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Patterns of Bryophyte Diversity in the Interior and Coastal Cedar-Hemlock Forests of British Columbia

By

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ABSTRACT

In Canadian cedar hemlock forest, floristic habitat sampling (FHS) methodology recorded more than twice as many bryophyte species as traditional plot sampling (PS). FHS samples a mosaic of mesohabitats (i.e., forest, streams, seeps, and cliffs) that are often not sampled in traditional plot studies, resulting in under estimates of species richness, including many rare species, and a full understanding of the patterning of diversity.

At the regional scale (i.e., provincial), climate and large-scale catastrophic disturbance (i.e., fire and logging) are the most important environmental variables influencing bryophyte vegetation patterns in the cedar hemlock landscape of British Columbia (B.C.). Species composition in coastal western hemlock (CWH) stands differ from those in the interior cedar hemlock zone (ICH). In general, the CWH has a higher abundance of bryophytes, particularly hepatics than the ICH. Floristic affinities are associated with bryophyte vegetation in the CWH and ICH. Temperate species, especially western North American endemics, are almost exclusive to the CWH. Boreal species are more common in the ICH.

At the stand scale, time since the last large-scale disturbance and habitat heterogeneity strongly influence the patterning of bryophyte diversity in the ICH and CWH. Old-growth cedar-hemlock forests have between 33% (ICH) and 66% (CWH) more species than young forests disturbed by either wildfire or logging. Stands with high mesohabitat quantity (i.e, number of different kinds) had high bryophyte diversity.

At the local scale, bryophyte diversity is largely dependent upon mesohabitat quality and quantity. Within an age class, mesohabitat quality is a function of the number and types of microhabitats. Ecosystem management plans must be aimed towards maintaining the diversification of mesohabitats/microhabitats for the preservation of high bryophyte diversity. Mesohabitat and microhabitat bio-indicators associated with high bryophyte diversity are listed for old growth forests in each biogeoclimatic zone. These bio-indicators can be used to preserve the crucial habitats for rare species, and identify "hot spots" for conservation. Large-scale disturbance such as forestry heavily threatens the sustainability of these highly diverse communities. Bryophyte diversity in the cedar-hemlock forests of British Columbia will be sustained through ecosystem management of old growth legacies (i.e., landscapes, stands and components of these) and the preservation of areas of high diversity.

Key words: biodiversity, bryophytes, species richness, rare species, old-growth, disturbance, floristic habitat sampling, patterning of diversity, cedar-hemlock, ICH, CWH, forest conservation, ecosystem management.

DEDICATION

I dedicate my thesis to Joan, Candice and Annabel who faithfully and patiently cheered me on for five years. I would also like to extend this dedication to my Mom and Dad who taught me that any task is attainable if you work hard enough.

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INTRODUCTION

In northern forests, bryophytes are as important as anthophytes, both quantitatively and qualitatively; they hold a key position in understanding forest ecosystem diversity and function (Smith 1982; Økland 1994b; Newmaster et al. 1999). Since bryophytes are closely associated with their surrounding substrate, habitat availability is more important to them than most phanerogams (Vitt & Belland 1997; Newmaster & Bell 2000). Consequently, patterning of rare bryophyte diversity, is in part, a function of the types and numbers of habitats (Vitt & Belland 1997, Newmaster et. al. 1997, 1998). In northern forest ecosystems, the diversity of meso/microhabitats is high, and therefore partially explains why bryophyte diversity, particularly species richness, is higher than anthophyte diversity (Johnston & Elliot 1996; Newmaster et al. 1997; Bell & Newmaster 1998; Newmaster & Bell 2000). Bryophytes are often the first plants to colonize habitats, especially harsh habitats such as rock. Their importance in nutrient cycling (Pocs 1980; Nadkarni 1981; Oechel & Van Cleve 1986; Chapin et al. 1987), moisture retention (Pocs 1976; Nadkarni 1981, 1983; Weber and Van Cleve 1983; Coxon 1991) and seedling establishment (Black & Bliss 1980; Cross 1981; Keizer et al. 1985; Nadkamura 1986; Nakamura & Obata 1984; Okada & Ohsawa 1984; Zasada 1986; Newmaster & Parker 1999) has been documented. Other important ecosystem functions include animal food chains, plant and animal interactions, colonization and primary succession, and soil stabilization (Slack 1988; During & Van Tooren 1990; Longton 1992). Nevertheless, the extinction of bryophyte species and loss of their diversity has not received the same attention as anthophyte extinction and loss of diversity.

Relatively few studies have examined the ecology of bryophytes. Traditionally, little importance has been given to this group, and herbs and woody plants have been the focus of ecological research (Spiess et al. 1982; Thompson 1982). A foundation for bryophyte ecology was set by some of the oldest studies in bryophyte population and community dynamics (Schuster 1949; Hale 1952; Tamm 1953; Gimingham & Birse 1957; Barkman 1958). The early population ecology work of Tamm (1953) set a framework for other ecological studies exploring the factors controlling establishment and growth (Busby et al. 1978; During et al. 1987; Li & Vitt 1994; Økland 1996). Since then many other researchers have expanded Tamm's ideas, increasing the knowledge of population dynamics of bryophytes (Hoddington & Bain 1979; Longton & Greene 1979; Wyatt 1982; Hobbs & Pritchard 1987; Jonsson & Söderström 1988; Söderström & Jonsson 1989; Hedenas et al. 1989; Herben et al. 1991; Vitt 1991b; Økland 1995, 1996). Early bryologists recognized the importance of habitats in community dynamics. Schuster (1949) recognized that species growing on wood could be arranged along a successional gradient reflecting the various decay stages of wood. This chronosequence has also been described by other researchers in North America, Europe and Scandinavia (Muhle & LeBlanc 1975; Söderström 1988a, 1989, 1993; Arsenault 1995). A handful of other research studies have investigated the close association of bryophyte communities and specific habitats (McCullough 1948; Hale 1952; Slack 1976, 1990; Hoffman & Boa 1977; Watson 1980; McCune & Antos 1982; Horton 1988; Oksanen 1988). The results of such studies show that there are specific communities of bryophytes for many different types of habitats (Yarranton 1972; Rasmussen 1975; Palmer 1986; Herben & Söderström 1992; McAlister 1995). However, few studies have attempted to link conservation of bryophyte diversity with preservation of crucial habitats within forested ecosystems (Newmaster 1997; Rambo and Muir 1998a; Fredricks 1999).

The community dynamics of bryophytes, and the effects of disturbance, are now considered in many integrated forest ecosystem studies (Carleton 1988, 1989; Brumelis & Carleton 1990; Gustafsson et al. 1992; Nieppola & Carlton 1991; Herben & Söderström 1992; Vitt & Belland 1995; Frego & Carleton 1995a; Bell & Newmaster 1998). Many researchers have recognized that bryophytes form a distinct coenocline and have investigated this gradient in community composition along environmental gradients (Watson 1980; Vitt & Slack 1984; Gignac & Beckett 1986; During & ter Horst 1987; Økland 1986, 1993, 1994a; Robinson et al. 1989; Gignac et al. 1991a, 1991b, 1991c; McCune 1993; Frego & Carleton 1995b). The close association of these communities to environmental gradients can be used to understand ecoclines (Hoffman & Kazmierski 1969; Gignac 1986; Oksanen 1986; Taylor et al. 1987; Gustafsson & Hallingbäck 1988; Gignac & Vitt 1990; Longton 1992; Herben 1994).

Large (e.g., fire, logging) and small scale (e.g., isolated wind throw) disturbance is an important event in the forest, and more specifically, the community dynamics of bryophytes (Zackrisson 1977; Leonard et al. 1985; Lindholm & Vasander 1987; Jonsson & Esseen 1990; Jonsson 1993; Kimmerer 1993; Økland 1994a; Sillet 1995; Newmaster et al. 1998). A forest that escapes large-scale disturbance for long periods of time (*old growth forest*) can offer a unique environment for bryophytes and other organisms. Although there are only a few studies, the ecological patterns in these old forests are quite similar throughout North America and Scandinavia (Söderström 1988; Anderson & Hytteborn 1991; Lesica et al. 1991; Arsenault 1992; Laaka 1992; Rambo and Muir 1998b). The diversity of tree sizes, log sizes and decay classes is much higher in old forest (Anderson & Hytteborn 1991; Lesica et al. 1991; Hyvärinen 1992). Several researchers have suggested that an increase in habitats in old forest may result in an increase in bryophyte diversity, but further research is needed to substantiate this claim (Hytteborn et al. 1987; Lesica et al. 1991; Anderson & Hytteborn 1991; Laaka 1992; Herban & Söderström 1992; Timoney & Robinson 1996). Time since the last large-scale disturbance may be a crucial variable in forests with high bryophyte diversity (Söderström 1988; Newmaster 1997; Rambo & Muir 1998a). Further research is needed to investigate bryophyte diversity in young and old forests (Gradstein 1992; Laaka 1992; Söderström 1995).

Perhaps the least studied area of bryophyte ecology concerns diversity and the scale in which it is investigated. The regularity in the patterns of diversity suggests they have been produced in conformity with a basic set of principles rather than accidents of history (Fisher et al. 1943). Research has only recently focused on factors that influence patterns of bryophyte diversity (Slack 1977; Benzing 1981; Oksanen 1983; Økland et al. 1990; Vitt et al. 1995; Vitt & Belland 1996). Habitats such as streams, fens and bogs exhibit unique patterns of diversity (Slack & Glime 1985; Muotka & Virtanen 1995; Vitt et. al 1995). Vitt and Belland (1997) have shown that patterns of rare bryophyte diversity are strongly correlated to habitat type and the scale of the investigation. Furthermore, they described how the landscape is made up of a mosaic of meso-habitats (e.g., streams, cliffs etc.) which are in turn made up of microhabitats (e.g., logs, rocks etc.), all of which affect diversity patterns of bryophytes. There are no published studies that compare bryophyte diversity in a forest ecosystem at different scales on the landscape.

Ecological studies that consider patterns of diversity at different scales on the landscape can offer practical applications for conservation strategies (Whittaker 1960,1972). Whittaker's definition of 'point diversity' (i.e., epsilon, gamma and point), and 'differentiation diversity' (i.e., delta, beta and pattern) can be applied to field research at all scales of diversity, including Vitt and Belland's (1997) mosaic of habitats on the landscape (see appendix III). Biogeography studies investigate patterns of diversity at the largest landscape scales (epsilon & gamma inventory diversity; delta differentiation diversity). Although uncommon, bryogeographical studies offer elegant, intuitive conclusions about species diversity, basic floristic concepts and conservation (Steere 1978; Brassard 1983; Schofield 1988; Belland & Brassard 1988; Vitt 1991a; Belland & Schofield 1994; Belland 1995). MacArthur (1965) suggested that species diversity should be investigated at both the 'regional' or between stands scale (alpha inventory diversity & beta differentiation diversity), and the 'local' or within stands scale (point inventory diversity & pattern differentiation diversity). Different environmental or historical factors may be correlated to patterns of diversity at different scales on the landscape (Pielou 1975; Krebs 1985; Magurran 1988). Conservation strategies consistently rank diversity as the most important criteria for site assessment (Magurran 1988). Consequently, there is a demand to investigate patterning of diversity at different scales on the landscape (Goward 1993; Rose 1992; Slack 1992: Söderström et al. 1992; Söderström 1995; Fanta 1995).

Traditionally, randomly placed bounded plots or quadrats have been used to sample communities for ecological fieldwork. Clements (1905) described the methods for collecting data using plots and quadrats. These methods have been used successfully in many population and community dynamic studies (Bonham 1989; Krebs 1997). Unfortunately, the stochastic bounded nature of these methods encourages the exclusion of uncommon, distinctive habitats that offer considerable diversity. Several researchers have found it difficult to separate which environmental factors are most influential in describing patterns of diversity (During 1979, 1992; Pøcs 1980; Kimmerer & Allen 1982; Leonard et al. 1985; Söderström 1989; Carlton 1990; Herben et al. 1991; Gradstein 1992;

Herben 1994; Økland 1995a). Ultimately, it would be desirable to quantify these factors in a statistical model to predict diversity and sensitivity of ecosystems. Although attempts have been made to quantify diversity, they have often produced unsatisfactory results perhaps because of the sampling techniques employed.

The appropriate sampling method for bryophyte diversity studies should include all the potential habitats in the ecosystem studied (Newmaster 1997 et al.). Belland (1981, 1987, 1988, 1989, 1994, 1995) has been using floristic sampling to investigate the diversity of bryophytes along the East Coast of Canada. His sampling method records species by meso-habitat in a qualitative manner. Vitt et al. (1992, 1995) used a similar method to successfully study patterning of bryophyte diversity in peatlands. Recently, Vitt and Belland (1996) have suggested that rare species richness can be appropriately quantified if species are recorded by meso-habitats (e.g., streams, cliffs etc.) and microhabitats (e.g., logs, stumps etc.) within an ecosystem. Furthermore, they insisted that sampling within the sampling unit by micro/meso habitat must continue until all the species are found. This sampling method produces a complete list of species by microhabitat and meso-habitat with environmental parameters for each sampling unit. Sampling in several areas in this manner allows a quantitative comparison of species richness using biometric and multivariate statistical techniques. Such a complete data set may elucidate complex community patterns using known environmental gradients. It may be possible to modify Vitt and Belland's sampling technique to address management and conservation questions in sensitive forest ecosystems.

In the North Temperate Zones there are cool, wet, conifer-dominated ecosystems typically called *Temperate Rain Forest* (Whittaker 1977; Alaback & Pojar 1997; Schoonmaker et al. 1997). Temperate rain forests are characterized by cool, wet climates, acidic soils, copious networks of flowing water, abundant bryophytes, large amounts of organic debris on the ground and dominant coniferous trees that include the largest and oldest living species (Kirk & Franklin 1992). Today there are only a few locations reported in the world where these forests exist. These are in North America, New Zealand, Chile, Norway, China and Japan. The largest temperate rainforest in the world are the *oceanic/coastal rainforests* (warmer, influenced by coastal weather patterns) along the Pacific coast of North America, which are dominated by the *Coastal Western Hemlock Zone* (CWH) in British Columbia (Meidinger & Pojar 1991). The living biomass in the coastal North American temperate rain forest (500 tons/acre) is greater than in the tropical forest (300 tons/acre) (Colinvaux 1986; Kirk & Franklin 1992). Inland from the west coast of North America are the *inland oroboreal rainforests* (cooler, influenced by interior continental weather patterns), which are dominated by the *Interior Cedar Hemlock Zone* (ICH) in British Columbia (Tuhkanen 1984; Barbour et. al 1987; Meidinger & Pojar 1991; Goward 1994, 1995; Arsenault 1995). In the ICH only the wettest subzones (ICHwk1 and ICHvk1) are properly described as rainforest. In the northern hemisphere, interior rain forests have only been reported in China and western North America. In British Columbia these rare, sensitive rainforests deserve special consideration as candidates for protected status (Goward & MacKinnon 1996).

The importance of bryophytes in British Columbia is considerable. With more than 850 species of mosses and hepatics, the province's bryoflora is the richest in North America and contains the largest percentage of endemic species and genera on the continent (Ireland et. al 1987; Schofield 1988). The Coastal Western Hemlock Zone (CWH) is characterized by extraordinary bryophyte richness (Schofield 1988) and contains the majority of western North American endemic species and genera. Many species that occur in this zone are unknown elsewhere in Canada. Some areas in the Interior Cedar Hemlock Zone (ICH) may be the only interior oroboreal rainforests in North America. Schofield (1968a, 1968b, 1968c, 1968d, 1980), has collected bryophytes extensively in the CWH. Furthermore, Godfrey (1977a, 1977b, 1979), has made considerable contributions to the hepatic flora of the CWH. Schofield (1984, 1988) noted that the CWH contains luxuriant carpets of bryophytes, which are supported by an abundant source of moisture in the form of rain and fog. Furthermore, the CWH shows considerable habitat diversity with frequent cliffs, canyons, outcrops, boulders, streams, rivers, waterfalls, fjords and bodies of water. It is not surprising that this area is characterized by extraordinary bryophyte richness and contains the majority of western North American endemic species and genera (Schofield 1984, 1988). Collections by Tan (1980) have contributed to a relatively complete list of mosses for the ICH. However, limited collections of hepatics have been made in the ICH (Wong unpublished). The Coastal and Interior zones show similarities in structure and composition, yet some evidence suggests differences in ecosystem diversity and community structure/dynamics (Arsenault 1995). There has been no quantitative research that investigates the patterning of bryophyte diversity in the ICH or CWH. Furthermore, it is unclear whether or not diversity really differs between the ICH and CWH or between young and old stands within either biogeoclimatic zones A comparison of bryophyte diversity in these two areas will provide useful information on their makeup and insight into how they should be managed.

This thesis investigates the patterning of bryophyte diversity in British Columbia's cedar hemlock forest. The two key areas of interest are the CWH and the ICH biogeoclimatic zones of British Columbia. In both, the history of either fire or logging disturbance influences the ecology of the forest ecosystem (Arsenault 1996). The result is a pattern of young (70-90 yrs.) and old (250+ yrs.) forests on the landscape. This research project sampled young and old stands within the CWH and ICH. The thesis questions were grouped into five research papers that focus at different scales on the landscape. The first paper investigates the appropriate sampling methodology for answering questions regarding bryophyte diversity. The second paper investigates community differences at a regional scale (i.e., ICH vs CWH). The third paper investigates the patterning of diversity at the stand scale within either the ICH or CWH. The last two papers investigate bryophyte diversity at a local scale and the indicator value of mesohabitats and microhabitats respectively.

DEFINITIONS

Microhabitat	At the local scale, diversity or species richness is related to microhabitat heterogeneity and these microhabitats are arranged in patterns associated with localized physiographic or physiognomic forms (Vitt et al. 1995; Vitt & Belland 1996). Logs, stumps and rocks are examples of microhabitats and they are habitat for both individual populations and communities.
Meso-habitat	Mesohabitats (e.g., streams, cliffs etc.) are found within the forest landscape. They contain sets of microhabitats, the diversity of which controls the quality of the mesohabitat (Vitt & Belland 1996). At the regional scale, patterns of diversity are arranged through the occurrence, quantity and quality of meso-habitats. A dominant mesohabitat can comprise a large portion of the landscape (e.g., a forest). Restricted mesohabitats are smaller and are fully contained within the dominant mesohabitats (e.g., a cliff within a forest).
Stand	A mosaic of dominant and restricted meso-habitats on the landscape. Defined by the dominant tree species, age, structure, elevation, slope position and aspect. In each stand there will be one meso-habitat that represents the dominant meso-habitat, and various restricted meso-habitats for cliffs, streams etc.
Floristic Habitat Sampling (FHS)	Based on the sampling methodology used by Belland (1981, 1987, 1988, 1989, 1994, 1995), Vitt (1991) and Vitt & Belland (1995, 1997). Their methodology has been expanded in FHS to incorporate forest stands and all the mesohabitats and microhabitats found within. It is similar to a floristic survey because it attempts to provide a method in which to record all species within a study area. In FHS the stand is the plot and meso/microhabitats are the sampling units. This method differs

from a relevé in several respects 1) relevés are bounded; FHS is not, 2) relevés are based on the investigator's preconceived concepts about the existence of certain types of communities; FHS is based on meso/microhabitats that are present in the stand, 3) relevés record sociability; FHS does not 4) relevés are used for vegetation classification; FHS is ideally suited for biodiversity studies. Although labor intensive, FHS provides an extensive list of species with habitat characteristics, from which many ecological and environmental questions can be answered.

Regional Scale

In western Canada, the cedar hemlock forests can be divided into either the ICH or CWH biogeoclimatic zones. Biogeoclimatic zones are areas of broadly homogeneous climates that influence patterns of vegetation across the landscape (Meidinger and Pojar 1991). At the largest scale, patterns of bryophyte diversity (gamma & delta) will be compared in biogeoclimatic zones.

Local Scale

Meso-habitats (e.g., streams, cliffs etc.) contain sets of microhabitats (e.g., logs, rocks etc.) arranged on the landscape (Vitt and Belland 1997). The finest scale of analysis will investigate local patterns of bryophyte diversity (alpha, beta, point & pattern) in mesohabitats and microhabitats.

BIBLIOGRAPHY

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Alaback, P. and Pojar, J. 1997. Vegetation from ridgetop to seashore. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home.* Island Press, Washington, DC.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. Ph.D. Thesis, Department of Botany, The University of British Columbia. pp. 187.

Arsenault, A. 1996. Comparison of the patterns of natural disturbances and harvesting patterns and their impact on stand structure dynamics in interior and coastal cedar-hemlock forests. Progress report to Science Council.

Arseneault, D & S. Payette. 1992. A postfire shift from lichen-spruce to lichen-tundra vegetation at the tree line. Ecology 73: 1067-1081.

Barbour, M.G., Burk, J.H. & W.D. Pitts. 1987. Terrestrial plant ecology. Benjamin/Cummings Publ., California.

Barkman, J.J. 1958. Phytosociology and ecology of crpytogamic epiphytes. Van Gorcum & Comp. Netherlands.

Bell, F.W. & S.G. Newmaster. 1998. The Fallingsnow Ecosystem Project: Plant Diversity and Succession. Unpublished manuscript, Ontario Forest Research Institute, Sault Ste. Marie, Ontario.

Belland, R.J. 1981. Ecology and phytogeography of the mosses of the Bonne Bay region, western Newfoundland. M.Sc., Memorial University of Newfoundland, St. John's.

Belland, R.J. 1987. The moss flora of the Gulf of St. Lawrence region: glacial and postglacial dispersal and migrational histories. Journal of the Hattori Botanical Laboratory 62: 205-267.

Belland, R.J. & G.R. Brassard. 1988. The bryophytes of Gros Morne National Park, Newfoundland Canada: ecology and phytogeography. Lindbergia 14: 97-118.

Belland, R.J. 1989. Floristic boundaries in the Gulf of St. Lawrence region: a numerical approach based on the moss flora. Canadian Journal of Botany 67: 1633-1644.

Belland, R.J. & W.B. Schofield. 1994. The Ecology and phytogeography of the bryophytes of Cape Breton Highlands Park, Canada. Nova Hedwigia 59: 275-309.

Belland, R.J. 1995a. The bryophytes of Prince Edward Island National Park, Canada: affinities, habitats, and diversity. Fragmenta Floristica et Geobotanica 40: 349-364.

Belland, R.J. & D.H. Vitt. 1995b. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

Benzing, D.H. 1981. Bark surfaces and the origin and maintenance of diversity among angiosperms epiphytes: a hypothesis. Selbyana 5: 248-255.

Bonham, C.D. 1989. Measurements for terrestrial vegetation. Wiley & Sons. New York.

Brassard, G.R. 1983. Bryogeography, with special reference to mosses. pp. 361-384. In South, G.R. (ed.), Biogeography and Ecology of the Island of Newfoundland. The Hague, The Netherlands

Braun-Blanquet, J. 1932. Plant sociology: the study of plant communities. McGraw-Hill. New York.

Brumelis, G, & T.J. Carleton. 1988. The vegetation of postlogged black spruce lowlands in central Canada. I. Trees and tall shrubs. Canadian Journal of Forest Resources 18: 1470-1478.

Brumelis, G, & T.J. Carleton. 1989. The vegetation of post-logged black spruce lowlands in central Canada. II. Understory vegetation. Journal of Applied Forestry 26: 321-339.

Busby, J.R. L. Bliss & C.D. Hamilton. 1978. Microclimate control of growth rates and bitats of the boreal forest mosses, *Tomenthypnum nitens* and *Hylocomium*

Carleton, T.J. 1990. Variation in terricolous bryophytes and macrolichen vegetation along primary gradients in Canadian boreal forest. Journal of Vegetation Science 3:585-594.

Clements, E.S. 1905. Ecological methods. Carnegie Institution of Washington, Washington D.C.

Conrad, H.S. 1935. The plant associations on central Long Island: a study in descriptive sociology. American Midland Naturalist 16:433-516.

Coxson, D.S. 1991. Nutrient release from epiphytic bryophytes in tropical montane rain forest (Guadeloupe). Canadian Journal of Botany 69: 2122-2129.

Colinaux, P. 1986. Ecology. John Wiley & Sons, Inc. New York.

Crites, S & M.R.T. Dale. 1995. Relations between nonvascular species and stand age and stand structure in aspen mixedwood forest in Alberta. pp. 91-112. In Stelfox, J.B. (ed.), Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forest in Alberta. Alberta Environment Centre, Alberta.

Cross, J.R. 1981. The establishment of *Rhododendron ponticum* in the Killarney Oakwoods. Journal of Ecology 69: 807-824.

During, H.J. 1979. Life strategies of bryophytes: a preliminary review. Lindbergia 5: 2-18.

During, H.J. & B. ter Horst. 1987. Diversity and dynamics in bryophyte communities on earth banks in a Dutch forest. Symposia Biologica Hungarica 35: 447-455.

During, H.J., van Tooren & F. Bart. 1987. Recent developments in bryophyte population ecology. Trends in Ecology and Evolution 2: 89-93.

During, H.J. & B.F. Van Tooren. 1990. Bryophyte interactions with other plants. Botanical Journal of the linnean Society 104: 79-98.

During, H.J. 1992. Ecological classifications of bryophytes and lichens. In Bates, J.W. & A.M. Farmer (eds.), Bryophytes and lichens in a changing environment, Clarendon Press, Oxford, pp. 1-31.

Fanta, J. 1995. Ecology of biodiversity in forest. Caring for the forest: research in a changing world. IUFRO XX World Congress. Tampere, Finland.

Fisher, R.A., A.S. Corbet and C.B., Williams. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. Journal of Animal Ecology 62: 27-32.

Fredricks, N.A. 1999. Managing for bryophyte and lichen diversity in Pacific northwest forests. pp 99-100. In J.D. Eckhoff (ed), proceedings to the second North American forest ecology workshop: Forest Ecology into the next millenium; putting the long view in practice. June 27-30. University of Maine, Orono, Maine.

Frego, K.A. & T.J. Carleton. 1995a. Microsite conditions and spatial pattern in a boreal bryophyte community. Canadian Journal of Botany 73: 544-551.

Frego, K.A. & T.J. Carleton. 1995b. Microsite tolerance of four bryophytes in a mature black spruce stand: Reciprocal transplants. The Bryologist 98: 452-458.

Gignac, D.L. & D.H. Vitt. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Gignac, D.L. 1986. Ecological tolerance and niche structure of Sphagnum along a pollution gradient near Sudbury, Ontario, Canada. Canadian Journal of Botany 65: 1268-1274.

Gignac, D.L. & P.J. Beckett. 1986. The effects of smelting operations on peatlands near Sudbury, Ontario, Canada. National Research Council of Canada 64: 1138-1147.

Gignac, L.D., D.H. Vitt & S.E. Baily. 1991a. Bryophyte response surfaces along ecological and climatical gradients. Vegetatio 93: 29-45.

Gignac, L.D., D.H. Vitt, S. Zoltai & S.E. Baily. 1991b. Bryophye response surfaces along climatic, chemical and physical gradients in peatlands of western Canada. Nova Hedwigia 53: 27-71.

Gignac, D.L., D.H. Vitt & S.E. Bayley. 1991c. Bryophyte response surfaces along ecological and climatic gradients. Vegetatio 93: 29-45.

Godfrey, J.D. 1977a. The Hepaticae and Anthocerotae of southwestern British Columbia. Ph.D. Thesis. Department of Botany, University of British Columbia.

Godfrey, J.D. 1977b. New an interesting hepatics from British Columbia, Canada, and Northern Washington State, U.S.A. I. The Bryologists 80: 539-543.

Godfrey, J.D. 1979. New an interesting hepatics from British Columbia, Canada, and Northern Washington State, U.S.A. II. The Bryologists 82: 162–170.

Goward, T. 1993. Epiphytic lichens: going down with the trees. pp. 153-158. In Rautio, S. (ed.), Community action for endangered species: a public symposium on B.C.'s threatened and endangered species and their habitat. Federation of British Columbia Naturalists, Vancouver, British Columbia.

Goward, T. 1994. Notes on old-growth dependent epiphytic macrolichens in inland British Columbia, Canada. Acta Botanica Fennica 150: 31-38.

Goward, T. 1995. Nephroma occultum and the maintenance of lichen diversity in British Columbia. Mitt. Eidgenoss. Forsch. Anst. Wald Schnee Landsch. 70, 1:93-101.

Goward, T. & A. MacKinnon. 1996. B.C.'s Inland rainforest. The Log, Fall issue. Ministry of Forest. Vacouver B.C.

Gradstein, R.S. 1992. The vanishing tropical rainforest as an environment for bryophytes and lichens. pp. 234-253. In Bates, J.W. & A.M. farmer (eds.), Bryophytes and lichens in a changing environment, Clarendon Press, Oxford.

Gimingham, C.H. & E.M. Birse. 1957. Ecological studies on growth-form in bryophytes I. Correlations between growth-form and habitat. Journal of Ecology 45: 533-45.

Gustafsson, L. & T, Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological conservation 44: 283-300.

Gustafson, L., A. Fiskesjö, T.Hallingbäck & T. Ingelög. 1992. Semi-natural deciduous broadleaved woods in southern Sweden - habitat factors of importance to some bryophyte species. Biological conservation 59: 175-181.

Hale, M.E. 1952. Vertical distribution of cryptogams in a virgin forest in Wisconsin. Ecology 33: 398-406.

Hedenas, L., T. Herben, H. Rydin & L. Söderström. 1989. Ecology of the invading species *Orthodontium lineare* in Sweden: substrate preference and interactions with other species. Journal of Bryology 15: 565-581.

Herben, T., H. Rydin & L. Söderström. 1991. Spore establishment probability and the persistence of the fugitive invading moss, *Orthodontium lineare*: a spatial simulation model. Oikos 60: 215-221.

Herben, T. & L.Söderström. 1992. Which habitat parameters are most important for the persistence of a bryophyte species on patchy, temporary substrates ? Biological Conservation 59: 121-126.

Herben, T. 1994. Local rate of spreading and patch dynamics of an invasive moss species, Orthodontium lineare. Journal of Bryology 18: 115-125.

Hobbs, V.J. & N.M. Pritchard. 1987. Population dynamics of the moss *Polytrichum piliferum* in North-East Scotland. Journal of Ecology 75: 177-192.

Hoddington, J & J., Bain. 1979. The influence of simulated canopy light on the growth of six acrocarpous moss species. Canadian Journal of Botany 57: 1236-1242.

Hoffman, G.R. & A.A. Boa. 1977. Ecological study of epiphytic crytogams on *populus deltoides* in northeastern South Dakota and adjacent Minnesota. The Bryologist 80: 32-47.

Hoffman, G.R. & R.G. Kazmierski. 1969. An ecological study of epiphytic bryophytes on *Pseudotsuga menziessii* on the Olympic Peninsula, Washington: I. A description of vegetation. The Bryologist 72: 1-19.

Horton, D. G. 1988. Microhabitats of New World Encalyptaceae (Bryopsida): distribution along edaphic gradients. Beifefte zur Nova Hedwigia 90: 261-282.

Hytteborn, H., J.R. Packham, & T. Verwijst. 1987. Tree population dynamics, stand structure and species composition in montane virgin forest of Vallibacken, northern Sweden. Vegetatio 72: 3-19.

Hyvärinen, M., P. Halonen & M. Kaupp. 1992. Influence of stand age and structure on the epiphytic lichen vegetation in the middle-boreal forests of Finland. Lichenologists 24: 165-180.

Ireland, R.R., G.R. Brassard, W.B. Schofield and D.H. Vitt. 1987. Checklist of the mosses of Canada II. Lindbergia 13: 1-62.

Johnston, M.H. & J.A. Elliot. 1996. Impacts of logging and wildfire on an upland black spruce community in northwestern Ontario. Environmental Monitoring and Assessment 39: 283-297.

Jonsson, B.G. & L.. Söderström 1988. Growth and reproduction in the leafy hepatic *Ptilidium pulcherrimum* (G. Web.) Vainio during a 4-year period. Journal of Bryology 15: 315-325.

Jonsson, B.G & P.A. Esseen. 1990. Treefall disturbance Maintains high bryophyte diversity in a boreal spruce forest. Journal of Ecology 78: 924-936.

Jonsson, B.G. 1993. The bryophyte diaspore bank and its role after small-scale disturbance in a boreal forest. Journal of Vegetation Science 4: 819-826.

Keizer, J.P., B.F. Van Tooren & H.J. During. 1985. Effects of bryophytes on seedling emergence and establishment of short-lived forbs in chalk grassland. Journal of Ecology 73: 493-504.

Kimmerer, R.W. & T.F.H. Allen. 1982. The role of disturbance in the pattern of a riparian bryophyte community. American Midland Naturalist 107: 370-383.

Kimmerer, R.W. 1993. Disturbance and dominance in *Tetraphis pellucida*: a model of disturbance frequency and reproductive mode. The Bryologist 96: 73-79.

Kirk, R. & J. Franklin. The Olmypic rainforest. University of Washington Press, Seatle, USA.

Krebs, C.J. 1985. Ecology: The experimental analysis of distribution and abundance. Harper & Row Publ., New York.

Krebs, C.J. 1997. Ecological Methodology. Harper Collins, New York.

Laaka, S. 1992. The threatened epixylic bryophytes in old primeval forest in Finland. Biological Conservation 59: 151-154.

Leonard, R.E., P.W. Conkling & J.L. McMahon. 1985. Recovery of bryophyte community on Hurricane Island, Maine U.S.A.U.S. Forest Service research note NE. 325: 1-4. Upper Darby, P.A.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

Li, Y., & D.H., Vitt. 1994. The dynamics of moss establishment: Temporal responses to nutrient gradient. The Bryologist 97: 357-364.

Lindholm, T. & H. Vasander. 1987. Vegetation and stand development of mesic forest after prescribed burning. Silva Fennica 21: 259-278.

Longton, R.E. & S.E. Greene. 1979. Experimental studies of growth and reproduction in the moss *Pleurozium schreberi* (Brid.) Mitt. Journal of Bryology 10: 321-338.

Longton, R.E. 1992. The role of bryophytes and lichens in terrestrial ecosystems. pp. 32-76. In Bates, J.W. & A.M. Farmer (eds.), Bryophytes and lichens in a changing environment. Oxford University Press, New York.

MacArhthur, R.H. 1965. Patterns of species diversity. Biology Review 40: 510-533.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton University Press, New Jersey.

McAlister, S. 1995. Species Interactions and substrate specificity among log-inhabiting bryophytes species. Ecology 76: 2184-2195.

McCullough, H.A. 1948. Plant succession on fallen logs in a virgin spruce-fir forest. Ecology 29: 508-513.

McCune, B. & J.A. Antos. 1982. Epiphytic communities of the Swan Valley, Montana. The Bryologist 85: 1-12.

McCune, B. 1993. Gradients in epiphytic biomass in three Pseudotsuga-Tsuga forest of different ages in western Oregon and Washington. The Bryoogist 96: 405-411.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. Special report series 6, Ministry of forest, Research Branch, Victoria, B.C.

Muhle, H. & F. LeBlanc. 1975. Bryophyte and lichen succession on decaying logs. I. Analysis along an evaporational gradient in eastern Canada. Journal of the Hattori Botanical Library 39: 1-33.

Muotka, T. & R. Virtanen. 1995. Stream as a habitat templet for brophytes: species distribution along gradients in disturbance and substratum heterogeneity. Freshwater Biology 33:141-160.

Nadkarni, N.M. 1981. Canopy roots: convergent evolution in rainforest nutrient cycles. Science 214: 1023-1024.

Nadkarni, N.M. 1983. Biomass and mineral capital of epiphytes in an *Acer macrophyllum* community of a temperate moist coniferous forest, Olympic Peninsula, Washington State.Canadian Journal of Botany 62: 2223-2228.

Nakamura, T. & K. Obata. 1984. Differences in ecological aharacter between *Abies veitchii* and *Tsuga diversifolia* II. Distribution of seedlings on the moss covered floor of *Tsuga* forest on Mt. Fuji. Bulliten of Tokyo University Forests 74: 67-79.

Nakamura, T. 1986. Bryophyte and lichen succession on fallen logs and seedling establishment in *Tsuga-Abies* forests central to Japan. Symposia Biologica Hungarica 35: 485-495.

Newmaster, S.G., Lehela A., Oldham M.J., Uhlig, P.W.C., and McMuray, S. 1997. Ontario Plant List. Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Forest Research Information Paper No. 123. 650 pp. + appendices.

Newmaster, S.G. 1997. Diversity of bryophytes in the ICH. Annual report to Kamloops Forest District, B.C. Forest Service.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1998. The effects of silvicultural herbicides on bryophytes. Pp. 223-225 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (comps.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Newmaster, S.G. 1998. Diversity of bryophytes in the CWH. Annual report to Kamloops Forest District, B.C. Forest Service.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Newmaster, S.G. & B. Parker. 1999. Biological interactions between conifer seedlings and bryophytes. Research report OMNR.

Newmaster, S.G. & F.W. Bell. 2000. Diversity of cryptogams after silvicultural disturbances. Submitted to Canadian Journal of Forest Research.

Nieppola, J.J. & T.J. Carleton. 1991. Relations between understory vegetation, site productivity, and environmental factors in Pinus sylvestris L. stands in southern Finland. Vegetatio 93: 57-72.

Økland, R.H. 1996. Population biology of the clonal moss Hylocomium splendens in Norwegian boreal spruce forest. II. Effects of density. Journal of Ecology 84: 63-69.

Økland, R.H. 1986. Rescaling of ecological gradients. I. Calculation of ecological distance between vegetation stands by means of their floristic composition. Nordic Journal of Botany 6: 891-907.

Økland, R.H. 1994a. Bryophyte and lichen persistence patterns in a Norwegian boreal coniferous forest. Lindbergia 19: 50-62.
Økland, R.H. 1994b. Patterns of bryophyte associations at different scales in a Norwegian boreal spruce forest. Journal of vegetation Science 5:127-138.

Økland, R.H. 1995. Population biology of the clonal moss *Hylocomium splendens* in Norwegian boreal spruce forest. I. Demography. Journal of Ecology 83: 697-712.

Økland, R.H., T.Økland & O. Eilertsen. 1990. On the relationship between sample plot size and beta diversity in boreal coniferous forest. Vegetatio 87: 187-192.

Oksanen, J. 1983. Diversity patterns along climatic gradients in the understorey of lichen-rich pine forest in Finland. Annales Botanica Fennicci 20: 151-155.

Oksanen, J. 1986. Succession, dominance and diversity in lichen-rich pine forest vegetation in Finland. Holarctic Ecology 9: 261-266.

Palmer, M.W. 1986. Pattern in corticolous bryophyte communities of the north Carolina piedmont: do the mosses see the forest or the trees ? The Bryologist 89: 59-65.

Pielou, E.C. 1975. Ecological diversity. John Wiley & Sons, New York.

Pøcs, T. 1976. The role of the epiphytic vegetation in the water balance and humus production of the rainforest of the Uluguru Mountains, East Africa. Boissiera 246: 499-503.

Pøcs, T. 1980. The epiphytic biomass and its effects on the water balance of two rain forest types in the Ilguru Mountains, Tanzania, East Africa. Acta Botanica Hungarica 26:143-167.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Rasmussen, L. 1975. The bryophyte epiphyte vegetation in the forest, Slotved Skov. Northern Jutland 3: 15-38.

Robinson, A.L., D.H. Vitt & K. P. Timoney. 1989. Patterns of community structure and forest-tundra of Northwestern Canada. The Bryologist 92: 495-512.

Rose, F. 1992. Temperate forest management: Its effects on bryophyte and lichen floras and habitats. In Bates, J.W. & A.M. Farmer (eds.), Bryophytes and lichens in a changing environment, Clarendon Press, Oxford, pp. 211-232.

Schofield, W.B. 1968a. Bryophytes of British Columbia. I. Journal of the Hattori Botanical Laboratory 31: 205-265.

Schofield, W.B. 1968b. Bryophytes of British Columbia. II. Journal of the Hattori Botanical Laboratory 31: 266-282.

Schofield, W.B. 1968c. Bryophytes of British Columbia. III. habitat and distributional information for selected mosses. Syesis 9: 317-354.

Schofield, W.B. 1968d. A checklist of Hepaticae and Anthocerotae of British Columbia. Syesis 1: 157-162.

Schofield, W.B. 1980. Phytogeography of the mosses of North America. pp131-170. In, the mosses of North America, Taylor R.J. and Leviton, A.E. (eds.). Pacific Division, American Association for the advancement of Science. San Francisco, CA.

Schofield, W.B. 1984. Bryogeography of the Pacific coast of North America. Journal hattori Botanical Laboratory 55: 35-43.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Schoonmaker, P.K., von Hagen, B. & Wolf, E.C.. 1997. *The Rain Forests of Home.* Island Press, Washington, DC. pp. 431.

Schuster, R. 1949. The ecology and distribution of Hepaticae in central and western New York. American Midland Naturalist. 42:513-712.

Sillet, S.C. 1995. Branch epiphyte assemblages in the forest interior and on the clearcut edge of a 700 year-old Douglas Fir canopy in western Oregon. The Bryologist 98:301-312.

Slack, N.G. 1976. Host specificity of bryophytic epiphytes in eastern North America. Journal of the Hattori Botanical Laboratory 41: 107-132.

Slack, N.G. & J.M. Glime. 1985. Niche relationships of mountain stream bryophytes. The Bryologist 88: 7-18.

Slack, N.G. 1988. Species diversity and community structure in bryophytes: New York State Studies. Bull. N.Y. State Museum 428: 1-70.

Slack, N.G. 1990. Bryophytes and ecological niche theory. Botanical Journal of the Linnaean Society 104: 187-213.

Slack, N.G. 1992. Rare and endangered bryophytes in New York state and eastern United States: Current status and preservation strategies. Biological Conservation 59: 233-241.

Smith, A.J.E. 1982. Epiphytes and epiliths, pp.191-228. In A.J.E. Smith (ed.), Bryophyte Ecology. Chapman and Hill. New York.

Söderström, L. 1995. Bryophyte conservation - Input from population ecology and metapopulation dynamics. Cryptog. Helv. 18: 17-24.

Söderström, L. 1988a. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8: 89-97.

Söderström, L. 1988b. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1989. Regional distribution patterns of bryophyte species on spruce logs in northern Sweden. The Bryologist 92: 349-355.

Söderström, L. 1990. Dispersal and distribution patterns in patchy, temporal habitats. pp. 103-113. In Krahulec, F., A.D.Q. Agnew, S. Agnew & J.H. Willems (eds.), Spatial processes in plant communities. SPB Academic Publishing, The Hague.

Söderström, L., T.Hallingbäck, L. Gustafson, N. Cronberg & L. Heden s. 1992. Bryophyte conservation for the future. Biological Conservation 59: 265-270.

Söderström, L. T. 1993. Substrate preference in some forest bryophytes: a quantitative study. Lindbergia 18: 98-103.

Söderström, L. 1981. Distribution of bryophytes in spruce forest on hill slopes in central Sweden. Wahlenbergia 7:141-153.

Söderström, L. & B.G. Jonsson. 1989. Spatial pattern and dispersal in the leafy hepatic *Ptilidium pulcherrimum*. Journal of Bryology 15: 793-802.

Spiess, L.D., B.B. Lippincott & J.A. Lippincott. 1982. Bacteria-moss interaction in the regulation of protenemal growth and development. Journal of the Hattori Botanical Laboratory 53: 215-220.

Steere, W.C. 1978. The Mosses of the arctic Alaska. Bryophyt. Biblioth. 14: I-x, 1-508. Journal Cramer, Vaduz.

Taylor, S.J., T.J. Carleton & P. Adams. 1987. Understory vegetation change in a *Picea mariana* chronosequence. Vegetatio 73: 63-72.

Tamm, C.O. 1953. Growth, yield and nutrition in carpets of a forest moss (*Hylocomium splendens*). Meddelanden Fran Statens Skogsforskningsinstitut 43: 1-140.

Thomsom, J.W. 1982. Cryptogam vegetation and ecological patterns in the high Arctic. Journal of the Hattori Botanical Laboratory 53: 361-364.

Timoney, K.P. & A.L. Robinson. 1996. Old-growth white spruce and balsam popular forest of the Peace River lowlands. Wood Buffalo National Park, Canada: Development, structure, and diversity. Forest Ecology and Management 81: 179-196.

Tuhkanen, S. 1984. A circumboreal system of climatic phytogeographical regions. Acta Bot. Fennica 127: 1-50.

Vitt, D.H. 1990. Growth and production dynamics of boreal mosses over climatic, chemical and topographic gradients. Botanical Journal of The Linnean Society 104:35-59.

Vitt, D.H. 1991. Distribution patterns, adaptive strategies, and morphological changes of mosses along elevational and latitudinal gradients on South Pacific Islands, pp. 205-231. In P.L. Nimis and T.J. Crovello (ed.), Quantitative Approaches to Phytogeography. Kluwer Academic Publishers, The Netherlands.

Vitt, D.H. 1991. Patterns of growth of the drought tolerant moss, *Racomitrium microcarpon*, over a three year period. Lindbergia 15: 181-187.

Vitt, D.H. & P. Kuhry. 1992. Changes in moss-dominated wetland ecosystems. In Bates, J.W. & A.M. Farmer (eds.), Bryophytes and lichens in a changing environment, Clarendon Press, Oxford, pp. 178-201.

Vitt, D.H. & N.G. Slack. 1984. Niche diversification of *Sphagnum* relative to environmental factors in northern Minnesota peatlands. Canadian Journal of Botany 62: 1409-1430.

Vitt, D.H. & R.J. Belland. 1995. The bryophytes of peatlands in continental western Canada. Fragmenta Floristica et Geobotanica 40: 339-348.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1-13.

Vitt, D.H., Y. Li & R.J. Belland. 1996. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Watson, M.A. 1980. Patterns of habitat occupation in mosses relevance to considerations of the niche. Bull. Torrey Botanical Club 107: 346-372.

Weber, M.G. & K. Van Cleve. 1983. Nitrogen transformations in feather moss and forest loor layers of interior Alaska black spruce ecosystems. Canadian Journal of Forest research 14:278-290.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30: 279-338.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Whittaker, R.H. 1977. Evolution of species diversity in land communities. pp. 1-67 In M.K. Hecht, W.C. Steere & B. Wallace (ed.), Evolutionary Biology, Vol. 10. Plenum, New York.

Wyatt, R. 1982. Population ecology of bryophytes. Journal of the Hattori Botanical Laboratory 52: 179-198.

Yarranton, G.A. 1972. Distribution and succession of epiphytic lichens on black spruce near Cochrane, Ontario. The Bryologist 75:462-480.

Zackrisson, O. 1977. Influence of forest fires on the northern Sweden boreal forest. Oikos 29: 22-32.

Zasada, J. 1986. Natural regeneration of trees and tall shrubs on forest sites in interior Alaska. pp.44-73. In Van Cleve, K., F.S. Chapin III, P.W. Flanagan, L.A. Viereck.

Chapter 1.

The Ones We Left Behind: Comparing Plot Sampling And Floristic Habitat Sampling For Estimating Bryophyte Diversity.

INTRODUCTION

Appropriate sampling methodology is crucial to understanding patterns of community and taxon diversity on the landscape. Traditionally, randomly placed, bounded plots have been used to sample communities for species diversity (e.g., Shafti & Yarranton 1972; Pike et al. 1975; Gustafsson & Hallingbäck 1988; Økland et al. 1990; Økland 1994a, 1994b; Johnston & Elliot 1996; Rambo & Muir 1998a; Bell & Newmaster 1998). As early as 1905, Clements described methods for collecting data using plots. Since that time many variations of quantitative measurements using plots have been used (e.g., Gleason 1925, Cain & Castro 1959, Bonham 1988, Krebs 1989). These methods have been used successfully in numerous population and community dynamics studies on bryophytes (e.g., Slack 1977; Söderström 1988a,1988b; Bonham 1989; Lesica et al. 1991; Selva 1994; Rambo & Muir 1998b; Gignac *et al.* 1998; McCune 1993, 1997a; Frego & Carlton 1995; Mornault et al. 1998). However, plot sampling is not ideal for biodiversity studies. Slack (1984) recognized that a completely random plot sampling method is likely to miss important types of variation within the sampling area unless the intensity of the sampling (i.e. number of quadrats) is very great. Intensive plot sampling in mature forest and areas disturbed by silvicultural operations did not record uncommon or distinctive habitats that offered considerable bryophyte diversity (Newmaster & Bell 2000).

Wallace (1878) proposed that regularity in the patterns of variation in diversity suggest they have been produced in conformity with a set of basic ecological variables. Several researchers have shown that bryophyte diversity is probably influenced by a multitude of ecological variables including microhabitat, stand age, disturbance, and available moisture (Vitt *et al.* 1975; Pøcs 1980; Söderström 1989; Herben *et al.* 1991; Gradstein 1992; Belland & Schofield 1994). It is difficult to separate how each of these factors influence or contribute to patterns of diversity (During & ter Horst 1987, During *et al.* 1987; Kimmerer & Allen 1982; Leonard *et al.* 1985; Carleton 1990; Herben & Söderström 1992; Økland 1994). Ultimately, it is desirable to quantify environmental variables in a statistical model to predict species richness in undisturbed and disturbed ecosystems. This requires a sampling methodology that includes all the habitats in the study area.

Recently Vitt and Belland (1997) presented a framework for understanding the patterning of bryophyte habitats on the landscape. Habitats can be defined as either mesohabitats or microhabitats. Microhabitats (e.g., logs and rocks) are the smallest landscape units and may be unique to one type of mesohabitat (i.e., submerged rock in a stream). Mesohabitats are localized physiographic (i.e., streams, seeps, cliffs) or physiognomic (i.e., forests) features. In a forested landscape they are arranged into a mosaic of dominant mesohabitats (e.g., forests) in which restricted mesohabitats (e.g., streams, seeps, cliffs) exist (Vitt & Belland 1997). Mesohabitat environmental quality (in the context of bryophyte diversity), is determined by the number of microhabitats (Vitt & Belland 1997).

Since bryophytes are closely linked to their habitats (Schuster 1949, Slack 1977, Söderström 1988), it is essential to consider the patterning of these habitats on the landscape. The importance of habitats in the patterning of bryophyte diversity has been documented in several studies (Slack 1976, 1984; Söderström 1988; Gignac & Vitt 1994; Vitt et al. 1995; Belland & Vitt 1995). Vitt et al. (1995) demonstrated that bryophyte diversity in wetlands is most strongly correlated with habitat heterogeneity. Vitt & Belland (1997) have shown that rare species diversity is in part a function of the types and distributions of all mesohabitats and the number of particular mesohabitats. The quality of the individual mesohabitats is expressed by the number and type of their microhabitats (Vitt & Belland 1997). Sampling by mesohabitats and microhabitats ensures a complete inventory of species richness, but to date has not been employed in forest diversity studies. Furthermore, there are no published reports that compare this sampling method with traditional sampling techniques such as plot sampling.

Sampling methods used for bryophyte diversity studies should include all of the potential habitats in an ecosystem, and incorporate the elements of a floristic inventory (Newmaster & Bell 2000). Belland's (Belland & Brassard 1988; Belland & Schofield 1994) method of sampling and analysis is derived from Bouchard et al. (1978) and used habitats as the sampling units. It attempts to sample all bryophytes from the diversity of habitat types within the study area. The method has been used successfully to document bryophyte diversity in National Parks of eastern Canada (Belland & Brassard 1988; Belland 1989, 1995; Belland & Schofield 1994; Belland & Vitt 1995). Vitt (1991) used a similar methodology in a study of south Pacific mosses. In this study, we refer to this method as floristic habitat sampling (FHS), a term reflecting its roots in the floristic tradition.

This paper contrasts patterns of diversity, using floristic habitat sampling (FHS) and plot sampling (PS) techniques in the same study area. More specifically this paper addresses the questions: 1) What is the more efficient sampling method for bryophyte diversity in stands, PS or FHS? 2) Are larger plots as efficient as FHS for sampling bryophyte diversity? 3) Are the patterns of bryophyte diversity in stands similar using PS or FHS?

STUDY AREA

Sampling was conducted in British Columbia, Canada, within two distinct biogeoclimatic zones; the Coastal Western Hemlock zone (CWH) and Interior Cedar Hemlock zone (ICH - Meidinger and Pojar 1991). The CWH is located on the westerly edge of the Coast Mountains and is also known as Canada's coastal temperate rainforest (Fig. 1-1). The ICH is located in the Caribou Mountains in B.C.'s interior and on the interior side of the Coast Mountains in Northern B.C. (Fig. 1-1). The wetter portions of the ICH (wk1 & vk1 variants) are known as inland oroboreal rainforests (Goward & Ahti 1992). Detailed descriptions of glacial history, climate and floristics can be found in Schofield (1988), Arsenault (1995), Hebda (1995), Schoonmaker et al. (1997) and Newmaster (thesis - chapter 2).

The ICH is divided into two geographically distinct areas. The smaller, most northerly area is located between 55° N and 57° N on the leeward slopes and adjacent lowlands of the Coast Mountains. The larger, more southerly area occupies a 200 km wide band from the Canada-U.S.A. border (at 49° N) to northern Caribou Mountains (approximately 54 ° N) (Goward 1995). The study area was located at 50-53° N and 199-120° W, within the Wells Gray (including Azure Lake and Mad River), upper Adams and upper Seymour watersheds of the ICH biogeoclimatic Zone. This sampling area represents the ICHmw3, ICHwk1 and ICHvk1 biogeoclimatic variants (Meidinger & Pojar 1991). Precipitation ranges from 900-1400 mm per year, with the highest precipitation in early winter. Snow pack over 1.5 meters deep is typical for much of the area. Mean temperatures during the warmest month averages between 16 °C and 21 °C, and during the coldest month from -3 °C to -10 °C. The ICH is the most productive zone in the interior and has the widest variety of coniferous tree species of any zone in B.C. Western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) are the dominant trees. The wettest sites are dominated by an under story of skunk cabbage (*Lysichiton americanum*) and devils club (*Oplopanax horridus*).

Within the CWH, research was focused on two geographically distinct areas: the mainland coast and the west coast of Vancouver Island. On the mainland coast sampling was conducted in the Capilano and Seymour watersheds of the greater Vancouver watershed. On the west coast of Vancouver Island, sampling was conducted in the Tofino, Clayoquot, Sidney and Walbran watersheds. All of the sampling occurred within the CWHvm1 biogeoclimatic variant. These coastal rainforests typify the most humid and highly oceanic region of North America. Mean annual precipitation ranges from 1000 to 4,400 mm, three-quarters of which occurs in the winter months as rain. Mean temperatures average between 13°C and 18.5°C in the warmest months and –6.5 °C and 4.5 °C during the coldest months. Predominant species are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*) and coastal douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) (Alaback & Pojar 1997).

METHODS

Definitions - A stand is defined as a standing growth of trees with similar physiognomy (Kimmins 1987; Barbour et al. 1987). In this study, a stand is similarly defined by the dominant tree species, its age, structure, elevation, slope position, and aspect. Stands vary in size, but most consist of a dominant mesohabitat (the forest) which encloses numerous restricted mesohabitats (e.g., cliffs, streams, seeps). Within each mesohabitat there are a number of microhabitats (i.e., tree base, stumps, acidic rocks) that may be specific to one type of mesohabitat (i.e., wet cliff crevices, submerged rocks in streams).

Plot Locations - Floristic habitat sampling (FHS) and plot method sampling (PS) were used to assess patterns of diversity in cedar-hemlock forests over two field seasons. In 1996, 102 stands were sampled in the interior cedar-hemlock (ICH) biogeoclimatic zone. Stands were chosen from the Wells Gray, upper Adams River, and Seymour watersheds. Within these watersheds, sampling was evenly distributed between stands that were burned approximately 80 years ago, and old growth stands of 250+ years in age. In 1997, 185 stands were sampled in the coastal western hemlock biogeoclimatic zone (CWHvm1). Stands were chosen from the Capilano and Seymour watersheds along the mainland coast and in the Sidney, Clayoquot, Tofino, and Walbran watersheds along the western coast of Vancouver Island. Extensive logging activities in the Capilano and Seymour watersheds allowed balanced sampling among stands that were burned approximately 80 years ago, stands that were logged 80 years ago, and old growth stands (>250 years). Sampling on Vancouver Island was limited to older stands due to the relatively recent logging activity and lack of fire disturbance.

Floristic Habitat Sampling - This study expands on the sampling methodology used by Belland & Brassard (1988), Belland (1989, 1995), Vitt (1991), Belland & Schofield (1994) and Belland & Vitt (1995). It incorporates forest stands and their mesohabitats to present a complete biodiversity-sampling regime. For discussion this method is termed *floristic habitat sampling* (FHS). FHS is similar to a floristic survey since it provides a method that records all species within a study area, but it differs because FHS is hierarchical; stands are further divided into dominant and restricted mesohabitats sampling units, and these are sampled further by microhabitat sample units. This method differs from plot sampling in several respects 1) PS usually restricts sampling to dominant mesohabitats, FHS samples the full diversity of mesohabitats and microhabitats, 2) PS is bounded by a relatively small sampling area; FHS is bounded by the actual limits of the stand, 3) PS provides a scaled, quantified list of common species and is useful for vegetation classification or population and community dynamics; FHS is floristic and emphasizes species presence/absence. It provides a complete or nearly so listing of species and habitat characteristics, from which many ecological and environmental questions can be answered.

All the potential mesohabitats and microhabitats (Table 1-1) were sampled in each stand. This was accomplished by systematically walking a grid of transects through each stand. Two steps were followed:

1) List all the species for each microhabitat that occurs within the dominant forest mesohabitat. An example of this would be recording all the bryophyte species that occur on rocks (one microhabitat), or on the forest floor. New microhabitats (e.g., logs) were surveyed until all the microhabitats within the dominant mesohabitat were recorded and no new species were found. Species abundance was recorded for each microhabitat within the dominant forest mesohabitat. Abundance was measured (ocular estimate) on a scale of one to three following Vitt et al. (1995): 1 = one to few occurrences, < 20% cover; 2 = several occurrences to frequent in one or some areas of the micro/mesohabitat, 30-50% cover; 3 = frequent throughout the micro/mesohabitat, > 70% cover.
2) Sample all restricted mesohabitats and list all the species and microhabitats for each type of restricted mesohabitat (i.e., stream, cliff, seep).

Sampling within a stand was influenced by time, space, and by natural stand or habitat boundaries. Fourteen hours (maximum) were spent at each stand; within each stand, the circular plot (used by PS, discussed later) was used as the starting point for collecting species data from microhabitats using FHS. Restricted mesohabitats within a one km radius of the plot were sampled. Sampling continued in the stand until all mesohabitats and microhabitats had been thoroughly sampled.

Three types of restricted mesohabitats were sampled:

1) Streams - Streams are the most complex mesohabitat and contain microhabitats that are also common to seeps, cliffs and the dominant forest mesohabitat (Table 1-1). Their physiography and physiognomy is unique within the cedar hemlock forest. We define the stream mesohabitat as a stream gully containing the stream itself and 5 m of bank (2.5 m on either side) habitat. Sampling started within the actual stream width (i.e., 1-5 m) and continued to include 5 m of bank. The stream banks were included because they offer a complex mix of microhabitats that contain considerable diversity not found elsewhere in cedar hemlock forests. Sampling continued along the stream (including the 5 m of bank) for 1000 m for a maximum sampling area of 5000 m^2.

2) Cliffs - Cliff mesohabitats offer a unique physiognomy and physiography. They are defined as large (> 100 m^2) rock faces or outcrops that may have trees, logs and stumps,

and which also may contain many microhabitats found in the dominant forest mesohabitat (Table 1-1). Sampling was limited to a maximum area of 5000 m^2.

3) Seeps - Seeps are swampy areas of cedar hemlock forest with poor drainage. Only seeps larger than 100 m^2 were considered for sampling. Seeps have many of the same microhabitats as the dominant forest mesohabitat. Sampling was limited to a maximum area of 5000 m^2.

Plot sampling - PS was conducted within a 20 m diameter circular sampling plot within the stand. All species were recorded with their abundance (ocular estimate of percent cover within the 20 m diameter circular plot).

Sample plot size- Sampling was conducted in successively larger areas to compare the efficiency of variously sized bounded plots to FHS. Plot size was quantitatively related to species richness and a proportional frequency index (Brillouin). Sample areas started at one square metre, and increased in size for nine areas (i.e., 1 m^2, 5 m^2, 25 m^2, 100 m^2, 250 m^2, 500 m^2, 1000 m^2, 2500 m^2, 5000 m^2). Species were recorded on each microhabitat within the specified area. Sample areas increased until no new microhabitats were sampled. The maximum area sampled was 5000 m^2.

Species nomenclature follows Anderson et al. (1990) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. Collections were made at each stand of common and rare species (occurring in less than 15% of stands). Voucher specimens are deposited in the University of Alberta Cryptogamic Herbarium (ALTA), Kamloops Forest Region Herbarium, and University of British Columbia Herbarium (UBC).

Diversity analyses - Bryophyte diversity was analyzed at several scales following the structure and terminology proposed by Whittaker (1972, 1977) (Fig. 1-2). Epsilon diversity is the total species richness for cedar hemlock forest sampled in British Columbia. Gamma diversity is a measure of species richness in watersheds, biogeoclimatic zones and variants. Alpha diversity is the number of species occurring in our sampling units (i.e., stands, mesohabitats or microhabitats). Diversity (inventory) was calculated for British Columbia's cedar hemlock forest (epsilon diversity), biogeoclimatic zones, variants, watersheds and mesohabitats (gamma diversity), and stands (alpha diversity). Species richness in stands (alpha diversity) was compared using ANOVA (SPSS 1999). An Index based on species and proportional frequencies (Brillouin index [eqn 1], Pielou 1966; Peet 1974; Clifford & Stephenson. 1975) were calculated for biogeoclimatic zones, variants, and watersheds for stands stratified by disturbance (logging, fire, old growth). Indices were calculated using Krebs/WIN (Krebs 1997). Abundance was recorded for each species on each type of microhabitat or mesohabitat (see FHS methods above) and averaged for each species within stands.

[eq. 2]

$$HB = \frac{\ln N! - \sum \ln n_i!}{N}$$

where, HB = Brillouin index

N = Number of individuals in entire collection

Patterns of mesohabitat species composition using FHS and PS were compared using Canonical Correspondence Analysis (CCA; ter Braak 1998), which ordinated all 287 stands, using 29 environmental variables to constrain the ordination. Four ordinations were constructed using all the species from PS or FHS and only the rare species or common species from FHS. Details of the environmental variable measurements can be found in (Newmaster thesis chapter 2).

RESULTS

What is the Most Efficient Sampling Method, FHS or PS?

The most efficient sampling method that captures greatest diversity in stands should consider all the different types of mesohabitats within a stand, and yield the highest species richness values. PS and FHS were compared in their ability to capture bryophyte diversity in stands. Typically, PS stratifies only the dominant forest mesohabitat and other mesohabitats such as streams, seeps, and cliffs are excluded resulting in decreased diversity estimates (Table 1-2, Fig. 1-3). FHS included sampling in the dominant forest mesohabitat and restricted mesohabitats (i.e., streams, cliffs and seeps must be included), all of these offer considerable diversity (Fig. 1-4). Streams and cliffs contain unique microhabitats that support communities of species that are only found on that specific microhabitat. Streams (70 species) and cliffs (26 species) have more unique species than the dominant forest mesohabitat (13 species - Fig. 1-4). Floristic habitat sampling captures the species diversity associated with the variability of mesohabitat types in the cedar-hemlock forests.

Epsilon and gamma diversity – Epsilon and gamma diversity estimates from plot sampling units (20m diameter circular plots) were compared with those from the dominant forest mesohabitat (FHS) to allow comparisons of bryophyte diversity within only the forest mesohabitat (one type of mesohabitat). There was a significant difference ($p < 0.05$) in these diversity estimates when using the two different types of sampling units. Epsilon was 196 species using the PS unit and 296 species using the FHS unit (i.e., the entire dominant forest mesohabitat as a sampling unit). Gamma diversity estimated using FHS was between 33% and 44% higher than gamma diversity estimated from the PS data (Fig. 1-3).

The estimates for epsilon and gamma diversity are more accurate when all the mesohabitats are considered in FHS. Epsilon diversity for cedar hemlock forests using all mesohabitats increases diversity dramatically from 196 species to 417 species. Floristic habitat sampling gamma diversity in biogeoclimatic zones and variants is higher (40-65%) than estimates from PS for either young or old forest (Table 1-2). Old forests are richer than younger forest using either sampling method. Using FHS, the CWH is slightly richer than the ICH and wetter variants (wk1 and vk1) are richer than dryer variants (mw3). Conversely, PS reveals that the ICH is slightly richer than the CWH, and variants have similar richness. Watersheds show a range of diversity using FHS. The highest diversity is in the Seymour (ICH), Walbran (CWH) or Sidney watersheds (CWH). Richness estimates from PS are very similar for all the watersheds (Table 1-2).

Alpha diversity – Alpha diversity (mean species richness of our sample units) using only the dominant forest mesohabitats in FHS is significantly ($p < 0.05$) higher when compared to PS. In the ICH, mean alpha diversity is 32 species using PS data and 65 species using FHS data. In the CWH, mean alpha diversity is 41 species using PS data and 98 species using FHS data.

Alpha diversity using all the mesohabitats in FHS is significantly higher ($p < 0.05$) than diversity estimates from PS (Fig. 1-5). If stands are arranged in order from lowest to highest diversity, it becomes apparent that alpha diversity is extremely variable. FHS alpha diversity ranges from 50 species per stand to 230 species per stand (Fig. 1-6), although the majority of stands have richness values greater than 100 species. Alpha diversity using PS data ranges from 25 species per stand to 125 species per stand, with the majority ranging between 25 and 100 species (Fig. 1-6). The ranking (order) of stand species richness from the FHS data differed from the ranking of stand richness obtained using PS data (Fig. 1-6). In stands with low alpha diversity, species richness from FHS is twice that of PS and in stands with high alpha diversity, species richness is more than three times higher using FHS (Fig. 1-6).

Diversity indices and abundance – Differences in diversity indices and species abundance support the differences in gamma and alpha diversity for the different sampling methods (Table 1-2). High indices are associated with high species richness and frequency. Brillouin indices using FHS data are greater than those calculated from PS data (Table 1-2). Species abundance estimates are also substantially higher for FHS data than PS data (Table 1-2).

Increasing Plot Size of Bounded Plots

An understanding of the relationship between increasing bryophyte diversity and increasing sample area serves to compare the efficiency of variously sized bounded plots to FHS. This included bounded plots in all types of mesohabitats. Nine sampling areas of increasing size were related to increasing bryophyte diversity (Fig. 1-7). In the forest mesohabitat, mean species richness for each sampling unit and diversity indices increased with sample area (Fig. 1-7). The 20m diameter plot used in the PS method, sampled 314 m^2 of forest mesohabitat and a mean species richness of 35 species. However, a plot of 314 m^2 is not large enough because an increase in area to 1000m^2 increases mean species richness by 18 species. Furthermore, species richness steadily increases even after 5000 m^2 has been sampled, increasing mean species richness in the dominant forest mesohabitat to just over 80 species (Fig. 1-7). The mean species richness within the dominant forest mesohabitat was 106 species using FHS. Even large plots do not sample for diversity as efficiently as FHS.

The size of a plot must be large enough to capture the heterogeneity of each type of mesohabitat. Bryophyte diversity in all mesohabitats types rises steadily with increasing sample area (Fig. 1-7). In streams, the first two areas (1-5 m^2) contained low diversity (< 20 species). Streams contain the most dramatic increase of richness and diversity indices with increasing sampling area because of the complex composition of microhabitats on the stream banks. The inclusion of the stream bank in the sampling area (> 5 m^2) increases mean species richness from 20 to 50 species after 100 m^2 of the stream and bank have been sampled (i.e., 20 m of stream including 5 m of shore with each linear metre of the stream). Another large jump in mean species richness (> 20 species) occurs as the sampling area increases to 250 m^2. Species richness increased steadily until 5000 m^2 of habitat was sampled (1000 m of stream gully - Fig. 1-7). Plot sampling usually does not include sample areas of this magnitude within one type of mesohabitat. Seeps and forest mesohabitats appear to have a continuous increase in richness with increasing sampling area. In cliffs, mean species richness and diversity indices rise quickly until 250 m^2 has been sampled; diversity tends to level off with increasing area greater than 250 m^2.

Patterns in Diversity

Patterns of alpha diversity following disturbance - Patterns of bryophyte diversity in stands are different when FHS and PS data are stratified by stand disturbance. Old growth stands (>250 years) sampled using PS have mean species richness values that are significantly ($p < 0.05$) higher than mean species richness in younger stands (80 yrs.) in the CWH (Fig. 1-5). However, with PS old growth species richness in the ICH is not significantly ($p > 0.05$) different from richness in young ICH stands. Floristic habitat sampling data indicate that species richness in old growth stands is significantly higher ($p < 0.05$) than in young stands in both ICH and CWH forest (Fig. 1-5).

Patterns of rarity and commonality - FHS and PS result in different patterns of bryophyte commonality and rarity (defined as species occurring in less than 15% of stands). In PS, 70 (34%) of the species are rare as compared with 270 (65%) rare species sampled using FSH. Consequently, the percentage of common species sampled using PS (66% - 126 species) is higher as compared FHS (35% - 147 species) (Fig. 1-8). This implies that PS does a moderate job of sampling common species but a poor job of sampling rare species (Fig. 1-8).

Patterns from gradient analysis - Canonical Correspondence Analysis (CCA) of the PS data (287 stands, 22 environmental variables) resulted in an ordination with overlapping stand groups representing old growth, and stands disturbed by fire (ICH) or logging (CWH - Fig. 1-9). Interset correlations and t-values were not significant (p>0.05) for any of the environmental variables (Table 1-4). It was not possible to define any groups (i.e., young, old, ICH or CWH) from the ordination of stands although the first three axis account for 52.6% of the variation in the species data, but interpretation of the ordination was not possible (Table 1-3). The low species-environment correlations indicate that the environmental variables are inadequate to explain variation in vegetation along an axis and result in distortion of the ordination. The low eigenvalues indicate that species scores are poorly dispersed along the axes (Table 1-3).

Relationships between species, stands, and environmental variables were interpretable in the ordination (CCA) when FHS data were analyzed (Fig. 1-10; Table 1-3). High species/environment correlations indicate a close association between the species (CA) and the environmental variables (CCA) for the first two axes (Table 1-3). Furthermore, the cumulative percentage of variance explained in the FHS ordination is much higher than in the PS ordination (i.e., 41.6 vs. 24.5 for the first axis) (Table 1-3). Using FHS, the first two axes of the ordination explained 60.6% of the variation in the species data set (Table 1-3). The relative values of the eigenvalues indicate that the dispersion of the species scores (a measure of species variation – ter Braak 1998) along axis one is greater than axes two which is greater than axis three (Table 1-3). Significant (p<0.05) interset correlations and t-values were used to identify important environmental variables for axis one (climatic variables) and axis two (time since disturbance -Table 1-5). The two distinct groups on the ordination indicate large differences in the composition of species between the ICH (right side of axis 1) and CWH (left side - Fig. 1-10). Furthermore, young stands (top of ordination) and old stands (bottom) are separated by the second axis (Fig. 1-10, Table 1-4). A Monte Carlo permutation test confirmed that the first axis is statistically significant ($p < 0.001$). A substantial portion (19%) of the species variation is explained by the second axis (Fig. 1-10).

Ordinations of common and rare FHS species indicate that rare species are crucial for the interpretation of environmental gradients (Figs. 11 & 12). Species/environment correlations were high using the rare species ordination (i.e., 0.99 rare vs. 0.70 common for the first axis) as compared to the common species ordination (Table 1-3). Eigenvalues from the rare species ordination were high (i.e., 0.71 vs. 0.05 for first axis) when compared to the common species ordination (Table 1-3). Using the rare species, the first three axes of the ordination explained 62.6% of the variation in the species data set (Table 1-3). The two distinct groups on the ordination indicate large differences in the composition of species between the ICH (right side of axis 1) and CWH (left side - Fig. 1-12). Furthermore, young and old stands are separated by the second axis (Fig. 1-12, Table 1-4).

The common species ordination distinguished the ICH and CWH with considerable overlap (Fig. 1-11). However, the second axis did not separate stands into different age classes. The low eigenvalues indicate that the axes explain a very small proportion of the variation in the species data even though the species-environment correlations may be misleadingly high, which is a common problem in CCA (Jongman et al. 1987; McCune 1997b).

DISCUSSION

The species we leave behind or exclude due to sampling technique may be crucial to understanding ecological patterns. The type of sampling used for estimating diversity depends on the organism being studied, and how closely that organism is associated with its substrate, and the nature of the ecological question (Krebs 1985). Bryophytes occur in close association with their substrate or habitat (Vitt & Belland 1997) and their usefulness as indicators of habitat and environmental change or sensitivity is well documented (Gignac 1986; Söderström 1988a; Gignac & Vitt 1994; Bell & Newmaster 1998; Newmaster & Bell 2000). In terrestrial ecosystems, moss habitat limitations are often associated with substrate availability and type (Horton 1988; Shaw 1981; Söderström 1988a). In peatlands, bryophyte species richness is closely related to microhabitat diversity (Vitt et al. 1995; Vitt & Belland 1995). Vitt and Belland (1997) proposed that rare species occurrence and diversity depends on the quality and quantity of mesohabitats found on the landscape. To understand patterning of bryophyte diversity we must incorporate sampling techniques that focus on habitats as the sampling units. The patterning of bryophyte diversity is intimately linked with habitat heterogeneity.

This study shows that FHS is much more efficient at capturing bryophyte richness than PS. Bryophyte diversity estimates compared within the dominant forest mesohabitat are much greater (i.e., species richness is 50% higher) when using FHS as compared to PS. We have also shown that PS within a mesohabitat will exclude microhabitats and their respective bryophyte communities even after sampling unconventionally large sample areas. Species richness may increase with increasing sample area, but a comprehensive hierarchical sampling technique (such as FHS) will sample greater species richness. Sampling large areas will not necessarily include the natural variety in microhabitats. Plots as large as 5000 m^2 are not as efficient sampling units as FHS. Plot sampling was designed to give a quantitative "snap shot" of a plant community in time and space, not a comprehensive sample of the species within the community. PS focuses on bounded plots as sampling units and these plots are too small and restrictive to consider the total variety of microhabitats in a mesohabitat.

FHS is ideal for biodiversity research because it focuses on the entire mesohabitat as the basic sampling unit and is flexible enough to include the diversity of microhabitats in a mesohabitat. Stream mesohabitats provide a particularly good example. The concept of a stream mesohabitat must include the stream gully, which includes the stream itself and its banks. The banks include microhabitats common to other mesohabitats, but they also contain microhabitats unique to the stream. Rich communities of bryophytes can be found on these unique bank microhabitats (i.e., logs and rocks) because of the moist humid stream environment, particularly in splash zones. It is common practice to sample only within the stream itself and not the stream gully. A study of the bryophyte flora of Bridal Veil Falls in the CWH recorded stream species richness (35 species) from within the stream itself (Djan-Chekar 1993). In our study of the CWH, mean species richness within the stream itself (40 species) was comparable to Djan-Chekar's study, but much higher (103 species) when we considered the entire stream gully. Intensive sampling can focus on the stream itself, not the stream gully and miss the unique microhabitats that exist on the immediate stream bank underestimating biodiversity in stream mesohabitats. Excluding these microhabitats from diversity studies could result in a misinterpretation of the value of streams in an ecosystem management plan.

The forest landscape consists of a hierarchy of mesohabitats and microhabitats, and efficient sampling of species diversity must reflect the natural variation and hierarchy of these habitat types. In cedar hemlock forests, bryophyte diversity can be partitioned within a hierarchy of stands, which contain mesohabitats, and these latter consists of microhabitats. PS is usually confined to the dominant forest mesohabitat in studies concerning biodiversity and the impacts of silvicultural disturbance (Bell & Newmaster 1998). Our study has shown that species diversity will be underestimated if the sampling method does not include the diversity of mesohabitats on the landscape. Comparisons of diversity estimates using PS and FHS (including all mesohabitats) show significant differences. Total species richness is 110% higher when using FHS methodology, a difference that results because FHS focuses on the entire mesohabitat as a sampling unit, including the variety of microhabitats within each type of mesohabitat, and includes also a complete floristic survey of the species within each mesohabitat.

The species we leave behind are predominately the rare ones. FHS is an efficient method for biodiversity studies because it samples both the rare and common species; these are equally important in biodiversity studies. While a community analysis that needs species abundance within fixed areas only considers the common species, diversity studies should always include rare species since these always comprise a large proportion of the flora being considered. Recent bryophyte studies have underscored this point (Vitt 1991, Vitt & Belland 1997, Newmaster et al. 1998). In FHS, measures of species abundance are less important because most bryophytes are found in low abundance.

In the multivariate analyses, the rare species contributed significantly to the patterning of diversity in cedar hemlock forests. Young and old cedar hemlock forests stands were not distinguished in PS ordinations because the sampling method records only the species that are common and present to both young and old stands. In the FHS ordinations, young and old cedar hemlock stands are separated in ordination space because the presence of rare species in old stands is recorded by FHS. Thus, rare species are crucial in distinguishing differences between young and old stands, and to understanding the patterning of diversity within them.

All sampling techniques have their disadvantages and advantages (Tilman 1996). The sampling methodology must be appropriate for the question being asked. The use of plot sampling to address diversity questions is inappropriate for the reasons previously discussed. Plot sampling method is appropriate for answering questions that require a fixed reference to the area being sampled (i.e., for biomass or abundance measures). These questions are at smaller landscape scales and include aspects of community dynamics, plant sociology, physiological ecology, and population ecology.

Floristic habitat sampling may be limited to questions concerning biodiversity at large scales on the landscape. It would be inappropriate to use this methodology to answer questions regarding treatment impacts on diversity within small research areas. The unbounded nature of this methodology limits its use to research blocks that are large enough to capture the natural variation in habitats. Vitt et al. (1995) successfully used a similar habitat sampling method on bounded research blocks in peatlands where the microhabitat diversity is relatively homogeneous. Floristic habitat sampling methodology can be modified to measure species diversity for different silvicultural treatments within large bounded treatment blocks (experimental disturbances in forests) with moderate habitat heterogeneity (Newmaster and Bell 1999), although a disadvantage of this approach is that many large treatment areas are needed for a balanced biometric analysis, and often this is not feasible or economical. Floristic habitat sampling is a superior methodology for answering questions about bryophyte diversity within and between stands, especially those with different disturbance histories. Further research is needed to investigate whether FHS methodology is useful in seed-bearing plant diversity studies.

Floristic habitat sampling may provide results that could be directly implemented into ecosystem management plans that attempt to preserve "rare species" and identify "hot spots" for conservation. It would be of tremendous value if it aids in the interpretation of the patterning of plant diversity using environmental variables in association with spatial landscape units such as mesohabitats and microhabitats. These landscape units can be identified in aerial or satellite photography and linked to GIS applications. A classification of mesohabitats and microhabitats as it relates to bryophyte diversity could be developed and incorporated into large-scale, multi-factored (i.e., soils, stand structure, climate, wildlife values, land use etc.) environmental plans.

Furthermore, FHS also records both rare and common species and their frequency in microhabitats and mesohabitats. This provides a method in which to identify the crucial habitats that need to be protected to preserve rare species. FHS can also be used to identify larger areas such watersheds that have significantly high diversity. One complicating factor that is perhaps more important than habitat availability is time since the last large-scale disturbance. The influence of time since disturbance on patterning of bryophyte diversity in cedar hemlock forests needs further investigation.

Table 1-1: A list of microhabitats for each type of meso-habitat within cedar hemlock stands (DMH = dominant mesohabitats; RMH = restricted mesohabitat).

Microhabitat	DMH	RMH		
	Forest	Cliff	Stream	Seep
Coniferous tree species	x	x	x	x
Deciduous tree species	x	x	x	x
Size of tree (10-25 cm dbh, 30-60 cm dbh, > 70 cm DBH)	x	x	x	x
Position on tree (trunk or base - 50 cm above tapered bowl)	x	x	x	x
Snag (dead coniferous or deciduous trees)	x	x	x	x
Twig (CWD < 10 cm diam.)	x	x	x	x
Log size (10-30 cm, 30-60 cm dbh, > 70 cm DBH)	x	x	x	x
Log decay class (D1,D3 or D5 – CWD codes)	x	x	x	x
Organic soils (LFH)	x	x	x	x
Mineral soil (sand, silt, loam, clay)	x	x	x	x
Moist depression (small isolated pools of water/mud)	x	x	x	
Intermittent stream (narrow and ephemeral)	x	x		x
Rock (sample type, pH)	x	x	x	x
Tree stump	x	x	x	x
Upturned tree roots ("tip-up")	x	x	x	x
Adjacent bank (sand, silt, clay, loam, gravel, cobble, rock)	x	x	x	x
Submerged habitat (rocks or logs)			x	x
Shallow bars (sand, silt, clay, loam, gravel or cobble; dry/wet)			x	
Waterfall (< 1 m, 1-2 m, 2-5 m, 5-10 m, >10 m)			x	
Depth (< 10 cm, 10-30 cm, > 30 cm)			x	
Rapid (flow rate (m/second))			x	
Crevice (horizontal/vertical; < 5 cm, .5-1 m, > 1m; wet/dry; seepage, soil cover, sand, silt, clay, loam)		x	x	
Ledges (size, wet/dry, seepage, soil covered)		x	x	
Caves (size, wet/dry, seepage)		x	x	
Vertical rock face (size, wet/dry, seepage)		x	x	
Talus		x	x	
Rock surface (rough/smooth)		x	x	

Table 1-2. Landscape gamma diversity for stands with different disturbance histories using both FHS and PS sampling [abundance values are relative, i.e., total abundance/number of plots; Plan. = Plantation/logging disturbance].

Landscape Elements		Hist.	Spp.richness		Abundance		Brillouin index	
			FHS	PS	FHS	PS	FHS	PS
Biogeoclimatic zones	**ICH**	Fire	188	123	269	203	6.4	5.8
		Old	300	141	374	251	6.9	6.1
	CWH	Plan.	114	99	120	103	5.5	5.2
		Old	317	134	621	286	6.9	5.6
Biogeoclimatic variants	**ICHmw3**	Fire	171	95	229	149	6.2	5.4
	ICHmw3	Old	235	93	309	146	6.6	5.4
	ICHwk1	Fire	162	96	218	162	6.1	5.5
	ICHwk1	Old	276	109	348	196	6.8	5.7
	ICHvk1	Fire	120	62	162	102	5.7	4.8
	ICHvk1	Old	266	94	342	167	6.8	5.5
ICH watersheds	**WG**	Fire	125	53	171	85	5.8	4.6
		Old	218	77	291	111	6.5	5.1
	Azure	Fire	138	75	184	124	5.9	5.2
		Old	242	80	314	141	6.6	5.3
	Adams	Fire	151	89	200	139	5.9	5.3
		Old	265	81	318	137	6.7	5.3
	Seymour	Fire	165	94	225	155	6.1	5.5
		Old	276	116	335	204	6.6	5.8
CWH watersheds	**Capilano**	Plan.	108	89	118	97	5.4	5.1
		Old	230	108	151	130	6.5	5.5
	Seymour	Plan.	87	42	113	91	5.4	5.1
		Old	111	87	219	117	6.3	5.3
	Tofino	Old	213	104	265	146	6.3	5.5
	Claquot	Old	231	107	281	148	6.5	5.5
	Sidney	Old	286	106	338	147	6.8	5.5
	Walbran	Old	288	113	340	155	6.8	5.6

Table 1-3. Summary of canonical correspondence analysis (CCA) of 287 stands in British Columbia's cedar hemlock forests and 22 environmental variables, using plot sampling (PS) or floristic habitat sampling (FHS). CCA analyses of rare or common species are presented for FHS.

Axis		1	2	3	4
Eigenvalue	PS	0.29	0.04	0.02	0.02
	FHS	0.48	0.23	0.07	0.04
	Rare	0.71	0.46	0.23	0.19
	Common	0.05	0.01	0.01	0.01
Species/environment correlation	PS	0.86	0.58	0.52	0.50
	FHS	0.99	0.89	0.85	0.81
	Rare	0.99	0.92	0.88	0.84
	Common	0.70	0.35	0.46	0.43
Cumulative % variance of species data explained	PS	24.5	40.6	52.6	61.8
	FHS	41.6	60.6	71.2	77.8
	Rare	33.8	53.1	62.6	69.7
	Common	71.5	77.0	81.1	84.3

Table 1-4. Plot sampling statistics for variables used in canonical correspondence analysis (CCA) of 287 stands in B.C.'s cedar hemlock forest. Value were not significant $p > 0.05$. Absolute t-values < 2.1 indicate unimportant canonical coefficients (ter Braak, 1998).

	Interset Correlation		Canonical coefficient		t-value	
Variable	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Site Series (SS)	-0.67	-0.05	0.03	-0.16	0.59	-1.13
Elevation (Elv)	0.72	0.03	0.38	-0.03	1.25	-0.19
Slope Position (SP)	0.22	0.19	-0.07	0.05	-1.65	-0.77
Aspect (As)	0.19	0.13	-0.01	0.04	-0.36	-0.66
Moisture Regime (Hyg)	-0.13	-0.06	0.04	0.09	1.01	1.28
Rock cover (RC)	0.41	-0.57	-0.14	0.85	1.47	2.03
Rock acidity (RA)	0.39	-0.43	-0.02	-0.09	1.12	-3.79
Soil Texture (ST)	0.26	0.07	0.03	0.01	0.98	0.28
Canopy height (CH)	-0.52	-0.04	-0.06	-0.10	-1.38	-1.38
Tree density (DT)	0.37	0.10	0.07	-0.06	1.84	-0.86
Tree basal area (BT)	-0.38	-0.05	-0.03	0.00	-0.89	-0.01
Snag density (DS)	0.09	0.17	0.05	0.14	1.53	2.65
Snag basal area (BS)	-0.48	-0.06	-0.08	-0.06	-1.84	-0.83
Log density (DL)	-0.74	-0.11	-0.27	0.14	-2.08	-0.92
Log basal area (BL)	-0.65	-0.09	-0.03	0.09	-0.49	-0.79
Shrub cover (SC)	-0.56	-0.13	-0.14	0.13	-2.07	1.52
Herb cover (HC)	0.44	-0.11	-0.01	-0.06	-2.02	-1.95
Disturbance (Ds)	-0.58	-0.07	-0.33	-0.15	-2.02	-1.78
Mean annual temperature (AT)	0.67	0.24	2.58	6.15	2.01	1.88
Rainfall (Rn)	0.59	0.17	-2.77	-0.91	-1.43	-0.65
Degree days > 0° C (Dd)	0.64	0.16	1.11	-0.87	-1.84	-0.99
6 month mean temperature (6T)	0.58	0.07	1.15	-2.88	-2.01	-1.68

Table 1-5. Floristic habitat sampling statistics for variables used in canonical correspondence analysis (CCA) of 287 stands in B.C.'s cedar hemlock forest. Asterisks indicate significance at $p < 0.05$. Absolute t-value > 2.1 are used to indicate important canonical coefficients (ter Braak, 1998). Bold values indicate variables with significant correlation and canonical coefficients.

	Interset Correlation		Canonical coefficient		t-value	
Variable	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Site Series (SS)	-0.83	-0.07	0.01	-0.08	0.62	-1.01
Elevation (Elv)	0.65	0.48	0.03	0.21*	1.09	2.32
Slope Position (SP)	-0.01	0.08	-0.01	-0.06	-0.59	-1.16
Aspect (As)	0.28	0.18	0.02	-0.04	1.85	-1.14
Moisture Regime (Hyg)	-0.46	-0.08	0.01	0.01*	0.21	2.34
Rock cover (RC)	0.03	-0.15	0.02	0.05*	1.21	2.44
Rock acidity (RA)	0.32	-0.22	0.03*	-0.15*	3.11	-3.79
Soil Texture (ST)	-0.02	0.27	0.01	0.06	1.67	1.83
Canopy height (CH)	-0.35	-0.58	-0.02	-0.08	-1.79	-1.58
Tree density (DT)	0.37	0.42	0.04*	0.09*	2.77	2.02
Tree basal area (BT)	-0.09	-0.42	-0.01	0.06	-0.75	-1.64
Snag density (DS)	0.22	0.09	0.02	0.11*	1.72	3.10
Snag basal area (BS)	-0.44	-0.44	-0.01	-0.03	-0.34	-0.74
Log density (DL)	-0.46	-0.61	-0.04	-0.19	-1.65	-1.89
Log basal area (BL)	-0.49	**-0.57**	-0.05	-0.24*	-1.99	-2.91
Shrub cover (SC)	-0.45	-0.52	0.02	-0.09	1.09	-1.74
Herb cover (HC)	0.08	-0.33	0.01	0.11*	0.66	2.29
Disturbance (Ds)	-0.21	**-0.67**	-0.03*	-0.41*	-2.35	-7.84
Mean annual temperature (AT)	**-0.98**	0.10	-2.29*	-1.06	-16.34	1.98
Rainfall (Rn)	**-0.96**	0.10	1.06*	-0.76	4.73	-0.89
Degree days > 0° C (Dd)	**-0.97**	0.10	1.55*	-0.37	-2.46	0.94
6 month mean temperature (6T)	**-0.94**	0.11	0.33*	0.26	-2.57	0.55

Figure 1-1. Map of the coastal western hemlock (CWH) and interior cedar-hemlock (ICH) biogeoclimatic zones in British Columbia.

Figure 1-2. Hierarchy of diversity terminology for cedar-hemlock rainforest in British Columbia (terminology for inventory and differentiation diversity follows Whittaker (1965, 1972, 1977).

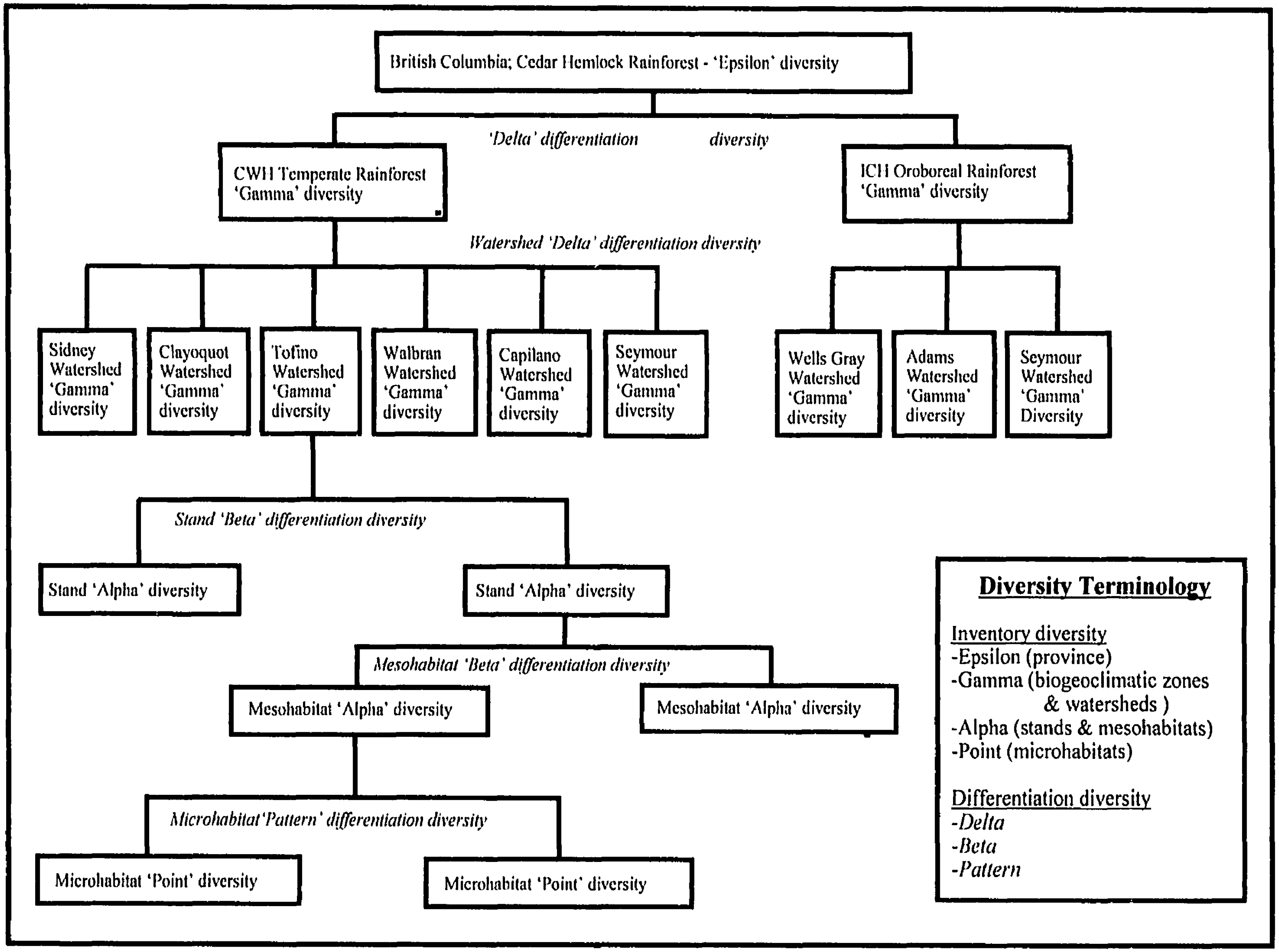


Figure 1-3. Gamma diversity assessed using floristic habitat sampling (FHS) and plot sampling (PS) in dominant mesohabitats and restricted mesohabitats (FHS only) within the interior cedar hemlock (ICH) or coastal western hemlock (CWH).

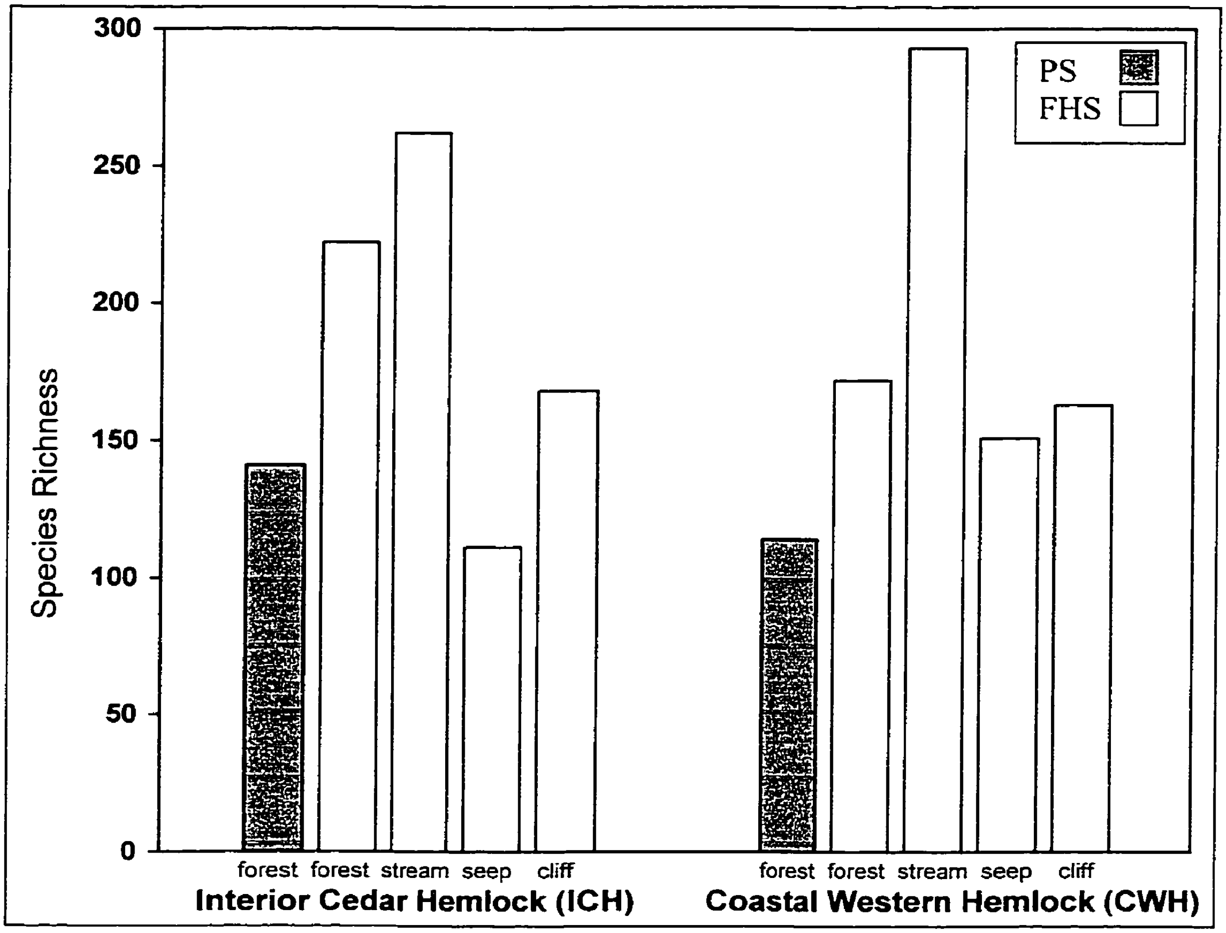


Figure 1-4. Species richness in mesohabitats for all cedar hemlock forests sampled (bold numbers refer to total species richness for each type of mesohabitat; number in parenthesis represent the number of species unique to each type of mesohabitat).

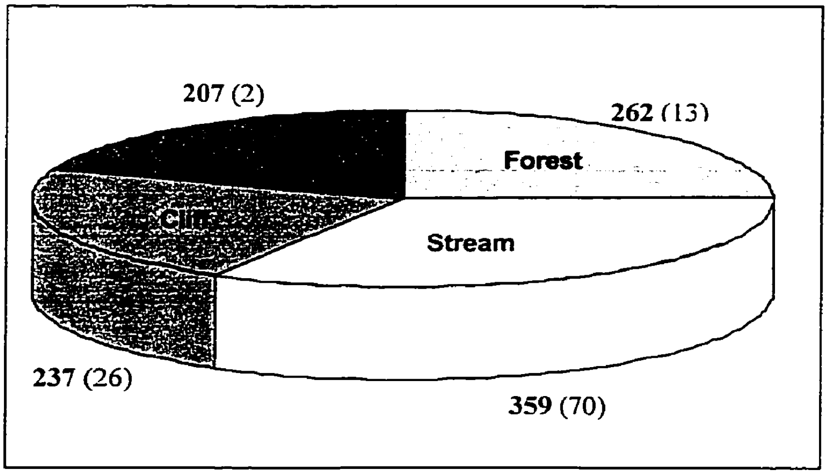


Figure 1-5. Alpha diversity of stands assessed using floristic habitat sampling (FHS including all mesohabitats) and plot sampling (PS) sampling. Cedar hemlock forests are divided into inland (ICH), coastal mainland (CWH-ML), coastal oceanic (CWH-ISL), and by age classes (class 4, young = 80 years and class 9, old >250 years). Error bars represent two standard errors on either side of the mean.

