INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

Macrofungus ecology and diversity under different conifer monocultures on southern Vancouver Island.

By

Renata Anna Maria Outerbridge
B.Sc., Dalhousie University, 1989
M.Sc., Dalhousie University, 1991

A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In the Department of Biology

We accept this dissertation as conforming
to the required standard

Dr. W. Hintz, Supervisor (Department of Biology)

Dr. R. Ring, Departmental Member (Department of Biology)

Dr. G. Allen, Departmental Member (Department of Biology)

Dr. S. Tuller, Outside Member (Department of Geography)

Dr. S.M. Berch, Additional Member

(Research Branch, BC Ministry of Forests)

Dr. R. Molina, External Examiner

(U.S. Department of Agriculture, Corvallis, Oregon)

Supervisor: Dr. W. Hintz

ABSTRACT

There is concern that growing forest plantations in close rotation may adversely impact the rate of litter decomposition and thus soil productivity. The impact of conifer monocultures of Sitka spruce - *Picea sitchensis*(Bong.) Carr., Douglas-fir -*Pseudotsuga menziesii* (Mirb.) Franco, western red cedar -*Thuja plicata* Donn ex D. Don in Lamb., and western hemlock -*Tsuga heterophylla* (Raf.) Sarg., on the diversity and abundance of macrofungi was researched. Study sites were established at three locations on the west-coast of Vancouver Island, based on soil moisture and nutrient regimes, and a systematic survey of fungus species was conducted throughout the growing seasons in 1997 and 1998. A total of 277 taxa were identified, a large portion of them belonging to the genus *Mycena* (45 species). ANOVA analysis showed that conifer species as well as site differences affect composition, diversity, and abundance of macrofungus communities. Overall, the lowest diversity and abundance were noted in western red cedar and the highest in Douglas-fir stands. Western hemlock supported the highest number of ectomycorrhizal fungi, and Sitka spruce habitat is characterized by a unique abundance of certain *Mycena* species, e.g. *M. tenax*. The following fungi were most commonly observed in this study, in descending order of their abundance: *Mycena amicta*, *Cantharellus formosus*, *Mycena metata* group, *Mycena rorida*, *Mycena aurantiidisca*, *Mycena galopus*, and *Clavulina cristata*. The most frequent genera, from the total of 95, were: *Mycena, Cortinarius, Inocybe, Lactarius, Russula, and Galerina.* Species composition differed amongst the four conifer habitats, with even some non-mycorrhizal macrofungi showing preferences for a given conifer litter. There were considerably more saprobic than ectomycorrhizal species in each habitat, the ratio for the whole study being 7:3. In both years, a vast majority of all macrofungi fruited in September and October, with the least productive months being June, July, and August, due to insufficient

precipitation. Ordination analyses suggest that in addition to conifer effects and some degree of spatial autocorrelation, site characteristics, such as soil moisture, nutrient availability, type of undergrowth, may have determined the observed differences in diversity and abundance of macrofungi.

EXAMINERS

Dr. W. Hintz, Supervisor, (Department of Biology)

Dr. R. Ring, Department Member, (Department of Biology)

Dr. R. Molina, External Examiner (U.S. Department of Agriculture, Corvallis, Oregon)

Dr. G. Allen, Department Member (Department of Biology)

Dr. S. Tuller, Outside Member, (Department of Geography)

Dr. S.M. Berch, Additional Member, (Research Branch, BC Ministry of Forests)

Table of contents

List of Tables

List of Figures

Acknowledgements

I feel grateful for being given the opportunity to conduct this research. I address my primary thanks to all the members of my supervisory committee for reviewing my thesis and also: Dr. Shannon Berch, for her patience and lots of good advice, and for providing the funds for my work; Dr. John Owens and Dr. William Hintz, for co-supervising this project; Dr. Geraldine Allen, Dr. Richard Ring, and Dr. Stanton Tuller, and Dr. Randy Molina for their support and input.

I also thank Christine Roberts, Chio Woo, Dr. Scott Redhead, John Dennis, and others for assistance in the field. Dr. Redhead also provided me with many hours of mycological advice and microscopy instruction, and his expertise was invaluable in working out the taxonomy of many collections. My computer work was made easier thanks to the help from John Dennis with data inputing and from Kevin Pellow with regards to the SAS program. Terry Holmes scanned all the pictures for me.

The weather data were obtained from Jamie MacDuff from Environment Canada, Victoria Weather Office at PFC. Rick Morrison and Brian Lowe kindly produced the colour map of Vancouver Island.

Laboratory space and equipment was used at the Glyn Road Research Station of BC Ministry of Forests. Funding was provided by Forest Renewal BC.

To Astra and John

Chapter One - General Introduction and Literature Review

I. Diversity and characterization of macrofungi.

1. Definition of macrofungi.

Macrofungi, macromycetes, or simply mushrooms are those fungi which can be observed without the use of a microscope, thus usually at least 1cm large. Because of the interest shown by mycologists, mycophagists, and others in fungi with macroscopic sporocarps, this artificial group has been created for convenience of dealing with fungi in the field. It generally encompasses the Basidomycetes minus the rusts, smuts, and yeast, and includes most larger Ascomycetes, such as cup fungi and truffles. Since there is no other basis for distinction between macrofungi and microfungi, most discussions on biology and ecology of macrofungi can be extended to all fungi in general, and vice versa. In this study, any reference to 'fungi' should be considered applicable, but not limiting to either group.

2. Functional niches of forest fungi.

In functional or ecological terms fungi can be defined as 'eukaryotic, heterotrophic, absorptive organisms that develop a rather diffuse branched tubular body, and which reproduce by means of spores' (Kendrick 1992).

Macrofungi and microfungi are ubiquitous. Not unlike other microorganisms, they can be found anywhere and in large numbers: in the soil and the air, in aquatic and terrestrial substrates, within plants and animals. While most microfungi, such as molds, soil fungi, and lichenized forms are extremely widespread in comparison with plants, most macrofungi, and especially the forest macrofungi, are restricted to the geographical range of their hosts or specific habitats (Hawksworth et al., 1996).

Forests create extremely complex and dynamic ecosystems, providing fungi with a multitude of organisms and substrates to exploit. We could say that the most important ecological functions of fungi in such ecosystems are: facilitation of energy exchange between above ground and below ground resources; promotion and alteration of niche development; and regulation of successional processes (Miller, 1995). Miller (1995) further categorized the known or theoretical functions of fungi in ecosystems into physiological/metabolic and mediative/integrative.

Though differences in terminology exist, mycologists typically divide macrofungi into ecological groups, dictated by the type of substrate on which these fungi grow, which in turn is predetermined by their physiological capabilities and requirements. These groups are mycorrhizal fungi and saprobic fungi.

2a. Ectomycorrhizal macrofungi

Frank (1887) distinguished two types of mycorrhizae (Gr. fungus – roots), a mutually beneficial association of a fungus and the roots of a plant: 1) ectotrophic, which is characteristic of forest trees with various basidiomycetes, such as species of *Boletus*, *Cortinarius*, or *Russula*, in which the fungus forms an intercellular hyphal network within the surface layers of the root (i.e. the Hartig net), and 2) endotrophic (e.g. those of orchids and *Ericaceae*), in which the fungus penetrates the cells inside the root tissues. The above terms were eventually replaced by "ectomycorrhizae" and "endomycorrhizae", adding an intermediate group "ectendomycorrhizae" (with both the Hartig net and the penetrative growth). Since then a few more categories have been established, e.g. arbutoid, ericoid, monotropoid (Allen, 1992; Hawksworth et al., 1996).

Ectomycorrhizae are a major feature of temperate and boreal forests with *c.*5000 species of fungi, which enable poorer soils to be exploited (Malloch et al., 1980). They are essential in elemental release and mineralization of N, P, K, S, and other nutrients. By enveloping the surface of fine roots and extending their hyphal mats throughout the humus layer ectomycorrhizae greatly extend the water and nutrient absorbing power of their hosts. In return the plants provide carbohydrates as the energy source to their non-photosynthetic partners.

Some plants form mycorrhizae with a multitude of fungi, while others are very species-specific. The former ones are especially important in facilitation of plant-to-plant

movement of essential elements and carbohydrates. Through their production of various enzymes and antibiotics, as well as by physical barriers, ectomycorrizal fungi protect fine roots from various pathogens. Ectomycorrhizae are an important group of macrofungi, essential for the survival and healthy growth of forests (Castello et al, 1995).

2b. Saprobic macrofungi

Saprobic macrofungi, better referred to as saprobes, use dead organic material, causing its decay (Ingold and Hudson, 1993). These fungi perform unique ecosystem function by decomposing wood, humus, plant litter, dung, bones, insects etc., and cycling nutrients. This action is possible due to a special set of enzymes which enable fungi to digest cellulose, lignin, keratin, and other bio-polymers (Kendrick, 1992). Saprobes are more diverse in form and size than ectomycorrhizal fungi. They include cup, shelf, earth tongue, mushroom, and toothed fungi, or *Plectania*, *Trametes*, *Geoglossum*, *Mycena*, and *Hericium*, respectively, amongst other genera.

Wood rotting fungi hollow out stumps and logs, allowing birds, reptiles, amphibians, insects, and mammals to find shelter in their interior (Harmon et al., 1986). A myriad of fungi perform the task of decomposing the unimaginable amounts of fallen branches and twigs, conifer needles, leaves and other plant remains. Without this unique activity (heterotrophic bacteria can also break down some of these substrates, but are limited to

working at surfaces only), our forests would suffocate due the large volumes of accumulating biomass.

A number of saprobic fungi can be categorized as pathogenic, able to cause disease in a host, or a range of hosts. Fungal epidemics of agricultural crops, for example: blights, powdery and downy mildews, rusts, and smuts, are far more common than those of forests. Undoubtedly, this can be linked to centuries-long practices of growing crops in extensive pure stands, or monocultures, and the use of genetically similar cultivars. Diversity of natural plant communities, such as many forest ecosystems, provides natural barriers to the spread of fungal infections. In such environments, the mere presence of a pathogenic fungus does not have to constitute a threat to the whole community. On the contrary, it can prove beneficial to some species. Trees, which are usually already weakened for some reason, and are subsequently killed by a fungus, create valuable gaps in the forest canopy. These gaps are quickly colonized by new tree seedlings and other plants. The decomposing logs and stumps provide habitat for a variety of wildlife.

Several macrofungal species can be very aggressive and are most commonly implicated in forest decline. In Canada, *Heterobasidion annosum* (Fr.) Bref. infects cut stumps, spreads from root to root system, and kills many conifers. Root rot caused by *Phellinus weirii* (Murrill) R.L. Gilbertson is widespread in west coast forests, and is especially severe in Douglas-fir. *Fomitopsis pinicola* Schwartz ex. Fr. and *Laetiporus gilbertsonii* Burdsall are destructive heart-rot fungi and are also prevalent in western forests.

Species of a common fungus *Ganoderma* usually grow on dead wood, but can attack a living tree as well.

It is important to monitor the distribution of pathogenic macrofungi in forest ecosystems, especially those dominated by a single tree species. Just as there is no sharp distinction between symbiotic and parasitic relationships, there is probably a thin line between a dynamic and a vulnerable forest.

3. Factors affecting growth, fruiting, and survival of macrofungi.

Our understanding of the various biotic and abiotic factors that influence fungal phenology has made significant progress since the early works of the 1930's and 1940's (Wilkins et al., 1938; Grainger, 1946). Nevertheless, large gaps remain, especially when dealing with individual species.

3a. Abiotic factors

It has been well documented that most fungi favour warm temperature and high humidity (Hering, 1966; Peredo et al., 1983). Wasterlund and Ingelog (1981) calculated that during wet years mycorrhizal fungi contributed 50% to the total sporocarp biomass in an area, but the value dropped to 10% in a dry year.

The importance of nutrient availability, especially nitrogen, phosphorus, and potassium, to sporocarp production has been addressed by many authors (Hunt and Trappe, 1987; Stark, 1972; Cromack et al., 1975; Vogt. et al., 1981; Mehus, 1986). Nevertheless, no clear relationship exists between amounts, timing and form of the nutrients and fungal fruiting processes. Ectomycorrhizal fungi are said to be discouraged from associating with their hosts when high influx of nitrogen occurs for a significant period of time (Harley and Smith, 1983; Menge and Grand, 1978; Ohenoja, 1978). Mehus (1986) further proposes that the periodicity of mushroom formation could be caused by the pulses of mineral availability from decay processes during heavy fruiting years.

Some species of fungi have been found to form sporocarps preferentially on certain soil types (Last et al., 1984), or on forest floors with particular characteristics , e.g. presence of large amounts of woody debris (Harvey et al., 1976; Cooke, 1948). Higher proportions of mycorrhizal sporocarps have been reported on lower productivity sites in both temperate (Hering, 1966) and tropical climates (Ashton, 1992). At least one study though (Laiho, 1970), showed the opposite to occur (i.e. more ectomycorrhizal mushroom production on rich sites). Perhaps the relationship depends on the particular species involved.

Mehus (1986) showed considerable variation in macrofungus diversity and biomass between different years, site localities and forest types. Perhaps fluctuations in fungal assemblages in space and time reflect different levels of ecological stability on a site

(Zak, 1992). Changes in macrofungal diversity are typically more dynamic in young forests than in old growth forests.

Soil fungi can be affected by small and large scale disturbances, such as small patch opening in the forest, or surface mining and agroecosystems, though generalizing statements are difficult to make due to frequently incomplete or inadequate data sets (Zak, 1992). Some information is available on the effects of clear-cutting, thinning, and other silvicultural practices (Hakkila, 1974; Veijalainen, 1976; Wasterlund and Ingelog 1981), as well as single species plantations (Last et al., 1981; Garbaye and Le Tacon, 1982) on sporocarp production. Very few sudies, however, separate mushrooms observed according to their ecological role (e.g. mycorrhizal vs. saprobic).

Air and ground water pollution are increasingly considered to be major abiotic agents responsible for decrease of some fungi in forests of Europe (Arnolds, 1988).

3b. Biotic Factors

Perhaps the most important factor determining the survival of a given fungus on a site is the presence of a specific host for mycorrhizal types (Trappe, 1962), and substrate for other types (Redhead and Berch 1996). Last et al. (1984) also showed that the production of macromycete fruiting bodies can differ depending on host genotype.

Richardson (1970) reported higher production of sporocarps in coniferous versus broadleaf forests. Evidence for the relationship between the forest age and seral stage and fungal species composition and biomass is provided by Vogt et al. (1981), Veijalainen (1976), and Dighton and Mason (1985) among others. Studies of mycorrhizal fungi associated with *Betula* led Mason et al. (1984) to suggest that succession of fungi is influenced by site history (natural stands versus previously treeless sites).

Fungi are a crucial element of terrestrial food chains. The numerous and complex interactions of fungi and other soil biota will inevitably reflect upon sporocarp production processes. A major study of the subject by Lussenhop (1992) provides good insight into various aspects of microarthropod - microbial interaction. For example, while many microarthropods feed on fungal mycelium and sporocarps, ultimately they in turn become food for the fungi. Among the most recent publications on the subject of fungal succession, that by Frankland (1998) contains an interesting reference to the role of insects in fungal inter-specific competition, namely that between *Mycena galopus* (Pers.: Fr.) Kumm. and *Marasmius androsaceous* (L. : Fr.) Fr.

Relatively little research has been done on similarities and differences in macromycete species composition with respect to all the potential factors affecting their fruiting. Most studies concentrate on sporocarp production. When diversity is considered, it is isolated in space and time, and limited to a single biotic or abiotic factor (e.g. producing a list of species from a forest type A in site X with no other forest types or sites to

Newell (1992) presents most recent developments in techniques for estimating fungal biomass and productivity in decomposing litter, while Vogt and Bloomfield (1992) cover sampling designs to determine sporocarp production and mention factors that impart error to biomass estimates. Mushroom distribution and abundance can be determined by methods involving counting sporocarps, distribution frequency, and/or biomass measurements. Guidelines pertaining to all of the above techniques are also presented in Vogt and Bloomfield (1992) and in Pilz and Molina (1996).

Redhead and Berch (1996) discuss two basic ways to survey macrofungi. The more commonly used one involves sampling their fruiting bodies, or sporophores; and is, therefore, constrained by their formation processes. The other method involves detecting the vegetative mycelium, spores, and other microscopic structures, and thus, calls for direct microscopic examination, cultivation, isolation, dilution, baits, and other techniques, similar to those used for microfungi. Systematic surveying of macrofungi is very labour intensive and the results quite unpredictable, more so than in sampling other microrganisms. The intricacies of the methods, their pitfalls and detailed requirements, with special reference to surveying British Columbia's macrofungi is presented in Redhead and Berch (1996).

II. Biodiversity and conservation.

1. Biodiversity and forest ecosystems.

Smitinand (1995) defines biodiversity as the variety and the variability among living organisms organized at many levels ranging from DNA sequences to whole ecological complexes, thus encompassing genes, species, ecosystems, and their relative abundance.

Wilson (1992) states that, unlike the rest of science, the study of biodiversity has a time limit. As species disappear so do the vast potential biological wealth and the sources of scientific information. Substantial efforts have only recently been directed at understanding the global role of biodiversity in natural environments (Wilson and Peter, 1988; Fenger et al., 1993; Perrings et al., 1995; Namkoong, 1997).

The single most important value of biodiversity to the human race is the ecological one. The preservation of species has numerous values perceived in purely social context, such as: scientific, aesthetic, moral, recreational, utilitarian, or cultural (Bormann and Kellert, 1991).

The hypothesis that diversity maintains stability, originally put forward by Elton (1958), has found more recent support. Naeem and Shibin (1997) showed that

communities with larger numbers of species should enhance ecosystem reliability and provide a consistent level of performance, such as biomass production over a given period of time. Though not without its share of sceptics (Bain, 1981), there is a general consensus that various ecosystems use diversity as a strategy for dealing with pathogens, which find it harder to spread if the host species are intermixed with non-target organisms (Gibson and Jones, 1977). Within biodiversity lies nature's ability to regenerate following various disturbances (Grubb, 1977). On a genetic level, populations characterized by limited within-species variability are prone to exhibit an overall decrease in viability and fitness (Raven and Johnson, 1986).

Other types of biological diversity can be described. Pojar and MacKinnon (1994) discuss diversity of structure, which affects wildlife living in the forests of the northern Pacific coastal region. The unique habitats created in these forests, as a result of many years of adaptation and evolution, as well as climatic changes, are irreplaceable. The future of biological diversity in these ecosystems depends on the intensity of human interference, especially timber harvesting and silvicultural practices. Studies on forest monocultures and their effects on soil biota are very limited. We need more baseline information, such as taxonomic evaluation of various microorganisms living in forest soils, to be able to approach the more complex questions.

Due to the hierarchical nature of biodiversity and the subjectivity of the various research methods involved, it is essential that studies attempt to answer a clearly defined question, rather than generate random lists of species (Namkoong, 1997). These

questions could address situations and factors that put biodiversity under threat, such as pollution, forest management, or invasion of non-indigenous species. Hence there is value in studying macrofungus diversity in the broader context of forest tree species composition and soil productivity.

Magurran (1988) points out two major applications of the various diversity measurements: environmental monitoring and nature conservation. While environmental monitoring reveals a general pattern of increased dominance coupled with a decrease in species diversity in response to stressors, Magurran urges conservationists to be clear whether or not an increase in diversity equates to an increase in ecological quality. Studies of forests' mycoflora offer us a better understanding of these concepts if species surveys include ecological function analyses.

2. Monocultures vs. mixed forests.

Monocultures differ from mixed species stands in the amount of genetic diversity. The amount of variation in shade tolerance, photosynthetic activity, height-growth patterns, root development and regeneration capabilities is greater between species than within species. Thus, mixed species stands also have more possible types of competitive interaction among neighboring trees and greater environmental variation (Larson 1992).

Species must use resources differently if they are to coexist on a site. There is a potential productivity advantage to be gained by incorporating mixed tree species

plantations into silvicultural management programs (Ewel, 1986; Vandermeer, 1989). However, information directly linking productivity and number of species in forest stands is very sparse (Kelty, 1992), mainly due to impractical time and space requirements to conduct such experiments. Thus, any patterns or principles of timber yield and soil productivity are based on a few incomplete studies and extrapolation from similar herbaceous plant studies (Hill and Shimamato, 1973).

Spatial stratification of foliage and roots is often the key to reduced competition (Kelty 1992; Wierman and Oliver 1979), increased stability (Kelty, 1992), and resistance to pests and diseases (Castello et al., 1995). Mixed species plantations have been used to facilitate nitrogen availability via increased rates of decomposition (Matthews, 1989), and by including tree species associated with nitrogen fixing bacteria (Binkley et al., 1984; Miller and Murray 1978). Kelty (1992) speculates that forests are more likely than herbaceous crops to show significant relationship between species composition, their interactions and productivity. Their greater life span and biomass, the complex associations with other organisms, the continued litter production and decomposition allow more opportunity for the establishment of facilitative effects.

