: COVER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	24	121948.92469065	5081.20519544	9.41	0.0001	0.462940	65.3645
ERROR	262	141474.09273096	539.97745317		ROOT MSE		COVER MEAN
CORRECTED TOTAL	286	263423.01742160			23.23741494		35.55052265

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	5	29900.67434266	11.07	0.0001	4	39463.50310846	18.27	0.0001
AGE	4	22162.12055111	10.26	0.0001	4	22787.80152686	10.55	0.0001
ASP	2	29060.75403311	26.91	0.0001	0	0.00000000	.	.
SLOPE	1	211.36279943	0.39	0.5321	1	3157.09815255	5.85	0.0163
ELEV	0	0.00000000	.	.	0	0.00000000	.	.
SPM	2	20247.09421980	18.75	0.0001	2	1889.06529822	1.75	0.1759
MREG	2	9221.25744467	8.54	0.0003	1	7474.59015315	13.84	0.0002
SPOS	0	0.00000000	.	.	0	0.00000000	.	.
SURF	3	5650.04355089	3.49	0.0163	3	6725.83349718	4.15	0.0068
PLCMT	5	5495.61774897	2.04	0.0741	5	5495.61774897	2.04	0.0741

Legend: Trtmt = Treatment ; Age = Site age ; Asp = Aspect ; Slope = slope ; Elev = Elevation ; Spm = Slope position moisture ; Mreg = Moisture regime ; Spos = Slope position ; Surf = Surface shape ; Plcmt = Placement.

APPENDIX 14.4 Results of multi-factor ANOVA on alder cover using treatment, site age and site attributes as factors.

DEPENDENT VARIABLE: COVER

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	30	6477.99358153	215.93311938	2.69	0.0001	0.402201	76.6334
ERROR	120	9628.37727939	80.23647733		ROOT MSE		COVER MEAN
CORRECTED TOTAL	150	16106.37086093			8.95748164		11.68874172

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
TRTMT	4	1338.24820497	4.17	0.0034	3	696.92018877	2.90	0.0381
AGE	4	239.41605460	0.75	0.5626	4	82.00513840	0.26	0.9058
ASP	4	912.10484989	2.84	0.0271	3	746.54096707	3.10	0.0293
SLOPE	2	468.91109989	2.92	0.0577	2	7.68029994	0.05	0.9533
ELEV	1	161.58338789	2.01	0.1585	1	358.94342616	4.47	0.0365
SPM	3	365.61707042	1.52	0.2131	3	1519.13697789	6.31	0.0005
MREG	2	324.91257762	2.02	0.1365	2	1245.87561761	7.76	0.0007
SPOS	1	149.72488858	1.87	0.1745	1	136.32077962	1.70	0.1949
SURF	3	242.25756098	1.01	0.3925	3	635.52637528	2.64	0.0526
PLCMT	6	2275.21788670	4.73	0.0002	6	2275.21788670	4.73	0.0002

Legend: Trtmt = Treatment ; Age = Site age ; Asp = Aspect ; Slope = slope ; Elev = Elevation ; Spm = Slope position moisture ; Mreg = Moisture regime ; Spos = Slope position ; Surf = Surface shape ; Plcmt = Placement.

APPENDIX 14.5 Results of multi-factor ANOVA on hemlock cover using treatment, site age and site attributes as factors.

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The Growth Response of Secondary Vegetation to Silvicultural Treatments, Soil and Site Conditions in the Carnation Creek Watershed, Vancouver Island

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