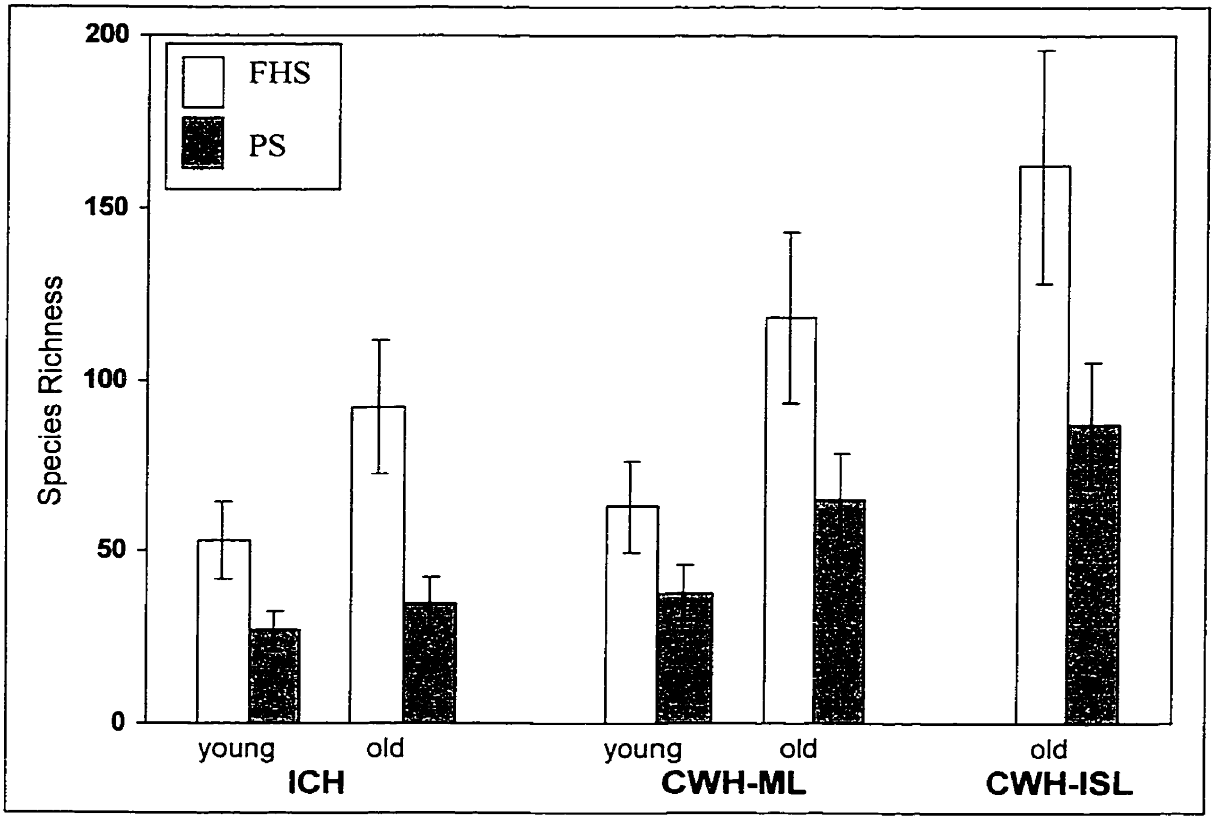


Figure 1-6. Alpha diversity curves for all 287 rainforests stands developed using floristic habitat sampling (FHS including all mesohabitats) or plot sampling (PS) data. Stands are ranked by species richness.

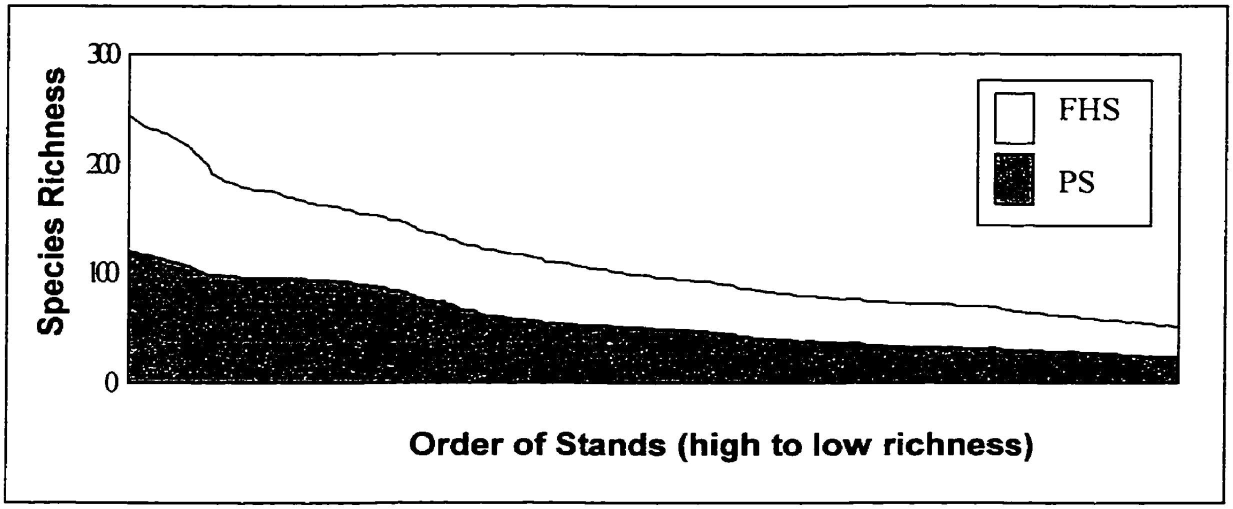


Figure 1-7. Area diversity curves for different meso-habitats in 287 rainforest stands. Total species richness is for each of the areas sampled. Total species frequency refers to the sum of all individual species' frequency for individual microhabitats within each of the areas sampled (SP = seep, CF = cliff, FS = forest, ST = stream).

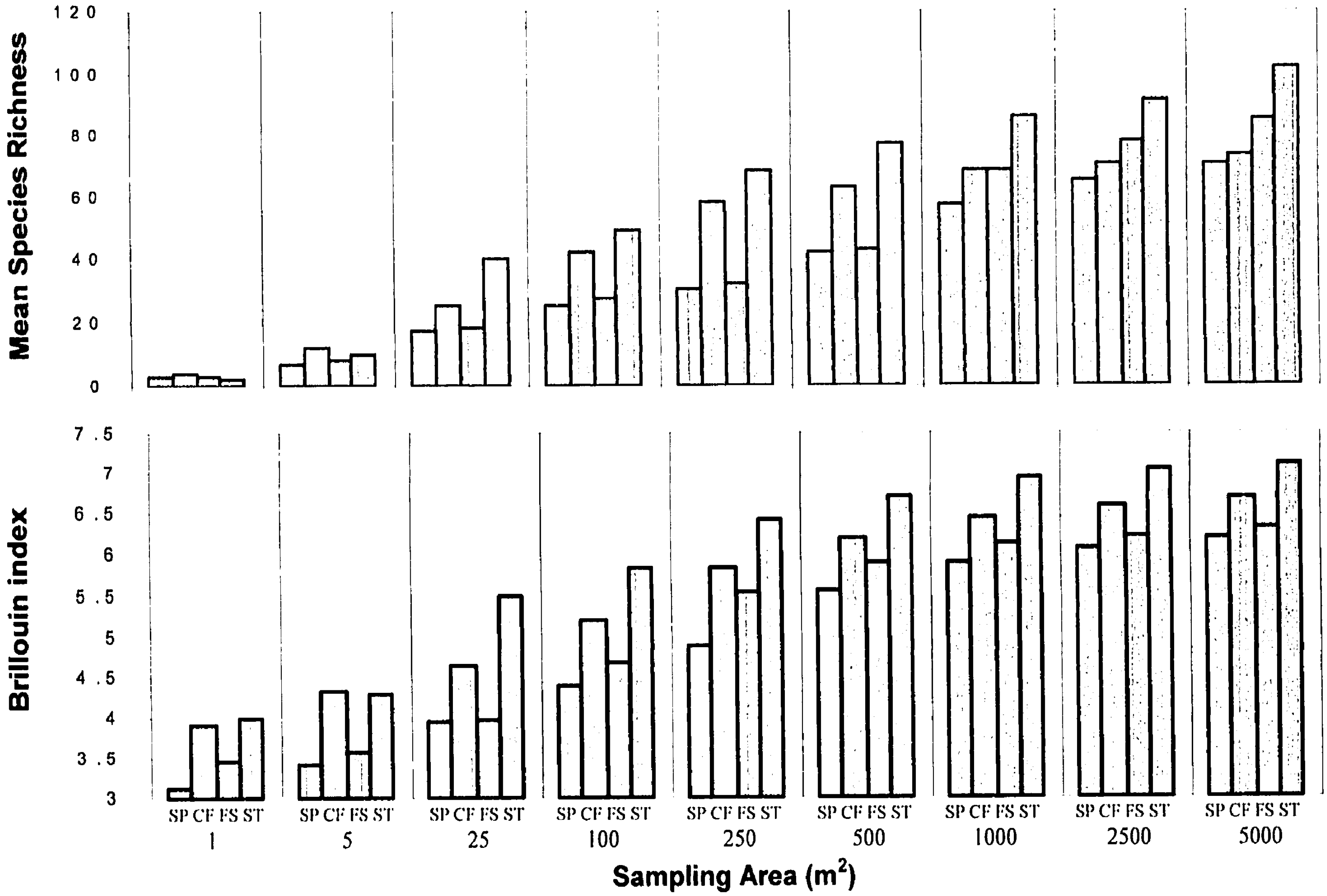


Figure 1-8. Species occurrence curves for all 417 rainforest species (CWH and ICH) in 287 stands using either floristic habitat sampling (FHS, including all mesohabitats) or plot sampling (PS) (dotted line represents division of species that occur in < 15 % of total stands).

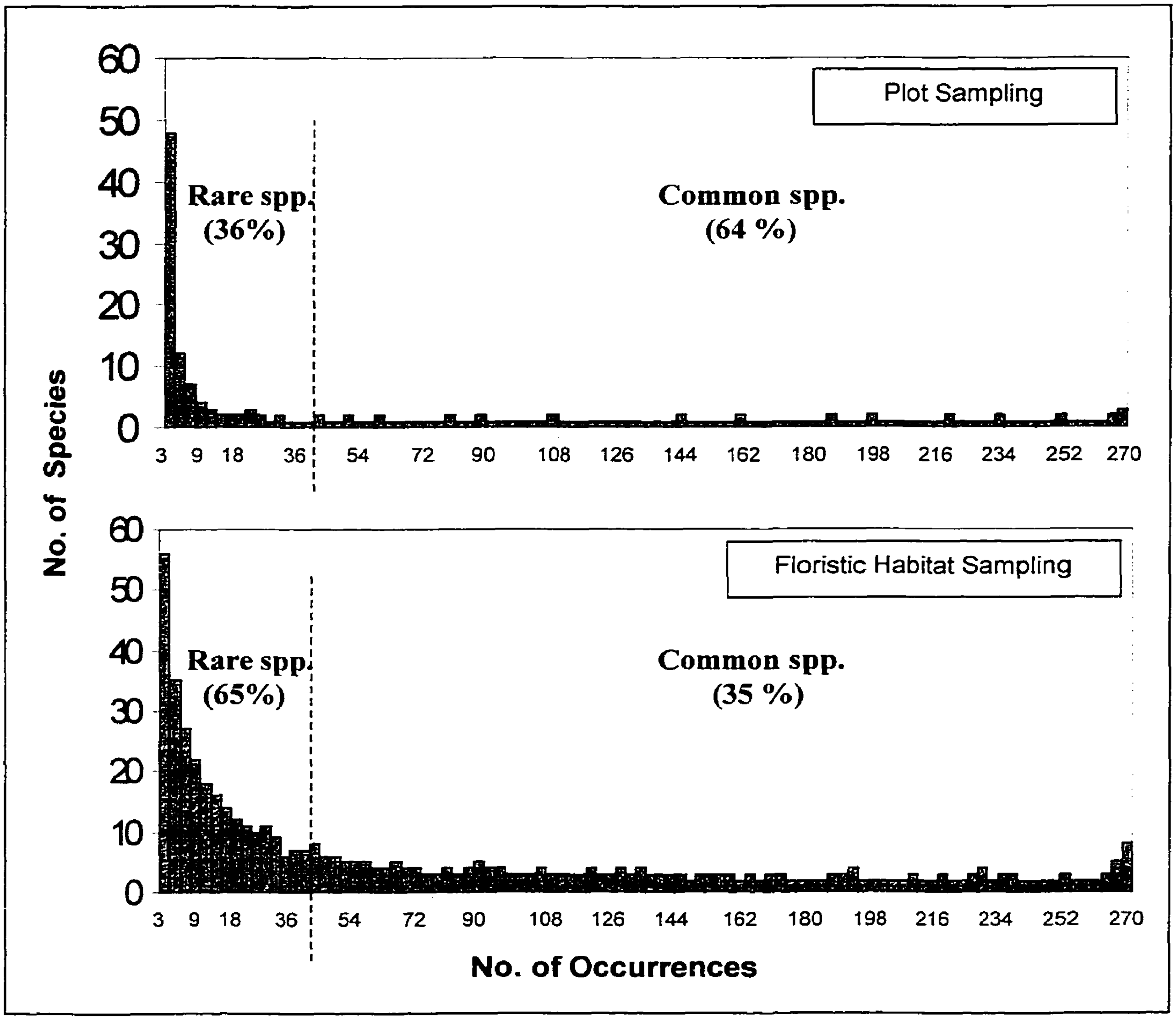


Figure 1-9. CCA ordination developed using plot sampling (PS) data to explore the relationships between 287 stands, 196 species and 22 environmental variables. Abbreviations are listed in Table 1-1.

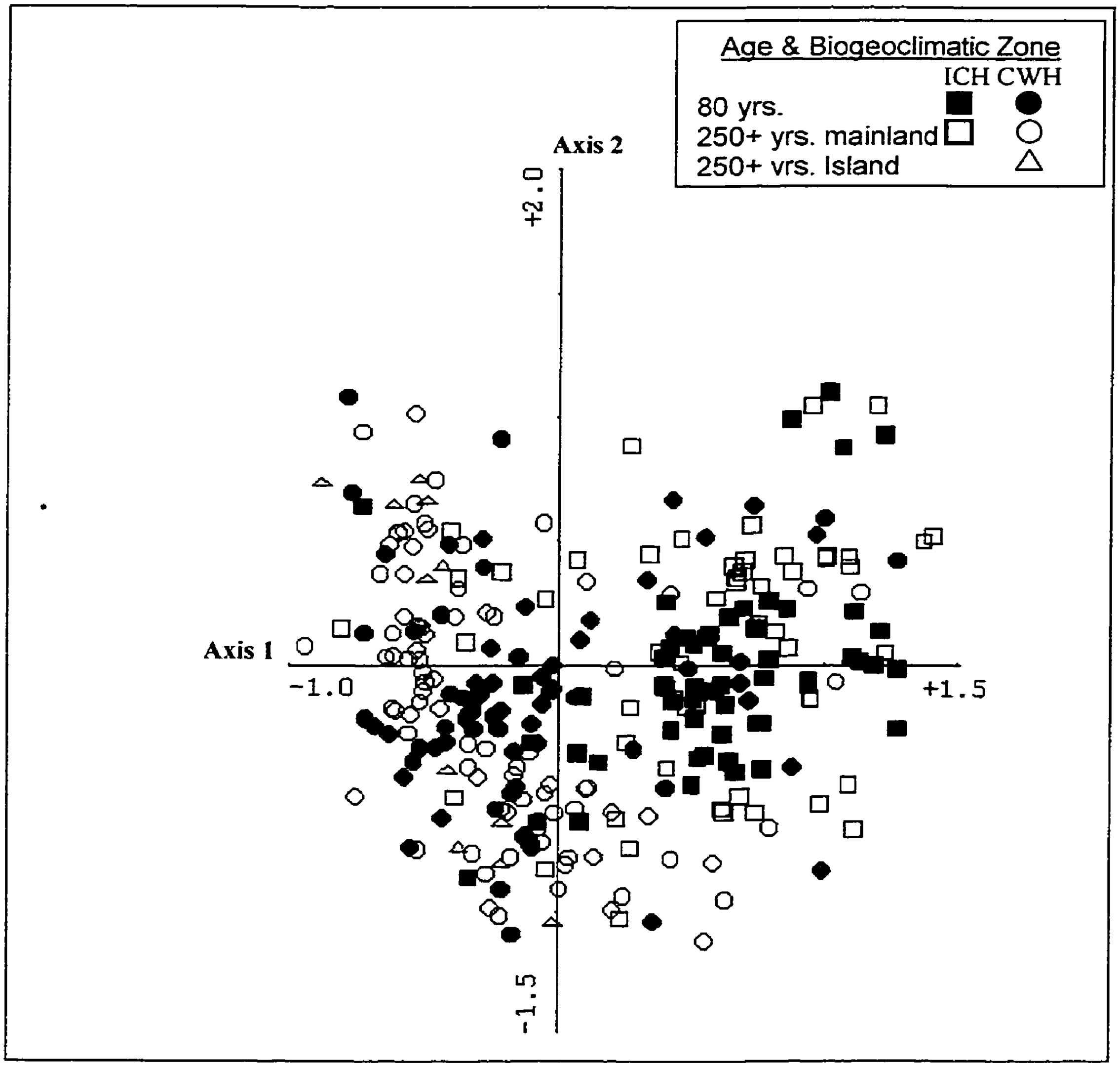


Figure 1-10. CCA ordination developed using floristic habitat sampling (FHS, including all mesohabitats) data to explore the relationships between 287 stands, 417 species and 22 environmental variables. Abbreviations are listed in Table 1-1.

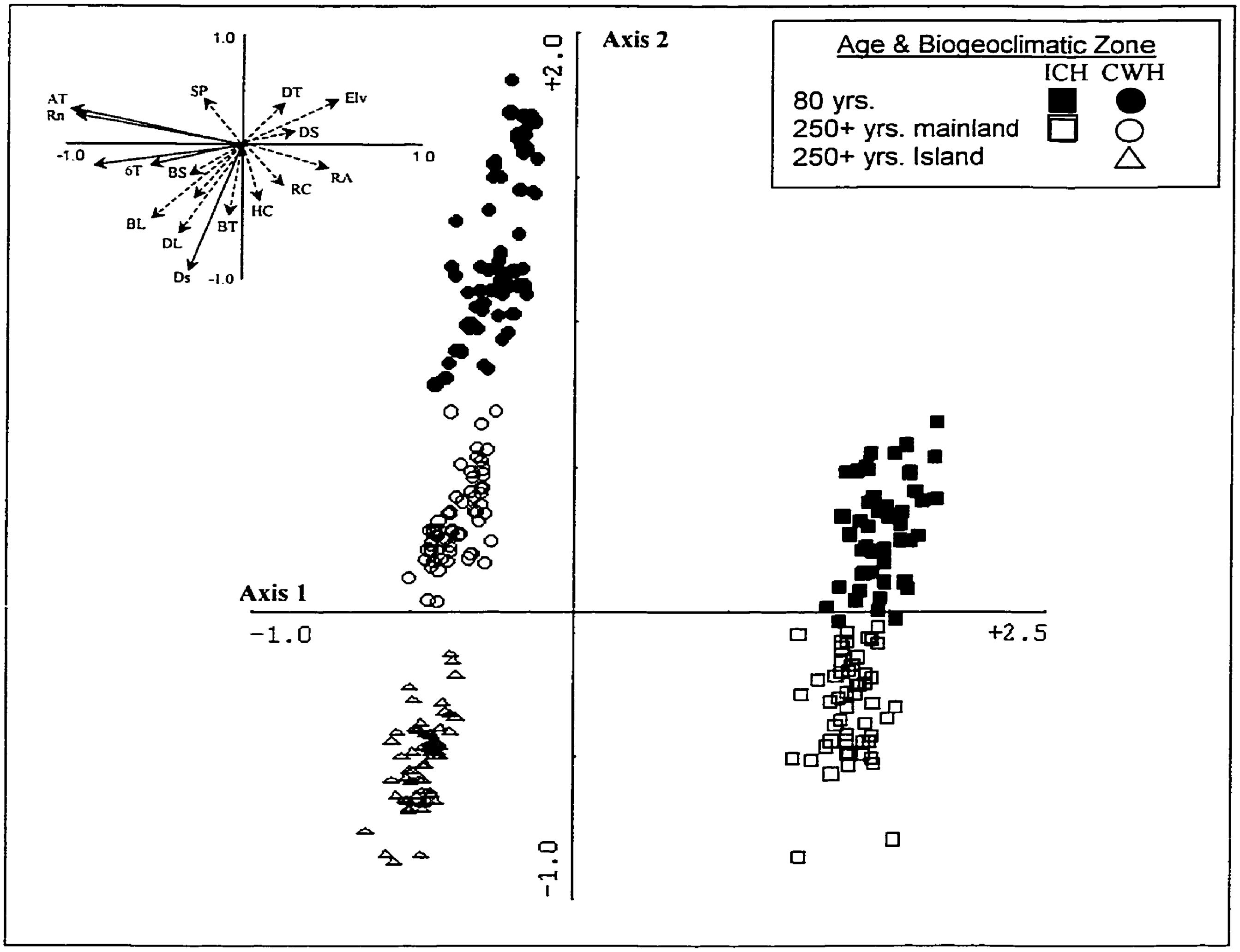


Figure 1-11. CCA ordination of common species using floristic habitat sampling (FHS, including all mesohabitats) common species data to explore the relationships between 287 stands, 147 species and 22 environmental variables. Abbreviations are listed in Table 1.

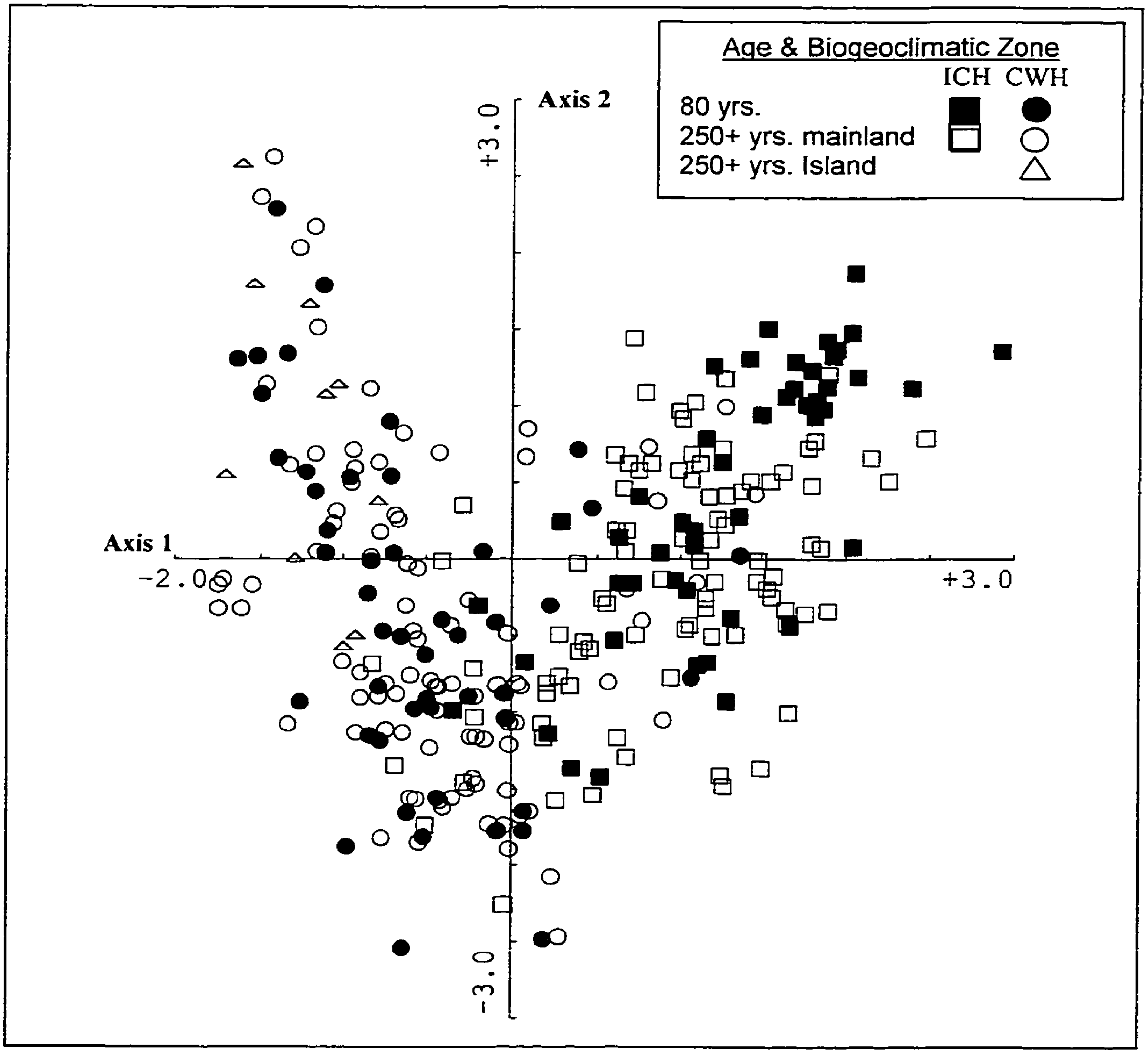
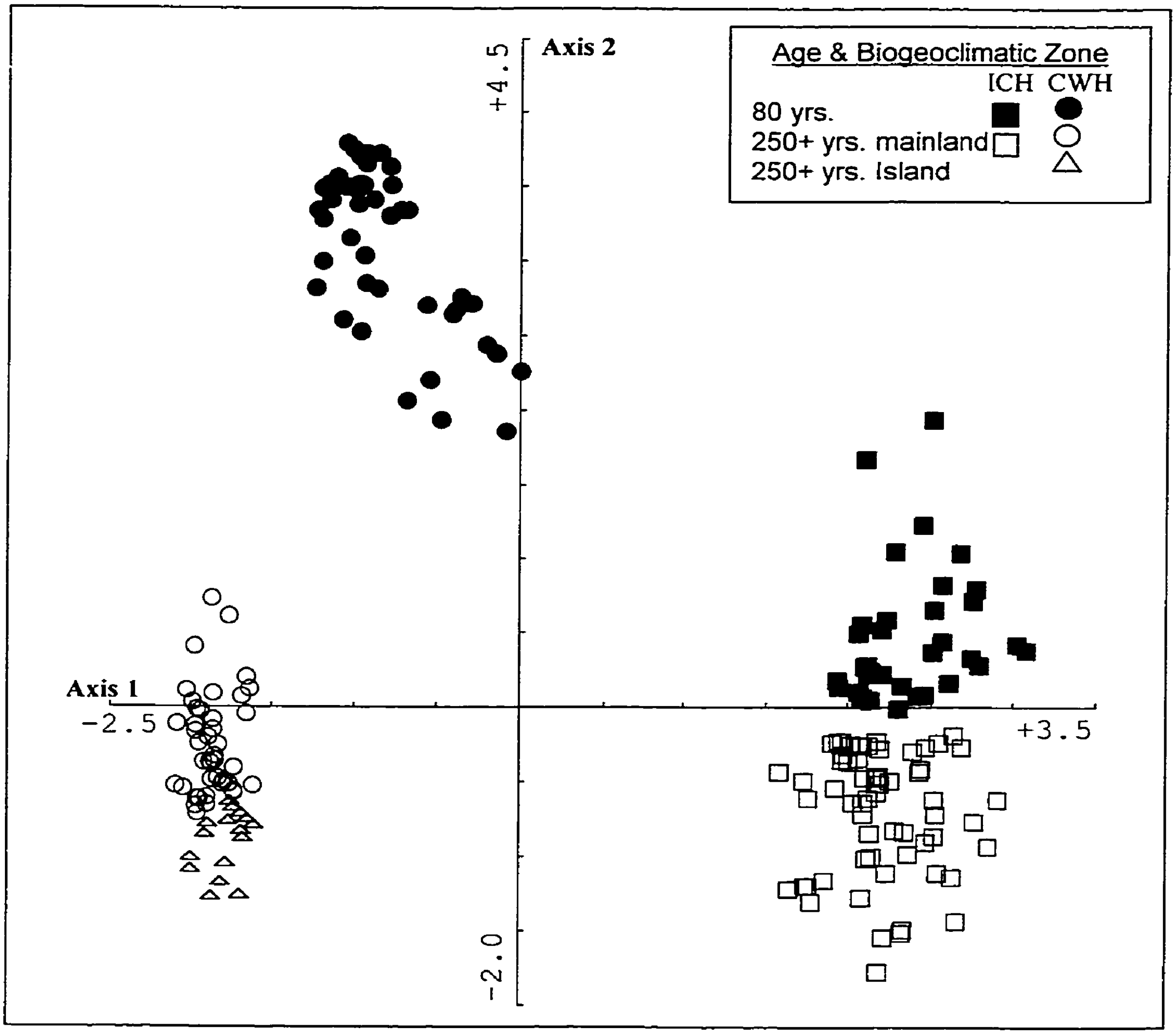


Figure 12. CCA ordination of rare species using floristic habitat sampling (FHS, including all mesohabitats) data to explore the relationships between 287 stands, 270 species and 22 environmental variables. Abbreviations are listed in Table 1.



LITERATURE CITED

Andersson, L.I. & H. Hytteborn. 1990. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Anderson, L.E., Crum, H.A. & W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93: 448-499.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. University of British Columbia, Department of Botany, Vancouver, B.C. Ph.D. Dissertation,

Barbour, M.G., Burk, J.H. & W.D. Pitts. 1987. Terrestrial Plant Ecology. Benjamin/Cummings Publ.

Bell, F.W. and S.G. Newmaster. 1998. Fallingsnow Ecosystem Project: Floral richness, abundance and diversity. pp. 45-47 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (eds.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Belland, R.J. 1989. Floristic boundaries in the Gulf of St. Lawrence region: A numerical approach based on the moss flora. Canadian Journal of Botany 67: 1633-1644.

Belland, R.J. & D.H. Vitt. 1995. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

Belland, R.J. & G.R. Brassard. 1988. The bryophytes of Gros Morne National Park, Newfoundland Canada: Ecology and phytogeography. Lindbergia 14: 97-118.

Belland, R.J. & W.B. Schofield. 1994. The ecology and phytogeography of the bryophytes of Cape Breton Highlands Park, Canada. Nova Hedwigia 59: 275-309.

Belland, R.J. 1995. The bryophytes of Prince Edward Island National Park, Canada: Affinities, habitats, and diversity. Fragmenta Floristica et Geobotanica 40: 349-364.

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons.

Bouchard, A., S. Hay & E. Rouleau. 1978. The vascular flora of St. Barbe south district Newfoundland: An interpretation based on biophysiographic areas. Rhodora 80: 228-308.

Braun-Blanquet, J. 1932. Plant Sociology: The Study of Plant Communities. McGraw-Hill.

Carleton, T.J. 1990. Variation in terricolous bryophytes and macrolichen vegetation along primary gradients in Canadian boreal forest. Journal of Vegetation Science 3:585-594.

Clements, F.E. 1905. Research Methods in Ecology. Woodruff-Collins, Lincoln, NB.

Clifford, H.T. & W. Stephenson. 1975. An Introduction to Numerical classification. Academic Press, London, UK.

Conard, H.S. 1935. The plant associations on central Long Island: A study in descriptive sociology. American Midland Naturalist 16: 433-516.

Djan-Chekar, N. 1993. The bryophyte flora of bridal veil falls, British Columbia: An analysis of its composition and diversity. Masters Thesis, University of British Columbia.

During, H.J. & B. ter Horst. 1987. Diversity and dynamics in bryophyte communities on earth banks in a Dutch forest. Symposia Biologica Hungarica 35: 447-455.

During, H.J., van Tooren & F. Bart. 1987. Recent developments in bryophyte population ecology. Trends in Ecology and Evolution 2: 89-93.

Frego, K.A. & T.J. Carleton. 1995. Microsite conditions and spatial pattern in a boreal bryophyte community. Canadian Journal of Botany 73: 544-551.

Gignac, D.L. 1986. Ecological tolerance and niche structure of *Sphagnum* along a pollution gradient near sudbury, Ontario, Canada. Canadian Journal of Botany 65: 1138-1147.

Gignac, D.L. & D.H. Vitt. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Gignac, D.L., B.J. Nicholson & S.A. Bayley. 1998. The utilization of bryophytes in bioclimatic modeling: Present distribution of peatlands in the Mackenzie River Basin, Canada. The Bryologist 101: 560-572.

Goward, T. & T. Ahti. 1992. Macrolichens and their zonal distribution in Wells Gray Provincial Park and its vicinity, British Columbia, Canada. Acta Botanica Fennica 147: 1-60.

Gradstein, R.S. 1992. The vanishing tropical rainforest as an environment for bryophytes and lichens. pp. 234-253. In, J.W. Bates & A.M. Farmer (eds.), Bryophytes and Lichens in a Changing Environment. Clarendon Press, Oxford, UK.

Gustafsson, L. & T. Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological Conservation 44: 283-300.

Herben, T. & L. Söderstrom. 1992. Which habitat parameters are most important for the persistence of a bryophyte species on patchy, temporary substrates? Biological Conservation 59: 121-126.

Herben, T., H. Rydin & L. Söderstrom. 1991. Spore establishment probability and the persistence of the fugitive invading moss, *Orthodontium lineare*: A spatial simulation model. Oikos 60: 215-221.

Horton, D.G. 1988. Microhabitats of new world Encalyptaceae (Bryopsida): distribution along edaphic gradients. Beifefte zur Nova Hedwigia 90: 261-282.

Johnston, M.H. & J.A. Elliot. 1996. Impacts of logging and wildfire on an upland black spruce community in northwestern Ontario. Environmental Monitoring and Assessment 39: 283-297.

Jongman, R.H.G., C.J.F. Braak and O.F.R. van Tongeren. 1987. Data analysis in community and landscape ecology. Pudoc Wageningen, Netherlands.

Kimmerer, R.W. & T.F.H. Allen. 1982. The role of disturbance in the pattern of a riparian bryophyte community. American Midland Naturalist 107: 370-383.

Kimmins J.P. 1987. Forest Ecology. MacMillan Publishing Company.

Krebs, C.J. 1985. Ecology. Harper & Row.

Krebs, C.J. 1997. Ecological Methodology. Harper Collins.

Leonard, R.E., P.W. Conkling & J.L. McMahon. 1985. Recovery of bryophyte community on Hurricane Island, Maine. U.S.D.A. Forest Service Research Note 325: 1-4.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

Magurran, A.E. Ecological diversity and its measurement. Princeton University Press.

McCune, B. 1993. Gradients in epiphytic biomass in three Pseudotsuga-Tsuga forest of different ages in western Oregon and Washington. The Bryologist 96: 405-411.

McCune, B. 1997a. Repeatability of common data: Species richness versus gradient scores in large-scale lichen studies. The Bryologist 100: 40-46.

McCune, B. 1997b. Influence of noisy environmental data on canonical correspondaence analysis. Ecology 78: 2617-2623.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6

Morneault, A.E., W.C. Parker, B.J.Naylor, T.L. Noland, F.W. Bell, S.G. Newmaster, D.C. Othermer, L.C. Duchesne, M.E. Woods, D.M. Burgess, S.S. Wetzel and F.N.L. Pinto. 1998. Ecological effects of site preparation in white pine stands managed under the shelterwood system. pp. 454- 456 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (eds.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1998. The effects of silvicultural herbicides on bryophytes. pp. 223-225. In Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (eds.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Newmaster, S.G. & F.W. Bell. 2000. Floristic diversity of cryptograms in a boreal-mixedwood stand after mechanical, manual and herbicide conifer release treatments. (Submitted manuscript CJFR).

Økland, R.H., T. Økland & O. Eilertsen. 1990. On the relationship between sample plot size and beta diversity in boreal coniferous forest. Vegetatio 87: 187-192.

Økland, R.H. 1994a. Bryophyte and lichen persistence patterns in a Norwegian boreal coniferous forest. Lindbergia 19: 50-62.

Økland, R.H. 1994b. Patterns of bryophyte associations at different scales in a Norwegian boreal spruce forest. Journal of Vegetation Science 5:127-138.

Peet, K.P. 1974. The measurement of species diversity. Annual Review of Ecology Systematics 5: 285-307.

Pielou, E.C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. Journal of Theoretical Biology 10: 370-383.

Pike, L.E., W.C. Denison, D.M. Tracey, M. A. Sherwood and F. M. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing in old-growth conifers in western Oregon. The Bryologist 78: 1-39.

Pøcs, T. 1980. The epiphytic biomass and its effects on the water balance of two rain forest types in the Ilguru Mountains, Tanzania, East Africa. Acta Botanica Hungarica 26:143-167.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Schuster, R. 1949. The ecology and distribution of Hepaticae in central and western New York. American Midland Naturalist. 42:513-712.

Selva, S.B. 1994. Lichen diversity and stand continuity in the northern hardwoods and spruce- fir forests of northern New England and western New Brunswick. The Bryologist 97: 424-429.

Shafti, M.I. & G.A. Yarranton. 1972. Diversity, floristic richness and species evenness during a secondary (post fire) succession. Ecology 54: 897-902.

Shaw, A.J. 1981. Ecological diversification among nine species of *Pohlia* (Musci) in western North America. Canadian Journal of Botany 59: 2359-2378.

Slack, N.G. 1977. Species diversity and community structure in bryophytes: New York State Studies. Bulletin New York State Museum 428: 1-70.

Slack, N.G. 1984. A new look at bryophyte community analysis: field and statistical methods. Journal Hattori botanical laboratory 55: 113-132.

Slack, N.G. 1976. Host specificity of bryophyte epiphytes in eastern North America. Journal Hattori botanical laboratory 41: 107-132.

Slack, N.G. 1988. The ecological importance of lichens and bryophytes. In J. Cramer and der Gebr (eds) Lichens, bryophytes and air quality. Biliographies in Lichenology 30: 23-53.

Söderström, L. 1988a. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8: 89-97.

Söderström, L. 1988b. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1989. Regional distribution patterns of bryophyte species on spruce logs in northern Sweden. The Bryologist 92: 349-355.

SPSS. 1999. Professional base system software for statistical analysis. Chicago, IL.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

ter Braak, C.J.F. 1998. CANOCO 4. Centre for Biometry, Wageningen, The Netherlands.

Tilman, D. 1996. Biodiversity: Population versus ecosystem stability. Ecology 77: 350-363.

Vitt, D.H. 1991. Distribution patterns, adaptive strategies, and morphological changes of mosses along elevational and latitudinal gradients on South Pacific Islands, pp. 205-236. In P.L. Nimis & T.J. Crovello (ed.), Quantitative Approaches to Phytogeography. Kluwer Academic Publishers, The Netherlands.

Vitt, D.H. & R.J. Belland. 1995. The bryophytes of peatlands in continental western Canada. Fragmenta Floristica et Geobotanica 40: 339-348.

Vitt, D.H., Y. Li & R.J. Belland. 1995. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Vitt, D.H., P. Achuff & R.E. Andrus. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Canadian Journal of Botany 53: 2776-2795.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1- 12.

Wallace, A. R. 1878. Tropical nature and other essays. MacMillan Co. London, UK.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities Science 147: 250-260.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Whittaker, R.H. 1977. Evolution of species diversity in land communities. pp. 1-67 In M.K. Hecht, W.C. Steere & B. Wallace (ed.), Evolutionary Biology, Vol. 10. Plenum, New York.

Chapter 2.

Bryophyte Community Composition in Oceanic and Continental Cedar-Hemlock Biogeoclimatic Zones of British Columbia, Canada.

INTRODUCTION

The cedar-hemlock forests of western Canada are known for their rich communities of bryophytes (Colinvaux 1986; Schofield 1988; Goward 1994; Alaback and Pojar 1997; Schoonmaker et al. 1997) The landscape on which they occur is diverse, and ranges from flat valley bottoms to steep mountain slopes dissected by cliffs, canyons and fjords. The cedar-hemlock forests we see today have developed on mountain watersheds for 5000-7000 years (Hebda 1995). These forests contain a reticulate network of streams, rivers and waterfalls that are replenished by heavy precipitation (up to 5000 mm/yr.). Consequently, the incidence of wildfire in this wet ecosystem is low (Agee 1993, Arsenault 1995), resulting in the development of old-growth cedar-hemlock forest. Individual trees within this forest can be over 1000 years old, and grow to over 6 m in diameter and greater than 60 m in height. The biomass of these forests is unparalleled in any other terrestrial ecosystem (Waring and Franklin 1979). The combinations of the above factors encourage luxuriant carpets of mosses and liverworts.

Cedar-hemlock forests dominate two biogeoclimatic zones in B.C. (Meidinger and Pojar 1991): the coastal western hemlock (CWH) and interior cedar hemlock (ICH). The CWH comprises the largest temperate rainforest in the world (Colinvaux 1986). Other countries that contain temperate rainforests include New Zealand, Chile, Norway, China, Japan and the U.S.A. Cedar-hemlock rainforests occur in Washington, Oregon and Alaska. The ICH stretches along the moist, mild valley bottoms and mid-slopes of the interior Columbia and Rocky Mountains (Meidinger and Pojar 1991). The wettest portion of the ICH (i.e., the ICHwk and ICHvk variants) are considered inland rainforests; these inland rainforests are found in no other continental region of the world (Arsenault & Goward 1999).

The importance of bryophytes in British Columbia is considerable. With more than 850 species of mosses and hepatics, the province's bryoflora is the richest in North America and contains the largest percentage (15 %) of western North American endemic species and genera on the continent (Schofield 1988; Ireland et. al 1987). Schofield (1968a, 1968b, 1968c, 1968d, 1980), has collected bryophytes extensively in the CWH. Furthermore, Godfrey (1977a, 1977b, 1979, 1980, 1984), has made considerable contributions to the hepatic flora of the CWH. Schofield (1984, 1988) noted that the CWH contains luxuriant carpets of bryophytes, which are supported by an abundant source of moisture in the form of rain and fog. Furthermore, the CWH shows considerable habitat diversity with frequent cliffs, canyons, outcrops, boulders, streams, rivers, waterfalls, fjords and bodies of water. It is not surprising that this area is characterized by extraordinary bryophyte richness and contains the majority of western North American endemic species and genera (Schofield 1984, 1988).

Collections by Tan (1980) have resulted in a relatively complete list of mosses for the ICH. However, limited collections of hepatics have been made in this biogeoclimatic zone (Wong unpublished). The bryoflora characteristic of CWH is also prevalent, in part, in the ICH (Schofield 1988). The CWH and ICH have similar forest structure and composition, yet there appear to be differences in ecosystem diversity and community structure/dynamics (Arsenault 1995). We are aware of no studies that have attempted to quantitatively compare and contrast the bryophyte communities of the CWH and ICH; a comparison of their composition will provide useful information on their makeup, and insight into how these diverse forests might be managed.

Bryophytes play an important role in the forest ecosystem. Their importance in nutrient cycling (Nadkarni 1981; Pocs 1980; Oechel & Van Cleve 1986; Chapin et al. 1987), moisture retention (Nadkarni 1981; Pocs 1976; Weber and Van Cleve 1983; Coxson 1991) and seedling establishment (Black & Bliss 1980; Cross 1981; Keizer et al. 1985; Nadkamura 1986; Nakamura & Obata 1984; Okada & Ohsawa 1984; Zasada 1986) is well documented. Other important ecosystem functions include animal food chains, plant and animal interactions, colonization and primary succession, and soil stabilization (Slack 1988; During & Van Tooren 1988; Longton 1992; Newmaster et al. 1999). The detailed analysis of bryophyte communities in different biogeoclimatic zones is undoubtedly important, but considerable sampling and analysis of data are necessary before forest management applications can be made (Schofield 1984, 1988). Schofield (1988) claimed that further comparisons should be made between bryophyte communities in disturbed forests and old-growth forests, with the information from the old-growth forests serving as a benchmark for the proper forest utilization and management.

Conservation of our future forest will best be served by understanding and maintaining the natural forest communities of today (Hebda 1997, Lertzman et al. 1997).

Landscapes can only be defined relative to a given organism and the spatial and temporal scales that impact that organism (Perera 1996). Only at large scales can natural forest disturbance be examined in a way to elucidate the effects of disturbance and their many implications for forest resource management (Perera 1999). Intensive bryophyte studies should begin at a regional landscape scale and then focus down to stand and local scales. This will allow research questions concerning bryophytes to be focused relative to the correct landscape scale and to the appropriate ecosystem management protocol.

This paper compares bryophyte community composition in cedar-hemlock forests at a regional landscape scale within British Columbia. More specifically, the objectives of this study are to compare communities of bryophytes in the cedar-hemlock ICH and CWH biogeoclimatic zones and determine: 1) the relationships between stands, species and environmental variables (including disturbance) in the cedar-hemlock forest landscape, 2) which environmental factors are associated with bryophyte vegetation patterns in the cedar-hemlock forest landscape, 3) the indicator species for the ICH and CWH, and whether these biogeoclimatic zones have the same indicator species for young and old-growth forests, 4) the floristic affinities associated with bryophyte vegetation patterns in the ICH/CWH biogeoclimatic zones and in young and old forest, and 5) the taxonomic and morphological patterns associated with the ICH, CWH and young and old forests.

STUDY AREA

Sampling was conducted in British Columbia, Canada, within two distinct biogeoclimatic zones; the Coastal Western Hemlock zone (CWH) and Interior Cedar Hemlock zone (ICH - Meidinger and Pojar 1991). The CWH is located on the westerly edge of the Coast Mountains and is also known as Canada's coastal temperate rainforest (Fig. 2-1). The ICH is located in the Caribou Mountains in B.C.'s interior and on the interior side of the Coast Mountains in Northern B.C. (Fig. 2-1). The wetter portions of the ICH (wk1 & vk1 variants) are known as inland oroboreal rainforests (Goward & Ahti 1992). Detailed descriptions of glacial history, climate and floristics can be found in

Schofield (1988), Arsenault (1995), Hebda (1995), Schoonmaker et al. (1997) and Newmaster et al. (2000).

The ICH is divided into two geographically distinct areas. The smaller, most northerly area is located between 55° N and 57° N on the leeward slopes and adjacent lowlands of the Coast Mountains. The larger, more southerly area occupies a 200 km wide band from the Canada-U.S.A. border (at 49° N) to northern Caribou Mountains (approximately 54 ° N) (Goward 1995). The study area was located at 50-53° N and 199-120° W, within the Wells Gray (including Azure Lake and Mad River), upper Adams and upper Seymour watersheds of the ICH biogeoclimatic Zone. This sampling area represents the ICHmw3, ICHwk1 and ICHvk1 biogeoclimatic variants (Meidinger & Pojar 1991). Precipitation ranges from 900-1400 mm per year, with the highest precipitation in early winter (Fig. 2-2). Snow pack over 1.5 meters deep is typical for much of the area. Mean temperatures during the warmest month averages between 16 °C and 21 °C, and during the coldest month from -3 °C to -10 °C. The ICH is the most productive zone in the interior and has the widest variety of coniferous tree species of any zone in B.C. Western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) are the dominant trees. The wettest sites are dominated by an under story of skunk cabbage *(Lysichiton americanum*) and devils club (*Oplopanax horridus*).

Within the CWH, research was focused on two geographically distinct areas: the mainland coast and the west coast of Vancouver Island. On the mainland coast sampling was conducted in the Capilano and Seymour watersheds of the greater Vancouver watershed. On the west coast of Vancouver Island, sampling was conducted in the Tofino, Clayoquot, Sidney and Walbran watersheds. All of the sampling occurred within the CWHvm1 biogeoclimatic variant. These coastal rainforests typify the most humid and highly oceanic region of North America. Mean annual precipitation ranges from 1000 to 4,400 mm, three-quarters of which occurs in the winter months as rain. Mean temperatures average between 13°C and 18.5°C in the warmest months and –6.5 °C and 4.5 °C during the coldest months (Fig. 2-2). Predominant species are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*) and coastal douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) (Alaback & Pojar 1997).

METHODS

Field sampling – Floristic habitat sampling (FHS - Newmaster et al. 2000) was used to sample bryophyte communities over the period of two field seasons. During the first season (May-Oct. 1996) 102 stands were sampled in the interior cedar-hemlock biogeoclimatic zone (ICH). Stands were chosen from the Wells Gray, upper Adams River, and Upper Seymour River valleys. Within these watersheds, sampling was evenly distributed between stands that were burned approximately 80 years ago, and old-growth stands of 250+ years in age. In the ICH only the wettest subzones (ICHwk1 and ICHvk1) are properly described as rainforest. In 1997 (May-Oct.), 185 stands were sampled in the coastal western hemlock biogeoclimatic zone (CWHvm1). Stands were chosen from the Capilano and Seymour river watersheds along the mainland coast and in the Sidney, Clayoquot, Tofino and Walbran river watersheds along the western coast of Vancouver Island. Extensive logging activities in the Capilano and Seymour watersheds allowed a balanced sampling between stands that were burned approximately 80 years ago, stands logged 80 years ago, and old-growth stands of 250+ years in age. Sampling on Vancouver Island was limited to old stands due to the relatively recent logging activity and lack of fire history.

Environmental variables – Twenty-five environmental variables were used for multivariate analyses. Stand dynamics, soil variables and general site variables were collected within a 20 m diameter plot that was located in the stand at least 500 m from any transition zone. Coarse woody debris data was obtained using two 50 m transects, with diameter measurements of logs for each decay class (Arsenault & Bradfield 1995) at each transect intersection.

Macroclimate data were obtained from the Canadian Climatic Normals and meterological stations within the local watersheds (Anonymous, 1982) and were used in climate diagrams (Walter & Lieth 1967) and as environmental variables in multivariate analyses. Microclimate data were collected only within in a subset of 20 stands (divided evenly between young and old forest) within each watershed. Within each stand, five replicate sites were randomly chosen to measure temperature and total precipitation. All microclimate stations were set out in May and measured/removed in October of 1997. Growing season temperature within stands (subset) was calculated using sucrose inversion (provides integrated temperature data for the length of the growing season) technique as described in (Damman 1975). Total precipitation over the growing season was measured using a 1.5 m graduated cylinders (2 inch plastic poly pipe) driven 30-50 cm into the soil, in a vertical position. Each cylinder contained 100 ml of canola oil to prevent evaporation of the accumulating precipitation.

Analyses of community composition - Patterns of bryophyte community composition were analysed using CCA and TWINSPAN. Canonical Correspondence Analysis (CCA) was used to ordinate all species data for all 287 stands using 24 environmental variables to constrain the ordination (ter Braak, 1998). Abundance was recorded for each species on each type of microhabitat or mesohabitat (see FHS methods chapter 1) and averaged for each species within stands. These abundance values were used in the CCA analysis. The ordination generated axis scores for each stand, with the axes correlated to the most important environmental variables in the analysis. TWINSPAN (Hill 1994) was used to group all 287 cedar-hemlock stands according to species compositions and identified the indicator species that are associated with specific stand groups. Climatic, temporal and silvicultural variables were related to each TWINSPAN group to identify environmental patterns in the classification by superimposing onto the CCA stand and species ordination.

The relative importance of an indicator species within the TWINSPAN classification was estimated using the method of Dufrêne and Legendre (1997) in PC-ORD software (McCune & Mefford 1997). Indicator values were calculated for species within each of the TWINSPAN groups. The "indicator value" combines, by multiplication, the abundance of a species in each TWINSPAN group relative to its abundance in all groups, with that species' frequency in the sample units of the designated group (Rambo 1998a, 1998b). The "indicator value" describes a species' reliability for indicating a TWINSPAN group, and is expressed as a percentage of perfect indication. A Monte Carlo analysis was used to assess statistical significance based on the proportion of 1,000 randomized trials that equaled or exceeded the maximum indicator value for a species.

Phytogeographic categories follow those of Belland (1998) for mosses and Godfrey (1977a) and Schofield (1988) for hepatics. Taxonomic category of the lineages of *Bryidae* and *Sphagnidae* follow Vitt (1984) with suborders raised to order rank; within the lineages, Jungermanniales, *Metzgeriales* and *Marchantiales* follow Stotler and Crandall-Stotler (1977). Species nomenclature follows Anderson *et al.* (1990) for bryophytes and Stotler & Crandall-Stotler (1977) for hepatics. Richness and species occurrence were calculated for each phytogeographic category and taxonomic lineage within the TWINSPAN groups. Occurrence was calculated as the number of sample units a species occurs in; sample units are microhabitats such as logs and rocks (see Newmaster et al. (2000) for a full list of microhabitats). Collections were made at each stand for common and rare species. Voucher specimens were prepared and deposited at the University of Alberta Cryptogamic Herbarium (ALTA), Kamloops Forest Region Herbarium, and University of British Columbia Herbarium (UBC).

RESULTS

Stand Ordination on the Cedar-Hemlock Landscape

Relationships between bryophyte species, stands and environmental variables are apparent when all cedar-hemlock stands (ICH/CWH) were analyzed using CCA 24 environmental variables (Table 2-1, Fig. 2-3). The species/environment correlation measures the relation between the stand scores resulting from a CA and those from a CCA (Belland and Vitt 1995). High species/environment correlations (>0.85) indicate that environmental variables for the first two axes will be useful in identifying gradients and account for 60.6% of the variation in the species data set (Table 2-2). The sharp drop between the first two eigenvalues (.477, .227, .071 and .044 respectively) indicate that stand vegetation is strongly dominated by climatic variables that forms a single gradient along the first axis. A Monte Carlo permutation test confirmed that the first axis is statistically significant ($p < 0.001$) in explaining 41.6 % of the variation in the species data. A substantial portion (19 %) of the species variation was explained by the second axis (Table 2-2).

Based on significant ($p < 0.05$) interset correlations and canonical coefficients (>2.1) climatic variables are the most important variables defining the first axis (Table 2-3). Mean annual temperature, rainfall, degree days > 0°C, and 6 month mean temperature are the most important variables correlated to axis 1. Warm wet stands (CWH) on the left side of the ordination are separated from cool dryer stands (ICH) on the right (Fig. 2-3). These two broad clusters based on bryophyte vegetation compliment the biogeoclimatic system of British Columbia Ministry of Forests, which is based on vascular plant data (Meidinger and Pojar 1991). Site series, latitude and longitude were also significant variables correlating to the first axis.

Large-scale catastrophic disturbance (i.e., fire and logging) explains considerable variation along the second axis. Stand age is defined as the time since last major disturbance and is significantly ($p<0.05$) and the most strongly correlated variable to the second axis (Table 2-3). Old-growth stands are on the bottom and young stands are at the top of the second axis (Fig. 2-3). Log basal area and canopy height were significantly correlated to the second axis, but they are also directly influenced by stand age (Table 2-3).

Stand Classification on the Cedar-Hemlock Landscape

TWINSPAN classified the stands into five groups (Fig. 2-4), which are evident on the CCA species ordination (Fig. 2-5). The primary division of groups in TWINSPAN separates the ICH from the CWH, supporting the grouping of stands on the first CCA axis. Groups 1-3 are on the left side of the ordination and groups 4-5 are on the right side of the ordination (Fig. 2-5). Climatic variables, such as temperature and rainfall separate the warm, wetter groups 1-3 from the cool, dryer groups 4-5 (Fig. 2-6). Examples of species from CWH (groups 1-3) are, *Apometzgeria pubescens, Dicranodontium denudatum, Douinia ovata, Eurhynchium oreganum, Fontinalis neomexicana, Hookeria acutifolia, Herbertus aduncus, Leucolepis acanthoneuron, Plagiomnium venustum* and *Riccardia palmata*. The ICH (groups 4-5) is characterized by species such as, *Andreaea rupestris, Atrichum undulatum, Barbilophozia attenuata, Buxbamia viridis, Gymnocolea inflata, Homalothecium aeneum, Hypnum pallescens, Hylocomium pyrenaicum, Leskeella nervosa, Pohlia wahlenbergii* and *Schistidium apocarpum*.

Group 1, is associated with the oldest least disturbed stands in oceanic CWH forests, and is clustered at the bottom of the second CCA axis (Fig. 2-5). The stands on Vancouver Island are wetter and warmer than those on the mainland coast (Fig. 2-6). Stand group one contains species that are restricted to island (oceanic) CWH stands or have higher abundance in these areas (e.g., *Bazzania pearsonii, Dendrobazzania griffithiana, Dicranodontium denudatum, Geheebia gigantea, Hookeria acutifolia, Riccardia palmata* and *Ulota drummondii*).

In the CWH (left side of the ordination), TWINSPAN groups 1-3 are further divided along the second ordination axis (Fig. 2-5). A gradient of increasing stand age is associated with a movement from the top to the bottom of the second CCA axis. Environmental variables associated with stand age are represented by vectors pointing in the same direction in the bi-plot of the environmental variables (Fig. 2-5). This gradient is supported by the separation (3rd TWINSPAN division) of groups two and three by temporal variables, such as time since the last major disturbance, stand age, tree basal area, canopy height and the number of microhabitats (Fig. 2-7). Group two is associated with old-growth CWH on the mainland coast, and forms a distinct cluster near the center of the second axis on the CCA ordination (Fig. 2-5). Group two contains species that are restricted to, or at least much more abundant in old-growth (250+ years) stands (e.g., *Cephalozia bicuspidata, Diplophyllum plicatum, Dicranum pallidisetum, Homalothecium nuttallii, Marsupella emarginata* and *Mylia taylorii,*). The third group is associated with young CWH stands on the mainland coast; stands in this group are clustered at the top of the second CCA axis. Group three contains species that are common in young (80 years) forest (e.g., *Eurhynchium oreganum, Homalothecium aeneum, Isothecium myosuroides, Plagiomnium venustum* and *Plagiothecium undulatum*).

In the ICH (right side of the ordination), TWINSPAN groups 4-5 are separated along the second ordination axis (Fig. 2-5). This TWINSPAN division separates ICH stands based on time since the last catastrophic disturbance. CCA environmental variables associated with a gradient in stand age are significantly ($p < 0.05$) correlated with the second axis. Environmental variables such as stand age, tree basal area, canopy height and the number of microhabitats separates groups four and five (Fig. 2-4 & 2-7). Group four is associated with young ICH stands; these stands are clustered at the top of the second axis in the CCA ordination. Stand group four contains several species that are more common in young forest (e.g., *Dicranum flagellare, Dicranum polysetum, Pohlia wahlenbergii and Schistidium apocarpum)*, and species that are common to group five but less abundant (e.g., *Barbilophozia lycopodioides, Hypnum pallescens, Hypnum* *revolutum, Jamesoniella autumnalis* and *Ptilidium pulcherrimum*). Group five is associated with old-growth stands, and is clustered at the bottom of the second CCA axis (Fig. 2-5). This group contains species that are restricted to, or at least more commonly abundant in stands that are age class 9 (250+ years), have larger trees and more microhabitats (Fig. 2-7). Species that are found abundantly in group five include, *Antitrichia curtipendula, Blepharostoma trichophyllum, Claopodium bolanderi, Heterocladium macounii, Hypnum circinale, Porella cordaeana, Ptilidium californicum, Rhizomnium glabrescens* and *Scapania bolanderi*).

Indicator Species

The distribution of species within the five TWINSPAN groups is shown in Table 2-4. The CCA species ordination indicates that there are some species that are associated with specific TWINSPAN groups, and other species that are ubiquitous throughout the groups (Fig. 2-8). Species that are unique to a specific TWINSPAN group could be considered indicator species. However, the relative importance of an indicator species within a group is best defined by a separate indicator analysis. Using the Dufrêne and Legendre analysis (1997), species with significant ($p < 0.05$) indicator values clearly identified clusters of the five TWINSPAN groups on the CCA species ordination (Fig. 2-8). Indicator species are listed for the ICH, CWH, old growth and young growth forests.

Some species are indicators of biogeoclimatic zone but are common to either young or old stands. Several indicator species common to the CWH include, *Eurhynchium oreganum, Homalothecium aeneum, Isothecium myosuroides, Mnium marginatum, Plagiomnium venustum,* and *Riccardia multifida.* These species are rare or have never been located in the ICH (Table 2-4). There are only a few species that are found in both young and old forest within the ICH that are not in the CWH. These include, *Cratoneuron filicinum, Dicranum polysetum, Hylocomium pyrenaicum* and *Pohlia wahlenbergii.*

Several species are commonly found in old-growth forest but are rare or do not occur in young forest regardless of biogeoclimatic zone (Table 2-4). Examples of these general old-growth indicators are, *Antitrichia curtipendula, Bazzania tricrenata, Calypogeia trichomanis, Cephaloziella divaricata, Claopodium bolanderi, Heterocladium macounii, Kindbergia praelonga, Metaneckera menziesii, Ptilidium* *californicum, Porella navicularis, Radula complanata* and *Thamnobryum neckeroides.* There are many old-growth indicators that are unique to either the ICH or CWH.

The CWH has many old-growth indicator species. Two-thirds of these indicator species are hepatics. All of the old-growth indicator species are more common in oceanic CWH forests (group 1). Examples of old-growth indicators specific to the CWH are, *Apometzgeria pubescens, Barbilophozia hatcheri, Dicranodontium denudatum, Douinia ovata, Herbertus aduncus, Homalothecium nutallii, Hookeria lucens, Jungermannia pumila, Lophozia incisa, Marsupella emarginata, Metzgeria temperata* and *Plagiochila asplenoides.*

The ICH also has many old-growth indicator species. Many of which are restricted to the ICH (Table 2-4). More than half of the indicator species are hepatics. Examples of old-growth indicators specific to the ICH are, *Anastrophyllum hellerianum, Barbilophozia attenuata, Barbilophozia quadriloba, Buxbaumia viridis, Calypogeia suecica, Gymnocolea inflata, Hygrohypnum smithii, Hylocomium pyrenaicum, Leskeella nervosa, Lophocolea minor, Lophozia ascendens* and *Porella platyphylla.*

There are few indicator species for young forest. Most of the species found in young forest are found with greater occurrence in old-growth forest. In the CWH, only one species (*Funaria hygrometrica*) is more abundant in young forests. The ICH has only a few species that are found more frequently or exclusively in young forest (Table 2-4). Examples of young growth indicator species in the ICH are *Dicranum flagellare, Dicranum polysetum, Funaria hygrometrica, Grimmia affinis, Pohlia wahlenbergii* and *Schistidium apocarpum.*

Floristic Affinities

Differences in species composition between the ICH and CWH can be attributed to the geographic distributions of species defined as floristic affinities. There are 417 species in B.C.'s cedar-hemlock forest of which 205 (49%) species are common to both the CWH and ICH. 114 (27%) species are found exclusively in the CWH, and 98 (24%) of the species are exclusively to the ICH. The differences in species composition between the CWH (groups 1-3) and the ICH (groups 4-5) can be related to differences in floristic affinities.

Moss floristic affinities – The ICH has substantially more moss species with boreal distributions than the CWH (60% ICH; 45% CWH - Fig. 2-9). Thirty-six species of mosses with boreal distributions are found in the ICH and not the CWH. (e.g., *Brachythecium reflexum, Campylium chrysophyllum, Dicranella grevilleana, Dicranum polysetum, Fissidens osmundoides, Gymnostomum aeruginosum, Hylocomium pyrenaicum, Meesia triquetra, Plagiomnium drummondii* and *Rhizomnium pseudopunctatum*). Sixty percent of these species have circumboreal distributions and forty percent have interrupted distributions between North America, Europe and Asia.

The CWH has more temperate species and higher temperate species occurrence than the ICH (40% CWH; 20% ICH - Fig. 2-9). Forty-three species of mosses with temperate distributions were found in the CWH, but were absent in the ICH. Forty percent of the temperate mosses are Western North American endemics such as *Amphidium californicum, Anacolia menziesii, Dendroalsia abietina, Eurhynchium oreganum, Homalothecium nutallii, Leucolepis acanthoneuron, Plagiomnium venustum, Ulota megalospora* and *Ulota obtusiuscula*. Ten percent of these mosses are widely distributed circum-temperate species such as, *Anoectangium aestivum, Dicranodontium denudatum, Fissidens grandifrons, Pseudotaxiphyllum elegans* and *Schistostega pennata*. Fifty percent of the temperate mosses have varied disjunctions between western North America, eastern Asia, and Europe (e.g., *Andreaea rothii, Campylopus flexuosus, Dicranodontium uncinatum, Geheebia gigantea, Hookeria acutifolia, Plagiothecium cavifolium* and *Tortula princeps*). The CWH has an even distribution of bryophytes with arctic, cosmopolitan and montane affinities (Fig. 2-9).

Hepatic floristic affinities – There are more boreal hepatics (richness and occurrence) in the ICH than the CWH (65% ICH; 40% CWH - Fig. 2-9). Seventeen species of liverworts with boreal distributions are found in the ICH, but not in the CWH (e.g., *Anastrophyllum helleranum, Barbilophozia kunzeana, Cephalozia pleniceps, Gymnocolea inflata, Lophocolea minor, Scapania curta* and *Tritomaria scitula*). Eighty percent of the boreal liverworts had circumboreal distributions and twenty percent had interrupted distributions with North America, Europe and Asia. Hepatics species with montane affinities are more common in the interior (20% ICH; <5% CWH - Fig. 2-9).

There are more temperate hepatics (richness and occurrence) in the CWH than the ICH (55% CWH; 5% ICH - Fig. 2-9). Fifty-four species of hepatics with temperate distributions are found in the CWH but not in the ICH. Ten percent of these hepatics consisted of widely distributed circum-temperate species such as *Barbilophozia floerkei, Douinia ovata, Jungermannia obovata, Lophozia obtusa, Odontoschisma denudatum, Porella cordaeana, Riccardia multifida* and *Scapania umbrosa.* Twenty percent of the temperate hepatics have varied disjunctions between western North America, eastern Asia, and Europe (e.g., *Anastrophyllum assimile, Bazzania pearsonii, Gymnomitrion obtusum, Herbertus aduncus, Jungermannia exsertifolia, Kurzia setacea, Lophozia opacifolia, Nardia scalaris* and *Riccardia multifida*). Sixty percent of the temperate hepatics are Western North American endemics, such as *Cololejeunea macounii, Dendrobazzania griffithiana, Diplophyllum imbricatum, Frullania californica, Frullania tamarisci ssp. nisquallensis, Gyrothyra underwoodiana, Jungermannia rubra, Kurzia makinoana, Lepidozia filamentosa, Marsupella boeckii, Plagiochila schofieldiana, Pleurozia purpurea, Porella navicularis, Ptilidium californicum, Radula bolanderi* and *Scapania americana.*

Taxonomic and Morphological Patterns

Moss taxonomic patterns - Taxonomic moss affinities are apparent between CWH (groups 1-3) and ICH (groups 4-5). There are 197 species of mosses in the ICH and 201 species of mosses in the CWH. Using the lineages of mosses proposed by Vitt (1984), the *Sphagnales, Polytrichales and Dicranales* are equally represented in the ICH and CWH (Fig. 2-10). Species in the *Orthotrichales, Isobryales* and *Pottiales* are however better represented in the CWH, and the Hypnales are better represented in the ICH. Species in the *Isobryales, Orthotrichales* and *Bryales* are less represented in the ICH (Fig. 2-10). Within the CWH, the Dicranales and Pottiales are well represented in the oceanic stands (group 1) than on the coastal mainland (group 2).

Hepatic taxonomic patterns – Patterns in hepatic taxonomic affinities are associated with the ICH and CWH. There are 120 species of hepatics in the CWH and 99 species in the ICH. Following the lineages proposed by Stotler and Crandall-Stotler (1977), the ICH/CWH are equally represented in the following proportions for each order: 85 % *Jungermanniales*, 10% *Metzgeriales* and 5% *Marchantiales*. Differences between the interior and coast are apparent at the suborder rank. The *Lepidoziineae, Geocalycineae* and *Porellineae* have more species in and higher species occurrence in the CWH, particularly oceanic CWH (Fig. 2-10). Species occurrence in the *Jungermanniineae, Metzgeriianeae* and *Herbertineae* is higher in the CWH. Only the CWH has representative species in the *Riccīineae* (Fig. 2-10). Oceanic CWH stands (group 1), have higher hepatic occurrence than any other taxonomic lineage.

Morphological patterns - Morphological patterns are similar between the ICH and CWH. Pleurocarpous mosses represent 30% of the flora, while 70% of the flora is either acrocarpous or cladocarpous. Among the mosses, 65% (ICH) or 69% (CWH) of the species are dioicous, and 35 % (ICH) or 31 % (CWH) are monoicous. 92% of the mosses had spore sizes < 25 µm for either the ICH or CWH.

DISCUSSION

Climate and Community Patterns

Climate is a well-known primary factor controlling vegetation at large scales on the landscape (Gignac and Vitt 1990; Hebda 1997), and more specifically bryophyte floras (Schofield 1988). Gignac and Vitt (1990) showed that species and stand groups are largely determined by climate in the mires of western Canada. Our CCA ordination indicates that climate is the most influential variable affecting bryophyte community composition in the cedar hemlock landscape. TWINSPAN groups for stands and species complimented the CCA ordination. The grouping of cedar hemlock stands using bryophyte communities at the regional scale (i.e., cedar-hemlock forests in BC) supports the existing biogeoclimatic classification (i.e., ICH & CWH) for cedar hemlock forest in BC (Meidinger & Pojar 1991). The distinct differences in the community composition of the CWH and ICH can be partially explained by modern day climatic patterns. The CWH is wetter and warmer and has a heavy influence from oceanic weather patterns (Redmond and Taylor 1997). The ICH is controlled by continental weather patterns.

Historical climatic patterns are also of primary importance in the development of cedar hemlock communities in these two biogeoclimatic zones and help in the interpretation of the origin of the ICH and CWH bryoflora. Cedar-hemlock forests developed during interglacial intervals recorded in the Pleistocene deposits 100 000 years ago (Heusser 1977). The last glaciation (Cordilleran) ended with a warming trend 15000 year ago. Tundra-like vegetation dominated the area between 12000-15000 years ago (Hebda 1997). Cedar–hemlock forest began to disperse and establish from 12000-6000 BP (before present). Hemlock forests (including *Thuja plicata* expanded in the CWH 6000-7000 BP, and the modern CWH flora became established between 6000 and 4000 BP (Hebda 1994, 1997). In the ICH, cedar-hemlock did not begin to disperse until 5000-6000 BP, leaving less time for the development of the ICH flora. The arrival of *Thuja plicata* in the ICH was slightly later than 4000 BP, with the development of the modern day flora between 4000 and 2000 BP (Hebda 1995). Therefore, modern cedar-hemlock bryophyte communities in the interior developed later than on the coast. In the CWH, several western North American endemics (i.e., *Leucolepis acanthoneuron, Dendroalsia, Diplophyllum imbricatum* and *Porella navicularis*) may exist partly due to the position of refugia during the Pleistocene glaciations (Schofield 1988; Godfrey 1977a). Areas along the coast escaped glaciation and served as refugia for today's endemic bryophytes.

The floristic elements of the interior and coastal cedar hemlock forests should be both compared and contrasted. Schofield (1988) has indicated that the ICH and CWH are similar both climatically and floristically. He realized that the bryoflora characteristic of the CWH is also partially present in the ICH. Furthermore, Schofield (1988) commented that some of the abundant bryophytes in the CWH are only found in local communities in the ICH; other bryophytes are equally frequent in both the CWH and ICH. My comparisons of the ICH and CWH quantitatively supports Schofield's qualitative observations. Several disjunct (western Europe or Asia) species are common in the CWH, but only locally abundant in the ICH (i.e., *Herbertus aduncus, Porella cordaeana, Antitrichia curtipendula, Cloapodium bolanderi* and others). However, my contrasts of the CWH and ICH indicate that there are many differences between the bryoflora of the CWH and ICH even though species richness (gamma diversity) is similar (i.e., ICH 300 spp, CWH 317 spp.). Some species are found exclusively in either the CWH (114 species - 36%) or ICH (98 species - 33%). Species with Circumboreal distributions are more common in the ICH. Conversely, species with temperate distributions are more common in the CWH. Finally there are more western North America endemics in the CWH than the ICH, some of which are exclusive to the CWH.

Climate greatly influences the microhabitat availability in either biogeoclimatic zone. Environmental conditions and habitat limitations restrict the development of the bryoflora. Some microhabitats will be more common to either the ICH or CWH. For example, the communities that are unique to big leaf maple (*Acer macrophyllum*) are unlikely to develop in the ICH because big leaf maple is not present in the ICH. However, some habitats are not related to climate but also limit community development within a biogeoclimatic zone. Specific species of bryophytes are often associated with either acidic or basic rocks, which offer specific environments for unique communities of bryophytes (Belland & Brassard 1988; Belland & Schofield 1984). Rock microhabitats are chiefly acidic in the CWH, while there are many basic rock microhabitats in the ICH (Montgomery 1997). Although rock microhabitats are present in forest, they were not a primary environmental variable explaining the community composition of bryophytes in the cedar hemlock landscape.

Vitt (1991) found that highly evolved groups such as the Isobryales are better represented in tropical floras and the least derived in continental temperate forest. It is interesting that even within a temperate flora there are some taxonomic differences, such as when comparing the ICH and CWH. The Isobryales, Orthotrichales, Metzgeriianeae and Herbertineae have a much greater diversity in the CWH. The Hypnales is the only lineage to be most diverse in the ICH. Schofield (1988) postulated that the unique flora of the CWH has many endemic species that can be interpreted as long-term survivors of a very ancient flora from which most of the previously associated seed plants have been extinguished from North America. Historically the CWH bryoflora retained some of these remnant species in areas of floristic refugia during the Pleistocene glaciation.

Disturbance and Community Patterns

Time since the last catastrophic disturbance (i.e., fire and logging) is the second most influential variable affecting bryophyte community composition in the cedar hemlock landscape. The CCA ordinations and TWINSPAN classification clearly displayed that within a specific biogeoclimatic zone, bryophyte communities in old-growth forests are different than those in young forests. These conclusions support several studies that have determined that old-growth forest have unique communities of bryophytes when compared to younger forests (Söderström 1988, Anderson and

Hyterborn 1991, Lesica et al. 1991, McCune 1993, Rambo & Muir 1998a). I present the first quantitative evidence to show the differences between the bryophyte community composition of old-growth stands and those disturbed by fire or logging in BC. My study demonstrates that old-growth stands contain more western North American endemics and rare species than young forests (Newmaster et al. 2000). This supports research in Ontario boreal mixed-wood forest that has shown that stands disturbed by logging have fewer rare species than mature forest (Bell & Newmaster 1998).

Many of the species restricted to old growth ICH and CWH are hepatics. Researchers in Scandinavia, (Söderström 1988), and the United States (Rambo & Muir 1998a) have also shown that many hepatics are more commonly found in old-growth forests. Furthermore, our study identified old growth indicator species for the ICH and CWH, and many of these are endemic hepatics and/or hepatics that are restricted to old-growth forests. Many bryophytes may serve as bio-indicators because the ICH or CWH unique old growth indicator species.

In British Columbia, forest managers are dealing with many old growth and biodiversity issues, including the challenge of managing biodiversity in forests with few large natural catastrophic disturbances (Jull 1997). Disturbances through human activities such as logging operations could pose serious threats to the long term functioning of forest ecosystems (Bradfield et al. 1997). Understanding the patterning of bryophyte communities in the ICH and CWH biogeoclimatic zones will help minimize the impact from forestry operations on biodiversity (Arsenault and Goward 1997). Although the present research identifies the differences between bryophyte communities in the CWH and ICH and the impacts of clear-cutting and forest fire, there is a need to further compare the patterning of bryophyte diversity and of species-habitat relationships. This will be useful information in the development of strategies for the conservation of bryophytes in managed forest landscapes of British Columbia. Old growth indicator species for each biogeoclimatic zone could be used to identify areas with unique bryophyte communities or bryophyte hot spots. Preservation of such areas are of paramount importance in the successful management for biodiversity in cedar-hemlock forests. Table 2-5 presents indicator species and the substrates on which they are commonly found for young and old forest in each biogeoclimatic zone.

Table 2-1: Summary of the twenty-four environmental variables used in the CCA analysis.

Variable	Abbrev.	Explanation
Site Series	SS	eco-site classification
Latitude	Lt	northerly bearing
Longitude	Ln	westerly bearing
Elevation	Elv	height above sea level (m)
Slope Position	SP	upper, mid, lower slope & toe
Aspect	As	local azimuth of slope direction
Moisture Regime	MR	hygric to xeric scale
Rock cover	RC	% cover rocks
Rock acidity	RA	acidic/basic rocks present
Soil Texture	ST	sand, silt, clay, loam & mixtures
Canopy height	CH	avg. tree height (m)
Tree density	DT	(m^2/ha)
Tree basal area	BT	mean dbh (cm^2)
Snag density	DS	snag density (m^2/ha)
Snag basal area	BS	snag basal area (cm^2)
Log density	DL	log density (m^2/ha)
Log basal area	BL	log basal area (cm^2)
Shrub	SC	% cover
Herb	HC	% cover
Disturbance (stand age)	Ds	wildfire, logging or old growth
Temperature	AT	Mean annual temperature (°C)
Rainfall	Rn	total yearly rainfall (mm)
Degree days > 0°C	°D	total thermal input
6 month mean temperature	6T	$\bar{x}$ temperature, May-October

Table 2-2. Summary of Canonical correspondance analysis (CCA) of 287 rainforest stands in British Columbia.

Axis	1	2	3	4
Eigenvalue	0.477	0.227	0.071	.0440
Species/environment correlation	0.991	0.894	0.851	0.809
Cumulative % variance of species data explained	41.66	60.62	71.27	77.81

Table 2-3. Statistics for variables used in canonical correspondence analysis (CCA) of 287 stands in B.C.'s temperate rainforest. Asterisks indicate significance at $p < 0.05$. Absolute t-value > 2.1 are used to indicate important canonical coefficients (ter Braak, 1998). Bold values indicate variables with significant correlation and canonical coefficients.

	Interset Correlation		Canonical coefficient		t-value	
Variable	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Site Series	-0.8312*	-0.0707	0.0140	-0.0877	0.6118	-1.0112
Latitude	0.9394*	-0.0652	-0.0710	0.0772	-1.9163	1.5922
Longitude	-0.9394*	-0.0732	0.0588	-0.0243	1.3663	-0.4312
Elevation	0.6450*	**0.4807***	0.0259	0.2106*	1.0864	2.3244
Slope Position	-0.0139	0.0844	-0.0086	-0.0572	-0.5901	-1.1587
Aspect	0.2765*	0.1755	0.0189	-0.0444	1.8465	-1.1378
Moisture Regime	-0.4620*	-0.0825	0.0029	0.0124*	0.2082	2.3348
Rock cover	0.0261	-0.1486	0.0223	0.0542*	1.2134	2.4356
Rock acidity	**0.3148***	**-0.2232***	0.0261*	-0.1487*	3.1108	-3.7869
Soil Texture	-0.0196	0.2761*	0.0123	0.0593	1.6652	1.8305
Canopy height	-0.3510*	**-0.5782***	-0.0273	-0.1358*	-1.7862	-2.2821
Tree density	**0.3730***	**0.4203***	0.0379*	0.0960*	2.7664	2.0160
Tree basal area	-0.0959	-0.4244*	-0.0080	0.0638	-0.7245	-1.6437
Snag density	0.2181*	0.0956	0.0188	0.1139*	1.7245	3.0963
Snag basal area	-0.4412*	-0.4391*	-0.0065	-0.0380	-0.3434	-0.7388
Log density	-0.4575*	-0.6005*	-0.0416	-0.1954	-1.6563	-1.8909
Log basal area	-0.4897*	**-0.5749***	-0.0472	-0.2417*	-1.9909	-2.9061
Shrub cover	-0.4512*	-0.5177*	0.0232	-0.0931	1.0787	-1.7443
Herb cover	0.0885	**-0.3282***	0.0047	0.1046*	0.6631	2.2984
Disturbance (stand age)	-0.2087*	**-0.6721***	-0.0327*	-0.4142*	-2.3515	-7.8401
Mean annual temperature	**-0.9758***	0.1074	-2.2979*	-1.0568	-16.3473	1.9769
Rainfall	**-0.9644***	0.1017	1.0636*	-0.7571	4.7329	-0.8858
Degree days > 0° C	**-0.9672***	0.1077	1.5451*	-0.3721	-2.4577	0.9347
6 month mean temperature	**-0.9423***	0.1062	0.3255*	0.2568	-2.5692	0.5517

Table 2-4. Bryophyte indicator values within six stand groups as delimited by TWINSPAN († Western North America endemics; General Species = non-indicator species).

Indicators	Species	Stand groups				
		1	2	3	4	5
OLD	*Herbertus aduncus*	56	23			
CWH	*Leucolepis acanthoneuron †*	55	21	1		
oceanic	*Pseudoleskea radicosa*	54	21		1	2
	Hookeria lucens	51	24		3	1
	Metzgeria conjugata	50	25			1
	Apometzgeria pubescens	50	18			1
	Dicranoweisia cirrata	42	13		1	1
	Fissidens adianthoides	42	12			3
	Porella cordaeana	42	13			1
	Claopodium crispifolium	41	6			
	Homalia trichomanoides	41	13			
	Douinia ovata	39	19		1	2
	Cephaloziella integerrima	38	18			
	Frullania tamarisci ssp nisquallensis †	38	20	2		2
	Lophozia wenzelii	33	6			
	Barbilophozia hatcheri	33	14			2
	Claopodium pellucinerve	28	7			
	Porella roellii †	24	7			
	Plagiochila semidecurrens †	22	6			
	Frullania californica †	22	2			
	Dicranodontium denudatum †	21	7			
	Radula bolanderi †	20				
	Lepidozia filamentosa †	19				
	Pseudoleskea julacea	17	7			
	Lophozia opacifolia	17	5			2
	Hookeria acutifolia †	16	5			
	Diplophyllum imbricatum †	16				
	Bazzania pearsonii	15	8			
	Radula obtusifolia †	15				
	Pleurozia purpurpea †	14				
	Plagiochila satoi	14	4			1
	Jungermania rubra †	13				
	Anacolia menziesii	12	3			
	Chiloscyphus pallescens	12	3			
	Pleuroclada albescens	12	3			
OLD	*Lophozia ventricosa var longifolia*	55	53	1		
CWH	*Marsupella emarginata*	53	39			3
	Scapania bolanderi	34	43	8		2
	Cephalozia bicuspidata	47	46	1		1
	Lophozia incisa	45	48			5
	Dicranoweisia crispula	44	18	1		1

Indicators	Species	Stand groups				
		1	2	3	4	5
OLD CWH	*Mylia taylori*	49	39	2		4
	Homalothecium nutallii	31	19			
	Fissidens osmundoides	26	26			
	Diplophyllum plicatum †	26	25			
	Dicranum pallidisetum	28	26			1
	Radula bolanderi	23	11	1		
	Fontinalis hypnoides	22	26			
	Jungermannia pumila	24	17			2
	Metzgeria temperata	14	22			
	Plagiochila asplenioides	19	21			
CWH	*Isothecium myosuroides*	51	45	4		2
	Plagiomnium venustum †	48	28	5		
	Eurhynchium oreganum †	48	47	5		
	Homalothecium aeneum †	43	28	13		
	Riccardia multifida	42	40	34		
	Mnium marginatum	41	39	37		
OLD	*Neckera douglasii*	54	23			19
	Lepidozia reptans	52	43	4	8	29
	Bazzania tricrenata	51	42			15
	Cephalozia bicuspidata	50	43			14
	Heterocladium macounii †	48	39	5	2	14
	Claopodium bolanderi †	48	37	1	2	15
	Ptilidium californicum	47	47	1	2	35
	Antitrichia curtipendula	46	35		2	18
	Kindbergia praelonga	45	43	1	2	26
	Bazzania denudata †	44	44	1	1	24
	Metaneckera menziesii	43	26	2	2	12
	Hypnum revolutum	43	40	3	4	48
	Radula complanata	41	12		1	17
	Cephalozia lunulifolia	32	20		3	43
	Plagiothecium undulatum	30	37	3	1	17
	Cephaloziella divaricata	29	23		2	31
	Rhizomnium glabrescens	28	34	3	1	15
	Calypogeia trichomanis	28	13		2	23
	Thamnobryum neckeroides †	20	25		1	13
	Porella navicularis	12	7		1	8
General Species	*Blepharostoma trichophyllum*	50	43	18	43	45
	Brachythecium frigidum †	47	37	15	44	36
	Jamesoniella autumnalis	47	44	19	42	44
	Eurhynchium pulchellum	47	48	15	49	43
	Rhytidiadelphus triquetrus	42	33	22	48	42
	Plagiomnium medium	42	42	13	41	38
	Mnium spinulosum	41	38	18	53	46
	Atrichum selwynii	39	38	22	40	31
	Rhytidiopsis robusta	34	34	33	32	42

Indicators	Species	Stand groups				
		1	2	3	4	5
General Species	*Hylocomium splendens*	47	33	20	48	46
	Dicranum fuscescens	45	42	12	48	52
	Dicranum scoparium	44	38	15	45	36
	Pohlia nutans	41	40	16	46	26
	Plagiothecium laetum	40	38	22	50	50
	Sanionia uncinata	38	35	27	53	47
	Hypnum revolutum	37	33	22	42	48
	Polytrichum juniperinum	35	33	31	49	38
	Pleurozium schreberi	34	35	29	54	46
	Dicranum tauricum	33	33	33	49	51
	Jamesoniella autumnalis	33	30	16	14	24
	Plagiomnium insigne	31	30	33	40	37
ICH-young	*Dicranum polysetum*				25	12
	Schistidium apocarpum		1	9	22	3
	Pohlia wahlenbergii	2	2		16	7
	Funaria hygrometrica				15	.
	Grimmia affinis				9	2
	Dicranum flagellare				8	2
ICH-old	*Buxbaumia viridis*				1	11
	Oligotrichum aligerum	2	1		1	10
	Brachythecium albicans				1	10
	Cephalozia pleniceps				1	11
	Myurella julacea				1	11
	Rhytidium rugosum		1		2	12
	Barbilophozia quadriloba				3	12
	Gymnocolea inflata				3	13
	Ricciocarpos natans				1	12
	Oncophorus wahlenbergii				2	13
	Porella platyphylla				4	14
	Dicranella grevilleana				3	14
	Hygrohypnum smithii				5	16
	Thuidium recognitum				4	19
	Blindia acuta	1	1		3	21
	Barbilophozia attenuata				4	22
	Anastrophyllum hellerianum				3	21
	Leskeella nervosa				2	22
	Lophozia ascendens				1	23
	Calypogeia suecica				4	28
	Heterocladium dimorphum	2	1		6	31
	Hylocomium pyrenaicum				6	38
	Cratoneuron filicinum				7	41
	Lophocolea minor				1	42
	Tetraphis geniculata		1		2	46

Table 2-5. Bio-Indicators of Old Growth Cedar Hemlock Forests In British Columbia

Indicator	**Species** (*† western North American Endemics)*	**Feature**
Cedar-hemlock Old growth	*Neckera douglasii*	-Epiphytic, also on cliffs & rocks.
	Bazzania tricrenata	-Epixylic, also on trees, cliffs & rocks.
	Heterocladium macounii †	-Saxicolic, also on trees & logs.
	Claopodium bolanderi †	-Saxicolic, rarely on tree trunks.
	Ptilidium californicum	-Epiphytic, also on logs.
	Antitrichia curtipendula	-Epiphytic, occasionally on cliffs & rocks.
	Bazzania denudata †	-Epixylic, also on tree bases & cliffs.
	Metaneckera menziesii	-Epiphytic, occasionally on cliffs & rocks.
	Thamnobryum neckeroides †	-Saxicolous, also on tree bases.
	Cephalozia lunulifolia	-Epixylic, also on cliffs & humus.
CWH Old growth	*Claopodium crispifolium*	-Epiphytic, also on cliffs & rocks.
	Dicranodontium denudatum †	-Saxicolous, also on humus & logs.
	Douinia ovata	-Epiphytic, also on humus & rocks.
	Herbertus aduncus	-Epixylic, also on trees & humus.
	Homalia trichomanoides	-Epiphytic, also on humus, cliffs & rocks.
	Hookeria lucens	-Epixylic, also on moist soil or rock.
	Marsupella emarginata	-Saxicolous, occasionally on soil.
	Metzgeria conjugata	-Saxicolous, also on trees, logs & humus.
	Mylia taylori	-Epixylic, also on trees, humus & wet soil.
	Porella cordaeana	-Epiphytic, also on rocks, cliffs, humus & soil.
ICH Old growth	*Lophocolea minor*	-Epixylic, also on humus or soil.
	Cratoneuron filicinum	-Saxicolous (streams), also on wet cliffs.
	Heterocladium dimorphum	-Saxicolous, also on humus & soil.
	Calypogeia suecica	-Epixylic, rarely on trees.
	Lophozia ascendens	-Epixylic, also on humus, rarely rocks & trees.
	Leskeella nervosa	-Saxicolous (streams), also on trees.
	Barbilophozia attenuata	-Saxicolous, also on logs.
	Blindia acuta	-Saxicolous (streams), also wet soil.

Figure 2-1. Map of British Columbia, Canada showing the Biogeoclimatic zones (Arsenault and Goward 1999).

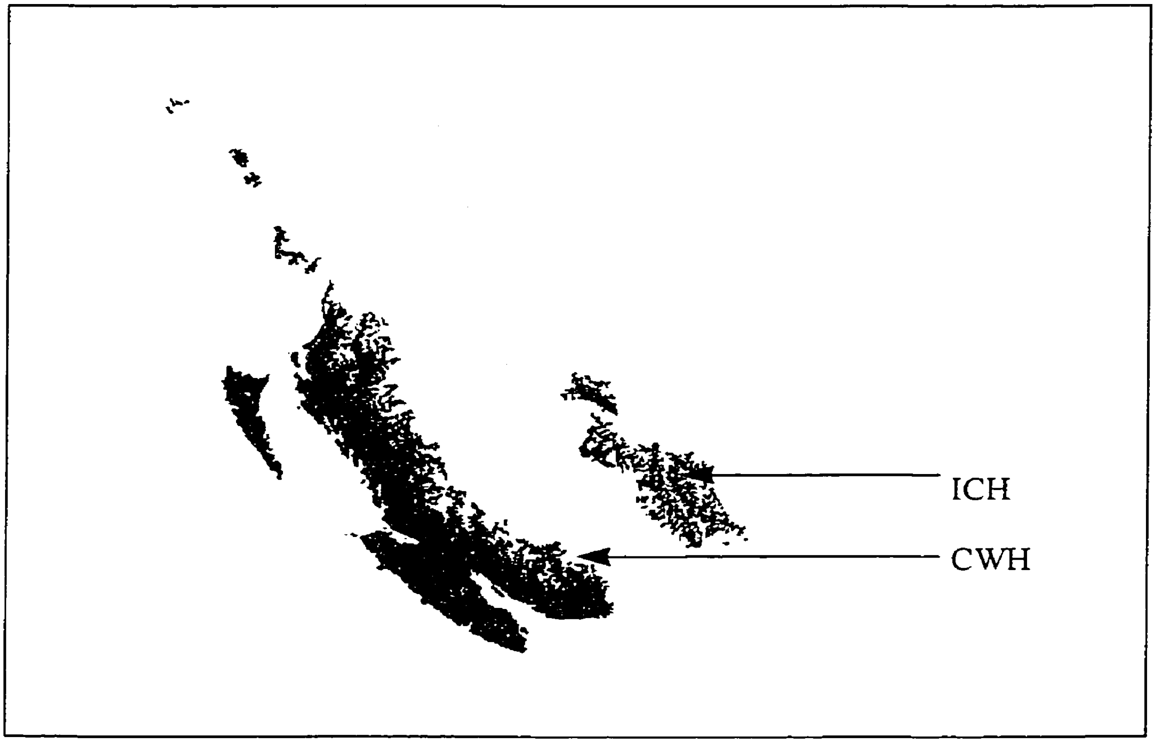


Figure 2-2. Climate diagrams (Walter and Lieth 1967) for ICH, mainland CWH and oceanic CWH forests in British Columbia. [each diagram includes elevation, mean annual temperature and total annual precipitation.].

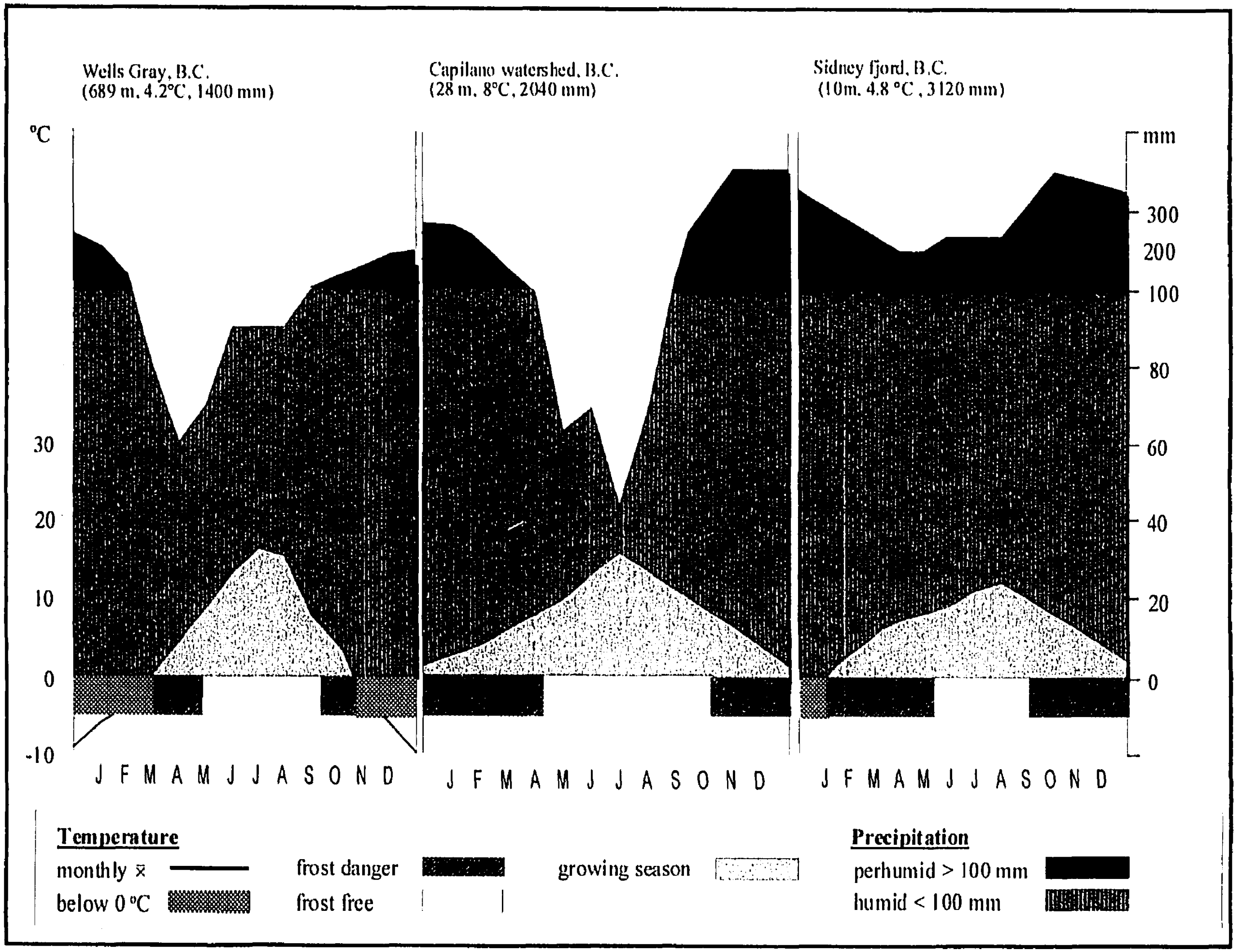


Figure 2-3. CCA ordination of 287 stands, 417 species, 24 environmental variables. The abbreviations for each variable are listed in Table 2-1.

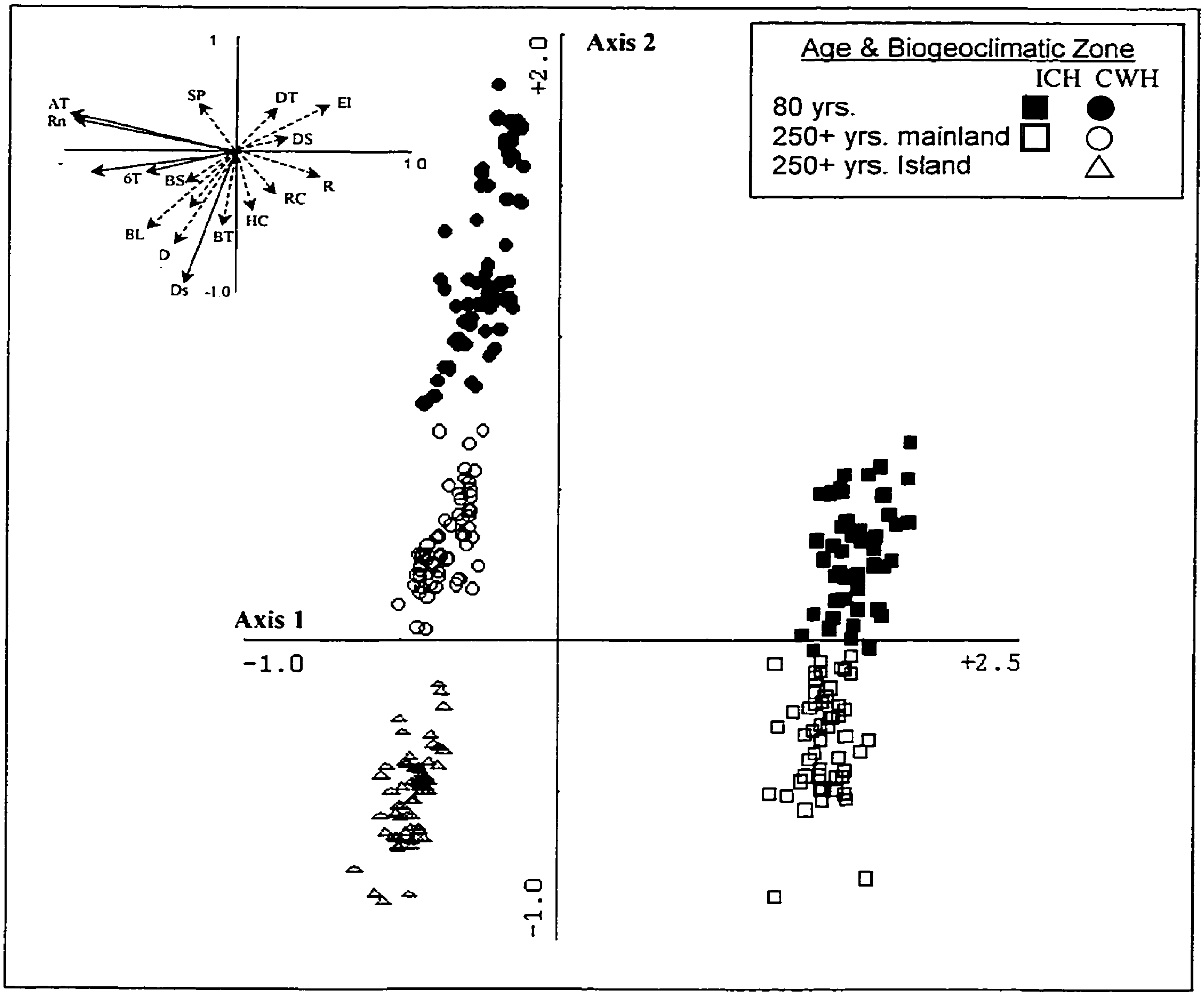


Figure 2-4. TWINSPAN derived bryophyte stand groups for 287 stands and 417 species. Indicator species are abbreviated using the first four letters of the genus and species and their pseudospecies cut level in parentheses; full names are given in Table 2-2. Numbers in brackets indicate the TWINSPAN division number. Eigenvalues are indicated for each successive division.