3. The importance of studying taxonomy and ecology of macrofungi.

Fungi are an integral and one of the most important components of the soil biota in forest ecosystems of the North Temperate Zone. Worldwide, all coniferous tree species

form symbiotic associations with various ectomycorrhizal fungi (with the exception of *Cupressaceae* which form only endomycorrhizae). The trees depend on the mycelial networks for nutrient uptake and protection from environmental hazards, such as drought, soil pollution, or pathogenic organisms.

All fungi contribute to global nutrient cycling, whether by mutualistic associations with plants, or by decomposing organic matter. Their unique powers of substrate degradation create habitat diversity for many forest organisms, while the sporocarps of many macrofungi are an important component of the forest food-chain. Fungal mats modify soil permeability and promote aggregation of soil particles. Furthermore, their ability to accumulate toxic materials plays an important role in soil detoxification.

Macrofungi, though by no means the most numerous or significant, are the most conspicuous of all fungi. They are easier to study in the field than microfungi, such as molds, yeasts, or endomycorrhizae, which are invisible to the naked eye, and often overwhelming due to their sheer numbers (Castellano et al., 1999). Thus, though periodic and ephemeral, fructifications of large, fleshy fungi provide us with invaluable insight into some aspects of the underground ecology.

A reliable identification of ectomycorrhizae involves tracing rhizomorphs or mycelial strands that connect the mycorrhizae to a sporocarp of known identity, or by comparing mycelium at the base of sporocarps to mycelium on ectomycorrhizae (Goodman, 1995).

Recently, DNA analyses and comparisons have also been used in fungal taxonomy (Egger, 1995; Mehmann et al., 1994).

Hundreds of macrofungal species remain to be documented in British Columbia, and even more ectomycorrhizae are yet to be described. Clearly, however, without detailed knowledge on growth and distribution of macrofungal species, further research on taxonomy of ectomycorrhizae will be impeded.

4. Conservation of macrofungi.

Estimates indicate there are roughly six species of fungi for every vascular plant species in a given temperate ecosystem (Hawksworth, 1991). The fungal flora of the Pacific Northwest is noticeably abundant and extremely diverse. Redhead (1997) quotes a total of 1,250 species of macrofungi "more or less documented" from British Columbia, and states further that this figure most likely covers only a fraction of species actually present, since his research shows that even some commonly occurring species have not yet been documented in the literature.

Conservation measures and red lists of macrofungi have long been in place in various European countries, where mycological research is more advanced, and where the human impact on the environment seems most acute. Forest decline in Europe has been accompanied by a chronic deterioration in diversity and abundance of forest fungi

(Arnolds, 1991). The reasons for the disappearance of the fungi, largely among ectomycorrhizal species, are still not clear. Intensive forestry practices, air and soil pollution, as well as human overharvesting are amongst the factors implicated in the decline (Arnolds, 1991). The important aspect of European investigations on the forest mushroom crisis is the existence of a century-long, scientific documentation on the status of macromycota in various habitats. Without these records, the so- called baseline information, the threatened status of the European macrofungi would have been unquantifiable.

The west coast of the United States and Canada is known for the presence of ancient rainforests, which have experienced little or no human disturbance and represent a valuable reserve of late-successional, climax stage forests. Strong public interest in conserving biological diversity in those forests continue to urge political leaders to the necessity of defining a new approach to forest management practices.

In the United States, in recent years, certain social and political events (Castellano et al., 1999) led to a Federal mandate to inventory forest species within eight groups of organisms associated with late successional forests (USDA and USDI 1994a). For the first time, fungi, nonvascular plants, and invertebrates were included in forest management issues in the Pacific Northwest. One of the documents generated as a result of the subsequently undertaken multilevel assessment of species at risk, contains a list of fungal species which are to be protected through surveys and the appropriate management guidelines (USDA and USDI 1994b). After many considerations, such as

availability of scientific information, benefits and cost of strategies' implementation, a panel of mycologists selected 234 fungal species (out of an initial 1,119 species) as requiring some level of protection. Of those, 129 species are known from only one or a few sites. Eighty species are listed as endemic to the Pacific Northwest. Needless to say, extirpation of these endemic species from the area would bring them to extinction.

To date no official red lists of macrofungi exist in Canada. The scarce information on the distribution of fungi, not only in British Columbia, but also throughout the country, continues to leave the issue of species protection at the stage of vague estimates and speculation.

III. Study objective

The objective of this study was three-fold. The main purpose was to find out if there are relationships between forest habitats, created by various conifer species, and the macromycota fruiting in the understory. It is hypothesised that different types of conifer forests support different macrofungus communities. To test this hypothesis, I surveyed monoculture stands of four conifer species for the presence of all epigeous macrofungi in the understory, and then analysed the data in terms of number of species, abundance of sporocarps, and guild structure. The same data were used to address the second objective: to establish if site characteristics have an effect on macrofungus diversity and abundance. Three sites were used, differing in soil nutrient and moisture content.

The answers to these two questions may be useful in forest management practices. Should there be significant influence of conifer species on macromycota, mixed forests rather than monoculture forests might be recommended. High productivity sites should be protected. The third aim of this research was to contribute more information on macrofungus diversity on Vancouver Island. Like many other areas in British Columbia it is still relatively unexplored. Mycological inventories are indispensible in decision making on protection of species or communities at risk.

Chapter Two – Study Description

I. EP 571 – historical review.

1. Establishment and subsequent results of the main study on the sites.

This macrofungus study used plots from another research project, the Species and Espacement Trial, also known as the Experimental Project (EP) 571, which was established in 1962 by the British Columbia Ministry of Forests Research Branch. The original mandate was to obtain information on the silviculture of four native conifer species: Sitka spruce, Douglas-fir, western hemlock, and western red cedar, planted at various densities. Study sites (see description below) were set up on the west coast of Vancouver Island; height-growth curves were calculated and compared to age 26 years (Omule and Krumlik, 1987). The results of the Species and Espacement Trial showed that Douglas-fir was significantly taller than the other species, followed in turn by western hemlock, Sitka spruce, and western red cedar. Salal's competitive and impeding growth in cedar was also noted (Omule and Krumlik, 1987).

Subsequently, the well established, circa fourty year old, monoculture forests provided an excellent opportunity for carrying out other research, such as forest floor nutrient analyses and various biodiversity studies, including macrofungal surveys.

2. Additional research on EP571 sites.

Klinka et al. (1984) provided ecological and supplementary height-growth analyses for the project. In general, the sites were found to be environmentally uniform, and humus types suggested similarity in decomposition processes as well as high nutrient content of the forest floor. Notwithstanding, great variability was present in microsites, canopy cover, and understory vegetation across the stands. As the canopy cover decreased, the improved light conditions caused the cover of understory shrubs to increase. Growth form (shape) of the four conifers improved from western red cedar to Douglas-fir to Sitka spruce to western hemlock. Low initial spacing, followed by tree mortality and failure of early crown closure, was pinpointed as the cause of the observed poor growth form of cedar.

The effects of salal encroachment on the sites was also apparent in a study of nutrient concentrations and nitrogen mineralization in forest floors of the four types of conifer plantation (Prescott et al., 2000). Although decomposition rate was fastest in the western hemlock forest floor and slowest in the western red cedar forest floor, no relationship could be found between nitrogen mineralization, rates of decomposition of foliar litter, and any of the litter chemistry parameters measured. It appeared that site factors, in particular the amount and composition of understory vegetation (related in turn to slope position) were significant enough to override the effects of tree species.

Berch et al. (2001) summarized a multiyear project on the impact of single conifer species plantations on soil biodiversity and processes. Several parallel studies were involved to address the issue, including research on macrofungi, an important component of the forest ecosystem and a good indicator of forest health in general. In addition to the surveys of macrofungi (a pilot study and this thesis), Berch et al. (2001) review other research on the sites: diversity of soil fauna, diversity and feeding habits of Collembola, decay of foliar litter from forest floor, rates of decomposition and N mineralization, and examination of earthworm communities. Apart from the nutrient data discussed above (Prescott et al., 2000), and some of the macrofungus data presented in this thesis, the only other site-specific differences were those pertaining to the earthworm abundance. Upper Klanawa site showed significantly higher numbers of a large Enchytraeid sp. than Fairy Lake did. All other measurements, i.e. the abundance of soil mesofauna (primarily mites and collembola), macrofauna, the decomposition of litter, and the biomass of soil microbes, seemed to support the hypothesis that conifer species affects soil biodiversity. The general trend is towards the lowest numbers of organisms under western red cedar, perhaps explained by the antifungal properties, and other chemical characteristics of its litter (Minore, 1983).

II. Description of Sites and Methods

1. Study Sites

The forest stands used in this project are located on the west coast of Vancouver Island (Figure 2.1). In ecological terms, the area is classified as the Submontane Very Wet Maritime Coastal Western Hemlock (CWHvm1) variant. Macrofungus research plots were established at three sites: Site1 – UK (Upper Klanawa; lat. = 48°52'00", long. = 124°47'00"), Site 2 – SL (Sarita Lake; lat. = 48°48'00", long. = 124°58'00") located in the Franklin River area, and Site 3 – FL (Fairy Lake; lat. = 48°35'00", long. = 124°21'00") near Port Renfrew. For our study we chose the plots with the closest tree spacing (2.7 x 2.7m), each plot measuring 0.03687 ha, for a total of 81 trees per plot. The layout of all the plots is presented in Figures 2.2 to 2.4.

All the sites initially supported old-growth forests dominated by western hemlock, western red cedar, and amabilis fir, with occasional occurrence of Sitka spruce and Douglas-fir. The original stands were logged and slash-burned by 1961, the area was planted with selected conifer monocultures in 1962, when various research plots were established within it. Upper Klanawa is flat, located in a valley bottom, and is the wettest and the richest of the three sites. Sarita Lake and Fairy Lake plots have varied topography, from slightly depressed to fairly steep (but scattered over generally mountainous, south aspect areas). Sarita Lake is characterized by medium rich, fresh

soil, while Fairy Lake is fairly dry and nutrient poor. These characteristics and the % vegetation cover are shown in Table 2.1.

The entire area typically has cool summers and wet but mild winters. Tables 2.2 and 2.3 provide information about temperature and precipitation for the three experimental sites. It is based on data recorded at two weather stations: Bamfield East (the closest station to sites 1 – Upper Klanawa and site 2 – Sarita Lake), and Port Renfrew (the closest station to site 3 – Fairy Lake). The information was obtained from Environment Canada, Weather Office at the Pacific Forestry Centre, Victoria, British Columbia (Tables 2.2. and 2.3.) and from a publication of the Canadian Climate Program: Canadian Climate Normals 1961-1990, British Columbia, Environment Canada. Soil properties of each plot at the three sites are tabulated in Appendix 2A. Prescott et al. (2000) carried out nutrient analyses of the EP 571 plots and a summary of those applicable to this study can be found in Appendix 2B.

More detail about the sites, the original experimental design, and previous research conducted there can be found in Klinka et al. (1984), Meidinger and Pojar (1991), and Omule and Krumlik (1987).

2. Macrofungus sampling

Four conifer habitats were selected for this study: Sitka spruce, Douglas-fir, western red cedar, and western hemlock. At all three sites two replicate plots of each conifer species

were established. Each plot measured 144m² and was further divided into 16 contiguous 3x3m subplots, allowing for sufficient margin area to minimize edge effects such as root encroachment and litter deposit from the adjacent plot. The total area covered by the 24 plots was 3456m². All macrofungi, at least 1 cm long or wide, were recorded in each subplot on a monthly basis, over a two year period 1997-1998, during the mushroom growing season (May to October). Additional sampling was carried out at the beginning of May each year, to ensure capturing the beginning of mushroom fructification, shortly after the last frost. The last sampling was scheduled for late October, just before the danger of first frost. The presence of all taxa observed in each subplot was recorded. Individual fruiting bodies were not counted, and most were left undisturbed. Representative specimens of fungal species requiring microscopic examination and/or vouchering as a herbarium specimen were collected, gross examined in the field and processed in the laboratory in accordance with the guidelines presented by Redhead and Berch (1996). In addition to the presence/absence data, notes were taken on the substrate on which the fungi were found growing. These notes and available literature on the subject (Arora 1986; Breitenbach and Kranzlin, 1984-1995; Phillips 1991; Trappe 1962) were used to group the fungi into four guilds: 1) mycorrhizal symbionts, 2) litter decomposers, 3) wood rotting fungi, and 4) the less specialized group of both litter and wood decomposers, or general decomposers. The macrofungi were identified to species or species group. No hypogeous fungi were included in the survey due to the disruptive nature of the sampling procedure that would have to be used.

3. Data Analysis

We used a method of recording presence or absence of a given fungus in each of the 16 subplots to determine its ultimate abundance (number of positive subplots, or number of observations), and frequency (% of positive subplots) in a plot. Thus, for example, *Mycena amicta* found in 4 out of the 16 subplots in Sitka spruce Ss 98 would be considered as having abundance = 4, and frequency = 25% in that plot, regardless of the number of its fruiting bodies. An observation is thus defined as 1 record of a given macrofungus species (1 positive subplot), with the maximum possible value per plot = 16 (= 100% frequency for that species). This method is very similar to that used by Bills et al. (1986), and is in general agreement with the ecological methodology and concepts outlined by Krebs (1989). Subplot records and frequencies were added within each sampling period to look at sporocarp occurrence over time. Data from all 7 trips per year were pooled to find the total number of genera, species, and their respective frequencies. Macrofungus frequencies from two years of sampling were further combined for some analyses. ANOVA statistical analysis was done using SAS (SAS Institute Inc., 1988). Diversity indices, cluster analysis, and ordination multivariate analysis were performed using PC-ORD (McCune and Mefford, 1995, version 2.0) computer program. Diversity and abundance of macrofungi per square meter was calculated for each plot, conifer, site, and the whole study area as follows:

Diversity / m^2 in plot x = number of species in plot x / 144 m^2

Abundance / m^2 in plot = number of observations in plot x / 144m^2

Diversity / m^2 per conifer x = total number of species in 6 plots of conifer x / 864 m^2

Abundance / m^2 per conifer x = total number of observations in 6 plots of conifer x / 864 m^2

Diversity / m^2 in site x = number of species in site x / 1152 m^2

Abundance / m^2 in site x = number of observations in site x / 1152m^2

Average diversity / m^2 per plot = (sum of indiv. diversities / m^2) / 24 plots

Average abundance / m^2 in plot = (sum of indiv. abundances / m^2) / 24 plots

Diversity / m^2 for the whole study area = total number of fungal species / 3456 m^2

Abundance / m^2 for the whole study area = total number of observations / 3456 m^2

Tables and Figures

Figure 2.1. Map of southern Vancouver Island with marked locations of the experimental sites. Shade of red corresponds to elevation.

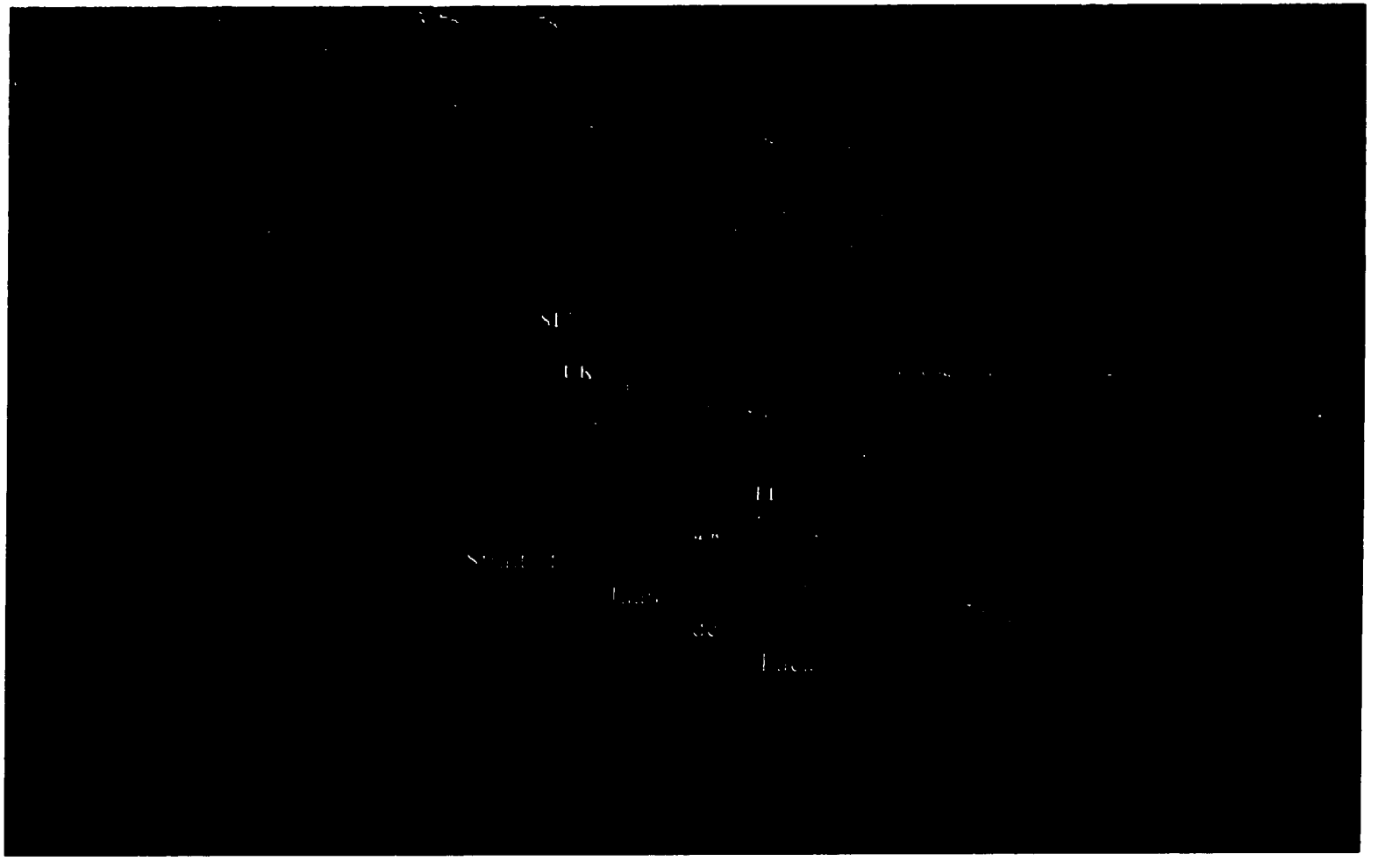
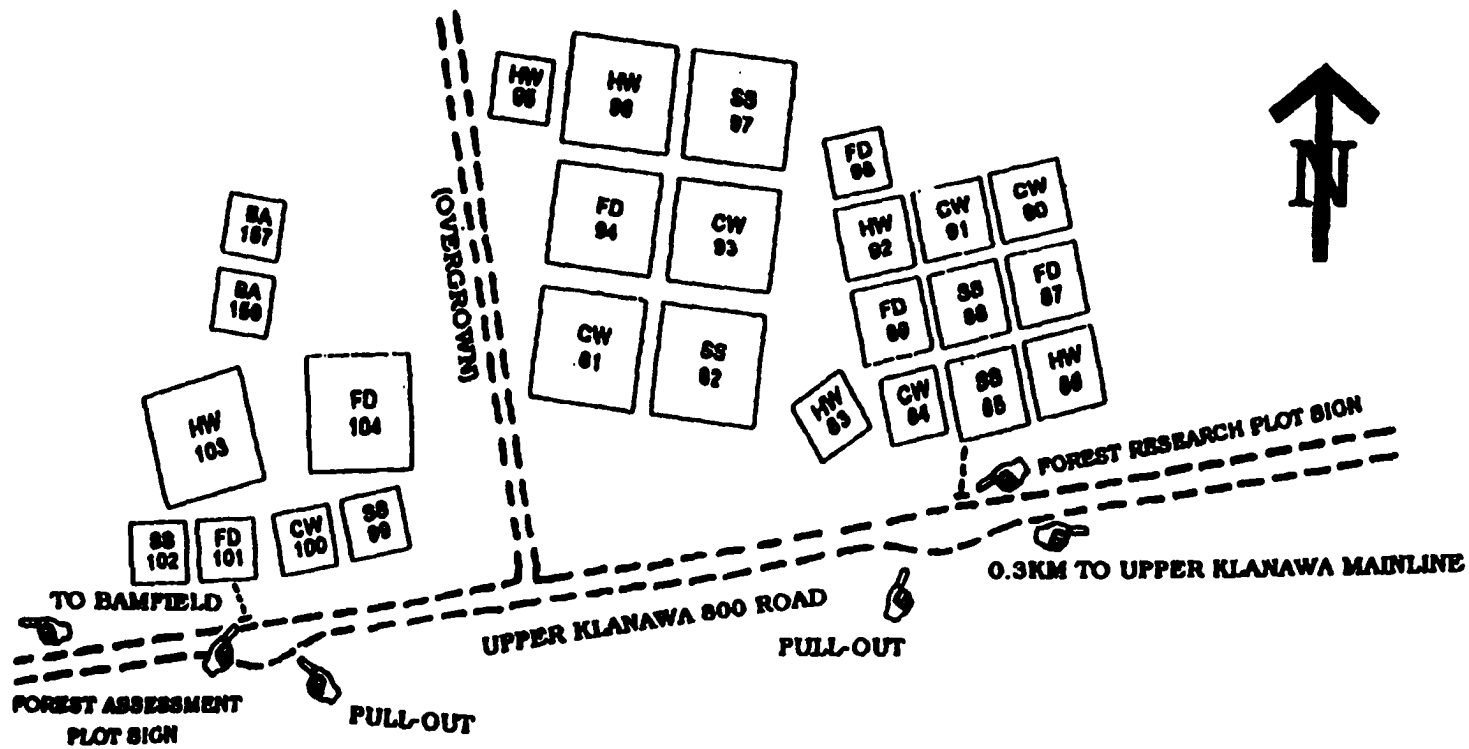


Figure 2.2. Layout of all the plots in site 1, Upper Klanawa. Note, only the plots with the closest tree spacing (the smallest squares in the diagram) were used.

EP 571

Upper Klanawa 800 Road Plots 81-104, 156 & 157



Approximate Scale 1:2000

Figure 2.3. Layout of all the plots in site 2, Sarita Lake. Note, only the plots with the closest tree spacing (the smallest squares in the diagram) were used.

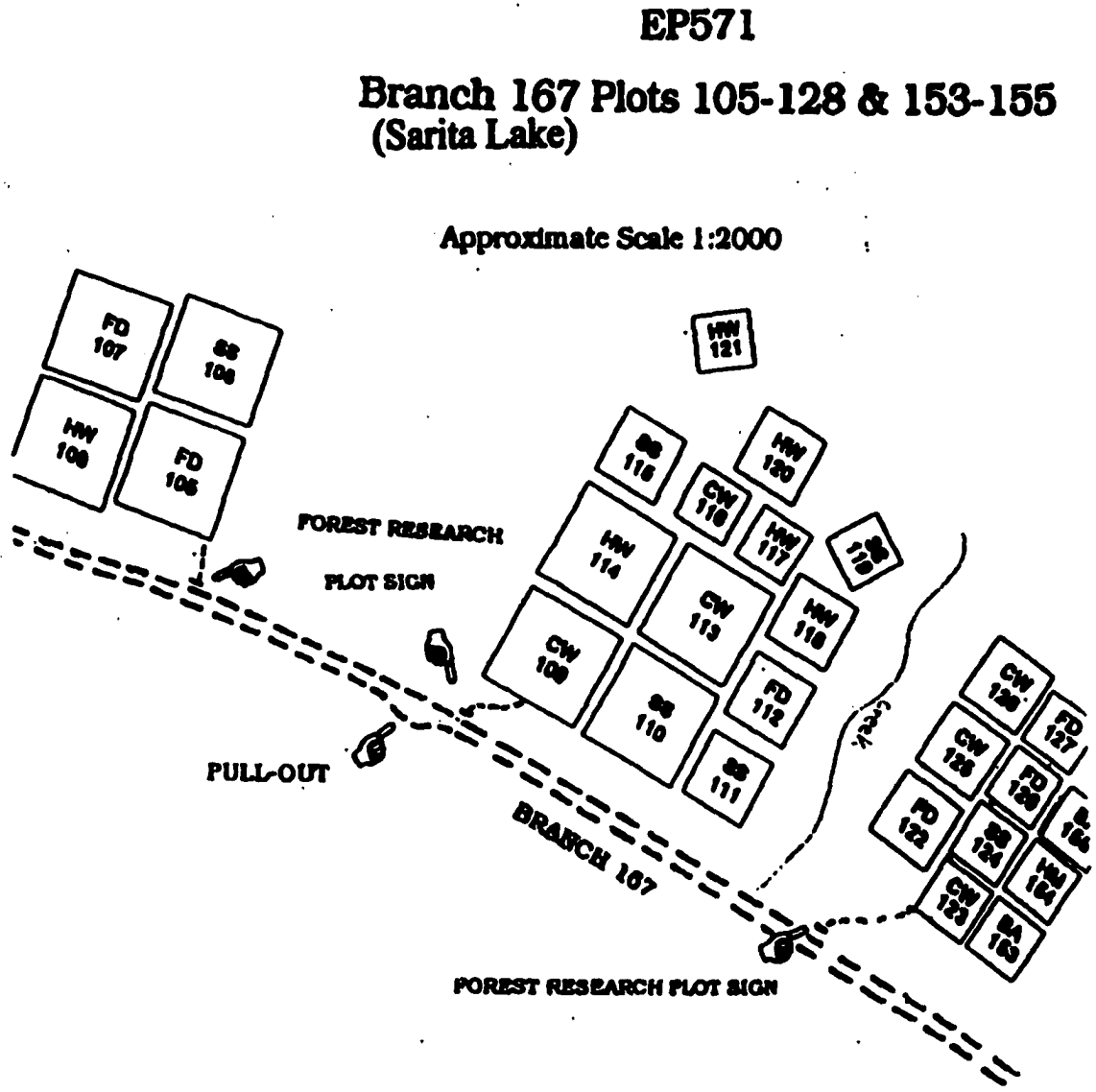


Figure 2.4. Layout of all the plots in site 3, Fairy Lake. Note, only the plots with the closest tree spacing (the smallest squares in the diagram) were used.

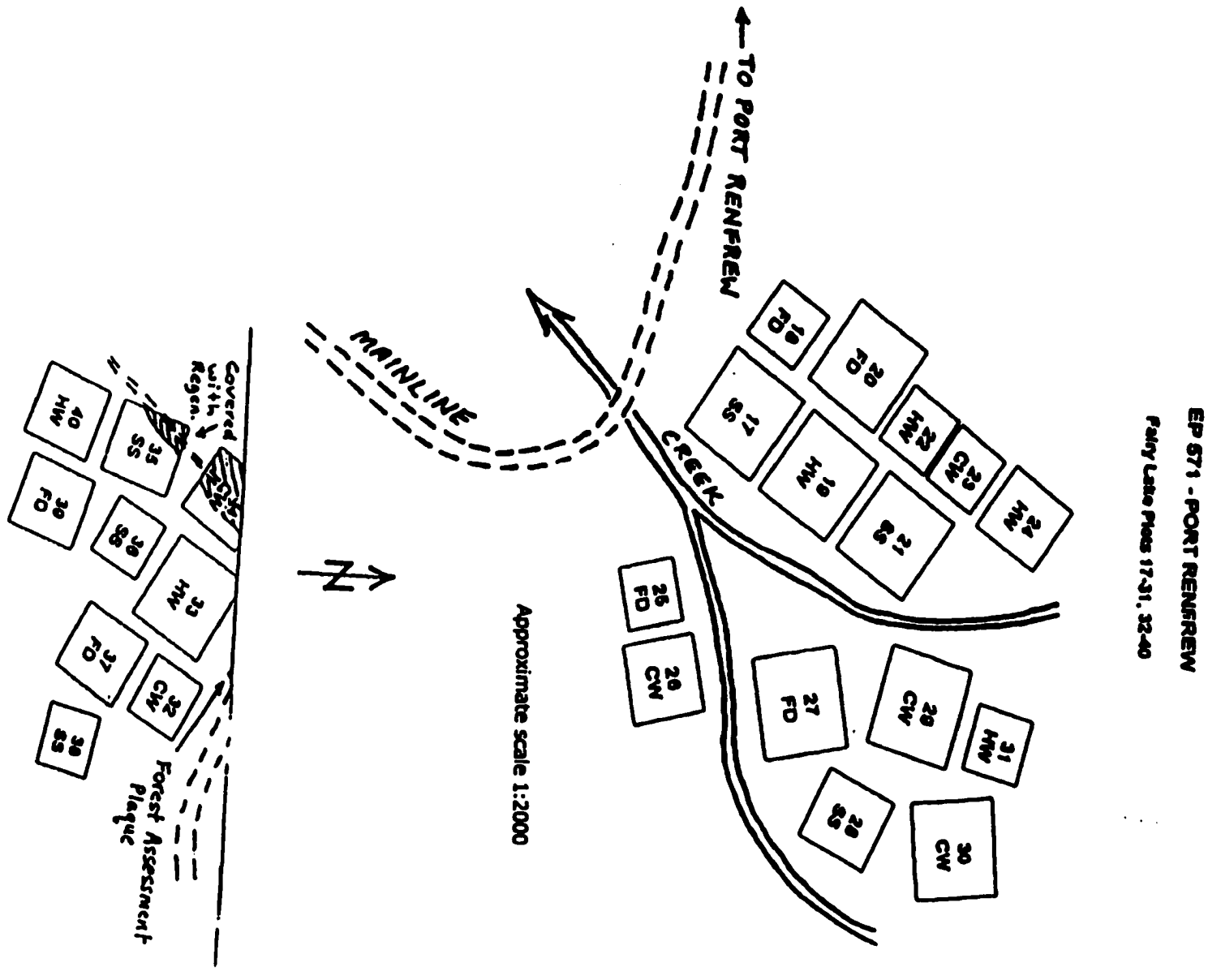


Table 2.1. Characteristics of the three study sites. Based on Prescott et al.(2000).

	Site 1. Upper Klanawa	Site 2. Sarita Lake	Site 3. Fairy Lake
Location	48° 49′ N, 124° 47′ W	48° 54′ N, 124° 54′ W	48° 35′ N, 124° 19′ W
Elevation	75-85m	150-190m	200-280m
Aspect	-	South-west	South South-west
Slope position	Flat	Mid slope	Mid slope
Slope gradient	-	30-45%	10-60%
Moisture and nutrients	Moist to very moist and rich to very rich	Fresh and poor to medium	Slightly dry and very poor to medium
Dominant humus form	Leptomoder	Mormoder-Leptomoder	Leptomoder-Mormoder
Understory composition and (% cover)	*Rubus spectabilis* Pursh (18) *Polystichum munitum* (Kaulf.) Presl.(4) *Tiarella trifoliata* L. (4) *Gaultheria shallon* Pursh (3)	*Gaultheria shallon* Pursh (23) *Vaccinium parvifolium* Smith (17) *Blechnum spicant* (L.) Roth (7) *Polystichum munitum* (Kaulf.) Presl.(6) *Vaccinium alaskense* Howell (2) *Rubus spectabilis* Pursh (2)	*Gaultheria shallon* Pursh (41) *Vaccinium parvifolium* Smith (6) *Blechnum spicant* (L.) Roth (4) *Vaccinium alaskense* Howell (4) *Polystichum munitum* (Kaulf.) Presl.(2) *Rubus spectabilis* Pursh (2)

Table 2.2. Climatic data pertaining to the sites. Mean monthly temperature from 1996 to 1998 for Bamfield and Port Renfrew.

BAMFIELD EAST — Mean Monthly Temperature (deg C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	4.4	5.4	6.9	9.0	10.0	12.9	15.8	15.4	12.9	10.2	6.2	3.5
1997	5.5	6.2	6.4	8.6	13.0	13.9	15.9	17.5	15.9	10.8	9.3	6.8
1998	5.6	7.2	7.9	8.6	11.7	13.6	15.7	16.2	14.8	11.7	8.3	Msng

PORT RENFREW — Mean Monthly Temperature (deg C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	3.7	4.2	6.7	8.7	9.7	12.9	16.3	15.8	12.2	8.8	4.9	2.0
1997	3.8	5.1	5.5	8.1	12.8	13.3	15.5	16.8	14.5	10.0	7.5	3.4
1998	4.0	6.3	7.1	8.5	11.8	14.1	16.2	16.1	14.3	10.1	7.5	3.4

Table 2.3. Climatic data pertaining to the sites. Total monthly precipitation from 1996 to 1998 for Bamfield and Port Renfrew.

BAMFIELD EAST — Total Precipitation (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	422.1	288.5	177.7	402.0	134.0	76.6	14.6	39.8	110.0	410.0	281.3	451.4
1997	563.0	221.0	528.8	252.1	191.0	256.0	144.0	138.0	310.2	416.8	422.2	573.3
1998	671.6	509.2	198.6	64.2	89.0	46.8	81.6	3.0	27.0	211.0	705.6	Msng

PORT RENFREW — Total Precipitation (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1996	554.2	423.8	195.8	419.0	183.4	63.4	32.6	37.4	126.8	474.8	445.6	465.8
1997	725.2	305.2	797.1	332.2	203.0	219.2	152.4	123.6	327.0	525.2	372.4	567.8
1998	627.2	418.2	223.6	72.8	108.4	51.0	82.2	6.6	11.0	220.2	971.4	975.8

Chapter Three - Diversity and ecology of macrofungi in four types of second growth forest on southern Vancouver Island, British Columbia.

Introduction

The rainforests of coastal British Columbia are biologically the most productive ecosystems in Canada. Abundant rainfall, mild temperatures, and the prevalence of conifers such as western hemlock, anabilis fir, Douglas-fir, western red cedar, and Sitka spruce, create ideal conditions for the growth of a multitude of macrofungal species. Many of them occur elsewhere in the Northern Hemisphere and thus, their identification has been possible through reference to the existing literature. Unfortunately, the status of mushroom taxonomy, though equipped with sophisticated technology, resembles that for vascular plants about 100 years ago. Vast areas of the world, including North America, are still relatively unexplored.

A comprehensive list of popular and technical texts on macrofungi from various countries is provided by Hawksworth et al., (1996). The North American mycological flora is described, amongst others, by Lincoff (1981), Arora (1986), Schalkwijk-Barendsen (1994), and Phillips (1991). Canadian mushroom guide literature includes Groves (1979), and Pomerleau (1980), while that of British Columbia is limited to the provincial handbook series by Hardy (1946) and Bandoni and Szczawinski (1964, 1976),

which cover less than 1% of the province's estimated 2000 agarics, boleti, and chanterelles (Redhead, 1997). Redhead (1989) expressed concerns about a mixture of useful data and misinformation based on incorrect identification, differing species concepts, or poorly documented habitats. His expert biogeographical overview of the Canadian mushroom flora is a good representation of the scientific knowledge of macromycete taxonomy and distribution.

Taxonomic literature used for identification of macrofungi in this study included but was not limited to the following: Breitenbach and Kranzlin (1984-1995) 'Fungi of Switzerland' vol. 1-4, Smith et al. (1981) 'How to know the non-gilled mushrooms', Smith et al. (1979) 'How to know the gilled mushrooms', Bas et al. (1995) ' Flora Agaricina Neerlandica' vol.3, Smith (1947) 'North American species of *Mycena*', Smith and Singer (1964) 'A monograph of the genus *Galerina* Earle', Maas Geesteranus (1992) 'Mycenas of the Northern Hemisphere' vol.1&2, , Hesler and Smith (1963) 'North American species of *Hygrophorus*', Moser (1983) 'Keys to Agarics and Boleti', Hesler and Smith (1979) 'North American species of *Lactarius*', Largent (1994) 'Entolomatoid fungi of western United States and Alaska', Bigelow (1982) ' North American species of *Clitocybe*', and Corner (1966) 'A monograph of Cantharelloid fungi'.

Up- to-date literature on macrofungi of British Columbia is still insufficient, though some progress has recently been made. Redhead and Berch (1996) outline inventory requirements with specific reference to British Columbia macrofungus taxonomy. Numerous articles have been published on local individual mushroom species or groups.

A good reference to those, with particular emphasis on potential threats to possibly rare macrofungi in various eco-regions of British Columbia, was written by Redhead (1997), who scrutinised the many scientific articles, databases, and indices pertaining to mycota of British Columbia. His paper includes, amongst others, the revised and annotated list of 488 species of agarics, boletes, and chanterelles reported for BC, as well as comprehensive lists of documented ascomycetes, polypores, aphyllophorales, and miscellaneous other basidiomycetes. Fernando et al. (1999) compiled a host-fungus index, which includes a listing of many macrofungus holdings at the Pacific Forestry Centre in Victoria. The index is regularly updated and is accessible on the internet: (http://www.pfc.forestry.ca/biodiversity/herbarium/herb_search_e.html).

Gamiet and Berch (1992) established sampling plots in an old growth forest in the Vancouver area with the idea of long term studies. They provide a preliminary report of 84 macrofungal species and assign them to various ecological groups. Countess (2001) studied the long term effects of clear-cutting on macrofungal communities in Douglas-fir dominated stands, and accumulated 301 macrofungal taxa. Berch et al. (2001), in their preliminary assessment of selected soil organisms under different conifer species, include 62 species of macrofungi from the single species plantations at Upper Klanawa, on southern Vancouver Island. To my knowledge, these two studies and this project represent the only systematic surveys of macrofungal flora on Vancouver Island. Goodman used the same Douglas-fir stands as Countess to research ectomycorrhizal fungi (Goodman, 1995). His study, however, focused on microscopic characterization of fungal hyphae on roots from soil samples and offered limited information for this project.

A few other studies contributed to the knowledge of macrofungus diversity in the Pacific Northwest, for example those of Durall et al. (1999), O'Dell et al. (1999), or Kranabetter and Kroeger (2001), but are restricted to ectomycorrhizal taxa only. They will be dealt with in more detail in Chapter 4.

No other systematic research has previously been done on epigeous macrofungus diversity and richness supported by second growth coniferous forests in this area, or anywhere else in Canada. Most surveys of mushroom species throughout the world involve mixed forests, or exotic pine plantations. A somewhat similar investigation to mine, but on a larger scale and less analytical, was reported from Denmark (Lange, 1993). Smith et al. (2002) studied macrofungi in Douglas-fir dominated forests and found that hypogeous fungi constituted a significant component of the ectomycorrhizal macromycota.

Various types of microhabitats exist within temperate coniferous forests. These are created due to the many differences between conifer species, such as needle litter composition, types and quantities of secondary metabolites produced, root structure, and symbiotic associations with soil microorganisms (Johansson 1995, Berg 1998, Eis 1978, Trappe 1962). Quality and availability of organic matter, climatic factors, as well as the nature of the soil biological community, have a profound effect on nutrient cycling processes (Trofymow 1998, Berch 1998, Prescott et al., 1998). Many studies concerned

with forest productivity consider the effects of soil properties and climate, while the role of soil biota is frequently overlooked.

Fungi are an integral component of the forest biological community. Wood and litter decomposing fungi play a key role in soil formation processes, while ectomycorrhizal species enhance forest health through symbiotic associations with the roots of trees and other plants. At the same time, these two groups, have potentially different, if not opposite, effects on the availability of dissolved organic nitrogen to plants and other organisms (Eviner and Chapin, 1997). These effects are in a constant flux as the fungi grow, senesce, and die. The intricacies of this complex system may hold some answers to the many problems of forest management and environmental protection.

Forest macrofungi can differ in their habitat and nutrient requirements. Soil structure, pH, moisture, or density of mycophagous organisms are amongst the many factors which can affect the diversity and abundance of mushrooms (Carroll and Wicklow 1992, Lange 1993). Presence of host species is an obvious prerequisite for the survival of many mycorrhizal fungi. The influence of tree species might, however, extend to other groups of fungi (Dighton et al.,1986; Senn-Irlet and Bieri 1999).

In this study, we investigated a possible link between various habitats created by conifer monocultures and the presence or absence of mushroom sporocarps, across all the recorded mushroom species.

Very little is known about the impact of single species plantations on diversity of macrofungi. In agroecosystems fungal species richness declines and species composition changes once a soil is cultivated and planted in a monoculture (Gochenauer 1981). There is concern that growing conifer monocultures in close rotation may be adversely impacting the fungal-plant relationships and thus the long-term soil productivity. Studies are needed in British Columbia to determine biological diversity of forest soils, and its functional significance, if we want to minimize human impact on our ecosystems.

It was hypothesized that pure stands of Sitka spruce, Douglas fir, western red cedar and western hemlock will differ from each other in the mushroom communities associated with them; in terms of diversity, abundance, and species composition.

Results

1. Diversity of species and genera

The two years of survey over the total area of 3456 m^2 yielded a cumulative number of 4629 observations. A total number of 277 taxa were found belonging to 95 genera. The listing of all the species, along with the names of the authorities can be found in Appendix 3A.

Table 3.1. lists the most prolific genera and their cumulative frequencies along with the total number of species within the genera. By far, the most common genus we found was *Mycena* with 45 distinct species. Other common genera found in this survey, in descending order of their frequency were: *Cortinarius*, *Inocybe*, *Lactarius*, *Russula* and *Galerina*.

The following species were most commonly observed across all the conifers in this study, in descending order of their frequency: *Mycena amicta*, *Cantharellus formosus*, *Mycena metata* group, *Mycena rorida*, *Mycena aurantiidisca*, *Mycena galopus*, *Guepiniopsis alpina*, and *Clavulina cristata* (Table 3.2).

Macrofungus diversity and abundance, expressed in number of species and number of observations / m^2 , were calculated for each plot, each type of conifer habitat, each site,

and for the entire study. The average diversity / m^2 per plot was 0.3 species. The average abundance / m^2 per plot was 1.3263 observations (Table 3.3).