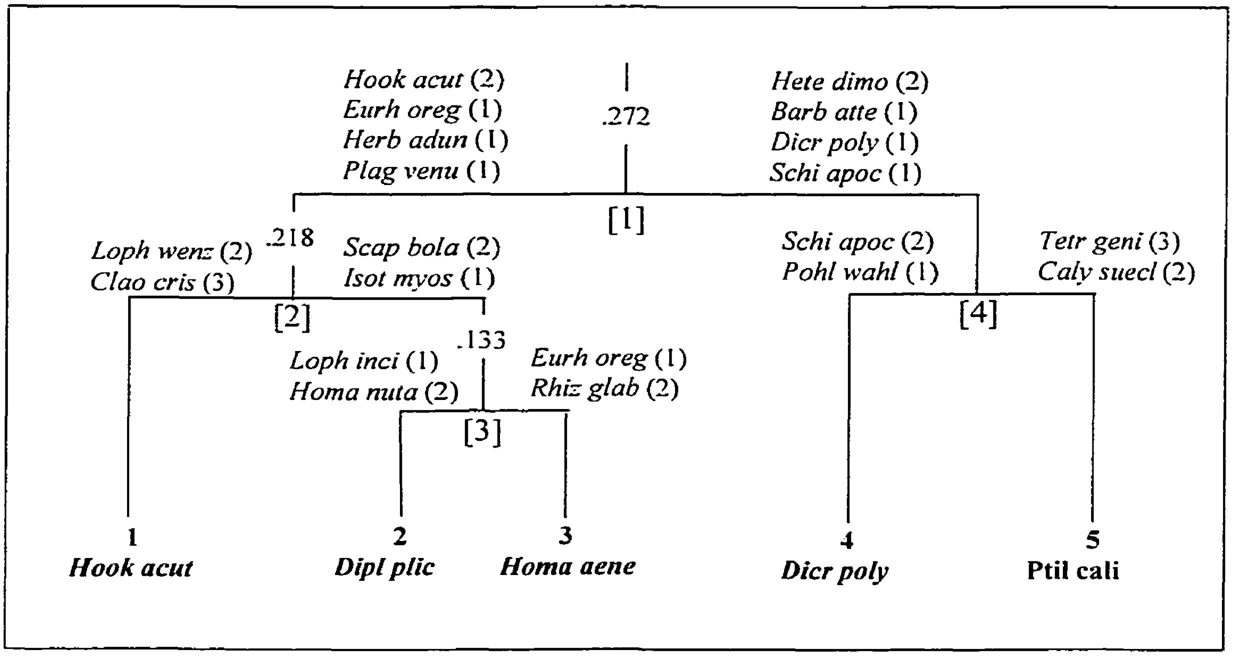


Figure 2-5. CCA ordination of stands showing the relationship of TWINSPAN groups with 24 environmental variables. The abbreviations for each variable are listed in Table 2-1 and those for stand groups are in Fig. 2-3.

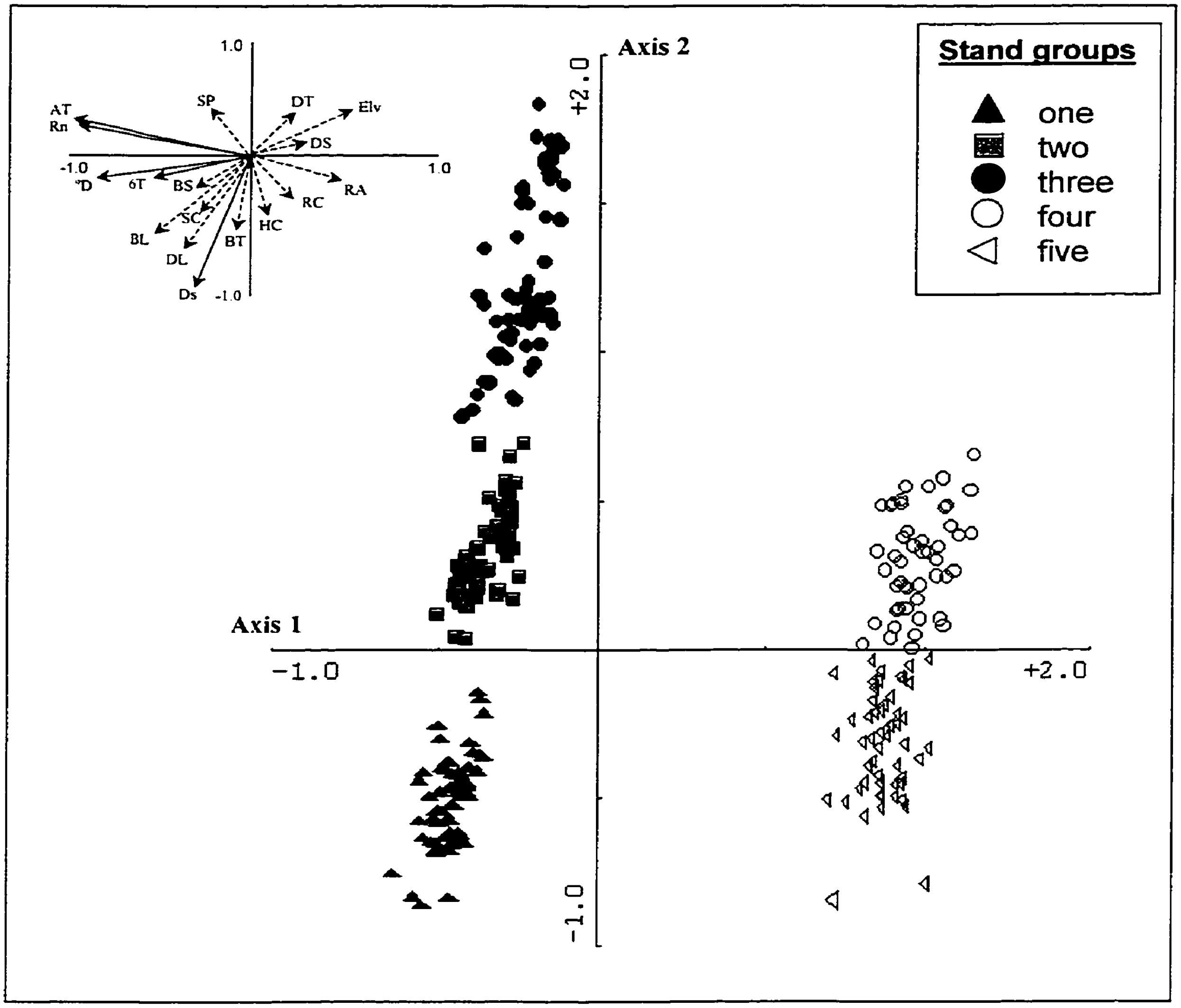


Figure 2-6. Climatic variables as related to the five TWINSPAN stand groups.

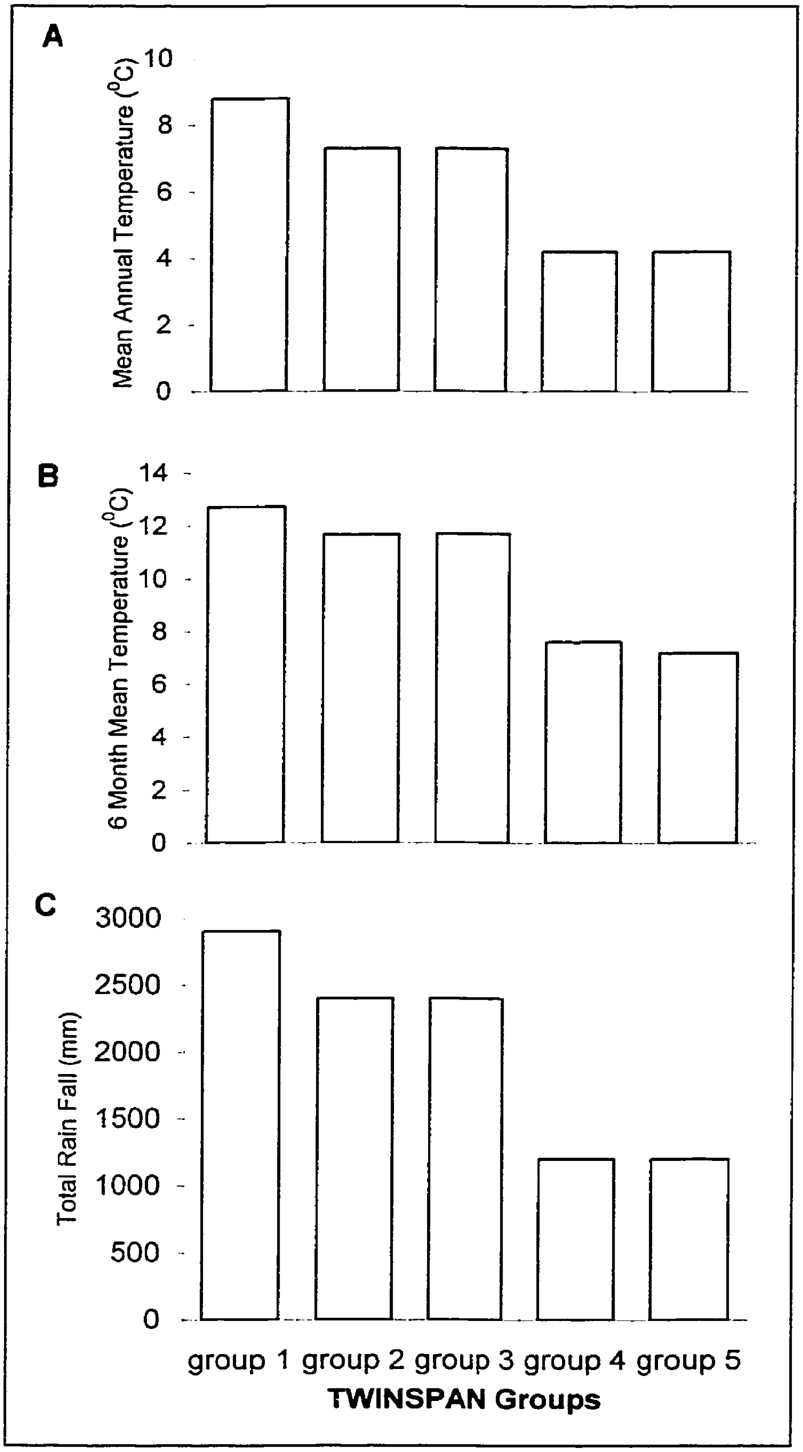


Figure 2-7. Environmental variables as related to five TWINSPAN stand groups.

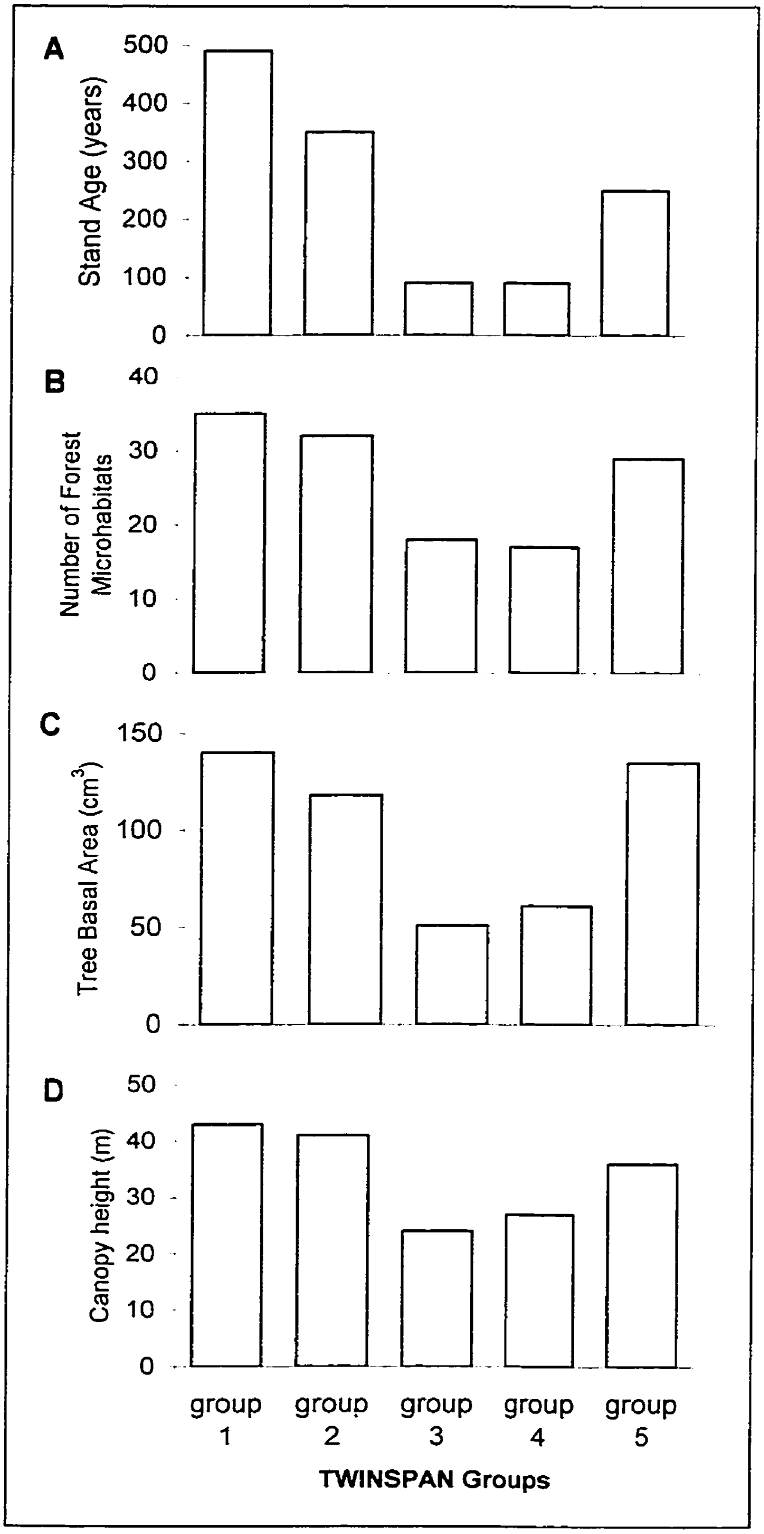


Figure 2-8. CCA species ordination. The species groups are those delimited by TWINSPAN in Figure 2-4. Species are abbreviated using the first four letters of the genus and species from Table 2-2.

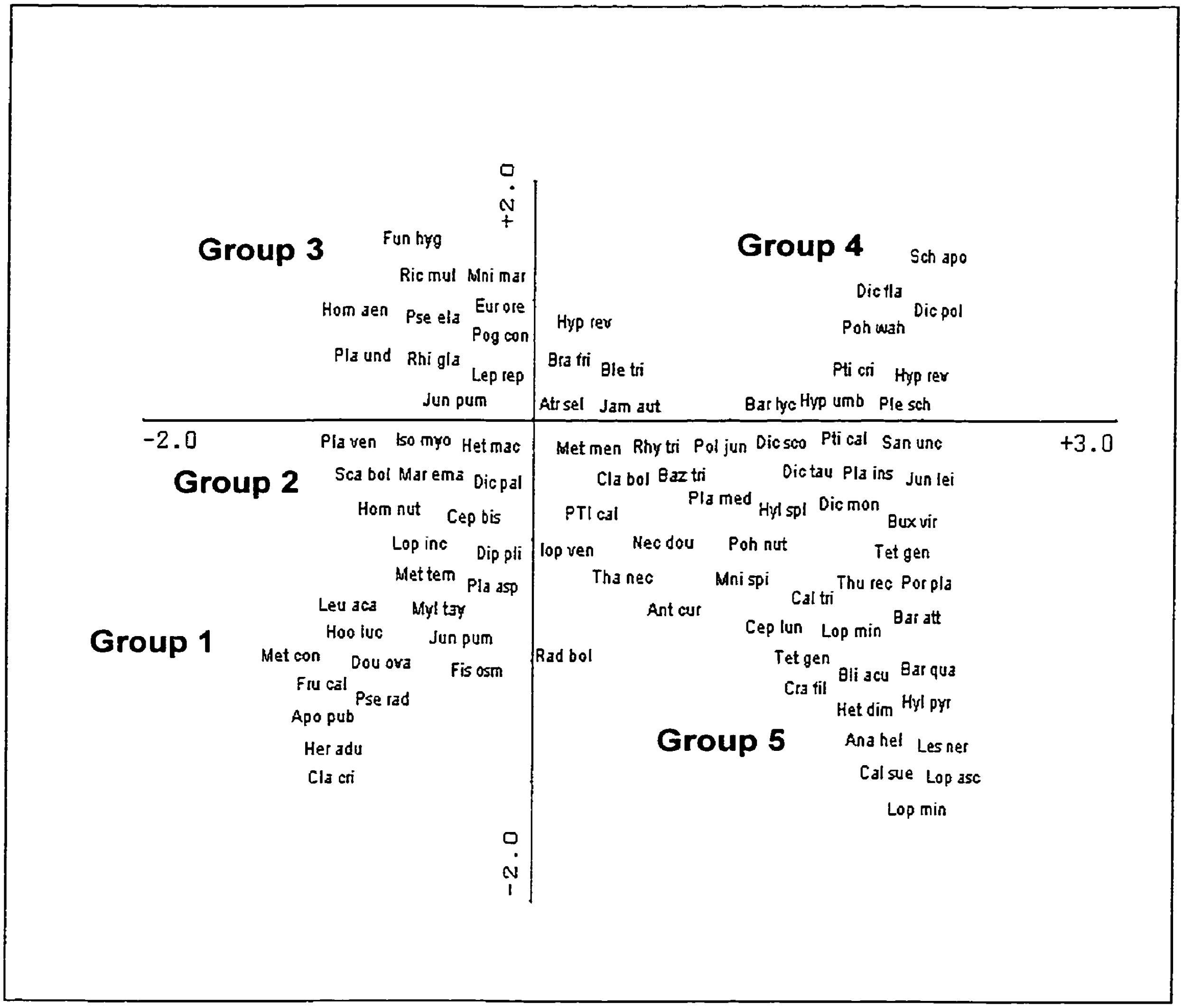


Figure 2-9. Comparison of the number of species and species frequency for each TWINSPAN group within five phytogeographic categories.

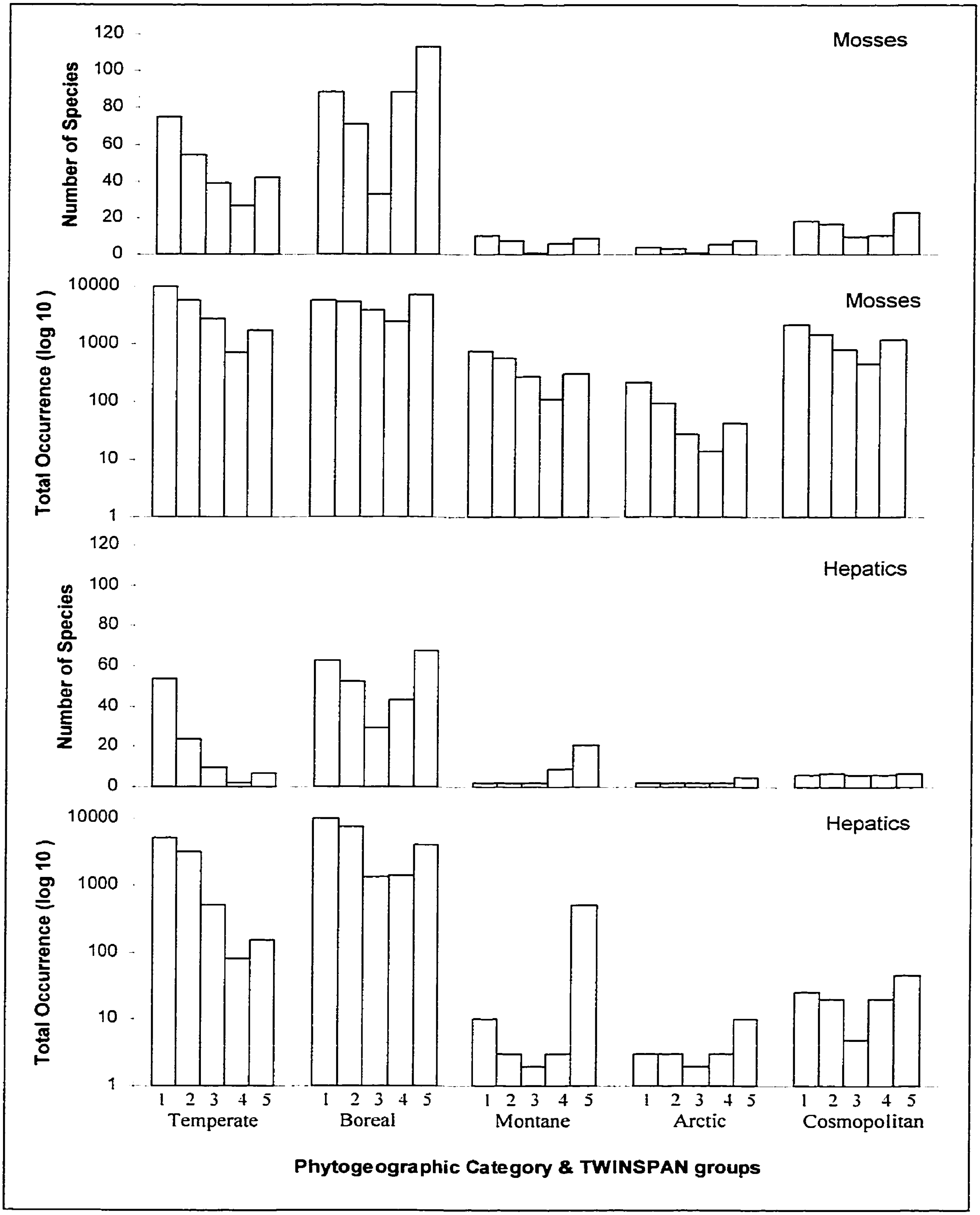
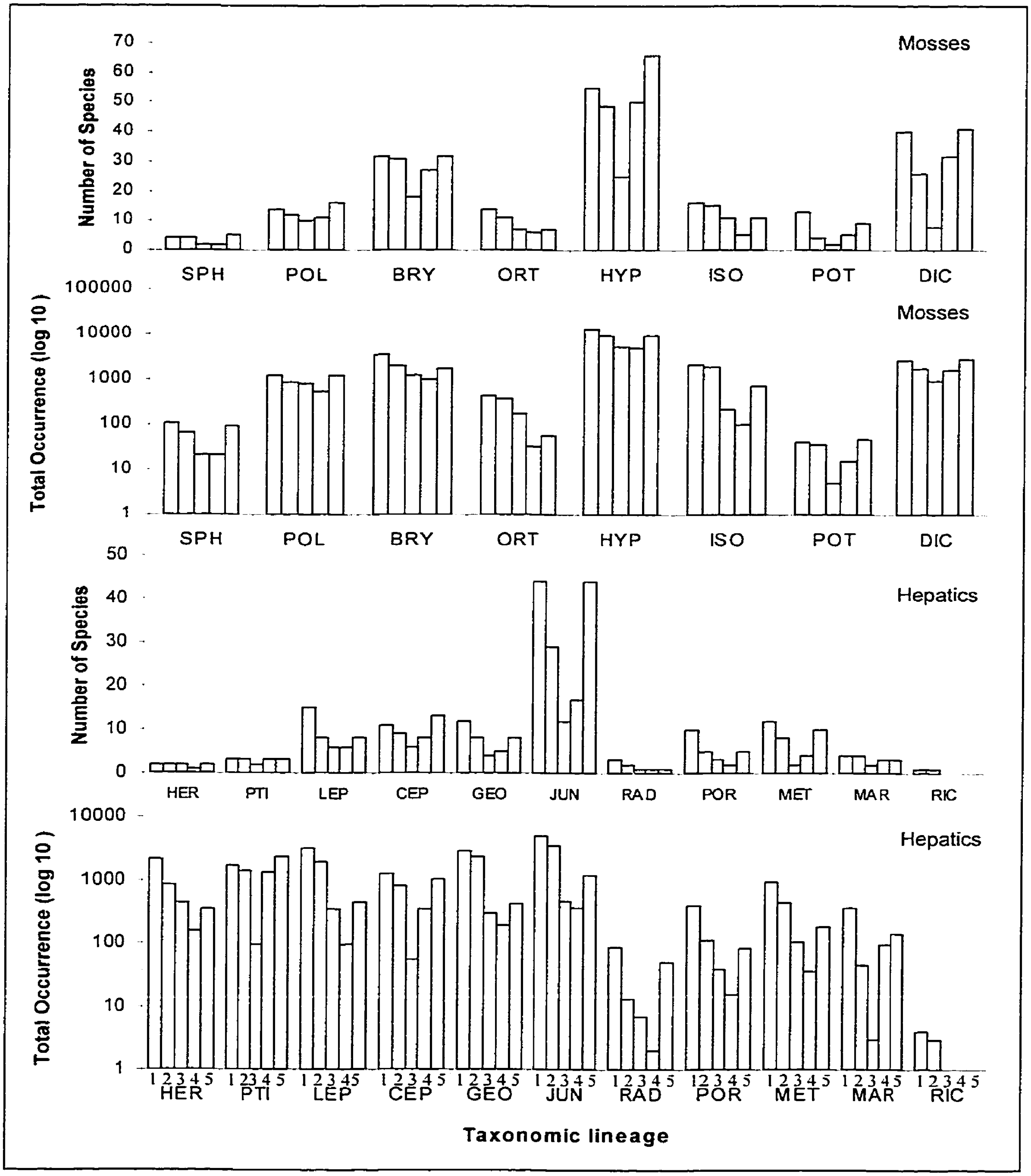


Figure 2-10. Comparison of the number of species and species frequency for each TWINSPAN group within the lineages of *Bryidae* and *Sphagnidae* (following Vitt 1984 with suborders raised to order rank; SPH = *Sphagnidae*, POL = *Polytrichales*, BRY = *Bryales*, ORT = *Orthotrichales*, HYP = *Hypnales*, ISO = *Isobryales*, POT = *Pottiales*, and DIC = *Dicranales*), and within the lineages Jungermanniales, *Metzgeriales* and *Marchantiales* (following Stotler and Crandel-Stotler 1977; HER = *Herbertineae*, PTI = *Ptilidiineae*, LEP = *Lepidoziineae*, CEP = *Cephaloziineae*, GEO = *Geocalycineae*, JUN = M*ungermanniineae*, RAD = *Radulineae*, POR = *Porellineae*, MET = *Metzgeriianeae*, MAR = *Marchantiineae*, and RIC = *Ricciineae*).



LITERATURE CITED

Agee, J.K. 1993. Fire ecology of Pacific Northwest Forests. Island Press, Washington, D.C.

Alaback, P. and Pojar, J. 1997. Vegetation from ridgetop to seashore. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Anderson, L.E., Crum, H.A. & W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93: 448-499.

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Anonymous, 1982. Canadian climate normals, 1951-1980. Vols 1-4. Environment Canada, Atmospheric Environment service, Ottawa, Ontario.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. Ph.D. Thesis, University of British Columbia, Department of Botany, Vancouver, B.C. 187 pages.

Arsenault, A. 1997. Disturbance ecology in forests of the interior cedar-hemlock zone. Proceedings to the ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. June 10-12, University of Northern British Columbia Press, Prince George B.C., Canada.

Arsenault, A. and Goward, T. 1999. Ecological characteristics of inland rainforests. Proceedings to the species at risk conference.

Belland, R.J. 1989. Floristic boundaries in the Gulf of St. Lawrence region: A numerical approach based on the moss flora. Canadian Journal of Botany 67: 1633-1644.

Belland, R.J. & G.R. Brassard. 1988. The bryophytes of Gros Morne National Park, Newfoundland Canada: Ecology and phytogeography. Lindbergia 14: 97-118.

Belland, R.J. & W.B. Schofield. 1994. The ecology and phytogeography of the bryophytes of Cape Breton Highlands Park, Canada. Nova Hedwigia 59: 275-309.

Belland, R.J. 1998. The rare mosses of Canada. Committee on the status of endangered wildlife in Canada, Canadian Wildlife Service, Environment Canada, Ottawa.

Black, R.A. & L.C. Bliss. 1980. Reproductive ecology of *Picea mariana,* at tree line near Inuvik, Northwest Territories, Canada. Ecological Monographs 50: 331-354.

Bradfield, G., Zhang, W. and Arsenault, A. 1997. Plant communities and natural disturbances in the ESSF of southern Wells Gray Park. Proceedings to the ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. June 10-12, University of Northern British Columbia Press, Prince George B.C., Canada.

Chapin, F.S., W.C. Oechel, K. Van Cleve & W. Lawrence. 1987. The role of mosses in the phosphorus cycling of an Alaskan black spruce forest. Oecologia 74: 310-315.

Colinaux, P. 1986. Ecology. John Wiley & Sons, Inc. New York.

Coxson, D.S. 1991. Nutrient release from epiphytic bryophytes in tropical montane rain forest (Guadeloupe). Canadian Journal of Botany 69: 2122-2129.

Cross, J.R. 1981. The establishment of *Rhododendron ponticum* in the Killarney Oakwoods. Journal of Ecology 69: 807-824.

Damman, A.W.H. 1975. Plant distribution in Newfoundland especially in relation to summer temperatures measured with the sucrose inversion method. Canadian Journal of Botany 54: 1561-1585.

Dufrêne, M. & P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67: 345-366.

During, H.J. & B.F. Van Tooren. 1988. Pattern and dynamics in the bryophyte layer of a chalk grassland. In Diversity and pattern in plant communities, H.J. During, M.J.A. Werger & J.M. Willems (ed.). SPB Academic Publishing, The Netherlands.

Godfrey, J.D. 1977a. The Hepaticae and Anthocerotae of southwestern British Columbia. Ph.D. Thesis. Department of Botany, University of British Columbia.

Godfrey, J.D. 1977b. New an interesting hepatics from British Columbia, Canada, and Northern Washington State, U.S.A. I. The Bryologists 80: 539-543.

Godfrey, J.D. 1979. New an interesting hepatics from British Columbia, Canada, and Northern Washington State, U.S.A. II. The Bryologists 82: 162-170.

Godfrey, J.D. 1980. Fullania Hattoriana, a new hepatic from British Columbia, Canada.

Goward, T. 1994. Living Antiquities. Nature Canada 21: 14-21.

Goward, T. 1995. Nephroma occultum and the maintenance of lichen diversity in British Columbia. Mitt. Eidgenoss. Forsch. Anst. Wald Schnee Landsch. 70, 1:93-101.

Hebda, R.J. 1994. The future of Britis Columbia's flora. In, L.E. Harding and E. McCullum, (eds.), *Biodiversity in British Columbia: our changing environment*. Vancouver, Canadian Wildlife Service.

Hebda, R.J. 1995. British Columbia vegetation and climatic history with focus on 6 KA BP. Géographie physique et Quaternaire 49: 55-79.

Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon, in E. Taylor and B. Taylor (eds.), "Future climate change in British Columbia and Yukon". Environment Canada and Ministry of the Environment, Lands and Parks, Province of British Columbia, Victoria, B.C.

Hebda, R.J. & C. Whitlock. 1997. Environmental history. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Heusser, C.J. 1977. Quaternary palynology of the Pacific slope of Washington. Quaterernary Research 8: 282-306.

Hill, M.O. 1994. TWINSPAN – A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, New York.

Ireland, R.R., G.R. Brassard, W.B. Schofield and D.H. Vitt. 1987. Checklist of the mosses of Canada II. Lindbergia 13: 1-62.

Jull, M. 1997. Northern wet-belt ICH and ESSF: searching for the big picture. Proceedings to the ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. June 10-12, University of Northern British Columbia Press, Prince George B.C., Canada.

Keizer, J.P., B.F. Van Tooren & H.J. During. 1985. Effects of bryophytes on seedling emergence and establishment of short-lived forbs in chalk grassland. Journal of Ecology 73: 493-504.

Krause, G. and Schofield, W.B. 1977. The moss flora of Lynn Canyon Park, North Vancouver, British Columbia. Syesis 10: 97-110.

Lertzman, K.P., T. Spies & F.Swanson. 1997. From ecosystem dynamics to ecosystem management. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

Longton, R.E. 1992. The role of bryophytes and lichens in terrestrial ecosystems. pp. 32-76. In Bates, J.W. & A.M. Farmer (eds.), Bryophytes and lichens in a changing environment. Oxford University Press, New York.

McCune, B. 1993. Gradients in epiphytic biomass in three Pseudotsuga-Tsuga forest of different ages in western Oregon and Washington. The Bryologist 96: 405-411.

McCune, B. & M.J. Mefford. 1997. PC-ORD. Multivariate analysis of ecological data, version 3.0. MjM Sofware Design, Gleneden Beach, OR.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6.

Montgomery, D.R. 1987. The influence of geological processes on ecological systems. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Nadkarni, N.M. 1981. Canopy roots: convergent evolution in rainforest nutrient cycles. Science 214: 1023-1024.

Nakamura, T. & K. Obata. 1984. Differences in ecological aharacter between *Abies veitchii* and *Tsuga diversifolia* II. Distribution of seedlings on the moss covered floor of *Tsuga* forest on Mt. Fuji. Bulletin of Tokyo University Forests 74: 67-79.

Nakamura, T. 1986. Bryophyte and lichen succession on fallen logs and seedling establishment in *Tsuga-Abies* forests central to Japan. Symposia Biologica Hungarica 35: 485-495.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 841-1101-1111.

Newmaster, S.G., R.J., Belland, D.H. Vitt & A. Arsenault. 2000. The ones we left behind; Comparing random quadrat sampling and floristic habitat sampling for estimating bryophyte diversity. University of Alberta, Department of biological sciences, Edmonton, Alberta, unpublished manuscript.

Oechel, W.C. & K Van Cleve. 1986. The role of bryophytes in nutrient cycling in the taiga. pp. 120-137. In Van Cleve, K. F.S. III Chapin, P.W. Flanagen, L.A. Viereck & C.T. Dymess (eds), Forest ecosystems in the Alaskan taiga. Springer, New York.

Okada, A. & M. Ohsawa. 1984. Structure and regeneration of *Cryptomeria japonica* forest in the Yaku-shima wilderness area, Yaku-shima Island, Hyushu, Japan. pp. 437-479. In Environment agency of Japan (ed.), Nature Conservation Bureau. Conservation reproductions, Yaku-shima, Japan.

Pocs, T. 1976. The epiphytic biomass and its effects on the water balance of two rain forest types in the Ilguru Mountains, Tanzania, East Africa. Acta Botanica Hungarica 26:143-167.

Pocs, T. 1980. The epiphytic biomass and its effects on the water balance of two rain forest types in the Ilguru Mountains, Tanzania, East Africa. Acta Botanica Hungarica 26: 143-167.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Redman, K. and Taylor, G. 1997. Climate of the coastal temperate rainforest. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.*), The Rain Forests of Home.* Island Press, Washington, DC.

Salmon, D.K. 1977. Oceanography of the Eastern North Pacific. . in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.*), The Rain Forests of Home.* Island Press, Washington, DC.

Schoonmaker, P.K., von Hagen, B. & Wolf, E.C.. 1997. *The Rain Forests of Home.* Island Press, Washington, DC. pp. 431.

Schofield, W.B. 1968a. Bryophytes of British Columbia. I. Journal of the Hattori Botanical Laboratory 31: 205-265.

Schofield, W.B. 1968b. Bryophytes of British Columbia. II. Journal of the Hattori Botanical Laboratory 31: 266-282.

Schofield, W.B. 1968c. Bryophytes of British Columbia. III. habitat and distributional information for selected mosses. Syesis 9: 317-354.

Schofield, W.B. 1968d. A checklist of Hepaticae and Anthocerotae of British Columbia. Syesis 1: 157-162.

Schofield, W.B. 1980. Phytogeography of the mosses of North America. pp131-170. In, the mosses of North America, Taylor R.J. and Leviton, A.E. (eds.). Pacific Division, American Association for the advancement of Science. San Francisco, CA.

Schofield, W.B. 1984. Bryogeography of the Pacific coast of North America. Journal hattori Botanical Laboratory 55: 35-43.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Slack, N.G. 1988. The ecological importance of lichens and bryophytes. Bibl. Lichenol 30: 23-53.

Söderström, L. 1988. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

Tan, B.C. 1980. A moss flora of Selkirk and Purcell mountain ranges, southwestern British Columbia. Ph.D. thesis, University of British Columbia, Vancouver, B.C.

ter Braak, C.J.F. 1998. CANOCO 4. Centre for Biometry, Wageningen, The Netherlands.

Vitt, D.H. 1984. Classification of the Bryopsida. pp. 696-759. In Schuster, R.M. (ed.), New Manual of Bryology, vol. 2. Hattori Botanical Laboratory, Nichinan.

Vitt, D.H. 1991. Distribution patterns, adaptive strategies, and morphological changes of mosses along elevational and latitudinal gradients on South Pacific Islands, Pp. 205-236. in P.L. Nimis and T.J. Crovello (ed.), Quantitative Approaches to Phytogeography. Kluwer Academic Publishers,The Netherlands.

Walter, H. & H. Leith. 1967. Klimadiagram Wetatlas. Fischer, Jena, GDR.

Waring, R.H. and Franklin, J.F. 1979. Evergreen coniferous forests of the Pacific Northwest. Science 204: 1380-1386.

Weber, M.G. & K. Van Cleve. 1983. Nitrogen transformations in feather moss and forest floor layers of interior Alaska black spruce ecosystems. Canadian Journal of Forest research 14:278-290.

Zasada, J. 1986. Natural regeneration of trees and tall shrubs on forest sites in interior Alaska. pp.44-73. In Van Cleve, K., F.S. Chapin III, P.W. Flanagan, L.A. Viereck and C.T. Dyrness (eds.), Forest ecosystems in the Alaskan taiga. Springer, New York.

Chapter 3.

Patterns of Bryophyte Diversity in Cedar-Hemlock forest.

INTRODUCTION

Perhaps the least studied area of bryophyte ecology concerns patterning of diversity on the landscape and the effects of large-scale disturbance. Wallace (1878) recognized that regularity in the patterns of diversity suggest they have been produced in conformity with a basic set of principles rather than accidents of history. Ecological research has investigated some of the factors that influence patterns of bryophyte diversity (Benzing 1981; Økland 1990; Gignac & Vitt 1994; Oksanen 1983; Slack 1977; Vitt et al. 1995; Belland & Vitt 1995; Vitt & Belland 1995; Newmaster thesis chapter 2). The results of such research indicate the importance of substrates and habitats. Habitats such as streams, fens and bogs exhibit unique patterns of bryophyte diversity (Muotka & Virtanen 1995; Slack & Glime 1985; Vitt et. al 1995). Vitt & Belland (1997) have shown that patterns of bryophyte diversity are strongly correlated to habitat type and the scale of the investigation. Furthermore, they described how the landscape is a hierarchical mosiac of meso-habitats (e.g., streams, cliffs, etc.) and microhabitats (e.g., logs, rocks etc.), the patterns of which affect patterning of bryophyte diversity. In forest ecosystems these patterns of diversity may also be affected by large-scale disturbance (i.e., fire, logging). The impacts of catastrophic disturbance on the patterning of bryophyte diversity in forest ecosystems have not been adequately researched.

Fire is the most prevalent large-scale natural disturbance and its effects on patterning of bryophyte diversity have not been studied in detail. Fire can change forest structure, stand age, stand composition, and in some cases, simplify the forest mosaic into an early seral one (Arsenault 1995, 1997). The result is a patchy mosaic of highly disturbed and undisturbed forests; the latter are refugia for regenerating future forests (Kershaw 1978, 1985; Larson 1980). Indirectly, fire maintains forest ecosystem diversity (at the landscape level) because of the randomness, varying intensities, and frequencies of the fires (Arseneault & Payette 1992; Connell & Slayter 1977, De-Las-Heras 1995; Lindholm & Vasander 1987; Zackrisson 1977). It is well known that for the eastern Canadian boreal forest the typical fire cycle is approximately 100-130 years. The frequency of fire disturbance in the coastal western hemlock (CWH) forest is greater than 250 years, but has been recorded as high as 750 years (Agee 1993; Arsenault 1995, 1997). However, there are a large number of small areas that are either lightly burned or that escape fire for longer than 750 years (Arsenault 1995; Ritchie 1976). Small, contained fires (lightning strikes on individual trees) create habitats that are invaded by species from the undisturbed forest. Large fires create a situation where a new forest must establish. The environmental conditions after a large fire are almost semi-arid, with dry surface soils and high surface temperatures (Auclair 1983; Clèment 1990; Garty & Binyamini 1990). Fugitives and early colonizing species such as *Ceratodon purpureus, Polytrichum juniperinum,* and *Marchantia polymorpha* are some of the first species that dominate burnt areas, probably originating from soil diaspore banks (During 1983, 1987; Heras-Ibánez et al. 1991; Newmaster et al. 1998, 1999). Forest fires initiated the vast majority of young stands in the interior cedar-hemlock (ICH) biogeoclimatic zone of British Columbia. The patterning of bryophyte diversity in these young stands in comparison to neighbouring old-growth stands is largely unknown.

Ecological studies that consider patterns of diversity at different scales on the landscape can offer practical applications for conservation strategies (Whittaker 1960, 1972; Lertzman et al. 1997). Whittaker's (1960, 1977) definition of 'point diversity' (i.e., epsilon, gamma, alpha and point), and 'differentiation diversity' (i.e., delta, beta and pattern) can be applied to field research at all scales of diversity, including Vitt & Belland's (1997) mosaic of habitats on the landscape. Biogeographical studies can be modified to investigate patterns of diversity in a quantitative maner at the largest landscape scale (epsilon & gamma inventory diversity; delta differentiation diversity). Although uncommon, bryogeographical studies offer elegant, intuitive conclusions about species diversity, basic floristic concepts, and conservation (Steere 1978; Brassard 1983; Belland and Brassard 1988; Schofield 1988; Vitt 1991; Belland & Schofield 1994; Belland 1995). At the smaller scales, diversity can be investigated at 1) 'regional' or MacArthur's (1965) between stands scale (alpha inventory diversity & beta differentiation diversity, 2) 'local' or MacArthur's (1965) within stands scale (point inventory diversity & pattern differentiation diversity) (Krebs 1985, 1997; Magurran 1988; Pielou 1966). Different environmental or historical factors may be correlated to patterns of diversity at different scales on the landscape. These correlations could be used to build diversity models and answer questions that are essential for conservation of bryophyte diversity. Conservation strategies often rank diversity as one of the most important criteria for site assessment (Magurran 1988; Söderström et al. 1992, 1995; Rose 1992; Slack 1992; Fanta 1995; Tilman 1996). Understanding the patterning of diversity in old ecosystems is our best model for future ecosystem conservation and management (Lertzman et al. 1997).

In British Columbia more than 250,000 hectares of forestlands are logged each year. In coastal temperate forests, over 60 percent of the original old-growth has been replaced by clear cuts and second-growth plantations (Goward 1994a; MacKinnon & Eng 1995). The effects of logging on bryophyte communities are poorly known and need further scientific investigation (Jonsson & Esseen 1990; Söderström 1992, 1995; Herben 1994; Newmaster et al. 1999). Bryophyte community dynamics has been linked to substrate and stand age in the northern forest of Ontario (Carleton 1990; Frego & Carleton 1995a, 1995b), Alberta (Crites and Dale 1995; Johnston & Elliot 1996), Europe (Edwards 1986) and Scandinavia (Söderström 1988b, 1993). Furthermore, bryophyte diversity is strongly correlated with habitat heterogeneity in Alberta (Vitt et al. 1995; Vitt & Belland 1997). Clear-cutting techniques reduce stand age, the number of habitats, and ultimately cryptogam diversity (Anderson & Hytterborn 1991; Brumelis & Carleton 1988, 1989; Gustafsson & Hallingbäck 1988; Lesica et al. 1991; Söderström 1988b; Newmaster thesis chapter 2). Furthermore, this disturbance creates environmental conditions that are unfavorable for many bryophytes and lichens (Laaka 1980; Goward 1992, 1993; Gustafssson et al. 1992; Johnston and Elliot 1996). Changes to microclimate after logging include humidity, moisture, temperature and light quality (Bell & Newmaster 1998; Newmaster & Bell 2000). In a study of biodiversity in the Ontario boreal mixedwood forest (Newmaster & Bell 2000), bryophyte diversity was dramatically reduced after clear-cut logging. Sensitive epixylic hepatics and forest mesophytes disappeared with the less humid microclimate and the reduction of microhabitats and stand age. A small number of fugitives and colonists dominated the site for eight years after the clear-cut. Eventually, forest mesophytes began to recolonize the area from habitat refugia surrounding and within the clear-cut. Re-establishment after clear-cutting may be difficult if the gap size created is larger than the dispersal capabilities of the species involved (Söderström 1988b). The patterning of diversity in these young stands initiated from logging disturbance in comparison to neighbouring old-growth stands is largely unknown (Newmaster thesis chapter 2). Clear-cut logging initiated the vast majority of young stands in the coastal western-hemlock (CWH) biogeoclimatic zone of British Columbia. The patterning of bryophyte diversity in these young stands in comparison to neighbouring old-growth stands is largely unknown.

The old-growth forest of the Pacific Northwest of North America have been the focus of considerable public debate in recent years (Harris 1984; Cadrin et al. 1991). Forest policy makers and managers are faced with difficult decisions: how much to preserve, and how much to dedicate to forestry interest (Goward 1994b; Schoonmaker 1997). Bryophytes are recognized as one of the most abundant vegetation types in the cedar-hemlock forest ecosystem (Alaback & Pojar 1997; Schofield 1988). This study compares the patterning of bryophyte diversity (at the regional scale) in old-growth forests with that of young forests affected by large-scale disturbances. Specifically, the objectives of this study are to determine, 1) if stand diversity changes after large-scale disturbance (fire and logging) within either the coastal western hemlock (CWH) or interior cedar hemlock (ICH) biogeoclimatic zones, 2) if a stand classification built on species composition will adequately partition species richness, and if species frequency curves can help interpret the classification, 3) the patterns of bryophyte diversity at a regional scale using relationships between stands, species, and environmental variables within either the ICH or CWH, 4) beta diversity within young and old stands, and species turnover as related to sample scores using Hill's scaling in a CCA analysis, 5) whether a discriminant model of regional diversity can predict species richness given a set of environmental variables for the ICH or CWH, and if regional diversity models for each biogeoclimatic zone are based on similar ecological variables or processes.

STUDY AREA

Sampling was conducted in British Columbia, Canada, within two distinct biogeoclimatic zones (Krajina 1965; Meidinger & Pojar 1991); the Coastal Western Hemlock zone (CWH) and Interior Cedar Hemlock zone (ICH). The CWH is located on the westerly edge of the Coast Mountains and is known as Canada's coastal temperate rainforest (Fig. 3-1). Sampling in the CWH was confined to the VM1 biogeoclimatic variant. The ICH is located on the westerly, windward slopes of the Columbia Mountains

(Fig. 3-1). Sampling in the ICH was confined to the ICHmw3, ICHwk1 and ICHvk1 biogeoclimatic variants. The wetter portions of the ICH (wk1 & vk1 variants) are known as inland oroboreal rainforests (Goward & Ahti 1992). Detailed descriptions of glacial history, climate and floristics can be found in Schofield (1988), Arsenault (1995), Hebda (1995), Schoonmaker et al. (1997) and Newmaster et al. (2000).

METHODS

Sampling method - Floristic habitat sampling (FHS - Newmaster thesis chapter 1) was used to assess patterns in bryophyte community composition over the period of two field seasons. In 1996, 102 stands were sampled in the interior cedar-hemlock (ICH). Stands were chosen from the Wells Gray, upper Adams River, and Seymour watersheds. Within these watersheds sampling was evenly distributed between stands that were burned approximately 80 years ago (age class 4), and old-growth stands of 250+ years in age (age class 9). In 1997, 185 stands were sampled in the coastal western hemlock (CWH). Stands were chosen from the Capilano and Seymour watersheds along the mainland coast and in the Sidney, Clayoquot, Tofino and Walbran watersheds along the western coast of Vancouver Island. Extensive logging activities in the Capilano and Seymour watersheds allowed a balanced sampling between stands that were logged 80 years ago, and old-growth stands of 250+ years in age. Sampling on Vancouver Island was limited to old stands due to the relatively recent logging activity and lack of fire history in the CWH.

Each species and its abundance was recorded for all mesohabitats (Vitt & Belland 1997) and microhabitats in each stand. Abundance was measured (ocular estimate) on a scale of one to three following Vitt et al. (1995): 1 = one to few occurrences, < 20% cover; 2 = several occurrences to frequent in one or some areas of the micro/mesohabitat, 30-50% cover; 3 = frequent throughout the micro/mesohabitat, > 70% cover.

Species nomenclature follows Anderson *et al.* (1990) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. Voucher specimens collected from each watershed were prepared and deposited at the University of Alberta Cryptogamic Herbarium (ALTA), Kamloops Forest Region Herbarium and University of British Columbia Herbarium (UBC).

Environmental variables – Twenty-two environmental variables were used for multivariate analyses. Stand dynamics, soil variables and general site variables were collected within a 20 m diameter plot that was located in the stand at least 500 m from any transition zone. Coarse woody debris data was obtained using two 50 m transects, with diameter measurements of logs for each decay class (Arsenault & Bradfield (1995) at each transect intersection. Meso-habitat heterogeneity was measured by the number of different mesohabitats in each stand.

Macroclimate data were obtained from the Canadian Climatic Normals and meterological stations within the local watersheds (Anonymous, 1982) and were used in climate diagrams (Walter & Lieth 1967) and as environmental variables in multivariate analyses. Microclimate data were collected only within in a subset of 20 stands (divided evenly between young and old forest) within each watershed. Within each stand, five replicate sites were randomly chosen to measure temperature and total precipitation. All microclimate stations were set out in May and measured/removed in October of 1997. Growing season temperature within stands (subset) was calculated using sucrose inversion (provides an integrated temperature data for the length of the growing season) technique as described in (Damman 1975).

Diversity analyses – Species richness (gamma and alpha diversity) was used to compare changes in stand diversity after large-scale disturbance in the ICH and CWH. Whittaker's (1960) terminology and concepts are used to describe diversity at different scales (Fig. 3-2). Inventory diversity is simply species richness, and is defined as either total richness (γ-gamma diversity) or mean stand richness (mean alpha diversity – α). Therefore, gamma diversity (γ) is the total number of species in the following landscape elements; biogeoclimatic zones, biogeoclimatic variants (a finer classification of zones) or watersheds (Table 3-1). Mean stand species richness is the mean number of species within stands for the ICH, CWH or the partition of stands into old-growth forest and young growth forest disturbed by either fire or logging (Krebs 1985). Species richness within and between stands was compared using ANOVA in SPSS (1999). Abundance was recorded for each species on each type of microhabitat or mesohabitat (see FHS methods above) and averaged for each species within stands.

Multivariate analyses - Patterns of bryophyte diversity were explored using canonical correspondence analysis (CCA) which ordinated the stands (ICH or CWH exclusively) using environmental variables to constrain the ordination (ter Braak, 1986). The multivariate structure of the data was explored using CANOCO 4 (ter Braak 1998). The ordination resulted in axis scores for each stand, with the axes correlated to the most important environmental variables in the analysis.

Classification of stands – Cluster analysis (e.g., average linkage Sequential Agglomerative Hierarchical Non-overlapping method-SAHN – euclidean distance measure) was used to classify stands (ICH or CWH) based on the weighted average of the species scores (using the CCA stands scores). A K-means cluster analysis provided an independent check for stand membership to the clusters defined in SAHN. The resultant classification was used to partition species richness using ANOVA, and identify groups of stands in the CCA ordination. Stands were labeled according to their cluster groups (SAHN) in the ordination diagrams using CANODRAW for both the CWH and ICH. Species richness for each cluster group will be related to the ordination. Species frequency curves were prepared for each of the groups defined in the cluster analyses within either the ICH or CWH.

Beta diversity/species turnover - Species turnover was evaluated after large-scale disturbance within the ICH or CWH. Whittaker (1960) used the term "differentiation diversity" as a broad term for species turnover. He further defined differentiation diversity at smaller scales; delta diversity (i.e., watersheds), beta diversity (i.e., stands), pattern diversity (i.e., microhabitats-Whittaker 1965). In our study delta diversity was defined as the change in species composition between biogeoclimatic zones (differences within ICH or CWH gamma diversity) or watersheds (differences in watershed gamma diversity). Beta diversity was the change in species composition between stands (alpha diversity - Fig 2). Differentiation diversity within an age class was calculated directly using Whittaker's (1965, 1972, 1977) beta diversity measure (β-eqn 1). Species turnover between stand clusters (SAHN) is also considered in our multivariate analysis. Canonical correspondence analysis (CCA) employing Hill's scaling was used to analyze species turnover between stands. Sample scores (SD) from CCA were used to represent the relative position of the stand on a complex gradient. Beta diversity is the separation of sample scores along the gradient axis. The scores of the samples are standardized such that the within-site variance equals 1 (ter Braak 1986). Hill & Gauch (1980) defining the length of the ordination axis to be a range of the site scores, expressed in multiples of the standard deviation. Therefore, samples or stands that are 2 SD apart can be interpreted as sharing less than one third of the species or have a species turnover of over 60% (Jongman et al 1987). Samples that are 4 SD would be expected to have no species in common. Beta diversity (changes in species composition) can be calculated between individual groups classified in the cluster analyses, enabling an evaluation of the effects of environmental variables on species richness turnover within a biogeoclimatic zone.

$$\beta_w = \left(\gamma / \alpha \right) - 1 \qquad \text{[eqn. 1]}$$

where, γ = gamma diversity (total species richness per age class)
α = alpha diversity (mean species richness per stand)

Regional diversity model – The Object of discriminant function analysis (DFA) is to predict multivariate responses that best discriminates the subjects in different groups (Ramsey & Schafer 1997). Discriminant analyses were used to model species richness using environmental variables for both the CWH and ICH. The cluster groups (i.e., SAHN and K-means) and the environmental parameters for each stand were used as input for a discriminant analysis which 1) determined if the classification was accurate, 2) provided discriminant functions that are used to predict stand membership in the classification, and, 3) indicates the most important environmental variables that define the clusters. The discriminant function was used to predict not only cluster membership of stands, but also richness. This allowed the modeling of bryophyte species richness using the environmental variables measured, complimenting the CCA analysis.

RESULTS

Stand Diversity

Interior Cedar Hemlock Zone - Diversity was greater in old-growth forests (age class 9; 250 yrs+) than young forests (age class 4; 80 yrs; disturbed by forest fire). Gamma diversity (γ) is 30% higher in old-growth forests than young forests (Table 3-1). Mean stand richness (α) is significantly ($p < 0.01$) higher in old-growth forest than young forests (Fig. 3-3). Furthermore, mean stand abundance is twice as high in old-growth forest, than in young forest (Fig. 3-4).

Differences in species richness are apparent between the different ICH biogeoclimatic variants. The wetter biogeoclimatic variants have the highest bryophyte diversity (Table 3-2). Old stands in the ICHwk1 and ICHvk1 have significantly ($p < 0.05$) higher species richness (15% higher) than in the ICHmw3 (Table 3-2). Bryophyte abundance follows the same pattern. Species richness within young stands is higher in the ICHwk1 than in the ICHmw3 (Table 3-2).

Coastal western Hemlock Zone - Diversity is greater in old-growth forests than young forests. Gamma diversity (γ) is over 50% higher in old-growth forests than young forests (Table 3-1). Alpha diversity (α) is significantly ($p < 0.01$) higher in old-growth forest than young forests (Fig. 3-3). Mean stand abundance is three times higher in old-growth forest than young forest (Fig. 3-4).

Old-growth forests along the west coast of Vancouver Island had higher diversity than mainland coastal, old-growth forests from the Vancouver watershed. Gamma diversity and relative abundance was more than 25% higher in oceanic old-growth forests than mainland coastal forests (Table 3-1). Mean species richness (α) was not significantly ($p > 0.05$) higher in oceanic forests (Fig. 3-3).

Canonical Correspondence Analysis

Interior Cedar Hemlock Zone – Distinct groups of stands on the ordination are defined by stand age and meso-habitat heterogeneity. High species/environment correlations (>0.902) indicate that environmental variables for the first three axes are useful in identifying gradients (Table 3-3). Interset correlations and significant canonical coefficients were used to identify the environmental variables that best explain the gradients for each axis. The age of the stand (time since last large-scale disturbance) is the most important variable defining the first axis (Table 3-4). Old stands form a distinct group on the left side of the first ordination axis (Fig. 3-5). Other variables that correlate to the first axis include forest structure related variables such as log density, and basal area of trees or logs (Fig. 3-5, Table 3-4). Meso-habitat heterogeneity as measured by the number of different mesohabitats in each stand is most strongly correlated to the second CCA axis (Table 3-4). Groups of stands with low meso-habitat heterogeneity are found near the bottom of axis two while stands with the highest meso-habitat heterogeneity are at the top (Fig. 3-5). Other variables correlated to the second axis include the abundance and pH of rock habitat (Table 3-4). Stand hygrotope (third axis) and local land slope (fourth axis) explain an additional 10 % and 7 %, respectively (sig. t-value, $p > 0.05$).

Coastal western Hemlock Zone – Distinct groups of stands on the ordination are defined by temporal and habitat gradients. High species/environment correlations (>0.862) indicate that environmental variables for the first two axes are useful in identifying gradients (Table 3-3). Based on interset correlations and significant canonical coefficients, age (time since last large-scale disturbance) of the stands the most important variable defining the first axis (Table 3-5). This is reflected in ordinations where old stands form a distinct group on the left side of the first axis (Fig. 3-6). Other variables that correlate to the first axis include stand structure related variables such as log density, and basal area of trees or logs (Fig. 3-6). Meso-habitat heterogeneity is most strongly correlated to the second CCA axis (Table 3-4). Groups of old stands with low meso-habitat heterogeneity are found near the bottom right side of the ordination and increase with habitat heterogeneity to the top left side of the ordination (Fig. 3-6). Logging and fire disturbance result in similar species associations. Slope position (i.e., toe, low, mid etc.) explains an additional 7 % of the species data on axis three (sig. t-value, $p > 0.05$).

Stand Classification

Interior Cedar Hemlock Zone – Cluster analysis (SAHN) classified all stands into five groups based only on the species optimum in stands. K-means cluster analysis provided an independent check for stand membership to the five clusters defined in SAHN. Differences in species richness between the five groups was significant (P <

0.05), but the sums of squares within the groups was low (Tables 6, 7 and 8). Species frequency is not only higher in the first two groups, but the tail of the curve (i.e., the rarer species) is more developed (Fig.7). There is a drop in the number of hepatics and endemics from group 1 (old stands) through to group 5 (young stands) (Table 3-7). Furthermore, there are fewer rare species, as identified by the shortening of the frequency curves from group 1 through to group 5 (Fig. 3-7).

Overlaying the clusters (SAHN) onto the CCA ordination of stands showed five distinct groups of stands that are clearly definable based on age and meso-habitat heterogeneity (Fig. 3-8; Table 3-4). Old forests with high meso-habitat heterogeneity (group 1) are on the top left side of the ordination (Fig. 3-8). Young forests with low meso-habitat heterogeneity (group 5) are on the bottom right side of the ordination.

Coastal western Hemlock Zone - Cluster analysis (SAHN) classified all stands into four groups based only on species optimum in stands. A K-means cluster analysis provided an independent check for stand membership to the four clusters defined in SAHN. Species richness is significantly different ($P < 0.05$) between the groups (Tables 3-6, 3-7 and 3-8). The sums of squares variance for species richness within groups is high when compared to the between groups sums of squares (Table 3-6). Species frequency in groups one and two is high, and the tail of these curves is more developed (i.e., more rare species) (Fig. 3-7). In the CWH, the within groups partition of variance can be attributed to the high species diversity within stands of old coastal forests (Table 3-1). Several corresponding patterns are evident from group 1 (old stands) through to 4 (young stands). The number of hepatics and endemics drop from group 1 through to group 4 (Table 3-7). There are twice as many hepatics and endemics in old growth forest than young forests (i.e., comparing groups 3 and 4) (Table 3-7). The shorting of the frequency curve from group one through to group five signifies a loss of many rare species (Fig. 3-7).

Four distinct groups of stands are apparent when the K-means/SAHN clusters are overlaid on the CCA ordination of stands (Fig. 3-9). The groups are clearly definable based on age and meso-habitat heterogeneity (Table 3-5). Old forests with high meso-habitat heterogeneity (group 1) are on the top left side of the ordination (Fig. 3-9). Old forest forests with low meso-habitat heterogeneity (group 3) are on the bottom right side of the ordination. Young forests, regardless of disturbance (group 4) are clumped on the right side of the ordination.

Beta Diversity (Species Turnover)

Interior Cedar Hemlock Zone – Beta diversity calculated for old stands is almost identical to beta diversity when calculated for young stands (Table 3-1). Sample scores from Hill's scaling of the CCA scores indicate that there is considerable species turnover (beta diversity) between cluster group 1 through to group 5. Groups 1 through to 5 are spread over 3 SD of the environmental gradient suggesting that species turnover between young and old stands is high (Fig. 3-10). Species turnover between young and old stands is apparent on the ordination when considering the relative sample scores (Fig. 3-10). Some old stands are 2 SD away from young stands. This suggests that they share only 1/3 of the same species. Furthermore, meso-habitat heterogeneity can account for the 30% (1 SD difference) of species turnover within an age class.

Coastal western Hemlock Zone – Beta diversity calculated for old-growth stands is only slightly higher than the beta diversity calculated for young forests (Table 3-1). The results from the CCA (using Hill's scaling) indicate that there is considerable species turnover between young and old stands. Groups 1 through to 4 are spread over 2 SD of the environmental gradient (Fig. 3-10). Species turnover from young stands to old stands is approximately 30% (1 SD). However, species turnover within old-growth stands themselves is approximately 30%. Species turnover within old-growth stands increases with meso-habitat heterogeneity (Fig. 3-10). The increase in sample scores (SD) from groups 1-3 corresponds to an increase from 1-4 meso-habitats per sample (Fig. 3-8; Table 3-7).

Regional Diversity Model

The proposed conceptual model (Fig. 3-11) of stand or regional diversity states that bryophyte diversity is essentially a function of two variables. 1) Stand age (time since last large scale disturbance), and 2) Mesohabitat heterogeneity. Data from the interior cedar hemlock forests and coastal western hemlock forests were used in separate discriminant analyses to build this model of diversity.

Interior Cedar Hemlock Zone – A discriminant analysis successfully used five cluster groups representing age and meso-habitat heterogeneity to predict bryophyte species richness with high accuracy. The discriminant analysis tested stand membership to 97.2% of the stands classified by the K-means/SAHN classification. The canonical correlation from the discriminant functions is the ratio of the between groups sums of squares to the total sums of squares. Thus, the first discriminant function is responsible for 93.6 % of the between group differences (variability in the discriminant scores). The second and third functions are only responsible for 6.1 % and 0.3 % of the between group variance (Table 3-9). Wilk's Lambda was used to test the hypothesis that in the population there are no differences between the groups (SPSS 1999). Seventy percent of the observed variability (between the groups) is explained by group differences using only the age of the stand. The unexplained variability drops from 30% to 4.8 % when meso-habitat heterogeneity is added, and down to 3.6 % when hygrotope is added to the discriminant model (Table 3-10). The final discriminant model uses two discriminant functions (eqn. 4 and eqn.5) to explain 94 % of the variation between the groups (Fig. 3-12). The territorial map clearly defines the relationship between groups 1-5 and the first two discriminant functions (Fig. 3-12).

Coastal western Hemlock Zone –The discriminant analysis tested stand membership to 94.6% of the stands classified using K-means/SAHN. The first discriminant function accounts for 97.0 % of the between group differences. The second and third functions are accountable for 2.5 % and 0.4 % of the between group variance (Table 3-9). Wilk's Lambda is the ratio of within groups sum of squares to total sum of squares (variance not explained by groups), and therefore can be used to identify influential environmental variables. Age of the stand was accountable for 75 % of the observed variability between the groups. The addition of meso-habitat heterogeneity and basal area of logs to the model reduces the unexplained variability from 25% to 2.1 % and 1.0 % respectively (Table 3-10). Two functions (eqn. 6 and eqn.7) are used in the final discriminant model to explain 97 % of the variation between the groups (Fig. 3-13). The relationship between groups 1-4 and the first two discriminant functions are arrayed in the territorial map (Fig. 3-13).

DISCUSSION

Why are Old Growth Forest Rich with Bryophytes?

Several studies have shown that bryophyte diversity is higher in old growth stands than younger stands (Pike et al. 1975; Edwards 1986; Söderström 1988a; Lesica et al. 1991; Crites & Dale 1995, 1998; Rambo & Muir 1998a, 1998b). All of these studies have concluded that old stands promote habitat and environmental conditions (i.e., high humidity, low wind and moderate light) that are favorable for rich bryophyte communities. These old forests have many unique habitats for epiphytic (Pike et al. 1975; Sillet 1995) and epixylic bryophytes. Old forests have a greater diversity of logs in a variety of decay classes and sizes than young forests (Andersson & Hytteborn 1991). Logs provide habitat for many species of bryophytes, and different decay classes and sizes of logs support different communities of bryophytes (Gustafsson, L. & T. Hallingbäck. 1988; Söderström 1988a). Disturbing these habitats can reduce bryophyte diversity dramatically (Muotka & Virtanen 1995).

Old growth cedar-hemlock stands in British Columbia are known to support rich carpets of bryophytes, but surprisingly, there has been no published quantitative data that compares bryophyte diversity in young and old growth cedar hemlock forests. Our research clearly shows that old-growth cedar-hemlock forests have many more species and higher abundance of bryophytes than young forests regardless of biogeoclimatic zone. Gamma and alpha diversity were approximately twice as high in old-growth cedar-hemlock forests than in young forests. Bryophyte abundance is twice as high in old forest compared to young forest within the ICH, and three times higher in the CWH.

Stand continuity and moisture - High diversity bryofloras may also occur in old growth forest because of the moist local micro climate (Hallingbäck 1977) and stand continuity (Edwards 1986). Stand continuity is defined as large stands having the least amount of fragmentation from large-scale disturbance such as fire or logging activities (Harris 1984). Stand continuity is directly affected by the size and number of catastrophic disturbances. Long forest continuity is associated with high bryophyte diversity (Rambo & Muir 1998a), and the support of rare and endemic species (Newmaster et al thesis chapter 2). Edwards (1986) has stated that long stand continuity favors rare Atlantic bryophyte distributions in Europe. Similarly, Aune (1994) recorded that the floristic composition of the continuous boreal forest in Norway is rich and abundant with rare oceanic and suboceanic bryophytes.

The high diversity in old growth cedar hemlock forests may be partially explained by the fact that these old growth forests are usually associated with very moist micro climates (Krajina 1965; Meidinger & Pojar 1991). In cedar hemlock forests stand continuity is intimately linked with moist climates, and both of these variables (i.e., stand age and moist climates) are associated with higher bryophyte diversity. Although forest fire is still a dominant force, in the wettest cedar-hemlock forest both fire history maps and the relative proportion of these forests older than 250 years suggest much lower fire frequencies (Arsenault 1997). The largest or most continuous stands are in watersheds that receive heavy annual rainfall. The unique forest structure in these moist, continuous old growth stands contributes to the diversity of microhabitats for bryophyte colonization. In the CWH, the oldest and most continuous stands (Sidney fjord, Clayoquot and Walbran Watersheds on the west coast of Vancouver Island) had the highest bryophyte diversity. These old-growth cedar-hemlock forests have a rich flora of oceanic and suboceanic western North American endemics. 15% of the bryoflora of British Columbia is confined to western North America (Schofield 1988). These are also the wettest cedar-hemlock forests studied. Preservation of large, old growth forests will ensure a refugium for many Western North American endemics (Schofield 1987). In the ICH, the wetter biogeoclimatic variants (i.e., ICHwk1 and ICHvk1) had higher species richness than dryer variants. Similar patterning of lichen diversity has been recorded in the ICH (Arsenault and Goward 1997; Goward and Arsenault 1999). These areas are also more continuous because they do not have the extensive disturbance history of the drier ICHmw3. Differences in species richness between the wet and dry biogeoclimatic variants are not clear and require further investigation.

Disturbance – Although our research does not allow a direct comparison of logging and forest fire disturbance. In the CWH, the main disturbance is clear-cutting and the extensive history of clear-cutting over the last one hundred years allow stands 80 years of age to be compared with the residual old-growth. In the ICH, the main disturbance was forest fire and the extensive logging history is relatively recent.

Following either clear-cutting or wild fire, microhabitats are disturbed or removed (i.e., logs, stumps and rocks), temperature extremes and the drying affect of the wind increase, drainage lowers the surface waters, and streams, cliffs, moist logs and stumps dry out (Hämet-Ahti 1983, Crites & Dale 1995; Newmaster et al. 1999, Laaka 1992). The number of suitable habitats decreases, ultimately decreasing cryptogam diversity (Gustafsson and Hallingbäck 1988, Soderstrom 1988, Laaka 1992, McCune 1993, Newmaster et al. 1999, Rambo and Muir 1998). These disturbances have severe consequences to the ecosystem because of the loss of many mesophytic forest species and the invasion of colonizers and fugitives (Newmaster et. al. 1999; Bell and Newmaster et al. 1998). The long-term differences in bryophyte diversity in logged and burnt old-growth forests needs to be monitored.

Community diversity – Patterning of diversity is closely linked with patterning of communities. Stands were classified based on differences in species optimums and these groups were further distinguished by differences in species richness and frequency patterns. Old forests not only have more species, but many of these are rare species that are unique to old forest. There are more than twice as many hepatics, endemics and rare species in old growth forests than young forests. These findings support earlier work (Newmaster thesis chapter 2) in the community dynamics of cedar hemlock forests.

We used beta diversity to consider species turnover both within and between stands of different age classes. Beta diversity is high when moving on a gradient of young to old stands as expressed in our CCA ordinations and site scores. In either biogeoclimatic zone, stands of the same age had similar beta diversity. This is well known in northern forest in Ontario (Newmaster et al. 1998, 1999), and Scandinavia (Söderström, L. 1988b), and the Pacific Northwest of U.S.A. (Rambo and Muir 1988). However, species richness and turnover between old growth stands can be quite variable. Species turnover is higher among old stands with high mesohabitat heterogeneity than old stands with low mesohabitat heterogeneity. These results support previous research showing variability in bryophyte communities among old growth cedar-hemlock forest (Newmaster thesis chapter 2). It appears that given enough time, bryophytes can occupy a large variety of habitats within a forest.

Old-growth forests have different communities of bryophytes than younger forests. Our community study (Newmaster thesis chapter 2) shows that old-growth stands had different species than younger forests, and more specifically, there is a rich flora of hepatics in old-growth ICH and CWH forest (Newmaster thesis chapter 2). Furthermore, there are many more western North American endemics and rare species associated with old-growth CWH and ICH. Söderström (1988b) demonstrated that hepatics are richer and more abundant in older forest and unique communities of hepatics and mosses in old-growth forests have been documented in many other research projects (Pike et al. 1978; Lesica et al. 1991; Sillet 1995; Laaka 1992; Rambo and Muir 1998). Rare epixylic hepatics are often associated with the abundance of logs in different decay classes and sizes in old-growth forest (Gustafsson & Hallinbäck 1988; Söderström 1988a; Rambo & Muir 1998a, 1998b). These epixylic specialists have habitat demands that are unique to older forest (Sermander 1936; Schuster 1949; Andersson & Hyterborn 1991). Succession of epixylic communities is continuous because the logs offer only temporary habitat for these rare hepatics; old growth forest ecosystems provide a continuous supply of logs that maintains rich communities of hepatics. These community differences support the differences in species richness between young and old growth cedar hemlock forests.

What are the Critical Environmental Variables?

The gradient analyses - Our multivariate analyses offered insights into the patterning of bryophyte diversity and the influence of environmental variables. The classification of stands using only bryophyte species optimums within stands, arranged old stands, and young stands in separate groups. Further divisions separated these groups based on habitat heterogeneity. Stands with the greatest mesohabitat heterogeneity had the highest bryophyte diversity. This follows patterning of bryophytes in wetlands (Vitt & Belland 1995a, 1995b) and rare bryophytes on the regional landscape of Alberta (Vitt & Belland 1997). Distinct patterns in bryophyte diversity at a regional scale were apparent using relationships between stands, species and environmental variables within either the ICH or CWH. The groups on the ordination were complementary to the SAHN stand classification, which used only species abundance. The two most influential correlating environmental variables were time since the last major disturbance and mesohabitat heterogeneity. Other environmental variables of secondary importance included stand structure variables that are related to stand age such as the size of trees and logs.

These results have several implications for forest managers concerned with sustainability of bryophyte diversity. Modeling natural disturbance in today's silvicultural prescriptions may not necessarily sustain bryophyte diversity. Old growth cedar hemlock forests have been developing for thousands of years and the age of any one stand may exceed 1000 years. Forest rotation cycles do not consider time spans of that length. We must consider preserving old growth forests that, in turn, will sustain bryophyte diversity.

Bryophyte diversity model - Our theoretical model of bryophyte diversity for forest stands suggests that both the amount of time since the last large scale disturbance and mesohabitat heterogeneity are very important variables in maintaining high bryophyte diversity. Time since disturbance and habitat heterogeneity are closely associated with one another. The large number of habitats associated within CWH forests has resulted from both geomorphological processes (Montgomery 1997), forests successional processes (Whittaker 1960) and climatic processes (Hebda 1998). Hebda and Whitlock (1997), describe CWH forest as a biogeochron, which embodies the changes in the living and physical (substrate and climate) components of the landscape. These living and physical components are the basic elements for habitat diversity. It is over long periods of time (1000's of years) that habitat heterogeneity develops. Cedar-hemlock forest began to disperse and establish starting about 12000 BP. Hemlock expanded in the CWH 6000-7000 BP (before present), and in the ICH 4000-6000 BP (Hebda 1994, 1995, 1997). Infrequent forest fire disturbance (250-750 year fire cycles), and successional patterns sustained the cedar-hemlock forests for the last 4000-7000 years (Hebda & Whitlock 1997). In this time bryophyte species could colonize an undisturbed, moist ecosystem with a highly diverse number of meso/microhabitats. Bryophytes are dependant on their ability to disperse and establish from local sources of bryophyte diversity. Some areas along the coast escaped glaciation and served as refugia for many of today's western north American endemic bryophytes (Schofield 1988). Dispersal and establishment of bryophytes on available habitats can only occur when there is a local source of propagules and sufficient time to develop rich communities.

CONCLUSION

A better understanding of the patterning of bryophyte diversity in forested ecosystems will provide an opportunity to minimize the impact of forest operations on biodiversity (Arsenault and Goward 1997). Management plans must consider stand age and mesohabitat heterogeneity as the two most influential environmental variables that influence the patterning of bryophyte diversity in cedar hemlock forest. The increase in species richness with older, more meso-habitat rich stands corresponds with an increase in rare species, endemics and hepatics (Newmaster thesis chapter 2). The loss of bryophyte species after logging and forest fire disturbance is well documented and of growing concern (Peet et al. 1983; Laaka 1992; Ehrlich 1990; Andersson 1987; Bell & Newmaster 1998, Newmaster et al. 1999). Recommendations from many analyses of bryophyte diversity suggest the protection of old-growth forests and consequently the rare species within (Gustafsson & Hallinbäck 1988; Söderström 1988b; Rambo & Muir 1998a; Schofield 1988). Researchers from Norway and other countries have stated the importance of preserving old-forest for the conservation of rare bryophytes (Prestø 1996; Weibull and Söderström 1995). Efforts in preservation of rare species and areas of high bryophyte diversity have been established throughout Europe (Söderström et al 1992; Söderström 1995) and North America (Slack 1992; Belland 1998; Oldham 1999; Rambo and Muir 1998; Newmaster et al. 1998). We suggest that bryophyte diversity in the cedar-hemlock forests of British Columbia will be sustained through ecosystem management of old growth legacies (i.e., landscapes, stands and components of these) and the preservation of areas of high diversity. Our research has identified the importance of old-growth forests and habitat heterogeneity. We suggest that the oldest, most continuous forests should be considered for protected areas. Several watersheds with very high diversity have been identified in our research. Furthermore, mesohabitat quality and quantity should have special consideration in old-growth management plans. Further research is needed to identify the mesohabitats and microhabitats that offer the greatest bryophyte diversity. Management plans that consider these habitats will be better equipped to manage cedar-hemlock forests for maximum biodiversity.

Table 3-1. Stand diversity in old growth (250+ yrs.) and young forests (80-90 yrs.) disturbed by fire or logging (n = number of stands sampled; Abundance = mean stand abundance; $\gamma\gamma$ = total richness or gamma diversity; α = mean richness or mean alpha diversity; β = beta diversity within age classes).

Biogeoclimatic Zone and Geographic Area	Disturbance	n	Abundance	Species Richness		Beta Diversity
CWH				γ	α	β
Oceanic rainforest	old growth	60	1127	317	162	.96
Mainland coastal rainforest	old growth	59	932	231	118	.96
	Logging	44	350	114	62	.84
ICH						
Inland rainforest	old growth	56	417	300	88	2.41
	wildfire	47	224	188	54	2.48

Table 3-2. Bryophyte diversity within ICH biogeoclimatic variants (n = number of stands sampled; gamma diversity = species richness within the biogeoclimatic variant; abundance = total accumulated abundance per stand).

Variants	n	disturbance	Gamma diversity	Abundance
ICHmw3	20	wildfire	171	229
	25	old-growth	235	309
ICHwk1	17	wildfire	162	218
	20	old-growth	276	348
ICHvk1	10	wildfire	120	162
	11	old-growth	266	342

Table 3-3. Summary of Canonical correspondence analyses (CCA) for 103 ICH stands, and 185 CWH stands with 22 environmental variables.

Biog.	Axis	1	2	3	4
ICH	Eigenvalue	.132	.092	.060	.052
	Species/environment correlation	.960	.906	.902	.847
	Cumulative % variance of species data explained	18.7	31.6	41.4	48.4
CWH	Eigenvalue	.150	.061	.021	.012
	Species/environment correlation	.973	.862	.690	.588
	Cumulative % variance of species data explained	48.8	68.5	75.3	79.3

Table 3-4. Statistics for variables used in canonical correspondence analysis (CCA) of 103 stands in the ICH and 22 environmental variables. Asterisks indicate significance at $p < 0.05$. Absolute t-value > 2.1 are used to indicate important canonical coefficients (ter Braak, 1998). Bold values are indicated for variables with significant correlation and canonical coefficients (Hyg. is the only sig. var for axis 3 - Int. Cor. = .5281 and t-value = 6.81; no sig. variables for axis 4).

	Interset Correlation		Canonical coefficient		t-value	
Environemtnal Variable	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Site Series (SS)	-0.15	-0.07	0.01	-0.03	0.06	-0.29
Elevation (Elv)	-0.38	0.06	-0.08	-0.01	-1.63	-0.11
Slope (SL)	-0.09	**-0.19**	-0.16*	-0.37*	-2.69	-2.97
Slope Position (SP)	-0.11	0.01	0.02	0.18	0.45	1.74
Aspect (As)	0.25	-0.16	0.12	-0.06	1.58	-0.64
Hygrotope (Hyg)	**-0.22**	0.25	-0.18*	0.08	-2.74	0.76
Rock cover (RC)	-0.44	**0.31**	0.09	-0.27*	1.66	-2.53
Rock acidity (RA)	0.49	**-0.28**	0.19	-0.29*	1.71	-2.74
Soil Texture (ST)	-0.01	-0.13	-0.11	-0.27	-1.52	-1.94
Canopy height (CH)	0.39	0.19	-0.03	-0.09	-0.58	0.76
Tree density (DT)	-0.37	-0.26	-0.07	0.15	-1.24	1.15
Tree basal area (BT)	-0.25	-0.40	0.03	0.58	0.53	5.19
Snag density (DS)	**0.35**	-0.10	0.22*	-0.02	4.55	-0.15
Snag basal area (BS)	-0.01	-0.19	-0.13*	0.06	-2.82	0.58
Log density (DL)	0.03	-0.14	0.03	0.07	0.56	-0.60
Log basal area (BL)	0.19	0.06	-0.12*	0.26*	-2.53	2.46
Shrub cover (SC)	-0.12	0.19	0.10	0.24	1.87	2.08
Herb cover (HC)	0.04	**0.19**	-0.17*	-0.49*	-3.14	-4.15
Age since dist. (Ds)	**-0.78**	-0.01	-068*	-0.38*	-11.49	-3.12
Rainfall (Rn)	0.01	0.01	0.00	0.00	0.01	0.01
6 month mean temp. (6T)	**-0.28**	0.08	-0.22*	0.27	-2.16	1.29
Meso-habitats (MsH)	-0.06	**-0.59**	0.46*	-0.49*	4.43	-9.71

Table 3-5. Statistics for variables used in canonical correspondence analysis (CCA) of 185 stands in the CWH, 22 environmental variables and 4 covariables. Asterisks indicate significance at $p < 0.05$. Absolute t-value > 2.1 are used to indicate important canonical coefficients (ter Braak, 1998). Bold values are indicated for variables with significant correlation and canonical coefficients.

	Interset Correlation		Canonical coefficient		t-value	
Environemtnal Variable	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Site Series (SS)	-0.05	0.32	-0.00	0.02	-0.01	0.54
Elevation (Elv)	0.05	-0.31	-0.01	-0.09	-0.27	-1.90
Slope (SL)	-0.00	-0.22	0.07*	0.02	3.32	0.98
Slope Position (SP)	0.05	-0.41	-0.01	-0.05	-0.08	-1.81
Aspect (As)	-0.10	-0.14	-0.03	0.01	-1.68	0.75
Hygrotope (Hyg)	0.00	0.33	0.02	-0.05	0.82	0.43
Rock cover (RC)	-0.01	0.01	-0.02	0.02	-1.09	0.81
Rock acidity (RA)	-0.01	0.01	-0.02	0.01	-0.99	0.79
Soil Texture (ST)	0.08	-0.07	0.01	-0.01	0.21	-0.69
Canopy height (CH)	-0.49	0.21	0.01	-0.03	0.31	-1.34
Tree density (DT)	0.55	-0.22	0.00	-0.03	0.09	-1.19
Tree basal area (BT)	-0.29	0.13	-0.02	-0.01	-1.06	-0.18
Snag density (DS)	**0.31**	-0.08	0.05*	0.01	3.07	0.41
Snag basal area (BS)	-0.09	0.04	-0.02	-0.01	-1.09	-0.40
Log density (DL)	-0.23	0.11	0.11	0.03	1.72	0.40
Log basal area (BL)	-0.28	-0.11	-0.02	-0.06	-0.56	-1.75
Shrub cover (SC)	-0.38	0.28	-0.02	0.04	-0.67	1.34
Herb cover (HC)	-0.24	0.41	-0.03	0.03	-1.09	1.25
Age since dist. (Ds)	**-0.73**	**0.31**	-0.31*	0.07*	-11.29	2.71
Rainfall (Rn)	0.01	0.01	0.01	0.01	0.01	0.01
6 month mean temp. (6T)	0.01	0.01	0.01	0.01	0.01	0.01
Meso-habitats (MsH)	-0.44	**-0.60**	-0.17	-0.09*	-1.68	-10.15

Table 3-6. Species richness analysis of variance for K-means cluster groups in the ICH and CWH (Levene Statistic not sig., $p > .05$).

Biog.	ANOVA	Sum of Squares	df	Mean Square	F	Sig.
ICH	Between Groups	76559.008	4	19139.752	162.542	< .001
	Within Groups	11422.011	97	117.753		
	Total	87981.020	101			
CWH	Between Groups	400446.773	3	133482.258	296.645	< .001
	Within Groups	81445.044	181	449.973		
	Total	481891.816	184			

Table 3-7. Diversity and floristic affinties for k-means species cluster groups within the ICH and CWH (MH = meso-habitat number, S = total species or gamma diversity, $\bar{s}$ = mean species richness or mean alpha diversity, HEP. = hepatics, E = Western North American endemics, A = arctic, M = montane, B = boreal, C = cosmopolitan, T = temperate).

BIO	Cluster grp.	Dist. age (yrs.)	MH	S	$\bar{s}$	Number of species with affinities							
				γ	α	Hep.	Moss	E	A	M	B	C	T
ICH	1	250+	4	298	126	99	197	20	11	11	190	30	56
	2	250+	2-3	262	91	79	183	11	5	9	179	27	42
	3	**	**	188	78	54	141	9	4	7	131	23	23
	4	90	2-3	164	54	47	110	7	3	7	111	23	20
	5	90	1	104	33	23	68	5	2	4	71	15	12
CWH	1	250+	4	321	220	120	201	36	10	11	152	28	118
	2	250+	2-3	287	147	110	177	33	9	10	137	23	109
	3	250+	1	198	100	68	130	28	7	8	96	18	69
	4	90	1-3	114	60	32	82	16	5	5	58	12	34

** Includes old growth stands 250+ yrs. old with one meso-habitat and young stands 90 yrs. old with four meso-habitats.

Table 3-8. Mean species richness with standard deviations and 95% confidence limits for K-means cluster groups within the ICH and CWH biogeoclimatic zone.

Biog. Zone	Cluster Group	(α) mean Richness	std dev.	Lower 95 % Confidence Limits	Upper 95 % Confidence Limits
ICH	1	126.1538	2.6767	120.3218	131.9859
	2	91.2308	2.4021	86.2835	96.1780
	3	78.1429	5.2799	65.2234	91.0623
	4	54.1489	1.4931	51.1434	57.1544
	5	33.1111	2.7961	26.6634	39.5588
CWH	1	220.0833	2.7838	213.9563	226.2104
	2	146.5417	3.5681	139.4270	153.6563
	3	99.5526	2.2907	94.9113	104.1939
	4	60.2857	1.4276	57.4319	63.1395

Table 3-9. Discriminant eigenvalues and canonical correlations for bryophyte diversity functions in the CWH and ICH.

Biog.	Function	Eigenvalue	% of Variance	Canonical Correlation
ICH	1	13.266	93.6	0.964
	2	0.859	6.1	0.680
	3	0.048	0.3	0.215
CWH	1	39.574	97.0	0.988
	2	1.033	2.5	0.713
	3	0.181	0.4	0.391

Table 3-10. Wilk's Lambda for environmental variables and functions used in discriminate analyses for the ICH and CWH (Age = time since large scale disturbance, MsH = number of meso-habitats, Hyg. = hygrotope - xeric, mesic, hygric).

Biog.	Env. Var.	Lambda
ICH	Age	0.297*
	MsH	0.048*
	Hyg	0.036*
CWH	Age	0.025*
	MsH	0.012*
	BCWD	0.010*

Figure 3-1. Map of the coastal western hemlock (CWH) and interior cedar-hemlock (ICH) biogeoclimatic zones in British Columbia.

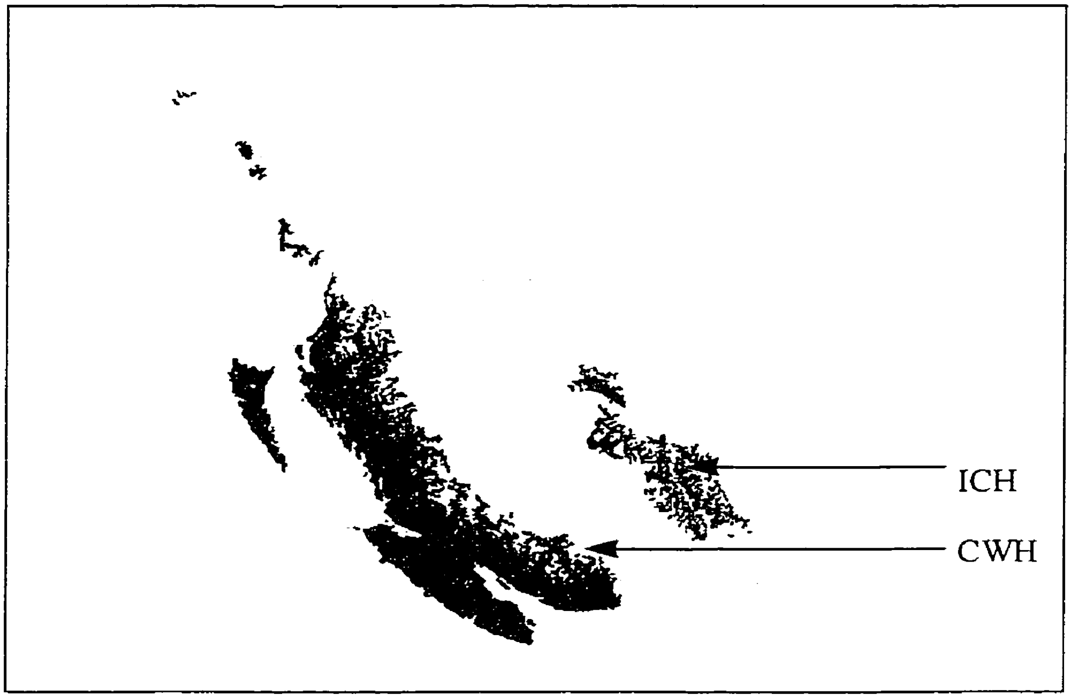


Figure 3-2. Hierarchy of diversity terminology for cedar-hemlock rainforest in British Columbia (terminology for inventory and differentiation diversity follows Whittaker (1965, 1972, 1977).

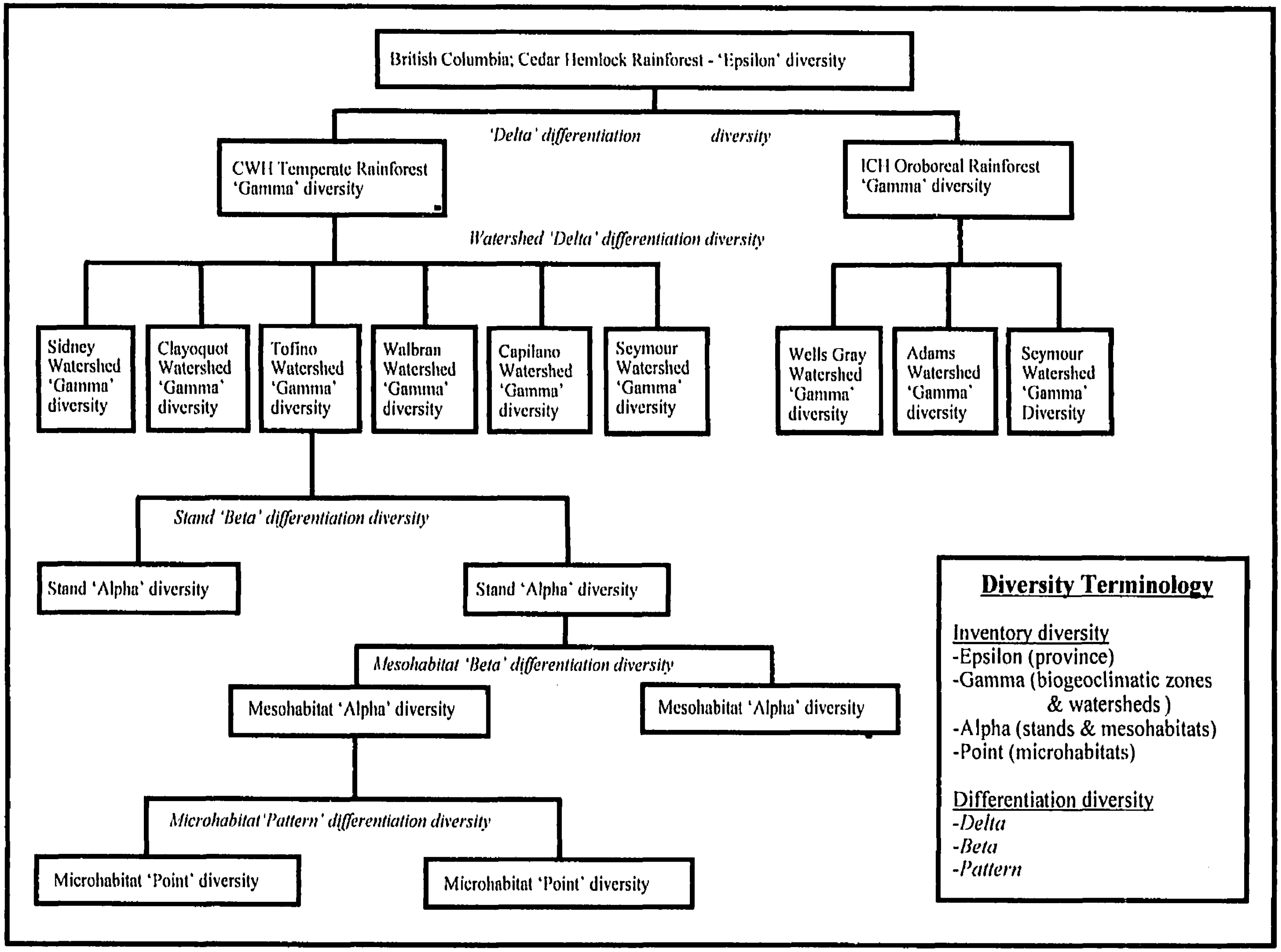


Figure 3-3. Mean species richness for young (90 yrs logging or wildfire) and old growth rainforests within the ICH or CWH (VWS and VISL). Error bars are shown for one standard deviation on either side of the mean. [ICH = Interior cedar hemlock, VWS = Vancouver watershed, VISL = Vancouver Island].

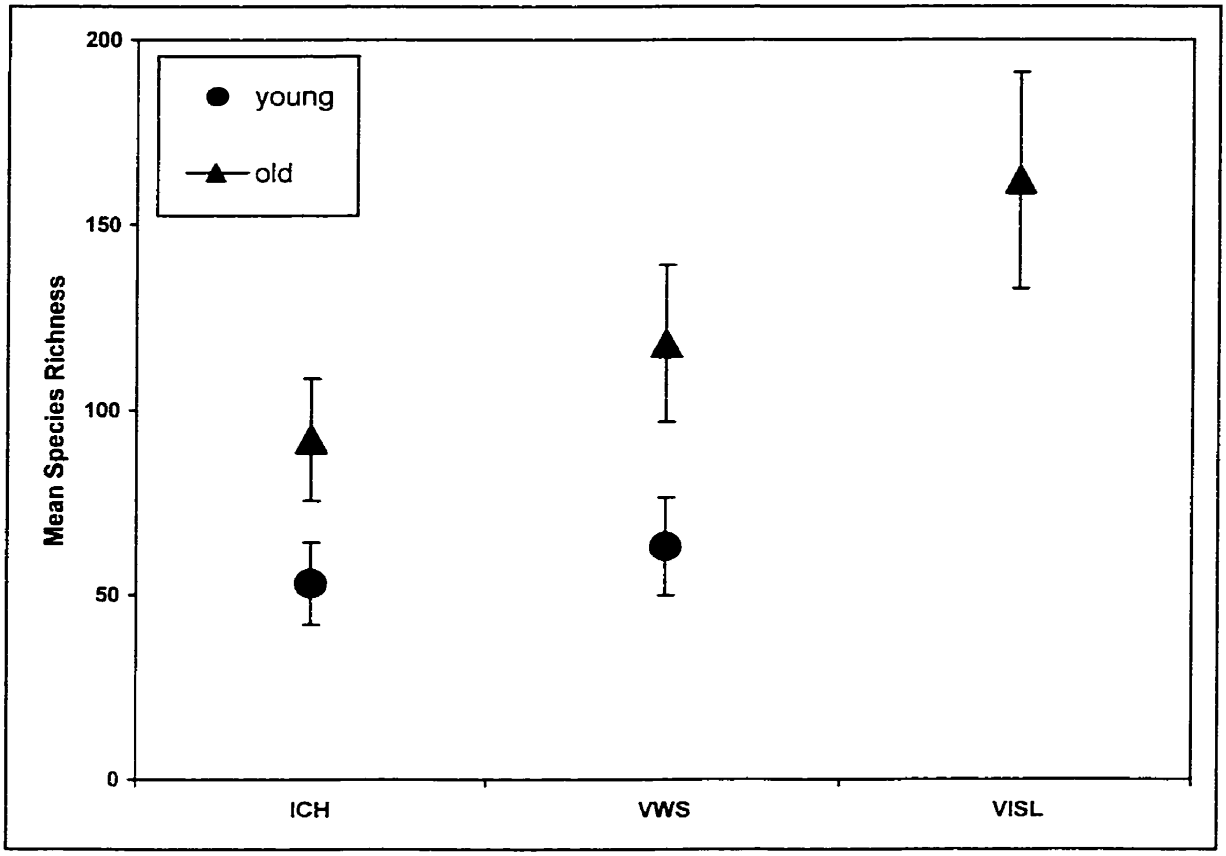


Figure 3-4. Mean stand abundance for young (90 yrs logging or wildfire) and old growth rainforests within the ICH or CWH (VWS and VISL). Error bars are shown for one standard deviation on either side of the mean. [ICH = Interior cedar hemlock, VWS = Vancouver watershed, VISL = Vancouver Island].