2. Ecological guilds

The guild structure used in this study included the following categories: ectomycorrhizal fungi, litter decomposers, wood decomposers, general decomposers, i.e. fungi able to colonise wood as well as grow on litter, and entomopathogenic fungi, i.e. fungi growing on insects. Of the 277 species found, the guild with the greatest diversity (at 41.16% of the species observed), were the litter decomposing fungi (Table 3.4). These were fructifications found on fallen twigs, conifer needles, decomposing understory vegetation, as well as those growing on bare soil (mostly some type of humus). The ectomycorrhizal fungi constituted 30.32% of the community, followed by wood decomposing fungi accounting for 22.74%. Only a fraction of all the species, 5.05%, was represented by general decomposers. Two entomopathogenic fungi were found growing on ants and a lepidopteran larva, *Cordyceps myrmecophila* and *Cordyceps militaris*.

Guild ranking was different with respect to relative frequencies of occurance, with general decomposers placing second (21.11%), after the litter decomposers (49.21%), and surpassing the ectomycorrhizal (18.28%), and wood rotting (11.38%) groups.

Guild structure in each conifer habitat is compared in Table 3.5. Western hemlock had the highest frequency and diversity of ectomycorrhizal species and the lowest frequency and diversity of saprophytic species. Western red cedar had the lowest frequency and diversity of ectomycorhizal fungi and the highest frequency and second highest diversity of saprophytic fungi.

3. Uncommon species

One hundred and fifteen species (41.52% of all the species) were recorded as only one observation (i.e. one positive subplot) of their fruiting. Many of these are possibly uncommon if not rare for these habitats (Table 3.6). Included in Table 3.6 are *Ascocoryne sarcoides*, *Calistosporium luteo – olivaceum*, *Clavulina ornatipes*, *Cudonia grisea*, *Entoloma sinuatum* group, *Entoloma trachyosporum var. purpureo-violaceum*, *Marasmius* sp., c.f. *wynnei*, and *Phaeocollybia phaeogaleroides*. These species were found on more than one occasion but are known to be rare for the British Columbia (Redhead, 1997; Paul Kroeger, mycological consultant and president of the Vancouver Mycological Society, personal communication). For comparison, a rather common species in the area, the edible chanterelle, *Cantharellus formosus*, had a cumulative abundance of 296 observations, constituting 6.4% of the whole macrofungus community.

4. New reports for British Columbia

Table 3.7 lists macrofungus species collected in this study, which until now have not been reported for British Columbia in any publications, based on the information provided by Redhead (1997) and on a search of more recent literature. Most of the reported here species have been confirmed by Dr. Redhead, some were identified by Paul Kroeger, and others keyed according to scientific taxonomic literature.

5. Conifer Effect

5a. Species diversity and abundance

The majority of the EP 571 macromycota are rarely observed species, with about 80% of them (in terms of abundance) recorded only once in the two years. About 20% of the macromycota are common species, and these formed the bulk of total abundance. This pattern is true for the overall diversity (Fig. 3.1), as well as diversity within the individual conifer habitats (Figs. 3.2. – 3.5).

Of the total of 277 taxa found, the highest number was associated with Douglas-fir habitat (cumulative total of 142 species), and the lowest in red cedar plots (101 species). Within the four conifer groups the average number of species per plot ranged from 22 (cedar, 1998) to 37.67 (Douglas-fir, 1997), while the average abundance spanned between 64.5 (cedar, 1998) and 132.33 (Douglas-fir, 1997) observations (Table 3.8).

From the total of 95 genera, 19 contained more than three species, with the leading genus being *Mycena*. Table 3.9 compares genus diversity between the four types of conifer habitats using the number of species found within the larger genera. No entry was made where fewer than 3 species were found in order to elucidate the more obvious patterns. Of the 19 larger genera listed, 10 were found predominantly in only one type of habitat. Western red cedar had the highest number of such genera: *Clavulinopsis*, *Hemimycena*, *Hygrocybe and Hypholoma.*

5b. Species composition

Species composition differed amongst the four conifer habitats. Although the majority of macrofungal species were found in all the forest types, a number of the more common species showed a definite or exclusive preference for one conifer type or the other. These are referred to as indicator species. Table 3.10 characterizes each of the ecosystems in terms of their exclusive macrofungal communities. Sitka spruce was the preferred habitat for 11 species, including three in the genus *Lycoperdon*. *Lycoperdon perlatum* and *Lycoperdon pyriforme* occurred exclusively under Sitka spruce in two different sites. Douglas-fir had 13 possible indicator species, the most prominent being *Clavulina cristata* and *Clavulina*. Western hemlock was characterized by 10 species with the highest frequency in its habitat, including two in the genus *Micromphale*, *Russula atropurpurea* group, and three exlusive species: *Chroogomphus tomentosus*, *Lactarius*

uvidus, and *Phellodon atratus*. It is interesting to note that of the 9 species found predominantly in western red cedar, 4 were in the genus *Hygrocybe*.

5c. Analysis of Variance (ANOVA)

There was a significant effect of conifer species on the total number of mushroom species and on their abundance in 1997, and on the abundance in 1998, (but no effect in 1998 with respect to species number) (Tables 3.11 and 3.12).

The highest values for both variables were noted in Douglas-fir and the lowest values were recorded in western red cedar. Wide variation between the replicate plots was probably responsible for the non-significance of diversity differences in 1998.

ANOVA analysis was also performed using only the most common fungi. Based on the two year data for the 50 most frequently recorded species, we see a definite influence of conifer habitat on the abundance of macrofungi, and a weaker, but still significant, effect on species diversity (Tables 3.11 and 3.12). As above, the highest values were recorded for Douglas-fir and the lowest for western red cedar. There were no statistical differences between the two years.

5d. Ranking of conifer habitats

Overall, with most of the data, the total diversity and abundance of all macrofungi show the following order in the selected conifer stands, from highest to lowest (Table 3.8):

1 – Douglas-fir (Fd)
2 – Sitka spruce (Ss)
3 – western hemlock (Hw)
4 – western red cedar (Cw)

6. Site Differences

Tables 3.11 to 3.12 also show the results of ANOVA analysis including sites as the source of variation. Some site differences were detected with regards to mushroom abundance but not diversity. All comparisons of macrofungus diversity between the sites demonstrate no significant differences at $\alpha = 0.05$. There was a significant site effect on abundance of macrofungi in 1997 ($P = 0.0352$) but not in 1998 ($P = 0.0744$). Based on combined 2-year data for the 50 most common species (Table 3.11), site was not a significant source of differences in either abundance ($P = 0.1895$) or diversity (0.0762) of macrofungi. The general trends in site differences can be seen in Figures 3. 6. and 3.7. The greatest year- to- year variability in the total number of mushroom species as well as their abundance occurred at the Sarita Lake site.

Results of Detrended Correspondence Analysis (DECORA) support the possibility that the observed differences in macrofungus abundance could be caused by site characteristics. Figure 3.8 (year 1997) shows a strong influence of tree species (each of the 4 canopy types is in a different region of the plot). In Figure 3.9 (year 1998), the only pattern visible is, again, that of site demarcation. With a few exceptions, the plots can be separated into three groups, corresponding to: UK (plots 83, 84, 95, 98, 100, and 101) SL (plots 117, 126, 127, 119, 116) vs. FL (plots 22, 24, 25, and 23). The trend of site separation seen in Figures 3.9 is also present more or less in Fig. 3.10, ordination of all the plots based on soil nutrient analysis provided by Prescott et al. (2000) (see Appendix 2B).

7. Phenology

Species abundance ranged from 1 to 323 observations during the entire survey, which in terms of frequency corresponded to a range of < .01 % to 6.98%. With a few minor exceptions, macrofungi were found on all trips and in all plots. A vast majority occurred during September and October in both years (Figures 3.11 and 3.12). During these months the rising precipitation levels coincided with the rapid drop in temperature (Figures 3.13 and 3.14). In 1998, a small peak of fungal fruiting was detectable in June, followed by fairly unproductive July and August (Figure 3.12), the driest and the warmest months (Figures 3.13 and 3.14). The late spring "flush" was not observed in 1997, both spring and summer fructifications were rather suppressed, despite the wet spring (Figures 3.11 and 3.13).

In general, both years yielded similar abundance of macrofungi, i.e. 2449 observations in 1997, and 2195 observations in 1998, but differed in species composition (see Appendix 3A for species which were found both years). However, the species exhibiting the greatest abundance were almost the same each year.

Discussion

1.Quantitative results.

Overall, our results are consistent with those of Countess (2001) who found 301 species in an area of 3840 m^2 in 1997, and added that if his data from 1995 and 1996 autumn field trips were included the number of species would increase to 389. These numbers represent macrofungus diversity of 0.0784 – 0.1013 species per m^2. Our survey yielded 277 species or 0.0802 species per m^2.

We did not have sufficient data to generate an informative species accumulation curve or attempt any predictions with respect to the actual mycofloristic capacity of the area. What can be stated, however, is that 80% of all the species were found during the first year, 47% of the species repeated fructification the second year, and the second year survey contributed 20% of the total species count. The average diversity per plot was relatively

high at 0.3 species per m^2. For comparison, Kranabetter and Kroeger (2001) found an average of 0.217 species per m^2 in a hemlock-cedar forest of northwestern British Columbia. This universal method of expressing species diversity is seldom encountered in mycological papers and should be used more widely.

Countess (2001) reports a mean of 114 species in Douglas-fir dominated immature forest (38-49 years old). This number is much higher than the average of 34 species per plot of Douglas-fir in my study. The duration and intensity of survey, as well as the total area covered were quite similar between the two studies. The sampling method of Countess was quite different, more elaborate (with quadrats of different sizes within transects), and evolving throughout the duration of his study, and therefore his average values for Douglas-fir habitat are hard to compare to mine. Countess (2001) does not seem to report the actual numbers of species (cumulative richness) for the different age groups of his Douglas-fir stands. In my study the average number of species per plot in all four conifer habitats is markedly lower than the total species richness within the given habitat (e.g. 34 versus 142 for Douglas-fir), which suggests that at least some, if not all, of the replicate plots contributed different species.

My results are not surprising and not incompatible with our knowledge about mushroom occurrence, although the species richness is higher than the numbers reported by other Canadian investigators. Villeneuve et al. (1989) did a 2 year survey of comparable size area in the Laurentide Mountains of Quebec, and found 48 and 58 macrofungus species in Balsam fir and red spruce, respectively. The ectomycorrhizal component constituted

26 –30 % of the macromycota in those stands. The reason for the higher richness in the stands I studied could be the different host trees, the earlier seral stage of the forest (enhanced by the old growth remnants of stumps and logs), and the relatively unspoiled environment on Vancouver Island (low pollution levels, low human population levels).

Generally, more mycological data are available from Europe than from North America. Arnolds and de Vries (1993) summarized long term records from 11 European countries to generate a list of 611 red listed macrofungal species from temperate coniferous forests.

Typically, biodiversity surveys tend to center on one or two types of conifer habitat. Scots pine was studied extensively in Netherlands (Termorshuizen, 1991), in Norway (Sastad, 1995), and, along with Norway spruce, in Finland (Ohenoja and Koistinen, 1984) and Sweden (Wasterlund and Ingelog, 1981). Garbaye and Le Tacon (1982) reports 40 species from spruce (*Picea excelsa* Link.) plantations in France, with 35% of them being mycorrhizal. These numbers compare to the average values for Sitka spruce plots, but, as noted before, the cumulative number of species in spruce habitat in our study was three times higher.

Direct comparison with other studies is very difficult because of missing information about the parameters, differences in area sampled, climatic conditions, forest stand, and so forth, as is evident from the comparison in Table 3.13. Furthermore, some macrofungal surveys focus primarily on ectomycorrhizal species (Termorshuizen, 1991; Bills et al. 1986), or on edible species only (Ohenoja and Koistinen, 1984). This is

probably due to the higher commercial interest in them, and partly because they form larger and more noticeable fruiting bodies than the usually inconspicuous saprobes, such as species of *Mycena*, *Marasmius*, or *Galerina* (Arnolds and de Vries., 1993).

Nevertheless, diversity and frequencies found in this study, as well research in other temperate regions (Table 3.13), suggest, that our survey was very thorough, and yielded a fairly good representation of the habitat specific macromycota.

2.Species composition

Many of the species found in this study have been reported previously in literature as fruiting in conifer plantations of temperate regions. The study which shares the highest number of species with ours, is that by Wasterlund and Ingelog (1981). Their studies of "larger fungal fruit bodies" in 15 year old spruce and pine plantations, with and without logging waste, yielded 44 of the same species, including 10 *Mycenae*, and covering 27 genera.

The authors who include litter decomposing fungi in their macrofungus surveys, inevitably mention the genus *Mycena* with at least several species (Wasterlund and Ingelog 1981, Senn-Irlet and Bieri 1999), followed by *Marasmius* and *Galerina* with usually fewer species. This is not necessarily because they are the most abundant taxa, or

because of their competitive hierarchy as that described by Newell (1984) and Frankland (1984).

The preponderance of *Mycena* in this study is most likely caused by its preferred habitat. Sitka and other spruce species have been reported to support either a high diversity of *Mycena* or high numbers of its sporocarps (Delzenne Van Haluvyn, 1972; Dighton et al. 1986, Senn-Irlet and Bieri 1998). In this study the most striking gregarious fructifications were those of *Mycena tenax* in Sitka spruce stands, especially those in Upper Klanawa. I have not found any reports of this phenomenon elsewhere. Frankland (1998) talks about *Mycena galopus* frequently growing in troops on needle litter of Sitka spruce in the English Lake District. She also points out that the same fungus forms only solitary basidiomata in deciduous and mixed forests, such as those dominated by *Quercus*. Frankland (1998) ascribes the difference in the growth habit of this fungus to continuous deep bed of needle litter in the Sitka spruce, versus discontinuous recources in decidous or mixed woodlands.

Overall, the area and stands studied support a relatively small number of dominant, abundant species, and a large proportion (circa 80%) of uncommon ones. Several authors comment on genera *Russula, Cortinarius*, *Inocybe*, or *Lactarius*, as being frequently the dominant genera, especially in climax type coniferous forests, both in old growth, and in mature plantations (Dighton et al, 1986). These genera, also well represented in our plots, have a very wide range of mycorrhizal hosts including conifers and broadleaf trees

(Trappe, 1962; Breitenbach and Kranzlin, 1984 -1995) and thus are likely to occur with them, throughout the hosts' geographical range.

3. Guilds

Despite the overwhelming numbers of *Mycena*, as well as the dominant nature of *Cantharellus formosus* and *Clavulina cristata*, the guild structure observed was not unusual or unexpected for temperate coniferous forests. The higher ratio of general and/or litter decomposers to ectomycorrhizal fungi has been previously reported. Wasterlung and Ingelog (1981) reported that, in a wet year, the fruit bodies of mycorrhizal fungi comprised about 50% of the weight of the total production, but only 10% in a dry year. Countess (2001) and Sastad (1995) calculated that saprobic species constituted 53% and 51.5%, respectively, of the communities they studied. Most other estimates of saprobic guild component are in the range of 60% - 70% (Garbaye and Le Tacon, 1982; Ohenoja and Koistinen, 1984; Villeneuve et al., 1989). Though litter quality as well as quantity tends to be higher in hardwood forests, the proportion of ectomycorrhizal fungi (circa 30%) seems to remain the same.

The proportion of wood decomposing fungi found in this study was fairly high (22%) in comparison to 6% reported by Sastad (1995) fom central Norway, and it was slightly higher than that of 18.5% in the study by Countess (2001). Villeneuve et al. (1989) reported 17 saprobic species out of 58 macrofungus species (29%), and also found a higher ratio of lignicolous to humicolous fungi than I did. The proportion of general

decomposers in my study corresponds to the proportion of 'other saprobes' of Countess (2001). Overall, the EP 571 macromycota showed a fairly balanced distribution of species within the different ecological groups.

4. New reports for British Columbia

Macrofungi of British Columbia are sparsely documented, with many collections awaiting taxonomic confirmation, entry into herbarium databases, etc. All published records of individual species or groups, as well as all recognized sources of information on the province macromycota have been outlined by Redhead (1997). In his paper Redhead consolidated all the published records and produced comprehensive listings of all the species (circa 1250), while stating at the same time that the lists are incomplete since even some common species have not yet been documented in the literature yet.

Of the 277 macrofungal species found in this study 34 have not been reported for British Columbia. They are: *Amanita farinosa* Schw., *Clavaria atkinsoniana* Leather, *Clavulina rugosa* (Fr.) Schroet., *Clavulinopsis subtilis* (Fr.) Corner, *Clitocybe ditopus* (Fr.:Fr.) Gill., *Clitocybula abundans* (Peck.) Sing., *Cortinarius decipiens* Fr., *Cortinarius junghunii* Moser, *Cortinarius renidens* Fr., *Cudonia grisea* Mains, *Cyptotrama chrysopeplum* (Berk. & Curt.) Singer, *Entoloma lividoalbum* (Kuhn. & Romagn.) Kubicka, *Entoloma trachysporum var. purpureo-violaceum* Largent, *Galerina cerina* A.H. Smith & Singer, *Galerina philipsii* Smith & Hesler, *Galerina pteridicola* (Smith) Smith & Hesler, *Geoglossum* sp. *affin. umbratile*, *Hydropus marginellus* (Pers.:Fr.) Sing., *Inocybe cookei*

Bres., *Inocybe eutheles* (Berk. & Br.) Quel., *Lactarius ligniotus var. canadensis* Smith & Hesler, *Lactarius olivaceoumbrinus* Hesler & A.H. Smith, *Leptonia albinella* Peck, *Marasmius sp. cf. wynnei* B. & Br., *Mycena alnetorum* Favre, *Mycena filopes* (Bull.:Fr.) Kumm., *Mycena maculata* Cleland, *Mycena* sp. (see comment below) *Naucoria sp. affin. pseudoamarescens* (Kuhner & Romagn.) Kuhner & Romagn., *Nolanea proxima* Largent, *Phellodon atratus* K.A. Harrison, *Podostroma alutaceum* (Pers. ex Fr.) Atk., *Russula farinipes* Romell.

Phaeocollybia phaeogaleroides Norvell, a new record for British Columbia, was described and reported by Norvell (2002) based on the specimen found in this survey.

With the exception of *Entoloma trachysporum* var. *purpureo-violaceum*, *Marasmius* sp. cf. *wynnei,* and *Mycena filopes* none of the newly reported species occured in significant quantities in this survey, the majority found on only one occasion.
Mycena filopes, *Mycena* sp, and *Mycena maculata* are included in the working draft of Redhead's key to the 'Pacific Northwestern and British Columbian Mycenoid Agarics' (Redhead, personal communication).

Mycena sp. is most likely a new species, briefly described by Redhead (unpublished draft, personal communication) as follows: '{unusual microscopic species} Pleurocystidia conspicuous and with dense contents (subrefractive), completely smooth, and narrowed at apex and the cheilocystidia very different, coralloid-diverticulate, forming a sterile band {plain small greyish brown species with broad lamellae, on

needles, similar to *M. latifolia*}..... *Mycena pseudolatifolia* sp. nov. ? Renata Outerbridge'.

5. Conifer influence

5a. General comments

Statistical analysis of the data shows that there are differences between conifers with respect to macrofungus diversity, abundance, and distribution within ecological guilds. Published evidence to support the differences is scattered throughout various studies, often dealing with only one or two of the above variables (Wasterlund and Ingelog 1981, Villeneuve et al. 1989, Dighton and Mason, 1985; Dighton et al. 1986). The merit of this study lies in the indepth treatment of macrofungus richness, composition, and guild structure within different conifer habitats.

Our results suggest that Douglas-fir maintained the highest diversity and abundance of macrofungi, and was followed by Sitka spruce, and western hemlock. Western red cedar supported the lowest overall macrofungus community. In general, our findings are compatible with preliminary observations made on one of these sites by other researchers (Berch et al. 2001). Based on initial assessment of macromycota in Upper Klanawa, Sitka spruce and Douglas-fir were overwhelmingly more productive than western red cedar (western hemlock plots were not included in that assessment). Kranabetter and Kroeger (2001), though focusing on mushroom response to partial cutting, also comments on

some evidence that western red cedar has a negative effect on average taxon richness. Indirect evidence, such as lists of mycorrhizal fungi known or suspected of forming association with the various conifers (Trappe, 1962; Trappe, 1963), or notes on preferred habitat of the saprobic species (e.g. in Smith 1947; Breitenbach and Kranzlin, 1984-1995; Arora, 1986; Phillips, 1991), also supported our data.

While ectomycorhizal mushroom richness and abundance were found to be comparable between Sitka spruce, Douglas-fir and western hemlock, the respective species compositions were quite different, suggesting various host- fungus specificities. Some overlap of ectomycorrhizal species did occur and involved various species, mainly from such genera as *Cantharellus*, *Russula*, *Cortinarius*, *Inocybe*, or *Lactarius*, which are known to have a very wide geographical distribution.

5b. Sitka spruce mycota

Sitka spruce habitat was most distinct from all the others. Its understory vegetation was almost non-existent, the forest floor seemed uniformly covered with a substantial layer of needles, and the canopy was closed in all the plots, creating an overall atmosphere of darkness and humidity.

Starting in late summer, providing sufficient moisture was present, the most conspicuous fungal fruitings in Sitka spruce stands were those of *Mycena*. A total of 45 species were identified from the spruce habitats, though the most spectacular ground cover was

consistently formed by *Mycena tenax* (Plate 2). This species belongs to the section Typicae, is medium brown , fairly robust (in comparison with most *Mycenae*), and generally "nondescript". Its gelatinized gill edge, separable from the gill tissue with the aid of a knife or a pin, is a useful feature for the species identification in the field. The stem of this species is pronouncedly viscid and its smell is cucumber-like, but these characteristics might not be detectable in dry weather. Other Mycena species very conspicuous in Sitka spruce habitat (but not exclusive to it) are *M. rosella*, *M. aurantiidisca*, *M. galopus*, and *M. oregonensis* (Plates 3, 4, 5, and 6).

In no other habitat in this study did *Mycenae* form such extensive fructifications. Consistent encountering of these large clusters (hundreds of fruiting bodies per $9m^2$ subplots), might lead us to suspect that Sitka spruce somehow creates more ideal conditions for the growth of *Mycenae* than the other conifers. A closer look at the data, however, does not support such a theory (Douglas-fir had just as many *Mycena* species), nor does it indicate that Sitka spruce supports higher diversity of saprobic fungi in general (Douglas-fir and western red cedar supported more). One might argue that our experimental design put certain constraints on diversity measurements by not allowing for clustered growth to enter into the equation (i.e. a cluster of 100 fruiting bodies of the same species within a subplot would still count as only 1 observation). This raises an interesting issue. Bruns (1995), in his treatment of ectomycorrhizal fungi, distinguishes two components of "diversity": richness, the number of species, and evenness, the abundance of individuals by species. He then reduces diversity to species richness only, based on the fact that individuals are seldom identified in mycorrhizal reasearch, thus

evenness being highly speculative. I would like to extend this line of reasoning past the ectomycorrhizal fungi, and apply it to most, if not all, fungi.

The technical nature of our survey did not allow us to determine the exact extent of fungal individuals. Indeed, it would take a few more research projects to determine and to map the different fungal genets involved. Sufficient to say (and in defence of our methodology), that, whether only 1, or more genets of *M. tenax* filled the subplots, it does not affect the actual measure of diversity. Overall, species richness of saprotrophic fungi under Sitka spruce was at best comparable to that of the other conifers.

Notwithstanding the issue of Mycenae, Sitka spruce habitat was also visibly identifiable at two sites by the consistant fruiting of three species of *Lycoperdon*, and at three sites by a rather obscure, but certainly abundant Ascomycete, *Podophacidium xanthomellum* (Plate 7). *P. xanthomellum* was only observed on or in the immediate vicinity of what appeared to be burnt wood or soil. I assume these burnt patches are remnants of the 1961 site preparation, so it is interesting to see its long -term effects.

5c. Douglas-fir mycota

Klinka et al. (1984) report the highest growth of trees in Douglas-fir plots in an ecological analysis for the same area (project EP571), and recommends a greater role of this conifer on these sites. According to a compilation of mycorrhizal associations of trees (Trappe, 1962), Douglas-fir is symbiotic with the largest number of fungi.

With its semi - closed canopy, and low to medium understory vegetation, composed of a variety of herbaceous and shrub plants, Douglas-fir seems to provide favourable conditions not only for ectomycorrhizal fungi, but for the saprobes as well. As many as 30 species of *Mycena*, 6 species of *Galerina*, and 4 species of *Clitocybe*, were collected in the plots. The most striking preference for this type of habitat, however, is that of *Clavulina cristata* (Plate 8). Its white and extensively branched fruiting bodies grew abundantly on the forest floor and filled some subplots entirely, similar to the way *Mycena tenax* did, in Sitka spruce plots. Perhaps, the fact that several species of *Clavulina* were found under all the conifers except the VAM forming cedar suggests that this genus is mycorrhizal rather than merely terrestrial.

In comparison with the other host conifers, Douglas-fir yielded a surprisingly low number of *Cortinarius* species, but featured instead numerous *Inocybes* and *Russulae*. Four species of fungi appeared consistently unique to Douglas-fir: *Cudonia monticola*, *Collybia confluens*, *Clitocybe sp.* affin. *ditopus*, and *Hygrophorus pratensis*. Their overall numbers, however, were not very high, so the preference is suggested here only tentatively.

5d. Western hemlock mycota

Coastal western hemlock is widely distributed and abundant in the Pacific Northwest. *Tsuga heterophylla* and *Abies amabilis* are the dominant climax conifers of the low

elevation rainforests along the coast. Hemlock seedlings are frequently found on rotten logs, or partially decomposed forest litter. It regenerates well and grows rapidly, as it thrives in shade and in full light (Farrar, 1995). In our sites, western hemlock formed well structured stands most similar to those of Douglas-fir.

Perhaps the greatest similarity between the two conifers was the high number of chanterelles, *Cantharellus formosus*, found in their stands. Undoubtedly, western hemlock revealed itself in this study as an ideal host for this commercially important edible mushroom (at least at this seral stage). This is supported by a study of chanterelle productivity in the Queen Charlotte Islands (Peterson et al., 2000, unpublished report). In contrast to Trappe (1962), western hemlock had more ectomycorrhizal fungi than Douglas-fir. Several of the mycorrhizal fungi were found to associate preferentially with hemlock: *Hydnum repandum* (the hedgehog mushroom), *Russula atropurpurea* group, *Lactarius scrobiculatus*, *Inocybe eutheles*, and possibly exclusively: *Chroogomphus tomentosus*, *Lactarius uvidus*, and *Phellodon atrium*. Nine species of *Lactarius* and as many as 12 species of *Cortinarius* were included in hemlock mycota. We also identified a representative of *Phaeocollybia*, a genus related to *Cortinarius*. Two fruiting bodies of this species only recently reported from Canada (Norvell 1998), *Phaeocollybia phaeogalleroides*, were found during the survey, one under hemlock, and the other under Douglas-fir.

Entoloma trachysporum var. *purpureo-violaceum* was found predominantly in western hemlock habitat. Certain plots of western hemlock were also inhabited by troops of the

saprobic *Micromphale perforans*, but only 18 species of *Mycena* were identified from the stands. Closer look at the species composition reveals relatively low diversity of litter decomposing fungi. That is why, despite its great mycorrhizae forming potential, hemlock rated third in the overall diversity comparison.

5e. Western red cedar mycota

While Sitka spruce plots were distinguished by a lack of understory vegetation, at the other end of the spectrum were western red cedar stands. Here, the most common plant associate, *Gaultheria shallon* Pursh (salal), formed dense thickets throughout, making the sampling of fungi most time consuming. Other common shrubs growing under cedar were: *Rubus spectabilis* Pursh (salmonberry), *Vaccinium parvifolium* Smith (red huckleberry), and juvenile western hemlock.

Despite the difficulties with sampling, our close investigation of the cedar forest floor revealed a substantial number of macrofungi. Since western red cedar forms only vesicular-arbuscular mycorrhizae its macrofungus diversity consisted almost entirely of saprobic taxa. These included as many as 22 species of *Mycena*, and 7 species of *Galerina*. The *Mycenae* found under cedar were mostly solitary types, e.g. *Mycena amicta* (the most frequent fungus under cedar), or *Mycena olivaceobrunnea* (although reported to grow gregariously in other areas by Arora, (1986)), and some were also fairly uncommon for this area. Three species of *Hemimycena* were also identified in association

with western red cedar habitat. Two of them, *H. albicolor*, and *H. pseudocrispula* colonized exclusively fallen cedar twigs. *Galerina badipes* (Plate 8) was the most frequently encountered representative of the genus. It can be recognized in the field by its solitary growth on humus, medium stature, opaque brown, helmet shaped cap, and a scurfy stem. Another commonly encountered species was *Galerina vittaeformis* (Plate 9) usually found on moss- covered logs, a typical habitat for the many small *Galerinae*.

Perhaps the largest terrestrial saprobes unique to western red cedar plots, were four species of the genus *Hygrocybe*. Of those, *Hygrocybe laeta* was the most abundant. Its large, somewhat "floppy" or frilled cap can vary considerably in colour, between orange and purple, but the cartilagenous, and extremely slippery stem, is unmistakable. More curiously, a possible association (or indirect association?) of *Cordyceps* and cedar habitat has been observed. However, since only a total of 9 fruiting bodies of this entomopathogenic genus have been found during the whole study (7 buried in cedar forest floor), it might be too early to claim the relationship.

Western red cedar plots yielded minimal fruiting of a few mycorrhizal species, in comparison with the other conifer plots, thus confirming the general belief that red wood conifers do not form ectomycorrhizal associations. The occasional fructifications of *Cantharellus formosus*, *Phylloporus rodoxanthus*, or a *Lactarius* occurred either on the edges of the plots, or within plots highly overgrown with salal, *Goultheria shallon*, as well as those containing some volunteer trees of other species (mostly young hemlock). We conclude therefore that proximity of hemlock stands and their encroachment was

most likely responsible for the growth of mycorrhizal fungi in cedar plots. Some macrofungi "associated" with conifers in this study, e.g. *Phylloporus rhodoxanthus* and *Hygrophorus cantharellus* (here *Hygrocybe* after Breitenbach and Krunzlin, 1991) found in cedar plots, are reported from hardwood forests by others (Bills et al., 1986), which further suggests the influence of understory shrubs.

Led by a popular motto: "Nothing grows under cedars" local mycophiles frequently avoid looking for fungi in the vicinity of these magnificent trees. Our research shows that the assumption of macrofungal 'desert' in western red cedar habitat is unjust. Overall, considering cedar's known antifungal properties (Minore, 1983) and the expected strong allelopathic potential, it was surprising to observe the still impressively rich macromycota in its understory. However, an enhancing role of the remaining legacy substrates from the previous forests cannot be excluded.

6. Site differences

Site characteristics such as soil type and moisture level can have a pronounced effect on fructification of macrofungi (Lange, 1993; O'Dell et al., 1999). In this sudy site differences played a less significant role than conifer species. However, had we used α = 0.1 for the ANOVA analysis as Countess did (Countess, 2001), there would have been significant site effect on the total number of mushroom species in both 1997 and 1998, and with the years combined. Based on the two year data, Upper Klanawa had the lowest

diversity and Fairy Lake had the highest, which suggests a gradient of diversity negatively correlated to soil richness and moisture.

The highest and lowest value sites were not the same for both years, however. This could be caused by the fact, that Sarita Lake is located on the steepest slope and would be more affected by a dry spring, while Upper Klanawa is flatter , located at the valley bottom, and subject to flooding during November rains and following a snowy winter or rainy spring. Additionally, the fact that Sarita Lake had the highest number of species in 1997, but the lowest number of species in 1998, might serve as further evidence that many macrofungi produce fruiting bodies biannually, or every few years (Carroll and Wicklow, 1992). Perhaps that particular site supports a higher proportion of such fungi.

Certain year- to- year differences could also be explained by the weather patterns. Summer and fall temperature and precipitation, as well as mean monthly temperatures during preceeding winters, were significantly different for the 1997 and 1998 growing seasons. Consequently, we found a significant site effect on the abundance of all fungi in 1997 (sufficient moisture), but not in 1998 (drier year, which lowered the overall diversity of mushrooms). O'Dell et al. (1999) studied species richness and abundance of ectomycorrhizal basidiocarps on a moisture gradient in a *Tsuga heterophylla* forest in Washington state. Their results also suggest that species richness can be partly explained in terms of environmental gradient, with a unimodal (hump-shaped) distribution with respect to precipitation.

7. Phenology

An important factor in year to year variation in species diversity and abundance is the weather. The climatic conditions during and preceeding the mushroom seasons were different for 1997 versus 1998 (Tables 2.2 and 2.3). In 1996/7, the cold and snowy winter was followed by a relatively wet spring and summer. The 1997/8 mild winter was followed by a hot spring and dry summer. This was reflected by the second years' diminished fruiting of drought sensitive, surface dwelling litter decomposers. Insufficient moisture during summer is a well documented factor in postponed and reduced mushroom crop in the fall. Notwithstanding the environmental conditions, it is well known that many species of macrofungi do not produce fruiting bodies, or at least not in the same quantities, on an annual basis (Carroll and Wicklow 1992). This is of particular relevance to commercially important species. Casual long term field observations on the Queen Charlotte Islands suggest that *Cantharellus formosus* "is on a two-year cycle", while *Boletus edulis*, apparently, fruits prolifically only every four years (Brian Eccles, personal communication). Perhaps the phenomenon should be studied more closely to exclude the possibility that, in fact, it is the weather pattern which is cyclic, and the relation to fungal fruiting is indirect. It seems likely that some environmental factor is causal.

Some species occurred consistently during springtime only, mainly Ascomycetes, such as *Plectania melastoma*, *Cordyceps spp.*, *Vibrissea truncorum*, *Cudonia spp.*, while many others, especially ectomycorrhizal basidiomycetes were probably stimulated by the cold

weather onset in October. This is consistent with work of Luoma et al. (1991), who found that sporocarp production of hypogeous Ascomycetes in Oregon was higher in the spring than in the fall. *Mycena amicta* was recorded throughout the whole season and was in fact the most frequently observed macrofungus in this study.

8. Mixed vs. pure forest plantations

Surveys of macrofungi, or any other group of forest organisms for that matter, in single tree species plantations raise a natural question: Do monocultures impoverish forest biodiversity? In Chapter One I reviewed some literature on the subject of mixed forests versus pure plantations, introducing some important concepts, such as spatial and temporal linkages, or competition and species replacement in forest ecosystems. Scientific evidence accumulates that mixed forests indeed create more habitats, which generate higher biodiversity than that found in forest monocultures (Kelty et al., 1992).

The results of my study suggest, that in the area of southern Vancouver Island covered by this project, the idea might hold true. The following arguments might be used in it's support:

In each of the four types of conifer habitat the cumulative macrofungus diversity was considerably lower than the total diversity for the whole area surveyed in this study. In the case of western red cedar the ratio was almost 1:3; At the other end of the spectrum, Douglas-fir contributed over ½ the species to the overall mycoflora. In each type of

monoculture there were unique species, i.e. restricted to one conifer, with many more species, and some genera, being very characteristic for a given habitat. Pure stands of western red cedar do not support the growth of ectomycorrhizal fungi, thus eliminating at least 30% of the local macrofungus diversity. Some macrofungi, normally associated with one type of habitat will tolerate the presence of other conifers (for example the ectomycorrhizal fungi which produced sporocarps in 'impure' cedar plots), or will use other conifers as their host (for example *Clavulina cristata* normally very characteristic of Douglas-fir forest, was occasionally spotted in Sitka spruce, and *Mycena tenax*, almost unique to Sitka spruce, produced a few fruiting bodies in a Douglas-fir plot).

It is possible that some fungi would be discouraged from fruiting in a mixed forest scenario, perhaps affected by various allellopathic interactions among the trees. I would certainly expect their pattern of fruiting to be changed. For example, I have never seen such dense and extensive fruiting of *Mycena tenax* or *Podophacidium xanthomellum* in local forests, as those in the pure Sitka spruce plots in my study. Similarly, if I was a commercial harvester of chanterelles, I would look for them in Douglas-fir-hemlock or spruce –hemlock stands, before I would invest my time in a cedar dominated forest.

Notwithstanding mushroom abundance, however, to maximize mycological diversity, trees of different species should be interplanted. Based on my analysis, there is a lot of overlap in macofungus biodiversity between the four conifer habitats, suggesting wide species adaptability and habitat flexibility. However, should any one of the conifers be cultivated in extensive 'pure' monoculture (fortunately, pure stands do not happen easily

in the Pacific Northwest), the biodiversity of macrofungi would almost certainly be vastly compromised. If plantations have to take place, then I would suggest increasing the proportion of Douglas-fir trees in a mixed plantation. It might be even better to plant a Douglas-fir dominated forest, with 'pockets' of the other species interspersed, to allow for the establishment of the 'exclusive' macrofungi.

Tables and Figures

Table 3.1. Dominant macrofungal genera, number of species within them, and their total frequencies in study plots, based on two years of survey of four conifer habitats: Sitka spruce, Douglas-fir, western hemlock, and western red cedar.

Genus	Number of species	Frequency (%)
Mycena	45	40.76
Cortinarius	16	0.78
Lactarius	14	3.54
Russula	13	1.71
Inocybe	13	1.75
Galerina	10	2.96

Table 3.2. Total frequencies of the most common macrofungus species found during the 2-year survey across all tree species.

Species	Frequency (%)
Mycena amicta	6.98
Cantharellus formosus	6.39
Mycena metata	6.11
Mycena rorida	5.14
Mycena aurantiidisca	4.69
Mycena galopus	4.23
Guepiniopsis alpina	4.0
Clavulina cristata	3.74

Table 3. 3. Diversity and abundance of macrofungi in EP571 expressed in numbers of species and number of observations per m^2. Plot area = 144 m^2. Total area = 3456 m^2.

Site	Area	Diversity / m^2	Abundance / m^2
Upper Klanawa	Plot SS 99	0.2803	1.1111
	Plot SS 102	0.2778	1.5278
	Plot FD 98	0.3333	1.4167
	Plot FD 101	0.2986	1.5347
	Plot CW 84	0.1736	0.9167
	Plot CW 100	0.1736	0.8750
	Plot HW 83	0.3611	1.1875
	Plot HW 95	0.2292	0.9306
Sarita Lake	Plot SS 111	0.3750	1.6111
	Plot SS 119	0.2361	1.1458
	Plot FD 126	0.3611	1.2361
	Plot FD 127	0.3194	1.3403
	Plot CW 116	0.2639	1.2986
	Plot CW 123	0.2847	1.0625
	Plot HW 117	0.2431	0.8750
	Plot HW 121	0.3542	1.1736
Fairy Lake	Plot SS 36	0.3958	1.9236
	Plot SS 38	0.3403	1.4167
	Plot FD 18	0.4375	3.0278
	Plot FD 25	0.3819	1.9861
	Plot CW 23	0.2986	0.8611
	Plot CW 32	0.2222	0.7361
	Plot HW 22	0.3125	1.4792
	Plot HW 24	0.2500	1.1597
	Total Sitka spruce	0.1470	1.4572
	Total Douglas-fir	0.1655	1.7894
	Total western red cedar	0.1181	0.9595
	Total western hemlock	0.1424	1.1516
	Upper Klanawa	0.1050	1.1884
	Sarita Lake	0.1415	1.2526
	Fairy Lake	0.1424	1.5786
	All plots combined	0.0802	1.3394
	Average per plot	0.3	1.3263

Table 3. 4. Ecological groups of macrofungi and their relative proportions and frequencies over the whole period of study.

Ecological group	Proportion (% of species)	Frequency (% observations)
Litter decomposers	41.16	49.21
Ectomycorrhizal fungi	30.32	18.28
Wood decomposers	22.74	11.38
General decomposers	5.05	21.11
Entomopathogenic fungi	0.72	0.19

Table 3.5. Comparison of ectomycorrhizal and saprobic macrofungus frequency (as proportion of the species within the whole macrofungus community for a given conifer) and diversity (cumulative number of species for a given conifer) among the four conifer habitats.

	Ectomycorrhizal frequency	Ectomycorrhizal diversity	Saprobic frequency	Saprobic diversity
Sitka spruce	15.0 %	32	85.0 %	95
Douglas-fir	20.5 %	36	79.5 %	106
Western red cedar	7.9 %	22	92.1 %	102
Western hemlock	32.3 %	47	67.7 %	76

Table 3.6. Potentially rare species of macrofungi in immature, even- aged conifer plantations on Vancouver Island. Based on a two year survey of 35 year old stands in four different conifer monoculture forests.

Note: Included are fungi identified to species or affinity with only 1 observation recorded and several species which are known to be rare for this region (Redhead, 1997; Paul Kroeger, personal communication). Excluded are *Mycenae* (see Table 5.3.), taxa generally known to be fairly common in other areas on Vancouver Island, and taxa of yet uncertain identity.