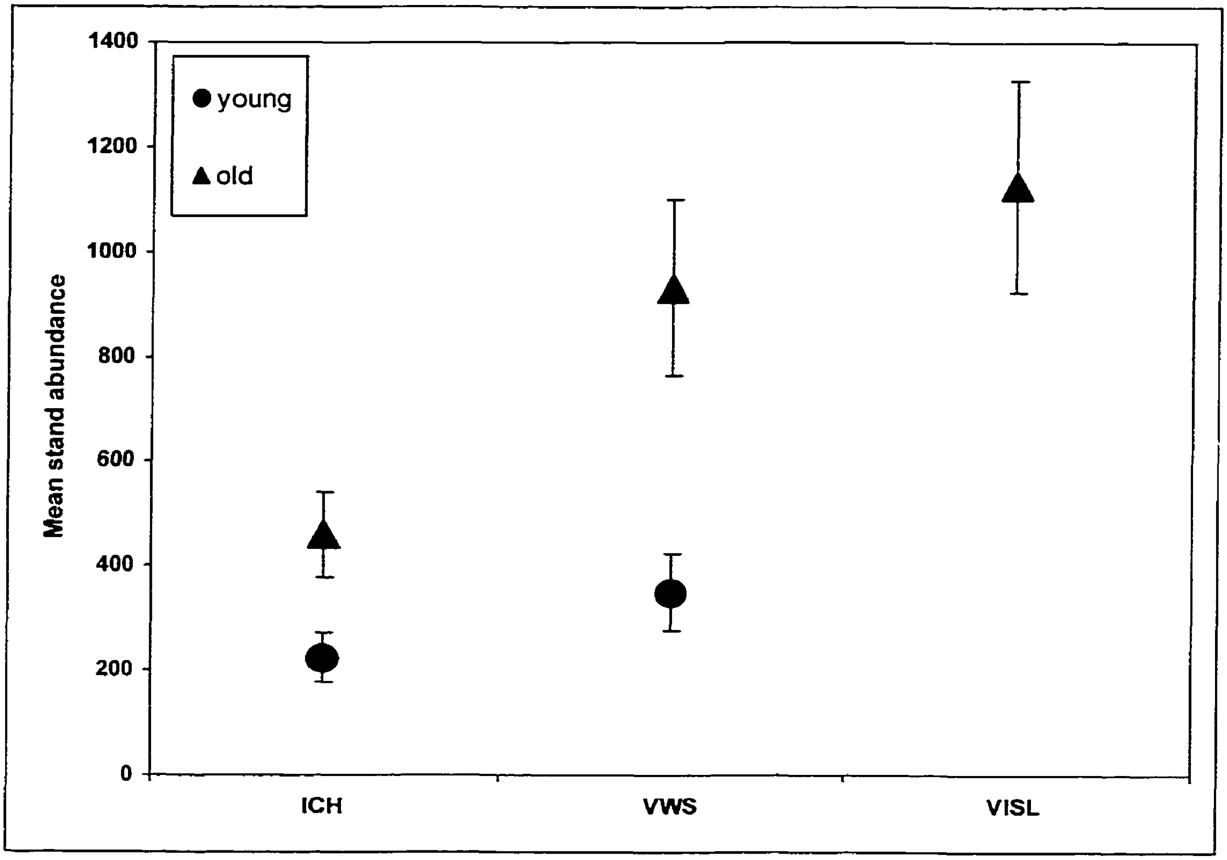


Figure 3-5. CCA ordination of 103 stands in the ICH using 22 environmental variables. The abbreviations for each variable are listed in Table 4. (#MH = no. of different mesohabitats)

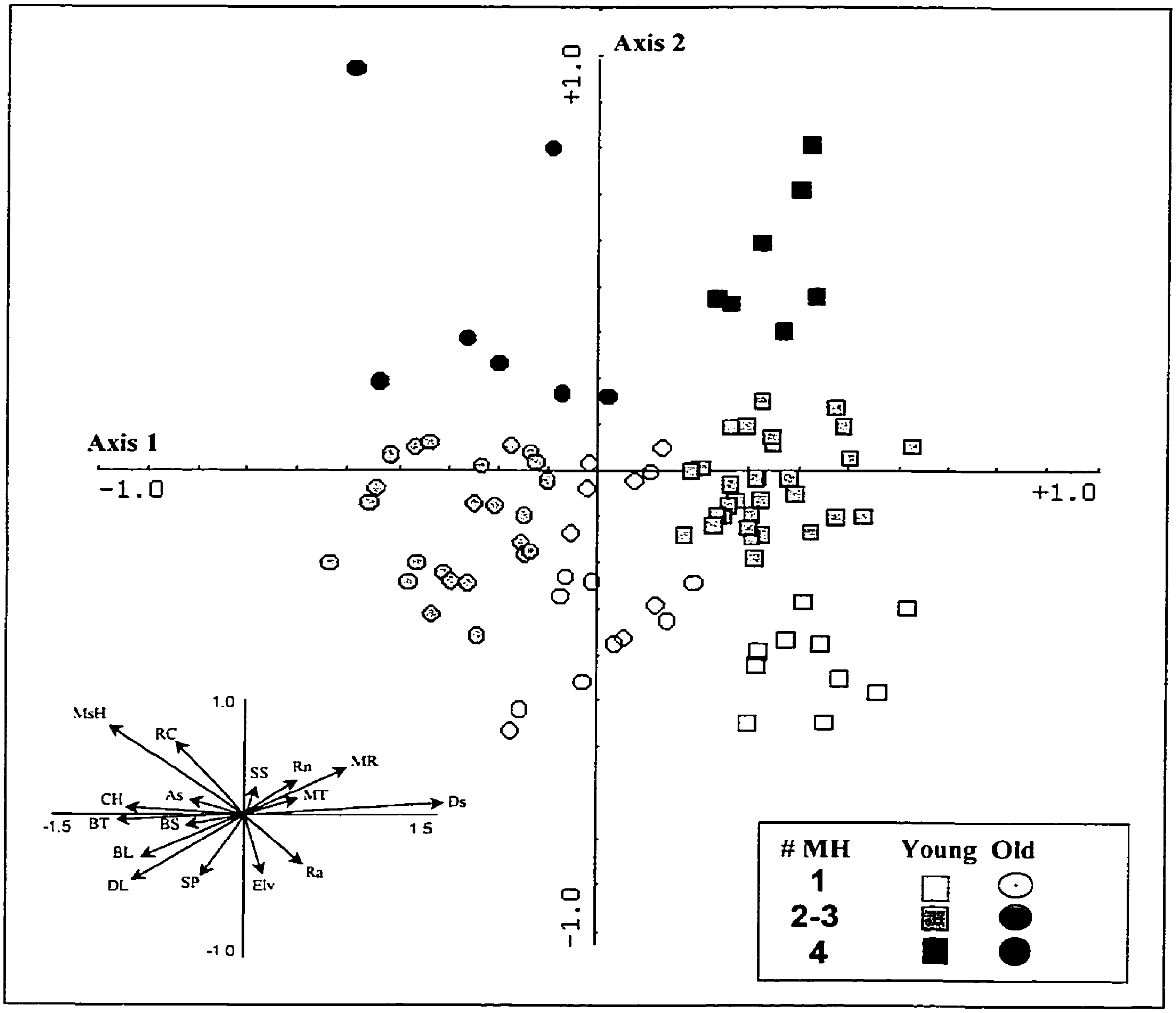


Figure 3-6. CCA ordination of 185 stands in the CWH using 22 environmental variables. The abbreviations for each variable are listed in Table 5. (#MH = no. of different mesohabitats)

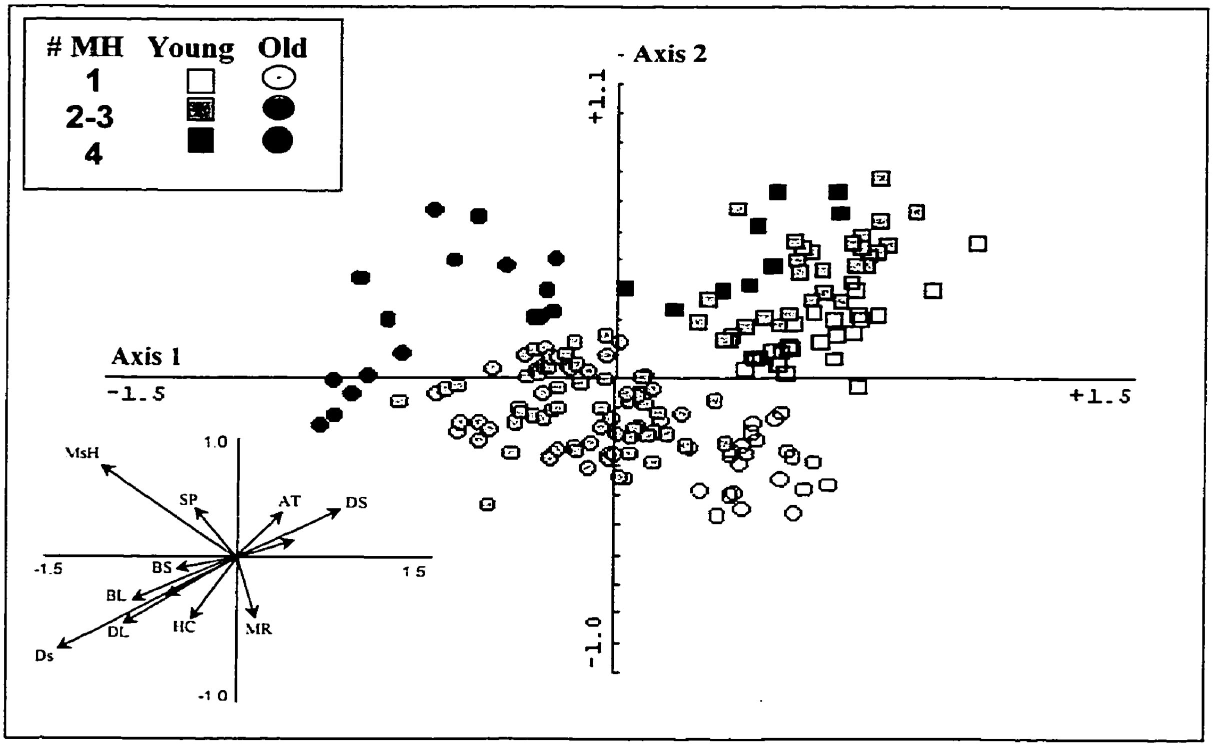


Figure 3-7. Species frequency curves for stand cluster groups defined by K-means and SAHN within the ICH or CWH.

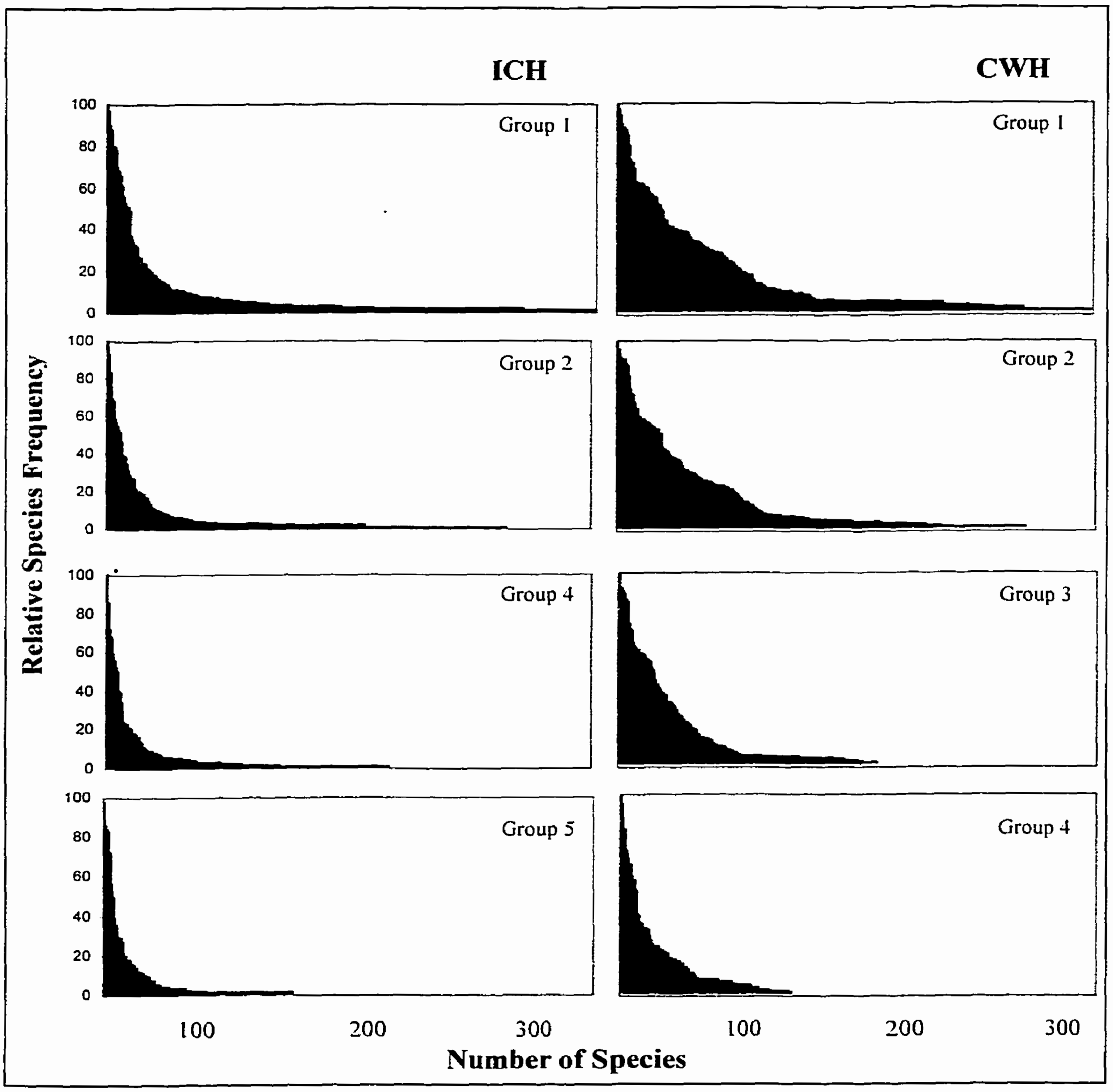


Figure 3-8. Overlay of stand clusters from K-means/SAHN on the CCA ordination of 102 stands in the ICH using 22 environmental variables. The abbreviations for each variable are listed in Table 4.

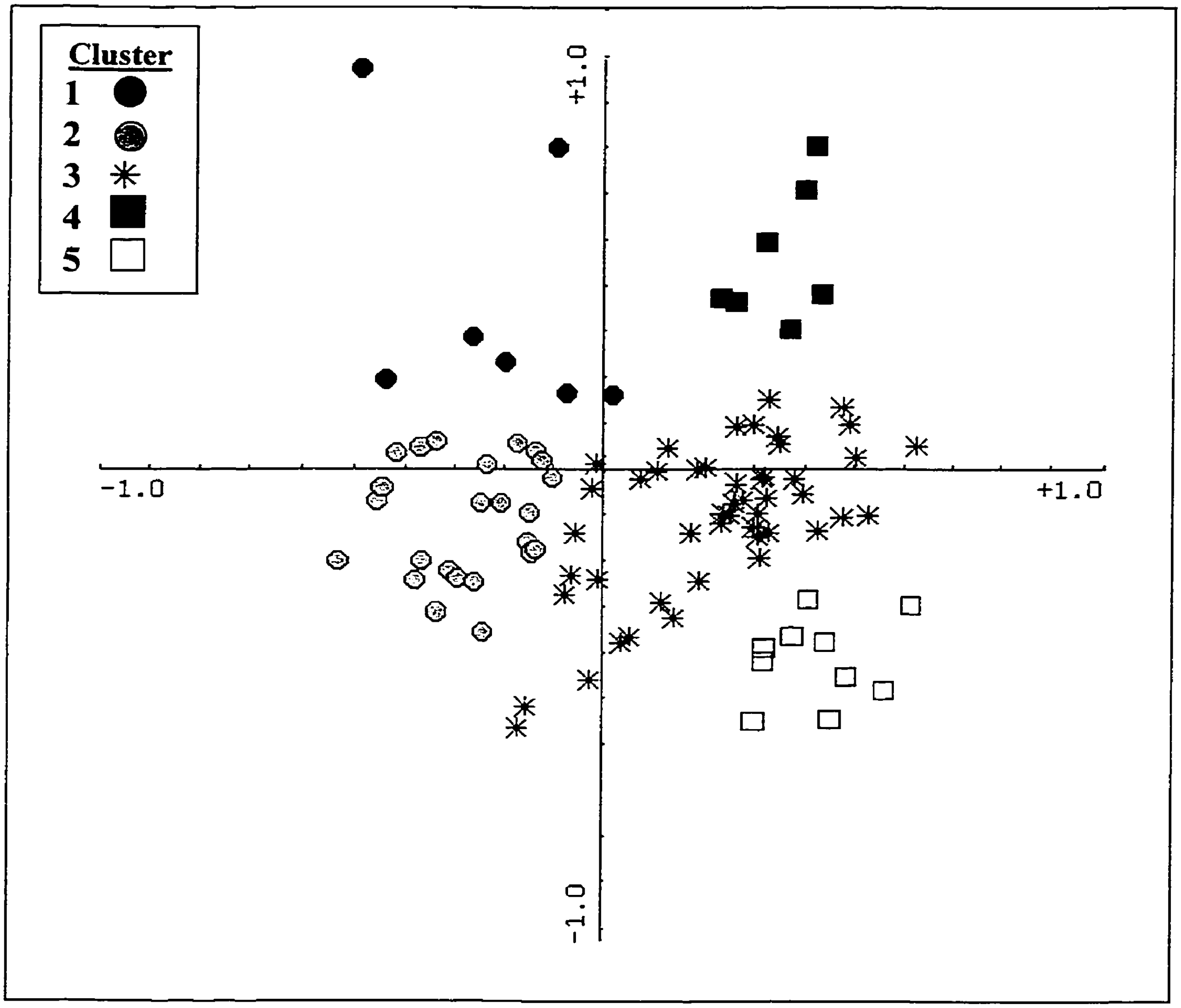


Figure 3-9. Overlay of stand clusters from K-means/SAHN on the CCA ordination of 185 stands in the CWH using 22 environmental variables. The abbreviations for each variable are listed in Table 5.

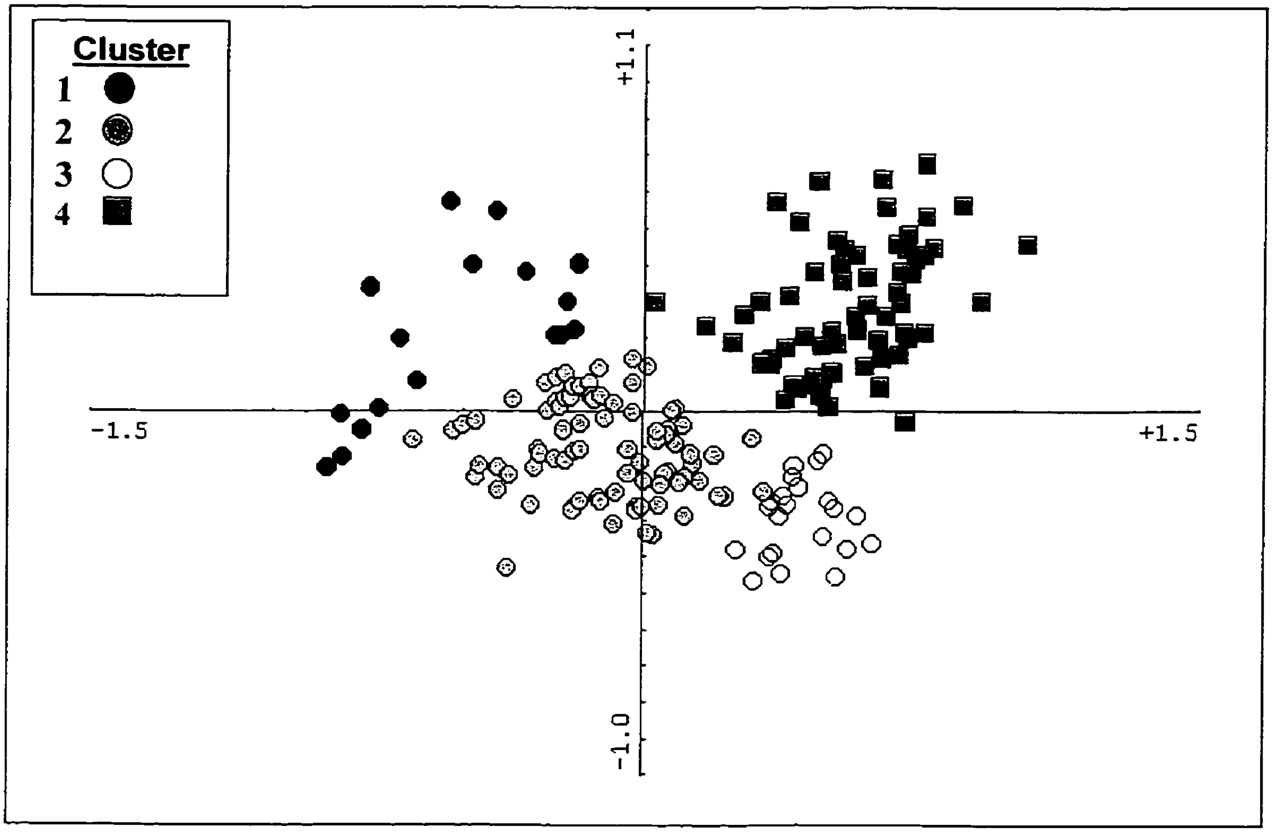


Figure 3-10. Species turnover across stand cluster groups defined by K-means and SAHN within the ICH or CWH (sample scores represent relative position of group along the environmental gradient).

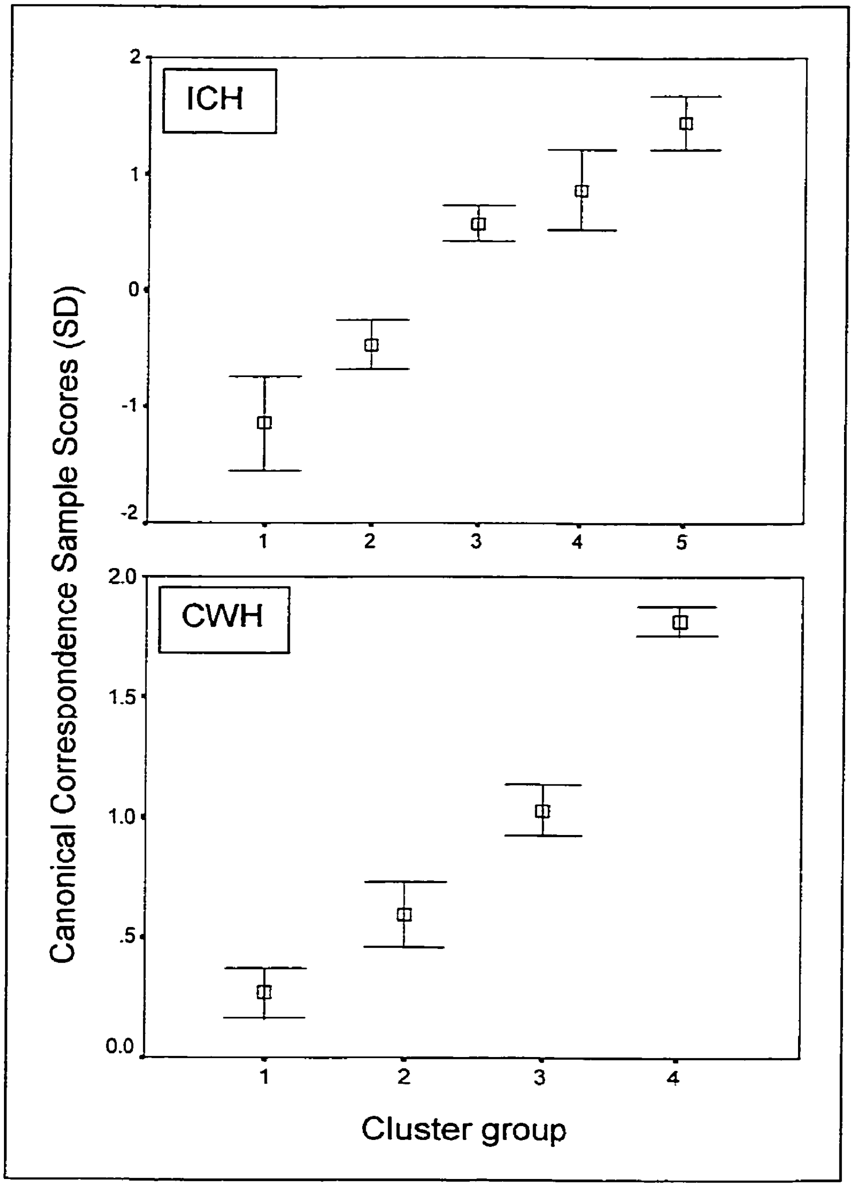


Figure 3-11. Conceptual model of Bryophyte diversity at the regional (stand) scale (AGE = number of years since last large scale disturbance; HABITAT HETEROGENEITY = diversity and abundance of meso/microhabitats).

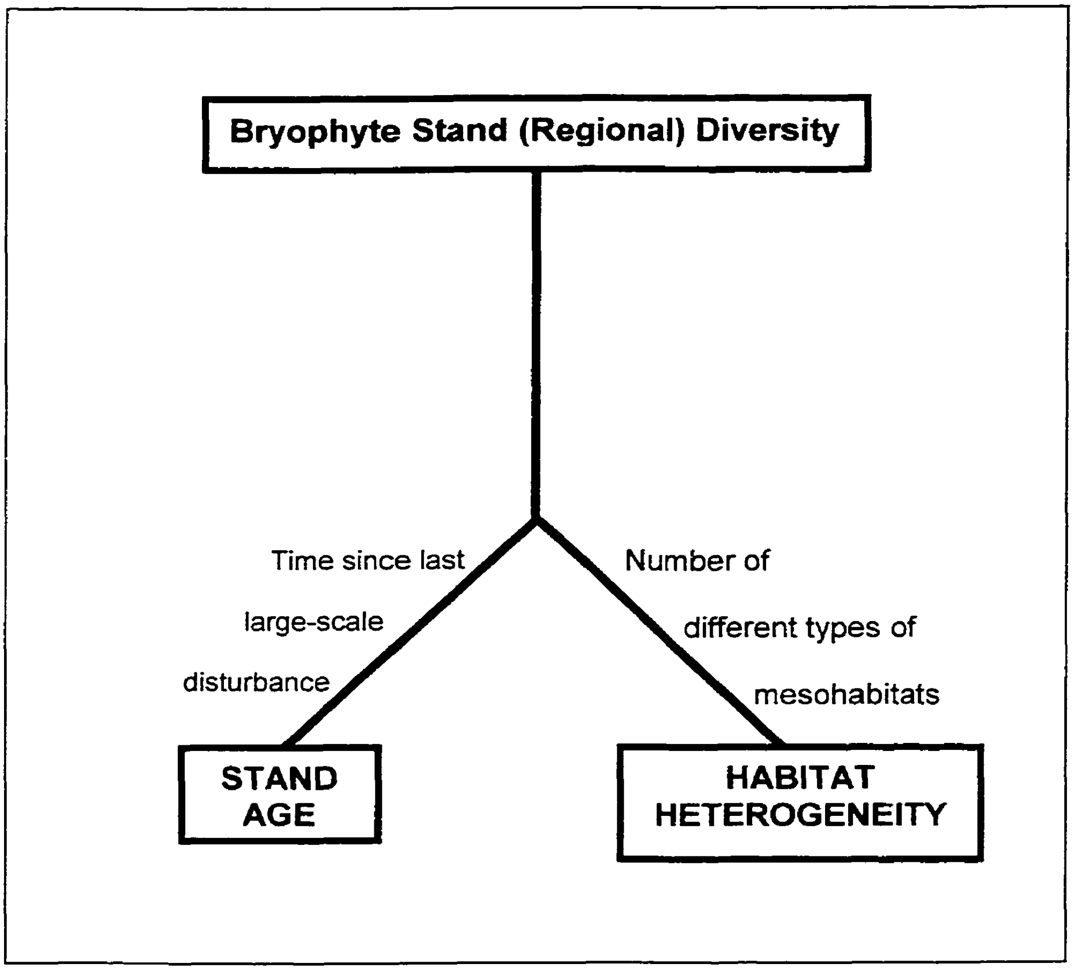
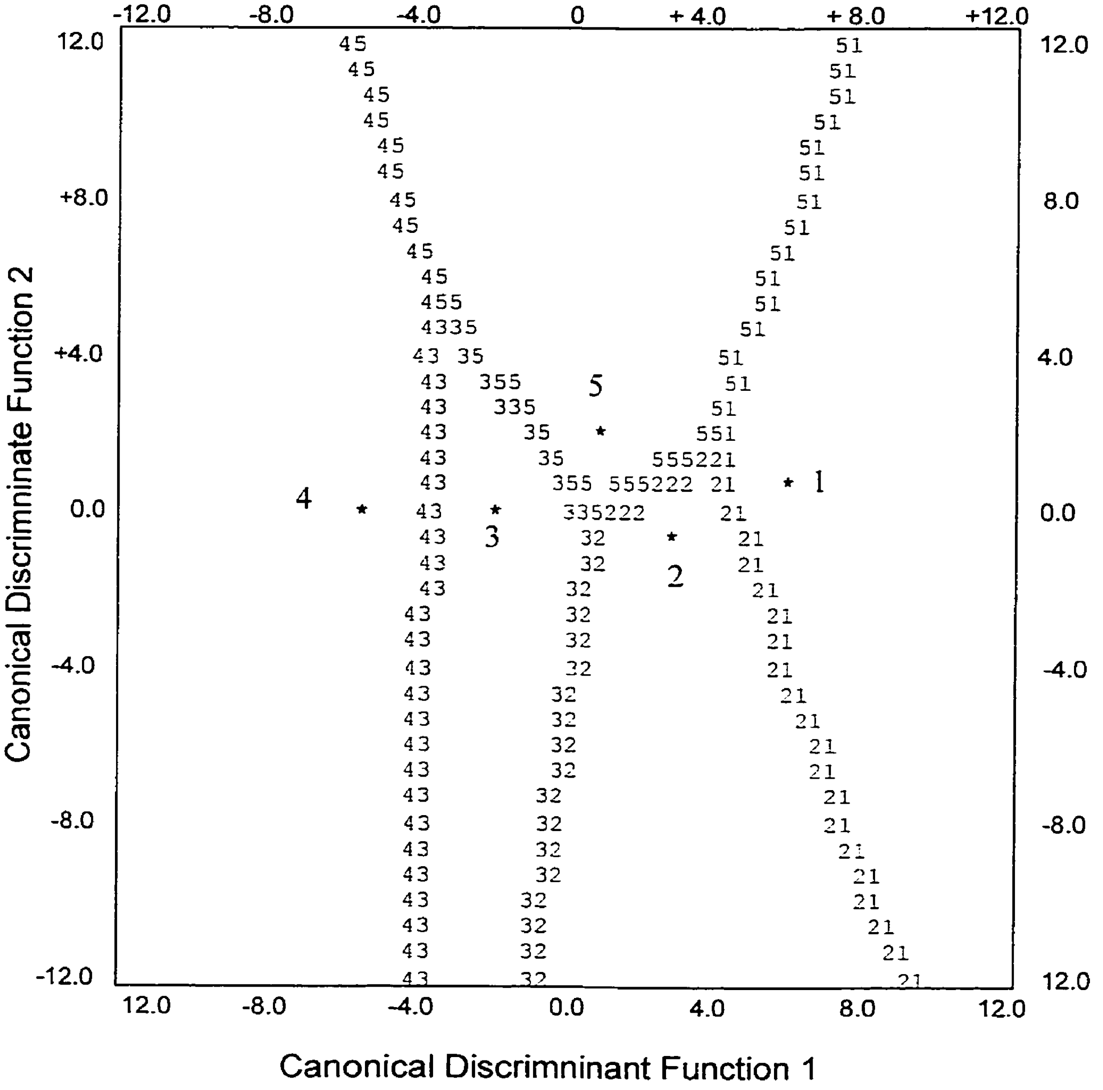


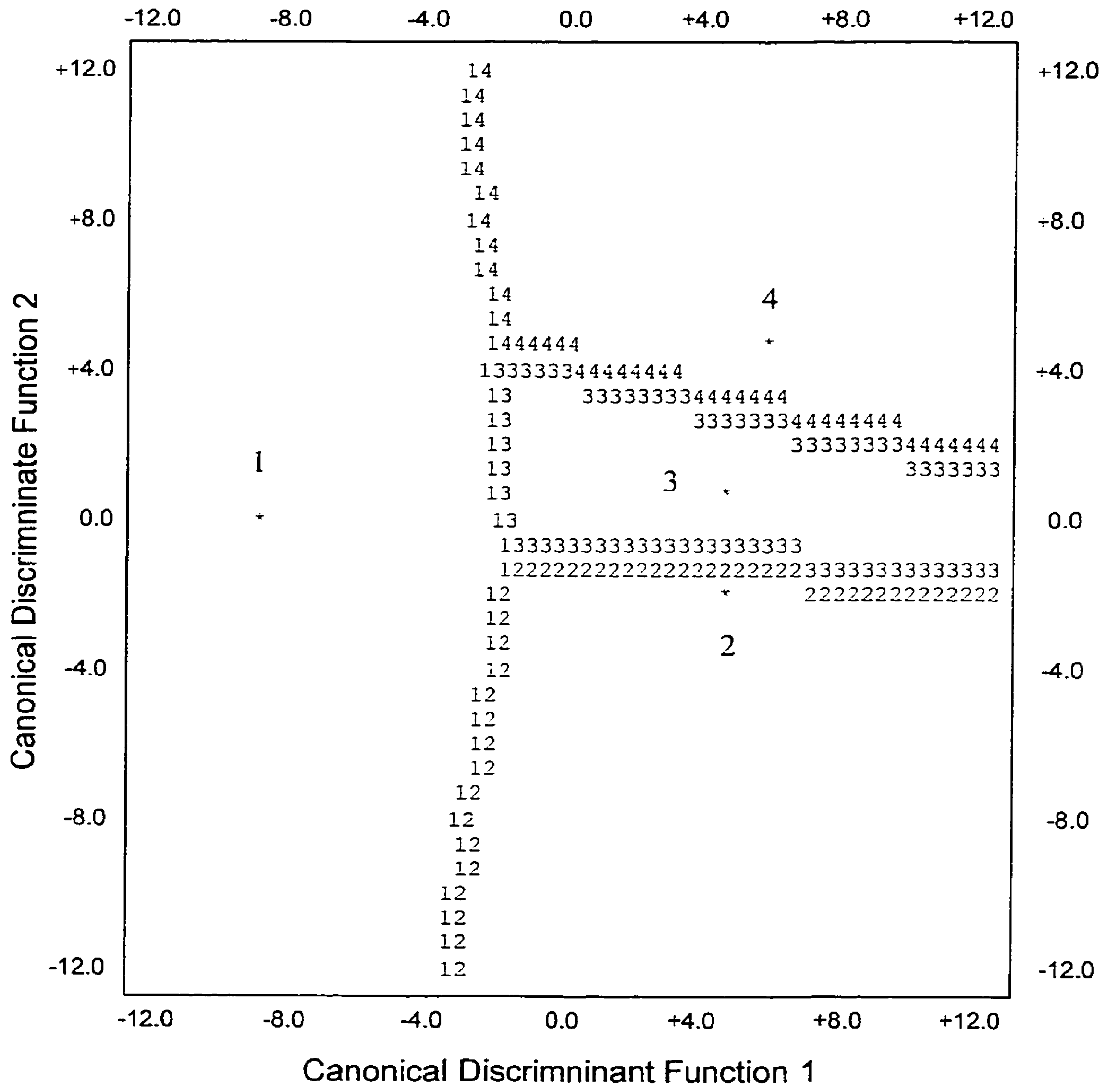
Figure 3-12. Territorial map displaying the relationship between ICH stand groups 1-5 and the first two discriminant functions. Functions can be used to predict group membership on map and therefore bryophyte diversity in table 3-6 (* indicates a group centroid).



Discriminant function 1 = 0.965 Age + 2.512 MsH + 0.559 Hyg – 14.290 (eqn. 1)

Discriminant function 2 = - 0.398 Age + 0.896 MsH + 0.071 Hyg + 0.153 (eqn. 2)

Figure 3-13. Territorial map displaying the relationship between CWH stand groups 1-4 and the first two discriminant functions. Functions can be used to predict group membership on map and therefore bryophyte diversity in table 3-6 (* indicates a group centroid).



Discriminant function 1 = 2.655 Age + .205 MsH + .000 BCWD – 19.765 (eqn. 4)

Discriminant function 2 = -0.094 Age + 1.795 MsH + .002 BCWD – 3.080 (eqn. 5)

LITERATURE CITED

Alaback, P. & J. Pojar. 1997. Vegetation from ridgetop to seashore. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Agee, J.K. 1993. Fire ecology of Pacific Northwest Forests. Island Press, Washington, D.C.

Anderson, L.E., Crum, H.A. & W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93: 448-499.

Andersson, L.I. 1987. Förekomsten av mossarter pävedsubstrat på vedsubstrat och tillgång på förmultnade ved I naturskog (Fiby urskog) och kulturskog. Medd Växtbiology 2: 1-54.

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Anonymous, 1982. Canadian climate normals, 1951-1980. Vols 1-4. Environment Canada, Atmospheric Environment service, Ottawa, Ontario.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. University of British Columbia, Department of Botany, Vancouver, B.C. Ph.D. Thesis.

Arseneault, D & S. Payette. 1992. A postfire shift from lichen-spruce to lichen-tundra vegetation at the tree line. Ecology73: 1067-1081.

Auclair, A.N.D. 1983. The role of fire in lichen-dominated tundra and forest-tundra. Pp. 235-256. In Wein, R.W. & D. MacLean (eds.), The role of fire in circumboreal ecosystems. J. Wiley & Sons, New York.

Aune, E.I. 1994. Kystgranskog. Pp. 1-9 in Fylkesmannen I Sør-Trøndelag (ed.), Kystgranskogen I midt-Norge.

Bell, F.W., and Newmaster, S.G. 1998. Fallingsnow Ecosystem Project: Floral richness, abundance and diversity. Pp. 45-47 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (comps.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Belland, R.J. 1995. The bryophytes of Prince Edward Island National Park, Canada: Affinities, habitats, and diversity. Fragmenta Floristica et Geobotanica 40: 349-364.

Belland, R.J. & G.R. Brassard. 1988. The bryophytes of Gros Morne National Park, Newfoundland Canada: Ecology and phytogeography. Lindbergia 14: 97-118.

Belland, R.J. & W.B. Schofield. 1994. The ecology and phytogeography of the bryophytes of Cape Breton Highlands Park, Canada. Nova Hedwigia 59: 275-309.

Belland, R.J. & D.H. Vitt. 1995. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

Belland, R.J. 1998. The rare mosses of Canada. Committee on the status of endangered wildlife in Canada, Canadian Wildlife Service, Environment Canada, Ottawa.

Benzing, D.H. 1981. Bark surfaces and the origin and maintenance of diversity among angiosperms epiphytes: a hypothesis. Selbyana 5: 248-255.

Brassard, G.R. 1983. Bryogeography, with special reference to mosses. pp. 361-384. In South, G.R. (ed.), Biogeography and Ecology of the Island of Newfoundland. The Hague, The Netherlands

Brumelis, G, & T.J. Carleton. 1988. The vegetation of postlogged black spruce lowlands in central Canada. I. Trees and tall shrubs. Canadian Journal of Forest Resources 18: 1470-1478.

Brumelis, G, & T.J. Carleton. 1989. The vegetation of post-logged black spruce lowlands in central Canada. II. Understory vegetation. Journal of Applied Forestry 26: 321-339.

Bunnel, F.L. & A.C., Chan-McLeod. 1997. Teerrestrial vertebrates. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Cadrin, C., E. Campbell & A. Nicholson. 1991. A bibliography on old-growth forests in British Columbia with annotations and abstracts. B.C. Ministry of Forests.

Carleton, T.J. 1990. Variation in terricolous bryophytes and macrolichen vegetation along primary gradients in Canadian boreal forest. Journal of Vegetation Science 3:585-594.

Clément, B. 1990. Plant strategies and secondary succession on Brittany heathlands after severe fire. Journal of Vegetation Science 1: 195-202.

Clifford, H.T. & W. Stephenson. 1975. An Introduction to Numerical classification. Academic Press, London, UK.

Connell, J.H. & R.O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. American Naturalist 111:1119-1144.

Crites, S & M.R.T. Dale. 1995. Relations between nonvascular species and stand age and stand structure in aspen mixedwood forest in Alberta. pp. 91-112. In Stelfox, J.B. (ed.), Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forest in Alberta. Alberta Environment Centre, Alberta.

Damman, A.W.H. 1975. Plant distribution in Newfoundland especially in relation to summer temperatures measured with the sucrose inversion method. Canadian Journal of Botany 54: 1561-1585.

De-Las-Heras, J., Guerra, J. & J.M. Herranz. 1995 Bryophyte succession after fire in Mediterranean ecosystems. Differences between N and S exposures, 3-5 years after fire (SE spain). Arcta-Oecol 16: 159-169.

During, H.J. & B. ter Horst. 1987. Diversity and dynamics in bryophyte communities on earth banks in a Dutch forest. Symposia Biologica Hungarica 35: 447-455.

During, H.J. & B. ter Horst. 1983. The diaspore bank of bryophytes and ferns in chalk grasslands. Lindbergia 9: 57-64.

Edwards, M.E. 1986. Disturbance histories of four Snowdonian woodlands and their relation to Atlantic bryophyte distributions. Biological conservation 37: 301-320.

Ehrlich, P.R. 1990. Habitats in crisis: why we should care about the loss of species. Forest Management and Ecology 35: 5-11.

Fanta, J. 1995. Ecology of biodiversity in forest. Caring for the forest: research in a changing world. IUFRO XX World Congress. Tampere, Finland.

Frego, K.A. & T.J. Carleton. 1995a. Microsite conditions and spatial pattern in a boreal bryophyte community. Canadian Journal of Botany 73: 544-551.

Frego, K.A. & T.J. Carleton. 1995b. Microsite tolerance of four bryophytes in a mature black spruce stand: Reciprocal transplants. The Bryologist 98: 452-458.

Garty, J. & N. Binyamini. 1990. Establishment of pioneer litho-microorganisms on chalk rocks after a severe forest fire in Israel. Environmental and Experimental Botany 30: 127-139.

Gignac, D.L. & D.H. Vitt. 1994. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Goward, T. 1994a. Living Antiquities. Nature Canada 21: 14-21.

Goward, T. & T. Ahti. 1992. Macrolichens and their zonal distribution in Wells Gray Provincial Park and its vicinity, British Columbia, Canada. Acta Botanica Fennica 147: 1-60.

Goward, T. 1993. Epiphytic lichens: going down with the trees. pp. 153-158. In Rautio, S. (ed.), Community action for endangered species: a public symposium on B.C.'s threatened and endangered species and their habitat. Federation of British Columbia Naturalists, Vancover, British Columbia.

Goward, T. 1994b. Notes on old-growth dependent epiphytic macrolichens in inland British Columbia, Canada. Acta Botanica Fennica 150: 31-38.

Goward, T. & Arsenault, A. 2000. Cyanolichen distribution in young unmanaged forests: a dripzone effect? The Bryologists 103: 28-37.

Gustafsson, L. & T. Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological Conservation 44: 283-300.

Gustafsson, L., A. Fiskesjö, T.Hallingbäck & T. Ingelög. 1992. Semi-natural deciduous broadleaved woods in southern Sweden - habitat factors of importance to some bryophyte species. Biological conservation 59: 175-181.

Hallingbäck, T. 1977. Översiktlig inventering av naturskogar I Värmlands län med kryptogamfloran som utgångspunkt. – Naturvårdsenheten, Länsstyrelsen I Värmlands län, (in Sweedish).

Hämet-Ahti, L. 1983. Human impacts on closed boreal forest. Pp. 201-211. in *Man's Impact on Vegetation* (eds.), W. Holzner, M.J.A. Werger & I. Ikusima. Wunk, The Hague.

Harris, L.D. 1984. The fragmented forest: Island biogeography theory and the preservation of biotic diversity. University of Chicago Press, Chicago, Ill.

Hebda, R.J. 1994. The future of Britis Columbia's flora. In, L.E. Harding and E. McCullum, (eds.), *Biodiversity in British Columbia: our changing environment.* Vancouver, Canadian Wildlife Service.

Hebda, R.J. 1995. British Columbia vegetation and climatic history with focus on 6 KA BP. Géographie physique et Quaternaire 49: 55-79.

Hebda, R.J. 1997. Impact of climate change on biogeoclimatic zones of British Columbia and Yukon, in E. Taylor and B. Taylor (eds.), "Future climate change in British Columbia and Yukon". Environment Canada and Ministry of the Environment, Lands and Parks, Province of British Columbia, Victoria, B.C.

Hebda, R.J. 1998. Atmospheric change, forests and biodiversity. Environmental monitoring and assessment 49: 195-212.

Hebda, R.J. & C. Whitlock. 1997. Environmental history. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Heras-Iba ez, J. de las, J. Guerra & J.M. Herranz. 1991. Changes in floristic diversity and fugacity of bryophytes in burnt sites of SE Spain. Lindbergia 17: 11-17.

Herben, T. 1994. Local rate of spreading and patch dynamics of an invasive moss species, Orthodontium lineare. Journal of Bryology 18: 115-125.

Hill, M.O. & H.G. Gauch. 1980. Detrended correspondence analysis, an improved ordination technique. Vegetatio 42: 47-58.

Johnston, M.H. & J.A. Elliot. 1996. Impacts of logging and wildfire on an upland black spruce community in northwestern Ontario. Environmental Monitoring and Assessment 39: 283-297.

Jonsson, B.G & P.A. Esseen. 1990. Treefall disturbance Maintains high bryophyte diversity in a boreal spruce forest. Journal of Ecology 78: 924-936.

Kershaw, K.A. 1976. Studies on lichen-dominated systems. An examination of some aspects of the northern boreal lichen woodlands in Canada. Canadian Journal of Botany 55: 393-410.

Kershaw, K.A. 1985. Physiological ecology of lichens. Cambridge University Press, London.

Krebs, C.J. 1985. Ecology. Harper & Row, New York.

Krebs, C.J. 1997. Ecological Methodology. Harper Collins, New York.

Laaka, S. 1992. The threatened epixylic bryophytes in old primeval forest in Finland. Biological Conservation 59: 151-154.

Larsen, J.A. 1980. The boreal ecosystem. Academic Press, New York.

Lertzman, K.P., T. Spies & F.Swanson. 1997. From ecosysytem dynamics to ecosystem management. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

Lindholm, T. & H. Vasander. 1987. Vegetation and stand development of mesic forest after prescribed burning. Silva Fennica 21: 259-278.

MacArthur, R.H. 1965. Patterns of species diversity. Biological review 40: 510-533.

Mackenzie, Ian. 1995. Ancient landscapes of British Columbia. Lone Pine Press, Edmonton Alberta.

MacKinnon A, & M. Eng. 1995. Old forest: inventory for coastal British Columbia. Cordillera 45: 20-33.

Magurran, A.E. Ecological diversity and its measurement. Princeton University Press, New Jersey.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6.

Montgomery, D.R. 1997. The influence of geological processes on ecological systems. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Muotka, T. & R. Virtanen. 1995. Stream as a habitat templet for brophytes: species distribution along gradients in disturbance and substratum heterogeneity. Freshwater Biology 33:141-160.

Newmaster, S.G., Lehela, A., Oldham, M.J., Uhlig, P.W.C., andMcMuray, S. 1998. Ontario Plant List. Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Forest Research Information Paper No. 123. 650 pp. + appendices.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research (accepted April 1999).

Newmaster, S.G. & F.W. Bell. 2000. Floristic diversity of cryptograms in a boreal-mixedwood stand after mechanical, manual and herbicide conifer release treatments. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Subiitted to CJFR.

Økland, R.H., T. Økland & O. Eilertsen. 1990. On the relationship between sample plot size and beta diversity in boreal coniferous forest. Vegetatio 87: 187-192.

Oksanen, J. 1983. Diversity patterns along climatic gradients in the understorey of lichen- rich pine forest in Finland. Annales Botanica Fennicci 20: 151-155.

Peet, R.K., D.C. Glenn-Levin & J.W. Wolf. 1983. Prediction of man's impact on plant species diversity. A challenge for vegetation science. Pp. 41-54 in *Man's Impact on Vegetation*, W. Holzner, M.J.A. Werger & I. Ikusima. Wunk, The Hague.

Pielou, E.C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. Journal of Theoretical Biology 10: 370-383.

Pike, L.E., W.C. Denison, D.M. Tracey, M. A. Sherwood and F. M. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing in old-growth conifers in western Oregon. The Bryologist 78: 1-39.

Presto, T. 1996. Monitoring of bryophytes in boreal rain forests: Effects of forestry. in Söderström, L. & T. Prestø (eds.), *State of Nordic Bryology Today and Towmorrow. Abstracts and shorter communications from a proceedings in Trondheim December 1995.* Raport Botanisk serie 1996-4, Trondheim Universitet, Norway.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Ritchie, J.C. 1976. The late quaternary vegetational history of the western interior of Canada. Cambridge University Press, New York.

Rose, F. 1992. Temperate forest management: Its effects on bryophyte and lichen floras and habitats. In Bates, J.W. & A.M. Farmer (eds.), *Bryophytes and lichens in a changing environment*, Clarendon Press, Oxford, pp. 211-232.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Schoonmaker, P.K., B. von Hagen & E.C. Wolf. 1997. The rain forests of home. Island Press, Washington, DC.

Schuster, R. 1949. The ecology and distribution of Hepaticae in central and western New York. American Midland Naturalist. 42:513-712.

Sermander, R. 1936. Granskär och Fiby urskog. En studie över stormluckornas och marbuskarnas betvdelse I den svenska granskogens regeneration. (the primitive forest of Granskär and Fiby). Acta Phytogeography, Suec 8. Almqvist and Wiksell, Uppsala.

Sillett, S.C. 1995. Branch epiphyte assemblages in the forest interior and on the clear-cut edge of a 700-year-old Douglas Fir canopy in western Oregon. The Byrologist 98: 301-312.

Slack, N.G. 1977. Species diversity and community structure in bryophytes: New York State Studies. Bulletin N.Y. State Museum 428: 1-70.

Slack, N.G. & J.M. Glime. 1985. Niche relationships of mountain stream bryophytes. The Bryologist 88: 7-18.

Slack, N.G. 1992. Rare and endangered bryophytes in New York state and eastern United States: Current status and preservation strategies. Biological Conservation 59: 233-241.

Ramsey, F.L. & D.W. Schafer. 1997. The statistical sleuth. Duxbury Press, London, England.

Söderström, L. 1988a. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8: 89-97.

Söderström, L. 1988b. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1995. Bryophyte conservation - Input from population ecology and metapopulation dynamics. Cryptog. Helv. 18: 17-24.

Söderström, L., T.Hallingbäck, L. Gustafsson, N. Cronberg & L. Hedenős. 1992. Bryophyte conservation for the future. Biological Conservation 59: 265-270.

Söderström, L. T. 1993. Substrate preference in some forest bryophytes: a quantitative study. Lindbergia 18: 98-103.

SPSS. 1999. Professional base system software for statistical analysis. Chicago, Illinois.

Steere, W.C. 1978. The Mosses of the arctic Alaska. Bryophyt. Biblioth. 14: I-x, 1-508. J. Cramer, Vaduz.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

Tilman, D. 1996. Biodiversity: Population versus ecosystem stability. Ecology 77: 350-363.

ter Braak, C.J.F. 1986 Canonical Correspondance analysis: A new eigenvector method for multivariate direct gradient analysis. Ecology, 67: 1167-1179.

ter Braak, C.J.F. 1998. CANOCO 4. Centre for Biometry, Wageningen, The Netherlands.

Vitt, D.H. 1991. Distribution patterns, adaptive strategies, and morphological changes of mosses along elevational and latitudinal gradients on South Pacific Islands, Pp. 205-236. in P.L. Nimis and T.J. Crovello (ed.), Quantitative Approaches to Phytogeography. Kluwer Academic Publishers,The Netherlands.

Vitt, D.H. & R.J. Belland. 1995a. The bryophytes of peatlands in continental western Canada. Fragmenta Floristica et Geobotanica 40: 339-348.

Vitt, D.H., Y. Li & R.J. Belland. 1995b. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1- 12.

Wallace, A. R. 1878. Tropical nature and other essays. MacMillan Co. London, UK.

Walter, H. & H. Leith. 1967. Klimadiagram Wetatlas. Fischer, Jena, GDR.

Weibull, H & L. Söderström. 1995. Red data listed hepatics of scandinavia in a regional and world-wide perspective - A preliminary study. Cryptog Helv. 18: 57-66.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30: 279-338.

Whittaker, R.H. 1965. Dominance and diversity in land plant communities Science 147: 250-260.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Whittaker. R.H. 1977. Evolution of species diversity in land communities. Pp. 1-67 in M.K. Hecht, W.C. Steere and B. Wallace (ed.), Evolutionary Biology, Vol. 10. Plenum, New York.

Zackrisson, O. 1977. Influence of forest fires on the northern Sweden boreal forest. Oikos 29: 22-32.

Chapter 4.

Mesohabitat Quality and Quantity: Basic Ingredients for Bryophyte Diversity.

INTRODUCTION

The understanding of ecosystem dynamics and patterns that maintained biological diversity in the past are our best model for doing so in the future (Lertzman et al. 1996). "Ecosystem-based management" is becoming part of the mandate of forest managers in both the U.S. and Canada (FEMAT 1993, USDA & USDI 1994). Currently the focus is on using natural disturbance patterns as models for management in temperate forests. However, understanding the processes shaping forests and maintaining their biodiversity is fundamental to successful ecosystem management (Franklin & Spies 1991). It is well known that old growth forests are richer and more abundant with bryophytes than young forests (Pike et al. 1975; Söderström 1988; Lesica et al. 1991; Rambo 1998a; Newmaster thesis chapter 3). Understanding the patterns of diversity in old-growth forests will allow better management decisions that conserve old-growth dynamics in young forests.

Adopting a conservation strategy that preserves habitats to maintain biological diversity is preferable to "species-focused conservation" (Franklin 1993). There are four key problems with the species based approach: 1) species cannot be maintained in situ without their habitat or the ecosystem that provides it, 2) species-specific plans are too expensive, time-consuming, and labor intensive to implement for more than a very small fraction of the species known to inhabit forests, 3) the vast majority of species have not had their ecological relationships investigated in detail, 4) because many species have conflicting needs, a management regime designed for one species is likely to have negative impacts on others (Lertzman et al. 1997). The "biodiversity guide book of British Columbia Forest Practices Code" (BC Ministry of Forests 1995) clearly states that the only feasible approach to conserve biological diversity is to place more emphasis on species habitats. To achieve this goal, we must improve our knowledge of which habitats are associated with high diversity. Those habitats that are important to maintaining high diversity can then be preserved or fostered in ecosystem management plans.

Bryophytes are closely associated with their habitats and these habitats can be defined as landscape units. They are excellent indicators of their environment and have long been used as indicators of physiochemical (Gignac et al. 1991; Newmaster et al. 1999) and environmental conditions (Crum 1983; Slack 1988; Marino & Salazar 1991; McAlister 1995; Nicholson & Gignac 1995; Virtanen 1995). On the landscape, the presence of microhabitats (e.g., logs and rocks) is largely related to the presence of larger localized physiographic features (i.e., streams, seeps, cliffs) or physiognomic (i.e., forests) features called mesohabitats (Vitt & Belland 1997). Mesohabitats are distributed on the landscape as either restricted (e.g., streams, cliffs) or dominant (e.g., forests) mesohabitats. Therefore, the regional landscape is a mosaic of dominant mesohabitats in which restricted mesohabitats exist.

Patterns of bryophyte diversity at the regional landscape scale is largely dependent on mesohabitat quantity and quality (Vitt et al. 1995; Belland & Vitt 1995; Vitt and Belland 1997). Mesohabitat quantity is the type and distribution of all mesohabitats and the number of particular mesohabitats. The quality of an indivual mesohabitat is expressed by the number and type of microhabitats they contain. Vitt and Belland (1997) showed that for regional landscapes rare bryophyte species occurrence and diversity is a function of both mesohabitat quality and quantity, and that restricted mesohabitats are most influential for the maintenance of rare species diversity. Patterning of bryophyte diversity in cedar-hemlock forests within British Columbia is largely dependent on the number of different types of mesohabitats (Newmaster thesis chapter 3). Cedar-hemlock stands with a greater variety of mesohabitats have higher bryophyte diversity. Vitt and Belland (1997) suggested that the environmental quality of each mesohabitat to bryophyte diversity is determined largely by the number of microhabitats. At the local scale it would be advantageous to understand the influence of microhabitats on mesohabitat bryophyte diversity. This would allow an understanding of the patterning of bryophyte diversity within a hierarchy of habitats on the landscape.

The ancient cedar-hemlock forests of British Columbia serve as examples of late-successional forests, an ecological "benchmark" for understanding species-habitat relationships and the processes and patterns that maintain high bryophyte diversity (Goward 1993, 1994a, 1994b). Bryophyte "indicator species" for different age classes and biogeoclimatic zones in B.C.'s cedar-hemlock forest have been recently identified (Newmaster thesis chapter 2). Understanding the habitat requirements of these species is a key element of ecosystem management. Furthermore, understanding the habitat requirements that support rich bryophyte diversity in old-growth forest will support the management of ecological integrity. The purpose of this study is to investigate the patterns of bryophyte diversity in cedar-hemlock forest mesohabitats. Specifically, the objectives of this study are to determine 1) what are the dominant environmental gradients affect the patterning of bryophyte diversity at the local landscape scale (mesohabitat scale), 2) how bryophyte diversity is distributed across the different mesohabitat types within similar large scale disturbances, and biogeoclimatic zones, 3) how communities of species are associated with one another in a given mesohabitat, 4) the mesohabitat requirements of old-growth indicator species within the interior cedar-hemlock (ICH) or coastal western hemlock (CWH), 5) what environmental factors influence bryophyte diversity within specific types of mesohabitats.

STUDY AREA

Sampling was conducted in British Columbia, Canada, within two distinct biogeoclimatic zones; the Coastal Western Hemlock zone (CWH) and Interior Cedar Hemlock zone (ICH - Meidinger and Pojar 1991). The CWH is located on the westerly edge of the Coast Mountains and is also known as Canada's coastal temperate rainforest (Fig. 4-1). The ICH is located in the Caribou Mountains in B.C.'s interior and on the interior side of the Coast Mountains in Northern B.C. (Fig. 4-1). The wetter portions of the ICH (wk1 & vk1 variants) are known as inland oroboreal rainforests (Goward & Ahti 1992). Detailed descriptions of glacial history, climate and floristics can be found in Schofield (1988), Arsenault (1995), Hebda (1995) and Schoonmaker et al. (1997).

The ICH is divided into two geographically distinct areas. The smaller, most northerly area is located between 55° N and 57° N on the leeward slopes and adjacent lowlands of the Coast Mountains. The larger, more southerly area occupies a 200 km wide band from the Canada-U.S.A. border (at 49° N) to northern Caribou Mountains (approximately 54 ° N) (Goward 1995). The study area was located at 50-53° N and 199-120° W, within the Wells Gray (including Azure Lake and Mad River), upper Adams and upper Seymour watersheds of the ICH biogeoclimatic Zone. This sampling area represents the ICHmw3, ICHwk1 and ICHvk1 biogeoclimatic variants (Meidinger & Pojar 1991). Precipitation ranges from 900-1400 mm per year, with the highest precipitation in early winter. Snow pack over 1.5 meters deep is typical for much of the area. Mean temperatures during the warmest month averages between 16 °C and 21 °C, and during the coldest month from -3 °C to -10 °C. The ICH is the most productive zone in the interior and has the widest variety of coniferous tree species of any zone in B.C. Western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) are the dominant trees. The wettest sites are dominated by an under story of skunk cabbage (*Lysichiton americanum*) and devils club (*Oplopanax horridus*).

Within the CWH, research was focused on two geographically distinct areas: the mainland coast and the west woast of Vancouver Island. On the mainland coast sampling was conducted in the Capilano and Seymour watersheds of the greater Vancouver watershed. On the west coast of Vancouver Island, sampling was conducted in the Tofino, Clayoquot, Sidney and Walbran watersheds. All of the sampling occurred within the CWHvm1 biogeoclimatic variant. These coastal rainforests typify the most humid and highly oceanic region of North America. Mean annual precipitation ranges from 1000 to 4,400 mm, three-quarters of which occurs in the winter months as rain. Mean temperatures average between 13°C and 18.5°C in the warmest months and –6.5 °C and 4.5 °C during the coldest months. Predominant species are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*) and coastal douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) (Alaback & Pojar 1997).

METHODS

Sampling method - Floristic habitat sampling (FHS - Newmaster thesis chapter 1) was used to assess patterns in bryophyte community composition over the period of two field seasons. In 1996, 102 stands were sampled in the interior cedar-hemlock (ICH). Stands were chosen from the Wells Gray, upper Adams River, and Seymour watersheds. Within these watersheds sampling was evenly distributed between stands that were burned approximately 80 years ago (age class 4), and old-growth stands of 250+ years in age (age class 9). In 1997, 185 stands were sampled in the coastal western hemlock (CWH). Stands were chosen from the Capilano and Seymour watersheds along the mainland coast and in the Sidney, Clayoquot, Tofino and Walbran watersheds along the western coast of Vancouver Island. Extensive logging activities in the Capilano and Seymour watersheds allowed a balanced sampling between stands that were logged 80 years ago, and old-growth stands of 250+ years in age. Sampling on Vancouver Island was limited to old stands due to the relatively recent logging activity and lack of fire history in the CWH.

Definitions - A stand is defined as a standing growth of trees with similar physiognomy (Kimmins 1987; Barbour et al. 1987). In this study, a stand is similarly defined by the dominant tree species, its age, structure, elevation, slope position, and aspect. Stands vary in size, but most consist of a dominant mesohabitat (the forest) which encloses numerous restricted mesohabitats (e.g., cliffs, streams, seeps). Within each mesohabitat there is a number of microhabitats (i.e., tree base, stumps, acidic rocks) that may be specific to one type of mesohabitat (i.e., wet cliff crevices, submerged rocks in streams).

Mesohabitats (e.g., streams, cliffs etc.) are found within the forest landscape. They contain sets of microhabitats, the diversity of which controls the quality of the mesohabitat (Vitt & Belland 1996). At the regional scale, patterns of diversity are arranged through the occurrence, quantity and quality of meso-habitats. A dominant mesohabitat can comprise a large portion of the landscape (e.g., a forest). Restricted mesohabitats are smaller and are fully contained within the dominant mesohabitats (e.g., a cliff within a forest).

The dominant forest mesohabitat is the forest stand (see definition above) excluding any streams, cliffs or seeps. The boundaries of the dominant mesohabitat are defined by the stand and include: the dominant tree species, its age, structure, elevation, slope position, and aspect. Forest microhabitats such as logs, stumps, tip-ups, trees and forest floor (humus, mineral soil) are extensively sampled in this mesohabitat. Sampling was influenced by time, space, and by natural stand boundaries. Fourteen hours (maximum) were spent at each stand; within each stand, 20 m diameter circular plot (used in plot sampling – Newmaster thesis chapter 1) was used as the starting point for collecting species data in the dominant forest mesohabitat.

Three types of restricted mesohabitats were sampled:

1) Streams - Streams are the most complex mesohabitat and contain microhabitats that are also common to seeps, cliffs and the dominant forest mesohabitat (Table 4-1). Their physiography and physiognomy is unique within the cedar hemlock forest. We define the stream mesohabitat as a stream gully containing the stream itself and 5 m of bank (2.5 m

on either side) habitat. Sampling started within the actual stream width (i.e., 1-5 m) and continued to include 5 m of bank. The stream banks were included because they offer a complex mix of microhabitats that contain considerable diversity not found elsewhere in cedar hemlock forests. Sampling continued up the stream (including the 5 m of bank) for 1000 m for a maximum sampling area of 5000 m^2.

2) Cliffs - Cliff mesohabitats offer a unique physiognomy and physiography. They are defined as large (> 100 m^2) rock faces or outcrops that may have trees, logs and stumps, and which also may contain many microhabitats found in the dominant forest mesohabitat (Table 4-1). Sampling was limited by a maximum area of 5000 m^2.

3) Seeps - Seeps are swampy areas of cedar hemlock forest with poor drainage. Only seeps larger than 100 m^2 were considered for sampling. Seeps have many of the same microhabitats as the dominant forest mesohabitat. Sampling was limited by a maximum area of 5000 m^2.

Each species and its abundance was recorded for all mesohabitats (Vitt & Belland 1997) and microhabitats in each stand. Abundance was measured (ocular estimate) on a scale of one to three following Vitt et al. (1995): A) one to few occurrences, < 20% cover; B) several occurrences to frequent in one or some areas of the micro/mesohabitat, 30-50% cover; C) frequent throughout the micro/mesohabitat, > 70% cover.

Species nomenclature follows Anderson *et al.* (1990) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. Voucher specimens collected from each watershed were prepared and deposited at the University of Alberta Cryptogamic Herbarium (ALTA), Kamloops Forest Region Herbarium and University of British Columbia Herbarium (UBC).

Mesohabitat Ordination – The relationship of community structure in mesohabitats to the major environmental gradients was analyzed with non-metric multidimensional scaling (NMS; Kruskal 1964; McCune & Mefford 1997). The Bray Curtis distance measure was used because of its robustness for both large and small ecological gradients (Minchin 1987). Data was standardized by species maxima. Two-dimensional solutions were appropriately chosen based on plotting a measure of fit ("stress") to the number of dimensions. One hundred iterations were used for each NMS run, using random start coordinates. The first two ordination axes were rotated to enhance interpretability with the apparent temporal (time since last major disturbance) and habitat heterogeneity (number of microhabitats) gradients. Multiple regression of environmental variables on all axes gives a p-value correlation, slope and coesines (-/+ vector direction) are used for reproduction of vector on the ordination centroid.

Mesohabitat Diversity analyses – We applied Whittaker's (1972) three kinds of diversity. Gamma (γ) diversity is the landscape-level diversity estimated as the total number of species across mesohabitats in either the ICH or CWH. Alpha (α) diversity is calculated here as mean species richness within the ICH or CWH for either old-growth forest stands or young forest stands disturbed by fire or logging. Beta diversity is a measure of heterogeneity in the mesohabitat data, and is expressed as a 50% change in species composition (half change) on the NMS ordinations. Abundance was recorded for each species on each type mesohabitat (see FHS methods above) and averaged for each species within stands.

A diversity index based on proportional frequencies (Brillouin eqn 2, Pielou 1966; Clifford and Stephenson 1975; Magurran 1988) were calculated for all mesohabitat types within each biogeoclimatic zone, and stratified by disturbance (logging, fire, old-growth). Indices were calculated using Krebs/WIN (1997).

[eqn. 2]

$$HB = \frac{\ln Ni! - \sum \ln ni!}{Ni}$$

where, ni = Number of individuals in each species

Ni = Total number of individuals.

Mesohabitat Indicator Species – The relative importance of an indicator species within a mesohabitat was estimated using the method of Dufrêne and Legendre (1997) as implemented in PC-ORD software (McCune & Mefford 1997). The "indicator value" describes a species' reliability for indicating a mesohabitat, and is expressed as a percentage of perfect indication. The indicator value combines, by multiplication, the abundance of a species in each mesohabitat relative to its abundance in all groups, with that species' frequency of occurrence in the sample units of the designated group (Rambo & Muir 1998a, 1998b). A Monte Carlo analysis (Krebs 1997) assessed statistical significance of indicator values based on the proportion of 1,000 randomized trials that equaled or exceeded the maximum indicator value for a species. Correspondence Analysis (CA) was used to ordinate species from 188 mesohabitats in the ICH and 363 mesohabitats in the CWH (ter Braak, 1986; ter Braak 1998). Indicator species for each mesohabitat type were identified on the ordination for the ICH and CWH.

Mesohabitat diversity models - Species richness was modeled using regression analyses in order to identify the important environmental variables that largely determine bryophyte diversity in specific types of mesohabitats. Stepwise multiple regression of mesohabitat species richness against environmental variables was used for each individual mesohabitat type (e.g., forest, cliff, stream & seep - Table 4-1). The regression analyses was run in SPSS (1998) statistical software.

RESULTS

Mesohabitat Ordination

Interior Cedar Hemlock Zone – Specific mesohabitats are distinguished on the NMS ordination and are strongly correlated with two environmental gradients. Mesohabitats are not similar in their community composition as exemplified using beta diversity to measure the distances between different mesohabitat clusters in the ordination. The strongest gradient ($r^2 = 0.846$) is temporal (i.e., time since last large-scale disturbance) and separates old growth on the right side of the ordination from young growth mesohabitats on the left side (Fig. 4-2). Differences in beta diversity (β) along the temporal gradient (first axis) can be observed for specific types of mesohabitats on the ordination; streams have highest beta diversity and seeps have the lowest. The second environmental gradient is microhabitat heterogeneity (i.e., number of different microhabitats). Differences in β along this gradient suggest that old growth mesohabitats (excluding cliffs) have greater microhabitat heterogeneity and a stronger influence on diversity than young mesohabitats (Fig. 4-2). Furthermore, specific types of mesohabitats are influenced more (i.e., beta diversity) by microhabitat heterogeneity than others; on the microhabitat heterogeneity gradient, streams have the highest β and cliffs have the lowest. The variability in beta diversity between mesohabitats suggests differences in species richness and community composition.

Coastal western Hemlock Zone – Clusters of mesohabitats well separated on the ordination axes (Fig. 4-3). The strongest gradient ($r^2 = 0.882$) is temporal (i.e., time since last large-scale disturbance) and separates old growth on the upper right side of the ordination from young growth mesohabitats on the lower left side (Fig. 4-3). Differences in beta diversity along the temporal gradient (first axis) can be observed for specific types of mesohabitats on the ordination; old and young streams are further apart than old and young forest mesohabitats. The second environmental gradient ($r^2 = 0.791$) is microhabitat heterogeneity (i.e., number of different microhabitats). Differences in β along this gradient suggest that old growth mesohabitats (excluding cliffs) have greater microhabitat heterogeneity and a stronger influence on diversity than young mesohabitats (Fig. 4-3). Furthermore, specific types of mesohabitats are influenced more (i.e., beta diversity) by microhabitat heterogeneity than others; on the microhabitat heterogeneity gradient, streams have the highest β and seeps have the lowest. The variability in beta diversity between specific types of mesohabitats suggests differences in species richness and community composition.

Mesohabitat Bryophyte Diversity

Interior Cedar Hemlock Zone – Bryophyte diversity is not distributed evenly among the four types of mesohabitats. In old growth forests, streams have higher total species richness, mean species richness and diversity indices than any other mesohabitat type (Fig. 4-4; Table 4-2 and 4-3). Total species richness, and diversity indices are highest in forest, cliff and seep mesohabitats respectively (Table 4-2 and 4-3). The forest mesohabitat has a higher abundance of bryophytes than any other mesohabitat (Fig. 4-5). Mean species richness and abundance is not significantly different ($p > 0.05$) among forest, cliff and seep mesohabitats.

In young stands, diversity is highest in the forest mesohabitat. Forest mesohabitats had the highest total species richness, abundance and diversity indices, followed by stream, cliff and seep mesohabitats respectively (Fig. 4-4 and 4-5; Table 4-2 and 4-3). Mean species richness was not significantly different ($p > 0.05$) among all types of mesohabitats.

Bryophyte diversity in mesohabitats is distinctively partitioned by age since the last large-scale disturbance. Total species richness (γ) and mean species richness (α) are significantly ($p < 0.05$) higher in old-growth mesohabitats (Table 4-2; Fig. 4-4). In streams, α in old-growth is more than twice as great as the α in young stands (Fig. 4-4). Species abundance in mesohabitats is also greater in old-growth stands than young stands (Fig. 4-5). Brillouin diversity indices had higher values for all mesohabitats in old-growth forests (Table 4-3).

Coastal Western Hemlock Zone – As with the ICH, bryophyte diversity is not equally distributed among the four types of mesohabitats. In old-growth forests, species richness and diversity indices are higher in streams than any other mesohabitat ($p < 0.05$) (Fig. 4-4). Cliffs have higher total species richness and diversity indices than either seep or forest mesohabitats. Abundance is highest in the forest mesohabitats.

Within young stands, the forest mesohabitat has the highest species richness, abundance and diversity indices (Fig. 4-4 and 4-5; Table 4-2 and 4-3). Total species richness and diversity indices are highest in streams, seeps and cliffs respectively (Table 4-2). Mean species richness and abundance are similar for streams, cliffs and seeps (Fig. 4-4 and 4-5).

Time since last large-scale disturbance and oceanity (i.e., mainland vs. island) greatly influence bryophyte diversity in mesohabitats. Old-growth mesohabitats have higher gamma diversity, alpha diversity, abundance, and diversity indices than mesohabitats in young forests (Fig. 4-4 and 4-5; Table 4-2 and 4-3). Species richness is significantly ($p < 0.05$) higher in all mesohabitats on Vancouver Island when compared to mesohabitats along the mainland coast (Fig. 4-4).

Mesohabitat Indicator Species

Differences in species frequency and abundance among the different mesohabitats imply that some species are associated with specific types of mesohabitats. Bryophyte associations are based upon mesohabitat indicator analyses for each biogeoclimatic zone (Table 4-4 and 4-5). Species with significant ($p < 0.05$) indicator values were identified in the four clusters (representing the four types of mesohabitats) in a CA species ordination for each respective biogeoclimatic zone (Fig. 4-6 and 4-7). These indicator species are representatives of the four distinct mesohabitat communities and are further defined for each biogeoclimatic zone:

Interior Cedar Hemlock Zone Forest mesohabitats – The dominant forest mesohabitat is made up of a community of species associated with either the forest floor (terricolous) or woody substrates (epixylics or epiphytes). Many of the species associated with the forest floor are common mosses: Atrichum selwynii, Hylocomium splendens, Pleurozium schreberi, Plagiothecium laetum, Ptilium crista-castrensis, Rhizomnium magnifolium, Rhytidiopsis robusta and Sanionia uncinata (Table 4-4). Liverworts are less common but may be found on the forest floor (e.g., Blepharostoma trichophyllum and Ptilidium ciliare). Some mosses are closely associated with woody substrates in the forest mesohabitat community: Amblystegium serpens, Brachythecium frigidum, Brachythecium salebrosum, Brachythecium velutinum, Buxbaumia piperi, Buxbaumia viridis, Dicranum tauricum, Dicranella grevilleana, Hypnum revolutum, Mnium spinulosum, Tetraphis pellucida, and Tetraphis geniculata. Hepatic species richness and abundance is highest on woody substrates in the forest mesohabitat community: Bazzania tricrenata, Cephalozia pleniceps, Cephalozia lunulifolia, Jamesoniella autumnalis, Jungermannia leiantha, Lophozia ventricosa, Lophozia incisa, Lophozia guttulata, Ptilidium pulcherrimum, and Ptilidium californicum.

Interior Cedar Hemlock Zone Streams & Seeps – Riparian or wetland bryophytes make up the majority of the community composition of stream mesohabitats (Table 4-4). Mosses such as Blindia acuta, Brachythecium rivularem, Calliergon stramineum, Campylium stellatum, Climacium dendroides, Cratoneuron filicinum, Drepanocladus aduncus, Drepanocladus brevifolius, Fissidens adianthoides, Fissidens osmundioides, Hygrohypnum luridum, Oncophorus wahlenbergii, Pohlia wahlenbergii, Preissia quadrata, Porotrichum bigelovii, Rhytidiadelphus squarrosus, Scapania undulata, Schistidium rivulare, Sphagnum angustifolium, Sphagnum capillifolium, Sphagnum squarrosum, and Warnstorfia fluitans are prominent species in the stream community. Hepatic species such as Aneura pinguis, Conocephalum conicum, Gymnocolea inflata, Gyrothyra underwoodiana, Marchantia polymorpha, Nardia scalaris, Pellia neesiana, and Riccardia multifida are dominant liverworts in the stream community.

Interior Cedar Hemlock Zone Seeps – Many of the wetland species found in streams are also found in seep mesohabitats (Table 4-4). Several species are more prominent in seep communities: *Aulacomnium palustre, Calypogeja muelleriana, Campylium chrysophyllum, Cephalozia lunulifolia, Hypnum revolutum,* and *Rhizomnium pseudopunctatum.*

Interior Cedar Hemlock Zone Cliffs – The cliff mesohabitat community comprises many species of saxicolous bryophytes. Some of these species are exclusively associated with cliffs, such as *Anastrophyllum minutum, Bryum argenteum, Chandonanthus setiformis, Encalypta procera, Funaria hygrometrica, Grimmia affinis, Grimmia torquata, Hypnum cupressiforme, Lophozia excisa, Orthotrichum pellucidum, Orthotrichum laevigatum, Paraleucobryum longifolium, Platygyrium repens, Polytrichum piliferum, Ptilidium ciliare, Racomitrium canescens, Timmia austriaca,* and *Tortula ruralis.* Several species are associated with cliffs, but can be found on rock microhabitats in other types of mesohabitats: *Amphidium lapponicum, Barbilophozia.barbata, Barbilophozia lycopodioides, Bartramia pomiformis, Bartramia ithyphylla, Ceratodon purpureus, Dicranum scoparium, Dicranoweisia crispula, Hedwigia ciliata, Polytrichum juniperinum, Lophozia gillmanii, Racomitrium heterostichum,* and *Schistidium apocarpum.*

Coastal Western Hemlock Zone Forest mesohabitats – The dominant forest mesohabitat is made up of a community of species that are associated with the forest floor or woody microhabitats. The forest floor is often covered in a continuous carpet of bryophytes: *Aulacomnium palustre, Aulacomnium androgynum, Blepharostoma trichophyllum, Dicranum fuscescens, Leucolepis acanthoneuron, Leptobryum pyriforme, Polytrichum piliferum, Plagiomnium venustum, Polytrichum formosum, Plagiomnium cuspidatum, Pleurozium schreberi, Rhizomnium magnifolium Rhytidiopsis robusta, Sphagnum girgensohnii,* and *Sphagnum squarrosum.* Many of the species in the forest mesohabitat are epiphytic or epixylic mosses: *Amblystegium serpens, Brachythecium frigidum, Buxbaumia piperi, Claopodium crispifolium, Dicranum tauricum, Dicranoweisia cirrata, Ditrichum heteromallum, Fissidens adianthoides, Funaria hygrometrica, Homalothecium aeneum, Homalia trichomanoides, Homalothecium fulgescens, Hypnum subimponens, Isothecium myosuroides, Oncophorus virens,* *Orthotrichum consimile, Orthotrichum lyellii, Pohlia cruda, Pohlia annotina, Pogonatum urnigerum, Plagiopus oederiana, Pseudoleskea radicosa,* and *Timmia austriaca.* Trees, snags, stumps and logs offer habitat for a rich community of forest mesohabitat hepatics: *Barbilophozia floerkei, Barbilophozia hatcheri, Bazzania denudata, Bazzania tricrenata, Calypogeia trichomanis, Cephalozia lunulifolia, Diplophyllum obtusatum, Frullania tamarisci ssp. nisquallensis, Lepidozia reptans, Lophozia incisa, Lophozia wenzelii, Lophozia excisa, Metzgeria conjugata, Ptilidium pulcherrimum, Porella cordaeana,* and *Radula complanata.*

Coastal Western Hemlock Zone Streams & Seeps – Stream mesohabitats are made up of a community of riparian or wetland bryophyte species. Streams often have shallow sections with large green mats dominated by mosses: *Brachythecium rivulare, Dicranodontium denudatum, Dicranum pallidisetum, Fissidens grandifrons, Fontinalis antipyretica, Fontinalis hypnoides, Fontinalis neomexicana, Hygrohypnum luridum, Hypnum lindbergii, Leskea polycarpa, Palustriella commutatum, Plagiothecium piliferum, Racomitrium aciculare, Racomitrium aquaticum, Scleropodium obtusifolium,* and *Schistidium rivulare.* Hepatics are often found in abundance on the logs and rocks that are continually irrigated by the stream: *Aneura pinguis, Bazzania pearsonii, Concephalum conicum, Gymnomitrion obtusum, Jungermannia pumila, Marsupella sparsifolia, Odontoschisma denudatum, Radula bolanderi, Riccardia latifrons, Scapania americana,* and *Tritomaria quinquedentata* (Table 4-4).

Coastal Western Hemlock Zone Seeps – Seep mesohabitats have many of the same species as stream mesohabitats: *Rhytidiadelphus squarrosus, Scapania bolanderi, Rhytidiadelphus triquetrus, Hypnum pratense, Scapania undulata, Claopodium pellucinerve, Diplophyllum taxifolium,* and *Metzgeria temperata.* Species that are more commonly found in seep mesohabitats are typically found growing on the wet forest floor: *Climacium dendroides, Diplophyllum plicatum, Eurhynchium pulchellum, Lophozia heterocolpos, Mnium spinulosum, Plagiomnium medium, Pogonatum contortum, Polytrichastrum alpinum,* and *Rhizomnium nudum.*

Coastal Western Hemlock Zone Cliffs – Communities on cliff mesohabitats are dominated by saxicolous bryophytes. Some of these species only occur on cliffs: *Andreaea rothii, Anoectangium aestivum, Bryum capillare, Ditrichum flexicaule,* *Encalypta procera, Geheebia gigantea, Grimmia incurva, Lophozia obtusa, Marsupella boeckii, Pterigynandrum filiforme, Racomitrium canescens, Racomitrium heterostichum, Racomitrium lanuginosum, Racomitium occidentale, Racomitrium muticum, Racomitrium lawtonae, Racomitrium elongatum,* and *Ulota phyllantha.* Many of the species in this community are also found on rock microhabitats in other types of mesohabitats: *Amblystegium serpens, Atrichum selwynii, Blepharostoma trichophyllum, Brachythecium frigidum, Dicranum fuscescens, Dicranum scoparium,Ditrichum heteromallum, Eurhynchium pulchellum, Heterocladium macounii, Hookeria lucens, Hypnum circinale, Hypnum revolutum, Hypnum subimponens, Isothecium myosuroides, Mnium spinulosum, Polytrichum juniperinum, Pogonatum, contortum, Plagiothecium laetum, Pleurozium schreberi, Pseudotaxiphyllum elegans, Polytrichastrum alpinum, Polytrichum commune, Plagiomnium cuspidatum, Pogonatum urnigerum, Ptilidium ciliare Rhytidiadelphus triquetrus, Rhytidiadelphus squarrosus, Rhytidiopsis robusta,* and *Sanionia uncinata.*

Old-Growth Indicator Species

There are different mesohabitat requirements for old-growth indicator species within either the CWH or ICH. Old growth indicator species have been identified for the ICH and CWH, but have not been associated with specific mesohabitats (Newmaster et al. 1999b). In general, old-growth indicator species are found in all types of mesohabitats. However, several species are associated with particular mesohabitats.

In the ICH, streams have almost 50% more old-growth indicator species than any other mesohabitat (Fig. 4-6; Table 4-4). Some of the more common old-growth indicators in streams include; *Apometzgeria pubescens, Blindia acuta, Cratoneuron filicinum, Calliergon stramineum, Fissidens osmundioides, Gymnocolea inflata, Oncophorus wahlenbergii, Marsupella emarginata,* and *Myurella julacea* (Table 4-4). Cliff, seep and forest mesohabitats have a comparable number of old-growth indicator species. Old growth indicator species common on cliffs include; *Brachythecium albicans, Dicranoweisia cirrata, Gymnmitrion obtusum,* and *Lophozia excisa.* In the forest mesohabitat, common old-growth indicators include; *Antitrichia curtipendula, Bazzania tricrenata,* and *Cephalozia pleniceps* (Table 4-4).

In the CWH, streams and seeps have almost 50% more old-growth indicator species than any other type of mesohabitat (Fig. 4-7; Table 4-5). Some of the common old-growth indicators in streams include; *Dicranodontium denudatum, Fontinalis hypnoides, Jungermannia pumila, Plagiochila asplenoiides,* and *Radula bolanderi* (Table 4-5). Several of the common old-growth species on cliffs include; *Ditrichum flecicaule, Homalothecium fulgescens, Hookeria lucens,* and *Psedoleskea radicosa*. In the forest mesohabitat, some common old-growth indicators include; *Homalothecium fulgescens, Metzgeria conjugata, Plagiopus oderiana, Porella cordaeana,* and *Scapania umbrosa* (Table 4-5).

Mesohabitat Species Richness Models

Within specific types of mesohabitats, several environmental variables can be used to explain patterns in species richness. Multiple regression analyses explained the variation in species richness using environmental variables from each type of mesohabitat (Table 4-6). Partitioning the mesohabitats by stand age increased the amount of explained variation using environmental variables unique to each type of mesohabitat within a specific age class. The result is a regression model of species richness, for each type of mesohabitat within young stands or old-growth stands. Attempts to generate species richness models without stratification by mesohabitat type or age-class resulted in non-significant regressions ($p > 0.05$) or very low correlation coefficients ($R^2 < 0.20$).

Interior Cedar Hemlock Zone - In the dominant forest mesohabitat, variation in species richness within old-growth or young forest can be adequately explained with several environmental variables. High species richness in old-growth forest is strongly correlated ($R^2 = 0.702, p < 0.05$) to the presence of large (> 70 cm) decay class L3 and L4 logs, high rock cover, intermittent streams and moist-wet hygrotope (Table 4-6). High species richness in young forests is strongly correlated ($R^2 = 0.666, p < 0.05$) to the presence of large (>70 cm) decay class L3 logs, high rock cover and the presence of "vets" or isolated large trees (dbh > 70 cm).

Species richness in restricted mesohabitats (i.e., streams, seeps and cliffs) is highly correlated ($R^2 = 0.78\text{-}0.84, p < 0.05$) to number of microhabitats and the presence of specific types of microhabitats. Streams that occur in old-growth forest have higher species richness with high numbers of microhabitats, the presence of waterfalls greater than two meters in height and a higher frequency of logs crossing the stream (Table 4-6). There is a strong correlation between the number of microhabitats and the variation in species richness within cliff and seep mesohabitats (Table 4-6).

Coastal Western Hemlock Zone - Variation in species richness within the dominant forest mesohabitat was stratified by stand age (i.e., 80 vs. 250+ years) and oceanity (i.e., mainland vs. island) and then modeled using several environmental variables. High species richness in old-growth forests on the mainland coast is strongly correlated ($R^2 = 0.881, p < 0.05$) with the number of microhabitats, the presence of deciduous trees and snags, and the basal area of logs on the forest floor (Table 4-6). Species richness in old-growth forests on Vancouver Island is positively correlated ($R^2 = 0.571, p < 0.05$) with the presence of deciduous trees and the position of the mesohabitat on a slope. Mesohabitats on mid or low slope positions had higher diversity than those did on the toe of the slope. The number of microhabitats was the only significant variable ($R^2 = 0.753, p < 0.05$) that is correlated to species richness in stands disturbed by logging (Table 4-6).

Regression models of stream mesohabitats were highly correlated ($R^2 = 0.81$-0.88) to several environmental variables. In old-growth forest, high stream species richness is strongly correlated to the number of microhabitats and the presence of waterfalls over 2 m in height (Table 4-6). High species richness in streams disturbed by logging are correlated with high numbers of microhabitats, wider streams and increasing canopy height (Table 4-6). Streams in CWH forests on Vancouver Island have higher diversity than streams in the mainland CWH forests (Fig. 4-4).

In cliff mesohabitats, the number of microhabitats is the only significant variable correlated ($R^2 = 0.74$-$0.81, p < .001$) to species richness, regardless of disturbance (Table 4-6). However, old cliffs have higher species richness than young cliffs (Table 4-2). Species richness increases with the number of microhabitats in either young or old forests.

Variation in species richness within seeps can be adequately explained without stratifying by age-class. Stratification by age-class is not possible because of the low number of seep mesohabitats found in cedar hemlock forests (under sampling). Species richness in seeps is strongly correlated ($R^2 = 0.867$, $p < 0.05$) with age-class, number of microhabitats, density of logs and basal area of logs. High species richness is fostered by old stands with many microhabitats and lots of large, old, remnant logs (Table 4-6).

DISCUSSION

Mesohabitat quality and quantity are the basic ingredients for bryophyte diversity at the local landscape scale. This supports Vitt and Belland's (1997) model of rare species richness. Mesohabitat quantity can be defined as the types and distributions of all mesohabitats and the number of particular mesohabitats on a landscape (Vitt & Belland 1997). In our study of bryophyte diversity in cedar-hemlock forest, species richness was largely dependent on the number of particular types of mesohabitats (Newmaster thesis chapter 3). The dominant forest mesohabitat maintains high abundance and frequency of bryophytes. Restricted mesohabitats are most influential in the maintenance of species diversity. Specifically, the presence of streams and cliffs offer the highest bryophyte diversity. As predicted in Vitt and Belland's model (1997), mesohabitat quality is expressed as the number and type of microhabitats. In cedar hemlock forest, high diversity in microhabitats within a particular mesohabitat was strongly correlated with high species richness.

My research shows that each type of mesohabitat has a list of variables that promotes high species richness. Mesohabitat quality is defined as the number of different types of microhabitats in a mesohabitat (Vitt & Belland 1997). We found that high mesohabitat quality is the most important variable correlated with high bryophyte diversity within mesohabitats. High variation in microhabitats is strongly correlated with high bryophyte species richness in cedar hemlock forests. The presence of specific types of microhabitats and the influence of some environmental variables are also correlated with high species richness within specific types of mesohabitats. Some of these correlations are well defined and others are more general and apply to both the ICH and CWH.

Patterning of species richness within the dominant forest mesohabitats is related to several factors when stratified by stands age and biogeoclimatic zone. In old growth forests, the presence of large, moderately decayed (i.e., L3 or L4) logs promotes rich communities of bryophytes and hepatics. Within young forest mesohabitats, the presence of "vets" or remnant old growth trees is correlated to high species richness. Rambo and Muir (1998a) found similar correlations within hemlock forests in western Oregon. We also found that old growth forest mesohabitats on West Coast of Vancouver Island have reduced species richness in low slope and toe position mesohabitats. These lower slope mesohabitats are often flooded because of the extremely high annual rainfall in these oceanic rainforests. Flooding disturbance prevents communities from establishing, and therefore lowers diversity. In ICH forests, mesohabitat species richness increases with the presence of calcareous rock. This is an uncommon habitat in the CWH, a product of historical geological processes (Schofield 1988). In CWH forests, mesohabitat species richness increases with the presence of deciduous trees, an uncommon habitat in the ICH due to floristic limitations of deciduous species. Other features that may influence bryophyte diversity are macroscale landforms that determine the floristic composition of the region (Belland 1989) and the ability of a species to disperse (Söderström 1990).

We found that streams are areas of high diversity and that species richness can be associated with several factors when stratified by age and biogeoclimatic zone. Species richness is highest in streams that are associated with many different kinds of microhabitats. Waterfalls in old-growth streams provide humid microhabitats that support the richest diversity of bryophytes (particularly hepatics) in either biogeoclimatic zone. Schofield (1988) and Djan-Chekar (1993) have also noted that bryophyte diversity is highest around waterfalls in the CWH. In the ICH, high species richness in old growth streams is associated with large well-decayed logs traversing the stream. These logs are sometimes piled up on one another and offer humid microhabitats that are protected from desiccation from the sun and wind. Bryophyte diversity in streams within young forests is more influenced by the width of the stream (CWH) or presence of calcareous substrates (ICH), both of which increase the number of unique microhabitats. In streams, species richness increases with oceanity. Streams on Vancouver Island had higher diversity than streams on the mainland coast. This may be do to the warmer wetter climate and/or the glacial history of these areas. Some oceanic areas served as refugia for western North American endemics during the Pleistocene glaciation (Schofield 1988). Old growth forest streams are ideal areas of refuge and serve as a reservoir of bryophyte diversity.

The value of old growth forest to biodiversity must not be underestimated. Clear-cutting techniques reduces stand age, the number of habitats, and ultimately cryptogam diversity in analysis of forest stands (Anderson & Hytterborn 1991; Gustafsson & Hallingbäck 1988; Lesica et al. 1991; Söderström 1988; Rambo and Muir 1998b; Newmaster et al. 1999). Patterning of bryophyte diversity in forests at the regional landscape scale is most strongly influenced by biogeoclimatic variables (Newmaster et. al. 2000c), and age since the last major disturbance (Pike et al. 1975; Newmaster et al. 2000c). We have shown that at the local "mesohabitat" landscape scale, bryophyte diversity is substantially higher in old growth forest mesohabitats (i.e., all types) when compared to those that have been disturbed by large-scale wildfire or clear-cut logging. Mesohabitats with high species richness are strongly correlated to the presence of specific microhabitats that are found abundantly in old growth forests. Species richness is promoted by an abundance of large logs in various decay classes that are common in old forest but scarce in young forest (Andersson & Hytteborn 1991). Logging and wildfire disturbance reduce water levels and humidity in streams (Naiman and Anderson 1997). In several instances, we recorded a rich diversity of bryophytes in an old growth portion of a stream and then moved downstream into a clearcut or burn to find very low bryophyte diversity. Mesohabitats in old growth forest are rich with microhabitats and a humid environment that fosters a rich bryoflora (Schofield 1988). We should consider mesohabitats in old growth forests as reservoirs of bryophyte diversity.

Unique communities of bryophytes exist for different types of mesohabitats. This association between bryophytes and habitat has long been known, and used for indicators of environmental change (Gignac & Vitt 1994) and quality (Gignac 1986; Newmaster et al. 1999). In peatlands, bryophytes have been used to indicate chemical and wetness gradients (Vitt et al. 1975; Vitt & Chee 1990) and patterning of species richness (Vitt et al. 1995; Belland & Vitt 1995). It would be expected that these trends would be true for upland habitats, where moss habitat limitations have been closely tied to substrate (Schuster 1949; Rose 1992; Söderström 1993; Vitt & Belland 1997; Horton 1988; Shaw 1981). Bryophyte communities are distinct and unique to each type of mesohabitat within the CWH and ICH forests. Old-growth indicators (Newmaster et al. 2000b) and rare species are commonly found in each type of mesohabitat. The consequence of this to preserving bryophyte diversity is significant. A specific type of mesohabitat should not have a greater value than any other mesohabitat; all types of mesohabitats need to be preserved to maintain high bryophyte diversity. A variety of mesohabitat types with the highest possible diversity of microhabitats should be preserved in every watershed management plan if sustainability of diversity is a priority. Each mesohabitat preserved should contain the highest bryophyte richness in order to sustain biodiversity on the landscape. Table 4-7 presents a list environmental bio-indicators that promote high bryophyte diversity in old growth forest.

Table 4-1: A list of microhabitats for each type of meso-habitat within cedar hemlock stands (DMH = dominant mesohabitats; RMH = restricted mesohabitat).

Microhabitat	DMH	RMH		
	Forest	Cliff	Stream	Seep
Coniferous tree species	x	x	x	x
Deciduous tree species	x	x	x	x
Size of tree (10-25 cm dbh, 30-60 cm dbh, > 70 cm DBH)	x	x	x	x
Position on tree (trunk or base - 50 cm above tapered bowl)	x	x	x	x
Snag (dead coniferous or deciduous trees)	x	x	x	x
Twig (CWD < 10 cm diam.)	x	x	x	x
Log size (10-30 cm, 30-60 cm dbh, > 70 cm DBH)	x	x	x	x
Log decay class (D1,D3 or D5 – CWD codes)	x	x	x	x
Organic soils (LFH)	x	x	x	x
Mineral soil (sand, silt, loam, clay)	x	x	x	x
Moist depression (small isolated pools of water/mud)	x	x	x	
Intermittent stream (narrow and ephemeral)	x	x		x
Rock (sample type, pH)	x	x	x	x
Tree stump	x	x	x	x
Upturned tree roots ("tip-up")	x	x	x	x
Adjacent bank (sand, silt, clay, loam, gravel, cobble, rock)	x	x	x	x
Submerged habitat (rocks or logs)			x	x
Shallow bars (sand, silt, clay, loam, gravel or cobble; dry/wet)			x	
Waterfall (< 1 m, 1-2 m, 2-5 m, 5-10 m, >10 m)			x	
Depth (< 10 cm, 10-30 cm, > 30 cm)			x	
Rapid (flow rate (m/second))			x	
Crevice (horizontal/vertical; < 5 cm, .5-1 m, > 1m; wet/dry; seepage, soil cover, sand, silt, clay, loam)		x	x	
Ledges (size, wet/dry, seepage, soil covered)		x	x	
Caves (size, wet/dry, seepage)		x	x	
Vertical rock face (size, wet/dry, seepage)		x	x	
Talus		x	x	
Rock surface (rough/smooth)		x	x	

Table 4-2. Gamma (γ) & mean alpha (α) stand diversity in old growth (250+ yrs.) rainforests and young rainforests (80-90 yrs.) disturbed by fire or logging.

Biogeoclimatic Zone and Geographic Area	Disturbance	Meso-habitat total (γ) and mean alpha (α)									
		Total		Forest		Stream		Cliff		Seep	
CWH		γ	α	γ	α	γ	α	γ	α	γ	α
Oceanic rainforest	old growth	317	162	151	113	293	137	166	83	151	101
Mainland coastal rainforest	old growth	231	118	128	90	204	103	130	67	91	72
	logging	114	62	112	57	76	40	44	30	57	45
ICH											
Inland rainforest	old growth	300	88	204	66	222	77	163	58	111	41
	wildfire	188	54	106	38	122	32	94	33	84	34
	TOTAL (Unique species)			**262 (13)**		**359 (70)**		**237 (26)**		**207 (2)**	

Table 4-3. Diversity indices for meso-habitats in old growth (250+ yrs.) and young cedar hemlock forests (80-90 yrs.) disturbed by fire or logging within the ICH or CWH.

Biogeoclimatic Zone and Geographic Area	Disturbance	Diversity Indices			
		Brillouin index (HB)			
CWH		Forest	Stream	Cliff	Seep
Oceanic rainforest	old growth	6.883	6.921	5.923	5.734
Mainland coastal rainforest	old growth	5.672	6.313	5.764	5.225
	logging	5.174	4.476	4.299	4.187
ICH					
Inland rainforest	old growth	6.522	6.591	6.049	5.445
	wildfire	6.095	5.682	5.207	5.076

Table 4-4. Bryophyte indicator values from 188 meso-habitats in the ICH. Indicator values are percentage of perfect indication (multiplication of a species abundance in a designated meso-habitat relative to its abundance in all meso-habitats, with that species' frequency of occurrence in the designated meso-habitat). Shown are species with p-values < 0.05 from a Monte Carlo test of significance. (Asterisk represents old-growth indicator species from Newmaster et al. 1999b).