Macrofungus species	Habitat	Substrate
Amanita farinosa	Ss, Cw	Ectomycorrhizal
Ascocoryne sarcoides	Ss, Fd	Litter, wood
Baeospora myosum	Ss	Litter
Callistosporium luteo-olivaceum	Ss, Cw	Wood
Chrysomphalina chrysophylla	Ss	Wood
Clavaria atkinsoniana	Ss	Litter
Clavulina ornatipes	Ss, Fd, Hw	Litter
Clavulina rugosa	Ss	Litter
Clavulinopsis subtilis	Cw	Litter
Clitocybe ditopus	Fd	Wood
Clitocybe lignitalis goup	Cw	Wood
Clitocybe sclerotoidea	Hw	Litter
Clitocybe sp. affin. *pseudodecolor*	Fd	Litter
Clitocybula abundans	Fd	Wood
Collybia racemosa	Cw	Litter
Conocybe sp.,*subgenus piliferae*	Ss	Litter
Cortinarius acutus gr.	Ss	Ectomycorrhizal
Cortinarius castaneus gr.	Hw	Ectomycorrhizal
Cortinarius cotoneus	Hw	Ectomycorrhizal
Cortinarius decipiens	Fd	Ectomycorrhizal
Cortinarius junghunii	Hw	Ectomycorrhizal
Cortinarius renidens	Hw	Ectomycorrhizal
Cudonia circinans	Fd	Wood
Cudonia grisea	Ss, Fd, Cw	Wood
Cudonia monticola	Fd	Wood
Cyptotrama chrysopeplum	Hw	Wood
Cystoderma amianthinum f. rogosoreticulatum	Fd	Litter
Dacrymyces stillatus	Ss	Wood
Dermocybe crocea	Fd	Ectomycorrhizal
Entoloma sinuatum gr.	Ss, Fd, Hw	Litter
Entoloma trachysporum var. *purpureo-violaceum*	Ss, Fd, Hw, Cw	Litter
Galerina cerina	Fd	Litter

Galerina philipsii	Fd	Litter
Galerina pteridicola gr.	Cw	Litter
Geoglossum sp., black	Cw	Litter
Hohenbouhelia sp.	Cw	Wood
Hydropus marginellus	Ss	Wood
Hygrophoropsis olida	Ss	Litter, wood
Hygrocybe cantharellus	Cw	Litter
Inocybe cookei	Ss	Ectomycorrhizal
Inocybe eutheles	Hw	Ectomycorrhizal
Inocybe idahoensis	Fd	Ectomycorrhizal
Lachnellula sp. c.f. *calyciformis*	Ss	Wood
Lactarius ligniotus var. canadensis	Hw	Ectomycorrhizal
Lactarius olivaceoumbrinus	Hw	Ectomycorrhizal
Lactarius pallescens	Ss	Ectomycorrhizal
Leptonia albinella gr.	Cw	Litter
Marasmius sp. c.f. *wynnei*	Fd, Hw	Litter
Naucoria sp. affin. *pseudoamarescens*	Cw	Litter
Nolanea proxima	Fd	Litter
Phellodon atratus	Hw	Ectomycorrhizal
Phaeocollybia pheogaleroides	Fd, Hw	Ectomycorrhizal
Pholiota decorata	Cw	Wood
Pholiota flavida	Fd	Wood
Pholiota scamba	Cw	Wood
Podostroma alutaceum	Ss	Litter, wood
Psilocybe pelliculosa	Cw	Litter
Ramaria flavobrunescens var. *aromatica*	Hw	Litter
Resinomycena saccharifera	Fd	Litter
Russula adusta	Fd	Ectomycorrhizal
Russula albonigra gr.	Ss	Ectomycorrhizal
Russula cyanoxantha gr.	Fd	Ectomycorrhizal
Russula farinipes	Ss	Ectomycorrhizal
Russula nigricans	Fd	Ectomycorrhizal
Russula occidentalis	Fd	Ectomycorrhizal
Suillus punctatipes	Hw	Ectomycorrhizal
Tyromyces chioneus	Hw	Wood

Table 3.7. New species records for British Columbia.

Amanita farinosa Schw.

Clavaria atkinsoniana Leather

Clavulina rugosa Fr.Schroet.

Clavulinopsis subtilis (Fr.) Corner

Clitocybe ditopus (Fr. :Fr.) Gill.

Clitocybula abundans (Peck.) Sing.

Cortinarius decipiens Fr.

Cortinarius junghunii Moser

Cortinarius renidens Fr.

Cudonia grisea Mains

Cyptotrama chrysopeplum (Berk. & Curt.) Singer

Entoloma lividoalbum (Kuhn. & Romagn.) Kubicka

Entoloma trachysporum var. *purpureo-violaceum* Largent

Galerina cerina A.H. Smith & Singer

Galerina philipsii Smith and Hesler

Galerina pteridicola (Smith) Smith and Hesler

Geoglossum sp. affin. *umbratile*

Hydropus marginellus (Pers.:Fr.) Sing.

Inocybe cookei Bres.

Inocybe eutheles (Berk. & Br.) Quel.

Lactarius ligniotus var. canadensis Smith & Hesler

Lactarius olivaceoumbrinus Hesler & A.H. Smith

Leptonia albinella Peck

Marasmius sp. cf. *wynnei* Ber. & Br.

Mycena alnetorum Favre

Mycena filopes (Bull.:Fr.) Kumm.

Mycena sp. nov.?

Mycena maculata Cleland

Naucoria sp. affin. *pseudoamarescens* (Kuhner & Romagn.) Kuhner & Romagn.

Nolanea proxima Largent

Phellodon atratus K.A. Harrison

Phaeocollybia phaeogaleroides Norvell

Podostroma alutaceum (Pers. ex Fr.) Atk.

Russula farinipes Romell

Figure 3.1. Dominance – diversity curve of macrofungi at EP 571 based on a two-year survey. Frequency decreases from left to right.

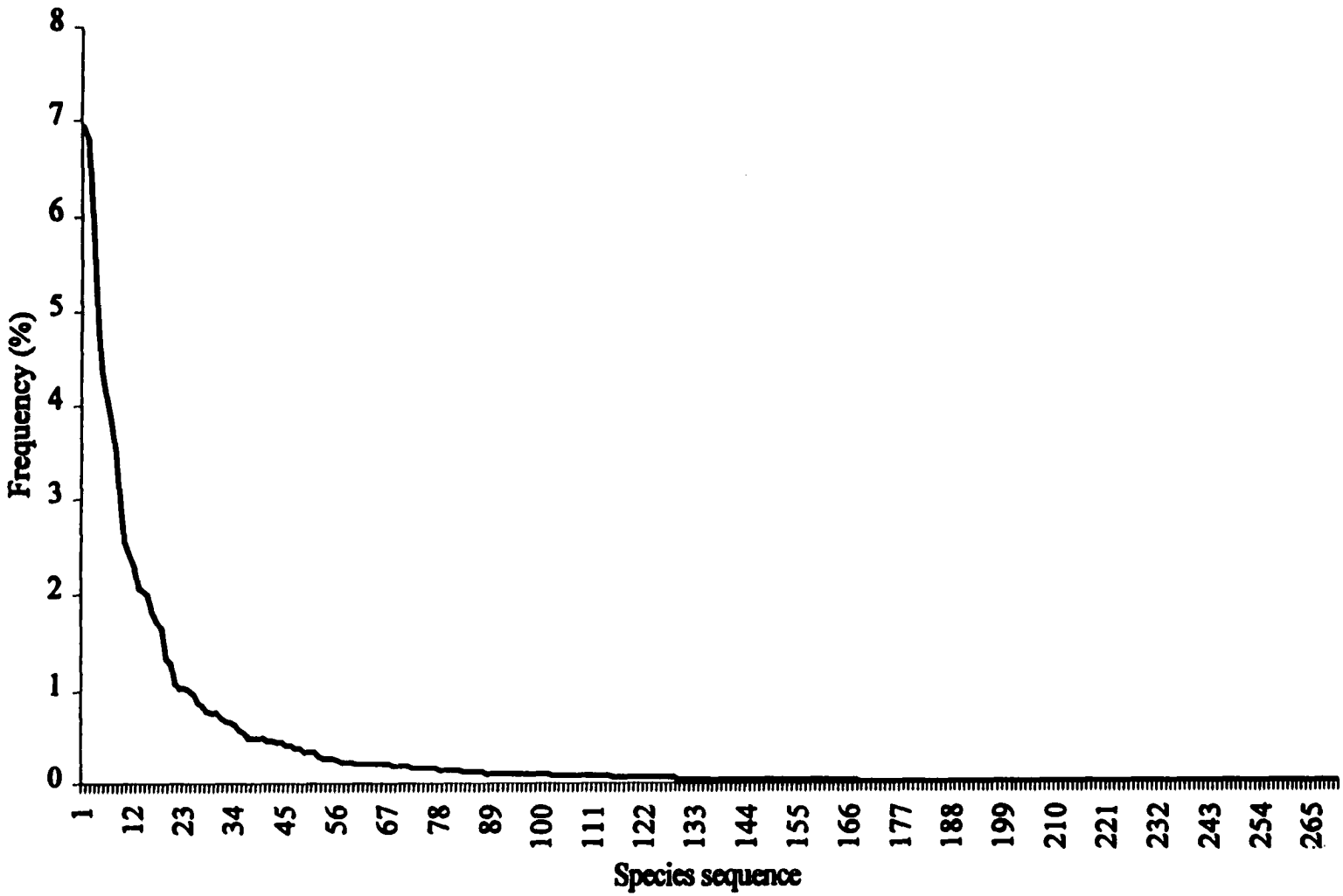


Figure 3.2. Dominance - diversity curve of macrofungi in Sitka spruce. Based on abundance data from 2 years

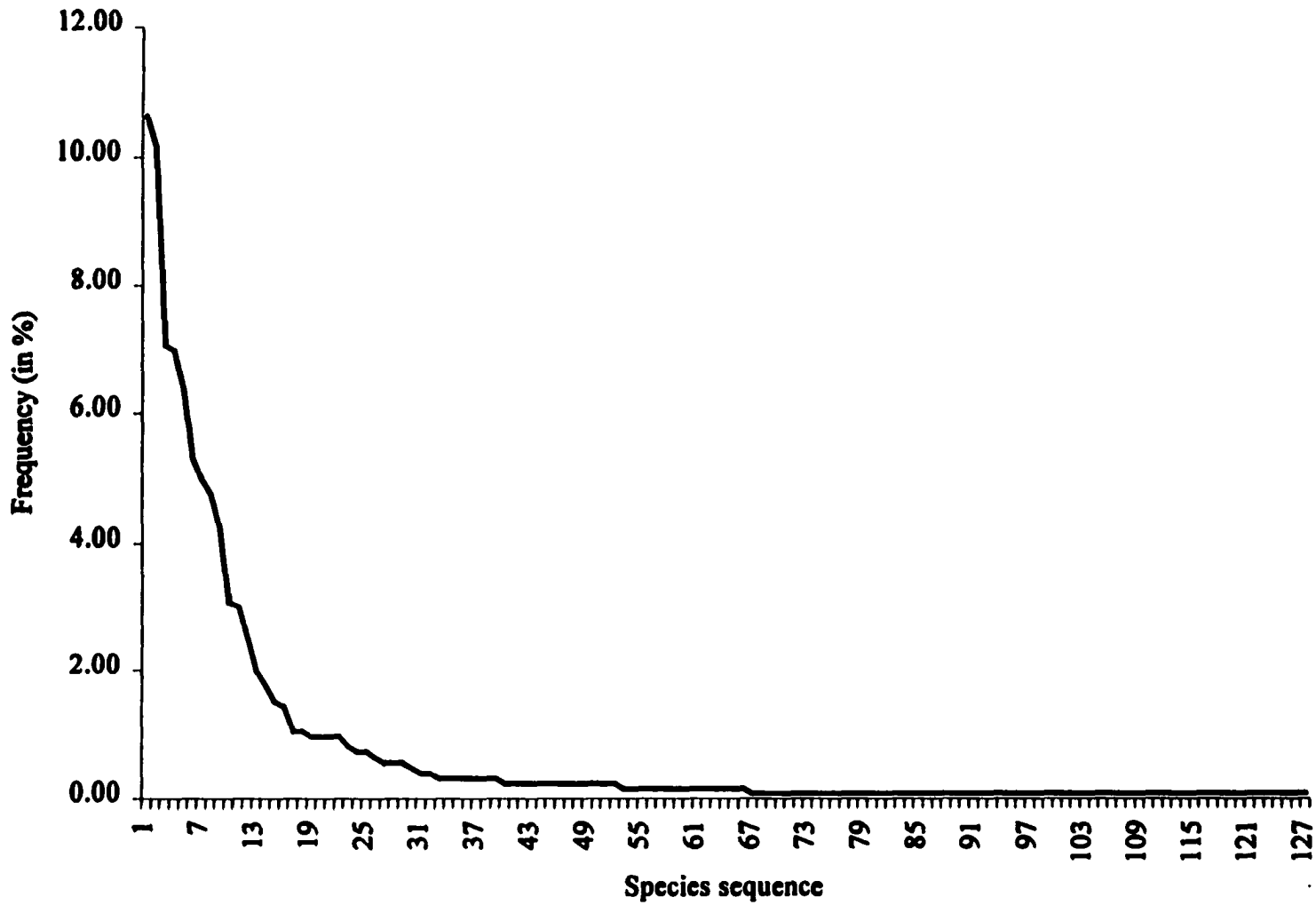


Figure 3.3. Dominance - diversity curve of macrofungi in Douglas-fir. Based on abundance data from 2 years

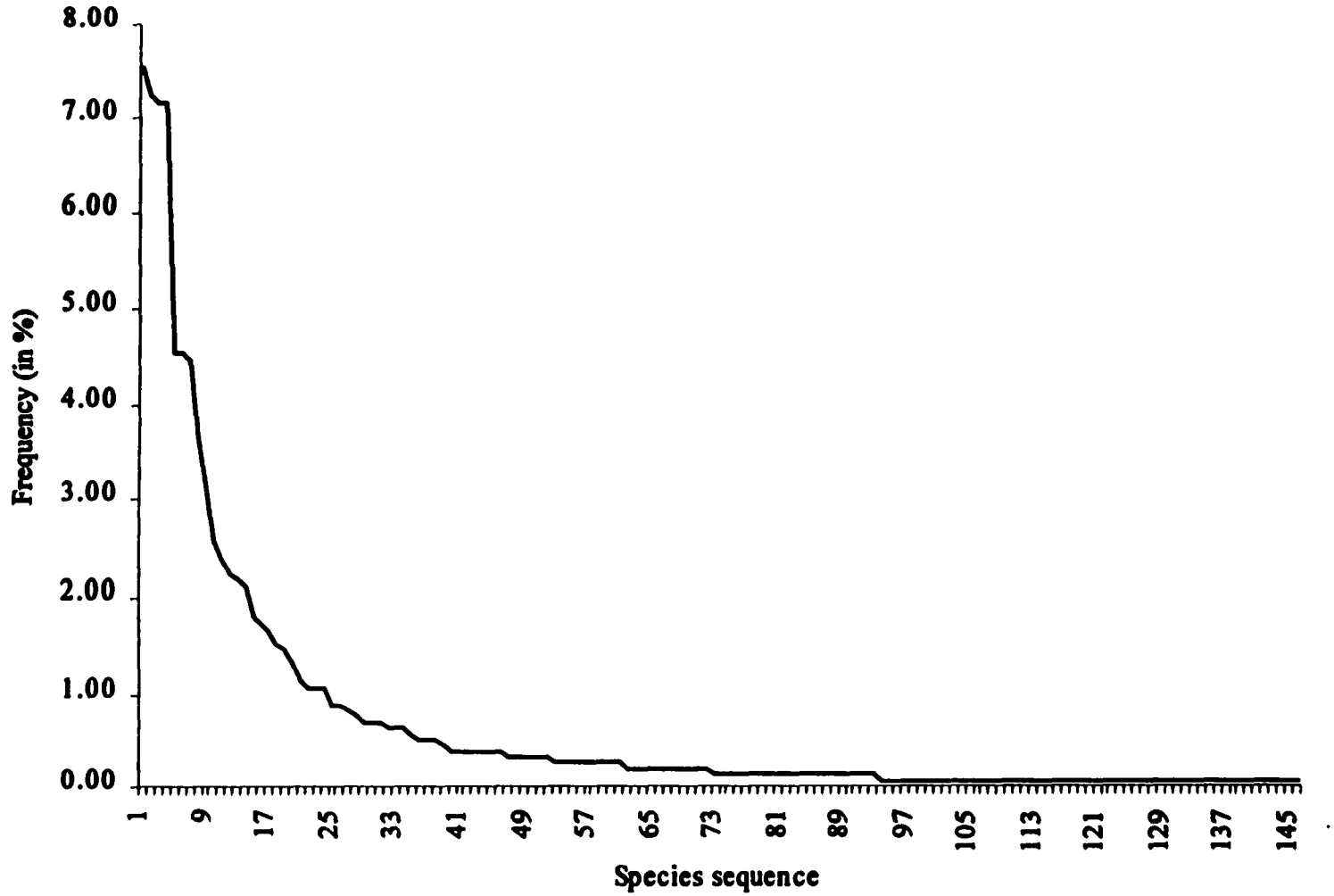


Figure 3.4. Dominance - diversity curve of macrofungi in western red cedar. Based on abundance data from 2 years.

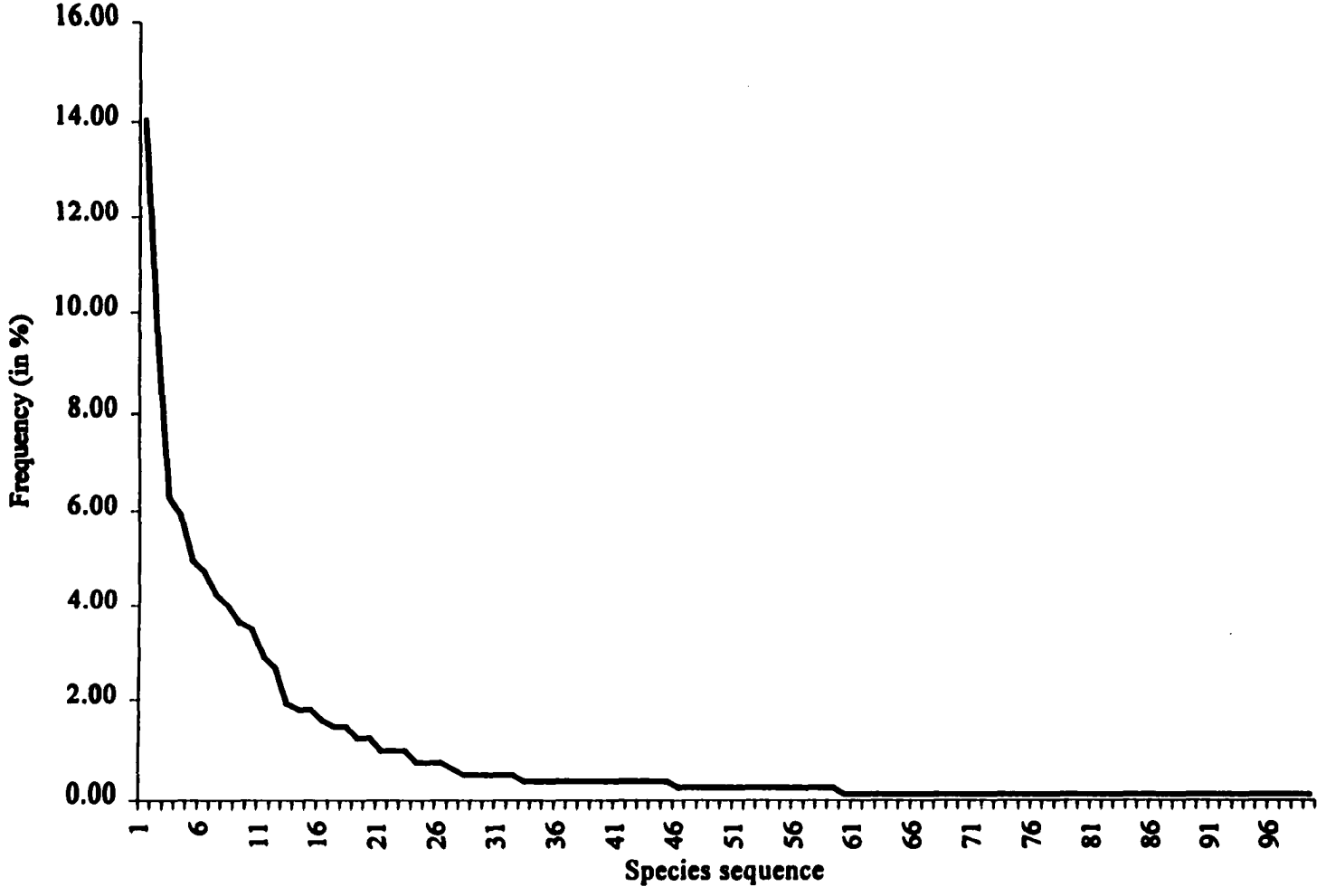


Figure 3.5. Dominance - diversity curve of macrofungi in western hemlock. Based on abundance data from 2 years

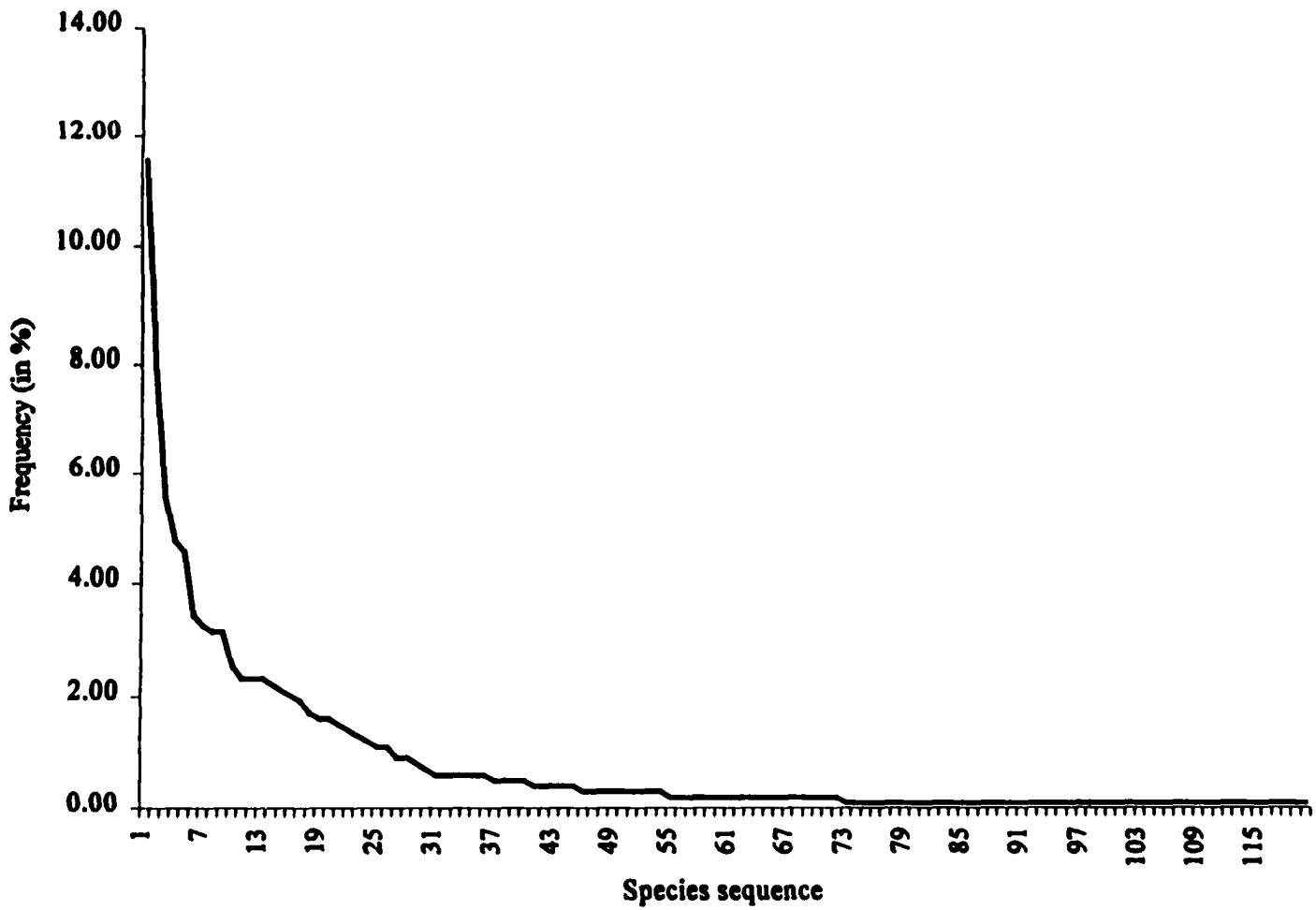


Table 3. 8. Comparison of macrofungus diversity and abundance amongst the conifer species for 1997 and 1998. Based on annual averages of the number of species and and the number of observations. Standard Deviations in brackets.

	1997 Average number of species	1997 Average abundance (observations)	1998 Average number of species	1998 Average abundance (observations)
Sitka spruce	33 (2.40)	116 (23.11)	26 (3.28)	96 (20.66)
Douglas-fir	38 (2.97)	132 (17.56)	30 (10.69)	125 (32.77)
Western red cedar	23 (6.12)	74 (8.70)	22 (4.69)	65 (13.61)
Western hemlock	31 (9.79)	86 (22.32)	24 (7.17)	80 (16.15)

Table 3.9. Comparison of genus diversity (number of species found within the larger genera) between the four types of conifer habitat. No entry = fewer than 3 species found.

Macrofungus genus	Sitka spruce	Douglas-fir	western hemlock	Western red cedar
Clavaria	3			
Clavulina	4	3	3	
Clavulinopsis				3
Clitocybe		4		
Conocybe	5			
Cortinarius	6	3	12	
Cudonia		3		
Entoloma	5	4	5	5
Galerina	3	6	5	7
Hemimycena				3
Hygrocybe				5
Hypholoma				3
Inocybe	7	8	4	
Lactarius	6	4	9	
Lycoperdon	3			
Mycena	27	30	18	22
Nolanea		3		
Pholiota		3		
Russula	5	8	4	

Table 3.10. Possible macrofungus indicators of conifer habitat. Lists of fungi found exclusively*, or predominantly (at least 75% of the total abundance for the species), in each of the four types of forest. Species listed in order of their abundance from highest to lowest. Rare fungi (recorded only once or twice) not included (see Table 3.6).

Sitka spruce	Douglas-fir	western hemlock	western red cedar
Mycena tenax	*Clavulina cristata*	*Micromphale perforans*	**Hygrocybe laeta*
Mycena rosella	*Clavulina cinerea*	*Russula atropurpurea* group	*Hemimycena albicolor*
Podophacidium xanthomellum	*Vibrissea truncorum*	*Hydnum repandum*	**Hygrocybe miniata*
Lycoperdon faetidum	*Omphalina ericetorum*	*Micromphale foetidum*	**Hemimycena* sp.
**Lycoperdon pyriforme*	**Cudonia monticola*	**Chroogomphus tomentosus*	**Geoglossum* sp. affin. *umbratile*
**Lycoperdon perlatum*	*Clavulina ornatipes*	*Entoloma trachyospermum* var. *purpureo-violaceum*	**Mycena olivaceo-brunnacea*
Inocybe sp. affin. *tigrina*	*Pseudohydnum gelatinosum*	*Lactarius scrobiculatus*	*Cordyceps militaris*
Inocybe fastigiata	*Russula bicolor*	**Lactarius uvidus*	**Hygrocybe virginea*
**Clavulina rugosa*	*Inocybe napipes*	**Phellodon atratus*	**Hygrocybe cantharelloides*
Mycena fusco-ocula	**Collybia confluens*	*Inocybe eutheles*	
Mycena abramsii	*Phylloporus rhodoxanthus*		
	**Clitocybe* sp. affin. *ditopus*		
	**Hygrophorus pratensis*		

Table 3. 11. ANOVA results for the effect of conifer species and site on diversity of macrofungi in 1997, 1998, with years combined, and with years combined for the top 50 most abundant species only. $\alpha = 0.05$. Significant tests in bold type.

	Source of Variation	SS	df	MS	F	P-value	F crit
1997	Conifer species	647.1250	3	215.7083	4.0540	**0.0333**	3.4903
	Site	346.0833	2	173.0417	3.2522	0.0744	3.8853
	Interaction	120.2500	6	20.0417	0.3767	0.8801	2.9961
	Error	638.5000	12	53.2083			
1998	Conifer species	227.4583	3	75.8194	1.5976	0.2416	3.4903
	Site	358.5833	2	179.2917	3.7779	0.0534	3.8853
	Interaction	333.4167	6	55.5694	1.1709	0.3828	2.9961
	Error	569.5000	12	47.4583			
Years combined	Conifer species	897.125	2	299.0417	4.731048	**0.02111**	3.4903
	Site	455.0833	6	227.5417	3.599868	0.05961	3.88529
	Interaction	319.25	12	53.20833	0.841793	0.56139	2.996117
	Error	758.5		63.20833			
Top 50 species (years combined)	Conifer species	288.1250	3	96.0417	5.0438	**0.0173**	3.4903
	Site	73.0000	2	36.5000	1.9168	0.1895	3.8853
	Interaction	66.0000	6	11.0000	0.5777	0.7417	2.9961
	Error	228.5000	12	19.0417			

Table 3.12. ANOVA results for the effect of conifer species and site on abundance of macrofungi in 1997, 1998, with years combined, and with years combined for the top 50 most abundant species only. $\alpha = 0.05$. Significant tests in bold type.

	Source of Variation	SS	df	MS	F	P-value	F crit
1997	Conifer species	13138.1250	3	4379.3750	14.0159	**0.0003**	3.4903
	Site	2801.0833	2	1400.5417	4.4823	**0.0352**	3.8853
	Interaction	2422.2500	6	403.7083	1.2920	0.3313	2.9961
	Error	3749.5000	12	312.4583			
1998	Conifer species	12098.7917	3	4032.9306	3.6637	**0.0440**	3.4903
	Site	6831.0833	2	3415.5417	3.1028	0.0820	3.8853
	Interaction	16538.5833	6	2756.4306	2.5040	0.0830	2.9961
	Error	13209.5000	12	1100.7917			
Years combined	Conifer species	49258.79	3	16419.6	9.207466	**0.0019**	3.4903
	Site	14419	2	7209.5	4.042805	**0.0455**	3.8853
	Interaction	26429.33	6	4404.889	2.470089	0.0861	2.9961
	Error	21399.5	12	1783.292			
Top 50 species (years combined)	Conifer species	39920.1250	3	13306.7083	8.1542	**0.0032**	3.4903
	Site	10490.5833	2	5245.2917	3.2143	0.0762	3.8853
	Interaction	18733.7500	6	3122.2917	1.9133	0.1596	2.9961
	Error	19582.5000	12	1631.8750			

Figure 3.6. Average number of all macrofungus species per plot at 3 sites, in 1997 vs. 1998.

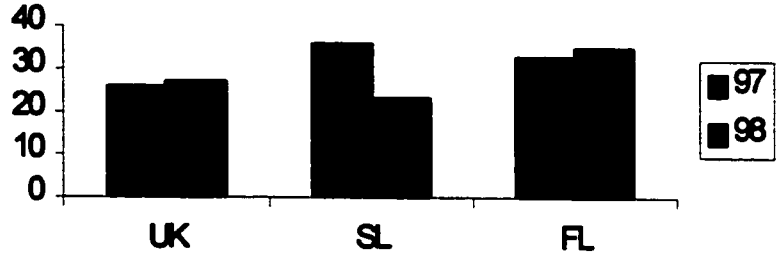


Figure 3.7. Average abundance of all macrofungi per plot at 3 sites, in 1997 vs. 1998.

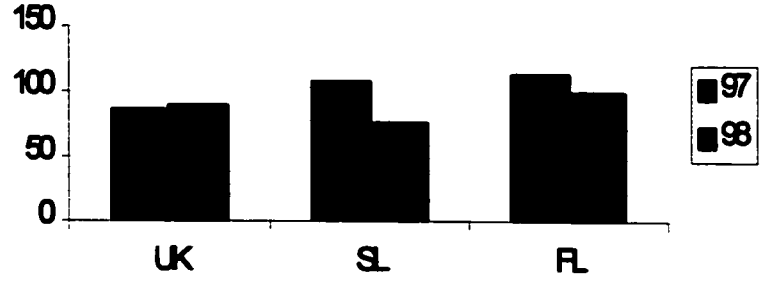


Figure 3.8. Detrended Correspondence Multivariate Analysis. Ordination of all conifer plots based on pooled abundance of macrofungi for 1997. Plots grouped together have similar abundance of macrofungi. FL plots: SS36, SS38, FD18, FD25, HW22, HW24, CW23, CW 32; UK plots: SS 99, SS102, FD 98, FD101, HW 83, HW 95, CW 84, CW 100; SL plots: SS111, SL 119, FD 126, FD 127, HW 117, HW 121, CW 116, and CW 123.

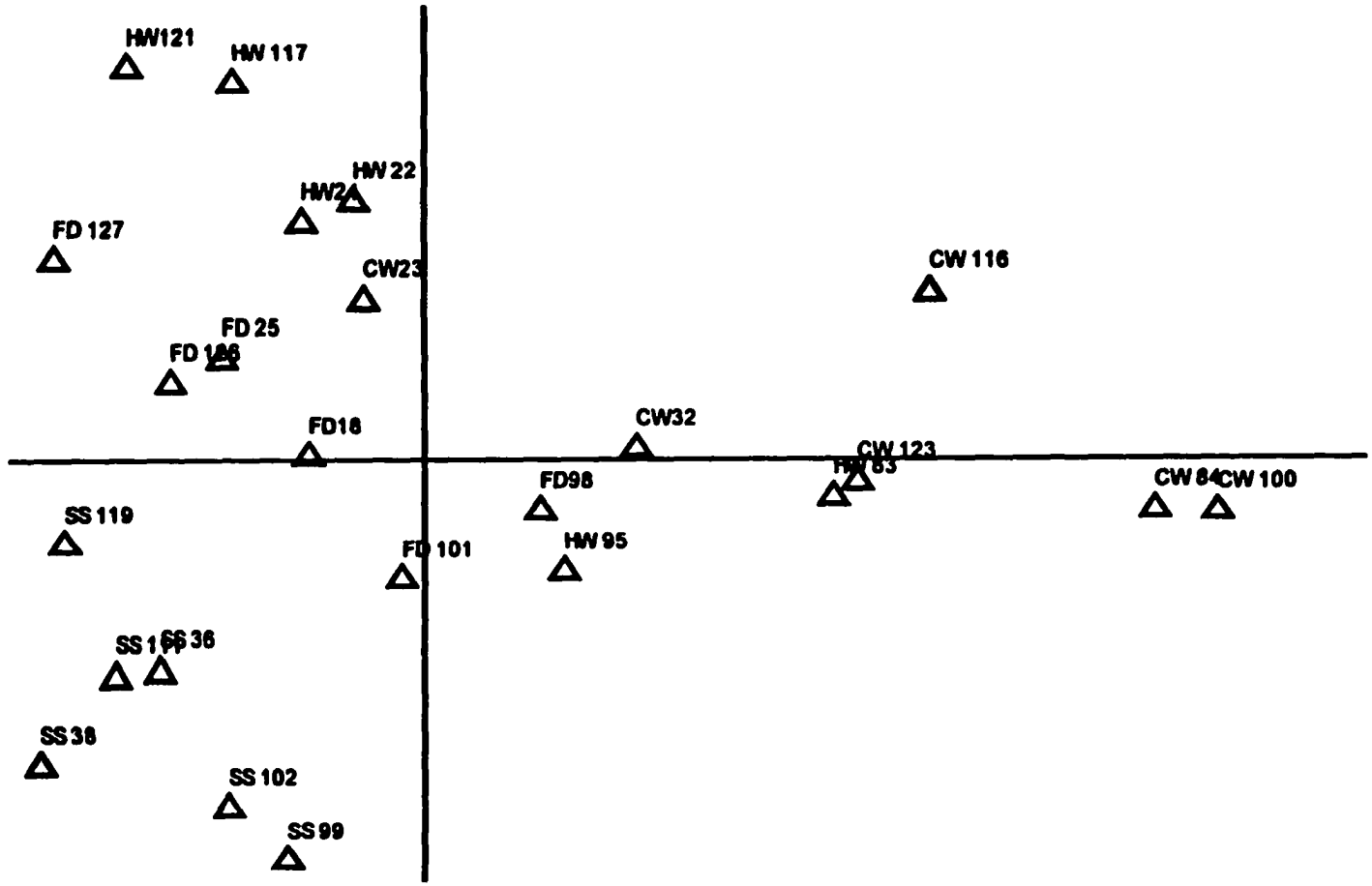


Figure 3. 9. Detrended Correspondence Multivariate Analysis. Ordination of all conifer plots based on pooled abundance of macrofungi for 1998. Plots grouped together have similar abundance of macrofungi. FL plots: SS36, SS38, FD18, FD25, HW22, HW24, CW23, CW 32; UK plots: SS 99, SS102, FD 98, FD101, HW 83, HW 95, CW 84, CW 100; SL plots: SS111, SL 119, FD 126, FD 127, HW 117, HW 121, CW 116, and CW 123.

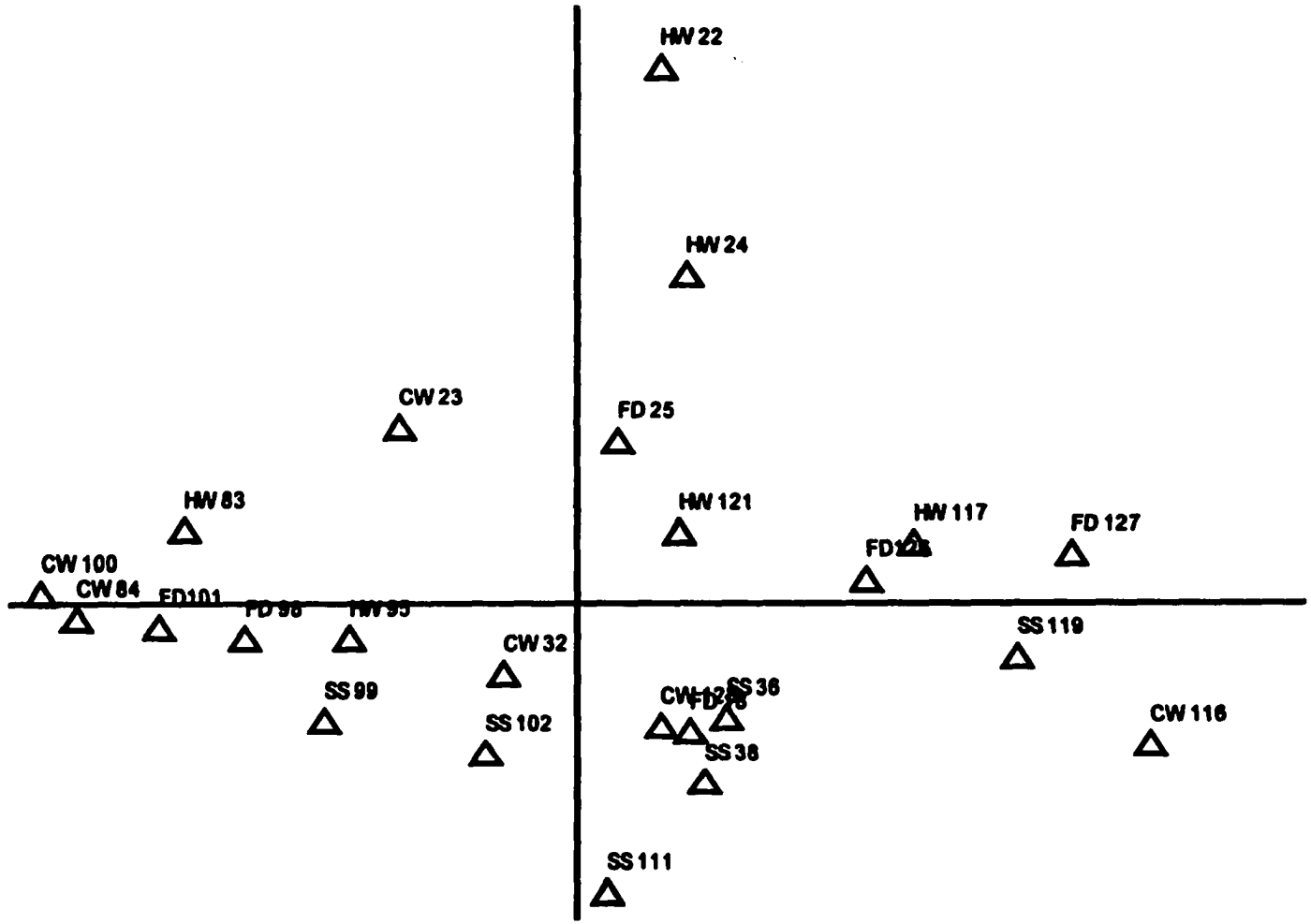


Figure 3.10. Detrended Correspondence Multivariate Analysis. Ordination of all conifer plots based on soil nutrient content. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121; cedar – 23, 32, 84, 100, 116 and 123.