Species	**CLIFF**	**FOREST**	**SEEP**	**STREAM**	**P**
	n=25	n=102	n=18	n=50	
Drepanocladus aduncus	0	0	4	59	0.0010
Pellia neesiana	0	0	14	59	0.0120
Scapania undulata	0	0	1	59	0.0000
*Fissidens osmundioides**	0	0	0	56	0.0000
Sphagnum capillifolium	0	0	0	56	0.0000
Aneura pinguis	0	0	0	51	0.0000
Marchantia polymorpha	0	1	9	51	0.0050
Warnstorfia fluitans	0	0	0	51	0.0000
Campylium stellatum	0	0	0	50	0.0000
Amphidium lapponicum	14	0	0	50	0.0000
Pohlia wahlenbergii	0	0	3	49	0.0010
*Blindia acuta**	0	0	0	47	0.0000
Climacium dendroides	0	1	16	46	0.0050
*Cratoneuron filicinum**	0	1	25	45	0.0270
Sphagnum squarrosum	0	0	5	45	0.0030
*Calliergon stramineum**	0	0	3	44	0.0010
*Oncophorus wahlenbergii**	0	0	2	43	0.0030
Conocephalum conicum	0	1	21	41	0.0520
Pleurozium schreberi	7	29	12	41	0.0070
Atrichum tenellum	0	0	0	40	0.0000
Rhizomnium gracile	0	0	0	40	0.0000
Sphagnum angustifolium	0	0	0	40	0.0010
Dicranoweisia crispula	0	0	0	37	0.0000
Drepanocladus brevifolius	0	0	0	36	0.0020
Sanionia uncinata	8	29	9	36	0.0010
Rhytidiadelphus squarrosus	0	0	17	35	0.0190
Schistidium rivulare	0	0	0	35	0.0250
Ptilidium pulcherrimum	8	31	10	35	0.0000
Brachythecium rivulare	0	0	0	34	0.0210
*Fissidens adianthoides**	0	0	0	34	0.0030
*Gymnocolea inflata**	0	0	0	33	0.0080
Hygrohypnum luridum	0	0	0	33	0.0020
Nardia scalaris	0	0	0	33	0.0020
Rhizomnium magnifolium	0	6	6	33	0.0390
Andreaea nivalis	1	0	0	33	0.0010
Gyrothyra underwoodiana	0	0	1	32	0.0010
Preissia quadrata	0	0	2	32	0.0130
Dicranella crispa	0	1	0	31	0.0030
Meesia triquetra	0	0	0	31	0.0180
Porotrichum bigelovii	0	0	1	31	0.0020
Riccardia multifida	0	0	0	31	0.0130
Bartramia pomiformis	24	0	0	31	0.0100

*Dichelyma falcatum**	0	0	0	30	0.0090
Dicranella heteromalla	0	0	1	30	0.0180
Cephaloziella divaricata	0	0	2	29	0.0120
*Hylocomiastrum pyrenaicum**	0	6	6	29	0.0280
Isothecium myosuroides	0	1	1	29	0.0060
*Dicranella grevilleana**	11	32	11	29	0.0000
Pohlia cruda	13	3	0	29	0.0280
Dicranella schreberiana	0	0	8	28	0.0490
Pohlia annotina	0	0	1	28	0.0200
Sphagnum girgensohnii	0	1	26	28	0.0380
Plagiothecium laetum	12	27	19	27	0.0320
Blepharostoma trichophyllum	0	30	7	25	0.0280
Calypogeja fissa	0	0	2	25	0.0490
Philonotis fontana	0	0	2	25	0.0480
Riccardia latifrons	0	1	0	25	0.0430
Riccardia palmata	0	2	1	25	0.0230
*Marsupella emarginata**	2	0	0	25	0.0290
Platydictya jungermannioides	4	0	0	25	0.0130
*Hygrohypnum smithii**	0	0	6	24	0.0380
*Leskeella nervosa**	0	1	3	24	0.0490
Pogonatum urnigerum	0	0	7	24	0.0330
*Plagiopus oederiana**	8	0	0	24	0.0250
Ptilium crista-castrensis	10	37	1	23	0.0000
*Heterocladium dimorphum**	1	7	0	22	0.0520
Isopterygiopsis pulchella	2	1	1	22	0.0310
Hylocomium splendens	19	26	16	22	0.0490
Dicranum tauricum	16	29	15	21	0.0220
*Apometzgeria pubescens**	5	0	0	20	0.0430
*Lophozia ventricosa**	5	33	8	20	0.0050
Mnium spinulosum	14	31	13	20	0.0010
Dicranum spadiceum	0	0	0	19	0.0180
*Plagiochila satoi**	0	0	0	19	0.0200
Sphagnum magellanicum	0	0	0	19	0.0150
*Blasia pusilla**	0	0	0	18	0.0210
*Fontinalis antipyretica**	0	0	0	18	0.0450
Marsupella sphacelata	0	0	0	18	0.0430
Scleropodium obtusifolium	0	0	0	18	0.0120
Campylium chrysophyllum	0	0	23	17	0.0460
Hygrobiella laxifolia	0	0	0	17	0.0520
Tetraphis pellucida	7	46	2	17	0.0000
Hygrohypnum ochraceum	0	0	0	16	0.0500
Jungermannia obovata	0	0	0	16	0.0460
Pellia endiviifolia	0	0	1	16	0.0450
Scapania subalpina	0	0	0	16	0.0160
Zygodon viridissimus	1	0	0	16	0.0450
Marsupella spacifolia	2	0	0	16	0.0490
Odontoschisma denudatum	0	2	0	15	0.0440
Encalypta rhaptocarpa	2	0	0	15	0.0540
Ptilidium californicum	2	27	5	15	0.0390
Campylium polygamum	0	0	0	14	0.0500
*Myurella julacea**	0	0	3	14	0.0500
Gymnostomum aeruginosum	1	0	0	14	0.0490
Aulacomnium palustre	0	0	26	13	0.0230

Neckera pennata	0	3	0	13	0.0490
Hypnum revolutum	12	30	22	13	0.0120
Pellia epiphylla	0	0	0	12	0.0500
Jungermannia leiantha	7	18	28	11	0.0480
*Cephalozia pleniceps**	0	45	1	10	0.0000
Polytrichum juniperinum	14	36	0	10	0.0040
Calypogeja muelleriana	0	7	28	9	0.0280
Brachythecium frigidum	6	31	7	9	0.0230
Schistidium apocarpum	23	1	0	8	0.0200
Barbilophozia lycopodioides	20	0	0	7	0.0190
Geocalyx graveolens	23	5	7	7	0.0520
Ceratodon purpureus	32	20	0	7	0.0180
Pterigynandrum filiforme	0	0	0	6	0.0500
Brachythecium salebrosum	2	29	0	6	0.0360
Barbilophozia barbata	32	1	0	6	0.0100
Racomitrium heterostichum	37	1	0	6	0.0030
Dicranum scoparium	18	31	1	5	0.0310
Bryum caespiticium	25	1	0	5	0.0160
Andreaea rupestris	26	0	0	5	0.0180
Hedwigia ciliata	29	6	0	5	0.0210
Brachythecium velutinum	0	27	1	4	0.0230
Rhizomnium pseudopunctatum	0	0	18	4	0.0330
Rhytidiopsis robusta	4	42	0	4	0.0010
Cephalozia lunulifolia	0	28	14	3	0.0380
Atrichum selwynii	15	35	0	3	0.0070
Scapania paludosa	0	0	7	2	0.0500
Amblystegium serpens	8	43	0	2	0.0030
*Bazzania tricrenata**	0	19	0	0	0.0490
*Buxbaumia viridis**	0	18	0	0	0.0329
*Lophozia incisa**	0	23	0	0	0.0260
Buxbaumia piperi	1	42	0	0	0.0000
*Dicranella palustris**	1	37	0	0	0.0090
Radula complanata	1	28	0	0	0.0160
Lophozia guttulata	2	20	0	0	0.0360
Barbula convoluta	6	0	0	0	0.0500
Kiaeria starkei	6	0	0	0	0.0500
*Lophozia opacifolia**	6	0	0	0	0.0490
Scapania mucronata	6	0	0	0	0.0500
Racomitrium sudeticum	8	1	0	0	0.0500
Ditrichum heteromallum	9	0	0	0	0.0500
Homalothecium aeneum	9	1	0	0	0.0500
Pseudoleskea atricha	9	1	0	0	0.0500
Brachythecium erythrorrhizon	10	0	0	0	0.0500
*Dicranoweisia cirrata**	10	0	0	0	0.0500
Leptobryum pyriforme	10	0	0	0	0.0500
Conostomum tetragonum	11	0	0	0	0.0490
Cynodontium strumiferum	11	0	0	0	0.0490
Didymodon vinealis	11	0	0	0	0.0490
Grimmia donniana	11	0	0	0	0.0490
Racomitrium ericoides	11	0	0	0	0.0490
*Brachythecium albicans**	13	1	0	0	0.0490
Bryoerythrophyllum recurvirostre	13	1	0	0	0.0450
*Gymnmitrion obtusum**	14	0	0	0	0.0470

Bartramia ithyphylla	15	0	0	0	0.0490
Grimmia trichophylla	15	0	0	0	0.0490
Encalypta ciliata	16	0	0	0	0.0430
Bryum capillare	18	1	0	0	0.0200
Lophozia gillmanii	19	5	0	0	0.0490
Tortula ruralis	19	0	0	0	0.0140
Anastrophyllum minutum	22	0	0	0	0.0050
Orthotrichum pellucidum	22	0	0	0	0.0050
*Lophozia excisa**	23	0	0	0	0.0120
Ptilidium ciliare	27	1	0	0	0.0150
Bryum argenteum	28	0	0	0	0.0050
Paraleucobryum longifolium	28	1	0	0	0.0080
Timmia austriaca	28	1	1	0	0.0090
Funaria hygrometrica	31	0	0	0	0.0050
Hypnum cupressiforme	32	0	0	0	0.0080
Chandonanthus setiformis	33	0	0	0	0.0090
Orthotrichum laevigatum	33	0	0	0	0.0090
Platygyrium repens	33	0	0	0	0.0040
Encalpta procera Bruch	39	0	0	0	0.0010
Grimmia torquata	39	0	0	0	0.0000
Grimmia affinis	48	0	0	0	0.0000
Polytrichum piliferum	51	0	0	0	0.0000
Racomitrium canescens	61	2	0	0	0.0000

Table 4-5. Bryophyte indicator values from 363 meso-habitats in the CWH. Indicator values are percentage of perfect indication (multiplication of a species abundance in a designated meso-habitat relative to its abundance in all meso-habitats, with that species' frequency of occurrence in the designated meso-habitat). Shown are species with *p*-values < 0.05 from a Monte Carlo test of significance (Asterisk represent old-growth indicator species from Newmaster et al. (1999c).

SPECIES	**CLIFF**	**FOREST**	**SEEP**	**STREAM**	**P**
	n=25	n=102	n=18	n=50	
*Fontinalis hypnoides**	0	0	0	50	0.000
*Hypnum lindbergii**	0	0	3	47	0.000
Racomitrium aciculare	0	0	0	47	0.000
Brachythecium rivulare	0	0	0	46	0.000
*Racomitrium aquaticum**•	0	0	0	45	0.000
*Fontinalis antipyretica**	0	0	0	44	0.000
Scapania americana	0	0	0	43	0.000
Hygrohypnum luridum	0	0	4	42	0.000
Aneura pinguis	0	0	1	40	0.000
Scleropodium obtusifolium	0	0	0	40	0.000
Palustriella commutatum	0	0	4	39	0.000
Schistidium rivulare	0	0	0	37	0.000
Fissidens grandifrons	0	0	12	35	0.000
Riccardia latifrons	0	0	9	34	0.000
*Dicranum pallidisetum**•	0	0	12	33	0.000
Odontoschisma denudatum	0	0	2	33	0.000
Ptilium crista-castrensis	0	0	15	33	0.000
Leskea polycarpa	0	0	9	32	0.000
Plagiothecium piliferum	0	0	9	32	0.000
Brachythecium velutinum	0	0	25	30	0.000
Marsupella sparsifolia	0	0	1	30	0.000
*Plagiochila asplenioides**	0	0	7	27	0.000
Rhytidiadelphus squarrosus	19	15	30	27	0.010
Thamnobryum neckeroides	0	0	16	26	0.000
Pogonatum contortum	20	21	29	26	0.015
Drepanocladus aduncus	0	0	10	25	0.000
Heterocladium procurens	0	0	13	25	0.000
Rhizomnium nudum	0	0	31	25	0.000
*Scapania bolanderi**	15	14	28	25	0.028
Rhytidiadelphus triquetrus	22	18	28	25	0.042
Plagiothecium laetum	28	18	28	25	0.031
Fontinalis neomexicana	0	0	0	24	0.000
*Jungermannia pumila**	0	0	11	24	0.000
*Radula bolanderi**	0	1	2	24	0.000
Tritomaria quinquedentata	0	0	1	24	0.000
Tetraphis pellucida	12	25	4	24	0.050
Polytrichum commune	21	27	22	24	0.000
Dicranella heteromalla	29	26	14	24	0.010
*Bazzania pearsonii**	0	0	0	23	0.001
*Dicranodontium denudatum**	0	0	1	23	0.000
*Diplophyllum plicatum**	0	0	27	23	0.000
*Gymnomitrion obtusum**	0	0	11	23	0.001
Marchantia polymorpha	0	0	27	23	0.000
Sanionia uncinata	27	18	28	23	0.050
Polytrichum juniperinum	29	29	10	23	0.000

Climacium dendroides	0	0	31	22	0.000
*Hypnum pratense**	0	0	24	22	0.001
*Lophozia heterocolpos**	0	0	31	22	0.000
Scapania undulata	0	0	17	22	0.001
Hypnum circinale	19	30	17	22	0.012
Polytrichastrum alpinum	22	19	29	22	0.017
Atrichum selwynii	23	29	23	22	0.004
Dicranum fuscescens	24	30	20	22	0.000
Mnium spinulosum	29	15	29	22	0.017
*Blasia pusilla**	0	0	1	21	0.001
*Calliergonella cuspidata**	0	0	5	21	0.000
*Jungermannia atrovirens**	0	0	5	21	0.000
*Pseudoleskea julacea**	0	0	0	21	0.000
Scapania paludosa	0	0	0	21	0.000
Sphagnum capillifolium	0	0	8	21	0.001
Bazzania denudata	17	28	14	21	0.036
Brachythecium frigidum	25	30	18	21	0.002
Pseudotaxiphyllum elegans	25	35	12	21	0.000
Warnstorfia fluitans	0	0	0	20	0.001
Dicranum scoparium	15	28	15	20	0.025
Plagiomnium medium	17	24	28	20	0.001
Isothecium myosuroides	20	36	20	20	0.000
Eurhynchium pulchellum	25	29	24	20	0.001
Brachythecium nelsonii	0	0	0	19	0.001
Heterocladium macounii	16	19	26	19	0.050
*Plagiochila satoi**	0	0	0	18	0.001
*Plagiochila schofieldiana**	0	0	0	18	0.002
Pleurozium schreberi	13	28	29	18	0.007
Hypnum subimponens	15	41	4	18	0.000
Rhytidiopsis robusta	18	34	14	18	0.000
Blepharostoma trichophyllum	23	32	22	18	0.001
*Claopodium pellucinerve**	0	0	15	17	0.007
Diplophyllum taxifolium	0	4	23	17	0.007
*Hookeria acutifolia**	0	0	1	17	0.004
*Porella roellii**	0	0	9	17	0.003
Ptilidium californicum	16	15	28	17	0.020
*Dicranum majus**	0	0	12	16	0.013
*Metzgeria temperata**	0	0	19	16	0.004
Pellia epiphylla	0	0	1	16	0.005
*Polytrichum longisetum**	0	0	9	16	0.009
Scouleria aquatica	0	0	0	16	0.002
Lepidozia reptans	13	34	14	16	0.001
Lophocolea heterophylla	15	18	29	16	0.009
*Dichelyma uncinatum**	0	0	16	15	0.006
*Douinia ovata**	0	4	18	15	0.034
*Frullania californica**	0	0	3	15	0.003
Plagiomnium cuspidatum	18	30	19	15	0.000
Bryum pallens	0	0	0	14	0.004
*Cirriphyllum cirrosum**	0	0	1	14	0.005
Isopterygiopsis pulchella	0	0	19	14	0.001
*Lepidozia filamentosa**	0	0	9	14	0.016
*Lophozia opacifolia**	0	0	4	14	0.011
Paraleptodontium recurvifolium	0	0	10	14	0.014
*Plagiochila semidecurrens**	0	0	9	14	0.010
Amblystegium serpens	10	32	17	14	0.000
Amphidium lapponicum	0	0	0	13	0.002

*Anacolia menziesii**	0	0	0	13	0.002
*Campylopus fragilis**	0	0	0	13	0.007
*Chiloscyphus pallescens**	0	0	0	13	0.002
*Cololejeunea macounii**	0	0	0	13	0.007
*Dicranella palustris**	0	0	0	13	0.005
Encalypta ciliata	0	0	0	13	0.002
Heterocladium dimorphum•	0	0	0	13	0.009
Jungermannia exsertifolia	0	0	0	13	0.002
Orthotrichum pulchellum	0	0	6	13	0.015
Pellia endiviifolia	0	0	4	13	0.007
*Pleuroclada albescens**	0	0	0	13	0.002
*Pleurozia purpurea**	0	0	0	13	0.007
Preissia quadrata	0	0	0	13	0.007
Riccardia multifida	8	29	33	13	0.000
Hypnum revolutum	17	12	26	13	0.019
Arctoa fulvella•	0	0	0	12	0.007
Brachythecium plumosum	0	0	0	12	0.007
Dichodontium pellucidum	0	0	10	12	0.018
Haplomitrium mniodes	0	0	0	12	0.006
*Jungermannia rubra**	0	0	0	12	0.006
*Loeskypnum badium**	0	0	0	12	0.004
Pohlia longicolla	0	0	0	12	0.005
*Radula obtusiloba**	0	0	0	12	0.007
Riccardia palmata	0	0	17	12	0.002
*Tortula princeps**	0	0	0	12	0.005
Andreaea rupestris	0	0	0	11	0.010
*Campylopus flexuosus**	0	0	0	11	0.013
*Cratoneuron filicinum**	0	0	0	11	0.009
Jungermannia obovata	0	0	0	11	0.012
Philonotis fontana	0	0	0	11	0.011
*Sphagnum palustre**	0	0	0	11	0.012
Tortula ruralis	0	0	10	11	0.022
*Lophozia incisa**	12	26	21	11	0.045
*Bazzania tricrenata**	13	27	7	11	0.014
Anastrophyllum minutum	0	0	0	10	0.014
Barbilophozia barbata	0	0	0	10	0.014
Chiloscyphus polyanthos	0	2	17	10	0.017
*Ditrichum montanum**	0	0	18	10	0.006
Gyrothyra underwoodiana	0	0	7	10	0.042
Nardia scalaris	0	0	0	10	0.014
Oligotrichum aligerum	0	0	0	10	0.016
Plagiothecium cavifolium	0	0	0	10	0.016
Riccia fluitans	0	0	0	10	0.014
Metaneckera menziesii	7	10	33	10	0.000
Anthelia julacea•	0	0	0	9	0.014
*Dicranodontium subporodictyon**	0	0	0	9	0.014
*Diplophyllum imbricatum**	0	0	7	9	0.039
Lophozia gillmanii	0	0	0	9	0.014
Philonotis capillaris	0	0	0	9	0.017
Targionia hypophylla	0	0	0	9	0.012
*Thuidium philibertii**	0	0	0	9	0.014
Tortula muralis•	0	0	0	9	0.019
*Anastrophyllum assimile**	0	0	0	8	0.011
Bazzania trilobata	0	0	0	8	0.012
Dicranodontium uncinatum	0	0	0	8	0.015
Lophocolea cuspidata	0	0	0	8	0.018

Bryhnia hultenii	0	0	0	7	0.040
*Cephaloziella phyllacanthanthoides**	0	0	16	7	0.003
*Frullania tamarisci ssp. nisquallensis**	7	22	12	7	0.048
*Hookeria lucens**	11	20	2	7	0.050
Pogonatum urnigerum	9	33	5	6	0.000
Ptilidium pulcherrimum	10	21	6	6	0.045
Antitrichia californica	0	0	0	5	0.050
*Lophozia wenzelii**	0	12	0	5	0.050
Timmia austriaca	5	45	6	5	0.000
Dicranum tauricum	7	58	3	5	0.000
Leucolepis acanthoneuron	7	51	2	5	0.000
Ditrichum heteromallum	9	34	6	5	0.000
*Homalothecium fulgescens**	9	31	0	5	0.000
*Scapania umbrosa**	9	22	6	5	0.031
Rhizomnium magnifolium	11	24	8	5	0.032
Diplophyllum obtusatum	0	15	8	4	0.050
*Lophozia excisa**	0	11	1	4	0.050
Aulacomnium palustre	6	43	5	4	0.000
Orthotrichum lyellii	7	14	0	4	0.050
Aulacomnium androgynum	8	42	5	4	0.000
*Pseudoleskea radicosa**	8	30	0	4	0.001
Ptilidium ciliare	10	52	0	4	0.000
*Barbilophozia hatcheri**	0	23	0	3	0.002
Cephalozia lunulifolia	0	11	15	3	0.050
Funaria hygrometrica	3	21	0	3	0.005
*Metzgeria conjugata**	0	40	0	2	0.000
*Barbilophozia floerkei**	1	35	0	2	0.000
Bartramia pomiformis	1	17	0	2	0.013
Buxbaumia piperi	1	12	0	2	0.039
Calypogeia trichomanis	1	15	0	2	0.027
*Claopodium crispifolium**	1	21	0	2	0.001
*Dicranoweisia cirrata**	1	21	0	2	0.003
*Fissidens adianthoides**	1	21	0	2	0.005
Oncophorus virens	1	28	0	2	0.000
*Porella cordaeana**	1	21	0	2	0.006
Radula complanata	1	18	0	2	0.015
*Schistostega pennata**	1	16	0	2	0.023
Sphagnum girgensohnii	1	39	0	2	0.000
*Sphagnum squarrosum**	1	34	0	2	0.000
Orthotrichum consimile	2	15	0	2	0.040
Homalothecium aeneum	5	50	1	2	0.000
Ceratodon purpureus	0	68	0	1	0.000
Conocephalum conicum	0	37	2	1	0.000
Bryum pseudotriquetrum	1	62	0	1	0.000
Leptobryum pyriforme	1	62	0	1	0.000
Plagiomnium venustum	1	60	0	1	0.000
*Plagiopus oederiana**	1	36	0	1	0.000
Pohlia annotina	1	56	0	1	0.000
Pohlia cruda	1	66	0	1	0.000
Polytrichum formosum	1	54	0	1	0.000
Polytrichum piliferum	1	65	0	1	0.000
Campylopus atrovirens	0	0	5	0	0.041
Hymenostylium insigne	0	0	5	0	0.050
Ulota drummondii	0	4	0	0	0.050
*Homalia trichomanoides**	1	24	0	0	0.000
Marsupella boeckii	5	0	0	0	0.013

Racomitrium elongatum	8	0	0	0	0.008
Geheebia gigantea	10	0	0	0	0.000
Ulota phyllantha	10	0	0	0	0.000
Racomitrium lawtonae	15	0	0	0	0.000
Andreaea rothii	18	0	0	0	0.001
Anoectangium aestivum	18	0	0	0	0.001
Grimmia incurva	18	0	0	0	0.000
Encalypta procera	20	0	0	0	0.000
Racomitium occidentale	20	0	0	0	0.000
Racomitrium muticum	20	0	0	0	0.000
Racomitrium lanuginosum	22	0	0	0	0.000
Pterigynandrum filiforme	23	0	0	0	0.000
Bryum capillare	30	0	0	0	0.000
*Ditrichum flexicaule**	30	0	0	0	0.000
Racomitrium heterostichum	30	0	0	0	0.000
Racomitrium canescens	33	0	0	0	0.000
Lophozia obtusa	35	0	0	0	0.000

Table 4-6. Species richness multiple regression models for different types of meso-habitats and disturbance in the ICH or CWH (old growth^1 = mainland rainforests and old growth^2 = Island rainforests; environmental variables and measurements defined in table 4-1; slope position codes, mid slope = 1, low slope = 2 and toe position = 3).

Meso-habitat	Disturbance	Regression Equation	R^2	p
ICH dominant (Forest)	old growth	y = 35.975 + 31.194 (large L3 logs) + 13.992 (rocks) + 10.023 (large L4 logs) + 13.218 (intermittent streams) + 3.172 (hygrotope)	0.702	< .001
	fire	y = 25.20 + 11.013 (large L3 logs) + 12.316 (rocks) + 3.943 (base of large trees i.e., vets)	0.666	< .001
ICH restricted				
Stream	old growth	y = -32.969 + 7.331 (No. of microhabitats) + 10.091 (waterfalls > 2m) + 8.406 (logs above stream)	0.838	< .001
	fire	y = 19.278 + 1.148 (No. of microhabitats) + 2.692 (caves) + 2.472 (calcareous rock)	0.816	< .001
Cliff	old growth	y = -47.857 + 8.978 (No. of microhabitats)	0.736	< .01
	fire	y = -5.5 + 3.625 (No. of microhabitats)	0.629	< .01
Seep	old growth	y = 1.4 + 4.0 (No. of microhabitats)	0.775	< .01
	fire	y = 20.935 + 1.226 (No. of microhabitats)	0.776	< .01
CWH dominant (Forest)	old growth^1	y = 12.648 – 6.940 (deciduous trees) + 3.537 (No. of microhabitats) + 6.021 (deciduous snags) – 0.0586 (basal area of logs)	0.811	< .05
	old growth^2	y = 115.690 + 9.906 (deciduous trees) – 1.232 (slope position)	0.571	< .01
	fire/plantation	y = -35.577 + 5.183 (No. of microhabitats)	0.753	< .05
CWH restricted				
Stream	old growth^1	y = 24.068 + 3.246 (No. of microhabitats) + 6.657 (height of falls over 2 m)	0.835	< .05
	old growth^2	y = -72.147 + 6.932 (No. of microhabitats) + 9.521 (height of falls over 2 m)	0.806	< .05
	fire/plantation	y = -9.297 + (No. of microhabitats) + 5.537 (width of stream) + 0.321 (canopy height)	0.877	< .05
Cliff	old growth	y = -3.937 + 2.190 (No. of microhabitats)	0.808	< .001
	fire	y = 13.196 + 0.623 (No. of microhabitats)	0.740	< .001
Seep	no split	y = -22.716 + 5.540 (stand age) + 2.434 (No. of microhabitats) – 0.0578 (density of logs) + 0.071 (basal area of logs)	0.867	< .05

Table 4-7. Environmental bio-indicators that promote high bryophyte diversity in old growth forest.

Biogeoclimatic Zone	**Mesohabitat**	**Environmental variables associated with high bryophyte diversity in old growth cedar-hemlock forest**
CWH (Island)	Forest	Presence of deciduous trees and mid-upper slope positions.
	Stream	High microhabitat diversity* and presence of waterfalls > 2m.
	Seep	High microhabitat diversity.
	Cliff	High microhabitat diversity.
CWH (Mainland Coast)	Forest	Presence of deciduous trees, high microhabitat diversity, deciduous snags, large moderately (L3-L4) decayed logs.
	Stream	High microhabitat diversity and presence of waterfalls > 2m.
	Seep	High microhabitat diversity.
	Cliff	High microhabitat diversity.
ICH	Forest	Large moderately (L3-L4) decayed logs, abundant rocks, frequent intermittent streams and moist hygrotope.
	Stream	High microhabitat diversity, presence of waterfalls > 2m and logs traversing stream.
	Seep	High microhabitat diversity.
	Cliff	High microhabitat diversity.

* High microhabitat diversity includes the maximum number of microhabitats from Table 4-1.

Figure 4-1. Map of the coastal western hemlock (CWH) and interior cedar-hemlock (ICH) biogeoclimatic zones in British Columbia.

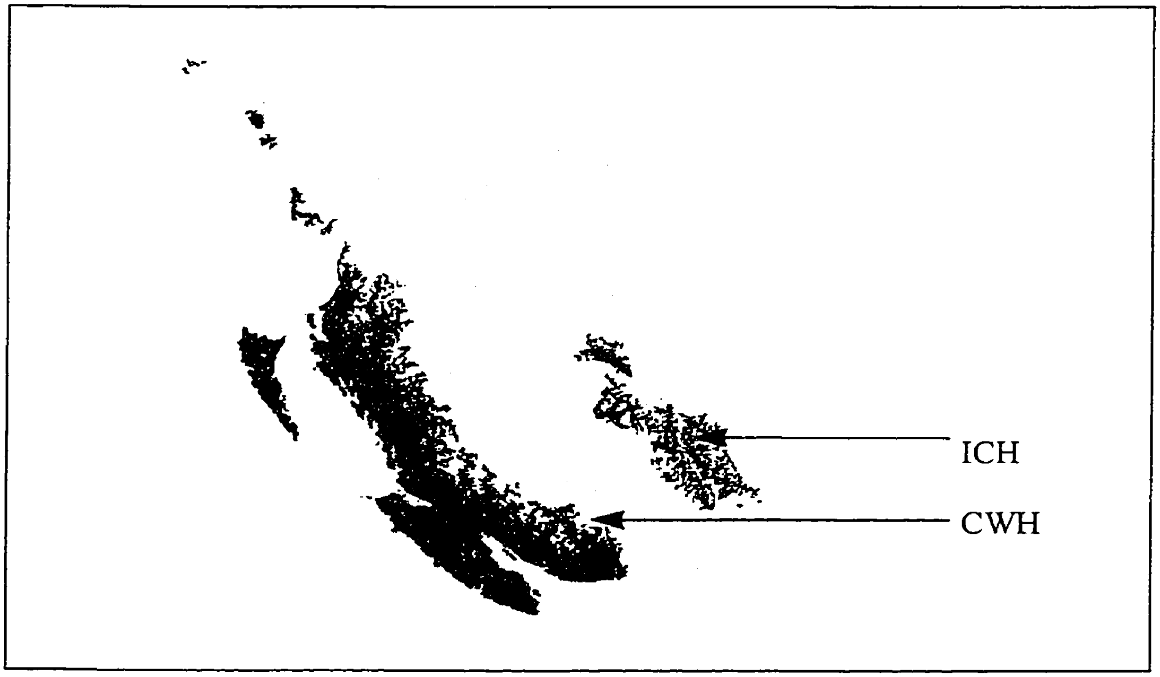


Figure 4-2. NMS ordination diagram of ICH mesohabitats with radiating environmental vectors from the centroid of points.

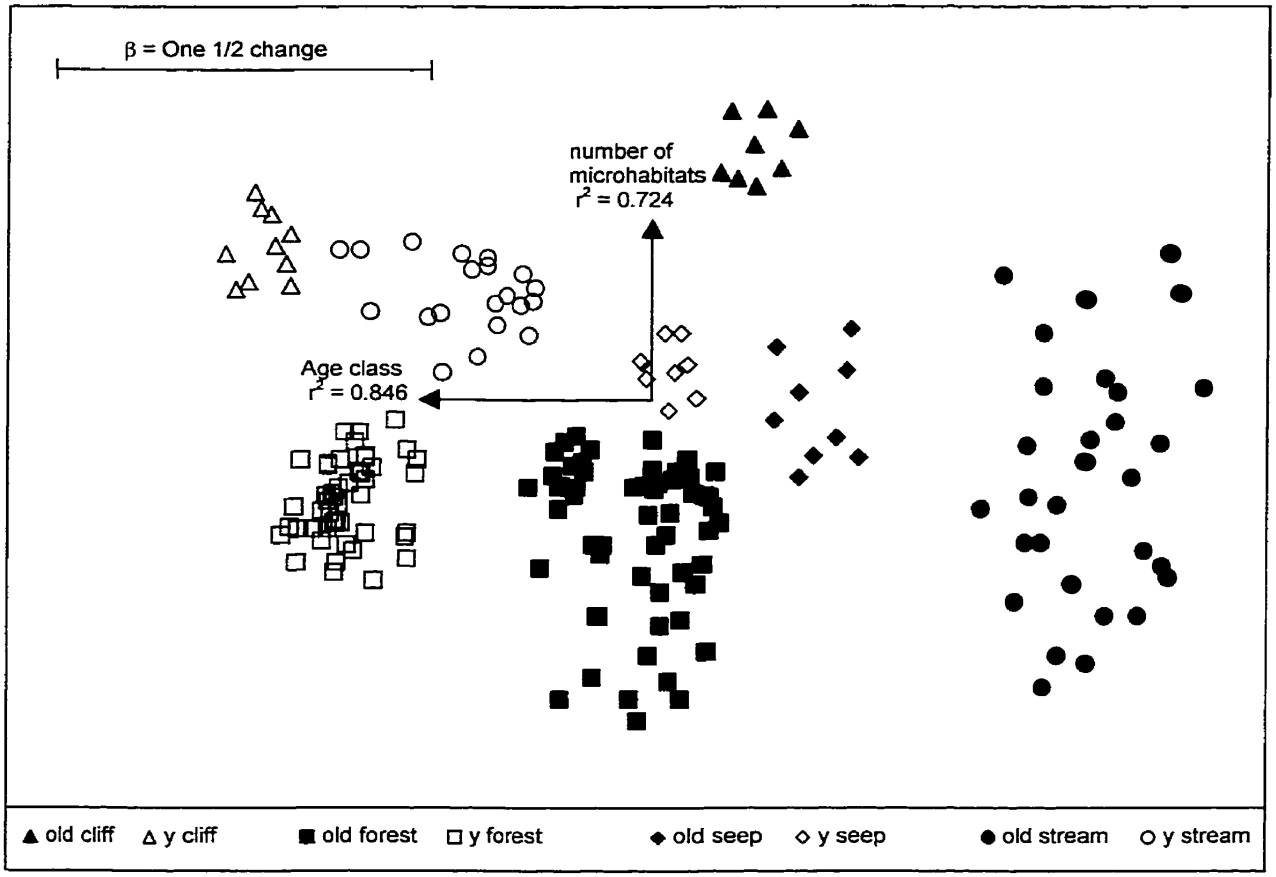


Figure 4-3. NMS ordination diagram of CWH mesohabitats with radiating environmental vectors from the centroid of points.

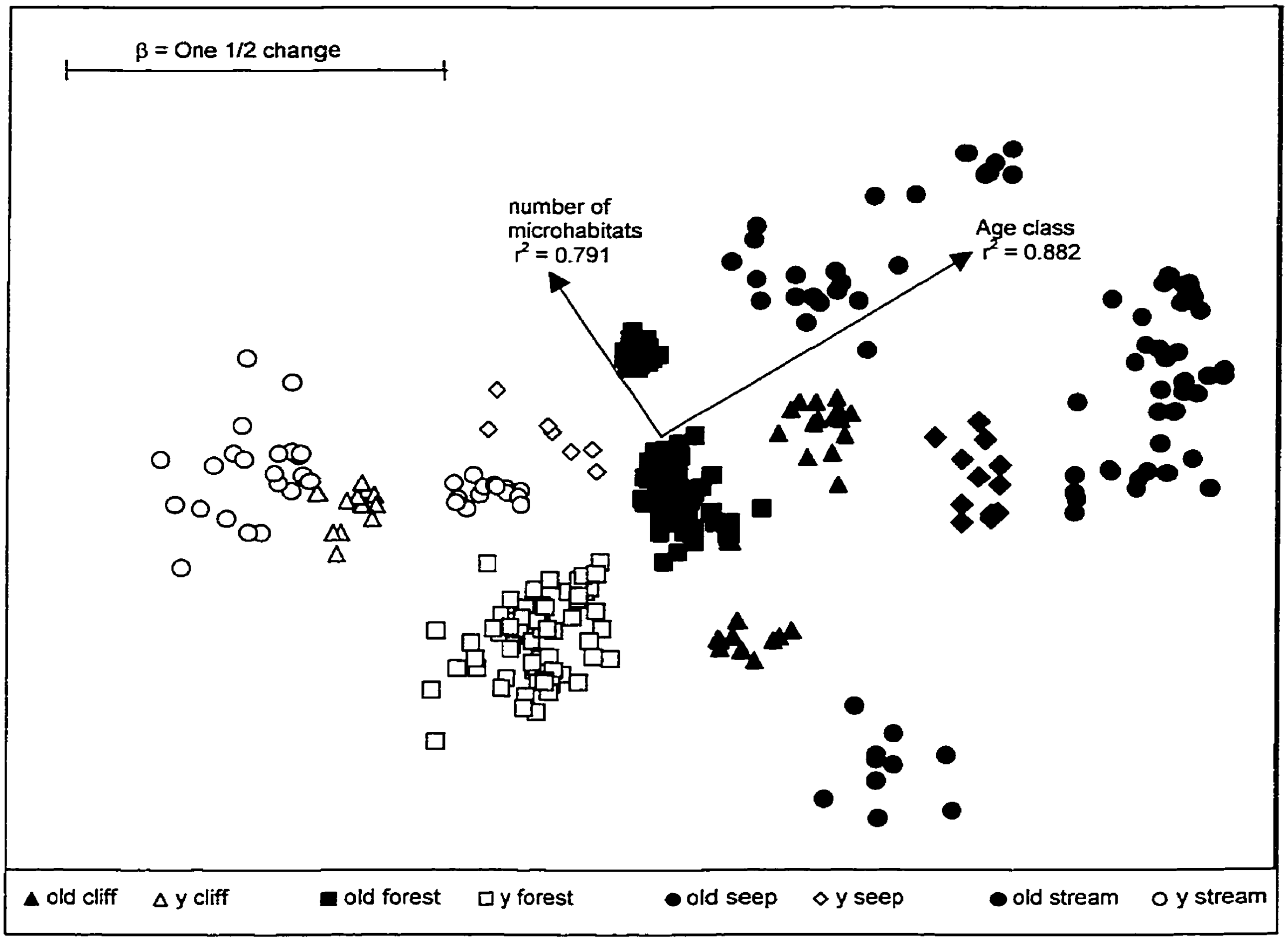


Figure 4-4. Species richness for different meso-habitats within the ICH and CWH. Stands are stratified by disturbance. Error bars are shown for one standard deviation on either side of the mean. (old growth = 250+ yrs, fire = 90 yrs. and logging = 90 yrs.).

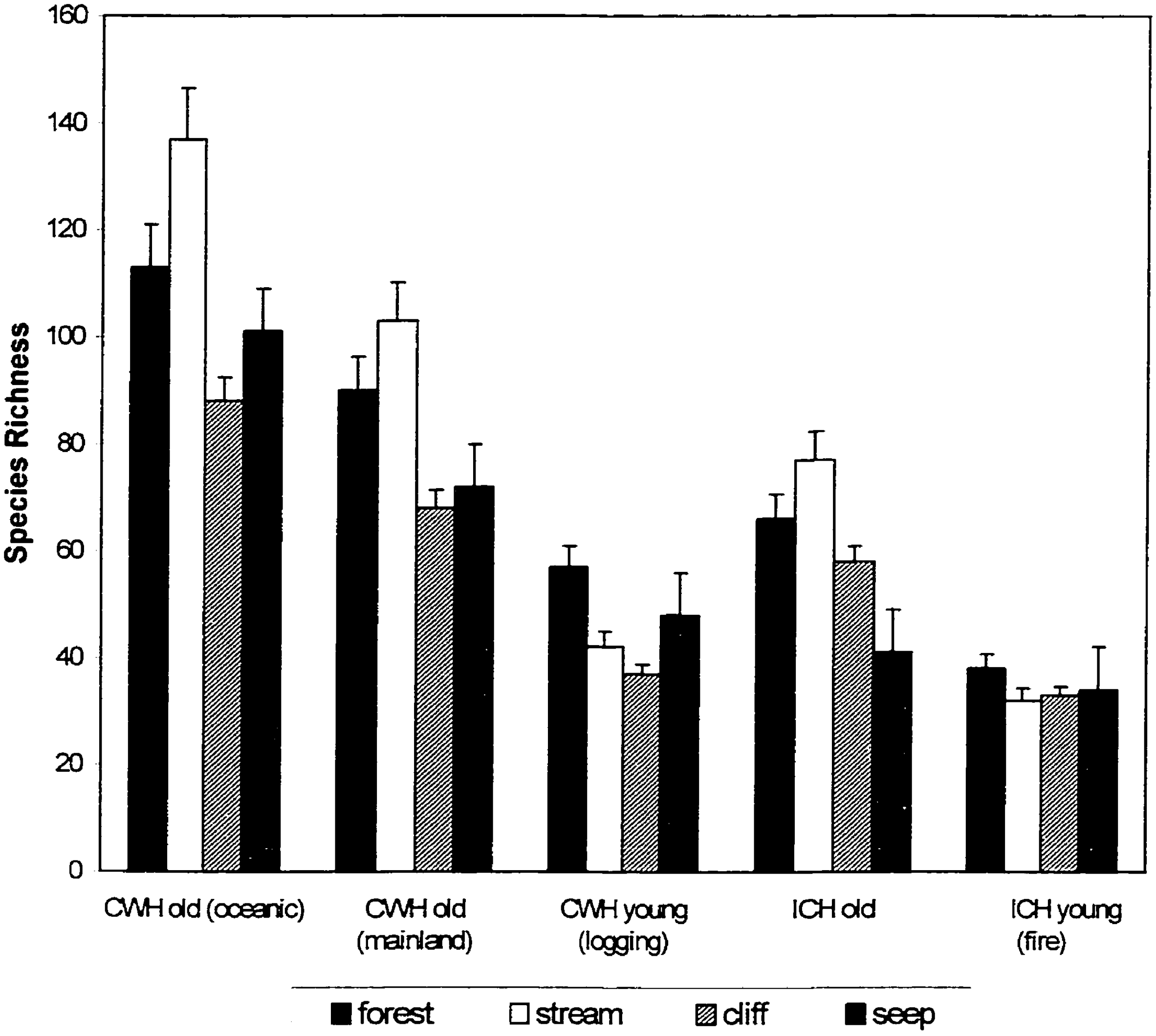


Figure 4-5. Species abundance for different meso-habitats within the ICH and CWH. Stands are stratified by disturbance. Error bars are shown for one standard deviation on either side of the mean. (old growth = 250+ yrs, fire = 90 yrs. and logging = 90 yrs.).

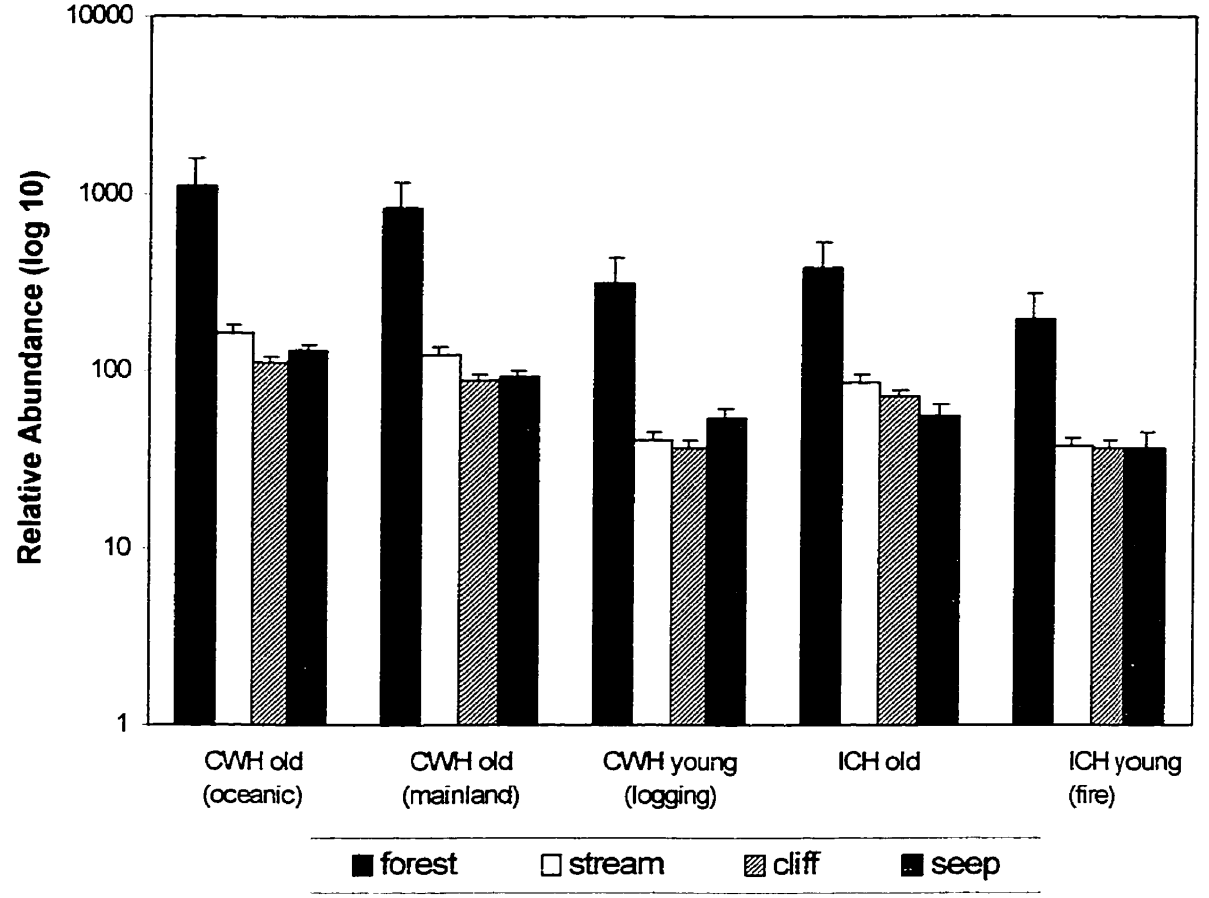


Figure 4-6. CA species ordination of 300 species from 188 meso-habitats in the ICH. Species groups are those delimited by significant (Monte Carlo $p < 0.05$) species indicator values from the PC-ORD Indicator Analysis. Non-indicator species are common to one or more types of mesohabitats.

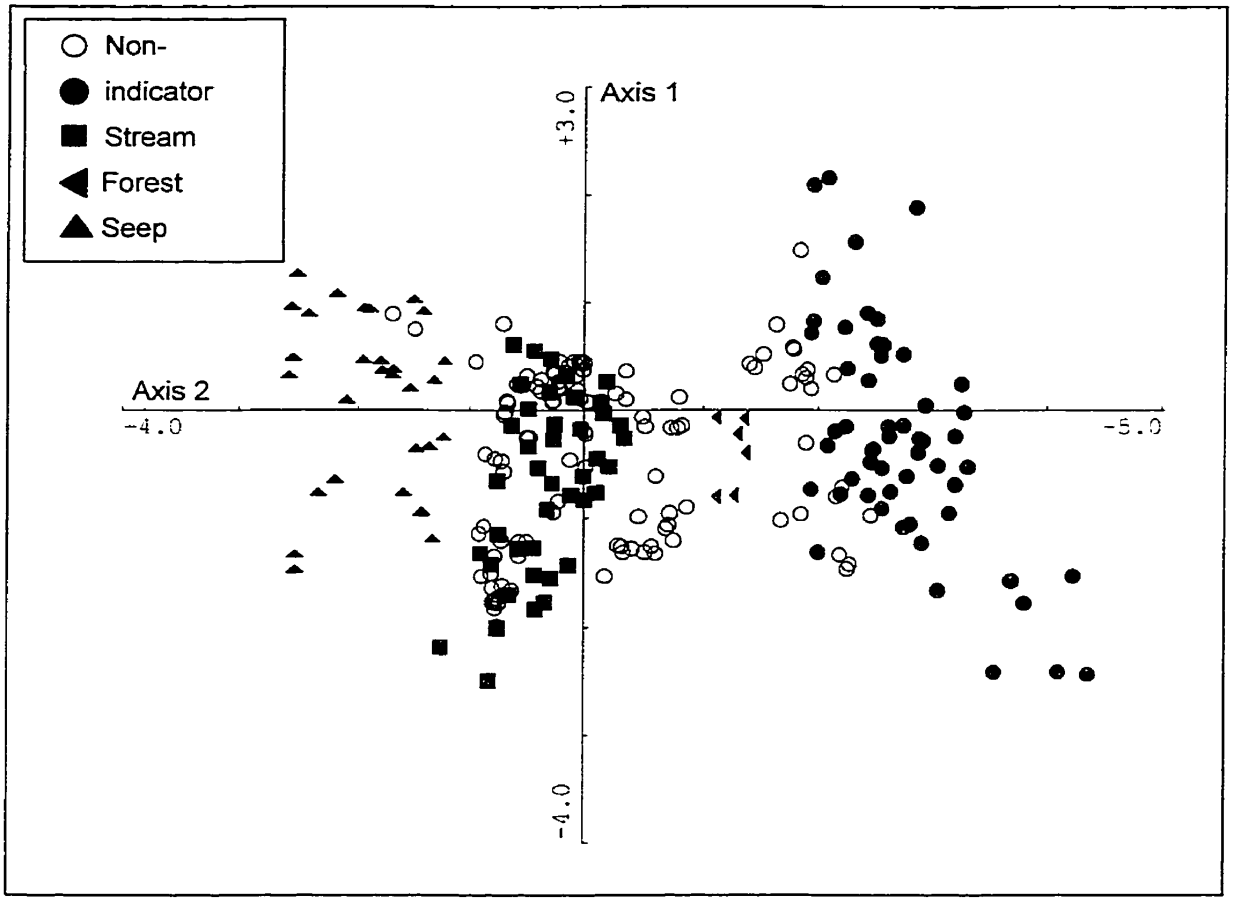
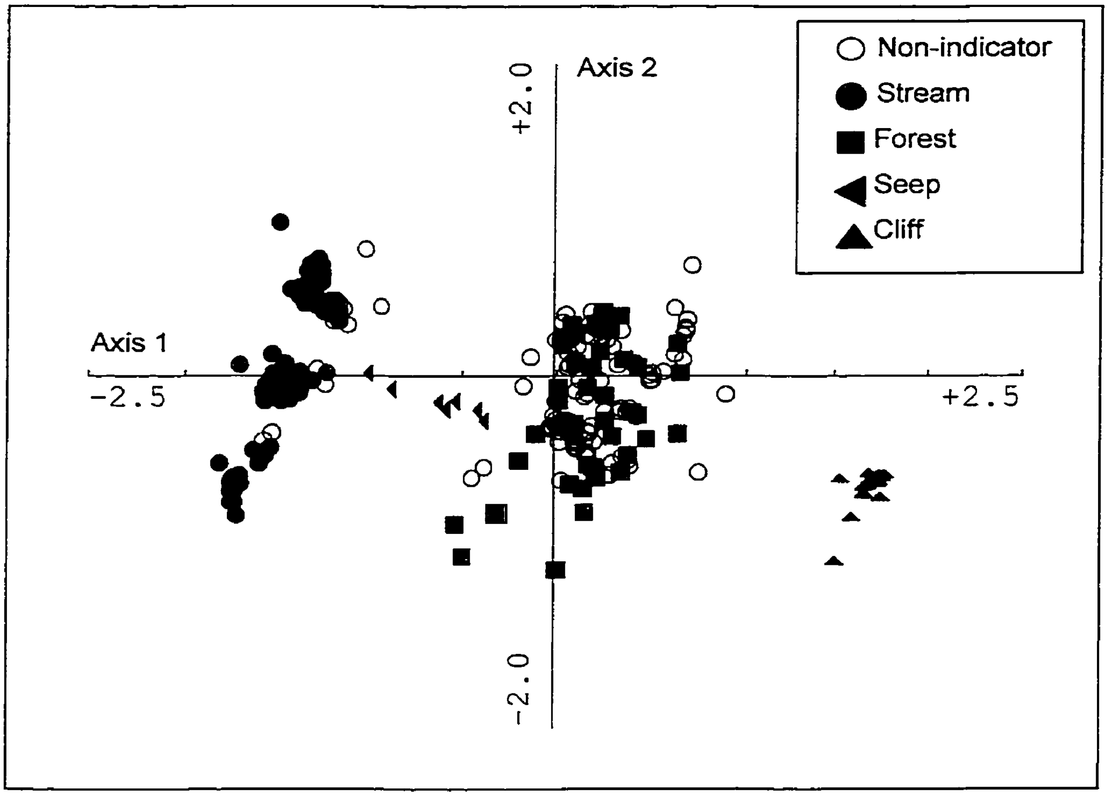


Figure 4-7. CA species ordination of 317 species from 363 meso-habitats. Species groups are those delimited by significant (Monte Carlo $p < 0.05$) species indicator values from the PC-ORD Indicator Analysis. Non-indicator species are common to one or more types of mesohabitats.



LITERATURE CITED

Anderson, L.E., Crum, H.A. & W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93: 448-499.

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Anonymous, 1982. Canadian climate normals, 1951-1980. Vols 1-4. Environment Canada, Atmospheric Environment service, Ottawa, Ontario.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. University of British Columbia, Department of Botany, Vancouver, B.C. Ph.D. Thesis,

Bell, F.W. and S.G. Newmaster. 1998. Fallingsnow Ecosystem Project: Floral richness, abundance and diversity. Pp. 45-47 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (comps.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Belland, R.J. 1989. Floristic boundaries in the Gulf of St. Lawrence region: A numerical approach based on the moss flora. Canadian Journal of Botany 67: 1633-1644.

Belland, R.J. & D.H. Vitt. 1995. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

British Columbia Ministry of Forests. 1995. Biodiversity Guidebook. Forest Practices Code of British Columbia, Victoria, B.C.

Clifford, H.T. & W. Stephenson. 1975. An Introduction to Numerical classification. Academic Press, London, UK.

Crum, H. 1983. Mosses of the Great Lakes forest. University of Michigan, Ann Arbor.

Dufrêne, M. & P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymetrical approach. Ecological Monographs 67: 345-366.

Djan-Chekar, N. 1993. The bryophyte flora of bridal veil falls, British Columbia: An analysis of its composition and diversity. Masters Thesis, University of British Columbia.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic, and social assessment. U.S. Government Printing Office, Washington, D.C.

Franklin, J.F. & T. Spies. 1991. Composition, function, and structure of old-growth douglas-fir forests. in L.F. Ruggiero, K.B. Aubury, A.B. Carey & M.H. Huff (eds.), *Wildlife and Vegetation of Unmanaged Douglas-fir Forests*. Technical Report PNW-GTR-285. USDA Forest Service, Pacific Northwest Research Station, Portland.

Franklin, J.F. 1993. Lessons from old-growth. Journal of Forestry 91: 10-13.

Gignac, D.L. 1986. Ecological tolerance and niche structure of *Sphagnum* along a pollution gradient near sudbury, Ontario, Canada. Can. J. Bot. 65: 1138-1147.

Gignac, D.L. & D.H. Vitt. 1994. Responses on northern peatlands to climatic change: Effects on byophytes. Journal of the Hattori Botanical Laboratory 75: 119-132.

Goward, T. & T. Ahti. 1992. Macrolichens and their zonal distribution in Wells Gray Provincial Park and its vicinity, British Columbia, Canada. Acta Botanica Fennica 147: 1-60.

Goward, T. 1993. Epiphytic lichens: going down with the trees. pp. 153-158. In Rautio, S. (ed.), Community action for endangered species: a public symposium on B.C.'s threatened and endangered species and their habitat. Federation of British Columbia Naturalists, Vancover, British Columbia.

Goward, T. 1994a. Living Antiquities. Nature Canada 21: 14-21.

Goward, T. 1994b. Notes on old-growth dependent epiphytic macrolichens in inland British Columbia, Canada. Acta Botanica Fennica 150: 31-38.

Gustafsson, L. & T. Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological Conservation 44: 283-300.

Horton, D. G. 1988. Microhabitats of New World Encalyptaceae (Bryopsida): distribution along edaphic gradients. Beifefte zur Nova Hedwigia 90: 261-282.

Krebs, C.J. 1997. Ecological Methodology. Harper Collins, New York.

Kruskal, J.B. 1964. Non-metric multidimensional scaling: a numerical method. Psychometrika 29: 115-129.

Lertzman, K.P., G. Sutherland, A. Inselberg, & S. Saunders. 1996. Canopy gaps and the landscape mosaic in a temperate rain forest. Ecology 77: 1254-1270.

Lertzman, K.P., T. Spies & F.Swanson. 1997. From ecosysytem dynamics to ecosystem management. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton University Press, New Jersey.

Marino, P.C. & N. Salazara. 1991. Tropical epiphyllous hepatic communities growing on two species of shrub in Barro Colorado Island, Panama: the influence of light and microsite.Lindbergia 17: 91-95.

McAlister, S. 1995. Species Interactions and substrate specificity among log-inhabiting bryophytes species. Ecology 76: 2184-2195.

McCune, B. & M.J. Mefford. 1997. PC-ORD. Multivariate analysis of ecological data, version 3.0. MjM Sofware Design, Gleneden Beach, OR.

Meidinger, D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6

Minchin, P. 1987. An evaluation of the relative robustness of techniques for ecological ordination. Vegetatio 69: 89-107.

Naiman, P.J. & E.C. Anderson. Streams and rivers: Their physical and biological variability. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Newmaster, S.G. & F.W. Bell. 2000. Floristic diversity of cryptograms in a boreal-mixedwood stand after mechanical, manual and herbicide conifer release treatments. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Submitted to CJFR.

Nicholson, B.J. & L.D. Gignac. 1995. Ecotope dimensions of peatland bryophyte indicator species along gradients in the Mackenzie River Basin, Canada. The Bryologist 98: 437-451.

Pielou, E.C. 1966. Species-diversity and pattern-diversity in the study of ecological succession. Journal of Theoretical Biology 10: 370-383.

Pike, L.E., W.C. Denison, D.M. Tracey, M. A. Sherwood and F. M. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing in old-growth conifers in western Oregon. The Bryologist 78: 1-39.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Rose, F. 1992. Temperate forest management: Its effects on bryophyte and lichen floras and habitats. In Bates, J.W. & A.M. Farmer (eds.), *Bryophytes and lichens in a changing environment*, Clarendon Press, Oxford, pp. 211-232.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Schuster, R. 1949. The ecology and distribution of Hepaticae in central and western New York. American Midland Naturalist. 42:513-712.

Shaw, A.J. 1981. Ecological diversification among nine species of *Pohlia* (Musci) in western North America. Canadian Journal of Botany 59: 2359-2378.

Slack, N.G. 1988. The ecological importance of lichens and bryophytes. Bibl. Lichenol 30: 23-53.

Söderström, L. 1988. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1990. Dispersal and distribution patterns in patchy, temporal habitats. pp. 103-113. In Krahulec, F., A.D.Q. Agnew, S. Agnew & J.H. Willems (eds.), Spatial processes in plant communities. SPB Academic Publishing, The Hague.

Söderström, L. T. 1993. Substrate preference in some forest bryophytes: a quantitative study. Lindbergia 18: 98-103.

SPSS. 1999. Professional base system software for statistical analysis. Chicago, Illinois.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

ter Braak, C.J.F. 1998. CANOCO 4. Centre for Biometry, Wageningen, The Netherlands.

USDA & USDI. 1994. Record of decision for amendments to Forest Service and bureau of Land Management planning documents within the range of the Northern Spotted Owl. 1994-589-111/00001. U.S. Government Printing Office, Washington, D.C.

Virtanen, V. 1995. Floristic composition and habitat ecology of stream bryophytes in Lohja parish, southern Finland. Annales Botanici Fennici 32:179-192.

Vitt, D.H., Y. Li & R.J. Belland. 1995. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Vitt, D.H., P. Achuff & R.E. Andrus. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Canadian Journal of Botany 53: 2776-2795.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1- 12.

Vitt, D.H. & W.L. Chee. 1990. The relationships of vegetation to surface water chemistry and peat chemistry in fens of Alberta, Canada. Vegetatio 89: 87-106.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21: 213-251.

Chapter 5.

Forest Microhabitat Heterogeneity: The Primary Roots of Bryophyte Diversity

INTRODUCTION

Bryophyte communities are closely associated with their substrate or microhabitat. It has long been known that some species occur on specific microhabitats (Watson 1980; Crum 1983; Horton 1988). Relationships between peatland microhabitats and bryophyte vegetation patterns have been well studied (Belland & Vitt 1995; Vitt et al. 1995; Slack et al. 1980). In terrestrial ecosystems, detailed studies of microhabitats have been completed on trees (Barkman 1958; McCune 1993; Sillet 1995; Slack 1976; Pike et al. 1975), logs (Soderstrom 1988a, 93; McAlister 1995; McCullough 1948; Muhle and LeBlanc 1975), rocks (Jonsgard & Brooks 1993; Jonsson 1993; Clerc and Herrera-Campos 1997; Garty & Binyamini 1990; Vitt 1991) and forest floor microhabitats (Carlton 1990; Frego & Carleton 1995a, 95b; Rambo & Muir 1998a; Newmaster et al. 1999). These studies clearly show that bryophytes are found in very specific habitats such as the vertical distribution of bryophytes on trees or among different log sizes and decay classes. Habitat heterogeneity is therefore one of the main processes that can account for patterns in community composition.

Diverse substrate types or microhabitats have been positively correlated with bryophyte species richness (Edwards 1986; Lee & La Roi 1979; Rambo & Muir 1998b). Bryophyte diversity increases with the number of suitable habitats (Slack 1977). Patterning of bryophyte diversity is largely dependent on the quantity and quality of mesohabitats (i.e., streams, cliffs), and the quality of a mesohabitat is determined by the number of microhabitats (i.e., rocks, logs) found within them (Vitt & Belland 1997; Belland & Schofield 1994; Newmaster thesis chapter 3). Habitat heterogeneity is therefore one of the main processes that can account for patterns in bryophyte diversity.

The Biodiversity Guidebook of the British Columbia Forest Practices Code (BC Ministry of Forests 1995) is predicated on the idea of conserving biological diversity by developing a conservation strategy with the emphasis on habitats, ecosystems and landscapes. Forest managers are now faced with the challenge of fostering old growth-associated biodiversity in younger managed stands (USDA & USDI 1994; Rambo & Muir 1998a). Patterning of bryophyte diversity in cedar-hemlock forests is largely determined by the quantity and quality of mesohabitats (Newmaster thesis chapter 3). The quantity of a mesohabitat refers to the number and types of mesohabitats in a forest stand. The quality of a mesohabitat refers to the number and types of microhabitats in a specific mesohabitat. An understanding of patterning of bryophyte diversity on different forest microhabitats at both temporal and spatial scales will assist in management decisions concerning bryophyte conservation.

My objectives are to relate patterning of diversity with habitat heterogeneity at both temporal and spatial scales. More specifically we attempt to answer the following questions: 1) At the local scale (between stands), do microhabitats have variable species richness, species communities and indicator values? If so, are there temporal differences (different age classes) in the patterning of bryophyte diversity on microhabitats, and which microhabitats are most important in fostering high bryophyte diversity, 2) At the regional scale (between biogeoclimatic zones), are there differences in the patterning of bryophyte diversity on microhabitats?

STUDY AREA

Sampling was conducted in British Columbia, Canada, within two distinct biogeoclimatic zones; the Coastal Western Hemlock zone (CWH) and Interior Cedar Hemlock zone (ICH - Meidinger and Pojar 1991). The CWH is located on the westerly edge of the Coast Mountains and is also known as Canada's coastal temperate rainforest (Fig. 5-1). The ICH is located in the Caribou Mountains in B.C.'s interior and on the interior side of the Coast Mountains in Northern B.C. (Fig. 5-1). The wetter portions of the ICH (wk1 & vk1 variants) are known as inland oroboreal rainforests (Goward & Ahti 1992). Detailed descriptions of glacial history, climate and floristics can be found in Schofield (1988), Arsenault (1995), Hebda (1995), Schoonmaker et al. (1997) and Newmaster (thesis chapter 2).

The ICH is divided into two geographically distinct areas. The smaller, most northerly area is located between 55° N and 57° N on the leeward slopes and adjacent lowlands of the Coast Mountains. The larger, more southerly area occupies a 200 km wide band from the Canada-U.S.A. border (at 49° N) to northern Caribou Mountains (approximately 54 ° N) (Goward 1995). The study area was located at 50-53° N and 199-120° W, within the Wells Gray (including Azure Lake and Mad River), upper Adams and upper Seymour watersheds of the ICH biogeoclimatic Zone. This sampling area represents the ICHmw3, ICHwk1 and ICHvk1 biogeoclimatic variants (Meidinger & Pojar 1991). Precipitation ranges from 900-1400 mm per year, with the highest precipitation in early winter. Snow pack over 1.5 meters deep is typical for much of the area. Mean temperatures during the warmest month averages between 16 °C and 21 °C, and during the coldest month from -3 °C to -10 °C. The ICH is the most productive zone in the interior and has the widest variety of coniferous tree species of any zone in B.C. Western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*) are the dominant trees. The wettest sites are dominated by an under story of skunk cabbage *(Lysichiton americanum*) and devils club (*Oplopanax horridus*).

Within the CWH, research was focused on two geographically distinct areas: the mainland coast and the west woast of Vancouver Island. On the mainland coast sampling was conducted in the Capilano and Seymour watersheds of the greater Vancouver watershed. On the west coast of Vancouver Island, sampling was conducted in the Tofino, Clayoquot, Sidney and Walbran watersheds. All of the sampling occurred within the CWHvm1 biogeoclimatic variant. These coastal rainforests typify the most humid and highly oceanic region of North America. Mean annual precipitation ranges from 1000 to 4,400 mm, three-quarters of which occurs in the winter months as rain. Mean temperatures average between 13°C and 18.5°C in the warmest months and –6.5 °C and 4.5 °C during the coldest months. Predominant species are western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), amabilis fir (*Abies amabilis*) and coastal douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) (Alaback & Pojar 1997).

METHODS

Sampling method - Floristic habitat sampling (FHS - Newmaster thesis chapter 1) was used to assess patterns in bryophyte community composition over the period of two field seasons. In 1996, 102 stands were sampled in the interior cedar-hemlock (ICH). Stands were chosen from the Wells Gray, upper Adams River, and Seymour watersheds. Within these watersheds sampling was evenly distributed between stands that were burned approximately 80 years ago (age class 4), and old-growth stands of 250+ years in age (age class 9). In 1997, 185 stands were sampled in the coastal western hemlock (CWH). Stands were chosen from the Capilano and Seymour watersheds along the mainland coast and in the Sidney, Clayoquot, Tofino and Walbran watersheds along the western coast of Vancouver Island. Extensive logging activities in the Capilano and Seymour watersheds allowed a balanced sampling between stands that were logged 80 years ago, and old-growth stands of 250+ years in age. Sampling on Vancouver Island was limited to old stands due to the relatively recent logging activity and lack of fire history in the CWH.

Species nomenclature follows Anderson et al. (1990) for mosses and Stotler & Crandall-Stotler (1977) for hepatics. Collections were made at each stand of common and rare species (occurring in less than 15% of stands). Voucher specimens are deposited in the University of Alberta Cryptogamic Herbarium (ALTA), Kamloops Forest Region Herbarium, and University of British Columbia Herbarium (UBC).

Analyses – Bryophyte diversity (Whittaker 1965) was assessed using total species richness (S) and mean species richness (s) for each forest microhabitat (Table 5-1). Species frequency was tabulated for each microhabitat. Both species richness and frequency were stratified by age class (young = 80 years; old 250 years) and biogeoclimatic zones (ICH/CWH). The CWH biogeoclimatic zones were divided into mainland temperate rain forests and island temperate rain forest. Stand dynamics, and general site variables (i.e., percent cover of rocks) were assessed within the 20 m diameter quadrat. Coarse woody debris data were obtained using two 50 m transects, with measurements of logs at each transect intersection.

Community structure in microhabitats (ICH or CWH exclusively) using the species data was analyzed with non-metric multidimensional scaling (NMS; Kruskal 1964; McCune & Mefford 1997). Grouping of microhabitats indicates similarity in beta diversity (measured as half changes), therefore distances between groups of microhabitats indicates differences in community structure. Microhabitats were stratified by age class (young = 80 years; old 250^{+} years) and in the CWH oceanity. The Bray Curtis distance measure was used because of its robustness for both large and small ecological gradients (Minchin 1987). Data were standardized by species maxima. Two-dimensional solutions were appropriately chosen based on plotting a measure of fit ("stress") to the number of dimensions. One hundred iterations were used for each NMS run, using random start coordinates. The first two ordination axes were rotated to enhance interpretability with the apparent temporal (time since last major disturbance) and habitat heterogeneity (number of microhabitats) gradients.

The relative importance of a microhabitat was estimated using the method of Dufrêne and Legendre (1997) in PC-ORD software (McCune & Mefford 1997) to analyze indicator values for species within *a priori* microhabitats. The "indicator value" combines, by multiplication, the abundance of a species in each microhabitat relative to its abundance in all microhabitats, with that species's frequency of occurrence in the sample units of the designated microhabitat (Rambo & Muir 1998a, 1998b). The "indicator value" describes the relative importance of a microhabitat with respect to the indicator species that occur on that microhabitat. A Monte Carlo (Krebs 1997) analysis was used to assess statistical significance based on the proportion of 1,000 randomized trials that equaled or exceeded the maximum indicator value for a species. Only significant indicator values ($p < 0.05$) are presented.

RESULTS

Local Patterns of Diversity on Microhabitats

At the local scale, patterning of bryophyte diversity on microhabitats is compared within stands in either the ICH or CWH biogeoclimatic zones. There are many types of microhabitats, each with its unique species richness, species composition, indicator value (species frequency) and density. Species richness is not the same for the 28 different microhabitats (Fig. 5-2, 5-3 & 5-4). Consideration of both the total and mean species richness is important for differentiating between common and isolated species occurrence. Pattern diversity (i.e., changes in community composition between different microhabitats (Whittaker 1965) is evident when there is a separation of site clusters along the NMS ordination axes (Fig. 5-5). Each group on the ordination axis is associated with a specific microhabitat and separation of groups of microhabitats indicates that beta diversity is variable between various types of microhabitats or at least groups of microhabitats (e.g., coniferous and deciduous tree microhabitats - Fig. 5-5; Table 5-2, 5-3, 5-4 & 5-5). Indicator value of microhabitats is not equal for different types of microhabitats (Figs. 5-3, 5-4 & 5-5). Differences in species richness, community composition and indicators for each type of microhabitat within a biogeoclimatic zone can be explored within the following broad groups of microhabitats; tree (epiphytic), log (epixylic) and ground (terricolous & saxicolous).

Tree Microhabitats

Interior Cedar Hemlock – Species richness, microhabitat community composition and indicator value can be used to identify important epiphytic microhabitats within either young (80 years) or old (250^{+} years) forests. Tree having bases of medium size (30-60 cm diameter) conifers had the highest species richness in either young or old forests (Fig. 5-2). NMS ordinations of all epiphytic microhabitats using species data resulted in distinct clusters of conifer epiphytes and deciduous epiphytes regardless of stand age (Fig. 5-5). The species composition on deciduous microhabitats is relatively similar to conifer microhabitats (Table 5-4). In old forest, the conifer epiphytes on tree bases are in a separate NMS group from the epiphytes found on the tree trunk. Many hepatics and other terricolous species were associated with the tree base and not the tree trunk in old growth forest (Table 5-3). Indicator values were highest for tree bases among the epiphytic microhabitats (Fig. 5-2).

Coastal Western Hemlock – Epiphytic richness and community composition is dependent on microhabitat type and stand age. In young stands, species richness is highest on medium-large (>30 cm diameter) tree bases or trunks (Fig. 5-2). Tree bases offer the highest mean species richness and indicator value. The number of epiphytes found on tree trunks in young forests is relatively low even though there is almost twice the density of trees than that found in old growth forests (Table 5-2). Deciduous trees in young forests offer habitats for a small but unique assemblage of epiphytes (Table 5-5). In old growth forest both medium-large tree bases and trunks have the highest species richness (Fig. 5-2). NMS ordinations clearly distinguish groups of tree microhabitats by size (> 30 cm diam.) and position (tree base or trunk). Furthermore, deciduous tree microhabitats seperated from coniferous tree microhabitats along the first NMS axis (Fig. 5-5). Several unique epiphytes are found specifically or more frequently on deciduous trees (Table 6). Indicator values for epiphytes are high for all microhabitats on trees greater than 30 cm in diameter.

Log Microhabitats

Interior Cedar Hemlock – Species richness, microhabitat community composition and indicator value can be used to identify important epixlyic microhabitats within either young (80 years) or old (250^{+} years) forests. In both young and old forest, species richness was highest on medium (30-60 cm diam.) or large (>70 cm diam.) logs of decay class D3. In old forest, log microhabitats are grouped using NMS into four broad groups (Fig. 5-5), 1) Deciduous snags, 2) conifer snags, twigs and decay class one logs, 3) decay class three logs, 4) decay class five logs. Hepatics are very frequent on medium and large well-decayed logs (decay class 3 & 5). Microhabitat indicator values are highest for medium to large logs of decay classes D3 and D5 (Fig. 5-3). Log density is higher in young forests and snag density is approximately equal in both age classes.

Coastal Western Hemlock – Important epixylic microhabitats can be identified using species richness, microhabitat community composition and indicator values. The patterns of species richness on microhabitats are similar for either young or old forests (Fig. 5-3). Logs greater than 30 cm in diameter of decay class three or five have the highest species richness. Species richness is higher in old forest, particularly on large logs that are infrequent in the young forest. Log density is twice as high in old growth forests than young forests (Table 5-2). In young forest, the NMS ordination of log microhabitats separated clusters based on size and decay class (Fig. 5-5). Epiphytic species associated with snags, twigs, and lowest decay class are on the right side of the ordination. Epixylic species associated with logs in decay classes three and five are on the left side of the ordination. In old forest, NMS clusters were well separated based on the size and decay class of the log microhabitat (Fig. 5-5). Deciduous snags were grouped on the far right side of the ordination. These habitats contain epiphytic species associated with deciduous trees (Table 5-6). Twigs, conifer snags and logs of low decay class are found in clusters near the center of the first ordination axis. Epiphytic species occur frequently on these microhabitats. Logs of decay class three and five are found on the left side of the ordination (Fig. 5-5). Epixylic species (mainly hepatics) are frequently found on these microhabitats (Table 5-6). Microhabitat indicator values are highest for logs larger than 30 cm in diameter in a decay class greater than three (Fig. 5-3).

Ground Microhabitats

Interior Cedar Hemlock – Ground microhabitats are distinguished by species richness, indicator values and to a lesser extent community composition. Rock habitats harbor the highest species richness of all the ground microhabitats in both young and old forest (Fig. 5-4). Species richness is higher in the older forest, but the percent cover of rock is not significantly different ($p > 0.05$). Tree roots and organic soil are also microhabitats with high species richness. In old forests, stumps offer habitat for relatively high species richness. The community composition of forest microhabitats is not as well defined as either epiphytic or epixylic microhabitats (Fig. 5-5). NMS ordination grouped stump and organic soil microhabitats in close proximity. Terricolous species commonly found on organic soils were found also on stumps, but with less frequency (Table 5-3, 5-4). NMS Ordination also grouped tree root and mineral soil microhabitats in close proximity. Colonizing species are associated with both types of microhabitats. Some saxicolous species are restricted to only rock microhabitats in old growth forests (Table 5-3). Some epixylic hepatics are associated with stumps in old growth forests. Microhabitat indicator values were high for rocks in young forests and rocks, mineral soil, and stumps in only the old growth forests (Fig.4).

Coastal Western Hemlock – Ground microhabitats are less distinct in terms of species richness, species composition and indicator value than either tree or log microhabitats. Tree roots, stumps, organic soil and rocks offer the highest species richness in both young and old forests (Fig. 5-4). In young stands, stumps offer refugia for both remnant epiphytic and epixylic species (mostly hepatics) (Table 5-6). The species composition of the remaining forest floor microhabitats are largely overlapping (Fig. 5-5; Table5). In old growth forests, saxicolous species are shared between intermittent stream and rock microhabitats (Fig. 5-5; Table 5-6). Mean species richness is higher in old growth forests (especially in oceanic forests), but the percent cover of rock is not significantly different (< 0.001 – Table 5-2). Terricolous and epixylic species are shared between tree root, organic soil, stump, and intermittent stream microhabitats. The species composition on mineral soil microhabitats is very different from the other forest microhabitats. Exposed mineral soil is an uncommon microhabitat in undisturbed forest and is usually quickly populated with colonizing species (Fig. 5-5).

Regional Patterns of Diversity on Microhabitats

At the regional scale, patterning of bryophyte diversity on microhabitats is compared between the ICH and CWH biogeoclimatic zones. There are many similarities and differences in species richness, community composition, and indicator value between ICH and CWH forests of similar age. Similarities include: high diversity of epiphytes on large (> 30 cm diameter) trees; high diversity of epixylics on large (> 30 cm diameter), well decayed (> D3) logs; high diversity of forest floor bryophytes on organic soil, tree stumps, upturned tree roots, and rocks. Differences in species richness and microhabitat community composition between the ICH and CWH biogeoclimatic zone can be explored more coherently within the following broad groups of microhabitats; tree (epiphytic), log (epixylic) and ground (terricolous & saxicolous).

Tree microhabitats – There are small differences in the patterning of epiphyte species richness, and community composition between the ICH and CWH biogeoclimatic zones. In young forests, species richness in young trees and deciduous microhabitats is higher in the ICH when compared to the CWH (Fig. 5-2). NMS ordinations group the deciduous microhabitats within young forests in the top right corner and the coniferous microhabitats near the center in both biogeoclimatic zones (Fig. 5-5). Only in the CWH do tree size and position (base and trunk) separate coniferous microhabitats. In old forest, species richness in all tree microhabitats is higher in the ICH when compared to the CWH (Fig. 5-2). Both tree size and position (trunk and base) define community composition of old growth epiphytes in the CWH; only position defines epiphyte communities in the ICH (Fig. 5-5). Epiphyte microhabitat indicator values are higher in the CWH for either young or old forest. Tree density is slightly higher in the ICH for either young or old forest (Table 5-2).

Log microhabitats - Differences in epixylic species richness and habitat community composition exist between the ICH and CWH. Snags and twigs have higher total species richness in the ICH, but lower mean species richness in the CWH regardless of stand age. Snag density in old forests is higher in the ICH, but not significantly different ($p = 0.382$) in young forests (Table 5-2). The ICH has higher total species richness for logs greater than 30 cm in diameter in decay classes greater than three, but the CWH has higher mean species richness on these same microhabitats (Fig.3). Log density in young forest is higher in the ICH, but for older forests it is higher in the CWH (Table 5-2). Indicator values for snags, twigs and logs are higher in CWH than the ICH in either young or old forests (Fig. 5-5-3, 5-4). Community composition in the ICH is less defined. Many of the NMS ordination groups overlap in the ICH in both young and old stands (Fig. 5-5). Within the CWH, the NMS ordination groups are well separated, particularly in the old growth forests.

Ground microhabitats – Patterning of species richness and community composition of bryophytes on ground microhabitats is not the same for different biogeoclimatic zones. Total species richness on rocks, upturned tree roots, stumps and organic soil is higher in the ICH than the CWH regardless of stand age (Fig. 5-4). Mean species richness and indicator value on upturned tree roots, stumps and organic soil is higher in the CWH in either young or old forest. In young forests, rock microhabitats have higher indicator values in the ICH. The percent cover of rocks is significantly higher ($p < 0.001$) in the ICH than the CWH for both young and old stands (Table 5-2). Upturned tree roots, stumps and organic soil microhabitats have the highest indicator values in the CWH. NMS clusters of ground microhabitats are not well separated and tend to be clustered in the center of the ordination for both biogeoclimatic zones (Fig. 5-5). However, in the CWH the stump microhabitats are clustered in the top left corner.

DISCUSSION

Forest microhabitat heterogeneity is the primary root of bryophyte diversity. Patterning of bryophyte diversity in cedar hemlock forests has been explained in the context of a hierarchy of stands (Newmaster et al. 1999c), mesohabitats (Newmaster thesis chapter 4.), and microhabitats. Microhabitat heterogeneity is most influential at local landscape scales (i.e., within specific types of mesohabitats). Variability in bryophyte species richness and community composition in cedar hemlock forests is clearly evident for different types of microhabitats.

Bryophytes can be grouped into communities of epiphylous, epixylous, saxicolous, and terricolous species. In both the ICH or CWH forests epiphytic communities can be further defined using tree type (i.e., deciduous or coniferous), size and vertical position on the tree. Species richness is highest on large trees (> 30 cm diam.), of which stand age is an important factor. These findings are supported by other epiphytic studies (Rambo & Muir 1998b; Pike et al. 1975; Slack 1976; Sillett 1995). Epixylic communities in the ICH or CWH can be further defined using log size and decay class. The large logs (> 70 cm diam.) of decay class three offered the highest diversity of bryophytes, many of which are hepatics. These patterns are supported by research in other types of forests in Europe and the United States (Söderström 1988a, 1988b, 1993; Rambo & Muir 1998b; Anderson & Hyterborn 1991). Forest floor bryophyte community composition is related to habitat heterogeneity. The most species rich communities were found on rocks, upturned tree roots, and stumps in both the ICH and CWH. Rambo and Muir (1998a) also found that rock microhabitats increased bryophyte diversity in old growth temperate rain forest in Oregon. Habitat availability is crucial precursor to high bryophyte diversity (Slack 1977).

Patterning of bryophyte diversity on microhabitats can be defined on a temporal scale. In a forest ecosystem, bryophyte diversity increases with time. Higher diversity of bryophytes (particularly hepatics) in old growth forests is consistent with other published accounts that have found richer diversity of mosses and hepatics associated with old growth than with young stands in Europe and North America (Gustafsson & Hallinbäck 1988; Lesica 1991; Rambo & Muir 1998a; Söderström 1988). Old growth cedar hemlock stands foster an environment that is rich with bryophytes. Moist microclimate and high habitat heterogeneity are associated with rich bryofloras and old growth cedar hemlock forests. Patterning of bryophyte diversity is positively correlated with mesohabitat quantity and quality (Newmaster thesis chapter 3). The quality of a mesohabitat is defined by habitat heterogeneity. As microhabitat heterogeneity increases so does bryophyte diversity in both the ICH and CWH. However, stand age is also intimately linked to habitat heterogeneity. As stands become older there is a greater abundance and diversity of microhabitats. Other factors that influence bryophyte diversity and are related to stand age include: bryophyte dispersal capability and, ability to establish in various microclimate conditions (Söderström 1987, 1988a, 1988b).

Dispersal ability is a limiting factor in floristic diversity. As stand age increases, so does the diversity of dispersal limited organisms by allowing more time for their colonization and establishment (Edwards 1986; Rambo & Muir 1998a). Many bryophytes, particularly hepatics are dispersal limited and are restricted to habitats with high humidity. Soderstrom & Jonsson (1989) found that nearly half of the spores from a common forest hepatic were deposited within 2.5 meters, and concluded that dispersal is limited by a distance /deficit of spores. Dispersal ability between stands and perhaps even within stands may limit the distribution of bryophytes (Söderström 1987; Herben & Söderström 1992; Herben et al. 1991; Hansen et al. 1992).

The time a community or species needs to establish itself is as important as microhabitat availability. Tree density in young stands is higher than old stands, but epiphyte diversity is lower. Habitat availability may be greater in the young stands but the time to establish rich communities of epiphytes on the tree bases and trunks is essential. In older stands, a distinct epiphytic community developed on the tree trunks above the base and in the CWH, this community became quite extensive and extended to the branches. As a stand matures, there is a greater vertical profile of favorable microclimate conditions; lower light, wind and less extreme temperature and moisture conditions (Rambo & Muir 1998a). The availability of coarse woody debris accumulates with stand age (Bingham & Sawyer 1991; Franklin et al. 1981), and is an important factor contributing to biological diversity (Esseen et al. 1992; Franklin et al. 1981; Rambo & Muir 1998a). Young stands in the ICH have a greater density of logs and lower species richness than old stands in the ICH. It is the greater diversity of log sizes and decay classes associated with old growth forests that foster high bryophyte diversity (Söderström 1988b; Anderson & Hyterborn 1991; Laaka, S. 1992; Gustafsson & Hallingbäck 1988). Time is intimately linked to habitat availability and establishment of communities. Consequently, preservation of old growth legacies will preserve the highest diversity of habitats and bryophytes.

Patterning of bryophyte diversity is evident at different scales on the landscape. At the local scale patterning of diversity in stands is dependent on mesohabitat quantity and quality (Newmaster thesis chapter 2) and microhabitat heterogeneity. At the regional scale, patterning of diversity in biogeoclimatic zones (ICH & CWH) can be identified for both mesohabitats (Newmaster thesis chapter 4) and microhabitats. Similar patterns suggest that the same ecological processes are present in both biogeoclimatic zones. In both biogeoclimatic zones, high bryophyte diversity is associated with microhabitats such as large trees, large well-decayed logs, tree stumps and rocks. Differences in diversity between the ICH and CWH can be based on the floristics (Newmaster thesis chapter 2), or patterning of species richness and community composition in forest mesohabitats (Newmaster thesis chapter 3) and microhabitats. Total species richness on microhabitats was often higher in the ICH. However, in the CWH, mean species richness was higher in the coastal forest and highest in island forests. It appears that the abundance or frequency of bryophytes on microhabitats increases with oceanity. The oceanic rainforests studied were also the largest in area, and contained the largest pool of species.

Conservation of bryophyte diversity should be included in all ecosystem management plans. The value of bryophytes both biologically, and esthetically should be taken into consideration (Slack 1988; Söderström 1995; Söderström et al. 1992). Factors that foster rich bryophyte diversity includes meso/microhabitat heterogeneity, increased stand age and perhaps stand continuity. The latter variable needs to be investigated in the context of forest fragmentation. Preserving a diversity of mesohabitats and microhabitats is essential for sustainability of bryophyte diversity. More specifically some microhabitats are essential for preserving bryophyte diversity and these microhabitats should be enriched through forest management practices. An example would be preserving a variety of logs of different sizes and decay classes during harvesting. It is not known if bryophyte communities can survive after logging disturbance. Perhaps areas of forest with high microhabitat heterogeneity could serve as refugia for a pool species that could repopulate an adjacent clear-cut. Table 5-7 lists microhabitats that foster high bryophyte diversity in old growth forest within the CWH or ICH biogeoclimatic zones.

Table 5-1. List of forest microhabitats and abbreviations.

	Microhabitat	Abbrev.
1	conifer base (10-25 cm diam.)	Csb
2	conifer trunk (10-25 cm diam.)	Cst
3	conifer base (30-60 cm diam)	Cmb
4	conifer trunk (30-60 cm diam.)	Cmt
5	conifer base (> 70 cm diam.)	Clb
6	conifer trunk (> 70 cm diam.)	Clt
7	deciduous base (10-25 cm diam.)	Dsb
8	deciduous trunk (10-25 cm diam.)	Dst
9	deciduous base (30-60 cm diam.)	Dmb
10	deciduous trunk (30-60 cm diam.)	Dmt
11	small log (10-30 cm diam.), decay class 1	Sd1
12	small log (10-30 cm diam.), decay class 2	Sd2
13	small log (10-30 cm diam.), decay class 3	Sd3
14	medium log (30-60 cm diam.), decay class 1	Md1
15	medium log (30-60 cm diam.), decay class 2	Md2
16	medium log (30-60 cm diam.), decay class 3	Md3
17	large log (> 70 cm diam.), decay class 1	Ld1
18	large log (> 70 cm diam.), decay class 2	Ld2
19	large log (> 70 cm diam.), decay class 3	Ld3
20	conifer snag	Cs
21	deciduous snag	Ds
22	twigs	Tw
23	organic soils	Org
24	mineral soil	Ms
25	acidic rock	Ra
26	tree roots (tip-up),	Tr
27	stump	Stp
28	intermittent stream	Istr

TABLE 5-2. Comparisons (ANOVA) of density and abundance of tree, log, snag and rock microhabitats between and within biogeoclimatic zones stratified by age class (young = 90 years; old = 250^{+} years; ICH = interior cedar-hemlock; CWH = coastal western hemlock).

Level of Comparison	n	Mean	Std. err.	n	Mean	Std. err.	p
BETWEEN SITES – young stands	ICH			CWH			
Tree density (m^2 ha^{-1})	50	812.94	47.58	66	703.64	30.70	0.047
Log density (m^2 ha^{-1})	50	268.01	21.87	66	157.22	14.40	< 0.001
Snag density (m^2 ha^{-1})	50	104.40	11.25	66	124.43	17.94	0.382
Rock percent cover	50	6.94	1.04	66	2.98	.38	< 0.001
BETWEEN SITES – old stands	ICH			CWH			
Tree density (m^2 ha^{-1})	52	446.23	22.55	87	367.99	10.73	< 0.001
Log density (m^2 ha^{-1})	52	211.79	18.85	87	321.24	18.40	< 0.001
Snag density (m^2 ha^{-1})	52	99.16	10.03	87	59.11	3.63	< 0.001
Rock percent cover	52	7.29	1.28	87	3.55	.32	< 0.001
WITHIN SITES – ICH	YOUNG			OLD			
Tree density (m^2 ha^{-1})	50	812.94	47.58	52	446.23	22.55	< 0.001
Log density (m^2 ha^{-1})	50	268.01	21.87	52	211.79	18.85	0.054
Snag density (m^2 ha^{-1})	50	104.40	11.25	52	99.16	10.03	0.728
Rock percent cover	50	6.94	1.04	52	7.29	1.28	0.833
WITHIN SITES – CWH	YOUNG			OLD			
Tree density (m^2 ha^{-1})	66	703.64	30.70	87	367.99	10.73	< 0.001
Log density (m^2 ha^{-1})	66	157.22	14.40	87	321.24	18.40	< 0.001
Snag density (m^2 ha^{-1})	66	124.43	17.94	87	59.11	3.63	< 0.001
Rock percent cover	66	2.98	.38	87	3.55	.32	0.512

TABLE 5-3. Species frequencies on selected microhabitats within old forests (250$^+$ years) in the ICH. Microhabitat acronyms are defined in table 5-1.

Species	csb	cmb	cml	clb	clt	dsb	dmb	dml	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	tr	st
Ptilidium pulcherrimum	93	95	91	91	84	14	13	9	54	82	34	14	59	16	88	7	96	9	7	29	77
Dicranum tauricum	82	95	88	84	80	2	9	7	50	54	4	14	36	5	71	2	48		7	11	41
Sanionia uncinata	95	91	59	73	39	14	11	7	45	63	45	14	64	18	70	7	91	29	11	29	46
Plagiothecium laetum	68	88	9	84	7	13	13	2	34	64	68	7	54	29	54	4	73	89	29	45	70
Dicranum fuscescens	36	86	18	79	30		4	2	41	86	43	11	52	21	66	2	63	27	25	32	79
Hypnum revolutum	36	73	27	77	39	7	4	2	39	64	27	9	36	11	61	4	52	4	27	14	39
Hypnum circinale	25	71	70	77	71	2	2		29	38	4	7	23	5	54		11	2	2	13	30
Ptilidium californicum	50	63	43	73	38				18	45	14	2	32	4	41		63	5	9	9	36
Amblystegium serpens	5	59	18	45	2	2				4			5		14	7	30		11		4
Mnium spinulosum	13	57	5	50		2	7	4	16	73	66	9	45	16	41	2	36	55	38	30	70
Dicranum montanum	2	46	32	63	52			2	2	11	4	2	13	4	23		4	2	7		14
Hylocomium splendens	14	34	7	29					7	64	75		50	25	27		27	91	34	29	32
Lophozia ventricosa	5	34	7	38	7				5	75	34	2	39	13	25	2	16	2	14	16	36
Cephaloziella divaricata		34		41	4					45		2	34	13	23		25		27		25
Pleurozium schreberi	9	29	2	29			4	2	18	88	84	7	43	32	23		39	95	34	45	55
Barbilophozia lycopodioides	4	27	4	30					2	27	27	2	16	13	7		21	79	25	5	16
Ptilium crista-castrensis	13	23	5	13		2	5		18	75	86	7	54	30	18	4	36	84	29	25	39
Rhytidiadelphus triquetrus	16	21	5	13			5		13	63	68	4	50	23	16	4	23	79	23	18	23
Diplophyllum albicans		20		27	2					36			38	13			4		4		48
Blepharostoma trichophyllum	4	16	5	27	4				4	64	21	2	32	9	9		14	16	18	7	32
Rhytidiadelphus loreus	14	16	4	13	4	4	2		7	38	36	5	38	18	13		13	59	25	18	18
Plagiomnium medium	2	16		23	2					63	4		21	2	5		4	9	2	4	4
Rhytidiopsis robusta	7	14	4	29					5	45	36	7	20	18	20		25	55	23	21	21
Eurhynchium pulchellum	4	14	2	27			5		4	25	11	4	14	4	7		16	32	30	14	9
Plagiomnium insigne	5	14	2	23					2	46	45		29	13	7	2	11	70	18	16	20
Dicranum scoparium	4	14		16	4				4	34	11		18	4	5		9	2	30	7	21
Bazzania denudata		14		20						7			29	11	4		20		5		18
Jamesoniella autumnalis	7	13	2	14	2		2		4	36	27	2	21	13	9		25		4	4	16
Cephalozia lunulifolia		13		27	2				4	43	32		34	18	4		23	4	5	9	23
Calypogeia trichomanis		11		29	2					34		2	29	5	4		7				13
Brachythecium frigidum	36	9		9			2		7	7	5	2	2		9	5	13	5	18	4	7
Antitrichia curtipendula	2	7	54	13	50				13	4		4			27		7		2	2	
Jungermannia leiantha		5		4						45	7		23	4			2		4		4
Tetraphis pellucida	2	4		7					2	80	50		45	29	14		13	2	4	29	96
Lophocolea heterophylla		4		4	2					27	7		14	4	7		11		4	4	13
Brachythecium salebrosum	2	2		5	2		2		4	13	4		5	2	5	2	7	13	4	9	4
Tetraphis geniculata		2		2						34	16		29	23	2		5			9	63
Lepidozia reptans		2		2						13	4		5	4					4		5
Geocalyx graveolens		2			2					9	5		5	2	2		2				5
Lophozia incisa		2		7						9	2		11	5							7
Polytrichastrum alpinum		2								5			7	2	2			4	18	29	13
Calypogeia muelleriana		2		2		2				5	4		13	4							11

(TABLE 5-3, continued)

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	lr	st
Hypnum pallescens	2	2		2						4			2	2					4	4	4
Porella navicularis		2		13						4	2		9		2						2
Kindbergia praelonga		2		25						2					2			2	7		
Brachythecium starkei		2		5						2		2	4								2
Riccardia latifrons		2								2			11								
Rhizomnium magnifolium		2											2				4	16	4	2	
Pohlia nutans		2									5		2		2		2		7	45	14
Pellia neesiana		2											2				2		4		
Rhytidiadelphus squarrosus		2												2				4			
Apometzgeria pubescens		2		5															7		
Heterocladium procurrens		2											2						5	2	
Tortula ruralis		2																	4		
Brachythecium reflexum		2										2							2		
Isopterygiopsis pulchella		2		13	2										2				2		
Heterocladium macounii			11		9					5		2	21	5					9	2	7
Chiloscyphus polyanthos	2								2	20	4		25	9	2						9
Plagiothecium undulatum									2	7		2	14								4
Lophozia guttulata										30	20		18	14							4
Tritomaria exsectiformis										16			30	5							13
Plagiothecium piliferum				2	2					14			20	2				4	4	2	4
Heterocladium dimorphum										14			9	9					7		11
Barbilophozia floerkei										14			16	7					7		7
Bazzania tricrenata										14		2	20						7		16
Buxbaumia piperi										13	7		9				5				41
Calypogeia suecica										11	2	2	16	4							2
Leskea polycarpa										11		2	39	5							9
Riccardia palmata										9			13								2
Polytrichum formosum										7	4		7	9	5			11	11	27	7
Polytrichum juniperinum										5	5		18	4	2			7	13	66	14
Polytrichum commune										5	2		11	9	2			7	13	30	9
Anastrophyllum hellerianum										5			20	11							11
Hylocomium umbratum				4		2				4	7		5	2	2		14	64	5	4	4
Dicranum polysetum										4	7		2	2			2	18	4		4
Rhizomnium nudum										2	2		2				2	20	2		
Diplophyllum taxifolium										2	2			2					39	39	
Thuidium recognitum											2						4	11	4		
Pogonatum contortum																	2	2		20	
Hylocomium pyrenaicum				2		4					2		2					16	13		2
Diplophyllum obtusatum																		16		9	
Hedwigia ciliata																			27		
Dichodontium pellucidum																			4	25	
Ceratodon purpureus													2						2	54	5
Atrichum selwynii																				71	5

TABLE 5-4. Species frequencies on selected microhabitats within young (90 years) ICH stands. Microhabitat acronyms are defined in Table 5-1.

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ta	tr	st
Ptilidium pulcherrimum	86	82	70	20	14	22	30	28	52	68	48	2	10	2	72	16	78	4	16	20	76
Dicranum tauricum	40	78	62	20	14		22	18	50	46	8	2	6		58	8	22		2	16	36
Plagiothecium laetum	68	74	8	18		24	24		38	64	54		10	2	58	12	60	74	38	24	58
Dicranum fuscescens	20	70	6	18	4	2	18	4	44	76	66	2	10	2	60	6	44	22	36	26	74
Sanionia uncinata	80	60	32	16	6	26	28	18	48	66	38	2	8	2	60	16	70	36	20	24	54
Hypnum revolutum	38	54	28	14	2	8	8	8	20	50	22	2	8	2	40	6	28	2	24	12	28
Mnium spinulosum	12	54	2	12		4	16		18	50	60		8	2	30	4	14	46	42	24	46
Hypnum circinale	16	42	32	12	10		8	6	10	14	4	2	4		20	2			4	2	12
Pleurozium schreberi	26	38	2	4		2	18	2	24	70	86		8		32	6	32	82	40	22	50
Hylocomium splendens	8	30		4		2	6			52	68		6	2	6	2	14	70	28	8	32
Barbilophozia lycopodioides	6	24	4	6			8			28	28		4		4		6	56	36	6	8
Ptilidium californicum	24	24	10	6	6				10	16			4		18		20		6	4	18
Rhytidiadelphus triquetrus	10	22	2	2			2		14	56	60		8	2	6	4	12	62	10	20	18
Rhytidiopsis robusta	2	22	2			2	4		2	32	30		2		8	2	10	44	30	4	8
Ptilium crista-castrensis	10	22		6			8	2	16	74	74		10		8		20	80	20	10	26
Lophozia ventricosa	12	14		4	2		6		2	48	38		4	2	10		10	2	10	2	40
Plagiothecium denticulatum	6	12					2		2	2	6			2	6		4	12	2	4	6
Brachythecium salebrosum	4	10				4	4		4	12	10				4	4	6	6	10	8	4
Eurhynchium pulchellum	8	10	2	4		4	8		6	12	14				8	4	6	32	32	12	16
Brachythecium frigidum	8	10					14		6	4	6				8	2	12	6	18	4	10
Jamesoniella autumnalis	8	10			2	2	4			34	28			2	10	2	20	2	10	6	14
Dicranum scoparium	4	8		4			4		4	40	10		6		6		2		32	2	16
Plagiomnium medium	2	8		2		4	2		2	40	10		2		6			10	6	2	8
Jungermannia leiantha	4	6			2		4			22	12							4	2		8
Plagiochila porelloides	2	6	2	2	2	2				8	2						2	6	12	2	2
Lophocolea heterophylla	4	4			2		2			16	12			2		2	6			6	12
Blepharostoma trichophyllum	6	4		2			4			50	24		4	2	6		8	12	14	4	24
Tetraphis pellucida	2	2		2						56	52		8	2			2			20	78
Cephalozia lunulifolia		2		2			2			36	20			2	4		6	2	2		12
Pohlia nutans		2				2				6	6		2				4	8	8	28	18
Ceratodon purpureus		2																12	4	38	10
Polytrichastrum alpinum		2									4							2	18	22	2
Rhytidiadelphus loreus	2		2	2					4	12	12		2			2		14	12	2	2
Plagiomnium insigne	2		2	2						14	18				4		6	38	4	8	6
Dicranum polysetum								2		6	8						2	16	12	2	8
Cephaloziella divaricata										18	10										
Orthotrichum obtusifolium							2	10	2												
Polytrichum juniperinum			2							8			2				2	10	16	44	12
Hylocomium umbratum										2	4						6	36	4		
Pohlia cruda						2					2								2	10	
Polytrichum commune										2	4							4	12	10	6
Atrichum selwynii																			2	46	4
Hedwigia ciliata																			24		

TABLE 5-5. Species frequencies on selected microhabitats within young (90 years) CWH stands. Microhabitat acronyms are defined in Table 5-1.

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	mdt	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	tr	st
Santonia uncinata	95	92	92	6					95	95	95		8	8	97		97	2	86		89
Isothecium myosuroides	59		64	5	5	5	2	2	65	70			6						3		
Hypnum circinale	53	55	58	5	5				59	56			6				61		24		
Plagiochila porelloides	21	21	21	6	5				21	23	23		8	8	21		23	23	18	58	21
Diplophyllum albicans	21	21	20	6	6				21	24			8		20		21	23	15		
Scapania bolanderi	17	18	21	6					21	24	23		8	8	18		20	20	11		23
Ptilidium californicum	9	11	9	6	6				11	11			8		9		11	9	3		11
Herbertus aduncus	6	9	9	3	5				6						6		6				6
Plagiothecium laetum		95	11	6						95	95		8	8	95		95	92	88	83	92
Blepharostoma trichophyllum										92	97		6	6			97	92	62	85	
Dicranum fuscescens		94	92	6						92	95		6	8	95		95	2	2		
Plagiothecium undulatum									95	92	95		8	8	92			62	88		95
Eurhynchium pulchellum										92	95		8	8			95		71		91
Plagiothecium denticulatum		58	59	6					61	61			6					52		86	50
Brachythecium frigidum		50	8	5	6				59	55			6		52		53	50		74	39
Lepidozia reptans		9	9	6	6				11	11	11		8	8	11		11	11		71	11
Lophocolea heterophylla				6					11	11			8		11		11				11
Cephalozia bicuspidata				5					11	11			8		9		11				11
Marsupella emarginata				3					9	8			6		8		9				8
Orthotrichum lyellii						12	12	12	6							6	6				
Orthotrichum striatum						12	11	12	6							5	5				
Homalothecium fulgescens						11	8	8	6							6	6				
Orthotrichum speciosum						11	11	11	6							6	6				
Frullania tamarisci						9	12	12	6							6	6				
Orthotrichum obtusifolium							6		6								6				
Orthotrichum consimile						2	3	2	6							5	5				
Ulota megalospora						2	3	2	5							5	5				
Rhytidiadelphus loreus		92	11							95	95		8	8	95		95	95	92	83	95
Hylocomium splendens		94	9	6					97		92			8				92		79	92
Pseudotaxiphyllum elegans		91	91	6	6					92			8						76		
Dicranum tauricum		88	11	5					82												74
Bazzania denudata		83	8	6	6					85			8					83		79	80
Dicranella heteromalla		62	11	6						62			8							89	56
Mnium spinulosum		61	9	6						62	61		8	8				8	2		
Dicranum scoparium		23		5						23			8					21	6	79	
Rhytidiadelphus triquetrus		23	11							23	23		8	8	23			23	12	73	23
Geocalyx graveolens		21	9	6					23	23			8		23		23				2
Heterocladium macounii		18	20	5															9		
Bazzania tricrenata		11	9	6					9	11			8		11		8	11			11
Eurhynchium oreganum		9	11	5	3					73			6					70	47		59
Kindbergia praelonga		9	9	6	5					11			8		11			8	5		9
Metaneckera menziesii		8	9	3	6														5		
Plagiomnium venustum																				65	

(TABLE 5-5 continued)

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	lr	st
Jamesoniella autumnalis			11	6						86			8								85
Riccardia multifida			9							9			6					9	5	83	8
Amblystegium serpens			8	6						8			6					8	3	79	3
Claopodium bolanderi			8	6														9	3		
Lophozia incisa				6						9			6	2	9						
Lophozia ventricosa				6						11			8		9						9
Mylia taylori				5	5					9			8					8			6
Aulacomnium androgynum																				71	
Ptilidium ciliare																				80	
Plagiomnium medium										21	23		8	8	23			20		73	20
Rhytidiopsis robusta										95	95		8	8				91	80	83	85
Pleurozium schreberi										21	23		8	8				23		88	
Rhizomnium glabrescens										95			8					94	86		97
Hypnum subimponens										95			8						2		
Polytrichum commune										92			8					80	58	73	83
Pohlia nutans										59			8						23		53
Pogonatum contortum										56			6					53		82	50
Plagiomnium cuspidatum										20			6					18	8	95	21
Hypnum revolutum										11			8						2		
Aulacomnium palustre																				77	
Barbilophozia floerkei													2	8							
Leucolepis acanthoneuron																				80	
Timmia austriaca																				83	
Polytrichum juniperinum																		94	70	73	
Mnium marginatum																		55		76	
Atrichum selwynii																		52	14	68	45
Plagiomnium insigne																		48		76	
Rhytidiadelphus squarrosus																		21	18	68	23
Pellia neesiana																		18		70	
Polytrichastrum alpinum																		5	62	79	86
Homalothecium aeneum																				71	
Rhizomnium magnifolium																				82	
Bryum pseudotriquetrum																				79	
Ceratodon purpureus																				76	
Pohlia annotina																			2	67	
Ditrichum heteromallum																				73	
Funaria hygrometrica																				67	26
Leptobryum pyriforme																				86	
Pogonatum urnigerum																				79	
Pohlia cruda																			2	82	
Polytrichum piliferum																				76	
Polytrichum formosum																				86	
Tetraphis pellucida																					56

TABLE 5-6. Species frequencies on selected microhabitats in young (90 years) CWH stands. Microhabitat acronyms are defined in table 5-1.

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	tr	st
Isothecium myosuroides	98		98	98	99				93	99		88	88	88							
Sanionia uncinata	96	96	99	96					93	97	97	89	88	87	93		93		92		71
Hypnum circinale	94	98	93	98	99				95	98		88	89	89			95		80		
Scapania bolanderi	94	93	95	93					96	89	99	88	88	87	98		95	98	67	78	60
Diplophyllum albicans	91	98	98	97	99				97	98		80	86	88	98		98	98	87	58	
Ptilidium californicum	88	95	98	99	97				96	98		88	86	88	92		98	98	72	60	72
Plagiochila porelloides	83	90	97	98	96				97	96	95	87	87	89	91		96	97	61	63	82
Herbertus aduncus	50	45	64	64	65				57			83			65		59				53
Dicranum fuscescens		97	97	98						96	98		88	88	98		97				
Cephalozia bicuspidata				98					98	98		89	89	83	97		93			62	60
Blepharostoma trichophyllum										96	98		87	88			91	98	73	63	
Plagiothecium laetum		97	94	98						98	98		89	90	98		98	97	93	62	88
Lepidozia reptans		98	98	98	97				97	96	98	83	89	88	98		98	98		62	86
Lophocolea heterophylla				98					98	89		88	89	88	93		95			59	84
Plagiothecium undulatum									98	97	98	88	88	90	99			59	98		87
Eurhynchium pulchellum										91	99		88	89			95		83		85
Plagiothecium denticulatum		93	96	94					96	94		79	86	88				93		53	73
Frullania tamarisci						10	11	11	63			89				61	61				
Homalothecium fulgescens						11	10	10	60			72				63	55				
Marsupella emarginata				69					70	58		87	89	86	69		70				51
Brachythecium frigidum		88	95	67	59				68	68		62	60	59	66		63	69		60	46
Orthotrichum lyellii						8	8	8	9			37				10	9				
Orthotrichum speciosum						8	8	8	9			37				9	9				
Orthotrichum striatum						7	8	8	9			37				10	8				
Orthotrichum obtusifolium							7		9								8				
Orthotrichum consimile						5	6	6	8			36				8	8				
Ulota megalospora						4	5	6	9			9				9	8				
Hylocomium splendens		80	98	96					98		98	84						98		54	83
Ptilidium pulcherrimum		51	55	62	63					58		89	87	82							39
Bazzania tricrenata		98	97	97					98	87		88	86	88	97		98	97		61	83
Rhytidiadelphus loreus		97	98							98	99		88	89	98		98	98	95	69	86
Dicranella heteromalla		96	97	99						98			88	89						63	85
Pseudotaxiphyllum elegans		95	98	97	98					98			90	88					94		
Dicranum tauricum		93	93	92					94			86									57
Mnium spinulosum		93	96	94						96	93		86	84							6
Bazzania denudata		91	96	97	94					98			88	87				94		61	85
Geocalyx graveolens		91	96	98					98	96		88	83	80	95		97			62	
Kindbergia praelonga		89	93	94	96					94			86	88	96			95	53	57	77
Rhytidiadelphus triquetrus		87	94							95	93		86	86	95			92	64	57	58
Eurhynchium oreganum		86	98	99	96					96			88	88				98	78	62	81
Dicranum scoparium		66		67						63			86	88				67	46	58	
Metaneckera menziesii		51	62	64	54														42		
Heterocladium macounii		47	88	96															60		

(TABLE 5-6 continued)

Species	csb	cmb	cmt	clb	clt	dsb	dmb	dmt	md1	md3	md5	ld1	ld3	ld5	cs	ds	tw	org	ra	tr	st
Claopodium crispifolium		44	37	42	48					46		47	41	45							
Porella cordaeana		44	43	50	43																
Neckera douglasii		43	53	46	46				42						48						
Plagiomnium venustum		39		48						42			39		43			37		53	28
Antitrichia curtipendula		2	78	73	79												70				58
Jamesoniella autumnalis			95	99						97			89	88						59	85
Amblystegium serpens			93	94						91			86	84				93	48	61	49
Riccardia multifida			89							97			86	88				96	80	68	59
Apometzgeria pubescens			57									62		60					52		
Claopodium bolanderi			51	63														65	44	53	
Dicranoweisia cirrata			46	48	48				44			48	38		42						
Lophozia ventricosa				88						88			80	77	93						68
Lophozia incisa				87						86			79	78	93						
Scapania umbrosa				63						62		86	85	87	58						35
Ptilidium ciliare				62								88		81				62	51	61	
Pseudoleskea radicosa				60	52								86	44					41		
Aulacomnium androgynum				58														62		57	50
Mylia taylori				58	65					52			84	77				62		52	45
Homalia trichomanoides				48	48																
Metzgeria conjugata				38	35					33			37	42				45		56	26
Fissidens adianthoides					45														46		
Radula complanata					43														40		
Homalothecium nutallii						9	8	10	40			43			47						
Plagiomnium medium										97	97		89	85	96			96		58	79
Rhytidiopsis robusta										98	99		84	89				99	87	76	71
Pleurozium schreberi										93	98		85	86				89		59	
Rhizomnium glabrescens										98			89	90				99	96	57	71
Hypnum subimponens										96			62	89							
Plagiomnium cuspidatum										93			85	76				93	59	57	78
Pogonatum contortum										93			83	87				93		58	67
Pohlia nutans										93			90	86					72		58
Polytrichum commune										93			88	88				95	68	58	57
Calypogeia integristipula										88			87	88						59	57
Calypogeia muelleriana										87			85	88							56
Hypnum revolutum										68			31	33							
Leucolepis acanthoneuron										63			86	88				62	43	58	48
Aulacomnium palustre										62			62	63				61		58	49
Hookeria lucens										53			56	60				56	42	57	
Barbilophozia floerkei										47			49	50				47	38	52	
Conocephalum conicum										45			43	48				48		52	
Calypogeia trichomanis										29			37	36							26
Barbilophozia hatcheri										13	8		30	5							
Calypogeia fissa										13	8		28	5							

(TABLE 5-6 continued)

Species	csb	cmb	cml	clb	clt	dsb	dmb	dml	md1	md3	md5	ld1	ld3	ld5	cs	ds	lw	org	ra	tr	st
Cephalozia lunulifolia										13	8		28	5							
Cephaloziella divaricata										13	8		28	5							
Diplophyllum obtusatum										13	8		34	4							
Lophozia guttulata										13	7		32	4							
Lophozia longidens										13	8		36	4							
Jungermannia leiantha										12	8		29	6							
Lophozia ventricosa										12	8		32	4							
Cephaloziella integerrima										11	9		31	5							
Diplophyllum taxifolium										8	8		17	4							
Douinia ovata										8	7		18	4							
Chiloscyphus polyanthos										7			16								
Lophozia excisa										7	7		18	5							
Lophozia wenzelii										7	8		18	4							
Tritomaria exsectiformis										7	8		18	4							
Buxbaumia piperi											18			20							23
Timmia austriaca														87				58		66	35
Rhytidiadelphus squarrosus																		98	87	78	64
Pellia neesiana																		94		61	
Polytrichum juniperinum																		94	83	57	
Atrichum selwynii																		93	59	52	75
Mnium marginatum																		93		54	
Plagiomnium insigne																		69		62	
Homalothecium aeneum																		63	52	59	48
Rhizomnium magnifolium																		60	52	55	
Sphagnum girgensohnii																		48		46	
Sphagnum squarrosum																		43		48	
Polytrichastrum alpinum																			78	60	67
Ditrichum heteromallum																				62	
Pogonatum urnigerum																			46	59	
Ceratodon purpureus																				59	
Bryum pseudotriquetrum																				53	
Plagiopus oederiana																				59	
Leptobryum pyriforme																				54	
Polytrichum piliferum																			48	62	
Pohlia cruda																				63	
Pohlia annotina																				57	
Oncophorus virens																				46	
Funaria hygrometrica																			1	12	11
Schistostega pennata																				28	11
Dicranoweisia crispula																			53		
Bartramia pomiformis																			43		1
Polytrichum formosum																				57	
Tetraphis pellucida																					87

Table 5-7. Microhabitats that foster high bryophyte diversity in old growth forest within the CWH or ICH biogeoclimatic zones.

Biogeoclimatic Zone	**Microhabitats associated with high Bryophyte diversity in old growth cedar-hemlock forest**
ICH	Medium (30-60 cm dbh) or larger (> 70cm dbh) conifer tree bases; medium or larger logs of decay class D3-D5; stumps, rocks and organic soils.
CWH	Medium conifer tree trunks or larger conifer tree bases and trunks; medium D3 logs or larger logs of decay class D3-D5; up-turned tree roots, stumps, rocks and organic soils.

* High microhabitat diversity includes the maximum number of microhabitats from Table 5-1.

Figure 5-1. Map of the coastal western hemlock (CWH) and interior cedar-hemlock (ICH) biogeoclimatic zones in British Columbia.

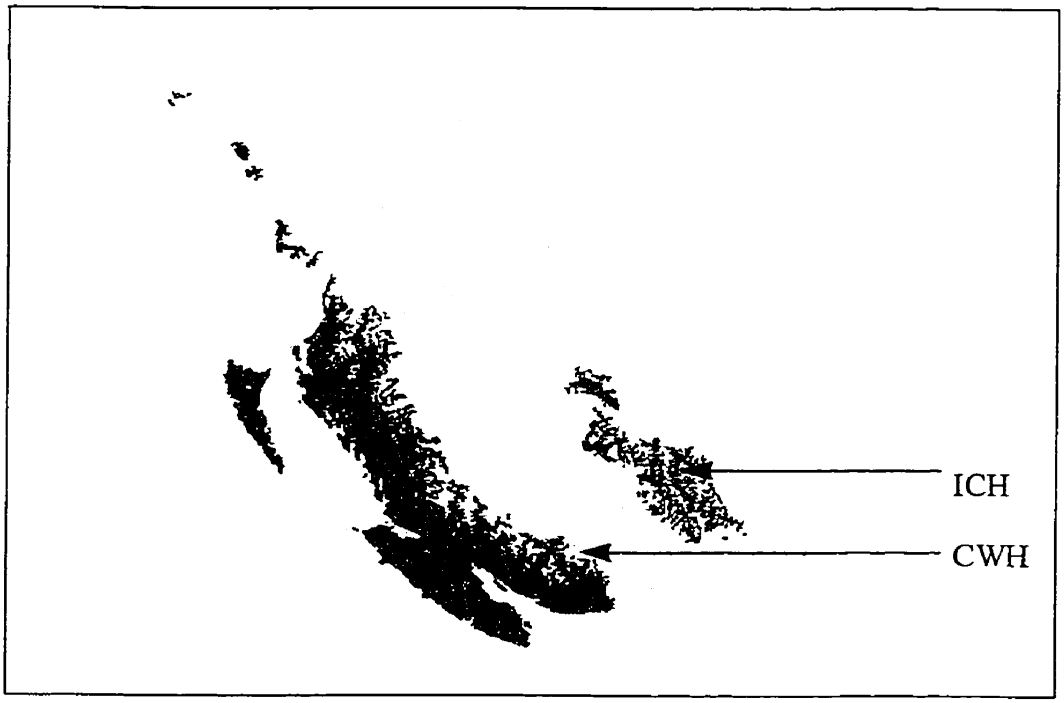


Figure 5-2. Species richness and indicator values for each tree microhabitat (see Table 5-1).

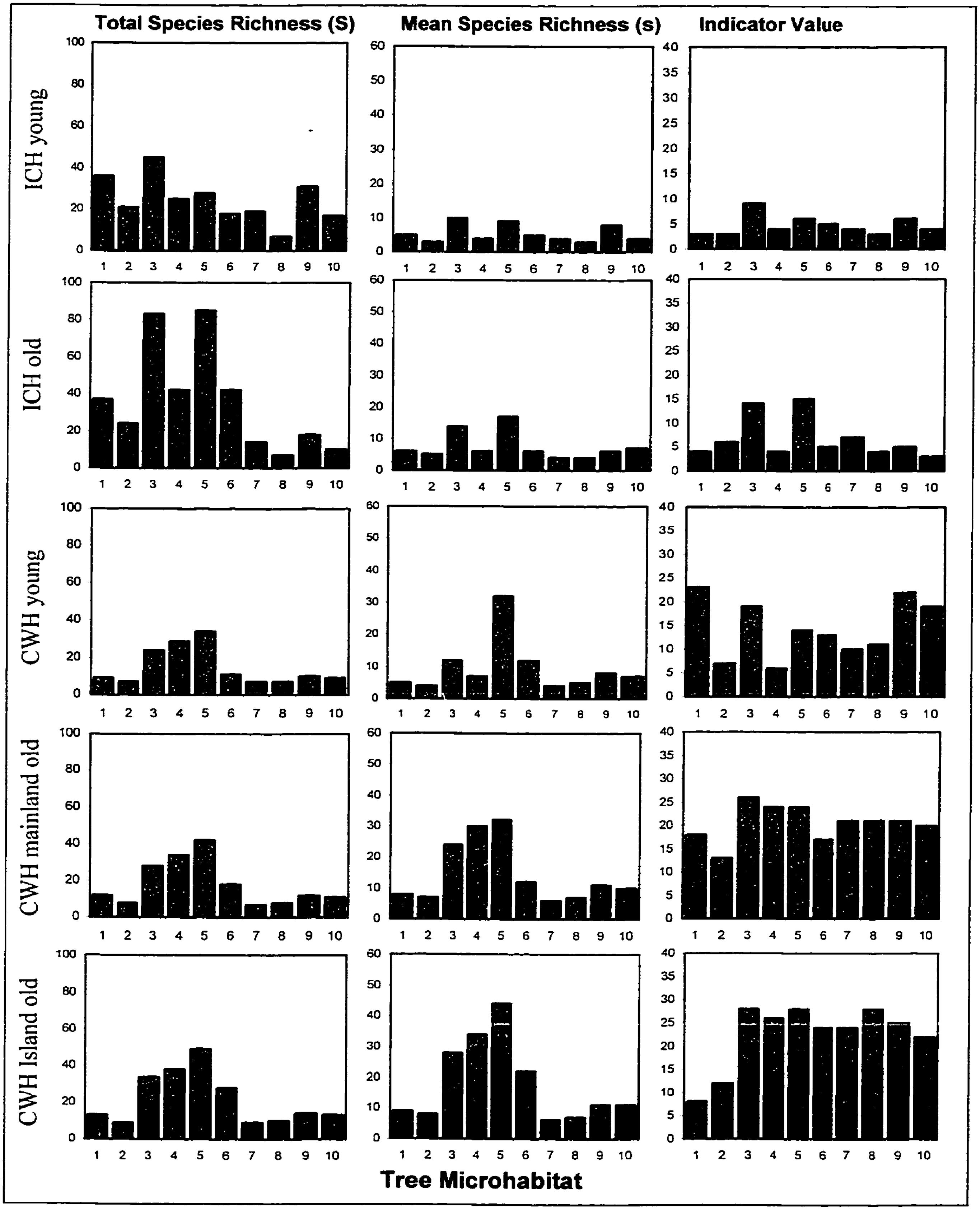


Figure 5-3. Species richness and indicator values for each log microhabitat (see table 5-1).

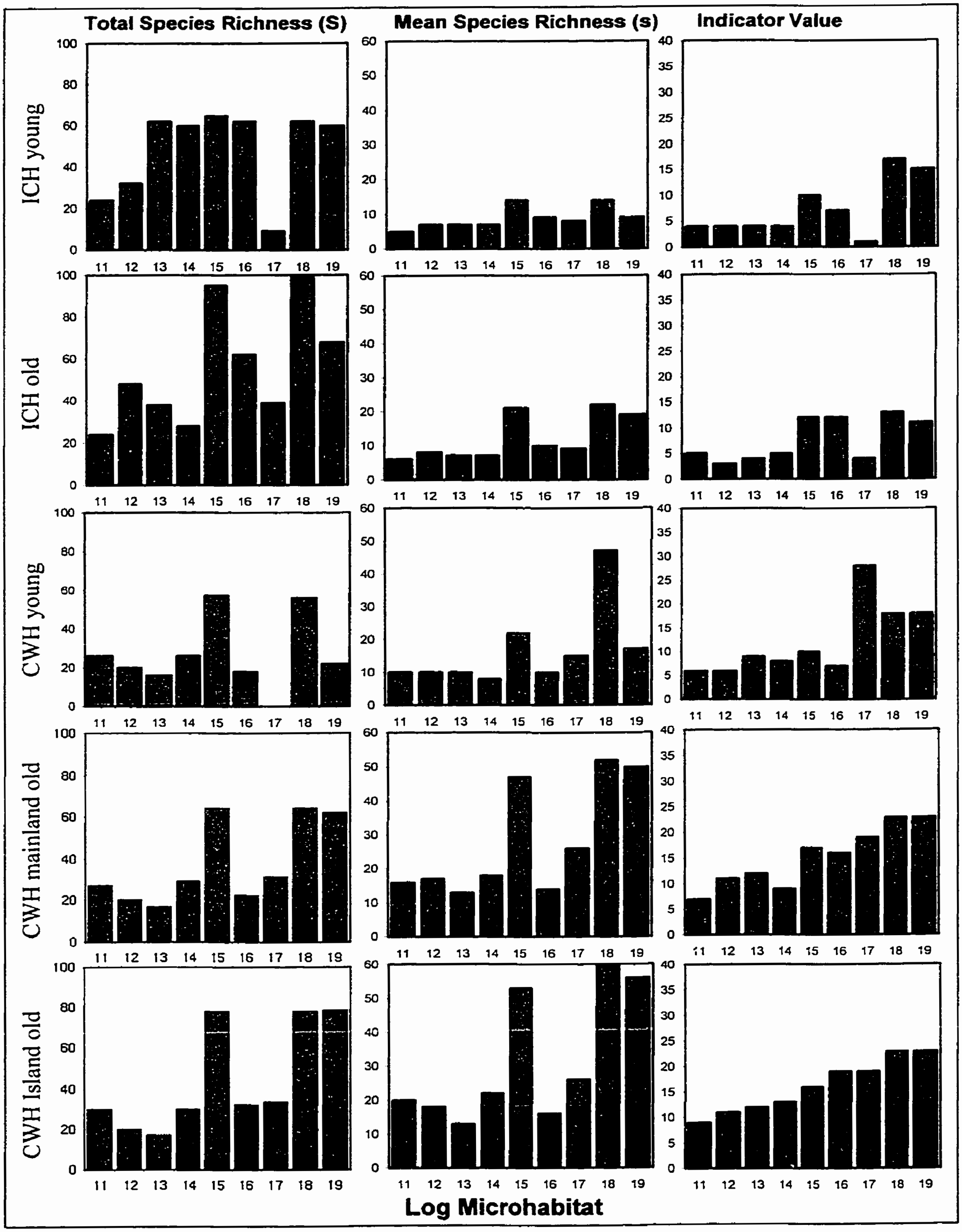


Figure 5-4. Species richness and indicator values for each microhabitat (see Table 5-1).

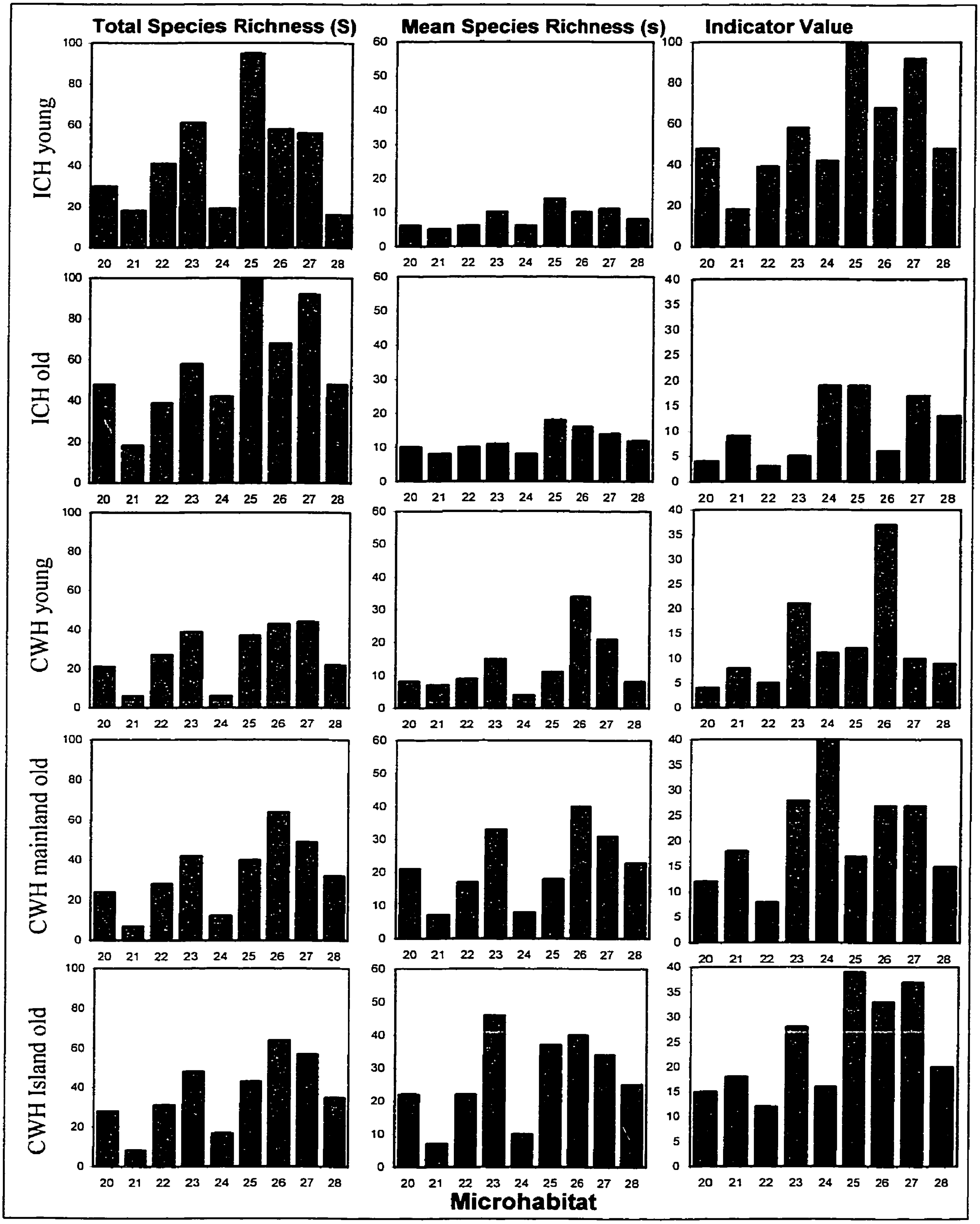
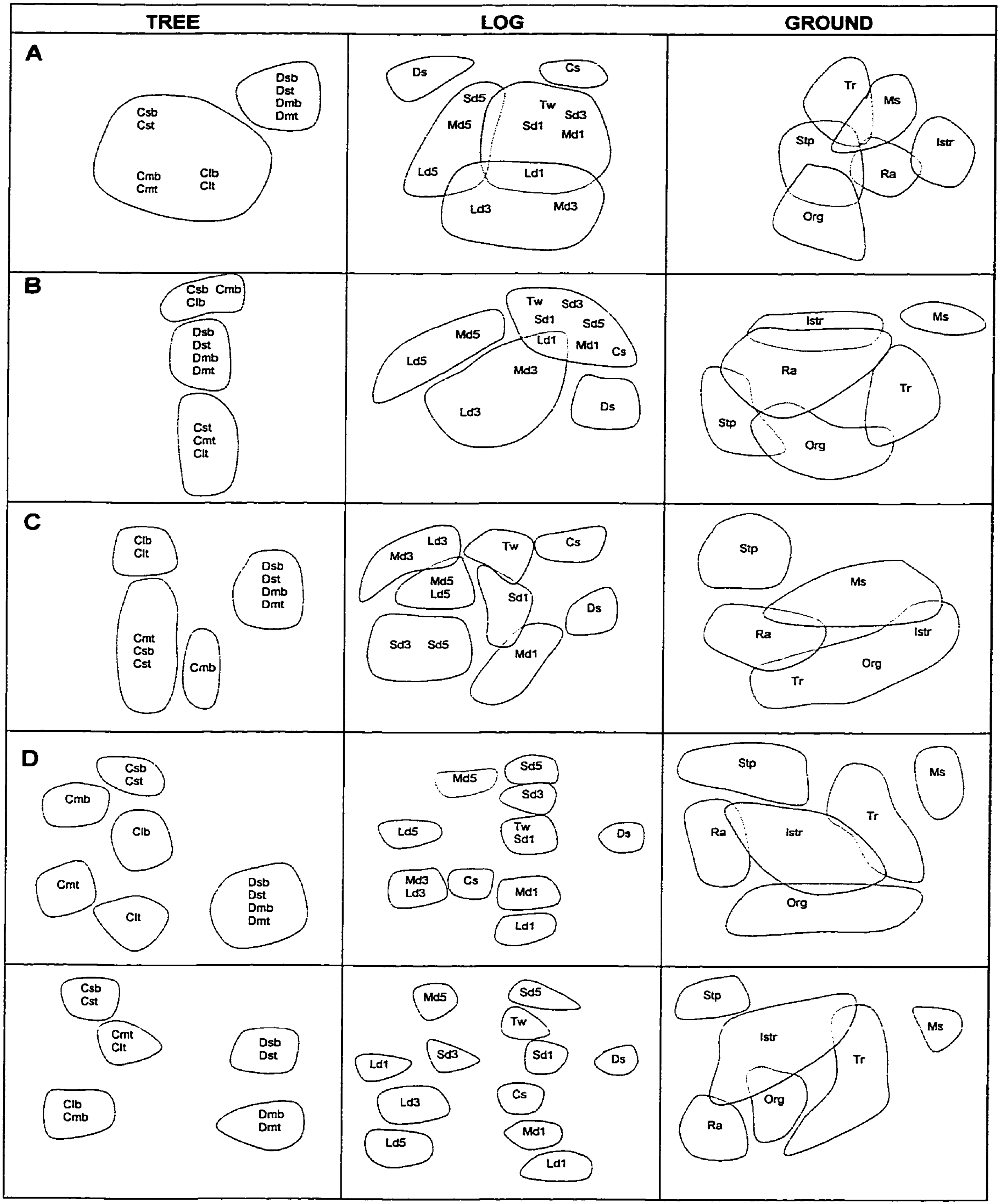


Figure 5-5. NMS ordinations of microhabitats (tree, log and ground) in the ICH and CWH (A= ICH young, B=ICH old, C=CWH young, D= CWH mainland old, E=CWH Island old).



LITERATURE CITED

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Anderson, L.E., Crum, H.A. & W.R. Buck. 1990. List of the mosses of North America North of Mexico. The Bryologist 93: 448–499.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. University of British Columbia, Department of Botany, Vancouver, B.C. Ph.D. Thesis,

Barkman, J.J. 1958. Phytosociology and ecology of crpytogamic epiphytes. Van Gorcum & Comp. Netherlands.

Belland, R.J. & D.H. Vitt. 1995. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

Belland, R.J. & W.B. Schofield. 1994. The ecology and phytogeography of the bryophytes of Cape Breton Highlands Park, Canada. Nova Hedwigia 59: 275-309.

British Columbia Ministry of Forests. 1995. Biodiversity Guidebook. Forest Practices Code of British Columbia, Victoria, B.C.

Carleton, T.J. 1990. Variation in terricolous bryophytes and macrolichen vegetation along primary gradients in Canadian boreal forest. Journal of Vegetation Science 3:585-594.

Clerc, P. & M.A. Herrera-Campos. 1997. Saxicolous species of usnea subgenus *Usnea* (lichenized *Ascomycetes*) in North America. The Bryologist 100: 281-302.

Crum, H. 1983. Mosses of the Great Lakes forest. University of Michigan, Ann Arbor.

Edwards, M.E. 1986. Disturbance histories of four Snowdonian woodlands and their relation to Atlantic bryophyte distributions. Biological conservation 37: 301-320

Frego, K.A. & T.J. Carleton. 1995a. Microsite conditions and spatial pattern in a boreal bryophyte community. Canadian Journal of Botany 73: 544-551.

Frego, K.A. & T.J. Carleton. 1995b. Microsite tolerance of four bryophytes in a mature black spruce stand: Reciprocal transplants. The Bryologist 98: 452-458.

Garty, J. & N. Binyamini. 1990. Establishment of pioneer litho-microorganisms on chalk rocks after a severe forest fire in Israel. Environmental and Experimental Botany 30: 127-139.

Gignac, D.L. 1986. Ecological tolerance and niche structure of *Sphagnum* along a pollution gradient near sudbury, Ontario, Canada. Can. J. Bot. 65: 1138-1147.

Gignac, D.L. & D.H. Vitt. 1994. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Gignac, D.L. & D.H. Vitt. 1990. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Goward, T. & T. Ahti. 1992. Macrolichens and their zonal distribution in Wells Gray Provincial Park and its vicinity, British Columbia, Canada. Acta Botanica Fennica 147: 1-60.

Gustafsson, L. & T. Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological Conservation 44: 283-300.

Horton, D. G. 1988. Microhabitats of New World Encalyptaceae (Bryopsida): distribution along edaphic gradients. Beifefte zur Nova Hedwigia 90: 261-282.

Jonsgard, B. & H.J.B. Brooks. 1993. Quantitative studies on saxicolous bryophyte-environment relationships in western Norway. Journal of Bryology 17: 579-611.

Jonsson, B.G. 1993. The bryophyte diaspore bank and its role after small-scale disturbance in a boreal forest. Journal of Vegetation Science 4: 819-826.

Krebs, C.J. 1997. Ecological Methodology. Harper Collins, New York.

Laaka, S. 1992. The threatened epixylic bryophytes in old primeval forest in Finland. Biological Conservation 59: 151-154.

Lee, T.D. & G.H. La Roi. 1979. Bryophyte and understory vascular plant beta diversity in relation to moisture and elevation gradients. Vegetatio 40: 29-38.

McAlister, S. 1995. Species Interactions and substrate specificity among log-inhabiting bryophytes species. Ecology 76: 2184-2195.

McCullough, H.A. 1948. Plant succession on fallen logs in a virgin spruce-fir forest. Ecology 29: 508-513.

McCune, B. & M.J. Mefford. 1997. PC-ORD. Multivariate analusis of ecological data, version 3.0. MjM Sofware Design, Gleneden Beach, OR.

McCune, B. 1993. Gradients in epiphytic biomass in three Pseudotsuga-Tsuga forest of different ages in western Oregon and Washington. The Bryologist 96: 405-411.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6

Muhle, H. & F. LeBlanc. 1975. Bryophyte and lichen succession on decaying logs. I. Analysis along an evaporational gradient in eastern Canada. Journal of the Hattori Botanical Library 39: 1-33.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Pike, L.E., W.C. Denison, D.M. Tracey, M. A. Sherwood and F. M. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing in old-growth conifers in western Oregon. The Bryologist 78: 1-39.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Sillet, S.C. 1995. Branch epiphyte assemblages in the forest interior and on the clearcut edge of a 700 year-old Douglas Fir canopy in western Oregon. The Bryologist 98:301-312.

Slack, N.G. 1977. Species diversity and community structure in bryophytes: New York State Studies. Bulletin N.Y. State Museum 428: 1-70.

Slack, N.G. 1976. Host specificity of bryophytic epiphytes in eastern North America. Journal of the Hattori Botanical Laboratory 41: 107-132.

Slack, N.G. 1988. The ecological importance of lichens and bryophytes. Bibltheotheca Lichenology 30: 23-53.

Slack, N.G., D.H. Vitt, & D.G. Horton. 1980. Vegetation gradients of minerotrophically rich fens in western alberta. Canadian Journal of Botany 58: 330-350.

Söderström, L. 1988a. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8: 89-97.

Söderström, L. 1988b. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1995. Bryophyte conservation - Input from population ecology and metapopulation dynamics. Cryptog. Helv. 18: 17-24.

Söderström, L., T.Hallingbäck, L. Gustafsson, N. Cronberg & L. Hedenős. 1992. Bryophyte conservation for the future. Biological Conservation 59: 265-270.

Söderström, L. T. 1993. Substrate preference in some forest bryophytes: a quantitative study. Lindbergia 18: 98-103.

SPSS. 1999. Professional base system software for statistical analysis. Chicago, Illinois.

Stotler, R. & B. Crandall-Stotler. 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405-428.

ter Braak, C.J.F. 1986 Canonical Correspondance analysis: A new eigenvector method for multivariate direct gradient analysis. Ecology, 67: 1167-1179.

ter Braak, C.J.F. 1998. CANOCO 4. Centre for Biometry, Wageningen, The Netherlands.

USDA & USDI. 1994. Record of decision for amendments to Forest Service and bureau of Land Management planning documents within the range of the Northern Spotted Owl. 1994-589-111/00001. U.S. Government Printing Office, Washington, D.C.

Vitt, D.H., Y. Li & R.J. Belland. 1995. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1- 12.

Vitt, D.H. 1991. Patterns of growth of the drought tolerant moss, *Racomitrium microcarpon*, over a three year period. Lindbergia 15: 181-187.

Watson, M.A. 1980. Patterns of habitat occupation in mosses relevance to considerations of the niche. Bull. Torrey Botanical Club 107: 346-372.

Whittaker, R.H. 1965. Diversity in land plant communities Science 147: 250-260.

CONCLUSION

Sampling Methodology for Biodiversity Studies

The species we leave behind or exclude due to sampling technique are crucial to understanding ecological patterns. The type of sampling used for estimating diversity depends on the organism being studied, how closely that organism is associated with its substrate, and on the nature of the ecological question (Krebs 1978). Bryophytes occur in close association with their substrate or habitat (Vitt & Belland 1997) and their use as indicators of habitat and environmental change or sensitivity is well documented (Gignac 1986; Söderström 1988a; Gignac & Vitt 1994; Bell & Newmaster 1998; Newmaster & Bell 2000). In terrestrial ecosystems, moss habitat limitations are often associated with substrate availability and type (Horton 1988; Shaw 1981; Söderström 1988b). In peatlands, bryophyte species richness is closely related to microhabitat diversity (Vitt et al. 1995; Vitt & Belland 1995). Vitt and Belland (1997) proposed that rare species occurrence and diversity depends on the quality and quantity of mesohabitats found on the landscape. To understand patterning of bryophyte diversity we must incorporate sampling techniques that focus on habitats as the sampling units. The patterning of bryophyte diversity is intimately linked with habitat heterogeneity.

Floristic habitat sampling (FHS) is a hierarchical sampling method that focuses on the entire mesohabitat as a sampling unit, including the variety of microhabitats within each type of mesohabitat, resulting in a complete floristic survey (Newmaster thesis chapter 1). When compared directly to plot sampling (PS), FHS records over twice as many species, including both the rare and common species; these are equally important in biodiversity studies. While a community analysis that needs species abundance within fixed areas only considers the common species, diversity studies should always include rare species, since these always comprise a large proportion of the flora being considered. Numerous recent bryophyte studies have underscored this point (Vitt 1991, Vitt & Belland 1997, Newmaster et al. 1998, 1999). In multivariate analyses, the rare species contribute significantly to the patterning of diversity in cedar hemlock forests. Young and old cedar hemlock forests stands were not distinguished in PS ordinations because the sampling method records only the species that are present and common to both young and old stands. In the FHS ordinations however, young and old cedar hemlock stands are separated in ordination space because the presence of rare species in old stands is recorded by FHS. Rare species are crucial in distinguishing differences between young and old stands, and to understanding the patterning of diversity within them.

Community differences in the ICH and CWH

Climate is well known as a primary factor influencing vegetation at large scales on the landscape (Hebda & Whitlock1997), and more specifically bryophyte floristics (Schofield 1988). Our classification of cedar hemlock stands using bryophyte communities at the regional scale (i.e., cedar-hemlock forests in BC) supports the biogeoclimatic classification (i.e., ICH & CWH) for cedar hemlock forest in BC (Meidinger & Pojar 1991). The CWH is wetter and warmer and has a heavy influence from oceanic weather patterns (Redmond and Taylor 1997). The ICH is controlled by continental weather patterns. The distinct differences in the community composition of the CWH and ICH can be partially explained by modern day climatic patterns.

The floristic elements of the interior and coastal cedar hemlock forests should be both compared and contrasted. Schofield (1988) has indicated that the ICH and CWH are similar both climatically and floristically. He realized that the bryoflora characteristic of the CWH is also partially present in the ICH. Furthermore, Schofield (1988) commented that some of the abundant bryophytes in the CWH are only found in local communities in the ICH; other bryophytes are equally frequent in both the CWH and ICH. Our comparisons of the ICH and CWH quantitatively support Schofield's qualitative observations. Several disjunct (Western Europe or Asia) species are common in the CWH, but only locally abundant in the ICH (for example *Herbertus aduncus, Porella cordaeana, Antitrichia curtipendula, Claopodium bolanderi,* and others). However, our contrasts of the CWH and ICH indicate that there are many differences between the bryoflora of the CWH and ICH even though species richness (gamma diversity) is very similar (i.e., ICH 300 spp, CWH 317 spp.). Some species are found exclusively in either the CWH (114 species - 36%) or ICH (98 species - 33%). Species with Circumboreal distributions are more common in the ICH. Conversely, species with temperate distributions are more common in the CWH. There are more western North America endemics in the CWH than the ICH, some of which are exclusive to the CWH.

Environmental conditions and habitat limitations limit development of the bryoflora. Some microhabitats will be more common to either the ICH or CWH. Climate greatly influences the microhabitats that are available in either biogeoclimatic zone. For example, the communities that are unique to big leaf maple (*Acer macrophyllum*) are unlikely to develop in the ICH since the species is restricted to the coast. However, some habitats are not related to climate but also limit community development within a biogeoclimatic zone. Specific species of bryophytes are often associated on either acidic or basic rock, which provides microhabitat for unique communities (Belland & Brassard; Belland & Schofield 1984). Rock microhabitats are chiefly acidic in the CWH and predominantly basic in the ICH (Montgomery 1997). Although rock microhabitats are present in forest, they were not a primary environmental variable explaining the community composition of bryophytes in the cedar hemlock landscape.

Patterning of Diversity

Old growth cedar-hemlock stands in British Columbia are known to support rich carpets of bryophytes, but surprisingly, there has been no published quantitative data that compares bryophyte diversity in young and old growth cedar hemlock forests. Our research clearly shows that old-growth cedar-hemlock forests have many more species and higher abundance of bryophytes than young forests regardless of biogeoclimatic zone. Gamma and alpha diversity were approximately twice as high in old-growth cedar-hemlock forests than in young forests. Studies from other forest ecosystems have shown that bryophyte diversity is higher in old growth stands when compared to younger stands (Pike et al. 1975; Söderström 1988a; Lesica et al. 1991; Crites & Dale 1995; Rambo & Muir 1998a, 1998b). These studies have concluded that old stands promote habitat and environmental conditions that are favorable for rich bryophyte communities. These old forests have many unique habitats for epiphytic (Pike et al. 1975; Sillet 1995) and epixylic bryophytes. Old forests have a greater diversity of logs in a variety of decay classes and sizes than young forests (Andersson & Hytteborn 1991). Logs provide habitat for many species of bryophytes, and different decay classes and sizes of logs support different communities of bryophytes (Gustafsson, & Hallingbäck 1988; Söderström

1988a). Furthermore, disturbing these habitats can reduce bryophyte diversity dramatically (Muotka & Virtanen 1995).

High diversity old growth forest may be due to moist local microclimate (Hallingbäck 1977) and stand continuity (Edwards 1986). Long forest continuity is associated with high bryophyte diversity (Rambo & Muir 1998a), and the support of rare endemic species (Edwards 1986; Aune 1994). Although forest fire is still a dominant force, in the wettest cedar-hemlock forest both fire history maps and the relative proportion of these forests older than 250 years suggest much lower fire frequencies (Arsenault 1995). The largest or most continuous stands are in watersheds that receive heavy annual rainfall. The unique forest structure in these moist, continuous old growth stands contributes to the diversity of microhabitats for bryophyte colonization. In the CWH, the oldest and most continuous stands (Sidney Fjord, Clayoquot and Walbran Watersheds on the west coast of Vancouver Island) had the highest bryophyte diversity. These old-growth cedar-hemlock forests have a rich flora of oceanic and suboceanic western North American endemics. 15% of the bryoflora of British Columbia is confined to western North America (Schofield 1988). These are also the wettest cedar-hemlock forests studied. Preservation of large, old-growth forests will ensure a refugium for many Western North American endemics (Schofield 1988). In the ICH, the wetter biogeoclimatic variants (i.e., ICHwk1 and ICHvk1) had higher species richness. These areas also appear to be more continuous because they do not have the extensive disturbance history of the drier ICHmw3. Similar patterning of lichen diversity has been recorded in the ICH (Arsenault and Goward 1997; Goward and Arsenault 2000).

The lack of large-scale disturbance in a forest promotes favorable environmental conditions (i.e., high humidity, low wind and moderate light) for the development of rich communities of bryophytes (Edwards 1986; Söderström 1988b; Gustafssson et al. 1992, Newmaster thesis chapter 3). Both logging and forest fire disturbance create environmental conditions that are unfavorable for many bryophytes and lichens (Laaka 1980; Goward 1992, 1993; Johnston and Elliot 1996). Changes to microclimate include humidity, moisture, temperature and light quality (Bell & Newmaster 1998; Newmaster et al. 1999). Following clear-cutting or wild fire, microhabitats are disturbed or removed (i.e., logs, stumps and rocks), temperature extremes and the drying effect of the wind increase, drainage lowers the surface water, and streams, cliffs, moist logs and stumps dry out (Hämet-Ahti 1983, Crites & Dale 1995; Newmaster et al. 1999, Laaka 1992). The number of suitable habitats decreases, ultimately decreasing cryptogam diversity (Gustafsson and Hallingbäck 1988, Soderstrom 1988a, Laaka 1992, McCune 1993, Newmaster et al. 1999, Rambo and Muir 1998a). These disturbances have severe consequences to the ecosystem because of the loss of many mesophytic forest species and the invasion of colonizers and fugitives (Bell and Newmaster 1998; Newmaster and Bell 2000).

Patterning of diversity is closely linked with patterning of communities. Old cedar hemlock forests not only have more species, but many of these are rare species that are unique to old forests. There are more than twice as many hepatics, endemics, and rare species in old growth forests than young forests. Species turnover is high when moving on a gradient of young to old stands or low to high mesohabitat heterogeneity. It appears that given enough time, bryophytes can occupy a large variety of habitats within a forest. Söderström (1988b) demonstrated that hepatics are richer and more abundant in older forests and unique communities of hepatics and mosses in old-growth forests have been documented in many other research projects (Pike et al. 1978; Lesica et al. 1991; Sillet 1995; Laaka 1992; Rambo and Muir 1998a). Rare epixylic hepatics are often associated with the abundance of logs in different decay classes and sizes in old-growth forest (Gustafsson & Hallinbäck 1988; Söderström 1988a; Rambo & Muir 1998a, 1998b). These epixylic specialists have habitat requirements that are unique to older forest (Sermander 1936; Schuster 1949; Andersson & Hyterborn 1991). Succession of epixyilic communities is continuous because the logs offer only temporary habitat for these rare hepatics; old growth forest ecosystems provide a continuous supply of logs that maintains rich communities of hepatics. These community differences help to interpret the differences in species richness between young and old growth cedar hemlock forests.

Mesohabitats

Mesohabitat quality and quantity are the basic ingredients for bryophyte diversity at the local landscape scale. This advocates Vitt and Belland's (1997) model of rare species richness. Mesohabitat quantity can be defined as the types and distributions of all mesohabitats and the number of particular mesohabitats on a landscape (Vitt & Belland 1997). In our study of bryophyte diversity in cedar-hemlock forest, species richness was largely dependent on the number of particular types of mesohabitats (Newmaster thesis chapter 3). The dominant forest mesohabitat largely determines high abundance and frequency of bryophytes. Restricted mesohabitats are most influential in the maintenance of species diversity. Specifically, the presence of streams and cliffs offers the highest bryophyte diversity. As predicted in Vitt and Belland's model (1997), mesohabitat quality is expressed as the number and type of microhabitats. In cedar hemlock forest, high diversity in microhabitats within a particular mesohabitat was strongly correlated with high species richness.

This research shows that each type of mesohabitat has a list of variables that promote high species richness. I found that high mesohabitat quality is the most important variable correlated with high bryophyte diversity within mesohabitats. High variation in microhabitats is strongly correlated with high bryophyte species richness in cedar hemlock forests. The presence of specific types of microhabitats and the influence of some environmental variables are also correlated with high species richness within specific types of mesohabitats. Some of these correlations are specific and others are more general and apply to both the ICH and CWH.

Microhabitats

Forest microhabitat heterogeneity is the primary root of bryophyte diversity. Patterning of bryophyte diversity in cedar hemlock forests has been explained in the context of a hierarchy of stands (Newmaster thesis chapter 1 & 3), mesohabitats (Newmaster thesis chapter 4) and microhabitats (Newmaster thesis chapter 5). Microhabitat heterogeneity is most influential at local landscape scales (i.e., within specific types of mesohabitats). Variability in bryophyte species richness and community composition in cedar hemlock forests is clearly evident among different types of microhabitats.

Bryophytes can be grouped into communities of epiphylous, epixylous, saxicolous and terricolous species. In both the ICH or CWH forests epiphytic communities can be further defined using tree type (i.e., deciduous or coniferous), size and vertical position on the tree. Species richness is highest on large trees (> 30 cm diam.), and stand age is an important integrated factor. These findings are supported in other epiphytic studies (Rambo & Muir 1998b; Pike et al. 1975; Slack 1976; Sillett 1995). Epixylic communities in the ICH or CWH can be further defined using log size and decay class. The large logs (> 70 cm diam.) of decay class three offered the highest diversity of bryophytes with a large proportion of hepatics. These patterns are supported by research in other types of forests in Europe and the United States (Söderström 1988a, 1988b, 1993; Rambo & Muir 1998b; Anderson & Hyterborn 1991). Forest floor bryophyte community composition is related to habitat heterogeneity. The most species rich communities were found on rocks, upturned tree roots and stumps in both the ICH and CWH. Rambo and Muir (1998a) also found that availability of rock microhabitats increased bryophyte diversity in old growth temperate rain forest in Oregon. Habitat availability is a crucial precursor to high bryophyte diversity (Slack 1977).

Patterning of bryophyte diversity on microhabitats can be defined on a temporal scale. In a forest ecosystem, bryophyte diversity increases with time. Higher diversity of bryophytes (particularly hepatics) in old growth forests, is consistent with other published accounts that have found richer diversity of mosses and hepatics associated with old growth than with young stands in Europe and North America (Gustafsson & Hallinbäck 1988; Lesica 1991; Rambo & Muir 1998a; Söderström 1988a). Old growth cedar hemlock stands foster an environment that is rich with bryophytes. Moist microclimate and high habitat heterogeneity are associated with rich bryofloras and old growth cedar hemlock forests. Patterning of bryophyte diversity is positively correlated with mesohabitat quantity and quality (Newmaster thesis chapter 3). The quality of a mesohabitat is defined by habitat heterogeneity. As microhabitat heterogeneity increases so does bryophyte diversity in both the ICH and CWH. However, stand age is also intimately linked to with habitat heterogeneity. As stands become older there is a greater abundance and diversity of microhabitats. Other factors that influence bryophyte diversity and are related to stand age include: bryophyte dispersal capability and, ability to establish in various microclimate conditions (Söderström 1988a, 1988b, 1987).

Management

Floristic habitat sampling provides results that can be directly implemented into ecosystem management plans for the preservation of "rare species" and identification of "hot spots" for conservation. It would be of tremendous value if it aids in the interpretation of the patterning of plant diversity using environmental variables in association with spatial landscape units such as mesohabitats and microhabitats. These landscape units can be identified in aerial or satellite photography and linked to GIS applications. A classification of mesohabitats and microhabitats as it relates to bryophyte diversity could be developed and incorporated into large-scale, multi-factored (i.e., soils, stand structure, climate, wildlife values, land use etc.) environmental plans. Furthermore, FHS also records both rare and common species and their frequency in microhabitats and mesohabitats. This provides a method by which to identify the crucial habitats that need to be protected to preserve rare species. FHS can also be used to identify larger areas such watersheds that have significantly high diversity.

In British Columbia, forest managers are dealing with many old growth and biodiversity issues, including the challenge of managing biodiversity in forests with few large natural catastrophic disturbances (Jull 1997). Disturbances through human activities such as logging operations could pose serious threats to the long term functioning of forest ecosystems (Bradfield et al. 1997). Understanding the patterning of bryophyte communities in the ICH and CWH biogeoclimatic zones will help minimize the impact from forestry operation on biodiversity (Arsenault and Goward 1999). Old growth indicator species for each biogeoclimatic zone could be used to identify areas with unique bryophyte communities or bryophyte hot spots. Preservation of such areas is of paramount importance in the successfully management for biodiversity in cedar-hemlock forests and will be useful information in the development of strategies for the conservation of bryophytes in managed forest landscapes of British Columbia.

A better understanding of the patterning of bryophyte diversity in forested ecosystems will provide an opportunity to minimize the impact of forest operations on biodiversity (Arsenault and Goward 1997). Management plans must consider stand age and mesohabitat heterogeneity as the two most influential environmental variables that influence the patterning of bryophyte diversity in cedar hemlock forest. The increase in species richness with older more meso-habitat rich stands corresponds with an increase in rare species, endemics and hepatics (Newmaster thesis chapter 2). The loss of bryophyte species after logging and forest fire disturbance is well documented and of growing concern (Peet et al. 1983; Laaka 1992; Ehrlich 1990; Andersson 1987; Bell & Newmaster 1998, Newmaster et al. 1999). Recommendations from many analyses of bryophyte diversity suggest the protection of old-growth forests and subsequently the rare species within (Gustafsson & Hallinbäck 1988; Söderström 1988b; Rambo & Muir 1998a; Schofield 1988). Norway and other countries have stated the importance of preserving old-forest for the conservation of rare bryophytes (Prestø 1996; Weibull and Söderström 1995). Efforts in preservation of rare species and areas of high bryophyte diversity have been established throughout Europe (Söderström et al. 1992, Söderström 1995) and North America (Vitt & Slack 1984; Slack 1988, 1992; Newmaster et al. 1997; Belland 1998; Rambo and Muir 1998a;). We suggest that bryophyte diversity, in the cedar-hemlock forests of British Columbia will be sustained through ecosystem management of old growth legacies (i.e., landscapes, stands and components of these) and the preservation of areas of high diversity. Our research has identified the importance of old-growth forests and habitat heterogeneity. We suggest that the oldest, most continuous forests should be considered as protected areas. Furthermore, mesohabitat quality and quantity should have special consideration in old-growth management plans.

Unique communities of bryophytes exist for different types of mesohabitats. This association between bryophytes and habitat has long been known, and used for indicators of environmental change (Gignac & Vitt 1994) and quality (Gignac 1986; Newmaster et al. 1999). In peatlands, bryophytes have been used to indicate chemical and wetness gradients (Vitt et al. 1975; Slack 1980; Vitt & Chee 1990) and patterning of species richness (Vitt et al. 1995; Belland & Vitt 1995). It would be expected that these patterns would be true for upland habitats, where moss habitat limitations have been closely tied to substrate (Schuster 1949; Rose 1992; Söderström 1993; Vitt & Belland 1997; Horton 1988; Shaw 1981). Bryophyte communities are distinct and unique to each type of mesohabitat within the CWH and ICH forests. Old-growth indicators (Newmaster thesis chapter 2) and rare species are commonly found in each type of mesohabitat. The consequence of this to preserving bryophyte diversity is significant. A specific type of mesohabitat should not have a greater value than any other mesohabitat; all types of mesohabitats need to be preserved to maintain high bryophyte diversity. A variety of mesohabitat types with the highest possible diversity of microhabitats should be preserved in every watershed management plan if sustainability of diversity is a priority. Each mesohabitat preserved should contain the highest bryophyte richness in order to sustain biodiversity on the landscape. Environmental variables that are associated with high bryophyte richness within and between specific mesohabitats have been listed for the ICH and CWH biogeoclimatic zones. The value of old growth forest to biodiversity must not be underestimated. Clear-cutting techniques reduces stand age, the number of habitats, and ultimately cryptogam diversity in analysis of forest stands (Anderson & Hytterborn 1991; Gustafsson & Hallingbäck 1988; Lesica et al. 1991; Söderström 1988; Rambo and Muir 1998b; Newmaster et al. 1999). We should consider mesohabitats in old growth forests as reservoirs of bryophyte diversity.

Conservation of bryophyte diversity should include the sustainability of high mesohabitat quality in all ecosystem management plans. Mesohabitat quality is largely determined by microhabitat heterogeneity. Microhabitats are essential for sustaining bryophyte diversity and these microhabitats should be enriched through forest management practices. Microhabitats that are associated with high bryophyte diversity have been listed for each mesohabitat and biogeoclimatic zone. An example would be preserving a variety of logs of different sizes and decay classes during harvesting. It is not known if bryophyte communities can survive after logging disturbance. Perhaps areas of forest with high microhabitat heterogeneity should preserved as refugia for a pool of species that could repopulate an adjacent clear-cut.

A truly ecosystem-based management regime requires an understanding of the patterning of diversity at several different landscape scales. If our objective is to conserve biological diversity, adopting a conservation strategy that places more emphasis on landscapes, ecosystems and habitats is the only feasible approach (Franklin 1993). Traditional approaches to conservation have focused on species as bio-indicators and have many problems (Lertzman et al. 1997). We have investigated the patterning of bryophyte diversity at the regional, stand and local scales. At the regional scale, patterning of diversity is associated with climatic variables and at the stand scale it is associated with time since the last major disturbance (stand age). These large-scale variables (climate & disturbance history) should be used to stratify management plans (i.e., micro-management). At the local scale, mesohabitat quantity and quality largely determine bryophyte diversity. The local scale provides habitat variables that are associated with high bryophyte diversity and these should be used as bio-indicators. Bio-indicators based on habitats are easy to learn and incorporate in management plans. By preserving habitats we make no assumptions about the needs of an indicator species. The natural ecosystem with its diversity of habitats serves as our best model for preserving diversity for the future.

LITERATURE CITED

Andersson, L.I. & H. Hytteborn. 1991. Bryophytes and decaying wood - a comparison between managed and natural forest. Holarctic Ecology 14: 121-130.

Andersson, L.I. 1987. Förekomsten av mossarter pävedsubstrat på vedsubstrat och tillgång på förmultnade ved I naturskog (Fiby urskog) och kulturskog. Medd Växtbiology 2: 1-54.

Aune, E.I. 1994. Kystgranskog. Pp. 1-9 in Fylkesmannen I Sør-Trøndelag (ed.), Kystgranskogen I midt-Norge.

Arsenault, A. 1995. Pattern and process in old-growth temperate rainforest of southern British Columbia. University of British Columbia, Department of Botany, Vancouver, B.C. Ph.D.Thesis,

Arsenault, A. and Goward, T. 1999. Ecological characteristics of inland rainforests. Proceedings to the species at risk conference. Kamloops, B.C.

Bell, F.W. and S.G. Newmaster. 1998. Fallingsnow Ecosystem Project: Floral richness, abundance and diversity. Pp. 45-47 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (comps.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Belland, R.J. & D.H. Vitt. 1995. Bryophyte vegetation patterns along environmental gradients in continental bogs. Ècoscience 2: 395-407.

Belland, R.J. 1998. The rare mosses of Canada. Committee on the status of endangered wildlife in Canada, Canadian Wildlife Service, Environment Canada, Ottawa.

Bradfield, G., Zhang, W. and Arsenault, A. 1997. Plant communities and natural disturbances in the ESSF of southern Wells Gray Park. Proceedings to the ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. June 10-12, University of Northern British Columbia Press, Prince George B.C., Canada.

Crites, S & M.R.T. Dale. 1995. Relations between nonvascular species and stand age and stand structure in aspen mixedwood forest in Alberta. pp. 91-112. In Stelfox, J.B. (ed.), Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forest in Alberta. Alberta Environment Centre, Alberta.

Edwards, M.E. 1986. Disturbance histories of four Snowdonian woodlands and their relation to Atlantic bryophyte distributions. Biological conservation 37: 301-320.

Ehrlich, P.R. 1990. Habitats in crisis: why we should care about the loss of species. Forest Management and Ecology 35: 5-11.

Franklin, J.F. 1993. Lessons from old-growth. Journal of Forestry 91: 10-13.

Gignac, D.L. 1986. Ecological tolerance and niche structure of *Sphagnum* along a pollution gradient near sudbury, Ontario, Canada. Can. J. Bot. 65: 1138-1147.

Gignac, D.L. & D.H. Vitt. 1994. Habitat limitations of *Sphagnum* along climatic, chemical, and physical gradients in mires of western Canada. The Bryologist 93: 7-22.

Gignac, D.L. & D.H. Vitt. 1994. Responses on northern peatlands to climatic change: Effects on bryophytes. Journal of the Hattori Botanical Laboratory 75: 119-132.

Goward, T. & T. Ahti. 1992. Macrolichens and their zonal distribution in Wells Gray Provincial Park and its vicinity, British Columbia, Canada. Acta Botanica Fennica 147: 1-60.

Goward, T. 1993. Epiphytic lichens: going down with the trees. pp. 153-158. In Rautio, S. (ed.), Community action for endangered species: a public symposium on B.C.'s threatened and endangered species and their habitat. Federation of British Columbia Naturalists, Vancover, British Columbia.

Goward, T. & Arsenault, A. 2000. Cyanolichen distribution in young unmanaged forests: a dripzone effect? The Bryologists 103: 28-37.

Gustafsson, L. & T. Hallingbäck. 1988. Bryophyte flora and vegetation of managed and virgin coniferous forest in south-west Sweden. Biological Conservation 44: 283-300.

Gustafsson, L., A. Fiskesjö, T.Hallingbäck & T. Ingelög. 1992. Semi-natural deciduous broadleaved woods in southern Sweden - habitat factors of importance to some bryophyte species. Biological conservation 59: 175-181.

Hallingbäck, T. 1977. Översiktlig inventering av naturskogar I Värmlands län med kryptogamfloran som utgångspunkt. – Naturvårdsenheten, Länsstyrelsen I Värmlands län, (in Sweedish).

Hämet-Ahti, L. 1983. Human impacts on closed boreal forest. Pp. 201-211. in *Man's Impact on Vegetation* (eds.), W. Holzner, M.J.A. Werger & I. Ikusima. Wunk, The Hague.

Hebda, R.J. & C. Whitlock. 1997. Environmental history. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Horton, D. G. 1988. Microhabitats of New World Encalyptaceae (Bryopsida): distribution along edaphic gradients. Beifefte zur Nova Hedwigia 90: 261-282.

Johnston, M.H. & J.A. Elliot. 1996. Impacts of logging and wildfire on an upland black spruce community in northwestern Ontario. Environmental Monitoring and Assessment 39: 283-297.

Jull, M. 1997. Northern wet-belt ICH and ESSF: searching for the big picture. Proceedings to the ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. June 10-12, University of Northern British Columbia Press, Prince George B.C., Canada.

Krebs, C.J. 1978. Ecology. Harper & Row, New York.

Laaka, S. 1992. The threatened epixylic bryophytes in old primeval forest in Finland. Biological Conservation 59: 151-154.

Lertzman, K.P., T. Spies & F.Swanson. 1997. From ecosysytem dynamics to ecosystem management. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Lesica, P., B. McCune, S.V. Cooper & W.S. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botany 69: 1745-1755.

McCune, B. 1993. Gradients in epiphytic biomass in three Pseudotsuga-Tsuga forest of different ages in western Oregon and Washington. The Bryologist 96: 405-411.

Meidinger D. & J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forest, Research Branch, Victoria, B.C. Special report series 6.

Montgomery, D.R. 1987. The influence of geological processes on ecological systems. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home*. Island Press, Washington, DC.

Muotka, T. & R. Virtanen. 1995. Stream as a habitat templet for brophytes: species distribution along gradients in disturbance and substratum heterogeneity. Freshwater Biology 33:141-160.

Newmaster, S.G., Lehela A., Oldham M.J., Uhlig, P.W.C., and McMuray, S. 1997. Ontario Plant List. Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Forest Research Information Paper No. 123. 650 pp. + appendices.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1998. The effects of silvicultural herbicides on bryophytes. Pp. 223-225 *in* Third International Forest Vegetation Management Conference: Forest Vegetation Management and Ecosystem Sustainability-Popular Summaries, R.G. Wagner and D.G. Thompson (comps.). Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, ON. Forest Research Information Paper No. 141.

Newmaster, S.G., D.H. Vitt, and F.W. Bell. 1999. The effects of triclopyr and glyphosate on common bryophytes and lichens in northwestern Ontario. Canadian Journal of Forest Research 29: 1101-1111.

Newmaster, S.G. & F.W. Bell. 2000. Floristic diversity of cryptograms in a boreal-mixedwood stand after mechanical, manual and herbicide conifer release treatments. Ontario Ministry of Natural Resources, Ontario Forest Research Institute, Sault Ste. Marie, Ontario, Submitted CJFR.

Peet, R.K., D.C. Glenn-Levin & J.W. Wolf. 1983. Prediction of man's impact on plant species diversity. A challenge for vegetation science. Pp. 41-54 in M*an's Impact on Vegetation*, W. Holzner, M.J.A. Werger & I. Ikusima. Wunk, The Hague.

Pike, L.E., W.C. Denison, D.M. Tracey, M. A. Sherwood and F. M. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing in old-growth conifers in western Oregon. The Bryologist 78: 1-39.

Prestø, T. 1996. Monitoring of bryophytes in boreal rain forests: Effects of forestry. in Söderström, L. & T. Prestø (eds.), *State of Nordic Bryology Today and Towmorrow. Abstracts and shorter communications from a proceedings in Trondheim December 1995.* Raport Botanisk serie 1996-4, Trondheim Universitet, Norway.

Rambo, T.R. & P.S. Muir. 1998a. Forest floor bryophytes of *Pseudotsuga menziesii-Tsuga hetrophylla* stands in Oregon: influences of substrate and overstory. The Bryologist 101: 116-130.

Rambo, T.R. & P.S. Muir. 1998b. Bryophyte species associations with coarse woody debris and stand ages in Oregon. The Bryologist 101: 366-377.

Redman, K. and Taylor, G. 1997. Climate of the coastal temperate rainforest. in P.K. Schoonmaker, B. von Hagen & E.C. Wolf (eds.), *The Rain Forests of Home.* Island Press, Washington, DC.

Rose, F. 1992. Temperate forest management: Its effects on bryophyte and lichen floras and habitats. In Bates, J.W. & A.M. Farmer (eds.), *Bryophytes and lichens in a changing environment*, Clarendon Press, Oxford, pp. 211-232.

Schofield, W.B. 1984. Bryogeography of the Pacific coast of North America. Journal hattori Botanical Laboratory 55: 35-43.

Schofield, W.B. 1988. Bryogeography and bryophytic characterization of biogeoclimatic zones of British Columbia, Canada. Canadian Journal of Botany 66: 2673-2686.

Schuster, R. 1949. The ecology and distribution of Hepaticae in central and western New York. American Midland Naturalist. 42:513-712.

Sermander, R. 1936. Granskär och Fiby urskog. En studie över stormluckornas och marbuskarnas betvdelse I den svenska granskogens regeneration. (the primitive forest of Granskär and Fiby). Acta Phytogeography, Suec 8. Almqvist and Wiksell, Uppsala.

Sillet, S.C. 1995. Branch epiphyte assemblages in the forest interior and on the clearcut edge of a 700 year-old Douglas Fir canopy in western Oregon. The Bryologist 98:301-312.

Shaw, A.J. 1981. Ecological diversification among nine species of *Pohlia* (Musci) in western North America. Canadian Journal of Botany 59: 2359-2378.

Slack, N.G. 1977. Species diversity and community structure in bryophytes: New York State Studies. Bulletin N.Y. State Museum 428: 1-70.

Slack, N.G. 1976. Host specificity of bryophytic epiphytes in eastern North America. Journal of the Hattori Botanical Laboratory 41: 107-132.

Slack, N.G., D.H. Vitt, & D.G. Horton. 1980. Vegetation gradients of minerotrophically rich fens in western alberta. Canadian Journal of Botany 58: 330-350.

Slack, N.G. 1988. The ecological importance of lichens and bryophytes. Bibl. Lichenol 30: 23-53.

Slack, N.G. 1992. Rare and endangered bryophytes in New York state and eastern United States: Current status and preservation strategies. Biological Conservation 59: 233-241.

Söderström, L. 1988a. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8: 89-97.

Söderström, L. 1988b. The occurrence of epixylic bryophyte and lichen species in an old natural and managed forest stand in northwest Sweden. Biological Conservation 45: 169-178.

Söderström, L. 1989. Regional distribution patterns of bryophyte species on spruce logs in northern Sweden. The Bryologist 92: 349-355.

Söderström, L. 1995. Bryophyte conservation - Input from population ecology and metapopulation dynamics. Cryptog. Helv. 18: 17-24.

Söderström, L., T.Hallingbäck, L. Gustafsson, N. Cronberg & L. Hedenős. 1992. Bryophyte conservation for the future. Biological Conservation 59: 265-270.

Söderström, L. T. 1993. Substrate preference in some forest bryophytes: a quantitative study. Lindbergia 18: 98-103.

Vitt, D.H. 1991. Distribution patterns, adaptive strategies, and morphological changes of mosses along elevational and latitudinal gradients on South Pacific Islands. Pp. 205-236. in P.L. Nimis and T.J. Crovello (ed.), Quantitative Approaches to Phytogeography. Kluwer Academic Publishers,The Netherlands.

Vitt, D.H. & R.J. Belland. 1995. The bryophytes of peatlands in continental western Canada. Fragmenta Floristica et Geobotanica 40: 339-348.

Vitt, D.H., Y. Li & R.J. Belland. 1995. Patterns of bryophyte diversity in peatlands of continental western Canada. The Bryologist 98: 218-227.

Vitt, D.H., P. Achuff & R.E. Andrus. 1975. The vegetation and chemical properties of patterned fens in the Swan Hills, north central Alberta. Canadian Journal of Botany 53: 2776-2795.

Vitt, D.H. & R.J. Belland. 1997. Attributes of rarity among Alberta Mosses: Patterns and prediction of species diversity. The Bryologist 100: 1- 12.

Vitt, D.H. & W.L. Chee. 1990. The relationships of vegetation to surface water chemistry and peat chemistry in fens of Alberta, Canada. Vegetatio 89: 87-106.

Vitt, D.H. & N.G. Slack. 1984. Niche diversification of *Sphagnum* relative to environmental factors in northern Minnesota peatlands. Canadian Journal of Botany 62: 1409-1430.

Weibull, H & L. Söderström. 1995. Red data listed hepatics of Scandinavia in a regional and world-wide perspective - A preliminary study. Cryptog Helv. 18: 57-66.

APPENDIX I: Summary of the twenty-four environmental variables used in the numerical analyses.

1. **Site Series (SS):** Eco-site classification following the site classification guide lines for each biogeoclimatic zone (B.C. Forest Service). The numerical site series value combines soil moisture regime, soil nutrient regime and common vascular plant species as bioindicators (Lloyd et al. 1990).

2. **Latitude (Lt):** Northerly bearing using a hand held "Silva Ranger" compass.

3. **Longitude (Ln):** Westerly bearing using a hand held "Silva Ranger" compass.

4. **Elevation (Elv):** Height above sea level (m) taken from 1:50000 topographical maps.

5. **Slope Position (SP):** Description of slope position into upper, mid, lower slope or toe (bottom) position.

6. **Aspect (As):** local azimuth of slope direction using a hand held "Silva Ranger" compass.

7. **Moisture Regime (MR):** Ecological moisture regime based on soil and site conditions. The scale includes, 0 = very xeric, 1 = xeric, 2 = subxeric, 3 = submesic, 4 = mesic, 5 = subhygric, 6 = hygric, 7 = subhygric and 8 = hydric.

8. **Rock cover (RC):** Visual estimate of % cover rocks within the stand.

9. **Rock acidity (RA):** Acidic/basic litmus text of powdered rock samples for each rock microhabitat sampled.

10. **Soil Texture (ST):** Field texture classification of mineral soil layer. Classification includes sand, silt, clay, loam and proportional mixtures of these basic soil textures.

Tree measurements

11-13. **Canopy height (CH) m; Tree density (DT) m2/ha; Tree basal area (BT) mean dbh (cm2):** A circular plot 20 m in diameter was established to record tree measurements. All standing trees greater than 1 cm dbh were recorded using the methodology given in Arsenault & Bradfield (1995).

Snag measurements

14-15. **Snag density (DS) m2/ha; Snag basal area (BS) cm2:** A circular plot 20 m in diameter was established to record snag measurements. All snags (standing dead trees) greater than 10 cm dbh were recorded using the methodology given in Arsenault & Bradfield (1995).

Log measurements

16-17. **Log density (DL) m2/ha; Log basal area (BL) cm2:** Coarse woody debris was assessed along two 50 m transects. Measurements included size and structural class and evaluated of decay class (Arsenault & Bradfield 1995).

Vegetation cover

18-19. **Shrub (SC); Herb (HC) %:** A circular plot 20 m in diameter was established to record shrub abd herb vegetaion layers for percent cover.

20. **Stand age (Ds):** A circular plot 20 m in diameter was established to record tree age. All standing trees greater than 1 cm dbh were recorded using the methodology given in Arsenault & Bradfield (1995). For trees between 1cm and 10 cm dbh, two cross-sections were collected for representative trees of each tree species; these were stored for later dendrochronological analysis. Trees greater than 10 cm dbh were cored at 30 cm height. Stand age was further classified into

age class 4 (80 yrs) disturbed by fire or logging or age class 9 old-growth stands of 250+ years in age.

Climate variables

21-23. Mean annual temperature (AT) ^{o}C; Total yearly rainfall (Rn) mm; Degree days (^{o}D): Taken from Environment Canada's weather stations and satellite temperatures for each water shed (Anonymous-Canadian Climate Normals 1998).

24. Six month mean temperature (6T) ^{o}C: Microclimate data were collected only within in a subset of 20 stands (divided evenly between young and old forest) within each watershed. Within each stand, five replicate sites were randomly chosen to measure temperature and total precipitation. All microclimate stations were set out in May and measured/removed in October of 1997. Growing season temperature within stands (subset) was calculated using sucrose inversion (provides an integrated temperature data for the length of the growing season) technique as described in (Damman 1975).

LITERATURE CITED

Anonymous, 1998. Canadian climate normals, 1951-1980. Vols 1-4. Environment Canada, Atmospheric Environment service, Ottawa, Ontario.

Arsenault, A. and G. Bradfield. 1995. Structural-compositional variation in three age-classes of temperate rainforests in southern coastal British Columbia. Can.J.Bot. 73:54-64

Damman, A.W.H. 1975. Plant distribution in Newfoundland especially in relation to summer temperatures measured with the sucrose inversion method. Canadian Journal of Botany 54: 1561-1585.

Lloyd, D., K. Angove, G. Hope & C. Thompson. 1990. A guide for site identification and interpretation of the Kamloops Forest Region. Volumes 1 and 2. British Columbia Ministry of Forests, Land Management Handbook 23: 1-399.

APPENDIX II. ICH environmental data

Environmental/Plots	1	2	3	4	5	6	7	8	9	10	11
Elevation	750	685	650	700	700	700	705	720	825	855	835
Latitude	51 57	51 57	51 57	52 09	52 09	52 09	51 56	51 56	51 56	51 58	51 58
Longitude	120 08	120 08	120 08	120 12	120 12	120 12	120 04	120 04	120 04	120 08	120 08
BCG zone	1	1	1	1	1	1	1	1	1	1	1
Site Series	1	1	6	7	1	7	7	1	5	7	1
Slope	1	10	1	20	15	12	10	3	2	4	12
Aspect	258	10	297	230	240	252	252	40	224	57	130
Slope Position	1	1	3	2	3	3	2	1	3	3	3
Moisture Regime	3	3	3	4	3	4	2	3	2	5	3
Rock cover	1	1	5	2	5	10	5	5	5	5	1
Soil Texture	6	7	2	2	2	6	2	2	2	7	2
Canopy height	27	40	27	42	33	25	42	28	23	38	30
Shrub cover	27	30	60	15	14	12	8	40	20	45	20
Herb cover	3	10	50	35	12	30	40	20	10	10	20
Tree density	1273	477	446	541	1019	573	732	605	1464	637	1019
Snag density	127	95	64	223	191	64	32	64	95	32	223
Log density	477	159	64	223	286	382	223	255	223	350	414
Tree basal area	39	90	82	180	61	31	130	93	36	99	57
Snag basal area	19	6	1	50	5	1	0	20	15	1	4
Log basal area	28	3	8	44	41	33	18	17	19	34	22
Disturbance (stand age)	4	4	9	9	4	4	9	4	4	9	4
Watershed	1	1	1	4	4	4	4	1	1	1	1
Mesohabitat number	1	1	2	2	2	2	2	3	2	2	2
Rock acidity	1	1	2	2	2	2	2	2	2	2	1
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
6 month temperature	8	8	8	8	8	8	8	8	8	8	8
Degree days	170	170	170	170	170	170	170	170	170	170	170

APPENDIX II. ICH environmental data

Environmental/Plots	12	13	14	15	16	17	18	19	20	21	22
Elevation	740	845	845	735	730	840	670	680	900	630	650
Latitude	51 58	51 58	51 58	51 58	51 57	51 58	52 04	52 04	51 58	51 58	51 58
Longitude	120 08	120 08	120 08	120 08	120 07	120 08	120 11	120 11	120 08	120 05	120 04
BCG zone	1	1	1	1	1	1	1	1	1	1	1
Site Series	8	5	1	1	6	6	1	1	1	8	7
Slope	3	16	1	5	10	5	10	8	1	1	13
Aspect	220	282	0	350	360	69	210	191	80	80	347
Slope Position	1	3	3	1	2	3	2	1	3	2	2
Moisture Regime	5	2	3	5	3	5	2	3	5	4	4
Rock cover	5	1	1	15	15	5	10	15	5	20	20
Soil Texture	1	7	2	2	7	5	7	2	6	2	7
Canopy height	40	31	30	36	33	38	34	33	21	35	44
Shrub cover	17	60	85	18	7	10	35	10	5	30	22
Herb cover	50	55	20	20	15	5	30	55	5	70	36
Tree density	700	668	891	1050	605	477	605	764	1019	637	1050
Snag density	95	32	32	32	191	95	127	95	191	255	127
Log density	223	350	191	318	605	446	223	255	477	605	223
Tree basal area	171	49	52	63	50	108	59	88	81	72	60
Snag basal area	2	2	2	4	15	2	8	3	3	14	11
Log basal area	7	12	7	33	33	29	14	17	88	115	23
Disturbance (stand age)	9	4	4	4	9	9	9	4	4	9	4
Watershed	1	1	1	1	1	1	1	1	1	1	1
Mesohabitat number	2	1	1	3	2	2	3	3	2	3	4
Rock acidity	2	1	1	2	2	2	2	2	2	2	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
6 month temperature	8	8	8	8	8	8	8	8	8	8	8
Degree days	170	170	170	170	170	170	170	170	170	170	170

APPENDIX II. ICH environmental data

Environmental/Plots	23	24	25	26	27	28	29	30	31	32	33
Elevation	695	700	685	625	700	635	690	740	690	780	830
Latitude	51 53	51 59	51 59	51 51	51 53	51 59	52 22	52 22	52 22	52 22	52 24
Longitude	119 07	119 04	119 04	119 07	119 07	119 05	119 59	119 59	119 58	119 58	119 58
BCG zone	2	3	3	2	2	3	2	2	3	2	2
Site Series	5	4	4	1	1	1	6	1	1	4	3
Slope	1	5	45	4	19	50	1	38	1	12	76
Aspect	0	240	260	44	164	315	0	302	0	318	202
Slope Position	3	5	4	2	2	3	2	3	2	5	3
Moisture Regime	4	2	2	3	3	2	4	3	4	2	3
Rock cover	5	1	1	20	1	15	5	5	5	5	10
Soil Texture	5	7	7	2	7	2	8	7	5	6	7
Canopy height	38	38	35	37	42	37	35	37	27	25	26
Shrub cover	23	25	14	15	10	15	30	10	20	10	17
Herb cover	80	60	11	40	38	25	40	25	30	18	4
Tree density	414	286	700	509	477	573	573	350	255	700	1019
Snag density	64	32	127	95	64	223	95	32	95	64	127
Log density	255	286	318	191	95	159	286	95	159	95	64
Tree basal area	353	81	62	133	228	204	99	145	30	51	25
Snag basal area	26	16	20	42	7	46	4	0	5	2	3
Log basal area	60	85	32	34	60	46	27	14	16	12	1
Disturbance (stand age)	9	9	9	9	9	9	9	9	9	4	4
Watershed	2	2	2	2	2	2	4	4	4	4	4
Mesohabitat number	2	1	1	4	1	2	2	2	1	2	1
Rock acidity	2	1	1	2	1	3	2	2	2	2	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
6 month temperature	7	7	7	7	7	7	7	7	7	7	7
Degree days	150	150	150	150	150	150	150	150	150	150	150

APPENDIX II. ICH environmental data

Environmental/Plots	34	35	36	38	39	40	41	42	43	44	45
Elevation	980	690	780	835	820	680	670	1170	980	930	1020
Latitude	52 24	52 22	52 22	52 22	52 22	52 22	52 04	51 51	51 51	51 51	51 51
Longitude	119 58	119 58	119 58	119 59	119 59	119 59	120 11	119 09	119 09	119 09	119 09
BCG zone	2	2	2	1	1	1	1	2	2	2	2
Site Series	2	5	1	1	8	6	8	1	1	1	1
Slope	45	25	22	1	1	1	7	57	27	45	50
Aspect	202	274	294	350	0	0	210	70	84	80	63
Slope Position	5	4	4	3	2	1	2	4	4	4	4
Moisture Regime	1	4	3	3	5	4	4	3	3	3	3
Rock cover	10	5	60	1	5	5	1	1	1	2	5
Soil Texture	7	8	2	2	4	2	2	2	2	5	2
Canopy height	22	31	33	25	31	41	35	40	40	32	30
Shrub cover	25	9	3	3	30	12	35	12	10	2	1
Herb cover	9	40	20	5	52	20	53	20	25	15	60
Tree density	764	541	382	1019	668	891	859	382	414	828	828
Snag density	95	32	350	127	382	382	64	32	64	95	255
Log density	64	159	223	255	414	127	223	64	286	350	796
Tree basal area	23	109	54	37	31	70	246	100	140	55	54
Snag basal area	28	1	15	5	15	19	25	8	7	46	13
Log basal area	1	23	13	10	23	21	14	21	93	29	35
Disturbance (stand age)	4	9	9	4	4	4	9	9	9	4	4
Watershed	4	4	4	1	1	1	1	2	2	2	2
Mesohabitat number	1	3	2	1	3	1	1	2	1	2	2
Rock acidity	2	2	2	1	2	2	1	1	1	2	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1100	1100	1100	1200	1200	1200	1200	1100	1100	1100	1100
6 month temperature	7	7	7	8	8	8	8	7	7	7	7
Degree days	150	150	150	170	170	170	170	150	150	150	150

APPENDIX II. ICH environmental data

Environmental/Plots	46	47	48	49	50	51	52	53	54	55	57
Elevation	700	730	730	820	800	760	685	685	730	730	750
Latitude	51 51	51 51	51 51	51 51	51 49	51 49	51 49	51 49	51 51	51 56	51 55
Longitude	119 09	119 09	119 09	119 09	119 07	119 07	119 07	119 07	119 05	119 05	119 04
BCG zone	1	1	1	2	2	2	2	2	2	3	3
Site Series	1	8	8	4	1	5	5	5	5	1	1
Slope	4	1	1	45	12	18	12	15	20	10	50
Aspect	55	0	0	256	270	8	170	15	350	270	280
Slope Position	6	2	2	3	2	3	2	1	3	3	3
Moisture Regime	3	4	5	2	3	3	4	3	4	3	3
Rock cover	1	1	1	30	10	5	1	10	5	8	5
Soil Texture	1	1	2	7	5	6	5	2	7	7	5
Canopy height	35	30	40	24	32	13	39	38	38	40	27
Shrub cover	60	15	50	8	9	38	15	7	7	66	42
Herb cover	65	30	42	10	15	25	45	25	25	56	75
Tree density	891	796	477	1528	764	1623	541	637	637	223	191
Snag density	64	64	95	159	64	32	32	32	64	64	64
Log density	95	350	159	286	350	414	127	127	127	159	605
Tree basal area	41	53	58	37	99	38	187	125	225	109	195
Snag basal area	44	16	20	13	7	2	12	6	6	52	34
Log basal area	7	25	19	35	89	98	45	27	27	107	129
Disturbance (stand age)	4	4	9	4	9	4	9	4	9	9	9
Watershed	1	1	1	2	2	2	2	2	2	2	2
Mesohabitat number	1	2	2	1	2	2	2	2	2	2	2
Rock acidity	1	1	1	2	2	2	1	2	2	3	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1200	1200	1200	1100	1100	1100	1100	1100	1100	1100	1100
6 month temperature	8	8	8	7	7	7	7	7	7	7	7
Degree days	170	170	170	150	150	150	150	150	150	150	150

APPENDIX II. ICH environmental data

Environmental/Plots	58	59	60	61	62	63	64	65	66	67	68
Elevation	700	1000	940	980	1075	690	690	1200	1100	1100	1200
Latitude	51 55	51 55	51 54	51 54	51 54	52 12	52 12	52 12	52 10	52 10	52 10
Longitude	119 04	119 04	119 03	119 03	119 03	120 13	120 13	120 13	120 13	120 13	120 13
BCG zone	3	3	3	3	3	1	2	2	2	1	1
Site Series	1	1	1	1	4	5	1	8	5	1	1
Slope	49	55	65	38	55	1	1	30	40	30	30
Aspect	272	280	340	360	2	0	0	62	72	90	80
Slope Position	3	4	4	3	3	2	2	3	3	3	4
Moisture Regime	3	2	3	4	3	4	4	5	3	3	3
Rock cover	10	15	10	2	20	5	1	5	1	1	1
Soil Texture	2	2	7	4	7	5	2	2	7	2	2
Canopy height	17	18	36	36	36	38	35	18	40	36	17
Shrub cover	20	13	11	37	4	1	5	25	13	4	40
Herb cover	9	34	55	58	14	40	40	25	60	28	20
Tree density	605	955	255	191	446	446	637	255	509	477	32
Snag density	95	127	191	95	127	95	95	64	64	95	159
Log density	159	318	127	191	127	95	318	477	32	127	605
Tree basal area	13	39	186	178	75	189	86	58	175	159	1
Snag basal area	83	26	31	85	85	6	19	1	15	5	41
Log basal area	91	56	69	39	72	33	15	90	16	80	64
Disturbance (stand age)	4	4	9	9	9	9	4	4	9	9	4
Watershed	2	2	2	2	2	4	4	4	4	4	4
Mesohabitat number	2	1	2	1	1	2	1	2	1	1	1
Rock acidity	2	2	2	2	2	2	1	2	1	1	1
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1100	1100	1100	1100	1100	1200	1100	1100	1100	1200	1200
6 month temperature	7	7	7	7	7	8	7	7	7	8	8
Degree days	150	150	150	150	150	170	150	150	150	170	170

APPENDIX II. ICH environmental data

Environmental/Plots	69	70	71	72	73	74	75	76	78	79	80
Elevation	1100	1150	700	690	700	750	670	850	810	650	640
Latitude	52 10	52 10	52 10	52 10	52 09	52 09	51 29	51 29	51 28	51 26	51 26
Longitude	120 13	120 13	120 13	120 13	120 12	120 12	118 54	118 54	118 54	118 53	118 53
BCG zone	1	2	1	1	1	1	2	2	2	2	2
Site Series	1	1	6	7	8	8	1	4	1	1	4
Slope	33	12	13	10	4	1	40	60	47	35	15
Aspect	60	50	90	110	253	0	100	100	111	124	148
Slope Position	4	3	2	2	2	2	4	4	4	3	4
Moisture Regime	3	3	4	3	4	4	2	1	3	3	2
Rock cover	1	1	1	1	1	1	15	15	10	15	30
Soil Texture	2	5	5	7	2	2	2	7	2	5	2
Canopy height	35	18	28	32	36	38	38	24	36	46	36
Shrub cover	7	5	25	15	22	3	23	1	14	10	21
Herb cover	40	6	55	15	75	25	30	2	25	16	14
Tree density	414	1560	796	414	382	1019	223	796	477	318	891
Snag density	127	32	32	127	64	127	32	95	32	95	32
Log density	255	414	286	382	318	255	191	32	127	255	255
Tree basal area	158	41	307	35	74	73	63	25	54	150	120
Snag basal area	2	13	41	7	10	5	17	14	8	7	1
Log basal area	29	47	19	54	59	10	46	1	24	51	21
Disturbance (stand age)	9	4	4	4	9	4	9	4	9	9	4
Watershed	4	4	4	4	4	4	3	3	3	3	3
Mesohabitat number	1	1	2	1	1	1	3	3	3	3	3
Rock acidity	1	1	1	1	1	1	2	2	2	2	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1200	1100	1200	1200	1200	1200	1100	1100	1100	1100	1100
6 month temperature	8	7	8	8	8	8	7	7	7	7	7
Degree days	170	150	170	170	170	170	150	150	150	150	150

APPENDIX II. ICH environmental data

Environmental/Plots	81	82	83	84	85	86	87	88	89	90	91
Elevation	660	730	760	730	1100	1100	1180	800	800	790	905
Latitude	51 25	51 25	51 25	51 26	51 35	51 35	51 35	51 35	51 35	51 35	51 35
Longitude	118 53	118 53	118 53	118 52	118 55	118 55	118 55	118 55	118 55	118 55	118 55
BCG zone	2	2	2	2	3	3	3	2	3	3	3
Site Series	4	4	4	1	4	3	3	4	1	1	1
Slope	65	55	55	39	20	45	32	30	20	10	10
Aspect	290	310	280	286	290	270	212	226	270	250	235
Slope Position	3	4	4	4	2	5	4	2	2	2	2
Moisture Regime	2	1	1	3	3	1	1	3	4	3	2
Rock cover	5	20	10	10	5	8	10	1	5	5	5
Soil Texture	2	7	2	2	8	6	7	7	4	2	7
Canopy height	34	30	35	37	38	27	36	32	36	38	34
Shrub cover	15	3	3	5	14	10	12	15	52	20	8
Herb cover	25	3	8	30	33	15	20	25	75	65	40
Tree density	318	732	700	446	414	509	414	191	191	350	318
Snag density	64	95	95	318	64	32	32	127	127	32	159
Log density	318	191	255	159	223	382	95	127	95	32	127
Tree basal area	121	51	120	216	83	83	50	145	53	252	118
Snag basal area	39	25	8	36	1	0	1	33	48	55	26
Log basal area	54	30	13	34	67	30	6	22	88	4	37
Disturbance (stand age)	9	4	4	9	9	9	4	9	9	9	9
Watershed	3	3	3	3	3	3	3	3	3	3	3
Mesohabitat number	2	3	2	2	2	3	3	2	2	2	1
Rock acidity	2	2	3	3	2	3	2	1	2	2	2
Temperature	4	4	4	4	4	4	4	4	4	4	4
Rainfall	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100	1100
6 month temperature	7	7	7	7	7	7	7	7	7	7	7
Degree days	150	150	150	150	150	150	150	150	150	150	150

APPENDIX II. ICH environmental data

Environmental/Plots	92	93	95	96	97	98	99	100	101	102
Elevation	970	1125	800	850	1190	1235	1190	1160	1220	1220
Latitude	51 36	51 36	51 12	51 12	51 12	51 12	51 12	51 12	51 12	51 12
Longitude	118 55	118 55	117 51	117 51	117 51	117 51	117 51	117 51	117 51	117 51
BCG zone	3	3	1	1	1	1	1	1	1	1
Site Series	1	3	6	5	6	1	6	7	6	6
Slope	55	40	5	3	50	22	24	1	38	40
Aspect	245	240	0	180	308	329	128	0	26	360
Slope Position	3	5	2	6	3	4	3	2	4	4
Moisture Regime	2	2	4	3	3	3	3	4	3	3
Rock cover	15	1	2	1	1	20	5	1	1	5
Soil Texture	2	2	6	5	2	2	4	4	1	1
Canopy height	39	35	20	19	33	30	28	30	26	21
Shrub cover	15	31	75	45	35	20	20	65	5	4
Herb cover	55	60	30	60	55	55	70	65	15	20
Tree density	318	286	573	573	796	637	541	382	732	637
Snag density	32	64	32	95	32	32	159	127	191	127
Log density	32	64	446	64	64	95	127	159	255	286
Tree basal area	301	133	42	16	82	84	89	40	84	40
Snag basal area	1	1	8	89	3	1	18	21	44	8
Log basal area	9	8	21	5	4	10	11	18	4	6
Disturbance (stand age)	9	9	4	4	4	4	9	4	4	4
Watershed	3	3	1	1	1	1	1	1	1	1
Mesohabitat number	3	1	2	1	1	1	2	1	1	1
Rock acidity	2	1	2	1	1	2	2	1	1	2
Temperature	4	4	4	4	4	4	4	4	4	4
Rainfall	1100	1100	1200	1200	1200	1200	1200	1200	1200	1200
6 month temperature	7	7	8	8	8	8	8	8	8	8
Degree days	150	150	170	170	170	170	170	170	170	170

APPENDIX III. ICH species data.

Species/Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Amblserp		1	1	2		1	1			1	1	1		1	1	1	1	
Amphlapp				1		1										2		2
Anashell												1						
Anasminu																		
Andmiva																		
Andrrupe															1	2		
Aneuping				2						1								1
Anticurt				3														
Apompube																1		
Atriselw		3	1	3		3	3	1	2	2	2	2	2	2	2	2	2	2
Atritene																		
Atriundu																		
Aulaandr							1			1					2			2
Aulapalu					1			1	1	1	1				1			1
Barbatte				1												2		1
Barbbarb	3					1		1							1	2		
Barbconv											1				1	1		
Barbfloe				1								1						
Barbhatc													1			1		
Barbkunz																		1
Barblyco	2	3	1		1	1	2	1			2	1	1	1	1	2		1
Barbquad																		
Barbtriq																2		
Bartithy																		
Bartpomi															1	2		
Bazzdenu							1		1			1				1		1
Bazztric				1														
Blaspusi							1											1
Bleptric	1		2	1	2	1	2	2	1		1	1		1	1	2	2	1
Blinacut			1	2												1		
Bracalbi																		
Braceryt																		
Bracfrig	1	2	2	2	1		2	1	2	2	1	1		1	1	2	2	3
Bracnels																		
Bracoedi																		
Bracplum				2						1						1	1	1
Bracrefl				1														
Bracrivu					1				1						2			1
Bracsale			1	2		1	2		2				1	2	1	2		1
Bracstar				1			1											1
Bracvelu			2	1			2					1	2	2	2	2	2	3
Bracvelv			2				2											
Bryorecu							1			1	1							
Bryuarge																1		
Bryucaes						1				1	1					2	1	
Bryucapi		1					2									1		
Bryupseu					1			1										1
Buxbaphy																		
Buxbpipe	1								1	1	1	1				2		
Buxbviri																		
Callstra			2	2								1						1
Calyfiss								1		1							1	1
Calyinte			1			1				1		1	1				1	1
Calymuel		1	1	1	1		2	1	1	1	1				1			1
Calysuec							1											
Calytric		1	1	1			1	1		1		1		1		1		2
Campchry							1	1			1	2						1
Camppoly																		
Campstel																	1	
Cephbicu			1	1		1				1								
Cephdiva				2			1			1	1					2		
Cephlunu	1	2	1	1		2	2	1		1		1	1	1	2	1	1	1
Cephplen																		

APPENDIX III. ICH species data.

Species/Plot	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Amblserp	1	1	1	1	1	1	2	1	2	1	2	1	2		2	2	2	2
Amphlapp			1					1		2							1	1
Anashell					1	1				1			1					
Anasminu	2		1														1	
Andrniva																		1
Andrrupe			1	2											1			1
Aneuping					1					1								1
Anticurt					2	2	2	1	1	2	2	2	2	1			2	2
Apompube										1								1
Atriselw	2		2	2	2	2	2	2	2	2	3	2					2	
Atritene								1		1								
Atriundu																		
Aulaandr															2		1	
Aulapalu			1	1				1						1	2			
Barbatte	2				1			1		2	1	2					3	2
Barbbarb	1		2	1	1			2			1	2			2	2	3	
Barbconv			1					1										1
Barbfloe					1		1		1	1	1		1				1	
Barbhatc					1	2									2			
Barbkunz								1										
Barblyco	1	1	1	1	1	2	1	1	1	2	2	2	1	2	2	1	2	2
Barbquad										1								
Barbtriq																		
Bartithy																	1	2
Bartpomi	2							1		2		1	1		2		1	2
Bazzdenu			1		1		1	1	1	1	1	2	2	1			1	1
Bazztric												2	2					1
Blaspusi										2	1							
Bleptric	1		2	1	1	1	1	1		1	1	2	3	1		1	3	2
Blinacut										1	1							1
Bracalbi			1					1		1							1	
Braceryt	1		2															
Bracfrig	2	1	1	2	1	1		2	1	1	1	2	2	1	2	1	1	2
Bracnels					1					1								
Bracoedi											1							
Bracplum																		
Bracrefl				2		1												2
Bracrivu	1		1					1			1							2
Bracsale			1	1	1			1	1		1				2		2	
Bracstar					1						1							
Bracvelu				2	1			1			1	2	2					2
Bracvelv			1															
Bryorecu	1		1	1														
Bryuarge			1															
Bryucaes	1	1	1					1		1							1	
Bryucapi			1		1			1				1						
Bryupseu		1		1								1						1
Buxbaphy																		
Buxbpipe	1	1		1			1			1	1	1	1				1	1
Buxbviri																		
Callstra		2	1							1								2
Calyfiss					1			1						1				
Calyinte						1							1					
Calymuel	1	1	1					1			2	2	2				1	
Calysuec					1				1		1						1	
Calytric			1		1	1	1	2	1	1	1	2	3				1	1
Campchry	1		1	1				1		2	1						1	
Camppoly		3								1	1							
Campstel		1						1		2								1
Cephbicu			1		1				1	2	1	1					1	2
Cephdiva		1	1	1	1	1	1	1	1	2	2		2	1			2	
Cephlunu	1		1	1	1	2	1	1		1	1	2	3				2	2
Cephplen			1							1								1

APPENDIX III. ICH species data.

Species/Plot	37	38	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Amblserp	1	2		2	2	2					1	1	2	2	2		1	2
Amphlapp																1		
Anashell					1	1							1					
Anasminu																		
Andmiva																		
Andrrupe																		
Aneuping													1		1			
Anticurt					1	2							2		1		2	1
Apompube																		
Atriselw	2		2			2	2	2		1			2		2			
Atritene																		
Atriundu																		
Aulaandr			1	2					2	2	2							
Aulapalu	1						1				1				1		1	
Barbatte								1					1		2			
Barbbarb	1											2	2			1		
Barbconv																		
Barbfloe						1												1
Barbhatc																		
Barbkunz													1					1
Barblyco	1	1	1	1	1	1	2	1	1	2	2	1	2	2	1	1	1	2
Barbquad																		
Barbtriq																		
Bartithy																		
Bartpomi												2				1		
Bazzdenu	1			1	1	1		1			1		2	1	1			1
Bazztric					1													
Blaspusi																		
Bleptric	1	2	1	2	1	2	1	1	2	1	2	2	2	1	2		1	2
Blinacut													1		1			
Bracalbi																		
Braceryt																		
Bracfrig	1	2	2	2	2	1		1	1	1	1	2	3	1	2	1	1	2
Bracnels																		
Bracoedi																		
Bracplum																		
Bracrefl																		
Bracrivu					1		1							1				1
Bracsale	1	3	2	2		2	2		1	1	2	2	2					2
Bracstar																		
Bracvelu	1				1					2	2	2		2			1	2
Bracvelv																		
Bryorecu																		
Bryuarge																		
Bryucaes																1		
Bryucapi																		
Bryupseu	1													1				
Buxbaphy																		
Buxbpipe	1		1		1	1	2		1	1	1	1	1	1	1	1	1	2
Buxbviri						2	2											
Callstra																		
Calyfiss								1		1			1					1
Calyinte					1					2	2	1						3
Calymuel						1	1	1	1	1	1		1	1	1			
Calysuec						1							1					
Calytric		2		1	2	2		1			1		1		1	1		
Campchry	1						1	1			1						1	
Camppoly																		
Campstel					1													1
Cephbicu					1								1					
Cephdiva					2	2			1		1		1	1	1		1	2
Cephlunu	1	2	2	1	1	2	2	1	2		1	2	2	1	2		2	2
Cephplen																		

APPENDIX III. ICH species data.

Species/Plot	56	57	58	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Amblserp	2		1	2		1	1		1	2	2		2			2	2	
Amphlapp																		
Anashell		1		1	1													
Anasminu																		
Andrniva																		
Andrrupe																		
Aneuping																		
Anticurt		1		3	1	2												
Apompube																		
Atriselw	2	2	2	1		1	1			2	2	1	2	1	2	2	2	2
Atritene																		
Atriundu																		
Aulaandr			1															
Aulapalu									2		1	2						
Barbatte			2	1											2		2	
Barbbarb	1		2															
Barbconv																		
Barbfloe		1					1		1								1	
Barbhatc			2	2			2											
Barbkunz																		
Barblyco	1	1	2	1	2	1	1	1	2	2	1		2	1	1	1	1	1
Barbquad		1																
Barbtriq																		
Bartithy																		
Bartpomi																		
Bazzdenu		1		1	1						1							
Bazztric		2		1	1													
Blaspusi																		
Bleptric	1	2	2	3	1	1	2	2	2	1	2	2	2	1	2		1	2
Blinacut		1																
Bracalbi							2											
Braceryt			1															
Bracfrig	1	2	2	3	1	2		2	2	1	2		2		2	2	2	2
Bracnels																		
Bracoedi																		
Bracplum							1											
Bracrefl																		
Bracrivu							1										2	
Bracsale		2	2	2	2	2	2	2	2		2		2		2	2		
Bracstar					1													
Bracvelu		2	2	2	2	2	2	2		2	2		2	1	2			2
Bracvelv																		
Bryorecu																		
Bryuarge			1															
Bryucaes																		
Bryucapi				1						1								
Bryupseu	1																	
Buxbaphy																		
Buxbpipe	1	1	1	1	1	1	1			1	1				1	1	1	
Buxbviri																		
Callstra																		
Calyfiss																		
Calyinte								1			2				3			1
Calymuel		1	2	1	1			1	1		1							2
Calysuec		1			1													
Calytric		1		2	1		2			2			2			1	2	
Campchry	1	1																
Camppoly																		
Campstel																		
Cephbicu				1	1				2			1						
Cephdiva		1	1	2	2		2		1		2			1	1		1	
Cephlunu	2	1	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1
Cephplen																		

APPENDIX III. ICH species data.

Species/Plot	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Amblserp	2	1		1	1				1	2			1	2	2	2	2	2
Amphlapp				1					1									1
Anashell	1		1							1		1						
Anasminu																		
Andrniva												1						1
Andrrupe				1									1					
Aneuping	1														1			
Anticurt	2		2	2	2		2		1	2	2	2	1	2	2	2	2	2
Apompube	2		1		2		1			2	1	2		1			1	
Atriselw			2		3	2	2	1	2		2	2	2	1	2	2	2	1
Atritene																		
Atriundu					1													
Aulaandr										1			1			1		1
Aulapalu	1		2		1			1										
Barbatte			2							1					2			
Barbbarb													2					
Barbconv					1								1					
Barbfloe	1		2		1	2				1		1		1	1	1	1	1
Barbhatc	2					1						2				1		
Barbkunz														1				
Barblyco	2	2	1	2	2	2	1	2	1	1	2	1	1	2	2	2	1	1
Barbquad	1		1									2		2	1	1		
Barbtriq																		
Bartithy																		1
Bartpomi		1											1				2	1
Bazzdenu	2	2	2	1	1		1					1	1	1		1	2	2
Bazztric	2		1		1		1			1	2	1		1	1		2	1
Blaspusi	1				1													
Bleptric	1	1	2	2		1	1	1	2	1	2	1	1	2	1	1	2	1
Blinacut	1				1							1			1			
Bracalbi							1											
Braceryt																		
Bracfrig				2	2			1			1		1		2		2	2
Bracnels	1											1				1		
Bracoedi														2				
Bracplum																		
Bracrefl																		
Bracrivu	1	1		1	1													
Bracsale			2			1	1							1	3	2	2	2
Bracstar					1		1											
Bracvelu	2							2							2	2		2
Bracvelv																	2	1
Bryorecu		1									1							
Bryuarge		1						1										
Bryucaes								1										
Bryucapi																		
Bryupseu																		
Buxbaphy																		
Buxbpipe	1		1		1		1	1	1		1	1						
Buxbviri	1		1				1		1	1	1	1						
Callstra	1				1		1							2				
Calyfiss		1						1		1		1			1	1		1
Calyinte												1						
Calymuel		1			1	1	1	1	1			1	1	1		1	3	
Calysuec	1		1				1			1	1	1		1	1			1
Calytric	1		1	1			1			3		2			1		2	2
Campchry	1							1	1	1	1	1	1		1	1		
Camppoly																		
Campstel			1						1			1		2				
Cephbicu	1									1			1					
Cephdiva	1	1	2		1	1	1			2	1	1		1	1	1	2	1
Cephlunu	2	2	2	2	2		2	1	1	1		1		2	1	2	3	2
Cephplen			1		1									1		1		

APPENDIX III. ICH species data.

Species/Plot	93	94	95	96	97	98	99	100	101	102
Amblserp	1	1	2				2	1	1	2
Amphlapp		1								
Anashell									1	
Anasminu		1								
Andmiva			1							
Andrrupe		1								
Aneuping										
Anticurt										
Apompube		2								
Atriselw	1	2						2	2	1
Atritene										
Atriundu										
Aulaandr		1								
Aulapalu							1			
Barbatte										
Barbbarb		2								
Barbconv		1								
Barbfloe		2						1		
Barbhatc						2			1	
Barbkunz		1								
Barblyco	1	2	1	2	2	2	1	1	1	2
Barbquad										
Barbtriq										
Bartithy		1								
Bartpomi		1	1							
Bazzdenu	2	2								
Bazztric	2	1								
Blaspusi										
Bleptric	2	1			2		1	1	1	1
Blinacut										
Bracalbi		1								
Braceryt										
Bracfrig	2	1	1	1			2			
Bracnels										
Bracoedi										1
Bracplum										
Bracrefl			2							
Bracrivu										
Bracsale	2		2				1		2	1
Bracstar										
Bracvelu	2			2						
Bracvelv										
Bryorecu										
Bryuarge										
Bryucaes										
Bryucapi										
Bryupseu										
Buxbaphy		1								
Buxbpipe	1				1	1	1	1	1	
Buxbviri					1				1	
Callstra							1			
Calyfiss										
Calyinte										
Calymuel										
Calysuec		1								
Calytric	2							1	2	
Campchry			2					1		
Camppoly										
Campstel										
Cephbicu										
Cephdiva	2	2								
Cephlunu		1								2
Cephplen										

APPENDIX III. ICH species data.

Species/Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Cerapurp		2	1			1	1	2			1		1	1	1	1		1
Chanseti																1		
Chilpoly			2	1	1		1			1		1			1	1	1	2
Claobola																		
Climdend				1	1			1			1					2	1	2
Conoconi					1		2	1	1		1	2				2	3	3
Conotetr																		
Cratfili		3	1	2	1		2	1	1	1	1	3			1		2	3
Cynostru																2		
Dichfalc										1						1	1	1
Dichpell				2			2			1	1	2				1		
Dicrcerv			1							1								
Dicrcirr																		
Dicrflag					2									1				
Dicrfusc	3	2	1	2	2	3	2	1	1	2	1	2	1	2	1	2	1	1
Dicrgrev							1											
Dicrhete				1	1	3	1					1			1	1	1	1
Dicrmont	2	1		1	1	1	1	1	1			1	1	1	1	1		1
Dicrpall																		
Dicrpalu								1	1	2	1						2	1
Dicrpoly	2	2					1	1	1		1	1	2	2	2		1	1
Dicrschr																		
Dicrscop	2	2			1	1		1		1		2		1	1		1	
Dicrspad																		
Dicrtaur	3	3	1	2	1	3	2	1	1	1	1	1	1	2	1	3	2	1
Dicwcris						1										2		
Didyvine																		
Diplalbi			2	1	1		1	1		1	1	1			1	2		1
Diplobtu				1										1		2		
Dipltaxi				1								1		1		1	1	1
Distcapi																1		
Ditrhete																		
Douiovat																		
Drepadun				1					1		1						1	1
Drepbrev																		
Encacili																1		
Encaproc						1										1		
Encarhap																		
Eurhprae				1	1		2	1			1				1	1		
Eurhpulc	2	1	1	2	1	3	2	1	2	2		2			2	2	2	3
Eurhripa																		
Fissadia																		1
Fissosmu																		
Fontanti																		1
Fontneom																		
Frulbola																		
Frultama																		
Funahygr						1	1							1		2		
Geocgrav	2		1		1	1					1				1	1	1	3
Grimaffi															1	2		
Grimdonn																		
Grimelat																		
Grimtorq						1										1		
Grimtric																		
Gymnaeru																1		
Gymninfl				1													1	
Gymnobtu																1		
Gyrounde																		
Hebeadun																		
Hedwcili									2				2		1	2		2
Hetedimo			2	3			1							1				1
Hetemaco				2														
Heteproc				2	1					1						1		1

APPENDIX III. ICH species data.

Species/Plot	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Cerapurp	2		2	1		1		1	1	1	2	2				1	1	2
Chanseti	2		1					1										
Chilpoly			1					2	1	1	2	2					1	
Claobola					1	1		1	2	1	1		2				2	1
Climdend		2	1	1				2			1			1			1	2
Conoconi			1	1	2			1		1	3	2		1			1	2
Conotetr			1															
Cratfili	1	1	1	1	3			1		1	2	2		1			1	
Cynostru			1															
Dichfalc			1							2								1
Dichpell		1	1			2	1			1	2	1					1	
Dicrcerv										1								
Dicrcirr																		
Dicrflag																		
Dicrfusc	1	2	1	2	1	1	3	2	2	1	1	2	2	3	1	2	2	2
Dicrgrev								1		1		1						1
Dicrhete	1		1	1	1	2	1	1	2	1					2			2
Dicrmont	1			1	1	1	1	2	1	1	1	1	2	1	1		1	2
Dicrpall																		
Dicrpalu				1	1			1		1		2		1			1	2
Dicrpoly	3	2	1	2	1										2	2		
Dicrschr										1								2
Dicrscop			2	1	1		1	1	2	2	1	1		2		1	1	2
Dicrspad																		2
Dicrtaur	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1	1
Dicwcris																		
Didyvine																		
Diplalbi	1		1		1	1	1	1	1	2	2	2	1	1			1	1
Diplobtu				1	1					1							1	
Dipltaxi			1		1	1	1	1		2	1	1	2	2			1	1
Distcapi																	1	
Ditrhete																	1	
Douiovat													1					2
Drepadun	1		1					1		2	1	1					1	2
Drepbrev								1			1							2
Encacili			1					1										
Encaproc				2				1									1	
Encarhap								1									1	2
Eurhprae			1		1		2			1	1	2	2	1			2	2
Eurhpulc		2	1	2	2			3	1	1	2	2	2	1	2		1	2
Eurhripa																		
Fissadia			1							1								2
Fissosmu										1							1	1
Fontanti								1										
Fontneom																		
Frulbola											2							
Frultama																		
Funahygr			2								1							
Geocgrav	2	2	1	1	1			1			1	2	2				1	
Grimaffi			1	2				1										
Grimdonn				1														
Grimelat																		
Grimtorq			1					1									1	
Grimtric			1															
Gymnaeru										1								
Gymninfl								1			1	1						
Gymnobtu																		
Gyrounde										1	1							1
Hebeadun																		
Hedwcili	1		2	1											1	2		1
Hetedimo			1		1		1	1		2	1	1	1			1	1	1
Hetemaco					1	1		1	1	1	1	2	1			1	1	1
Heteproc		1	1					1		1	1				2	1	1	1

APPENDIX III. ICH species data.

Species/Plot	37	38	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Cerapurp	1		2			1	1	2		1			2		2	1		
Chanseti																		
Chilpoly			2	2	2					1			1				1	2
Claobola					2	2			2		1		2				1	2
Climdend					2	1	1			1	1		2	1				
Conoconi	1			1	2	1				2	1		2	1	1	1	1	2
Conotetr																		
Cratfili	1				2	1	1	1		1	1		1		1		1	
Cynostru																		
Dichfalc																	1	
Dichpeli											2				1		1	
Dicrcerv																		
Dicrcirr																		
Dicrflag							1	2									1	
Dicrfusc	2	1	1	2	1	2	1	1	2	1	1	2	2	1	3	2	1	2
Dicrgrev													1				1	
Dicrhete					2	2							2					
Dicrmont	1		1	1	2	1	1				1	1	2	1	2	1	1	2
Dicrpall																		
Dicrpalu							1						1				1	
Dicrpoly										1	1				1			
Dicrschr													1					
Dicrscop					2	2	2	1	1		1	2	2	1	2	1	1	2
Dicrspad																		
Dicrtaur	1	1	2	1	1	2	1	1	1	1	1	2	2	1	1	1	1	1
Dicwcris																		
Didyvine																		
Diplalbi	1	2		2	2	2				1	1		1		2		1	2
Diplobtu						1								1				
Dipltaxi						1					1		1		1		1	1
Distcapi													1					
Ditrhete																		
Douiovat																		
Drepadun					1		1			1			2	1	1			
Drepbrev																		
Encacili																		
Encaproc																		
Encarhap																		
Eurhprae	1			2		2	2						1		1		1	2
Eurhpulc		1	1	1	1	1	1	1	2	1	1	2	1	2	1	1	1	2
Eurhripa					2	2												
Fissadia							1											
Fissosmu																		
Fontanti																		
Fontneom					1													
Frulbola																		
Frultama																		
Funahygr																		
Geocgrav		2		1				1	1		1			1	1			
Grimaffi																		
Grimdonn																		
Grimelat																		
Grimtorq																1		
Grimtric																		
Gymnaeru					1													
Gymninfl													1				1	
Gymnobtu																		
Gyrounde																		
Hebeadun													2					
Hedwcili											1	1	1			1		1
Hetedimo					2	1						2					2	
Hetemaco					1	1							1		1		1	2
Heteproc										1	1		1				1	2

APPENDIX III. ICH species data.

Species/Plot	56	57	58	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Cerapurp		1	1	2		1			2	1	1	1	1	1	1	2	2	1
Chanseti				1														
Chilpoly		1		1		2	2	2		2	2							2
Claobola	2	1		2	2		2				2					2		
Climdend	1						2	1					1		2		2	
Conoconi		1					2	2	2		2		2		2	1	2	
Conotetr																		
Cratfili	1	1					2				2		2			1	2	
Cynostru																		
Dichfalc																		
Dichpell				2														
Dicrcerv																		
Dicrcirr																		
Dicrflag												1						
Dicrfusc	1	1	2	3	3	2	2	2	2	2	2	1	1	2	2	2	2	2
Dicrgrev																		
Dicrhete			2		2			2		2	2		2		2	2	2	
Dicrmont	1	1	1	2	1		1	2		1	1		1		2		1	
Dicrpall																		
Dicrpalu																		
Dicrpoly			2	1			2		1	2		1	2					
Dicrschr																		
Dicrscop	2	2	1	2	2	1	1	1	2	2	2		2	2	2	1	1	2
Dicrspad																		
Dicrtaur	1	1	1	2	1	1	2	2	2	2	1	1	1	2	2	1	2	1
Dicwcris																		
Didyvine																		
Diplalbi		1		2	1		2				2		2			1	1	
Diplobtu			1							1	1					1	1	1
Dipltaxi		1	2	1	1	1				1								
Distcapi																		
Ditrhete																		
Douiovat																		
Drepadun									1									
Drepbrev																		
Encacili																		
Encaproc																		
Encarhap																		
Eurhprae		1		2	2					2	2		2					
Eurhpulc	1	2	1	2	2	1	2	2	2	1	2	2	2		2	2	1	2
Eurhripa																		
Fissadia											2							
Fissosmu																		
Fontanti																		
Fontneom		1																
Frulbola		1																
Frultama				1						1								
Funahygr																	1	
Geocgrav	1	1	2			1	1	2	1				2	1	2		2	1
Grimaffi			1															
Grimdonn																		
Grimelat																		
Grimtorq																		
Grimtric				1														
Gymnaeru																		
Gymninfl																		
Gymnobtu																		
Gyrounde																		
Hebeadun																		
Hedwcili			1		1													
Hetedimo		1		1	1								1					
Hetemaco		1		1	1						1							
Heteproc		1					1											

APPENDIX III. ICH species data.

Species/Plot	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Cerapurp		1	2	1	2	1	1	1	1		2	1	1		2	1	1	1
Chanseti		1																
Chilpoly	1	1	2	2			2			1		1			1	1	2	1
Claobola	2		1		1		2		2	2	1	1		1	2	2	2	2
Climdend	1		2		1		1			1	1	1	1	1		2	1	
Conoconi	1	1	2	1	1	2	1	1	2	2	1	2	1	2		1	2	1
Conotetr																		1
Cratfili	1	1	2	1	1	1		1	2	1	1	2	1		1	1	2	1
Cynostru																		
Dichfalc					1						1							
Dichpell					1		1				1						2	1
Dicrcerv	1				1													
Dicrcirr							1			1	1	1				1	1	1
Dicrflag													1					
Dicrfusc	1	1	2	1	1	2	1	1	2	2	2	2	1	1	2	2	2	1
Dicrgrev	1										1				1			
Dicrhete	2		2			2		2		3				2		2	1	2
Dicrmont	1		2	2	1	1	1	1		1	1	1	1	1	1	1	1	1
Dicrpall	2												1				2	
Dicrpalu	1			1	1										1			
Dicrpoly		1									1	1	1					
Dicrschr																1		1
Dicrscop	2	2	2	2	2	1	1	2	1	2	2	2	2	1	2	2	2	1
Dicrspad			1															
Dicrtaur	1	1	2	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Dicwcris																		1
Didyvine																		1
Diplalbi	1	1	2	1	1	1	1			2	1	1	1	1	2	2	2	2
Diplobtu					1		1						1				1	
Dipltaxi	1		1		1	1	1			1	1	1		1	1	1	1	1
Distcapi									1			1						
Ditrhete			1															
Douiovat	1		1		1		1			1		1						
Drepadun	1			1	1		1	1		1	1	2				1		
Drepbrev			1															
Encacili																		
Encaproc													1					
Encarhap												1						
Eurhprae	1	1	2	2	1	1	2	1	2	1	1	1	1	1	1	2	2	1
Eurhpulc	1	1	1	2	2	2	1	2	2	1	2	1	1	1	2	1	2	1
Eurhripa																		
Fissadia			1				1											
Fissosmu																		
Fontanti																		
Fontneom											1							
Frulbola			1														1	
Frultama	1		1				1			1	1			1	1	1	1	1
Funahygr		1						1										
Geocgrav		1		1	1	1	1			2			1			1		2
Grimaffi				1	1													
Grimdonn																		1
Grimelat																		
Grimtorq													1					
Grimtric								1										
Gymnaeru																		
Gymninfl	1																	
Gymnobtu					1					1				1				
Gyrounde											1	1						
Hebeadun	1						1							1			1	
Hedwcili	1				1			1		2	1	1	1	2		1	2	2
Hetedimo			1					1	1			1					2	
Hetemaco	1		2		1		1			1		1		1	1			1
Heteproc	1		2	2	2		1		2			1				1		

APPENDIX III. ICH species data.

Species/Plot	93	94	95	96	97	98	99	100	101	102
Cerapurp	1	1		1				2	2	1
Chanseti										
Chilpoly		2	2						1	
Claobola	2	1								
Climdend			2				2			
Conoconi							1			
Conotetr										
Cratfili							1			
Cynostru										
Dichfalc										
Dichpell									1	
Dicrcerv										
Dicrcirr	1	1								
Dicrflag										
Dicrfusc	1	1	2	2	2	2	1	2	1	2
Dicrgrev										
Dicrhete	2		2			2	1			
Dicrmont	2	2				2				1
Dicrpall										
Dicrpalu										
Dicrpoly				1	2					
Dicrschr										
Dicrscop	2	1	2	1	2	2	1	2	1	2
Dicrspad										
Dicrtaur	1	1	2	1	1	1	1	1	2	1
Dicwcris										
Didyvine		1								
Diplalbi	2	1					2	1	2	
Diplobtu	1									
Dipltaxi		1					1	1	1	
Distcapi										
Ditrhete		1								
Douiovat	1	1								
Drepadun							1			
Drepbrev										
Encacili		1								
Encaproc		1								
Encarhap										
Eurhprae										
Eurhpulc	2	2	2	2	2	2	2	1	1	1
Eurhripa										
Fissadia										
Fissosmu			2							
Fontanti										
Fontneom										
Frulbola										
Frultama		1								
Funahygr		1								
Geocgrav		1							1	
Grimaffi		1								
Grimdonn										
Grimelat										
Grimtorq										
Grimtric							1			
Gymnaeru										
Gymninfl										
Gymnobtu		1								
Gyrounde										
Hebeadun										
Hedwcili		2	2	1	2	2	1	1		1
Hetedimo		1						1		
Hetemaco	1									
Heteproc			2		1		1			

APPENDIX III. ICH species data.

Species/Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Homaaene																		
Homafulg																		
Homatric																		
Hookluce																		
Hygrlaxi																		
Hygrluri			1													1		1
Hygrochr																		3
Hygrsmit																		
Hylopyre			3	1					1			2				2		1
Hylosamp							0			0								
Hylosple	3	2	1	2	1	2	2	1	1	2	1	2	2	1	1	2	1	1
Hyloumbr		1		1	1	1	1		1	1		1	1	1	1	1	1	1
Hypncirc				2	1	1	1									2	2	2
Hypncupr			1												1			
Hypnpall	3	1		1		2	2			1		1			1			
Hypnrevo	2		1	3	1	1	1	1	2	2	1	2	1	1	1	1	2	1
Hypnsubi																		
Isoppulc				2												1	1	
Isotmyos																		
Jameautu	1		1	1	1	1	2	1	1	1	1	2	1	1	1	1	1	1
Jungexse																		
Jungleia	1		2	2	1	1	1	1	3	2	1	1		1	2	1	2	1
Jungobov							1										1	
Jungpumi																		
Jungrubr																		
Jungspha																		
Kiaestar																1		
Lepirept	1					1		1							1			
Leptpyri			1								1					2		
Leptripa		1					1		1			2		1			1	1
Lesknerv							1											1
Leskpoly			1		1		1									1		1
Lophasce			1	1													1	
Lophcusp																		
Lophexci																1		
Lophgill																1		1
Lophgutt			1				1			1		1				1		1
Lophhete		1	1	1	1	1	1	1		1	1	2			2	1	1	1
Lophinci							1					1				1		
Lophlong	2	2	1	2	1	2	1					1		1	2	1	1	1
Lophmino			1	1			1			1								
Lophobtu																		
Lophopac																		
Lophvent	1	1	2	2	1	1	1	1				1	1	1	1	1	2	1
Lophvenv			1		1	1	1	1			1					1	1	
Lophwenz																		
Lphchete				1					2	1							1	
Marcpoly				2	1			1	1	2	1	2			1	3	2	2
Marsemar			1															
Marsspar																		
Marsspha																		
Meestriq				1														1
Metamenz				1			1									1		
Metzconj																		
Mniumarg							1				1				1	2		
Mniuspin	2	2	2	2	1	1	2	1	1	2	1	1	2	2	1	2	2	2
Mniuthom																		
Mylitayl							1											
Myurjula																		
Nardscal																		
Neckdoug				1														
Neckpenn							1									2		
Newscho																		

APPENDIX III. ICH species data.

Species/Plot	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Homaaene			2	1				1							2	1		
Homafulg				2	1	1										2		
Homatric																		
Hookluce																		
Hygrlaxi										1								
Hygrluri					1					2								2
Hygrochr										1		1						
Hygrsmit								1		1								1
Hylopyre					1			2		2	2	2	2		2		1	2
Hylosamp					3	2	2	2	1	2								
Hylosple	1	1	1	1	2	3	2	3	3	3	2	2	2	1		2	1	2
Hyloumbr	1	1	1	1	1	1	1	1	1	1	2	1	2	1		1	1	2
Hypncirc	2		1		1	1	2	2	1	1	1	2	2	2			1	2
Hypncupr								1										
Hypnpall				1	1	2				1		2					3	2
Hypnrevo	1	2	1	2	2	3	1	2	1	1	2	1	1	1	2	1	1	2
Hypnsubi																		
Isoppulc										1								
Isotmyos										1								2
Jameautu	1		1	1	1	1	1	1	1	1	2	2	3	1	2	2	1	1
Jungexse												2						
Jungleia	1	1	1	1			1	1	1		3		3	1			1	2
Jungobov					1					2								
Jungpumi																		
Jungrubr																		
Jungspha																		
Kiaestar																		
Lepirept	1			1				2			1	3	2				3	2
Leptpyri			1															
Leptripa	1	1			2			1		1	1	1	1	1		1	1	1
Lesknerv					1			1			1			1			1	1
Leskpoly					1	1	1	1	1	2	1	1	1				1	2
Lophasce					1			1		1	1							
Lophcusp																		
Lophexci			1	1				1									1	
Lophgill								1			1						1	
Lophgutt			1		1	1			1	1	1	1	1					
Lophhete	1	1			1	1		1	2	1	1	2		2			2	
Lophinci					1	1	1	1		1	1						1	
Lophlong			1		1	1		2			2			1			1	2
Lophmino			1		1	1		1	1	1		1	1				1	
Lophobtu																		
Lophopac																		
Lophvent	1		1	1	1	1	1	1	1	1	1	2	3	1	2	1	1	2
Lophvenv			1	1		1	1	1	1				1	1			1	
Lophwenz																		
Lphchete					1					1	1							
Marcpoly		1	1	1	1			2		1								2
Marsemar		2	1					1		1								
Marsspar										2								
Marsspha										1								
Meestriq			1	2						1	1							
Metamenz				1	2			1	1		1		2		2		2	1
Metzconj					1													
Mniumarg								1										
Mniuspin	1	1	1	1	1	1	1	2	1	1	1	2	1	1		1	1	2
Mniuthom																		
Mylitayl					1	1							1				1	
Myurjula			1		1					1								
Nardscal										1								2
Neckdoug						1			1	1	1						1	
Neckpenn					1			1			1		2					1
Newscho																		

APPENDIX III. ICH species data.

Species/Plot	37	38	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Homaaene																	1	
Homafulg						1							1					
Homatric																		
Hookluce																		
Hygrlaxi																		1
Hygrluri																		1
Hygrochr													1					
Hygrsmit											1		1		1		1	
Hylopyre		2								1	1	2	2		1			2
Hylosamp		0	0		1		0	0			0							
Hylosple	1	2	2	1	1	3	1	1	2	1	1	2	3	1	1	2	1	1
Hyloumbr	1			1	1					1	1	1	2	1	1	1	1	2
Hypncirc	1	2			1	2	1	1			1		1		1	1	1	2
Hypncupr																1		
Hypnpall							2						2					
Hypnrevo	1	1	2	2	1	3	1	1		1	1	2	2	1	1	1	1	2
Hypnsubi					1													
Isoppulc													1					
Isotmyos																		
Jameautu	1	2	1	1	1	3	2	1	2	1	1	1	1	1	1	1		2
Jungexse													1		1			
Jungleia	1		1	2	1	2	2	1		1	1			1	1	1	1	2
Jungobov																	1	1
Jungpumi													1					
Jungrubr																		
Jungspha																		
Kiaestar																		
Lepirept	1		1		1	2	1	1	1	2	1	1	3		1	1	2	
Leptpyri																		
Leptripa	1	1		1	1	1	1		1	1		1	1	1	1	1	1	1
Lesknerv	1										1				1			1
Leskpoly					1						1		1		1		1	
Lophasce															1			
Lophcusp						1												
Lophexci													1		2			
Lophgill						1					1				1			1
Lophgutt		1									1		1		1		1	1
Lophhete		2		2	1	2	2	1	1	2	1		2	1		1		2
Lophinci		2				1											1	
Lophlong			1	2	2	2	1	1	2	1	1			1	1			
Lophmino						1							1				1	1
Lophobtu																		
Lophopac																		
Lophvent	1	2	1	2	2	2	1	1	2	1	2	1	2		1		1	2
Lophvenv								1		1	1		1	1		1		
Lophwenz																		
Lphchete					1	1							1					
Marcpoly	1			1						1			2	1	1		1	2
Marsemar					1						1		2		1			1
Marsspar																		
Marsspha																		
Meestriq																		
Metamenz					2	1							2					2
Metzconj					1													
Mniumarg																1		2
Mniuspin	1	1	2	1	1	2	1	1	1	1	1	2	1	1	1	1	1	2
Mniuthom																		1
Mylitayl						1							1		1			
Myurjula													1				1	1
Nardscal						1							1					
Neckdoug																		1
Neckpenn																		
Newscho																		2

APPENDIX III. ICH species data.

Species/Plot	56	57	58	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Homaaene																		
Homafulg		1			1													
Homatric																	1	
Hookluce																		
Hygrlaxi																		
Hygrluri																		
Hygrochr																		
Hygrsmit																		
Hylopyre	2	2		2	2			2		2			2	2		2		2
Hylosamp	0			0														
Hylosple	1	1	1	2	1	2	2	1	2	2	2	1	2	1	2	2	2	1
Hyloumbr	1	1		2	1	1	1	1	1	1	1		1	1		1	1	1
Hypncirc	2	1	1	3	2	3	1	2		1	2	1	2	2	2	2	2	
Hypncupr																		
Hypnpall																		
Hypnrevo	2	3	2	2	1	2	2	1	2	2	2	1	1	1	2	2	2	2
Hypnsubi					1													
Isoppulc																		
Isotmyos													1				1	
Jameautu	1	1	2	2	3	2	2	2			2	2	2	1	2			2
Jungexse																		
Jungleia	1	3	2	2	3	2	2	2	2	2	2		2	2	2		2	2
Jungobov					1													
Jungpumi																		
Jungrubr																		
Jungspha																		
Kiaestar																		
Lepirept									2	2			2	2		2	2	
Leptpyri																		
Leptripa		1	1	1	1	1	1			1	1			1	1	1	1	1
Lesknerv		1			1					1							1	
Leskpoly	1	1			1													
Lophasce				1														
Lophcusp				1							1							
Lophexci			1															
Lophgill		1		1														
Lophgutt				1							1		1			1		
Lophhete	1	1		2			1	2	2	2	2		2	1	2		1	2
Lophinci				1	1						1						2	
Lophlong	1	1	1						1	2	2	1	2		2			2
Lophmino		1			1													
Lophobtu																		
Lophopac																		
Lophvent	2	1	2	2	1	2	1	2	2	2	2	2	2	1	2	2	2	2
Lophvenv		1	1	1			1			1								
Lophwenz																		
Lphchete		1																
Marcpoly	1						2	2	3			1			1	1	2	
Marsemar																		
Marsspar				1														
Marsspha																		
Meestriq																1		
Metamenz		1		1	3						1					1		
Metzconj				1												1		
Mniumarg																		
Mniuspin	1	2	2	2	2	2	2	2	2	1	2	1	1	2	1	2	1	3
Mniuthom																		
Mylitayl				1														
Myurjula																		
Nardscal				1			1											
Neckdoug					1													
Neckpenn																		
Newscho																		

APPENDIX III. ICH species data.

Species/Plot	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Homaaene																		
Homafulg					1		1							1	1			
Homatric										1								
Hookluce	1		2	2	1		1		2			1		1				1
Hygrlaxi										1		1						
Hygrluri	1					1												
Hygrochr			1								1							
Hygrsmit					1		1		1			1				1		1
Hylopyre	2	1	2								1	1		1	2	2	2	
Hylosamp			0										0					
Hylosple	1	1	2	1	1	3	1	1	2	2	1	2	1	1	1	1	1	1
Hyloumbr	1	1	1	1	1	1	1	1	1	1		2	1	1	1	1	1	1
Hypncirc	1	1	1	2	1	1	1	1	1	2	1	2	2	1	1	1	1	1
Hypncupr		1											1					
Hypnpall	2		2															
Hypnrevo	1	1	2	2	2	2	1	2	2	2	3	2	1	1	1	1	1	1
Hypnsubi	1		1		1					1	1	1		1	1			
Isoppulc	1		2		1		1				1	1		1	1	1	2	1
Isotmyos	1		1		1					1	1	1				1	1	1
Jameautu	1	1	1	1	2	1	1	2	2	1		1	1	1	1	1	2	1
Jungexse														1	1			
Jungleia	1	1	1				1	1	2	1	2	1	1	1	1	2	1	1
Jungobov			1								1							
Jungpumi																		
Jungrubr										1								
Jungspha												1				1	1	1
Kiaestar																		
Lepirept	2	2	3	1	1	1						2						1
Leptpyri																		
Leptripa	1	1	1	1	1	1	1	1	2	1	1	1		2	1	1		
Lesknerv	1				1					1	1							1
Leskpoly	1		1		1		1			1	1	1			1	1	2	1
Lophasce			1				1								1	1	1	1
Lophcusp	1				1		1				1	1				1		1
Lophexci												1						
Lophgill	1				1						1			1				
Lophgutt	1		1													1	1	
Lophhete	2	1	1	2	1	1	1			1	2			1		2		1
Lophinci											1	1		1		1	1	
Lophlong		2				1	1			3	1	2	1			1		
Lophmino							1					1		1		1	1	1
Lophobtu			1													1		1
Lophopac					1													
Lophvent	1	2	2	1	2	1	1	2	1	1	2	1	1	1	1	2	2	1
Lophvenv	1	1	1	1	1		1				1	1	1		1	1		
Lophwenz													1	1			1	
Lphchete	1				1		1					1					1	
Marcpoly	1		2	1		1	1	1	2	2	1	2		1	2	2	1	1
Marsemar	1										1	1						1
Marsspar																		
Marsspha										1								
Meestriq			1			1			1	1								
Metamenz			1		2				1	1					1	3	2	2
Metzconj							1					1						
Mniumarg				2				1					1					
Mniuspin	1	1	1	1	1	2	1	1	2	2	1	2	1	2	1	1	2	1
Mniuthom												1						
Mylitayl			1				1					1					1	
Myurjula	1								1			1						
Nardscal			1		1						1							
Neckdoug			1		1		1			1	1	1					1	
Neckpenn	1				1													1
Newscho																		

APPENDIX III. ICH species data.

Species/Plot	93	94	95	96	97	98	99	100	101	102
Homaaene										
Homafulg		1								
Homatric										
Hookluce										
Hygrlaxi										
Hygrluri										
Hygrochr										
Hygrsmit										
Hylopyre			1				1	2		
Hylosamp										
Hylosple		2			1	2	2	1	2	
Hyloumbr					1					
Hypncirc	1	1							1	1
Hypncupr		1								
Hypnpall										
Hypnrevo	2	2					1		1	1
Hypnsubi		1								
Isoppulc		1								
Isotmyos		1								
Jameautu	2	2	2				1		2	
Jungexse										
Jungleia							1			1
Jungobov										
Jungpumi										
Jungrubr										
Jungspha		1								
Kiaestar										
Lepirept					1					
Leptpyri										
Leptripa						1	1	1		
Lesknerv										
Leskpoly		1								
Lophasce	1									
Lophcusp	1									
Lophexci										
Lophgill		1								
Lophgutt								1		
Lophhete		1								
Lophinci										
Lophlong		1			2	2		1	2	1
Lophmino										
Lophobtu		1								
Lophopac										
Lophvent	2		2		1	2	2	1	1	1
Lophvenv										
Lophwenz										
Lphchete		1							1	
Marcpoly										
Marsemar										
Marsspar		1								
Marsspha										
Meestriq										
Metamenz	2	1								
Metzconj										
Mniumarg										
Mniuspin	1	1	1	1	2	2	2	2	2	2
Mniuthom										
Mylitayl										
Myurjula										
Nardscal										
Neckdoug		1								
Neckpenn										
Newscho										

APPENDIX III. ICH species data.

Species/Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Odondenu							1											
Oligalig																1		
Oncovire							1	1								1	1	1
Oncowahl				1			2					1						1
Orthchry							2									1		
Orthlaev															1			
Orthlyel																		
Orthobtu			2	1			1								2			
Orthpell																1		
Orthspec			1			2	2			1	1					1	1	2
Palucomm					1			1		1	1						1	1
Paralong							1									1		
Pellendi				2														
Pellepip																		
Pellnees				1	1		1	1	1	1	1						2	3
Philcapi												1					1	1
Philfont					1							2						
Plagcusp	3	3	2	3		2						2			2	2	2	
Plagdent	2	2	1	2	1	1	1	1	1	1	1	1		1		1	1	1
Plagdrum			1				1											1
Plaginsi		2	2	2	2	1	2			3	1	3			1	2	3	2
Plaglaet	2	2	2	2	1	2	2	1	1	2	1	3	2	1	2	1	2	1
Plagmedi	2	1	2	2	1	1		1	2		1	1	1	1	2	1	2	1
Plagoede																1		1
Plagpili				1								1					1	
Plagpore	1	1		2	1		2		1	1		3			1	1	3	
Plagrost			1															
Plagsato							1											
Plagundu																		
Platjung																		
Platrepe						1									1	1		
Pleuschr	3	3	2	2	1	3	2	1	1	2	3	2	3	3	1	1	2	2
Pogocont										1				1	1			
Pogoumi																		1
Pohlanno					1		1		2									
Pohlcrud		1	1	1		1		2							2	1		
Pohlnuta	1	2	1	1		1	2	2	2			1			2	2		1
Pohlwahl				1	1			1								2		1
Polyalpi									2	1		1			1	2		
Polycomm							1		1			3						1
Polyform				1	2	1	2	1							1			
Polyjuni	3	2		2		1	2	2	2	1	1	1	3	2	1	1	1	3
Polypili															1			1
Porecord												1				1		
Porenavi																		
Poreplat				1														
Porobige																		
Preiquad					1			1	1						1			
Pseuatri																1		
Pseuelag																		
Pseuradi																		
Pterfili																		
Ptilcali				2			1		1	1		1		1		1		
Ptilcili						1												1
Ptilcris	3	3	1	1	2	2	2	1	1	2	1	2	2	2	2	2	1	2
Ptilpulc	2	2	2	2	2	2	2	1	1	2	1	3	2	2	2	3	3	2
Pylapoly			3	3		1	1			3			1	1		1		
Racoacic																1		
Racocane													2	1				
Racoeric																		
Racofasc							1											1
Racohete						1							2		1			
Racosude																		

APPENDIX III. ICH species data.

Species/Plot	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Odondenu					1				1	2								2
Oligalig						1					1							
Oncovire				1	1								1				1	
Oncowahl	1			1	1					1		2	1				1	2
Orthchry																		2
Orthlaev	1		2	2													1	
Orthlyel																1		
Orthobtu			1	1									1		1	1		
Orthpell								1										
Orthspec	1		1					1				1			1			
Palucomm	1	1	1	1				1		1		1		1			1	2
Paralong	2		2												2	1		
Pellendi								1										2
Pellepip																		
Pellnees	1		1	1	2			2		2	2	2		1			1	2
Philcapi	1		1															
Philfont										1	2							1
Plagcusp				1														
Plagdent	1		1	1	1	1	1	1		1	1	1		1			1	
Plagdrum		2																
Plaginsi		3	1	1	1	1	2	1	1	2	2	2	1				1	1
Plaglaet	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	1	1	1
Plagmedi	1		1	1	1	1	1	1	1	1	2	1	1			1	1	1
Plagoede			1					1							2		1	2
Plagpili				2	1	1		1	1	2	1		1		2		3	2
Plagpore			1		1			1		1	2		1				1	2
Plagrost										1								
Plagsato					1													
Plagundu			1		1			1										
Platjung								1		1								1
Platrepe			1					1										
Pleuschr	3	1	1	1	2	1	1	3	1	1	2	2	2	1	2	2	2	2
Pogocont			1		1							2					1	
Pogourni								1		1							1	
Pohlanno					1			1		1								1
Pohlcrud			2	1	1			2		1	2	1	1	2				1
Pohlnuta	2			1		1	1	1	1	2		2		1		2	1	2
Pohlwahl		2		2				1		1		1					1	1
Polyalpi	1		2		2					1	1							1
Polycomm	1		2		1	2	1	1	1	1	1	2	2	1	2		1	1
Polyform	1		1	1	1	2	1	1	1	1	2	2	2	1	2		1	1
Polyjuni	1	1	1	2	1	2	3	1	3	2	2	2		1	1		2	2
Polypili			2					1							2	1	1	
Porecord			1	1					1						2	1	1	
Porenavi										1								
Poreplat	1			2	1	1						1	1					
Porobige						1				1								1
Preiquad	1			1	1					2	1	1						2
Pseuatri					1					1								
Pseuelag																		
Pseuradi																		
Pterfili							1											
Ptilcali					1	1	1	1	1	1	2	2	1				1	2
Ptilcili	1			2											2	1	2	
Ptilcris	3	2	1	1	1	2	1	3	1	3	2	2	2	2	2	2	1	2
Ptilpulc	1	3	1	2	2	3	3	3	2	2	2	2	2	1	2	1	1	2
Pylapoly			1	3											1	1		
Racoacic					1					2								
Racocane	2		2	2							1				2	2		2
Racoeric																		
Racofasc					1													
Racohete			2	2	2			2								1		1
Racosude																	1	

APPENDIX III. ICH species data.

Species/Plot	37	38	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Odondenu				1									1		1			1
Oligalig						1							1					
Oncovire	1						1	1			1							1
Oncowahl	1				1			1									1	
Orthchry													1					
Orthlaev																		
Orthlyel														2				1
Orthobtu		2	1						2									
Orthpell																		
Orthspec		1	1															
Palucomm										1				1	1		1	1
Paralong																		
Pellendi													1					
Pellepip																		
Pellnees	1			2	2		1			1	1		2	1	1		1	1
Philcapi													1				1	
Philfont							1							1				1
Plagcusp					2				2	2	1			2				
Plagdent	1				1					1	1	1	1	2	1		1	2
Plagdrum					1								1					
Plaginsi		3	1	1	1	1			1	2	1		2	2	1	2	2	2
Plaglaet	1	1	1	2	2	2	1	1	1	2	1	2	1	1	1	2	1	2
Plagmedi		1	2	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2
Plagoede					1													
Plagpili		2			2					2	1	2			1		1	1
Plagpore			1		2	2				2		2		1	2	1	1	2
Plagrost					1					1	2						1	1
Plagsato					1								1					1
Plagundu																		
Platjung													2					
Platrepe																		
Pleuschr	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	2	2
Pogocont						1					1		1					
Pogourni					1						1				1			1
Pohlanno																	1	
Pohlcrud			2						1							1		
Pohlnuta	2		1			2	1	2		1	2	1	1	2		1		
Pohlwahl							1			1		2						
Polyalpi							2	1		1		2	1	1	1			2
Polycomm	1			1	2	1	1	1		1		2	2	1	1		1	1
Polyform	1			1	2	1		1		1			1	1	1			1
Polyjuni	1		2	2	1	1	1	2	1	1		2	1	2	2			2
Polypili																1		
Porecord		1				1						1	1					1
Porenavi											1							
Poreplat					1	1							1					
Porobige													1					
Preiquad													1					
Pseuatri						1												
Pseuelag																	1	
Pseuradi																		
Pterfili																		1
Ptilcali		1		1	2	1	2	1				1	2		1		1	2
Ptilcili																		
Ptilcris	2	2	2	2	2	1	1	1	1	2	2	1	3	2	2	2	2	2
Ptilpulc	1	2	2	1	2	2	1	1	2	2	1	2	1	2	1	2	3	2
Pylapoly		3									1							
Racoacic																	1	
Racocane																1		
Racoeric																		
Racofasc					1												1	
Racohete																1		
Racosude												2						

APPENDIX III. ICH species data.

Species/Plot	56	57	58	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Odondenu				1														
Oligalig																		
Oncovire																		
Oncowahl	1																	
Orthchry																		
Orthlaev				1														
Orthlyel					1					1								
Orthobtu				1														
Orthpell																		
Orthspec				1														1
Palucomm							1									1		
Paralong																		
Pellendi																		
Pellepip									2									
Pellnees	1	1					1	2	2		2					1		2
Philcapi																		
Philfont	1																	
Plagcusp				2					2					2	2		2	
Plagdent	1	1		2	1	1		1		1	1			1			2	
Plagdrum																		
Plaginsi	1	1	2	2	3		2	1		2	2	2	2	1	2	2	2	2
Plaglaet	1	1	1	2	2	2	2	2	2	2	2	1	1	2	2	1	1	1
Plagmedi	1	1	1	2	1	1	1	1		1	1		1			1		
Plagoede																		
Plagpili			2		1		1									2		
Plagpore	2		2	2	2	2	2	2		2	2				2	1		
Plagrost																		
Plagsato		1																
Plagundu		1		1	1													
Platjung																		
Platrepe																		
Pleuschr	1	1	1	1	2	2	2	1	2	3	2	2	2	1	2	2	2	2
Pogocont				1							2							
Pogourni																		
Pohlanno																		
Pohlcrud	2		1				2				2							
Pohlnuta	1	1	1	2		1	1		2	1	2	1			2		2	
Pohlwahl	1								2									
Polyalpi	1	1	1	2	2	2	1	2	2	1	2		1	1	1	2	2	1
Polycomm	1	1	1	2		1	1	1		1	1		1		1	1		
Polyform	1	1	1	1			1	1	2	1	1		1		2			
Polyjuni	2	1	1	1	1	1	1		2	2	2	2	2		1	2	2	2
Polypili			1	1														
Porecord	1	2	1	1		2												
Porenavi				2	1													
Poreplat				1														
Porobige							1											
Preiquad									2									
Pseuatri																		
Pseuelag									1								1	
Pseuradi																		
Pterfili																		
Ptilcali	1	1		2	1	1	1			1	1		1	1				
Ptilcili				1														
Ptilcris	1	2	1	2	1	1	1	3	2	3	2	1	1	2	2	2	2	2
Ptilpulc	1	1	2	2	2	3	2	3	3	3	2	2	2	2	2	2	2	2
Pylapoly																		
Racoacic																		
Racocane		2	1	1														
Racoeric																		
Racofasc		2																
Racohete	2		1	1		1												
Racosude				2														

APPENDIX III. ICH species data.

Species/Plot	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Odondenu										1	1	1						
Oligalig					1						1							
Oncovire							1		1	1		1						
Oncowahl				1													2	
Orthchry			1						1			1						
Orthlaev													1					
Orthlyel			1		1		1				1							
Orthobtu																		
Orthpell		1																
Orthspec							1											
Palucomm	1	1		1				1		1		1		1	1			
Paralong	1			1	1			1								1		1
Pellendi												1			1			
Pellepip	1	1		2			1		1						1			
Pellnees	1		2	1	1		1	1	1	1	1	2	1	1	1	1		1
Philcapi																		
Philfont	1							1		1					1	1		
Plagcusp																		
Plagdent	1	1	1		1	1	1				1	1	1	1	1		2	1
Plagdrum																		
Plaginsi	1		1	2	1	2	1			2	1	2		1	1	1	1	1
Plaglaet	1	1	2	1	2	2	1	1	2	1	1	2	1	1	1	1	2	1
Plagmedi		1	2	1	1		1		1		1	1	1		1	1	1	1
Plagoede					1					1			1			1		
Plagpili	1		2		1		1			1							2	3
Plagpore	2	1	2	2	2	1	2	1	1	2	2	2				2	2	1
Plagrost																		
Plagsato									1	1	1	1						
Plagundu	1		2	2	1		1				1	1		1		1	2	1
Platjung					1				1									
Platrepe													1					
Pleuschr	1	1	2	1	1	2	2	1	2	2	1	1	1	1	1	1	1	1
Pogocont					1				2			2			2			
Pogourni	1										1					1		
Pohlanno							1					1			1			
Pohlcrud		1						2				2	1				2	
Pohlnuta		1	1		1	1	1	1	1	1	2	2	1	1	1	2	2	1
Pohlwahl	1							1			1	1						
Polyalpi	2		2	1	2	1	2	1	1	1	1	2	1	1	2	1	2	2
Polycomm	2	1	2	1	1		1	1		2		1	1	1	1		1	1
Polyform	1	1	1	1	1		1	1				1	2	1	1	1	1	1
Polyjuni		2	2	2	2	2	2	1	1	1	2	2	2	1	3	1	1	1
Polypili		1						1					1					
Porecord					1		1			1		1				1	1	1
Porenavi	1		1							1		1			1	1		
Poreplat			1									1		1	1			
Porobige	1																	
Preiquad		1	1												1			1
Pseuatri																		
Pseuelag	1				1												1	
Pseuradi			1				1											1
Pterfili										1		1						
Ptilcali	1	1	2	1	1	2	1	1	2	2	1	2	2	1	1	1	2	1
Ptilcili		1			1								2					
Ptilcris	2	1	1	1	2	2	1	2	1	2	1	1	1	1	2	2	2	3
Ptilpulc	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2
Pylapoly																		
Racoacic						1							2					1
Racocane		1		1	1		2	1					1	1				1
Racoeric													1					1
Racofasc	1																	
Racohete					1								1					2
Racosude																		

APPENDIX III. ICH species data.

Species/Plot	93	94	95	96	97	98	99	100	101	102
Odondenu										
Oligalig										
Oncovire										
Oncowahl							1			
Orthchry										
Orthlaev										
Orthlyel										
Orthobtu			2							
Orthpell		1								
Orthspec										
Palucomm										
Paralong		1								
Pellendi										
Pellepip										
Pellnees							1			
Philcapi							1			
Philfont										
Plagcusp										
Plagdent		1					1			
Plagdrum										
Plaginsi	1	2	3			1	2	2		
Plaglaet	1	1	2	2	1	2	2	1	1	2
Plagmedi	1	1	2		2				1	
Plagoede										
Plagpili		1					1			
Plagpore		2					2			
Plagrost										
Plagsato										
Plagundu										
Platjung		1								
Platrepe										
Pleuschr	1	1	1	3	2	2	2	1	2	2
Pogocont		1					1		1	
Pogourni										
Pohlanno										
Pohlcrud										
Pohlnuta		2		2	1	1	1	2	1	1
Pohlwahl										
Polyalpi	1	2	1							
Polycomm	1		1					1	1	1
Polyform										
Polyjuni	1	2	1	2	1			2	2	2
Polypili										
Porecord	1						1			
Porenavi										
Poreplat		1								
Porobige	1									
Preiquad										
Pseuatri		1								
Pseuelag								1		
Pseuradi										
Pterfili										
Ptilcali	2	2			1	1	2	1	1	1
Ptilcili										
Ptilcris		1	1	1	2	1	2	1	1	2
Ptilpulc	2	2	2	2	2	2	2	1	2	2
Pylapoly										
Racoacic										
Racocane		1								2
Racoeric										
Racofasc										
Racohete		2								
Racosude										

APPENDIX III. ICH species data.

Species/Plot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Raducomp				1			1	1		1						1		
Rhizglab												3					2	
Rhizgrac																		
Rhizmagn			3	2	1					2					1	2		1
Rhiznudu								1	1		1							
Rhizpseu											1						1	1
Rhytlore			2	2	2	1	2			2		1			1	2	2	1
Rhytrobu	2			2	1		1											
Rhytrugo																		
Rhytsqua				2				1							1	2		1
Rhyttriq	3	2	2	2	1	2	2	1	1	2	1	2	2	1	2	2	1	2
Ricclati																		
Riccmult																		
Riccnata				1								1					1	1
Riccpalm							1		1						1			
Saniunci	2	2	1	2	1	2	2	1	2	1	2	2	1	2	1	2	2	2
Scapamer																1		
Scapbola																		
Scapcurt																		
Scapmucr																		
Scapnew																2		
Scappalu																		
Scapsuba																		
Scapumbr																		
Scapundu				2				1		1						1	1	1
Schiapoc						1							2		1			2
Schirivu					1			1										1
Scleobtu																		1
Scouaqua																		
Sphaangu																		
Sphacapi																		
Sphagirg									1	1	1	3					1	
Sphamagi																		
Sphasqua									1									
Tetrgeni				2			1	1		1	1	3	1			1	3	
Tetrpell	2	2	2	1	2	3	2	1	3	1	3	1	3	1	2	1	3	2
Thamneck															2			
Thuireco									3								3	
Timmaust	2					1									1	1		
Tortrura		1					1									2		1
Torttort			2				1											
Tritexse				1		1	1	1	1	1	1						1	1
Tritpoli								1										1
Tritquin																		1
Tritscit																1		
Warnflui			1					1							1			1
Zygoviri																		

APPENDIX III. ICH species data.

Species/Plot	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Raducomp								1		1			2					
Rhizglab				2								2	3				2	2
Rhizgrac										1								2
Rhizmagn	1			3	1					1	2	2	1				1	1
Rhiznudu	1			1	1			1									1	1
Rhizpseu			1															
Rhytlore			1		2	2	2	1	1	1	2	2	2				1	2
Rhytrobu	1		1		1	1	2	1	1	2			1			2	1	
Rhytrugo					3													
Rhytsqua	1		1	1	1	1				1	1	2		1			1	2
Rhyttriq	1	1	1	2	3	3	3	3	3	3	2	2	2	1		1	2	2
Ricclati					1					1		2						1
Riccmult										1			3					1
Riccnata																	1	
Riccpalm			1					1		1	3	2						2
Saniunci	1	2	1	2	2	1	1	2	1	2	1	2	2	1	1	2	1	2
Scapamer																		
Scapbola													1					
Scapcurt																		
Scapmucr																		
Scapnew													1					
Scappalu																		
Scapsuba																		2
Scapumbr												1	1					1
Scapundu	1			1	1			1		2	1	1						1
Schiapoc	1		1	2						1		2			2	2		2
Schirivu	1									1		1						1
Scleobtu																		2
Scouaqua					1													
Sphaangu								1										1
Sphacapi							2	2		2	1							1
Sphagirg	1	1	1	1				2		1	2	2	1	2			1	1
Sphamagi								3			1							
Sphasqua			1		1			3		3	2	1						1
Tetrgeni			2	1	2	2	2	2	3	2	1	2	1	2			1	1
Tetrpell	2	1	3	3	1	2	2	2	3	2	2	2	1	2		1	1	2
Thamneck			1					1										
Thuireco													1		2	1		2
Timmaust	2				1					1								
Tortrura			1									1						
Torttort																	1	1
Tritexse	1		1	1			1	1	1	1		1	1	1			1	
Tritpoli										1								
Tritquin					1					1	1	2			1		1	1
Tritscit																		
Wamflui	1	1										1						
Zygoviri																		1

APPENDIX III. ICH species data.

Species/Plot	37	38	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Raducomp		1				2					1		2		1		1	1
Rhizglab																		
Rhizgrac																		
Rhizmagn	1			1	2	2	1			2			2		1		1	2
Rhiznudu										1		1	3					2
Rhizpseu						1							1		1			
Rhytlore	1	2	2	1	2	2	1				1	1	2	1	1		1	2
Rhytrobu	1	1	1		2	2	2	1		2		1	1	1	2	2		2
Rhytrugo																		
Rhytsqua	1			1						1	1		1	1			1	2
Rhyttriq	1	2	1	3	2	1	1	1	1	1	1	1	1	1	1	2	1	2
Ricclati					1					1								2
Riccmult													1					
Riccnata					1													
Riccpalm											1				1			1
Saniunci	1	2	2	1	2	2	1	1	2	2	1	2	2	1	2	2	1	2
Scapamer																		
Scapbola		1			1								1					
Scapcurt																		
Scapmucr																		
Scapnew																		2
Scappalu													2					
Scapsuba					2													
Scapumbr					1													
Scapundu				1						1			1					1
Schiapoc																		
Schirivu	1				1								1					1
Scleobtu					1												1	
Scouaqua																	1	1
Sphaangu																		
Sphacapi																		
Sphagirg	1				1		1				1				1		1	1
Sphamagi																		
Sphasqua											1				1			
Tetrgeni					1	2					2		2		1			2
Tetrpell	2	2	2	3	2	2	2	1	2	1	2	2	2	3	2	2	2	2
Thamneck						1												2
Thuireco						1			1		2		2		1			2
Timmaust													2					
Tortrura																1		
Torttort																		
Tritexse	1				1	2	1	1		1	1		1				1	1
Tritpoli						1												
Tritquin															1			1
Tritscit																		
Warnflui	1												1				1	
Zygoviri																		

APPENDIX III. ICH species data.

Species/Plot	56	57	58	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
Raducomp		1			1	1					1					1		
Rhizglab																		
Rhizgrac																		
Rhizmagn		1		2			2	2	2	2	2	2	2		3	2	3	2
Rhiznudu		2	1	2	1	1	2	1	1	1	1		1	1	2			1
Rhizpseu																		
Rhytlore		1		2	2	1	1							1			2	1
Rhytrobu	2	1	1	2	2	3	2	2	2	2	3	2	3	1	2	1	1	2
Rhytrugo																		
Rhytsqua																		
Rhyttriq	1	2	1	1	2	1	1	3	1	1	2	1	2	1	1	1	1	2
Ricclati					1						2							
Riccmult																		
Riccnata							1											
Riccpalm				1														
Saniunci	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	1
Scapamer											2							
Scapbola					1												1	
Scapcurt																		
Scapmucr																		
Scapnew																		
Scappalu																		
Scapsuba																		
Scapumbr							1											
Scapundu							1		2									
Schiapoc			1															
Schirivu																		
Scleobtu																		
Scouaqua																		
Sphaangu																		
Sphacapi																		
Sphagirg											1				2			
Sphamagi																		
Sphasqua								2							2			
Tetrgeni		1		2	1	1	2			1	1				1	1	1	
Tetrpell	1	2	2	2	2	2	2	2	2	2	1	1	2	2	3	2	2	2
Thamneck		2		1												1		
Thuireco		1					2								1	1		
Timmaust			1	1		2		2	2			1			2			
Tortrura																		
Torttort				1														
Tritexse	1	1	1	1	1								1					
Tritpoli																		
Tritquin		1																
Tritscit																		
Warnflui	1	1					1		2	2								
Zygoviri																		

APPENDIX III. ICH species data.

Species/Plot	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Raducomp	2		1		1		2			1	1	1		1	1	1	1	1
Rhizglab																	2	
Rhizgrac																		
Rhizmagn	1	1	2	2		2	1	1	2	2		2		2	2	1	2	
Rhiznudu			2	2		2	2		1	2	1	2		1	2	1	1	1
Rhizpseu			2			1						1						
Rhytlore	1	1	2	2	1	2	1		2	1	1	2	1	2	2	1	1	1
Rhytrobu	1	2	2	2	2	2	2	1	2	2	2	2	3	2	1	2	3	2
Rhytrugo										2	3	3	3	2			2	2
Rhytsqua	1				1	1				1		1	1				2	1
Rhyttriq	1	1	1	2	1	1	1	1	1	2	1	1	1			1		1
Ricclati			1							1	1	1		1		1	3	1
Riccmult	1		1		1							1			1			1
Riccnata			1															
Riccpalm							1	1		1		1					1	
Saniunci	1	1	2	1	2	1	1	1	2	1	1	2	1	1	1	1	1	1
Scapamer					1												1	1
Scapbola															1			
Scapcurt											1							
Scapmucr					1													
Scapnew																		
Scappalu	1											1			1			
Scapsuba																1		
Scapumbr					1		1			1					1		1	1
Scapundu			1	2	1			1	2	1		1					3	1
Schiapoc		1						1	1				1					
Schirivu					1			1				1			1			
Scleobtu	1																	
Scouaqua							1				1					1		
Sphaangu																		
Sphacapi																		
Sphagirg	1			1							1	2	1		1			
Sphamagi																		
Sphasqua				1														
Tetrgeni	1		2		2		2	1	2	2	2	2		1	1	2	2	2
Tetrpell	2	2	2	1	2	1	2	2	2	1	2	2	2	1	2	2	2	2
Thamneck	2				1						1	1		1		1	2	
Thuireco			2							1		1				2	2	
Timmaust		1			1			1										
Tortrura				1														
Torttort													1					1
Tritexse	1	1	1	1	1	1	1	1			1	1			1	1	1	
Tritpoli	1				1					1								1
Tritquin		1			1					1								
Tritscit										1								
Warnflui	1			1	1	1	1	1			1				1	1		1
Zygoviri																		1

APPENDIX III. ICH species data.

Species/Plot	93	94	95	96	97	98	99	100	101	102
Raducomp	1	1								
Rhizglab										
Rhizgrac										
Rhizmagn							2			
Rhiznudu		1					2	1	2	1
Rhizpseu							1			
Rhytlore		2					1	1		
Rhytrobu	2	2			2	2	2	1	1	2
Rhytrugo		2					2			
Rhytsqua										
Rhyttriq	1	2	1				1			
Ricclati		1								
Riccmult										
Riccnata										
Riccpalm										
Saniunci	1	1	2	1	1	2	1	1	1	1
Scapamer		1								
Scapbola										
Scapcurt										
Scapmucr										
Scapnew										
Scappalu										
Scapsuba	1	1								
Scapumbr		1								
Scapundu							1			
Schiapoc		2								1
Schirivu										
Scleobtu										
Scouaqua										
Sphaangu										
Sphacapi										
Sphagirg										
Sphamagi										
Sphasqua										
Tetrgeni		1								
Tetrpell	2	1	2	1	2	2	2	1	1	2
Thamneck										
Thuireco										
Timmaust										
Tortrura										
Torttort		1								
Tritexse		1					1			
Tritpoli										
Tritquin					2				1	2
Tritscit										
Warnflui							1			
Zygoviri										

APPENDIX IV. CWH environmental data.

Environmental/plots	**103**	**104**	**105**	**106**	**107**	**108**	**109**	**110**	**111**	**112**	**113**
Elevation	762	762	762	762	610	610	610	762	762	762	762
Latitude	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	14	14	14	13	14	13	9	9	9	14
Slope	45	50	10	12	7	25	25	30	55	55	60
Aspect	128	20	100	70	160	163	165	90	90	150	317
Slope Position	4	4	3	3	2	4	3	4	4	4	4
Moisture Regime	4	4	4	4	4	4	4	3	3	3	4
Rock cover	0	0	0	1	2	5	1	1	1	1	2
Soil Texture	7	7	6	7	7	7	7	7	7	3	3
Canopy height	45	50	30	23	21	40	35		22	32	35
Shrub cover	2	55	19	7	24	20	6	20	20	30	18
Herb cover	2	30	12	10	30	40	12	10	15	20	12
Tree density	891	509	509	637	318	135	446	390	637	430	334
Snag density	191	32	32	286	64	0	64	64	32	127	0
Log density	477	95	223	223	64	64	286	95	0	191	159
Tree basal area	64	234	122	61	38	143	39	117	46	99	182
Snag basal area	4	1	1	5	3	0	17	3	0	20	0
Log basal area	38	17	36	53	11	5	184	5	0	23	54
Disturbance (stand age)	4	9	9	4	4	9	4	9	4	9	9
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	0	0	1	1	3	4	1	1	1	4	4
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**114**	**115**	**116**	**117**	**118**	**119**	**120**	**121**	**122**	**123**	**124**
Elevation	762	762	762	762	762	762	762	762	762	762	762
Latitude	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	4	4	5	5	5	4	4	4	4	4	4
Site Series	9	9	9	9	14	11	14	14	13	9	14
Slope	50	40	25	25	10	65	55	65	60	7	4
Aspect	84	60	194	210	194	180	190	110	80	165	352
Slope Position	4	4	4	4	3	4	4	4	4	4	2
Moisture Regime	3	3	3	3	4	4	4	3	3	3	4
Rock cover	1	3	0	0	0	1	2	3	4	5	0
Soil Texture	2	7	6	2	2	8	7	7	7	7	6
Canopy height	33	24	40	40	42	30	36	36	32	23	47
Shrub cover	3	2	35	48	74	4	18	20	4	2	50
Herb cover	5	4	5	10	10	4	5	30	4	0	15
Tree density	796	732	629	732	923	637	310	382	891	891	454
Snag density	64	32	95	64	64	0	96	127	255	541	0
Log density	255	95	95	32	0	95	64	159	95	382	382
Tree basal area	78	57	122	117	95	51	67	146	61	61	82
Snag basal area	4	0	8	6	6	0	76	32	5	8	0
Log basal area	18	2	7	2	0	23	36	26	10	5	32
Disturbance (stand age)	4	4	9	9	9	4	9	9	4	4	9
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	4	4	0	0	3	0	0	1	1	1	0
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	8	8	8	9	9	9	9	9	9
Rainfall	2600	2600	2000	2000	2000	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	10	10	10	12	12	12	12	12	12
Degree days	340	340	280	280	280	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**125**	**126**	**127**	**128**	**129**	**130**	**131**	**132**	**133**	**134**	**135**
Elevation	762	762	762	762	762	762	762	762	762	762	610
Latitude	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 25
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	13	14	14	14	14	14	13	14	13	13
Slope	10	25	65	40	4	30	15	25	60		7
Aspect	160	160	160	200	220	160	270	225	10	0	170
Slope Position	3	3	3	3	2	3	3	4	4	4	2
Moisture Regime	4	4	4	4	5	5	5	5	4	3	4
Rock cover	0	2	0	0	0	1	0	0	0	0	1
Soil Texture	6	7	7	7	1	6	7	7	4	5	7
Canopy height	40	32	45		40	38	36	13	38	15	40
Shrub cover	30	27	40	14	35	16	11	4	33	25	24
Herb cover	30	16	50	14	25	30	25	8	15	30	23
Tree density	406	263	231	382	470	342	477	509	350	700	334
Snag density	8	40	0	0	32	40	32	0	32	0	48
Log density	191	32	191	95	318	159	286	191	95	95	223
Tree basal area	44	28	154	60	128	87	113	11	67	29	39
Snag basal area	11	10	0	0	0	23	1	0	6	0	44
Log basal area	26	3	39	50	64	62	105	71	31	10	47
Disturbance (stand age)	9	9	9	9	9	9	9	4	9	4	9
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	2	2	0	0	4	0	1	0	0	1	1
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**136**	**137**	**138**	**139**	**140**	**141**	**142**	**143**	**144**	**145**	**146**
Elevation	610	610	610	610	610	610	610	610	610	610	610
Latitude	49 25	49 25	49 25	49 25	49 30	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	4	4	4	4	4	5	5	5	4	5	5
Site Series	14	13	9	14	4	14	13	13	9	13	9
Slope	2	4			35	20	10	10	30	50	50
Aspect	0	0	0	0	200	58	65	50	150	90	190
Slope Position	3	3	4	4	4	3	3	4	4	4	4
Moisture Regime	4	4	3	3	4	4	5	5	3	4	3
Rock cover	0	0	1	0	10	3	0	0	1	0	1
Soil Texture	6	7	2	7	7	7	6	6	6	3	7
Canopy height	22	21	35	40		40	46	13	15	43	43
Shrub cover	8	17	2	1		43	70	45	30	28	30
Herb cover	15	15	4	3		33	22	50	55	29	5
Tree density	605	891	302	318	382	239	430	637	764	517	772
Snag density	127	0	215	191	0	0	64	0	0	16	0
Log density	191	95	255	191	95	32	64	32	32	95	95
Tree basal area	72	43	86	73	28	93	82	14	22	187	152
Snag basal area	38	0	45	83	0	0	2	0	0	82	0
Log basal area	35	18	57	21	1	1	7	4	11	3	14
Disturbance (stand age)	4	4	9	4	4	9	9	4	4	9	9
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	2	3	3	1	1	1	0	0	1	1	4
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	8	8	8	9	8	8
Rainfall	2600	2600	2600	2600	2600	2000	2000	2000	2600	2000	2000
6 month mean temperature	12	12	12	12	12	10	10	10	12	10	10
Degree days	340	340	340	340	340	280	280	280	340	280	280

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Environmental/plots	**147**	**148**	**149**	**150**	**151**	**152**	**153**	**154**	**155**	**156**	**157**
Elevation	762	762	762	762	762	762	762	762	610	610	762
Latitude	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	13	9	9	11	11	13	11	9	14	13
Slope	65	60	55	55	70	57	7	40	8	55	15
Aspect	245	280	245	260	184	220	0	220	220	230	190
Slope Position	4	4	4	4	5	4	3	4	3	4	4
Moisture Regime	4	3	3	3	4	4	4	3	3	4	3
Rock cover	3	1	2	0	0	5	0	3	0	0	20
Soil Texture	6	7	7	7	7	7	3	7	7	7	7
Canopy height	41	40	17		45	38	47	38	26	25	40
Shrub cover	5	30	11	1	15	5	20	3	0	1	6
Herb cover	12	30	13	1	10	6	15	7	0	1	13
Tree density	382	334	700	286	589	517	247	151	987	668	279
Snag density	119	175	32	0	8	0	8	72	64	95	40
Log density	255	191	350	159	127	159	255	64	255	255	64
Tree basal area	53	73	12	43	62	158	99	118	70	31	147
Snag basal area	197	69	105	0	10	0	11	36	1	1	22
Log basal area	16	108	135	36	12	19	79	3	51	24	28
Disturbance (stand age)	9	9	4	4	9	9	9	9	4	4	9
Watershed	6	6	6	6	6	6	6	6	6	6	6
Mesohabitat number	1	1	1	0	0	0	2	0	1	1	2
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**158**	**159**	**160**	**161**	**162**	**163**	**164**	**165**	**166**	**167**	**168**
Elevation	762	610	610	610	610	610	610	610	610	610	610
Latitude	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	13	13	13	9	13	14	13	9	14	13	14
Slope	20	30	50	55	60	25	50	40	27	45	8
Aspect	170	220	236	234	280	255	270	0	115	220	154
Slope Position	4	4	4	4	4	4	4	4	3	4	3
Moisture Regime	3	3	3	3	4	5	4	3	4	4	5
Rock cover	5	1	0	3	0	0	3	0	0	0	0
Soil Texture	7	7	3	2	6	6	3	6	2	6	2
Canopy height	23	22	47	23	38	40	42	42	42	38	40
Shrub cover	4	8	3	2	13	17	20	35	25	25	30
Herb cover	0	2	30	15	20	40	19	30	25	35	40
Tree density	987	732	271	955	247	430	470	183	223	470	350
Snag density	0	95	0	32	16	32	32	72	80	16	80
Log density	64	159	127	159	95	64	95	159	318	64	127
Tree basal area	111	41	166	51	96	129	125	98	66	91	109
Snag basal area	0	1	0	0	13	67	0	9	49	61	40
Log basal area	8	34	27	21	35	24	26	23	32	3	11
Disturbance (stand age)	4	4	9	4	9	9	9	9	9	9	9
Watershed	6	6	6	6	6	6	6	6	6	6	6
Mesohabitat number	1	1	0	0	1	1	2	0	2	1	1
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**169**	**170**	**171**	**172**	**173**	**174**	**175**	**176**	**177**	**178**	**179**
Elevation	610	610	610	762	762	762	762	762	762	610	610
Latitude	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	14	14	9	4	9	9	14	9	13	13
Slope	2	25	25	25	40	20	45	20	20	28	35
Aspect	180	220	200	290	280	310	310	250	0	264	260
Slope Position	2	4	3	4	4	4	4	3	4	3	4
Moisture Regime	4	4	4	3	4	3	4	4	4	3	3
Rock cover	0	0	0	0	0	5	3	0	4	1	0
Soil Texture	8	2	7	2	6	7	2	3	7	4	7
Canopy height	45	12	15	43	42	26	45	15	18	38	46
Shrub cover	50	19	7	26	60	4	20	2	2	2	23
Herb cover	48	16	20	5	30	2	25	7	5	4	40
Tree density	350	446	637	263	406	477	382	605	923	557	255
Snag density	8	0	0	56	8	95	64	32	0	40	72
Log density	127	127	0	159	127	159	350	95	159	159	127
Tree basal area	36	18	26	112	111	63	41	22	40	127	107
Snag basal area	12	0	0	64	13	2	2	0	0	64	38
Log basal area	44	188	0	42	20	21	55	1	9	15	34
Disturbance (stand age)	9	4	4	9	9	4	4	4	4	9	9
Watershed	6	6	6	6	6	6	6	6	6	6	6
Mesohabitat number	3	1	2	4	1	1	1	3	1	0	1
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**180**	**181**	**182**	**183**	**184**	**185**	**186**	**187**	**188**	**189**	**190**
Elevation	610	610	610	610	610	610	610	610	610	610	610
Latitude	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	122 55	123 10	123 10
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	13	13	13	13	13	13	13	9	14	14	14
Slope	5	0	2	3	20	6	45	30	35	40	20
Aspect	240	0	300	270	270	260	240	245	250	138	290
Slope Position	2	2	2	2	4	4	4	4	3	4	4
Moisture Regime	4	4	4	4	4	4	4	3	4	4	5
Rock cover	0	0	0	0	1	20	4	2	0	1	0
Soil Texture	5	1	5	6	2	7	2	7	4	6	3
Canopy height	41	40	20	15	18	20	45		18	44	40
Shrub cover	11	40	1	10	3	3	8	2	7	60	16
Herb cover	85	50	2	10	1	1	6	1	4	20	30
Tree density	279	255	573	764	764	1050	653	700	668	446	462
Snag density	0	0	223	32	0	0	143	191	0	8	8
Log density	64	95	159	32	127	95	509	605	64	127	64
Tree basal area	74	112	20	25	47	58	105	63	20	141	235
Snag basal area	0	0	3	1	0	0	60	128	0	18	7
Log basal area	18	9	26	2	15	18	114	153	0	19	4
Disturbance (stand age)	9	9	4	4	4	4	9	4	4	9	9
Watershed	6	6	6	6	6	6	6	6	6	5	5
Mesohabitat number	0	1	0	3	3	3	0	3	3	1	2
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**191**	**192**	**193**	**194**	**195**	**196**	**197**	**198**	**199**	**200**	**201**
Elevation	610	610	610	610	610	762	762	762	762	610	610
Latitude	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25	49 25
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	5	4	4	4	4	4	4	4	4	4	4
Site Series	14	14	14	13	14	13	13	14	13	14	13
Slope	15	7	35	0	5	20	40	60	45	50	2
Aspect	195	320	270	0	300	200	0	230	50	194	115
Slope Position	3	4	4	3	3	4	4	4	4	3	2
Moisture Regime	4	4	4	3	4	3	4	4	4	4	4
Rock cover	0	0	1	1	0	1	0	0	0	2	0
Soil Texture	7	7	7	7	6	7	2	7	2	7	2
Canopy height	42	28	25	30	28	28	25	22	42	20	16
Shrub cover	25	6	13	5	0	1	1	0	16	2	2
Herb cover	25	8	16	13	5	1	2	0	13	4	15
Tree density	517	700	923	796	732	1050	1082	1178	398	700	796
Snag density	48	350	159	64	127	159	255	541	32	32	159
Log density	32	191	32	0	64	223	95	191	191	32	0
Tree basal area	136	57	56	78	98	68	66	84	142	38	58
Snag basal area	32	139	213	1	3	194	5	62	14	2	4
Log basal area	0	138	5	0	1	105	32	31	50	4	0
Disturbance (stand age)	9	4	4	4	4	4	4	4	9	4	4
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	4	0	1	0	0	0	0	1	0	2	1
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	8	9	9	9	9	9	9	9	9	9	9
Rainfall	2000	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	10	12	12	12	12	12	12	12	12	12	12
Degree days	280	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**202**	**203**	**204**	**205**	**206**	**207**	**208**	**209**	**210**	**211**	**212**
Elevation	762	762	762	762	762	610	610	762	762	762	762
Latitude	49 25	49 25	49 25	49 25	49 30	49 30	49 30	49 30	49 30	49 30	49 30
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10	123 10
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	13	13	14	14	14	14	4	13	13	13	13
Slope	50	25	30	20	15	0	40	20	15	7	65
Aspect	80	45	0	70	85	0	80	255	224	215	340
Slope Position	4	4	4	4	3	3	4	4	4	3	4
Moisture Regime	4	4	4	4	4	4	3	4	4	4	4
Rock cover	2	0	1	0	3	0	2	5	5	0	0
Soil Texture	8	6	2	2	2	6	2	7	7	7	7
Canopy height	38	20	23	30	22	34	45	22	30	14	42
Shrub cover	1	40	3	2	14	1	4	9	10	0	36
Herb cover	2	34	10	1	14	1	26	63	70	3	28
Tree density	668	414	796	541	668	923	605	414	573	1592	191
Snag density	0	95	159	382	191	700	64	0	0	95	8
Log density	127	255	350	32	95	286	95	95	95	95	95
Tree basal area	64	17	28	69	71	78	58	35	34	58	57
Snag basal area	0	3	8	8	4	14	1	0	0	2	30
Log basal area	13	46	85	2	9	8	20	17	3	12	38
Disturbance (stand age)	4	4	4	4	4	4	4	4	4	4	9
Watershed	5	5	5	5	5	5	5	5	5	5	5
Mesohabitat number	0	3	0	1	1	0	0	1	0	1	6
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**213**	**214**	**215**	**216**	**217**	**218**	**219**	**220**	**221**	**222**	**223**
Elevation	762	762	762	762	762	762	762	610	610	610	610
Latitude	49 30	49 30	49 30	49 30	49 30	49 30	49 30	49 25	49 25	49 25	49 25
Longitude	123 10	123 10	123 10	123 10	123 10	123 10	123 10	122 55	122 55	122 55	122 55
BCG zone	4	4	4	4	5	5	5	4	4	4	4
Site Series	13	13	9	9	13	9	9	14	13	14	14
Slope	43	50	65	65	1	30	30	45	10	65	50
Aspect	334	320	308	300	0	325	300	40	70	60	54
Slope Position	4	4	4	4	3	4	4	3	5	4	4
Moisture Regime	3	3	4	3	4	3	3	4	3	4	4
Rock cover	0	1	10	2	0	2	0	0	1	1	2
Soil Texture	6	6	7	7	7	2	6	1	4	3	6
Canopy height	46	42	35		35	38	37	25	32	25	34
Shrub cover	40	10	2	1	60	36	50	16	5	14	7
Herb cover	50	35	2	4	20	23	13	17	10	34	35
Tree density	286	255	955	764	414	318	470	477	318	223	414
Snag density	0	64	127	382	40	103	64	255	159	95	95
Log density	95	191	286	95	0	159	0	127	255	255	159
Tree basal area	114	118	60	79	102	124	66	65	62	38	54
Snag basal area	0	2	3	14	11	36	6	12	4	2	1
Log basal area	16	42	100	2	0	12	0	3	36	24	30
Disturbance (stand age)	9	9	4	4	9	9	9	4	4	4	4
Watershed	5	5	5	5	5	5	5	6	6	6	6
Mesohabitat number	1	1	1	1	1	1	0	3	1	1	2
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	8	8	8	9	9	9	9
Rainfall	2600	2600	2600	2600	2000	2000	2000	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	10	10	10	12	12	12	12
Degree days	340	340	340	340	280	280	280	340	340	340	340

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Environmental/plots	**224**	**225**	**226**	**227**	**228**	**229**	**230**	**231**	**232**	**233**	**234**
Elevation	610	610	610	610	75	85	90	65	85	200	210
Latitude	49 25	49 25	49 25	49 25	49 5	49 5	49 5	49 5	49 5	49 5	49 5
Longitude	122 55	122 55	122 55	122 55	125 60	125 60	125 60	125 60	125 60	125 60	125 60
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	9	9	9	13	14	14	14	14	13	13	14
Slope	40	55	35	4	28	22	24	18	35	28	30
Aspect	240	220	160	165	120	122	124	126	122	120	122
Slope Position	4	4	4	3	3	3	3	3	3	4	4
Moisture Regime	3	3	3	5	3	4	4	4	4	3	4
Rock cover	0	3	3	2	3	3	4	4	5	4	6
Soil Texture	2	7	7	7	7	6	3	7	7	2	2
Canopy height	27	30	30	27	35	38	42	50	45	44	38
Shrub cover	16	5	1	3	45	55	45	45	55	35	35
Herb cover	14	15	1	6	25	25	35	45	35	15	25
Tree density	509	541	955	1146	318	382	255	350	286	255	350
Snag density	159	95	223	286	95	95	127	95	64	95	95
Log density	159	64	223	127	955	1019	1019	1114	923	732	891
Tree basal area	54	45	77	67	240	143	60	171	71	60	154
Snag basal area	18	3	4	9	153	165	124	131	82	88	131
Log basal area	9	4	25	28	278	366	390	348	230	185	370
Disturbance (stand age)	4	4	4	4	9	9	9	9	9	9	9
Watershed	6	6	5	5	7	7	7	7	7	7	7
Mesohabitat number	0	1	1	0	3	1	0	1	2	5	0
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

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Environmental/plots	**235**	**236**	**237**	**238**	**239**	**240**	**241**	**242**	**243**	**244**	**245**
Elevation	225	205	210	25	15	10	20	30	70	65	80
Latitude	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5
Longitude	125 60	125 60	125 60	125 60	125 60	125 60	125 60	125 60	125 50	125 50	125 50
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	14	13	23	23	23	13	14	14	14	14
Slope	30	32	32	0	0	0	0	0	22	35	18
Aspect	124	126	122	0	0	0	0	0	120	115	112
Slope Position	4	4	4	2	2	2	2	2	3	3	3
Moisture Regime	4	4	4	6	6	6	3	6	3	4	4
Rock cover	5	8	5	8	4	8	8	7	5	4	8
Soil Texture	2	6	7	3	2	2	2	7	7	2	2
Canopy height	41	47	50	46	44	38	47	42	41	45	44
Shrub cover	50	70	55	65	60	75	70	65	35	55	45
Herb cover	25	25	35	55	65	55	45	55	25	25	25
Tree density	350	286	318	350	318	382	318	350	446	350	350
Snag density	95	64	64	64	64	64	32	64	95	64	64
Log density	955	1050	1019	1146	828	987	828	732	700	828	923
Tree basal area	107	94	202	163	106	153	125	176	131	60	118
Snag basal area	164	115	104	51	115	100	21	114	138	142	101
Log basal area	354	396	246	279	96	246	332	263	167	259	270
Disturbance (stand age)	9	9	9	9	9	9	9	9	9	9	9
Watershed	7	7	7	7	7	7	7	7	8	8	8
Mesohabitat number	3	3	2	0	1	0	1	0	0	2	1
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**246**	**247**	**248**	**249**	**250**	**251**	**252**	**253**	**254**	**255**	**256**
Elevation	65	75	200	205	215	195	200	20	20	40	15
Latitude	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5	49 5
Longitude	125 50	125 50	125 50	125 50	125 50	125 50	125 50	125 50	125 50	125 50	125 50
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	14	14	14	13	14	14	14	23	14	23	23
Slope	26	32	38	34	28	22	24	0	0	0	0
Aspect	120	115	120	115	112	120	115	0	0	0	0
Slope Position	3	3	4	4	4	4	4	2	2	2	2
Moisture Regime	4	3	4	3	4	4	4	6	4	6	6
Rock cover	5	3	6	4	4	6	5	4	3	6	8
Soil Texture	2	2	7	2	7	2	2	7	2	2	2
Canopy height	43	42	46	41	39	43	46	50	48	47	38
Shrub cover	55	65	55	45	50	60	65	60	55	50	45
Herb cover	25	35	35	15	10	20	35	55	45	55	65
Tree density	286	255	382	286	350	382	382	318	286	318	350
Snag density	64	95	95	64	64	32	95	64	95	95	95
Log density	923	955	1114	1050	1305	955	1019	955	1019	987	923
Tree basal area	95	178	174	70	118	171	147	270	91	80	203
Snag basal area	85	193	144	35	119	30	124	76	153	186	176
Log basal area	237	259	584	333	275	259	399	186	350	205	360
Disturbance (stand age)	9	9	9	9	9	9	9	9	9	9	9
Watershed	8	8	8	8	8	8	8	8	8	8	8
Mesohabitat number	2	1	1	3	0	2	2	0	2	1	0
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**257**	**258**	**259**	**260**	**261**	**262**	**263**	**264**	**265**	**266**	**267**
Elevation	25	80	75	60	100	80	220	210	190	200	215
Latitude	49 5	49 50	49 50	49 50	49 50	49 50	49 50	49 50	49 50	49 50	49 50
Longitude	125 50	126 30	126 30	126 30	126 30	126 30	126 30	126 30	126 30	126 30	126 30
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	23	14	14	14	14	14	14	13	14	13	14
Slope	0	38	45	32	36	25	35	45	40	50	36
Aspect	0	120	122	124	126	122	120	122	124	126	122
Slope Position	2	3	3	3	3	3	4	4	4	4	4
Moisture Regime	6	4	4	4	4	3	4	3	5	3	4
Rock cover	5	4	10	8	5	5	6	8	5	5	6
Soil Texture	2	2	2	2	3	7	2	2	2	7	7
Canopy height	42	39	45	42	46	48	41	49	44	47	37
Shrub cover	50	70	65	60	55	45	45	55	55	55	55
Herb cover	50	35	35	45	40	35	25	10	15	15	25
Tree density	414	318	318	350	382	286	350	382	446	414	286
Snag density	32	95	64	32	64	95	32	64	64	95	95
Log density	923	987	1050	987	891	923	987	1210	1114	1178	1114
Tree basal area	205	148	49	136	337	110	154	92	158	133	193
Snag basal area	45	156	76	26	113	162	96	92	138	152	78
Log basal area	360	256	295	296	215	177	234	450	473	409	469
Disturbance (stand age)	9	9	9	9	9	9	9	9	9	9	9
Watershed	8	9	9	9	9	9	9	9	9	9	9
Mesohabitat number	2	0	2	2	3	1	3	3	3	2	3
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**268**	**269**	**270**	**271**	**272**	**273**	**274**	**275**	**276**	**277**	**278**
Elevation	20	40	15	20	25	55	45	45	40	35	175
Latitude	49 50	49 50	49 50	49 50	49 50	48 40	48 40	48 40	48 40	48 40	48 40
Longitude	126 30	126 30	126 30	126 30	126 30	124 35	124 35	124 35	124 35	124 35	124 35
BCG zone	4	4	4	4	4	4	4	4	4	4	4
Site Series	23	14	23	23	23	14	14	14	14	14	13
Slope	0	0	0	0	0	18	22	24	16	28	24
Aspect	0	0	0	0	0	15	10	240	160	80	15
Slope Position	2	2	2	2	2	3	3	3	3	3	4
Moisture Regime	6	5	6	6	6	5	4	3	5	5	3
Rock cover	12	4	3	5	6	8	8	6	5	10	5
Soil Texture	7	7	7	6	2	7	7	2	2	2	7
Canopy height	44	39	49	44	46	41	48	46	43	47	40
Shrub cover	55	55	55	60	70	35	65	60	45	50	45
Herb cover	55	40	50	45	55	35	35	45	35	35	20
Tree density	286	382	350	318	446	414	382	318	286	286	255
Snag density	32	64	64	64	64	64	32	95	64	32	64
Log density	955	1050	891	796	891	1019	1050	955	1019	1019	987
Tree basal area	129	92	183	92	129	216	191	126	134	66	61
Snag basal area	22	86	89	66	99	77	59	158	81	65	63
Log basal area	336	183	319	164	293	481	227	333	348	200	494
Disturbance (stand age)	9	9	9	9	9	9	9	9	9	9	9
Watershed	9	9	9	9	9	10	10	10	10	10	10
Mesohabitat number	1	0	2	0	2	1	1	1	0	1	2
Rock acidity	1	1	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340	340	340

APPENDIX IV. CWH environmental data.

Environmental/plots	**279**	**280**	**281**	**282**	**283**	**284**	**285**	**286**	**287**
Elevation	165	170	190	200	35	25	20	15	20
Latitude	48 40	48 40	48 40	48 40	48 40	48 40	48 40	48 40	48 40
Longitude	124 35	124 35	124 35	124 35	124 35	124 35	124 35	124 35	124 35
BCG zone	4	4	4	4	4	4	4	4	4
Site Series	13	14	14	13	23	14	23	23	23
Slope	22	26	18	22	0	0	0	0	0
Aspect	10	240	160	80	0	0	0	0	0
Slope Position	4	4	4	4	2	2	2	2	2
Moisture Regime	3	5	5	3	6	5	6	6	6
Rock cover	5	6	10	6	12	5	6	8	5
Soil Texture	2	2	2	3	2	2	3	2	2
Canopy height	48	47	48	44	42	39	41	44	48
Shrub cover	35	45	40	50	45	55	55	50	60
Herb cover	15	20	30	30	65	45	60	55	45
Tree density	223	318	318	446	382	382	446	446	382
Snag density	95	95	64	32	95	95	64	64	127
Log density	828	987	891	987	1369	1401	1369	1273	1146
Tree basal area	121	215	197	100	164	99	120	196	97
Snag basal area	124	193	106	27	245	112	66	60	218
Log basal area	183	286	161	230	406	459	583	338	389
Disturbance (stand age)	9	9	9	9	9	9	9	9	9
Watershed	10	10	10	10	10	10	10	10	10
Mesohabitat number	1	1	1	2	4	0	4	0	4
Rock acidity	1	1	1	1	1	1	1	1	1
Temperature	9	9	9	9	9	9	9	9	9
Rainfall	2600	2600	2600	2600	2600	2600	2600	2600	2600
6 month mean temperature	12	12	12	12	12	12	12	12	12
Degree days	340	340	340	340	340	340	340	340	340

APPENDIX V. CWH species data.

Plot Number	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Amblserp		1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt						1												
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping			1			1		1								1		
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt			2			2	1			1				2	2	2		
Apompube			2			2				2								
Arctfulv																		
Atriselw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulaandr	1		1		1	1	1		1	1			1		1	1	1	1
Aulapalu	1	1	1	1	1	1		1		1	1	1	1		1		1	1
Barbbarb																		
Barbfloe		1	1				2	1		1					1			1
Barbhatc			1		1	1	1				1					1		
Barthall																		
Bartpomi			1															
Bazzdenu	1	2	2	1	1	2	1	2	1	2	2	1	1	2	2	2	1	2
Bazzpear																		
Bazztric		1	1			1	1	1		1	1			1	1	1		1
Bazztril																		
Blaspusi																		
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																		
Bracfrig		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bracnels																		
Bracplum			1							1								
Bracrivu			1			1		1			1							
Bracvelu			1			1		1		1	1					1		
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall			1			1		1										
Bryupseu		1	1	1	1			1		1			1	1	1		1	1
Buxbpipe			1															
Calicusp																		
Calyfiss							1			1								
Calyinte		1	1			1	1	1		1	1			1	1	1		1
Calymuel		1	1			1	1	1		1	1			1	1	1		1
Calytric			1															
Campatro																		
Campflex																		
Campfrag																		
Cephbicu		2	2			2	1	2		2	2			2	2	2		2
Cephdiva		2				2				2	2							
Cephinte		1				1				1	1							
Cephlunu		1	1								1					1		
Cephphyl																		
Cerapurp		1	1	1									1	1	1	1	1	1
Chilpall																		
Chilpoly		1	1			1										1		
Cirrcirr																		
Claobola			2			2	1	1			1			1	1	2		1

APPENDIX V. CWH species data.

Plot Number	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping						1			1		1				1			
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt				2	2	2			2				2		2			2
Apompube				1	1	2							1					
Arctfulv																		
Atriselw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulaandr	1	1	1	1	1	1	1	1		1	1	1	1	1		1	1	1
Aulapalu	1		1	1	1	1	1		1	1	1	1	1	1		1	1	1
Barbbarb																		
Barbfloe				1			1	1			1							
Barbhatc					1	1	1	1	1						1			1
Barthall																		
Bartpomi																		
Bazzdenu	2	1	1	2	2	2	2	2	2	2	2		2	1	2	1	1	2
Bazzpear																		
Bazztric	1			1	1	1	1	1	1	1	1		1		1			1
Bazztril																		
Blaspusi																		
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																		
Bracfrig	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bracnels																		
Bracplum						1												
Bracrivu						1			1						1			1
Bracvelu					1	1			1		1				1			1
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall						1												1
Bryupseu		1	1	1	1	1	1	1	1	1		1	1	1		1	1	
Buxbpipe																		
Callcusp																		
Calyfiss				1		1	1	1	1	1								1
Calyinte	1			1	1	1	1	1	1	1	1		1		1			1
Calymuel	1			1	1	1	1	1	1	1	1		1		1			1
Calytric																		
Campatro																		
Campflex																		
Campfrag																		
Cephbicu	2			2	2	2	2	2	2	2	2		2		2		1	2
Cephdiva					2		2	2	2	2	2							
Cephinte				1	1	1				1	1							1
Cephlunu									1	1	1		1					1
Cephphyl																		
Cerapurp	1			1	1		1	1	1	1		1	1	1			1	
Chilpall																		
Chilpoly						1				1	1		1		1			
Cirrcirr																		
Claobola	2			1	1	2		1	2	1	2		1		2		1	2

APPENDIX V. CWH species data.

Plot Number	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
Amblserp		1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping			1				1	1	1	1								
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt			2	2			1	2					2	1	2			
Apompube								2										
Arctfulv																		
Atriselw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulaandr	1	1	1		1	1		1	1			1	1	1		1		
Aulapalu	1	1		1	1	1		1		1	1	1	1	1	1		1	1
Barbbarb																		
Barbfloe				1			1	1	1				1	1	1	1		
Barbhatc							1								1			
Barthall																		
Bartpomi																		
Bazzdenu	1	1	2	2	1	1	2	2	2	2	1		2	2	2	2	1	1
Bazzpear																		
Bazztric			1	1			1	1	1	1			1	1	1	1		
Bazztril																		
Blaspusi																		
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																		
Bracfrig	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1
Bracnels																		
Bracplum								1										
Bracrivu								1										
Bracvelu			1				1	1		1								
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall								1										
Bryupseu	1	1		1	1	1		1	1	1		1	1	1		1		1
Buxbpipe																		
Callcusp																		
Calyfiss			1												1			
Calyinte			1	1			1	1	1	1			1	1	1	1		
Calymuel			1	1			1	1	1	1			1	1	1	1		
Calytric																		
Campatro																		
Campflex																		
Campfrag																		
Cephbicu			2	2			2	2	2	2			2	2	2	2		1
Cephdiva							2											
Cephinte			1				1	1							1			
Cephlunu															1			
Cephphyl																		
Cerapurp		1	1	1	1	1	1	1	1		1		1			1	1	1
Chilpall																		
Chilpoly							1	1										
Cirrcirr																		
Claobola			2	1			2	2	2	2				1	2	1		

APPENDIX V. CWH species data.

Plot Number	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping	1					1					1	1					1	
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt	2	1					2	2	2	2	2	2	2			1	1	
Apompube	2						1	1				1	2					
Arctfulv																		
Atriselw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulaandr	1	1	1		1	1	1	1	1			1	1	1	1	1		1
Aulapalu	1	1		1	1		1	1	1	1		1	1	1	1		1	1
Barbbarb																		
Barbfloe	1			1		1		1	1		1	1	1			1		
Barbhatc	1						1	1	1	1			1					
Barthall																		
Bartpomi	1												1					
Bazzdenu	2	1	1	2	1	2	2	2	2	2	2	2	2	1	1	2	2	1
Bazzpear																		
Bazztric	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Bazztril																		
Blaspusi																		
Bleptric	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																		
Bracfrig	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bracnels																		
Bracplum	1											1	1					
Bracrivu	1						1			1	1	1	1					
Bracvelu	1									1	1	1				1	1	
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall	1						1						1					
Bryupseu	1		1		1	1	1	1		1	1		1	1	1			1
Buxbpipe	1																	
Callcusp																		
Calyfiss	1						1	1	1	1	1	1						
Calyinte	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Calymuel	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Calytric	1												1					
Campatro																		
Campflex																		
Campfrag																		
Cephbicu	2	1	1	2		2	2	2	2	2	2	2	2			2	2	
Cephdiva							2	2	2	2	2	2	2					
Cephinte	1												1			1	1	
Cephlunu								1	1	1	1	1	1					
Cephphyl																		
Cerapurp	1	1	1	1	1	1			1			1	1	1	1		1	1
Chilpall																		
Chilpoly	1						1		1	1	1	1	1			1		
Cirrcirr																		
Claobola	2	1	1			2	1	2		2	2	2	2			2	2	

APPENDIX V. CWH species data.

Plot Number	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																	1	
Amphlapp																	1	
Anacmenz																	1	
Anasassi																		
Anasminu																	1	
Andrblyt																		
Andrniva																	1	
Andrroth																		
Andrrupe																		
Aneuping					1		1								1	1	1	
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt					2	2	2								2	2	2	1
Apompube					1	1	2								2	1	2	
A.ctfulv																		
Atriselw	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulaandr	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aulapalu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbbarb					1												1	
Barbfloe				1	1	1	1									1	1	1
Barbhatc					1	1	1									1		1
Barthall																	1	
Bartpomi											1						2	
Bazzdenu	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	1
Bazzpear																		
Bazztric				1	1	1	1					1			1	1	1	1
Bazztril																	1	
Blaspusi																		
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																	1	
Bracfrig	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Bracnels																	1	
Bracplum					1		1									1	1	
Bracrivu					1		1								1	1	1	
Bracvelu					1		1								1		1	
Brotroel																		
Bryhhult																		
Bryucapi																	1	
Bryumini																		
Bryupall					1		1								1	1	1	
Bryupseu	1	1	1	1	1			1	1	1	1		1	1			1	1
Buxbpipe																	1	
Callcusp																		
Calyfiss						1	1								1			1
Calyinte				1	1	1	1					1			1	1	1	1
Calymuel				1	1	1	1					1			1	1	1	1
Calytric																	1	
Campatro																		
Campflex																		
Campfrag																		
Cephbicu		1		2	2	2	2		1			2			2	2	2	1
Cephdiva							2								2			1
Cephinte					1	1	1								1			1
Cephlunu					1										1	1		
Cephphyl																		
Cerapurp	1	1	1	1		1	1	1		1	1		1	1			1	1
Chilpall																	1	
Chilpoly						1	1									1	1	
Cirrcirr																		
Claobola		1		1	2	1	2				1				2	1	2	1

APPENDIX V. CWH species data.

Plot Number	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
Amblserp	1		1				1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping																		
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt							2							1			1	
Apompube																		
Arctfulv																		
Atriselw	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Aulaandr		1		1	1			1	1		1	1		1	1		1	1
Aulapalu	1	1		1	1	1							1	1	1		1	1
Barbbarb																		
Barbfloe																		
Barbhatc																		
Barthall																		
Bartpomi																		
Bazzdenu	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
Bazzpear																		
Bazztric	1						1							1			1	
Bazztril																		
Blaspusi																		
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Blinacut																		
Bracfrig	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bracnels																		
Bracplum																		
Bracrivu																		
Bracvelu																		
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall																		
Bryupseu					1	1		1	1	1	1	1	1	1	1	1	1	1
Buxbpipe																		
Callcusp																		
Calyfiss																		
Calyinte	1						1							1			1	
Calymuel	1						1							1			1	
Calytric																		
Campatro																		
Campflex																		
Campfrag																		
Cephbicu	1						2		1		1			1			1	
Cephdiva																		
Cephinte																		
Cephlunu																		
Cephphyl																		
Cerapurp	1	1	1		1	1			1	1	1	1	1	1	1		1	1
Chilpall																		
Chilpoly																		
Cirrcirr																		
Claobola	1								1		1			1			1	

APPENDIX V. CWH species data.

Plot Number	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
Amblserp	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1
Amphcali																		
Amphlapp																		
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth																		
Andrrupe																		
Aneuping		1	1				1	1										1
Anoeaest																		
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt		2	2	2			2	2	2	1				1	1			3
Apompube		2						2										2
Arctfulv																		
Atriselw	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	2
Aulaandr	1	1	1				1	1								1	1	2
Aulapalu	1			1	1			1	1	1	1		1	1			1	2
Barbbarb																		
Barbfloe				1			1	1	1	1				1	1			1
Barbhatc		1								1				1				2
Barthall																		
Bartpomi																		1
Bazzdenu	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	2
Bazzpear																		1
Bazztric		1	1	1			1	1	1	1				1	1			2
Bazztril																		
Blaspusi																		1
Bleptric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Blinacut																		
Bracfrig	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Bracnels																		1
Bracplum		1						1										
Bracrivu		1						1										1
Bracvelu		1	1				1	1										1
Brotroel																		
Bryhhult																		
Bryucapi																		
Bryumini																		
Bryupall		1						1										
Bryupseu	1			1	1	1				1	1		1	1		1	1	1
Buxbpipe																		1
Callcusp																		1
Calyfiss										1				1	1			
Calyinte		1	1	1			1	1	1	1				1	1			1
Calymuel		1	1	1			1	1	1	1				1	1			1
Calytric																		1
Campatro																		
Campflex																		
Campfrag																		
Cephbicu		2	2	2			2	2	2	1				1	1	1		2
Cephdiva										1				1	1			
Cephinte		1												1				1
Cephlunu										1				1	1			1
Cephphyl																		1
Cerapurp	1		1	1	1	1	1	1	1	1	1	1	1	1			1	2
Chilpall																		
Chilpoly		1								1				1	1			1
Cirrcirr																		1
Claobola		2	2	2			2	2	1	1				1	1	1		2

APPENDIX V. CWH species data.

Plot Number	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																		
Amphlapp																		1
Anacmenz																		
Anasassi																		
Anasminu																		
Andrblyt																		
Andrniva																		
Andrroth								1										1
Andrrupe																		
Aneuping	1				1											1	1	1
Anoeaest								1										1
Anthjula																		
Anthpunc																		
Anticali																		
Anticurt	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apompube	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Arctfulv																		
Atriselw	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aulaandr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aulapalu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Barbbarb																		
Barbfloe	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbhatc	2	2	2			2	2	2	2	2	2	2		2	2	2		
Barthall																		
Bartpomi		1	1	1				1	1	1	1	1	1	1	1	1	1	1
Bazzdenu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazzpear	1				1											1	1	1
Bazztric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazztril																		
Blaspusi	1				1		1		1							1	1	1
Bleptric	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Blinacut																		
Bracfrig	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bracnels	1		1		1													
Bracplum																		
Bracrivu	1				1		1				1		1			1	1	1
Bracvelu	1				1		1	1	1				1			1	1	1
Brotroel																		
Bryhhult																		
Bryucapi							1	1								1		1
Bryumini																		
Bryupall																		
Bryupseu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Buxbpipe	1	1						1	1		1	1	1	1	1	1	1	1
Callcusp	1				1		1	1	1				1			1	1	1
Calyfiss	1	1		1	1	1			1	1	1	1	1	1	1	1	1	1
Calyinte	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calymuel	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calytric															1	1	1	1
Campatro																		
Campflex																		
Campfrag																		
Cephbicu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cephdiva		2	2		2	2	2			2	2	2	2	2	2	2	2	2
Cephinte			1	1		1	1	1			1	1	1	1	1	1	1	1
Cephlunu	1			1	1		1	1	1		1	1	1	1	1	1	1	1
Cephphyl	1															1	1	1
Cerapurp	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Chilpall																		
Chilpoly	1		1		1		1		1							1	1	1
Cirrcirr					1						1		1					
Claobola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali																		
Amphlapp																	1	1
Anacmenz																	1	1
Anasassi		1															1	1
Anasminu																	1	1
Andrblyt																		
Andrniva																		
Andrroth																	1	
Andrrupe																	1	1
Aneuping	1	1			1	1								1	1	1		1
Anoeaest																	1	
Anthjula																	1	1
Anthpunc																		
Anticali																		
Anticurt	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apompube	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Arctfulv																	1	1
Atriselw	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2
Aulaandr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aulapalu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Barbbarb																	1	1
Barbfloe	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	2	2
Barbhatc	2	2		2		2			2	2	2		2	2	2		2	2
Barthall																		
Bartpomi	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	1
Bazzdenu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazzpear	1	1			1	1							1	1	1	1	1	1
Bazztric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazztril																	1	1
Blaspusi	1				1	1		1						1	1	1	1	1
Bleptric	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Blinacut																		
Bracfrig	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bracnels					1	1									1	1	1	1
Bracplum																		
Bracrivu	1	1			1	1		1	1		1		1	1	1	1	1	1
Bracvelu	1	1	1		1	1		1	1		1			1	1	1	1	1
Brotroel		1																
Bryhhult																	1	1
Bryucapi			1														1	
Bryumini											1							
Bryupall																		
Bryupseu	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Buxbpipe	1	1	1	1	1	1	1	1				1		1		1	1	1
Callcusp	1	1	1		1	1		1			1		1	1	1	1	1	1
Calyfiss	1			1	1		1	1	1		1	1	1	1		1	1	1
Calyinte	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calymuel	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calytric	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Campatro																		
Campflex																	1	1
Campfrag																	1	1
Cephbicu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cephdiva	2	2	2		2	2		2	2	2	2		2	2	2		2	2
Cephinte	1	1	1			1	1	1	1		1		1	1	1	1	1	1
Cephlunu	1	1	1	1			1	1		1	1	1	1	1	1	1	1	1
Cephphyl	1	1			1	1		1					1	1	1	1	1	1
Cerapurp	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Chilpall																	1	1
Chilpoly	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Cirrcirr					1	1			1		1				1	1	1	1
Claobola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
Amblserp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Amphcali	1																	
Amphlapp	1	1	1						1	1			1	1	1	1		1
Anacmenz	1	1	1						1	1			1	1	1	1		1
Anasassi	1	1	1							1				1	1	1		1
Anasminu	1	1	1						1	1				1	1	1		1
Andrblyt																		
Andrniva	1																	
Andrroth		1	1								1						1	
Andrrupe	1	1	1							1			1	1	1	1		1
Aneuping	1	1	1	1		1		1	1				1	1	1	1		1
Anoeaest		1	1											1			1	
Anthjula	1	1	1						1	1				1	1	1		1
Anthpunc													1					
Anticali									1	1			1					
Anticurt	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Apompube	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Arctfulv	1	1	1						1	1			1	1		1		1
Atriselw	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aulaandr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Aulapalu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Barbbarb	1	1	1						1	1				1	1	1		1
Barbfloe	2	2	2	1	1	1	1	1	1	1	1	1	1	2	2	2	1	2
Barbhatc	2	2	2	2	2		2		2	2		2	2	2	2	2	2	2
Barthall	1																	
Bartpomi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bazzdenu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazzpear	1	1	1							1			1	1	1	1		1
Bazztric	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bazztril	1	1	1											1	1	1		1
Blaspusi	1	1	1						1	1			1	1	1	1		1
Bleptric	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Blinacut	1																	
Bracfrig	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bracnels	1	1	1	1		1		1	1	1			1	1		1		1
Bracplum	1																	
Bracrivu	1	1	1	1		1		1	1	1			1	1	1	1		1
Bracvelu	1	1	1	1		1		1	1	1			1	1	1	1		1
Brotroel	1																	
Bryhhult	1	1	1											1		1		1
Bryucapi		1	1								1			1			1	
Bryumini										1								
Bryupall																		
Bryupseu	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Buxbpipe	1	1	1					1		1			1	1	1			1
Callcusp	1	1	1	1		1		1	1	1			1	1	1	1		1
Calyfiss	1	1	1	1			1	1	1	1		1	1	1	1	1	1	1
Calyinte	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calymuel	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calytric	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Campatro																		
Campflex	1	1	1						1	1			1	1	1	1		1
Campfrag	1	1	1						1	1			1	1	1	1		1
Cephbicu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cephdiva	2	2	2		2	2		2	2	2	2		2	2		2	2	2
Cephinte	1	1	1	1		1		1	1	1		1	1	1	1	1	1	1
Cephlunu	1	1	1		1	1	1	1		1	1		1	1	1	1		1
Cephphyl	1	1				1		1	1	1			1					
Cerapurp	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Chilpall	1	1	1						1	1			1	1	1	1		1
Chilpoly	1	1	1			1		1	1	1			1	1	1	1		1
Cirrcirr	1	1	1	1		1		1						1		1		1
Claobola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Plot Number	283	284	285	286	287
Amblserp	1	1	1	1	1
Amphcali					
Amphlapp	1		1		1
Anacmenz	1		1		1
Anasassi					
Anasminu					
Andrblyt	1				
Andrniva					
Andrroth					
Andrrupe	1		1		
Aneuping					
Anoeaest					
Anthjula					
Anthpunc					
Anticali	1		1		1
Anticurt	3	3	3	3	3
Apompube	2	2	2	2	2
Arctfulv	1		1		1
Atriselw	2	2	2	2	2
Aulaandr	2	2	2	2	2
Aulapalu	2	2	2	2	2
Barbbarb					
Barbfloe	1	1	1	1	1
Barbhatc	2	2	2	2	
Barthall					
Bartpomi	1	1		1	1
Bazzdenu	2	2	2	2	2
Bazzpear	1		1		
Bazztric	2	2	2	2	2
Bazztril					
Blaspusi	1		1		1
Bleptric	3	3	3	3	3
Blinacut					
Bracfrig	2	2	2	2	2
Bracnels	1		1		1
Bracplum					
Bracrivu	1		1		1
Bracvelu	1		1		1
Brotroel					1
Bryhhult					
Bryucapi					
Bryumini			1		
Bryupall	1				
Bryupseu	1	1	1	1	1
Buxbpipe	1	1	1	1	1
Callcusp	1		1		1
Calyfiss	1	1	1		1
Calyinte	1	1	1	1	1
Calymuel	1	1	1	1	1
Calytric	1	1	1	1	1
Campatro					1
Campflex					1
Campfrag	1		1		1
Cephbicu	2	2	2	2	2
Cephdiva	2	2	2	2	2
Cephinte	1		1	1	1
Cephlunu	1	1	1	1	1
Cephphyl	1		1		1
Cerapurp	2	2	2	2	2
Chilpall	1		1		1
Chilpoly	1		1		1
Cirrcirr					1
Claobola	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Claocris			1															
Claopell																		
Climdend			1			1		1			1					1		
Colomaco																		
Conoconi		1	1			1		1							1	1		1
Cratfili			1			1				1								
Dendabie			1		1	1	1											
Dendgrif																		
Dichpell			1			1		1		1	1					1		
Dichunci																		
Dicrcirr			1															
Dicrcris			1			1				1								
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	1	2	2	1	1	2	1	2	1	2	2	1	1	2	2	2	1	2
Dicrmaju																		
Dicrpaci																		
Dicrpall			1			1		1		1	1					1		
Dicrpalu			1			1				1								
Dicrscop		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi		2	2		1	2	1	2	1	2	2	1	1	2	2	2		2
Diplimbr																		
Diplobtu		1	1			1				1								
Diplplic			1			1		1		1	1					1		
Dipltaxi			1			1		1			1					1		
Distcapi																		
Ditrflex																		
Ditrhete	1		1	1		1		1		1	1	1	1	1	1	1	1	1
Ditrmont																		
Douiovat			2			2		2		2	2					2		
Drepadun			1			1		1		1	1							
Encacili																		
Encaproc																		
Eurhoreg	2	2	2	1	2	2	2	2	1	2	2	2	1	2	2	2	1	2
Eurhprae		1	2			2	1	2		2	2			1	1	2		1
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia			1															
Fissgran			1			1		1		1	1					1		
Fontanti			1			1		1		1	1							
Fonthypn			1			1		1		1	1					1		
Fontneom																		
Frul1																		
Frulbola					1	2	1											
Frulcali																		
Frulfran																		
Frulhatt																		
Frultama		1	1		1	1	1			1	1							1
Funahygr	1		1	1			1					1	1				1	
Gehegiga																		
Geocgrav		2	2	1	1	2	1	1		2	2		1	1	1	1		1
Grimincu																		
Gymnobtu			1			1		1		1	1							
Gyrounde																		
Haplmnio																		
Harpflot																		
Herbadun		1	2			2	1			2	1			2	2	2		1
Hetedimo			1							1								
Hetemaco		1	2		1	2	1	2		2	2		1	2	2	2		2

APPENDIX V. CWH species data.

Plot Number	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Claocris																		
Claopell																		
Climdend					1	1			1						1			1
Colomaco																		
Conoconi	1				1	1	1		1	1			1		1	1		1
Cratfili						1												
Dendabie																		
Dendgrif																		
Dichpell					1	1			1						1			
Dichunci																		
Dicrcirr																		
Dicrcris				1		1												
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	2	1	1	2	2	2	2	2	2	2	2	1	2	1	2	1	1	2
Dicrmaju																		
Dicrpaci																		
Dicrpall					1	1			1		1				1			1
Dicrpalu						1												
Dicrscop	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2		2		2	2	2	2
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi	2	1	1	2	2	2	2	2	2	2	2		2		2	1	1	2
Diplimbr																		
Diplobtu				1		1	1			1	1		1		1			1
Diplplic	1				1	1			1						1			1
Dipltaxi					1	1			1		1				1			1
Distcapi																		
Ditrflex																		
Ditrhete	1			1	1	1	1	1	1	1	1	1	1	1		1		1
Ditrmont																		
Douiovat					2	2			2						2			2
Drepadun						1												
Encacili																		
Encaproc																		
Eurhoreg	2	2	2	2	2	2	2	2	2	2	2		2	1	2	2	1	2
Eurhprae	2			1	2	2	1	1	2	1	1		1		2			2
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Fissadia																		
Fissgran						1			1		1				1			1
Fontanti						1			1						1			1
Fonthypn						1			1		1				1			1
Fontneom																		
Frul1																		
Frulbola						2												
Frulcali																		
Frulfran																		
Frulhatt																		
Frultama	1			1	1	1	1	1	1	1	1		1		1			1
Funahygr		1	1											1		1	1	
Gehegiga																		
Geocgrav	1	1	1	1	1	1	2	2	2	2	2		1		2	1	1	1
Grimincu																		
Gymnobtu					1	1			1						1			1
Gyrounde																		
Haplmnio																		
Harpflot																		
Herbadun	2			2	2	2	1	1	2	1	2		2		2			2
Hetedimo						1												
Hetemaco	2	1	1	2	2	2	1	1	2	1	2		2		2	1	1	2

APPENDIX V. CWH species data.

Plot Number	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
Claocris																		
Claopell																		
Climdend								1										
Colomaco																		
Conoconi							1	1	1	1			1			1		
Cratfili																		
Dendabie																		
Dendgrif																		
Dichpell								1										
Dichunci																		
Dicrcirr																		
Dicrcris								1										
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	1	1	2	2	1	1	2	2	2	2	1	1	2	2	2	2	1	1
Dicrmaju																		
Dicrpaci																		
Dicrpall			1				1	1	1	1								
Dicrpalu								1										
Dicrscop	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi	1		2	2			2	2	2	2			2	2	2	2		1
Diplimbr																		
Diplobtu			1					1							1			
Diplplic			1				1	1	1	1								
Dipltaxi			1				1	1	1	1								
Distcapi																		
Ditrflex																		
Ditrhete		1	1		1	1		1	1			1	1	1		1	1	
Ditrmont																		
Douiovat																		
Drepadun								1										
Encacili																		
Encaproc																		
Eurhoreg	1	2	2	2	2	1	2	2	2	2	2		2	2	2	2	2	2
Eurhprae			2	1			2	2	2	2			1	1	2	1		
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Fissadia																		
Fissgran			1				1	1	1	1								
Fontanti								1										
Fonthypn			1				1	1	1	1								
Fontneom																		
Frul1																		
Frulbola								2										
Frulcali																		
Frulfran																		
Frulhatt																		
Frultama			1	1			1	1	1	1			1	1	1	1		1
Funahygr	1	1			1	1					1	1					1	1
Gehegiga																		
Geocgrav	1		2	2			2	2	1	1			1	1	2	1		1
Grimincu																		
Gymnobtu								1										
Gyrounde																		
Haplmnio																		
Harpflot																		
Herbadun			2	1			2	2	2	2			1	1	2	1		
Hetedimo								1										
Hetemaco			2	1			2	2	2	2			2	2	2	2		1

APPENDIX V. CWH species data.

Plot Number	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174
Claocris	1												1					
Claopell																		
Climdend	1						1			1	1	1	1					
Colomaco																		
Conoconi	1			1				1					1			1		
Cratfili	1											1	1					
Dendabie	1																	
Dendgrif																		
Dichpell	1						1			1	1	1	1					
Dichunci																		
Dicrcirr	1												1					
Dicrcris	1							1				1	1					
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	2	1	1	2	1	2	2	2	2	2	2	2	2	1	1	2	2	1
Dicrmaju																		
Dicrpaci																		
Dicrpall	1					1	1			1	1	1	1				1	
Dicrpalu	1											1	1					
Dicrscop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi	2	1	1	2		2	2	2	2	2	2	2	2	1	1	2	2	
Diplimbr																		
Diplobtu	1						1	1		1	1	1	1			1	1	
Diplplic	1									1	1	1	1			1	1	
Dipltaxi	1						1			1	1	1					1	
Distcapi																		
Ditrflex																		
Ditrhete	1		1		1		1	1	1			1	1	1	1			
Ditrmont																		
Douiovat	2									2	2	2	2					
Drepadun	1						1					1	1					
Encacili																		
Encaproc																		
Eurhoreg	2	1	2	2	1	2	2	2	2	2	2	2	2	1	1	2	2	2
Eurhprae	2	1	1	1		2	2	2	1	2	2	2	2			2	2	
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2
Fissadia	1												1					
Fissgran	1					1	1			1	1		1				1	
Fontanti	1						1			1	1	1	1					
Fonthypn	1					1	1			1	1	1	1				1	
Fontneom																		
Frul1																		
Frulbola	2											2	2					
Frulcali																		
Frulfran																		
Frulhatt																		
Frultama	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Funahygr	1		1										1					1
Gehegiga																		
Geocgrav	2	1	1	1		2	1	1	2	2	2	1	1	1	1	2	2	
Grimincu																		
Gymnobtu	1										1		1					
Gyrounde																		
Haplmnio																		
Harpflot																		
Herbadun	2	1		1		1	1	2	1	2	2	2	2			2	2	
Hetedimo	1						1					1	1					
Hetemaco	2	1	1	2		2	1	2	2	2	2	2	2	1	1	2	2	

APPENDIX V. CWH species data.

Plot Number	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
Claocris																	1	
Claopell																		
Climdend					1		1								1	1	1	
Colomaco																		
Conoconi					1		1								1	1	1	
Cratfili					1		1								1		1	
Dendabie					1	1	1											
Dendgrif																		
Dichpell					1		1								1	1	1	
Dichunci																		
Dicrcirr																	1	
Dicrcris					1		1								1	1	1	
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	1
Dicrmaju																		
Dicrpaci																		
Dicrpall					1		1									1	1	
Dicrpalu					1		1								1		1	
Dicrscop		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi		1	1	2	2	2	2		1	1	1	2	1	1	2	2	2	1
Diplimbr																		
Diplobtu							1								1		1	
Diplplic					1		1								1		1	
Dipltaxi					1		1								1	1	1	
Distcapi																	1	
Ditrflex																		
Ditrhete	1	1	1		1	1	1	1		1	1			1	1	1	1	
Ditrmont																		
Douiovat					2		2								2	2	2	
Drepadun					1		1								1	1	1	
Encacili																	1	
Encaproc																		
Eurhoreg	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1
Eurhprae				1	2	1	2					1			2	2	2	1
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia																	1	
Fissgran					1		1								1	1	1	
Fontanti					1		1								1	1	1	
Fonthypn					1		1								1	1	1	
Fontneom																		
Frul1																		
Frulbola					2	2	2									2		
Frulcali																		
Frulfran																		
Frulhatt						1										1		
Frultama		1		1	1	1	1					1			1	1	1	
Funahygr	1	1	1						1	1	1		1	1			1	1
Gehegiga																		
Geocgrav		1	1	1	1	1	1		1	1	1	2	1	1	1	1	1	1
Grimincu																	1	
Gymnobtu					1		1								1	1	1	
Gyrounde																		
Haplmnio																		
Harpflot							1										1	
Herbadun		1		1	2	2	2					1			2	2	2	1
Hetedimo					1		1									1	1	
Hetemaco		1	1	2	2	2	2				2				2	2	2	1

APPENDIX V. CWH species data.

Plot Number	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
Claocris														1				
Claopell																		
Climdend																		
Colomaco																		
Conoconi																		
Cratfili																		
Dendabie																		
Dendgrif																		
Dichpell																		
Dichunci																		
Dicrcirr																		
Dicrcris																		
Dicrdenu																		
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	1	1		1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
Dicrmaju																		
Dicrpaci																		
Dicrpall																		
Dicrpalu																		
Dicrscop	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2
Dicrunci																		
Didyfall																		
Didyvine																		
Diplalbi	1					1	2	1	1		1			1			1	
Diplimbr																		
Diplobtu																		
Diplplic																		
Dipltaxi																		
Distcapi																		
Ditrflex																		
Ditrhete		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Ditrmont																		
Douiovat																		
Drepadun																		
Encacili																		
Encaproc																		
Eurhoreg	1	2	2	2	2	2	2	2	2	1	2	2	2	1	2	2	2	
Eurhprae	1						1							1			1	
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia																		
Fissgran									1									
Fontanti																		
Fonthypn																		
Fontneom																		
Frul1																		
Frulbola																		
Frulcali																		
Frulfran																		
Frulhatt																		
Frultama	1								1		1			1			1	
Funahygr		1		1	1	1			1	1	1	1	1	1	1	1		1
Gehegiga																		
Geocgrav	1					1	1	1	1		1			1			1	
Grimincu																		
Gymnobtu																		
Gyrounde																		
Haplmnio																		
Harpflot																		
Herbadun									1		1			1				
Hetedimo																		
Hetemaco	1					1	1	1	1		1			1			1	

APPENDIX V. CWH species data.

Plot Number	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
Claocris																		1
Claopell																		1
Climdend		1					1	1										1
Colomaco																		
Conoconi		1	1	1			1	1									2	2
Cratfili								1										
Dendabie															1			
Dendgrif																		
Dichpell		1						1										
Dichunci																		1
Dicrcirr																		1
Dicrcris		1						1										1
Dicrdenu																		1
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	2
Dicrmaju																		1
Dicrpaci																		
Dicrpall		1	1				1	1										1
Dicrpalu		1						1										
Dicrscop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2
Dicrunci																		
Didyfall																		1
Didyvine																		
Diplalbi		2	2	2	1	1	2	2	2	1	1	1	1	1	1	1		2
Diplimbr																		1
Diplobtu		1												1	1			1
Diplplic		1	1				1	1										1
Dipltaxi		1	1				1	1										1
Distcapi																		
Ditrflex																		
Ditrhete	1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1
Ditrmont																		1
Douiovat								2										2
Drepadun								1										1
Encacili																		
Encaproc																		
Eurhoreg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eurhprae		2	2	2			2	2	1	1				1	1		2	2
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia																		1
Fissgran			1				1	1										1
Fontanti								1										1
Fonthypn		1	1				1	1										1
Fontneom																		1
Frul1																		
Frulbola		2								1					1			
Frulcali																		1
Frulfran																		
Frulhatt																		
Frultama		1						1		1					1	1		1
Funahygr	1				1	1				1	1	1		1	1	1	1	1
Gehegiga																		
Geocgrav		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		2
Grimincu																		
Gymnobtu								1										1
Gyrounde																		1
Haplmnio																		
Harpflot																		
Herbadun		2	2	2			2	2	1	1				1	1	1		3
Hetedimo		1						1										
Hetemaco		2	2	2	1	1	2	2	1	1	1	1	1	1	1	1		2

APPENDIX V. CWH species data.

Plot Number	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
Claocris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Claopell	1		1		1		1	1	1		1		1			1	1	1
Climdend	1		1		1						1		1			1	1	1
Colomaco																		
Conoconi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cratfili																		
Dendabie																		
Dendgrif																		
Dichpell					1													
Dichunci					1		1	1			1		1			1	1	1
Dicrcirr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrcris		1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
Dicrdenu	1		1		1						1		1			1	1	1
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrmaju	1		1		1						1		1			1	1	1
Dicrpaci																		
Dicrpall					1		1	1	1		1		1			1	1	1
Dicrpalu																		
Dicrscop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																		
Dicrtaur	1	2	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2
Dicrunci																		
Didyfall	1		1															
Didyvine																		
Diplalbi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diplimbr	1										1		1			1		
Diplobtu	1	1	1			1	1		1	1	1			1	1	1	1	1
Diplplic	1		1								1		1			1	1	1
Dipltaxi	1	1	1	1			1	1		1	1	1	1		1	1	1	1
Distcapi																		
Ditrflex							1	1								1		1
Ditrhete	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
Ditrmont	1		1										1			1	1	1
Douiovat	2	2	2	2	2			2	2		2	2	2			2	2	2
Drepadun	1										1		1			1	1	1
Encacili																		
Encaproc								1										1
Eurhoreg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eurhprae	2	1	2	2	2	1	2	2	2	1	2	1	2	1	1	2	2	2
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fissgran	1		1								1		1			1	1	1
Fontanti	1		1		1						1		1			1	1	1
Fonthypn	1										1		1			1	1	
Fontneom	1		1								1		1			1	1	1
Frul1																		
Frulbola																		
Frulcali	1				1						1		1			1	1	1
Frulfran																		
Frulhatt										1					1			
Frultama	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Funahygr	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Gehegiga								1										
Geocgrav	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Grimincu								1								1		1
Gymnobtu	1		1													1	1	1
Gyrounde	1															1		
Haplmnio																		
Harpflot																		
Herbadun	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hetedimo																		
Hetemaco	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
Claocris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Claopell	1				1	1		1	1		1		1	1	1	1	1	1
Climdend	1	1	1		1	1		1	1		1			1	1	1	1	1
Colomaco																	1	1
Conoconi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cratfili																		
Dendabie		1																
Dendgrif																1		
Dichpell					1									1			1	
Dichunci	1	1			1	1		1	1		1		1	1	1	1	1	1
Dicrcirr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrcris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrdenu	1	1	1		1	1		1			1		1	1	1	1		1
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrmaju	1				1	1		1	1		1			1	1	1	1	1
Dicrpaci																		
Dicrpall	1	1	1		1	1		1	1		1		1	1		1	1	1
Dicrpalu																		
Dicrscop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp																	1	1
Dicrtaur	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2
Dicrunci																	1	1
Didyfall																		
Didyvine																		
Diplalbi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diplimbr		1	1		1	1		1			1		1	1		1		1
Diplobtu	1	1	1	1	1	1			1	1		1	1	1			1	1
Diplplic	1	1	1		1	1		1			1			1	1	1	1	1
Dipltaxi	1	1	1		1	1	1	1		1	1		1	1	1		1	1
Distcapi																		
Ditrflex			1			1									1		1	
Ditrhete	1	1	1			1		1	1	1	1	1	1	1	1	1	1	1
Ditrmont	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Douiovat	2	2	2	2		2	2	2	2		2	2	2	2		2	2	
Drepadun	1	1	1		1	1		1			1		1	1	1	1	1	1
Encacili																	1	1
Encaproc			1												1			
Eurhoreg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eurhprae	2	2	2	1	2	2	1	2	2	1	2	1	2	2	2	2	2	2
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fissgran	1	1	1		1	1		1	1		1		1	1	1	1		1
Fontanti		1			1	1		1	1		1		1	1	1	1	1	1
Fonthypn					1	1		1	1		1			1	1	1	1	1
Fontneom					1	1		1	1				1	1	1	1	1	1
Frul1																		
Frulbola																		
Frulcali	1				1	1							1	1		1		1
Frulfran																		
Frulhatt																	1	
Frultama	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Funahygr		1															1	1
Gehegiga																		
Geocgrav	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Grimincu															1			
Gymnobtu	1	1			1	1		1			1			1	1	1	1	1
Gyrounde		1			1			1			1		1	1	1	1	1	1
Haplmnio																		
Harpflot																		
Herbadun	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hetedimo																		
Hetemaco	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
Claocris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Claopell	1	1	1	1		1		1	1	1			1	1	1	1		1
Climdend	1	1		1		1		1	1	1			1	1		1		1
Colomaco	1	1	1						1	1			1	1	1	1		1
Conoconi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cratfili	1																	
Dendabie																		
Dendgrif												1						
Dichpell	1																	1
Dichunci	1	1	1	1		1		1	1	1			1	1	1			1
Dicrcirr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrcris	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
Dicrdenu	1	1	1					1	1	1			1	1	1	1		1
Dicrfusc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Dicrmaju	1	1	1	1				1	1	1			1	1	1	1		1
Dicrpaci	1																	
Dicrpall	1	1		1		1		1	1	1				1	1			1
Dicrpalu																		
Dicrscop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicrsubp	1	1	1						1	1				1	1	1		1
Dicrtaur	2	2	2	1	2	2	2	1	2	2	2	2	2	2	2	2	2	2
Dicrunci	1	1	1											1	1	1		1
Didyfall	1																	
Didyvine	1																	
Diplalbi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diplimbr	1	1												1	1	1		1
Diplobtu	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Diplplic	1	1	1			1		1						1	1	1		1
Dipltaxi	1	1	1	1	1	1		1	1	1			1	1	1	1		1
Distcapi	1																	
Ditrflex		1	1								1						1	
Ditrhete	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ditrmont	1	1						1	1	1				1	1			1
Douiovat	2	2	2		2	2	2	2	2	2	2		2	2	2	2	2	2
Drepadun	1	1							1	1			1	1	1	1		1
Encacili	1	1	1						1	1			1	1	1	1		1
Encaproc		1	1											1			1	
Eurhoreg	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Eurhprae	2	2	2	2	1	2	1	2	2	2	2	1	2	2	2	2	2	2
Eurhpulc	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Fissadia	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Fissgran	1	1	1						1	1			1	1	1	1		1
Fontanti	1	1	1	1		1		1		1				1				1
Fonthypn	1	1							1	1			1		1			1
Fontneom	1	1	1						1	1			1	1	1	1		1
Frul1	1																	
Frulbola										1			1			1	1	1
Frulcali	1	1		1				1	1	1			1	1				1
Frulfran									1	1			1			1	1	1
Frulhatt		1			1			1	1	1		1	1	1				
Frultama	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Funahygr	1	1	1											1	1	1		1
Gehegiga		1												1			1	
Geocgrav	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Grimincu		1	1															
Gymnobtu		1	1						1	1			1	1	1	1		1
Gyrounde	1	1							1	1			1	1	1			1
Haplmnio	1																	
Harpflot	1																	
Herbadun	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hetedimo																		
Hetemaco	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	283	284	285	286	287
Claocris	1	1	1	1	1
Claopell	1		1		1
Climdend	1		1		1
Colomaco	1		1		1
Conoconi	2	2	2	2	2
Cratfili					
Dendabie					
Dendgrif			1		1
Dichpell					
Dichunci	1		1		1
Dicrcirr	1	1	1	1	1
Dicrcris	1	1	1	1	1
Dicrdenu					1
Dicrfusc	2	2	2	2	2
Dicrhete	2	2	2	2	2
Dicrmaju	1		1		1
Dicrpaci					
Dicrpall					1
Dicrpalu	1				
Dicrscop	1	1	1	1	1
Dicrsubp					
Dicrtaur	2	2	2	2	2
Dicrunci					
Didyfall					1
Didyvine					1
Diplalbi	2	2	2	2	2
Diplimbr					1
Diplobtu	1	1	1	1	1
Diplplic	1		1		1
Dipltaxi	1		1	1	1
Distcapi					
Ditrflex					
Ditrhete	1	1	1	1	1
Ditrmont	1		1		1
Douiovat	2		2	2	2
Drepadun	1		1		1
Encacili	1		1		1
Encaproc					
Eurhoreg	2	2	2	2	2
Eurhprae	2	1	2	1	2
Eurhpulc	2	2	2	2	2
Fissadia	1	1	1	1	1
Fissgran	1		1		1
Fontanti					
Fonthypn	1		1		1
Fontneom					1
Frul1					
Frulbola	1	1	1	1	1
Frulcali	1		1		1
Frulfran	1	1	1	1	1
Frulhatt	1		1		
Frultama	1	1	1	1	1
Funahygr					
Gehegiga					
Geocgrav	2	2	2	2	2
Grimincu					
Gymnobtu	1		1		1
Gyrounde	1		1		1
Haplmnio					
Harpflot					
Herbadun	3	3	3	3	3
Hetedimo	1				
Hetemaco	2	2	2	2	2

APPENDIX V. CWH species data.

Plot Number	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Heteproc			1			1										1		
Homaaene			1			1				1	1			1	1		1	1
Homafulg		1	1		1	1	1			1	1							1
Homanutt			1			1												
Homatric			1															
Hookacut																		
Hookluce		1	1			1		1		1				1	1			1
Hygrluri			1			1		1		1	1					1		
Hygrochr																		
Hylosple	2	3	3	2	2	3	2	3	2	3	3	2	2	3	3	3	2	3
Hymeinsi																		
Hymerecu																		
Hypncirc		2	2	1	1	2	1	2	1	2	2	1	1	2	2	2		2
Hypndiec																		
Hypnlind			1			1		1			1					1		
Hypnprat			1			1		1		1	1					1		
Hypnrevo		1	1			1	1	1		1	1			1	1	1		1
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																		
Isotmyos	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2		2
Jameautu	1	2	2	1	1	2	1	2	1	2	2	1	1	2	2	2	1	2
Jungatro			1			1				1						1		
Jungexse																		
Jungleia			1		1	1	1			1	1							
Jungobov																		
Jungpumi			1			1		1			1					1		
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1	1	1	1	1	1	1	1		1	1	1		1	1	1		1
Lepisand																		
Leptpyri	1		1	1	1	1	1		1		1	1	1	1	1	1		1
Leskpoly			1			1				1						1		
Leucacan	1	1	1	1	1	1	1		1	1	1		1	1	1		1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		
Lophgill																		
Lophgutt		1	1		1	1	1			1	1							
Lophhetc			1			1				1						1		
Lophhete		2	2			2	1	2		2	2			2	2	2		2
Lophinci		2	2			2	2	2		2	2			2	2	2		2
Lophlong		1	1			1				1	1							
Lophobtu																		
Lophopac																		
Lophvenl		1	1			1	1	2		1	1			2	2	1		2
Lophvens			1			1	1			1	1							
Lophwenz																		
Marcpoly			1			1		1		1	1					1		
Marsalpi																		
Marsboec																		
Marsemar		1	1			1	1			1	1			1	1	1		1
Marsspar			1			1		1		1	1							
Metamenz			1			1	1			1				1	1	1		
Metzconj		1	1			1		1		1					1			
Metztemp						1				1						1		
Mniuambi																		
Mniumarg		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2		2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Heteproc					1	1			1						1			
Homaaene	1	1	1	1	1	1	1	1		1	1	1	1				1	1
Homafulg	1			1	1	1	1	1	1		1		1		1			1
Homanutt				1	1	1							1					
Homatric																		
Hookacut																		
Hookluce	1			1	1	1		1	1	1			1					1
Hygrluri						1			1		1				1			1
Hygrochr																		
Hylosple	3	2	2	2	2	2	3	3	3	3	3	2	2	2	3	2	2	3
Hymeinsi																		
Hymerecu																		
Hypncirc	2	1	1	2	2	2	2	2	2	2	2		2		2	1	1	2
Hypndiec																		
Hypnlind						1			1		1				1			1
Hypnprat					1	1			1		1				1			1
Hypnrevo	1			1	1	1	1	1	1	1	1		1		1		1	1
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																		
Isotmyos	2	2	2	2	2	2	2	2	2	2	2		2	1	2	2	1	2
Jameautu	2	1	1	2	2	2	2	2	2	2	2	1	2	1	2	1	1	2
Jungatro					1	1			1						1			
Jungexse																		
Jungleia				1	1	1	1	1			1						1	1
Jungobov																		
Jungpumi					1	1			1						1			1
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1	1
Lepisand																		
Leptpyri	1	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1
Leskpoly						1			1		1				1			
Leucacan	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		
Lophgill																		
Lophgutt					1		1	1			1		1		1			
Lophhetc					1	1			1		1				1			
Lophhete	2			2	2	2	2	2	2	2	2		2		2		1	2
Lophinci	2			2	2	2	2	2	2	2	2		2		2			2
Lophlong				1	1	1	1	1	1				1		1			1
Lophobtu																		
Lophopac																		
Lophvenl	2			2	1	1	1	1	1	1	1		2		1		1	2
Lophvens				1	1				1	1					1			1
Lophwenz																		
Marcpoly					1	1			1		1				1	1		1
Marsalpi																		
Marsboec																		
Marsemar	1			1	1	1	1	1	1	1	1		1		1			1
Marsspar						1												1
Metamenz				1	1	1			1				1		1		1	1
Metzconj	1			1	1	1		1			1		1					1
Metztemp					1	1			1						1			
Mniuambi																		
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	2	2	2	2	2	2	2	2	2	2		2	1	2	2	1	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
Heteproc								1										
Homaaene		1	1	1	1	1		1		1	1	1	1		1	1		1
Homafulg			1	1			1	1	1	1			1	1	1	1		
Homanutt								1										
Homatric																		
Hookacut																		
Hookluce				1				1	1				1	1	1	1		
Hygrluri			1				1	1	1	1								
Hygrochr																		
Hylosple	2	2	3	2	2	2	3	3	3	3	2	2	3	3	3	3	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	1	1	2	2			2	2	2	2	1	1	2	2	2	2	1	1
Hypndiec																		
Hypnlind			1				1	1	1	1								
Hypnprat			1				1	1		1								
Hypnrevo		1	1	1			1	1	1	1			1	1	1	1		1
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																		
Isotmyos	1	1	2	2		1	2	2	2	2	2	1	2	2	2	2	2	2
Jameautu	1	1	2	2	1	1	2	2	2	2	1	1	2	2	2	2	1	1
Jungatro								1										
Jungexse																		
Jungleia			1					1							1			
Jungobov																		
Jungpumi								1										
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1
Lepisand																		
Leptpyri	1	1		1	1	1	1		1		1						1	1
Leskpoly			1				1	1	1	1								
Leucacan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		
Lophgill																		
Lophgutt			1				1											
Lophhetc			1				1	1	1	1								
Lophhete			2	2			2	2	2	2			2	2	2	2		1
Lophinci			2	2			2	2	2	2			2	2	2	2		1
Lophlong			1				1	1							1			
Lophobtu																		
Lophopac																		
Lophvenl			1	1			1	1	2	2			2	2	1	2		1
Lophvens			1				1	1							1			
Lophwenz																		
Marcpoly			1				1	1	1	1								
Marsalpi																		
Marsboec																		
Marsemar			1	1			1	1	1	1			1	1	1	1		
Marsspar								1										
Metamenz								1							1			1
Metzconj				1			1	1	1	1				1		1		
Metztemp								1										
Mniuambi																		
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	1	2	2			2	2	2	2	2	2	2	2	2	2	2	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174
Heteproc	1						1			1	1	1	1					
Homaaene	1	1		1	1	1	1	1	1	1		1	1	1	1		1	1
Homafulg	1			1		1	1	1	1	1	1	1	1			1	1	
Homanutt	1	1	1				1	1				1	1					
Homatric	1												1					
Hookacut																		
Hookluce	1						1	1		1		1	1			1		
Hygrluri	1									1	1	1				1	1	
Hygrochr																		
Hylosple	3	2	2	3	2	2	2	2	3	3	3	2	2	2	2	3	3	2
Hymeinsi																		
Hymerecu																		
Hypncirc	2	1	1	2		2	2	2	2	2	2	2	2	1	1	2	2	1
Hypndiec																		
Hypnlind	1					1	1			1	1	1	1			1	1	
Hypnprat	1						1			1	1	1	1			1	1	
Hypnrevo	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																		
Isotmyos	2	1	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2
Jameautu	2	1	1	2	1	2	2	2	2	2	2	2	2	1	1	2	2	1
Jungatro	1										1	1	1					
Jungexse																		
Jungleia	1						1	1	1				1				1	
Jungobov																		
Jungpumi	1						1			1	1	1	1					
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lepisand																		
Leptpyri	1	1	1		1			1	1			1	1	1				1
Leskpoly	1					1	1			1	1		1			1	1	
Leucacan	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		
Lophgill																		
Lophgutt							1				1	1	1			1	1	
Lophhetc	1					1	1			1	1	1	1			1	1	
Lophhete	2	1	1	2		2	2	2	2	2	2	2	2			2	2	
Lophinci	2		1	2		2	2	2	2	2	2	2	2			2	2	
Lophlong	1							1				1	1			1	1	
Lophobtu																		
Lophopac																		
Lophvenl	1	1	1	2		1	1	1	1	1	1	1	2			1	1	
Lophvens												1	1			1	1	
Lophwenz																		
Marcpoly	1									1	1	1	1			1	1	
Marsalpi																		
Marsboec																		
Marsemar	1	1	1	1		1	1	1	1	1	1	1	1			1	1	
Marsspar	1						1					1	1					
Metamenz	1	1						1		1	1	1	1					
Metzconj	1			1			1	1			1	1	1			1		
Metztemp	1						1			1	1	1	1					
Mniuambi																		
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	1	2	2		2	2	2	2	2	2	2	2	1	1	2	2	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
Heteproc					1		1								1	1	1	
Homaaene	1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	
Homafulg				1	1	1	1					1			1	1	1	
Homanutt					1	1	1								1	1	1	
Homatric																	1	
Hookacut																		
Hookluce				1	1	1	1								1	1	1	
Hygrluri					1		1								1		1	
Hygrochr																	1	
Hylosple	2	2	2	3	2	2	2	2	2	2	2	3	2	2	2	2	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	1		1	2	2	2	2		1	1	1	2	1	1	2	2	2	1
Hypndiec																	1	
Hypnlind					1		1								1	1	1	
Hypnprat					1		1									1	1	
Hypnrevo		1		1	1	1	1		1		1	1			1	1	1	1
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																	1	
Isotmyos	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	2	2	1
Jameautu	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	1
Jungatro					1		1								1		1	
Jungexse																	1	
Jungleia					1	1									1	1		
Jungobov																		
Jungpumi					1		1								1	1	1	
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lepisand																		
Leptpyri	1	1	1					1	1	1	1		1	1	1	1	1	1
Leskpoly					1		1								1	1	1	
Leucacan		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp							1										1	
Lophexci																		
Lophgill																		
Lophgutt					1										1	1		
Lophhetc					1		1								1	1	1	
Lophhete		1		2	2	2	2		1		1	2			2	2	2	1
Lophinci		1		2	2	2	2		1			2			2	2	2	1
Lophlong					1	1										1		1
Lophobtu																	1	
Lophopac																		
Lophvenl		1		2	1	2	2		1		1	1			1	1	2	1
Lophvens					1	1	1										1	
Lophwenz																		
Marcpoly					1		1								1	1	1	
Marsalpi																		
Marsboec																		
Marsemar				1	1	1	1								1	1	1	1
Marsspar					1		1								1	1	1	
Metamenz		1			1	1	1		1		1				1	1	1	1
Metzconj					1		1									1	1	
Metztemp					1		1									1	1	
Mniuambi							1											
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	1	1	2	2	2	2	2	2	1	1	2	2	1	2	2	2	2
Mniuthom																	1	

APPENDIX V. CWH species data.

Plot Number	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
Heteproc																		
Homaaene	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1
Homafulg									1					1			1	
Homanutt	1													1			1	
Homatric																		
Hookacut																		
Hookluce							1											
Hygrluri																		
Hygrochr																		
Hylosple	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	1	1		1	1	1	2	1	1	1	1	1	1	1	1	1	1	
Hypndiec																		
Hypnlind																		
Hypnprat																		
Hypnrevo	1						1	1	1		1			1			1	
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Isoppulc																		
Isotmyos	1	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2	2	
Jameautu	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1
Jungatro																		
Jungexse																		
Jungleia																	1	
Jungobov																		
Jungpumi																		
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila																		
Lepirept	1					1	1	1	1	1	1	1	1	1	1	1	1	1
Lepisand																		
Leptpyri	1	1	1	1	1			1	1	1	1	1	1		1	1	1	1
Leskpoly																		
Leucacan	1	1	1	1	1			1	1	1	1			1	1	1	1	1
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		
Lophgill																		
Lophgutt																		
Lophhetc																		
Lophhete	1						2	1	1		1			1			1	
Lophinci	1						2		1		1			1			1	
Lophlong																		
Lophobtu																		
Lophopac																		
Lophvenl	1						1	1	1		1			1			1	
Lophvens																	1	
Lophwenz																		
Marcpoly																		
Marsalpi																		
Marsboec																		
Marsemar	1						1							1			1	
Marsspar																		
Metamenz	1								1		1			1			1	
Metzconj							1											
Metztemp																		
Mniuambi																		
Mniumarg	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1
Mniuspin	2	2		2	2	2	2	2	2	2	2	2	2	2	2	1	2	
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
Heteproc		1						1										1
Homaaene	1	1	1		1		1	1	1	1		1	1	1				1
Homafulg		1						1		1					1			1
Homanutt		1						1		1					1			
Homatric																		1
Hookacut																		1
Hookluce		1	1	1				1	1									1
Hygrluri		1	1				1	1										1
Hygrochr																		
Hylosple	2	2	2	2	2	2	3	3	2	2	2	2	2	2	2	2	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	3
Hypndiec																		
Hypnlind		1	1				1	1										1
Hypnprat		1	1				1	1										1
Hypnrevo		1	1	1			1	1	1	1				1	1	1		1
Hypnsubi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Isoppulc																		1
Isotmyos	1	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	3
Jameautu	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	2
Jungatro		1						1										1
Jungexse																		
Jungleia		1													1			1
Jungobov																		
Jungpumi		1						1										1
Jungrubr																		1
Kurzmaki																		
Kurzseta																		
Lepifila																		1
Lepirept	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	2
Lepisand																		
Leptpyri	1			1	1		1	1	1	1	1				1	1	1	1
Leskpoly		1	1				1	1										1
Leucacan	1	1			1	1	1	1	1	1	1	1		1			1	2
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci																		1
Lophgill																		
Lophgutt										1								1
Lophhetc		1	1				1	1										1
Lophhete		2	2	2			2	2	2	1				1	1	1		2
Lophinci		2	2	2			2	2	2	1				1	1	1		2
Lophlong																		
Lophobtu																		
Lophopac																		1
Lophvenl		1	1	1			1	1	1	1				1	1	1		2
Lophvens		1								1								1
Lophwenz																		1
Marcpoly		1	1				1	1					1				1	1
Marsalpi																		
Marsboec																		
Marsemar		1	1	1			1	1	1	1				1	1			2
Marsspar		1						1										1
Metamenz		1					1	1	1	1				1	1	1		1
Metzconj		1	1	1			1	1										1
Metztemp		1						1										1
Mniuambi																		
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	1	2	2	2	1	1	2	2	2	2	2	2	2	2	2	2	2	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
Heteproc	1		1		1		1	1	1		1		1			1	1	1
Homaaene	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homafulg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homanutt															1	1	1	1
Homatric	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hookacut	1				1											1		
Hookluce	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hygrluri	1		1		1						1		1			1	1	1
Hygrochr																		
Hylosple	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hypndiec																		
Hypnlind	1		1		1		1	1	1		1		1			1	1	1
Hypnprat	1		1		1											1		
Hypnrevo	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1	1
Hypnsubi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Isoppulc					1		1	1	1		1		1			1	1	1
Isotmyos	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jameautu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jungatro	1		1		1													
Jungexse																		
Jungleia	1	1		1	1	1			1	1	1	1	1	1		1	1	1
Jungobov																		
Jungpumi	1															1	1	1
Jungrubr																		
Kurzmaki																		
Kurzseta																		
Lepifila	1		1								1		1			1	1	1
Lepirept	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lepisand																		
Leptpyri	1	1	1		1	1		1	1	1	1	1	1	1	1	1	1	1
Leskpoly	1				1						1		1			1	1	1
Leucacan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Loesbadi																		
Loph1																		
Loph2																		
Lophcusp																		
Lophexci	1	1	1	1	1	1		1	1	1			1	1		1	1	1
Lophgill																		
Lophgutt	1	1	1	1	1	1	1		1	1	1			1	1	1	1	1
Lophhetc	1		1		1		1	1			1		1			1		
Lophhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophinci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophlong	1	1	1	1	1	1	1	1		1	1	1			1	1	1	1
Lophobtu							1	1								1		1
Lophopac	1				1						1		1			1	1	
Lophvenl	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophvens		1	1	1	1	1	1	1	1		1	1	1			1	1	1
Lophwenz	1			1	1	1	1	1	1	1		1	1	1			1	1
Marcpoly	1		1		1						1		1			1		
Marsalpi																		
Marsboec								1										
Marsemar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Marsspar	1		1								1		1					
Metamenz	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metzconj	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metztemp	1		1		1						1		1			1		
Mniuambi																		1
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
Heteproc	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Homaaene	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homafulg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homanutt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homatric	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hookacut					1	1							1	1		1	1	1
Hookluce	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hygrluri	1	1			1	1		1	1		1		1	1	1	1	1	
Hygrochr																		
Hylosple	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hymeinsi																		
Hymerecu																		
Hypncirc	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hypndiec																		
Hypnlind	1	1	1		1	1		1	1		1		1	1		1	1	1
Hypnprat					1	1		1			1		1	1	1	1	1	
Hypnrevo	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hypnsubi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Isoppulc	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Isotmyos	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jameautu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jungatro					1	1			1						1	1	1	1
Jungexse																	1	1
Jungleia	1	1	1	1	1		1	1	1		1	1	1	1	1		1	1
Jungobov																	1	1
Jungpumi	1				1	1		1			1			1	1	1	1	1
Jungrubr																	1	1
Kurzmaki					1													
Kurzseta					1													
Lepifila	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Lepirept	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lepisand					1													
Leptpyri	1			1		1	1	1	1	1	1	1	1	1	1	1	1	1
Leskpoly	1	1			1	1		1			1		1	1	1	1		
Leucacan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Loesbadi																	1	1
Loph1																		
Loph2																		1
Lophcusp																		1
Lophexci			1	1	1		1	1	1		1	1	1			1	1	1
Lophgill								1									1	1
Lophgutt	1	1	1	1	1	1		1	1	1	1	1		1			1	1
Lophhetc		1	1		1			1	1		1		1	1	1	1	1	1
Lophhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophinci	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2
Lophlong	1	1	1		1	1	1	1	1	1	1		1	1	1		1	1
Lophobtu			1			1									1		1	
Lophopac					1						1			1	1	1	1	
Lophvenl	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophvens	1	1	1			1	1	1		1	1	1	1	1		1	1	1
Lophwenz		1		1			1	1	1		1	1	1		1		1	1
Marcpoly		1	1		1	1		1	1		1		1	1		1	1	1
Marsalpi																		
Marsboec																		
Marsemar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Marsspar					1	1			1		1				1	1	1	
Metamenz	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metzconj	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metztemp					1	1		1			1		1	1	1	1		
Mniuambi																		
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mniuthom																		

APPENDIX V. CWH species data.

Plot Number	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
Heteproc	1	1						1	1					1		1		1
Homaaene	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homafulg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homanutt	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Homatric	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hookacut	1	1	1	1				1	1				1	1	1	1		1
Hookluce	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hygrluri		1	1			1		1	1	1			1	1	1	1		1
Hygrochr	1																	
Hylosple	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Hymeinsi																		
Hymerecu			1															
Hypncirc	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Hypndiec	1																	
Hypnlind	1	1						1	1	1			1	1	1	1		1
Hypnprat	1	1		1		1		1	1	1				1	1	1		1
Hypnrevo	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Hypnsubi	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Isoppulc		1	1	1		1		1	1	1			1	1		1		1
Isotmyos	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Jameautu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Jungatro	1	1							1	1			1	1	1			1
Jungexse	1	1	1						1	1			1	1	1	1		1
Jungleia	1	1	1	1		1	1	1	1	1		1	1	1	1	1		1
Jungobov	1	1	1						1	1			1	1		1		1
Jungpumi	1	1	1						1	1			1	1	1			1
Jungrubr	1	1	1						1	1			1	1	1	1		1
Kurzmaki										1								
Kurzseta	1																	
Lepifila	1	1								1			1	1	1			1
Lepirept	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lepisand	1																	1
Leptpyri	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Leskpoly		1				1		1	1	1			1	1	1			
Leucacan	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Loesbadi	1	1	1						1				1	1	1	1		1
Loph1									1	1		1						
Loph2		1																
Lophcusp	1	1	1						1					1		1		1
Lophexci	1	1	1			1	1	1	1	1	1	1	1	1		1		1
Lophgill	1	1	1						1	1				1	1	1		1
Lophgutt	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Lophhetc	1	1	1			1		1	1					1	1			1
Lophhete	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophinci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophlong	1	1	1		1			1	1	1		1	1	1	1	1		1
Lophobtu		1	1								1			1			1	
Lophopac		1	1						1	1			1	1	1	1		1
Lophvenl	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Lophvens	1	1	1	1		1		1	1	1	1		1	1	1	1	1	1
Lophwenz	1	1	1		1		1		1	1	1	1	1	1	1	1		1
Marcpoly	1			1		1		1	1	1								1
Marsalpi	1																	
Marsboec		1																
Marsemar	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Marsspar			1						1	1			1	1	1			1
Metamenz	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metzconj	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Metztemp	1	1		1		1		1	1	1				1		1		
Mniuambi	1													1				
Mniumarg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mniuspin	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Mniuthom	1																	

Plot Number	283	284	285	286	287
Heteproc	1				1
Homaaene	1	1	1	1	1
Homafulg	1	1	1	1	1
Homanutt	1	1	1	1	1
Homatric	1	1	1	1	1
Hookacut	1		1		1
Hookluce	1	1	1	1	1
Hygrluri	1		1		1
Hygrochr					
Hylosple	2	2	2	2	2
Hymeinsi					1
Hymerecu					
Hypncirc	3	3	3	3	3
Hypndiec					
Hypnlind	1		1		1
Hypnprat	1		1		
Hypnrevo	1	1	1		1
Hypnsubi	2	2	2	2	2
Isoppulc	1		1		1
Isotmyos	3	3	3	3	3
Jameautu	2	2	2	2	2
Jungatro	1		1		1
Jungexse	1		1		1
Jungleia	1	1	1		1
Jungobov	1		1		
Jungpumi	1		1		1
Jungrubr	1		1		
Kurzmaki			1		
Kurzseta			1		
Lepifila	1		1		1
Lepirept	2	2	2	2	2
Lepisand					
Leptpyri	1	1	1	1	1
Leskpoly	1		1		1
Leucacan	2	2	2	2	2
Loesbadi	1		1		1
Loph1		1		1	
Loph2					
Lophcusp					
Lophexci	1	1	1	1	1
Lophgill					
Lophgutt	1	1	1		1
Lophhetc	1		1		1
Lophhete	2	2	2	2	2
Lophinci	2	2	2	2	2
Lophlong	1		1	1	1
Lophobtu					
Lophopac	1		1		1
Lophvenl	2	2	2	2	2
Lophvens	1		1	1	1
Lophwenz	1	1	1		1
Marcpoly	1		1		1
Marsalpi					
Marsboec					
Marsemar	2	2	2	2	2
Marsspar	1		1		1
Metamenz	1	1	1	1	1
Metzconj	1	1	1	1	1
Metztemp	1				
Mniuambi					
Mniumarg	1	1	1	1	1
Mniuspin	2	2	2	2	2
Mniuthom					

APPENDIX V. CWH species data.

Plot Number	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Mylitayl		1	2			2	1			2	1			1	1	2		1
Nardcomp																		
Nardscal																		
Neckdoug						1				1								
Neckpenn			1		1	1	1	1			1							
Odondenu			1			1		1			1					1		
Oligalig			1															
Oligpara																		
Oncovire			1					1						1	1			
Orthcons		1	1			1	1			1	1							1
Orthlyel		1	1		2	2	2			1	1							1
Orthobtu						1	1			1								
Orthpulc						1										1		
Orthspec		1	1		1	1	1			1	1							1
Orthstri		1	1		1	1	1			1	1							1
Palucomm			1			1				1						1		
Pararecu			1			1		1			1					1		
Pellendi																		
Pellepip																		
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Philcapi			1															
Philfont			1			1				1								
Plagaspl			1			1		1			1					1		
Plagcavi			1															
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent		1	2	1	1	2	1	2	1	2	2	1	1	1	1	2	1	1
Plaginsi		1	2	1	1	2	1		1	2		1	1	1	1	2	1	
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede			1			1		1		1	1							
Plagpili			1			1		1			1					1		
Plagpore	1	2	2	1	1	2	1	2	1	2	2	1	1	2	2	2	1	2
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	1	1	1	2	1	1	1	1	2	1	1	2	2	1	1	1	1	1
Plagvenu	1	1	1	1	1	1	1		1		1	1		1	1	1	1	1
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr		2	2	1	2	2	2	2	1	2	2	1	1	2	2	2	1	2
Pogocont		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogourni		1	1	1	1	1	1			1	1	1	1				1	
Pohlanno	1	1	1		1			1	1	1			1	1	1			
Pohlcrud			1	1	1		1	1	1				1	1	1		1	1
Pohllong			1			1		1			1							
Pohlnuta		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform		1	1	1	1	1	1		1				1	1			1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1	1	1	1		1	1	1	1			1	1			1	1
Porecord			1															
Porenavi			1		1	1	1											
Poreroel																		
Porobige																		
Preiquad																		
Pseuelag	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	1	2
Pseujula																		
Pseuradi		1	1			1				1	1							1
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Mylitayl	2			1	2	2	1	1	2	1	2		1		2		1	2
Nardcomp																		
Nardscal																		
Neckdoug				1	1	1							1					
Neckpenn						1												1
Odondenu					1	1			1		1				1			1
Oligalig						1												
Oligpara																		
Oncovire	1					1	1	1							1			1
Orthcons	1			1		1	1	1	1	1	1				1			1
Orthlyel	1			2		1	1	1	1	1	1				1			1
Orthobtu				1		1												
Orthpulc					1	1			1		1				1			
Orthspec	1			1		1	1	1	1	1	1				1			1
Orthstri	1			1		1	1	1	1	1	1				1			1
Palucomm						1			1		1				1			
Pararecu					1	1			1		1				1			1
Pellendi																		
Pellepip																		
Pellnees	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Philcapi						1												
Philfont						1												
Plagaspl					1	1			1		1				1			1
Plagcavi						1												
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	2	2	1	1	2	1	2	1	1	1	2	1	1	2
Plaginsi	2	1	1	1	2	2	1	1	2	1	2		1	1	2	1	1	2
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede	1					1	1	1		1	1		1		1			1
Plagpili					1	1			1		1				1			1
Plagpore	2		1	2	2	2	2	2	2	2	2	1	2	1	2	1	1	2
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	1	1	1	2	2	1	1	1	1	1	1	1	2	1	1	1	1	1
Plagvenu		1	1	1	1			1		1			1			1		
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	2	1	1	2	2	2	2	2	2	2	2	1	2	1	2	2	1	2
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogourni	1	1	1	1	1	1		1			1	1	1	1	1		1	
Pohlanno		1	1	1	1	1		1	1				1	1		1	1	1
Pohlcrud		1	1	1	1	1	1		1			1	1	1			1	1
Pohllong						1												1
Pohlnuta	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform		1	1	1	1			1				1		1		1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1	1			1	1			1		1	1	1		1	1	1
Porecord																		
Porenavi						1												
Poreroel																		
Porobige																		
Preiquad																		
Pseuelag	2	1	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Pseujula																		
Pseuradi	1			1	1	1	1	1	1	1	1		1		1			1
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
Mylitayl			2	1			2	2	2	2			1	1	2	1		1
Nardcomp																		
Nardscal																		
Neckdoug								1										
Neckpenn								1										
Odondenu			1				1	1	1	1								
Oligalig								1										
Oligpara																		
Oncovire			1	1									1	1	1			
Orthcons			1	1			1	1	1	1			1	1	1	1		
Orthlyel			1	1			1	1	1	1			1	1	1	1		
Orthobtu								1										
Orthpulc			1				1	1		1								
Orthspec			1	1			1	1	1	1			1	1	1	1		
Orthstri			1	1			1	1	1	1			1	1	1	1		
Palucomm			1				1	1	1	1								
Pararecu			1				1	1		1								
Pellendi																		
Pellepip																		
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi								1										
Philfont																		
Plagaspl			1				1	1	1	1								
Plagcavi								1										
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	2	1	1	1	2	2	2	2	1	1	1	1	2	1	1	1
Plaginsi	1	1	2	1	1	1	2	2	2	2	1	1	1	1	2		1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1			1	1	1	1		1
Plagoede			1	1				1		1			1	1	1			
Plagpili			1				1	1	1	1								
Plagpore			2	2			2	2	2	2		1	2	2	2	2	1	1
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	2	1	1	1	1	1	1	2	1	1	2	2	1	1	1	1	2	2
Plagvenu	1	1	1	1	1	1	1	1	1		1			1	1	1	1	
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	1	1	2	2	1	1	2	2	2	2	1	1	2	2	2	2	1	1
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogourni		1	1	1	1			1	1		1		1	1	1		1	
Pohlanno	1	1	1	1	1	1	1	1	1	1	1			1	1		1	
Pohlcrud	1	1		1	1	1	1	1	1		1				1	1		1
Pohllong																		
Pohlnuta	1	1	1	1			1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform	1	1		1	1	1	1		1		1	1		1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1		1	1	1	1		1	1	1	1	1	1			1	
Porecord																		
Porenavi								1										
Poreroel																		
Porobige																		
Preiquad																		
Pseuelag	1	2	2	2	2	1	2	2	2	2	2		2	2	2	2	2	1
Pseujula																		
Pseuradi			1	1			1	1	1	1			1	1	1	1		
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174
Mylitayl	2	1	1	1		2	1	2	1	2	2	2	2			2	2	
Nardcomp																		
Nardscal																		
Neckdoug	1						1	1				1	1					
Neckpenn	1											1	1					
Odondenu	1					1				1	1	1	1				1	
Oligalig	1											1	1					
Oligpara																		
Oncovire	1					1	1	1		1		1	1					
Orthcons	1			1		1			1	1	1					1	1	
Orthlyel	2	1		1		1			1	1	1	2	1			1	1	
Orthobtu	1	1	1									1	1					
Orthpulc	1									1	1	1	1				1	
Orthspec	1	1		1		1			1	1	1	1	1			1	1	
Orthstri	1			1		1			1	1	1	1				1	1	
Palucomm	1									1	1	1				1	1	
Pararecu	1									1	1	1	1				1	
Pellendi																		
Pellepip																		
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi	1											1	1					
Philfont	1											1	1					
Plagaspl	1					1				1	1		1			1	1	
Plagcavi	1											1	1					
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	2	1	1	1	1	1	2	2	1	2	2	2	2	1	1	1	2	1
Plaginsi	2	1	1	1	1	2	1	2		2	2	2	2	1	1	2	2	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede	1			1				1			1	1	1					
Plagpili	1						1			1	1	1	1			1	1	
Plagpore	2	1	1	2	1	2	2	2	2	2	2	2	2	1	1	2	2	1
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	2	1	1	1	1	1	2	2	1	1	1	2	2	2	1	1	1	2
Plagvenu	1	1		1	1	1	1			1		1	1				1	1
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	2	1	2	2		2	2	2	2	2	2	2	2	1	1	2	2	1
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogourni	1	1			1	1	1	1		1		1	1	1	1	1	1	1
Pohlanno	1				1	1		1	1	1		1	1	1	1			1
Pohlcrud	1	1	1		1	1	1	1	1		1	1	1	1	1	1		
Pohllong	1											1	1					
Pohlnuta	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform	1	1	1		1	1	1		1	1		1	1	1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1	1	1	1	1	1	1	1			1	1		1		1	1
Porecord	1												1					
Porenavi	1											1	1					
Poreroel																		
Porobige																		
Preiquad																		
Pseuelag	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1
Pseujula																		
Pseuradi	1			1		1	1	1	1	1	1	1	1			1	1	
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
Mylitayl		1		1	2	1	2		1						2	1	2	1
Nardcomp																		
Nardscal																	1	
Neckdoug					1	1	1								1	1	1	
Neckpenn					1	1	1									1		
Odondenu					1		1								1	1	1	
Oligalig					1		1										1	
Oligpara																	1	
Oncovire				1	1	1	1					1			1	1	1	
Orthcons				1	1	1	1					1			1	1	1	
Orthlyel				1	2	2	2					1			2	1	2	
Orthobtu					1	1	1								1		1	
Orthpulc					1		1								1		1	
Orthspec				1	1	1	1					1			1	1	1	
Orthstri				1	1	1	1					1			1	1	1	
Palucomm					1		1								1	1	1	
Pararecu					1		1								1	1	1	
Pellendi																	1	
Pellepip																		
Pellnees	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Philcapi							1										1	
Philfont					1		1								1		1	
Plagaspl					1		1								1		1	
Plagcavi					1		1										1	
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	2	1	2	1	1	1	1	1	1	1	2	2	2	1
Plaginsi	1	1	1	1	2	1	2		1	1	1		1	1	2	1	2	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Plagoede				1	1	1									1	1	1	
Plagpili					1		1								1	1	1	
Plagpore	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	1
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	2	2	2	1	1	1	1	2	2	2	2	1	2	2	2	2	2	1
Plagvenu								1	1	1		1		1	1		1	
Platjung																	1	
Pleualbe																	1	
Pleupurp																		
Pleuschr	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	2
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogourni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlanno	1	1	1	1	1		1	1	1	1	1			1		1	1	1
Pohlcrud	1	1	1	1	1	1		1	1	1	1		1	1	1		1	1
Pohllong							1								1		1	
Pohlnuta	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1
Pohlwahl																	1	
Polyalpi	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform	1	1	1	1	1	1			1	1	1		1	1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
Porecord																	1	
Porenavi					1	1	1									1		
Poreroel																		
Porobige							1										1	
Preiquad																	1	
Pseuelag	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2
Pseujula																		
Pseuradi				1	1	1	1								1	1	1	
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
Mylitayl	1							1	1		1			1			1	
Nardcomp																		
Nardscal																		
Neckdoug																		
Neckpenn																	1	
Odondenu																		
Oligalig																		
Oligpara																		
Oncovire																		
Orthcons									1					1			1	
Orthlyel									2		2			2			2	
Orthobtu	1													1			1	
Orthpulc																		
Orthspec									1					1			1	
Orthstri									1		1			1			1	
Palucomm																		
Pararecu																		
Pellendi																		
Pellepip																		
Pellnees	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi																		
Philfont																		
Plagaspl																		
Plagcavi																		
Plagcusp	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaginsi	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1		1		1	1	1	1	1	1	1		1	1	1	1	1	1
Plagoede																		
Plagpili																		
Plagpore	1					1	2	1	1		1	1	1	1	1	1	1	1
Plagsato																		
Plagscho																		
Plagsemi																		
Plagundu	1	2	1	2	2	2	1	2	1	2	1	2	2	1	2	2	1	3
Plagvenu	1	1		1	1			1	1		1	1	1	1		1	1	1
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	2	1	1	1	1	1	2	1	2	1	2	1	1	2	1	1	2	1
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pogoumi	1	1						1	1	1	1	1	1	1	1		1	1
Pohlanno	1	1			1			1	1		1	1		1			1	1
Pohlcrud	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1
Pohllong																		
Pohlnuta	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform		1	1	1		1	1	1	1	1		1	1	1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Polylong																		
Polypili	1	1	1	1	1		1	1	1		1	1			1		1	1
Porecord																		
Porenavi																	1	
Poreroel																		
Porobige																		
Preiquad																		
Pseuelag	2	1	2	1	1	1	2	1	2	2	2	2	1	2	2	2	2	2
Pseujula																		
Pseuradi																		
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
Mylitayl		2	2	2			2	2	1	1				1	1	1		1
Nardcomp																		
Nardscal																		
Neckdoug		1						1										
Neckpenn		1								1					1			
Odondenu		1	1				1	1										1
Oligalig		1						1										
Oligpara																		
Oncovire			1	1			1	1	1									1
Orthcons								1		1					1			
Orthlyel		1						1		2					1			
Orthobtu		1						1		1					1			
Orthpulc		1	1					1										
Orthspec								1		1					1			
Orthstri								1		1					1			
Palucomm		1	1				1	1										1
Pararecu		1	1				1	1										
Pellendi																		1
Pellepip																		1
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1
Philcapi		1						1										
Philfont								1										
Plagaspl		1	1				1	1										1
Plagcavi		1						1										
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Plagdent	1	2	2	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1
Plaginsi	1	2	2	2	1	1	2	2	1	1	1	1	1	1	1	1	1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Plagoede		1	1	1				1	1									1
Plagpili		1	1				1	1										1
Plagpore	1	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	2
Plagsato																		1
Plagscho																		1
Plagsemi																		1
Plagundu	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	3
Plagvenu			1	1	1	1	1		1	1		1	1		1		1	1
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	1	2	2	2	1	1	2	2	2	2	2	1	2	2	2	1	1	2
Pogocont	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Pogourni	1	1	1		1	1		1	1	1	1	1	1	1	1	1		1
Pohlanno	1	1	1		1				1	1	1		1	1	1		1	1
Pohlcrud	1	1	1	1		1	1		1	1	1	1	1	1			1	1
Pohllong								1										
Pohlnuta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl																		
Polyalpi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1
Polyform	1		1			1		1	1	1	1	1	1	1	1			1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong																		1
Polypili	1	1		1					1							1	1	1
Porecord																		1
Porenavi		1								1					1			
Poreroel																		1
Porobige																		
Preiquad																		
Pseuelag	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	1
Pseujula																		1
Pseuradi		1						1										1
Pterfili																		

APPENDIX V. CWH species data.

Plot Number	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
Mylitayl	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nardcomp																		
Nardscal																		
Neckdoug	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neckpenn																		
Odondenu	1		1		1													
Oligalig																		
Oligpara																		
Oncovire		1	1		1	1		1	1	1	1	1	1	1		1	1	1
Orthcons																		
Orthlyel																		1
Orthobtu																1	1	1
Orthpulc																		
Orthspec																1	1	1
Orthstri																1	1	1
Palucomm	1				1		1	1	1		1		1			1	1	1
Pararecu																		
Pellendi	1		1		1		1		1							1		
Pellepip	1				1		1	1	1									
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi																		
Philfont																		
Plagaspl	1		1										1					
Plagcavi																		
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaginsi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede		1	1		1		1	1	1	1	1	1	1	1	1	1	1	1
Plagpili	1		1		1						1		1					
Plagpore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagsato	1				1		1											
Plagscho	1		1		1													
Plagsemi	1		1		1											1	1	1
Plagundu	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Plagvenu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Platjung																		
Pleualbe																		
Pleupurp																		
Pleuschr	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pogocont	2	1	2	2	2	1	2	2	2	1	2	1	2	1	1	2	2	2
Pogoumi	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
Pohlanno	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
Pohlcrud	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohllong																		
Pohlnuta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl																		
Polyalpi	2	1	2	2	2	1	2	2	1	1	2	1	2	1	1	2	2	2
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform					1		1	1	1	1	1	1	1	1	1			
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong	1		1		1						1		1			1	1	
Polypili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porecord	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porenavi															1			
Poreroel	1				1		1	1	1				1			1	1	1
Porobige																		
Preiquad																		
Pseuelag	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pseujula	1		1		1		1											
Pseuradi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pterfili							1	1										2

APPENDIX V. CWH species data.

Plot Number	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
Mylitayl	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nardcomp																		
Nardscal																	1	1
Neckdoug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neckpenn																		
Odondenu					1	1									1	1		1
Oligalig																		
Oligpara																		
Oncovire	1			1	1	1	1	1	1		1				1		1	1
Orthcons																	1	
Orthlyel																	1	
Orthobtu	1	1						1									1	
Orthpulc		1																
Orthspec		1						1									1	
Orthstri	1	1						1									1	
Palucomm	1	1			1	1		1	1		1		1	1	1	1	1	
Pararecu																		
Pellendi					1	1		1	1		1		1	1	1	1		1
Pellepip					1	1			1		1					1	1	1
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi																		
Philfont					1										1			
Plagaspl					1				1						1	1	1	
Plagcavi																		
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaginsi	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagpili					1	1			1						1	1	1	1
Plagpore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagsato					1	1			1						1	1	1	1
Plagscho					1	1										1	1	1
Plagsemi	1				1	1		1	1		1		1	1	1	1		1
Plagundu	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Plagvenu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Platjung								1										
Pleualbe																	1	1
Pleupurp																	1	1
Pleuschr	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pogocont	2	2	2	1	2	2	1	2	2	1	2	1	2	2	2	2	2	2
Pogourni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlanno	1	1			1	1	1	1				1	1	1	1	1	1	1
Pohlcrud	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohllong																		
Pohlnuta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl								1										
Polyalpi	2	2	2	1	2	2	1	2	2	1	2	1	2	2	2	2	2	2
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform												1	1	1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong		1	1		1	1		1	1		1		1	1	1	1	1	
Polypili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porecord	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porenavi																		
Poreroel	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Porobige			1															
Preiquad																	1	1
Pseuelag	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Pseujula					1	1									1	1	1	1
Pseuradi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pterfili															2			

APPENDIX V. CWH species data.

Plot Number	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
Mylitayl	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Nardcomp	1																	
Nardscal	1	1	1						1	1				1	1	1		1
Neckdoug	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Neckpenn										1			1				1	1
Odondenu		1	1			1		1	1	1				1	1			1
Oligalig	1																	
Oligpara																		
Oncovire	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1		1
Orthcons									1								1	
Orthlyel		1	1						1	1	1						1	
Orthobtu		1	1						1	1	1						1	
Orthpulc																		
Orthspec			1						1		1		1				1	
Orthstri			1						1	1							1	
Palucomm	1	1						1	1	1			1	1				1
Pararecu																		
Pellendi	1		1						1	1				1		1		
Pellepip		1		1		1		1	1	1			1	1				
Pellnees	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Philcapi	1																	
Philfont																		
Plagaspl	1	1	1							1			1		1			1
Plagcavi	1																	
Plagcusp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagdent	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaginsi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plaglaet	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagmedi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagoede	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Plagpili		1	1			1		1	1	1			1	1	1			1
Plagpore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Plagsato	1		1						1	1			1	1		1		
Plagscho	1	1	1						1	1			1		1	1		1
Plagsemi	1	1	1	1		1		1	1				1	1	1	1		1
Plagundu	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Plagvenu	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Platjung	1																	
Pleualbe	1	1	1						1	1			1	1	1	1		1
Pleupurp	1	1	1						1	1			1	1	1	1		1
Pleuschr	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2
Pogocont	2	2	2	2	1	2		2	2	1	1	1	2	2	2	2	1	2
Pogourni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlanno	1	1	1						1	1	1	1	1	1	1	1	1	1
Pohlcrud	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohllong																		
Pohlnuta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pohlwahl	1																	
Polyalpi	2	2	2	2	1	2	1	2	2	2	2	1	1	2	2	2	2	2
Polycomm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polyform	1	1	1						1	1	1	1	1	1	1	1	1	1
Polyjuni	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Polylong	1	1		1		1		1	1	1			1	1	1	1		
Polypili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porecord	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Porenavi									1	1			1			1		1
Poreroel	1	1		1				1	1	1			1	1				1
Porobige	1												1					
Preiquad	1	1	1						1	1			1	1		1		1
Pseuelag	1	2	2	2	2	2	2	2	2	2	2	2	2	1	2	1	1	2
Pseujula	1	1	1			1		1	1	1			1	1	1			1
Pseuradi	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pterfili		2	2								2			2			2	

APPENDIX V. CWH species data.

Plot Number	283	284	285	286	287
Mylitayl	1	1	1	1	1
Nardcomp	1				
Nardscal					
Neckdoug	1	1	1	1	1
Neckpenn	1	1	1	1	1
Odondenu					
Oligalig					
Oligpara	1				
Oncovire	1	1	1	1	1
Orthcons	1	1	1	1	1
Orthlyel	2	2	2	2	2
Orthobtu	1	1	1	1	1
Orthpulc	1		1		1
Orthspec	1	1	1	1	1
Orthstri	1	1	1	1	1
Palucomm	1		1		1
Pararecu					1
Pellendi					
Pellepip	1		1		1
Pellnees	1	1	1	1	1
Philcapi					
Philfont	1				
Plagaspl	1		1		1
Plagcavi					
Plagcusp	1	1	1	1	1
Plagdent	1	1	1	1	1
Plaginsi	1	1	1	1	1
Plaglaet	2	2	2	2	2
Plagmedi	1	1	1	1	1
Plagoede	1	1	1	1	1
Plagpili	1		1		1
Plagpore	2	2	2	2	2
Plagsato	1		1		1
Plagscho	1		1		1
Plagsemi	1		1		1
Plagundu	3	3	3	3	3
Plagvenu	1	1	1	1	1
Platjung	1				
Pleualbe	1		1		1
Pleupurp	1		1		1
Pleuschr	2	2	2	2	2
Pogocont	2	1	2	1	2
Pogourni	1	1	1	1	1
Pohlanno	1	1	1	1	1
Pohlcrud	1	1	1	1	1
Pohllong	1				
Pohlnuta	1	1	1	1	1
Pohlwahl	1				
Polyalpi	2	1	2	1	2
Polycomm	1	1	1	1	1
Polyform	1	1	1	1	1
Polyjuni	1	1	1	1	1
Polylong	1		1		1
Polypili	1	1	1	1	1
Porecord	1	1	1	1	1
Porenavi	1	1	1	1	1
Poreroel	1		1		1
Porobige					
Preiquad	1		1		1
Pseuelag	2	2	2	2	2
Pseujula	1		1		1
Pseuradi	1	1	1	1	1
Pterfili					

APPENDIX V. CWH species data.

Plot Number	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Ptilcali		2	2			2	1	2		2	2			2	2	2		2
Ptilcili	1	1	1	1	1	1	1	1		1	1	1	1		1		1	1
Ptilcris			1					1		1	1					1		
Ptilpulc		1	1			1				1	1							1
Racoacic			1			1										1		
Racoaqua			1			1		1		1	1					1		
Racocane																		
Racoelon																		
Racohete																		
Racolanu																		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola			1		1	1	1	1			1							
Raducomp			1															
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn		1	1	1		1	1	1	1	1		1		1		1	1	1
Rhiznudu			1			1		1		1	1					1		
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua		1	2	1	1	2	1	2	1	2	2	1	1	1	1	2		1
Rhyttriq		2	2	1	2	2	2	2	1	2	2	1	1	2	2	2	1	2
Ricccham																		
Riccflui																		
Ricclati			1			1				1						1		
Riccmult		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer			1			1		1		1	1					1		
Scapbola		1	2	1	1	2	1	2		2	2		1	1	1	2		1
Scappalu																		
Scapumbr		1	1			1				1	1							1
Scapundu			1			1		1		1	1							
Schiapoc	1												1					
Schipenn		1	1					1						1	1			1
Schirivu			1			1		1		1	1					1		
Scleobtu			1			1		1		1	1					1		
Scouaqua			1			1		1		1	1							
Sphacapi			1			1		1			1					1		
Sphagirg		1	1					1		1				1	1	1		1
Sphapalu																		
Sphasqua			1							1	1				1			1
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell			1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Thamneck			1			1		1		1	1					1		
Thuiphil																		
Timmaust		1	1		1	1	1	1	1	1	1	1	1	1		1	1	1
Tortmura																		
Tortprin																		
Tortrura			1			1				1						1		
Torttort																		
Tritexse			1			1		1								1		
Tritquin			1			1		1		1	1							
Ulotdrum																		
Ulotmega						1	1											
Ulotobtu					1	1	1			1								
Ulotphyl																		
Warnflui			1			1		1										
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138
Ptilcali	2			2	2	2	2	2	2	2	2		2		2		1	2
Ptilcili	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris					1	1			1		1				1			1
Ptilpulc	1			1	1	1	1	1	1	1	1		1		1			1
Racoacic						1			1		1				1			
Racoaqua						1			1		1				1			1
Racocane																		
Racoelon																		
Racohete																		
Racolanu																		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola																		1
Raducomp																		
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn		1	1	1	1	1	1	1		1		1	1	1	1	1	1	
Rhiznudu					1	1			1		1				1			1
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	2	1	1	1	2	2	1	1	2	1	2	1	1		2	1	1	2
Rhyttriq	2	1	1	2	2	2	2	2	2	2	2	1	2	1	2	2	1	2
Ricccham																		
Riccflui																		
Ricclati					1	1			1						1			
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer						1			1						1			1
Scapbola	2	1	1	1	2	2	1	1	2	1	2		1		1	1	1	2
Scappalu																		
Scapumbr				1	1	1	1	1	1	1	1		1		1			1
Scapundu					1	1			1						1			
Schiapoc																		
Schipenn	1			1	1	1	1		1	1								
Schirivu						1			1						1			
Scleobtu						1			1						1			
Scouaqua						1												
Sphacapi					1	1			1		1				1			
Sphagirg	1				1	1	1	1					1		1	1		
Sphapalu																		
Sphasqua	1			1	1	1	1	1			1		1		1	1		1
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell	1	1	1	1	1	1			1	1	1		1		1	1	1	1
Thamneck					1	1			1		1				1			
Thuiphil																		
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1
Tortmura																		
Tortprin																		
Tortrura					1	1			1						1			
Torttort																		
Tritexse					1	1			1						1			
Tritquin					1	1			1						1			1
Ulotdrum																		
Ulotmega				1		1												
Ulotobtu				1		1												
Ulotphyl																		
Warnflui						1												
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156
Ptilcali			2	2			2	2	2	2			2	2	2	2		1
Ptilcili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris			1				1	1	1	1								
Ptilpulc			1	1			1	1	1	1			1	1	1	1		
Racoacic			1				1	1	1	1								
Racoaqua			1				1	1	1	1								
Racocane																		
Racoelon																		
Racohete																		
Racolanu																		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola																		
Raducomp																		
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn	1	1			1	1		1	1	1	1	1		1	1	1	1	1
Rhiznudu			1				1	1	1	1								
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	1	1	2	1		1	2	2	2	2		1	1	1	2	1		1
Rhyttriq	1	1	2	2			2	2	2	2	1	1	2	2	2	2	1	1
Ricccham																		
Riccflui																		
Ricclati			1				1	1	1	1								
Riccmult		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer			1				1	1	1	1								
Scapbola	1		2	1			2	2	2	2			1	1	2	1		1
Scappalu																		
Scapumbr			1	1			1	1	1	1			1	1	1	1		
Scapundu								1										
Schiapoc		1							2									1
Schipenn			1	1			1	1	1				1		1			
Schirivu			1				1	1		1								
Scleobtu			1				1	1	1	1								
Scouaqua								1										
Sphacapi			1				1	1	1	1								
Sphagirg				1			1							1	1	1		
Sphapalu																		
Sphasqua							1	1	1	1			1		1	1		
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell	1	1	1				1	1	1	1	1	1	1	1	1	1	1	1
Thamneck			1				1	1	1	1								
Thuiphil																		
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura																		
Tortprin																		
Tortrura			1				1	1		1								
Torttort																		
Tritexse								1										
Tritquin								1										
Ulotdrum																		
Ulotmega								1										
Ulotobtu								1										
Ulotphyl																		
Warnflui								1										
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	**157**	**158**	**159**	**160**	**161**	**162**	**163**	**164**	**165**	**166**	**167**	**168**	**169**	**170**	**171**	**172**	**173**	**174**
Ptilcali	2			2		2	2	2	2	2	2	2	2			2	2	
Ptilcili	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris	1					1				1	1	1	1				1	
Ptilpulc	1			1		1	1	1	1	1	1	1	1			1	1	
Racoacic	1					1				1	1	1	1			1	1	
Racoaqua	1					1	1				1	1	1				1	
Racocane								1								1		
Racoelon																		
Racohete								1										
Racolanu																1		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola	1						1					1	1					
Raducomp	1												1					
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn	1	1	1	1	1		1	1				1	1	1	1	1		1
Rhiznudu	1						1			1	1	1	1			1	1	
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	2	1	1	1		2	2	2	1	2	2	2	2	1	1	2	2	1
Rhyttriq	2	1	2	2	1	2	2	2	2	2	2	2	2	1	1	2	2	1
Ricccham																		
Riccflui																		
Ricclati	1					1	1			1	1	1	1				1	
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer	1					1	1			1	1	1					1	
Scapbola	2	1	1	1		2	2	1	1	2	2	2	1	1	1	2	2	
Scappalu																		
Scapumbr	1			1		1	1	1	1	1	1	1	1			1	1	
Scapundu	1						1			1	1	1	1					
Schiapoc		1			1													
Schipenn	1						1	1	1		1	1	1					
Schirivu	1										1	1					1	
Scleobtu	1					1					1	1	1			1	1	
Scouaqua	1											1						
Sphacapi	1						1			1	1	1	1			1	1	
Sphagirg	1						1	1	1	1		1	1			1		
Sphapalu																		
Sphasqua	1			1				1	1	1	1		1			1		
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1
Thamneck	1					1	1				1	1	1				1	
Thuiphil																		
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura																		
Tortprin																		
Tortrura	1										1	1					1	
Torttort																		
Tritexse	1									1	1	1						
Tritquin	1						1			1	1	1						
Ulotdrum																		
Ulotmega	1	1																
Ulotobtu	1											1	1					
Ulotphyl																		
Warnflui	1						1					1	1					
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
Ptilcali		1		2	2	2	2		1		1	2			2	2	2	1
Ptilcili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris					1		1									1	1	
Ptilpulc				1	1	1	1					1			1	1	1	
Racoacic					1		1								1		1	
Racoaqua							1								1	1	1	
Racocane																	1	
Racoelon																	1	
Racohete																	1	
Racolanu																	1	
Racolawt																		
Racomuti																		
Racoocci																		
Radubola					1	1	1									1		
Raducomp																	1	
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn	1	1	1		1	1	1	1	1	1	1	1		1	1		1	1
Rhiznudu					1		1								1	1	1	
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																	1	
Rhytsqua	1	1	1	1	2	1	2	1	1	1	1	1	1	1	2	2	2	1
Rhyttriq	1	1	1	2	2	2	2	1	1	1	1	2	1	1	2	2	2	2
Ricccham																		
Riccflui																	1	
Ricclati					1		1								1	1	1	
Riccmult	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer					1		1								1	1	1	
Scapbola	1	1	1	1	2	1	2		1	1	1	1	1	1	2	2	2	1
Scappalu																		
Scapumbr				1	1	1	1					1			1	1	1	
Scapundu					1		1								1	1	1	
Schiapoc										1	1							
Schipenn				1	1	1										1	1	
Schirivu					1		1								1		1	
Scleobtu					1		1								1		1	
Scouaqua					1		1								1	1	1	
Sphacapi					1		1								1	1	1	
Sphagirg					1	1	1				1	1			1		1	
Sphapalu																	1	
Sphasqua				1		1						1			1	1	1	
Takalepi																		
Targhypo																	1	
Tetrgeni																		1
Tetrpell	1			1	1	1	1			1	1		1	1	1	1	1	1
Thamneck					1		1								1	1	1	
Thuiphil																		
Timmaust		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura																		
Tortprin																		
Tortrura					1		1								1		1	
Torttort																	1	
Tritexse					1		1								1		1	
Tritquin					1		1								1	1	1	
Ulotdrum																		
Ulotmega					1	1	1								1	1	1	
Ulotobtu					1	1	1								1	1	1	
Ulotphyl																		
Warnflui							1								1	1	1	
Zygorein																		
Zygoviri															1			

APPENDIX V. CWH species data.

Plot Number	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
Ptilcali	1						2		1		1			1			1	
Ptilcili	1	1		1	1	1	1	1				1	1	1	1		1	
Ptilcris																		
Ptilpulc																		
Racoacic																		
Racoaqua																		
Racocane																		
Racoelon																		
Racohete																		
Racolanu																		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola																	1	
Raducomp																		
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhizmagn	1	1	1		1		1	1		1	1			1			1	1
Rhiznudu																		
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	1				1	1	1	1	1	1	1	1	1	1	1		1	1
Rhyttriq	2	1	1	1	1	1	2	1	2	1	2	1	1	2			2	1
Ricccham																		
Riccflui																		
Ricclati																		
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm																		
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer																		
Scapbola	1					1	1	1	1		1			1			1	
Scappalu																		
Scapumbr																		
Scapundu																		
Schiapoc																		1
Schipenn																		
Schirivu																		
Scleobtu																		
Scouaqua																		
Sphacapi																		
Sphagirg							1											
Sphapalu																		
Sphasqua																		
Takalepi																		
Targhypo																		
Tetrgeni																	1	
Tetrpell	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	
Thamneck																		
Thuiphil																		
Timmaust	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1
Tortmura																		
Tortprin																		
Tortrura																		
Torttort																		
Tritexse																		
Tritquin																		
Ulotdrum																		
Ulotmega									1					1				
Ulotobtu									1		1			1			1	
Ulotphyl																		
Warnflui																		
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
Ptilcali		2	2	2			2	2	2	1				1	1	1		2
Ptilcili	1	1	1	1	1			1	1	1			1	1		1	1	1
Ptilcris		1	1					1										1
Ptilpulc		1						1										1
Racoacic		1	1					1										1
Racoaqua		1	1				1	1										1
Racocane																		
Racoelon																		
Racohete																		
Racolanu																		
Racolawt																		
Racomuti																		
Racoocci																		
Radubola										1					1			1
Raducomp																		1
Raduobtu																		
Rhizglab	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Rhizmagn	1	1		1	1	1		1		1	1	1	1	1	1		2	1
Rhiznudu		1	1				1	1										2
Rhytlore	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	1	2	2	2	1	1	2	2	1	1	1	1	1	1	1	1	1	2
Rhyttriq	1	2	2	2	1	1	2	2	2	2	2	1	2	2	2	1	1	2
Ricccham																		
Riccflui																		
Ricclati		1	1				1	1										1
Riccmult		1	1	1		1	1	1	1	1	1	1	1	1	1	1		1
Riccpalm																		1
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer		1	1				1	1										1
Scapbola		2	2	2	1	1	1	2	1	1	1		1	1	1	1		2
Scappalu																		
Scapumbr		1						1										1
Scapundu		1						1										1
Schiapoc																		
Schipenn			1	1					1									
Schirivu		1	1				1	1										
Scleobtu		1	1				1	1										1
Scouaqua								1										
Sphacapi		1	1				1	1										
Sphagirg		1		1			1										1	1
Sphapalu																		
Sphasqua		1					1		1									1
Takalepi																		
Targhypo																		
Tetrgeni										1				1	1			
Tetrpell	1	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1
Thamneck		1	1				1	1										
Thuiphil																		
Timmaust	1	1	1		1	1		1	1	1		1					1	1
Tortmura																		
Tortprin																		
Tortrura		1	1				1	1										
Torttort																		
Tritexse		1						1										1
Tritquin		1						1										
Ulotdrum																		
Ulotmega								1		1								
Ulotobtu								1		1					1			
Ulotphyl																		
Wamflui								1										
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246
Ptilcali	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ptilcili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris	1		1		1						1		1			1	1	1
Ptilpulc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Racoacic	1				1						1		1			1	1	
Racoaqua	1		1		1											1		
Racocane							2	2								2		2
Racoelon								1										
Racohete							2	2								2		2
Racolanu							2	2										2
Racolawt								1										
Racomuti							1	1										1
Racoocci								1										1
Radubola	1		1		1		1	1	1		1		1			1		
Raducomp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Raduobtu																	1	1
Rhizglab	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhizmagn	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2
Rhiznudu	2				2						2		2			2	2	2
Rhytlore	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	2	1	2	2	2	1	2	2	2	1	2	1	2	1	1	2	2	2
Rhyttriq	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ricccham																		
Riccflui																		
Ricclati	1		1		1		1		1		1		1			1	1	
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm	1		1		1						1		1			1	1	1
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer	1		1		1						1		1			1		
Scapbola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scappalu					1		1	1	1		1		1			1	1	
Scapumbr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scapundu	1		1		1		1	1								1	1	1
Schiapoc																		
Schipenn															1	1	1	1
Schirivu					1		1	1					1					
Scleobtu					1		1											
Scouaqua								2										
Sphacapi																		
Sphagirg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sphapalu					1													
Sphasqua	1			1		1		1		1	1	1		1	1	1	1	1
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thamneck					1								1			1	1	
Thuiphil																		
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura					1		1	1										
Tortprin					1								1					
Tortrura																		
Torttort																		
Tritexse	1	1			1	1	1	1	1	1	1		1	1	1	1	1	1
Tritquin																		
Ulotdrum																		
Ulotmega																1	1	1
Ulotobtu																1	1	1
Ulotphyl								1										1
Warnflui					1													
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
Ptilcali	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ptilcili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris	1	1	1		1	1		1	1		1		1	1	1	1	1	1
Ptilpulc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Racoacic		1			1	1		1	1		1		1	1	1	1	1	1
Racoaqua		1	1		1	1		1					1	1	1	1	1	
Racocane			2												2		2	
Racoelon															1			
Racohete			2												2		2	
Racolanu			2														2	
Racolawt															1		1	
Racomuti			1												1		1	
Racoocci			1												1		1	
Radubola		1			1	1			1		1		1	1	1	1		1
Raducomp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Raduobtu																	1	1
Rhizglab	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhizmagn	2	2	2	1	1	2	1	2		1	2	1	2	2	2	1	2	2
Rhiznudu	2	2	2		2	2		2	2		2		2	2	2	2	2	2
Rhytlore	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	2	2	2	1	2	2	1	2	2	1	2	1	2	2	2	2	2	2
Rhyttriq	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2	2
Ricccham																		
Riccflui																		
Ricclati		1	1					1	1		1		1	1		1		1
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm	1	1	1					1			1		1	1	1	1	1	
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1																		
Scapamer								1	1				1	1	1	1	1	1
Scapbola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scappalu		1	1					1	1				1	1				1
Scapumbr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scapundu	1							1			1		1	1	1	1	1	
Schiapoc																		
Schipenn	1	1			1	1								1	1	1	1	1
Schirivu									1		1						1	
Scleobtu											1					1	1	1
Scouaqua								1										
Sphacapi											1							
Sphagirg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sphapalu																	1	1
Sphasqua	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Takalepi																		
Targhypo																		
Tetrgeni																		
Tetrpell	1	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1
Thamneck		1						1	1		1			1			1	1
Thuiphil																	1	1
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura																	1	1
Tortprin									1		1							1
Tortrura																	1	
Torttort																		
Tritexse	1		1		1			1	1	1	1	1	1	1		1	1	1
Tritquin																	1	1
Ulotdrum																		
Ulotmega	1	1						1										
Ulotobtu								1										
Ulotphyl																		
Warnflui																		1
Zygorein																		
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282
Ptilcali	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ptilcili	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ptilcris	1			1		1		1	1	1			1	1	1	1		1
Ptilpulc	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Racoacic	1	1	1			1		1	1	1					1	1		1
Racoaqua		1		1				1	1					1	1	1		
Racocane		2	2								2			2			2	
Racoelon																		
Racohete		2	2											2			2	
Racolanu			2								2			2			2	
Racolawt											1			1			1	
Racomuti														1			1	
Racoocci											1			1			1	
Radubola	1	1				1		1		1			1	1		1		1
Raducomp	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Raduobtu	1	1	1						1	1			1	1		1		1
Rhizglab	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhizmagn	2	2	2	1	1	2	1	2	2	2	2	1	1	2	2	2	2	2
Rhiznudu				2		2		2	2	2			2	2		2		2
Rhytlore	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Rhytrobu	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rhytrugo																		
Rhytsqua	2	2	2	2	1	2	1	2	1	2	2	1	2	2	2	2	2	2
Rhyttriq	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Ricccham		1																
Riccflui																		
Ricclati	1	1	1	1		1		1	1	1			1			1		
Riccmult	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Riccpalm	1			1		1		1	1	1			1		1	1		1
Saniunci	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scap1	1																	
Scapamer	1	1	1						1	1								
Scapbola	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Scappalu		1	1						1	1			1		1	1		
Scapumbr	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scapundu	1	1	1			1		1	1	1			1		1	1		1
Schiapoc	1																	
Schipenn	1	1	1											1	1	1		1
Schirivu			1	1				1	1	1			1		1	1		1
Scleobtu	1		1	1		1		1	1	1			1		1	1		1
Scouaqua		1																
Sphacapi		1							1	1			1			1		
Sphagirg	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sphapalu	1	1				1		1	1	1					1	1		1
Sphasqua	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Takalepi			1															
Targhypo		1													1	1		1
Tetrgeni																		
Tetrpell	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Thamneck	1			1		1		1	1	1			1		1	1		1
Thuiphil	1	1	1						1	1				1	1	1		1
Timmaust	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tortmura		1	1					1	1						1			1
Tortprin	1	1	1	1				1	1	1					1			1
Tortrura	1	1																
Torttort																		
Tritexse	1	1	1	1		1		1	1	1	1	1	1	1	1	1	1	1
Tritquin	1	1	1						1	1			1	1	1			1
Ulotdrum																1	1	
Ulotmega			1							1			1					
Ulotobtu									1				1					
Ulotphyl														1			1	
Warnflui	1	1	1					1	1	1					1			1
Zygorein																		1
Zygoviri																		

APPENDIX V. CWH species data.

Plot Number	283	284	285	286	287
Ptilcali	2	2	2	2	2
Ptilcili	1	1	1	1	1
Ptilcris	1		1		1
Ptilpulc	1	1	1	1	1
Racoacic					
Racoaqua					
Racocane					
Racoelon					
Racohete					
Racolanu					
Racolawt					
Racomuti					
Racoocci					
Radubola	1		1		1
Raducomp	1	1	1	1	
Raduobtu	1		1		1
Rhizglab	3	3	3	3	3
Rhizmagn	2	1	2	1	1
Rhiznudu	2		2		2
Rhytlore	3	3	3	3	3
Rhytrobu	2	2	2	2	2
Rhytrugo					
Rhytsqua	2	1	2	1	2
Rhyttriq	2	2	2	2	2
Ricccham					1
Riccflui					
Ricclati	1		1		1
Riccmult	1	1	1	1	1
Riccpalm	1		1		1
Saniunci	2	2	2	2	2
Scap1					
Scapamer					
Scapbola	2	2	2	2	2
Scappalu	1		1		1
Scapumbr	1	1	1	1	1
Scapundu	1		1		1
Schiapoc					
Schipenn	1	1	1	1	1
Schirivu	1		1		1
Scleobtu					1
Scouaqua	1		2		
Sphacapi	1		1		1
Sphagirg	1	1	1	1	1
Sphapalu					
Sphasqua	1	1	1	1	1
Takalepi					
Targhypo					
Tetrgeni	1				
Tetrpell	1	1	1	1	1
Thamneck	1		1		1
Thuiphil					
Timmaust	1	1	1	1	1
Tortmura					
Tortprin					
Tortrura					
Torttort	1				
Tritexse	1		1		1
Tritquin					1
Ulotdrum	1	1	1	1	1
Ulotmega	1	1	1	1	1
Ulotobtu	1	1	1	1	1
Ulotphyl					
Warnflui					
Zygorein					
Zygoviri	1				