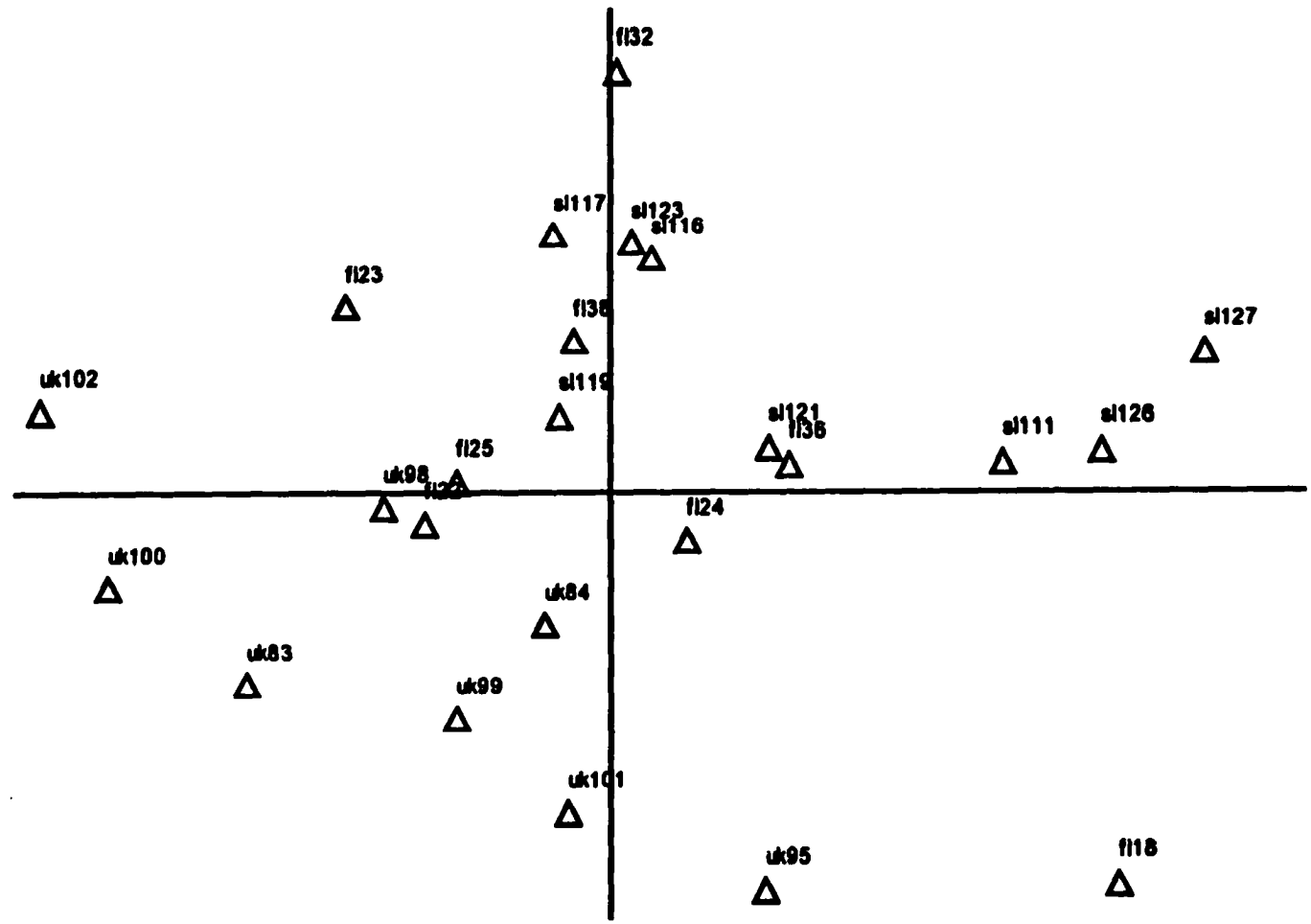


Figure 3.11. Macrofungus occurrence over time – 1997.

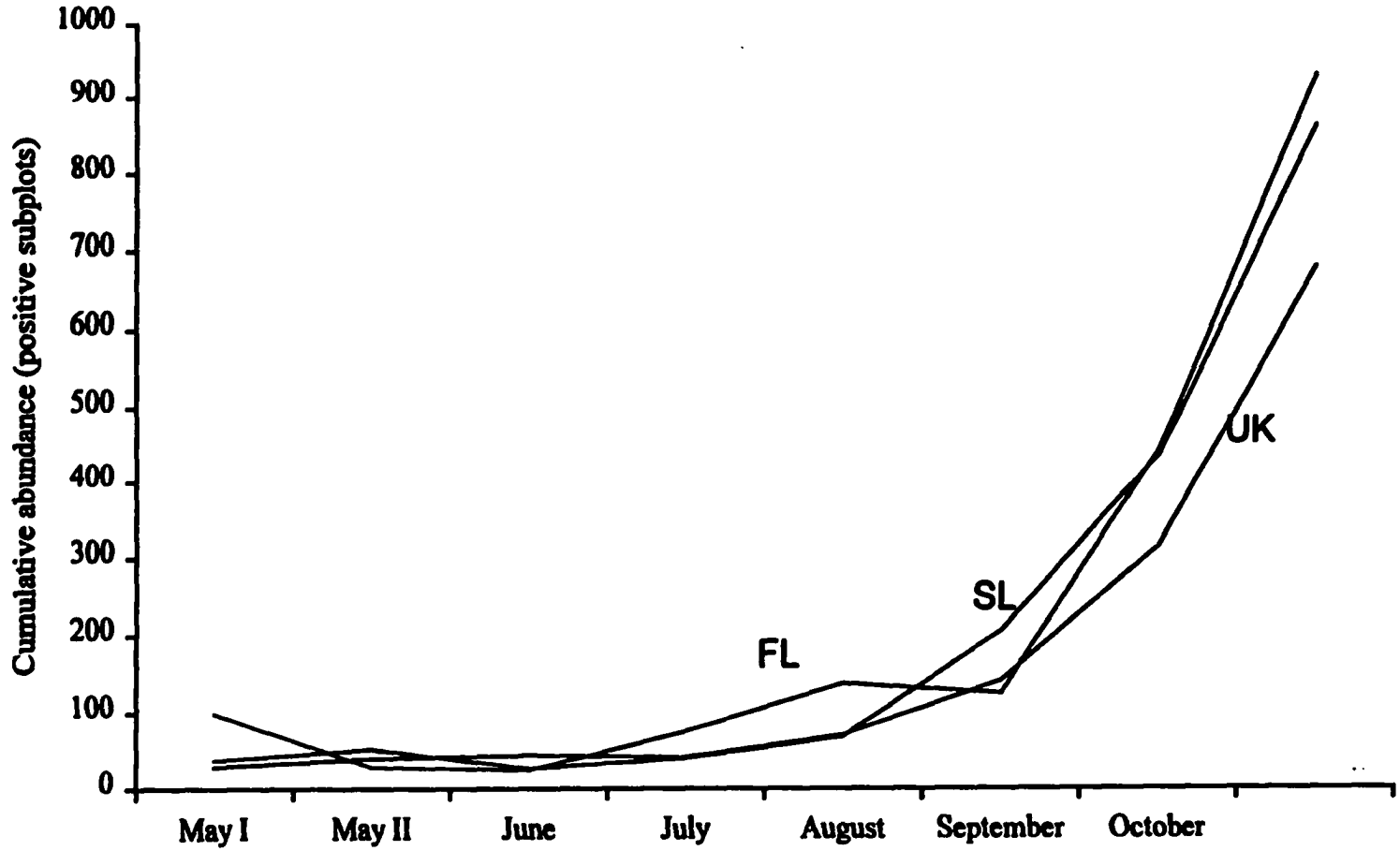


Figure 3.12. Macrofungus occurrence over time at the three sites in 1998.

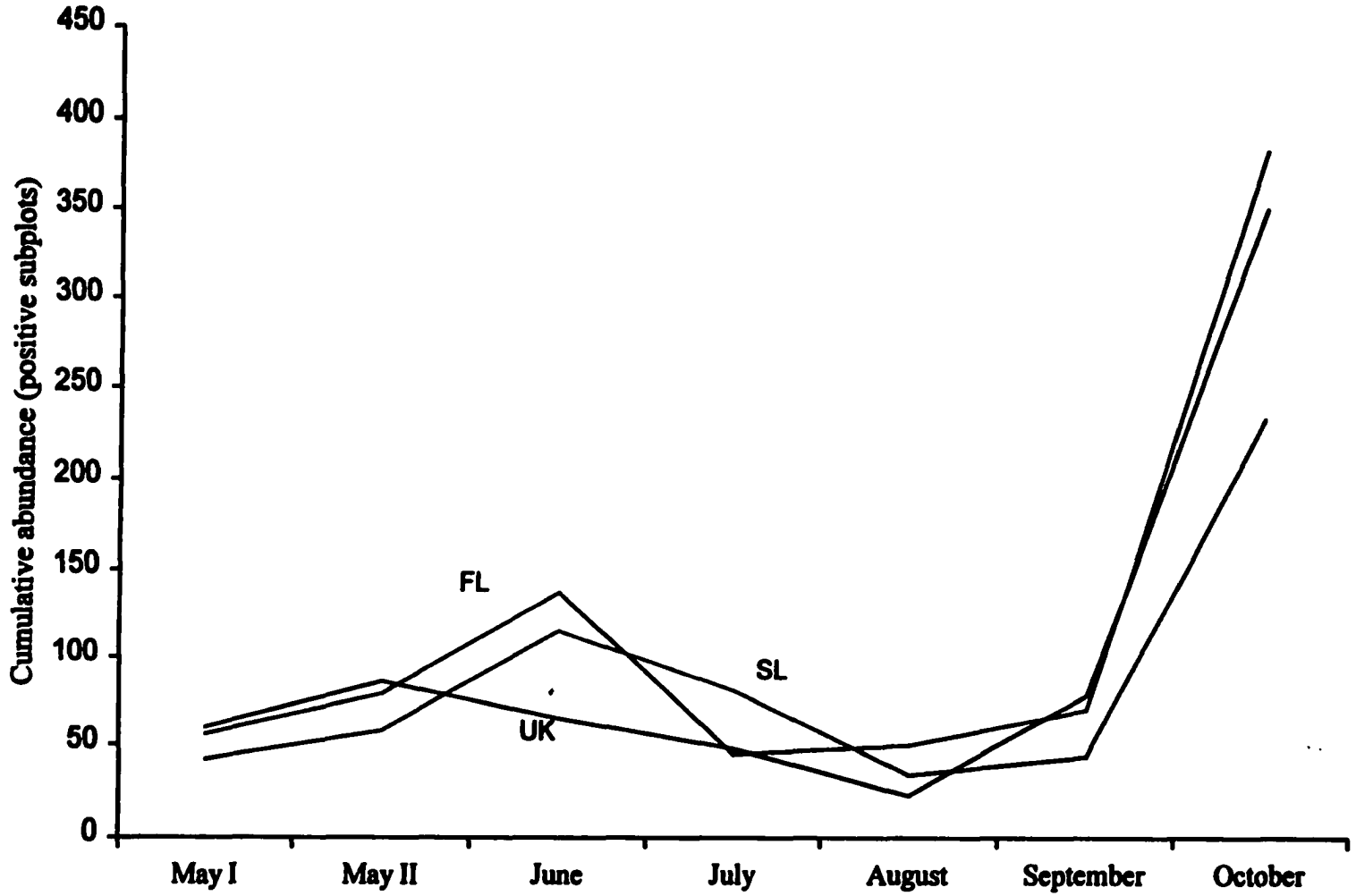


Figure 3.13. Mean monthly temperature from 1996 to 1998 for Bamfield (UK and SL) and Port Renfrew (FL). Based on weather data obtained from Environment Canada, Weather Office at the Pacific Forest Centre, Victoria, British Columbia.

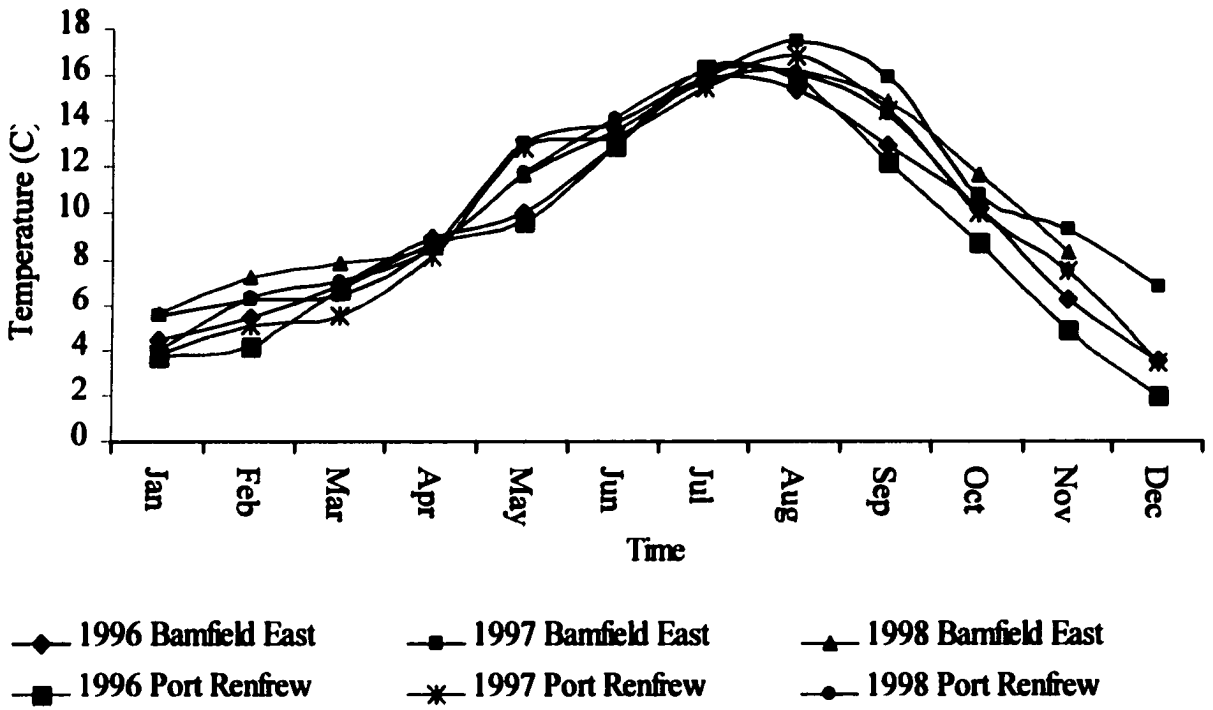


Figure 3.14. Total monthly precipitation from 1996 to 1998 for Bamfield (UK and SL) and Port Renfrew (FL). Based on weather data obtained from Environment Canada, Weather Office at the Pacific Forest Centre, Victoria, British Columbia.

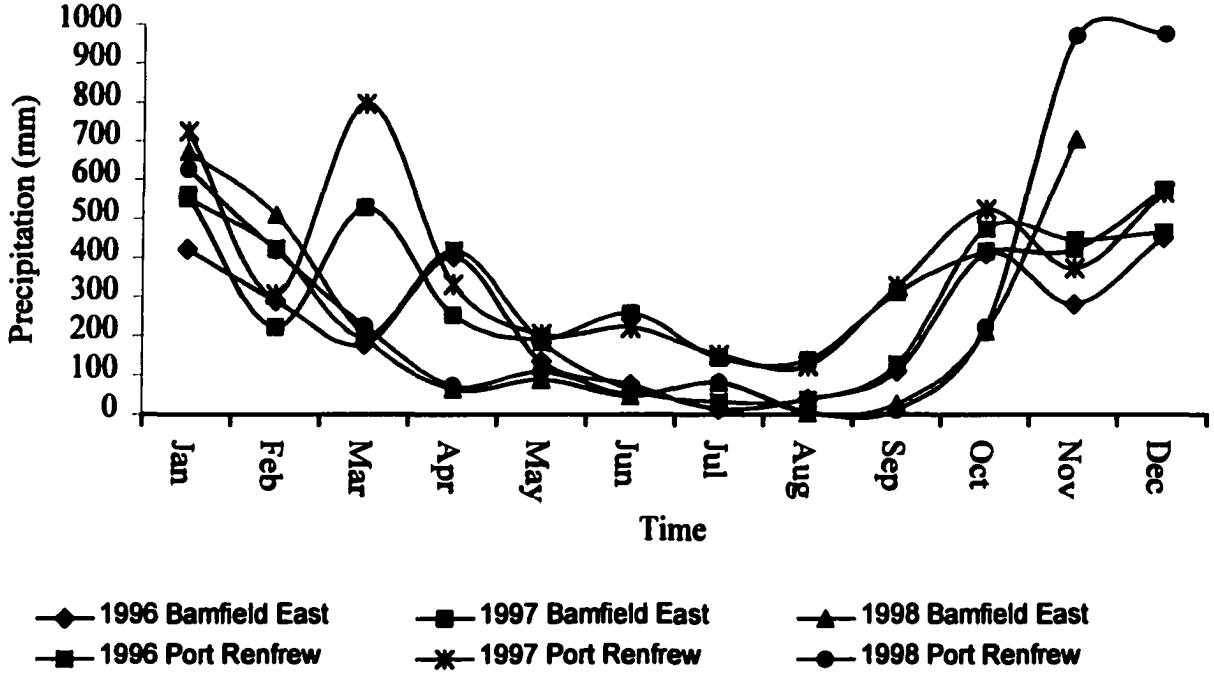


Table 3.13. Results of some studies on macrofungus species richness in coniferous forests of temperate regions.

Reference	Forest type	Location	Study area	Duration	Number of species	Guilds or groups included	Ectomycorrhizal species (%)
Outerbridge, 2002 (this study)	Monocultures of Sitka spruce, Douglas-fir, western red cedar, and western hemlock	Southern Vancouver Island, British Columbia, Canada	3456 m²	2 years	277	Ectomycorrhizal, saprobic: litter, wood, & general decomposers	31.4 overall Ss – 15.0 Df – 20.5 Cw (with Hw) – 7.9 Hw – 32.3
Countess, 2001	Douglas-fir dominated chronosequences	Vancouver Island, B. C. Canada	3840 m²	1 year	301	Ectomycorrhizal, saprobic: litter, wood, & general decomposers	48.5
Gamiet and Berch, 1992	Old growth Coastal Western Hemlock	Univ. of B.C. research forest	-	-	84	-	21
Villeneuve et al. 1988	Balsam fir & red spruce	Quebec, Canada	4000 m²?	2 years	48 - 58	Ectom., sapr.: humic., lignic.	26 - 30
Bills et al. 1986	Red spruce	West Virginia, USA	1536 m²	3 years	27	Ectomycorrhizal	100
Sastad, 1995	Scots Pine	Norway	200 m²	2 years	60	Ectom., saprobic lignicolous	47
Termorshuizen, 1991	Scots Pine	Netherlands	35,050 m²	2 years	42	Ectomycorrhizal	100
Ohenoja et al., 1984	Scots pine & Norway spruce	Finland	15,200m²?	3 years	122	Edible only	37
Wasterlung et al., 1981	Scots pine & Norway spruce	Sweden	10,837.5m	3 years	125	Ectom., saprobic	10 - 50
Garbaye et Le Tacon, 1982	Spruce plantation	France	-	-	40	Ectom., saprobic	35
Arnolds et al., 1993	coniferous forests	11 countries from Europe	-	Long term	611 red listed	Ectomycorrhizal, various saprobic	31

Chapter four: The ectomycorrhizal macrofungus community.

Introduction

Worldwide scientific literature pertaining to ectomycorrhizal macrofungi is fairly abundant, and that of mycorrhizae, in general, quite overwhelming. Needless to say there is considerable overlap (as well as contradiction) in published research in some areas, such as commercially important aspects of ectomycorrhizal fungi, while other topics are still obscure. Marks and Kozlowski (1973), Harley and Smith (1983), Allen (1991), and more recently Isaak (1992), and Varma and Hoch (1995), provide good general reference to the structure, physiology and ecology of ectomycorrhizae.

In Canada, as far as I know, there is no national compendium of ectomycorrhizal mycota *per se*. Fungus-tree symbiotic relationships, if known, are mentioned in most mushroom guides to North America (Phillips, 1991; Arora, 1986; Lincoff, 1981), and to some degree are similar to those observed in Europe (Breitenbach and Kranzlin, 1984 - 1995). Recently, Goodman et al. (1996) initiated publication of detailed microscopic descriptions and illustrations of mycorrhizae in 'A Manual of Concise Descriptions of North American Ectomycorrhizae". It is my hope, that more descriptions are submitted to this ongoing project and that the root-mycelium information is related to sporocarp observations.

Trappe (1962) synthesized 407 references to generate comprehensive fungus – host tree lists. The lists include Sitka Spruce (*Picea sitchensis*), Douglas-fir (*Pseudotsuga menziesii*), and western hemlock (*Tsuga heterophylla*). Though the relationships in Trappe's paper are mainly based on reports of *in situ* consistent observations of mushroom sporocarps in the vicinity of a given host species, some of them have been confirmed thanks to advances in laboratory culture of ectomycorhizal fungi and molecular techniques (Egger, 1995; Mehmann et al., 1994; Horton et al., 1999; Molina, 1979; Molina and Trappe, 1982).

Recently, a number of studies have been undertaken in the Pacific North West of the United States and Canada on the biology, ecology, and social aspects of commercially viable ectomycorrhizal fungi (Pilz and Molina 2002; Berch and Wiensczyk, 2001; Tedder et al., 2000, unpublished report; Peterson et al., 2000, unpublished report; Ciesla, 1998; Pilz and Molina, 1996; de Geus, 1995; Norvell, 1995; Schlosser and Blatner, 1995; Molina et al., 1993).

In Canada, research on ectomycorrhizae has been intensifying over the years, as the forest industry, more focused on disease causing fungi in the past, took interest in non-timber forest products. A number of experiments were carried out to investigate the ectomycorrhizal enhancement of forest seedling survival and growth, with applications in timber production and reforestation (Roth, 1990; Kernaghan et al., 1995).

Kranabetter and Wylie (1997), and Kranabetter et al. (1999) studied the effects of silvicultural practices, such as forest gap edge formation, thinning, and retention of isolated host trees on ectomycorrhizal fungi. Goodman (1995) looked at types and abundance of ectomycorrhizal root tips in clear-cuts and different age classes of Douglas-fir forest on Vancouver Island. Countess (2001) used the same chronosequence plots to quantify the above ground mushroom flora, including ectomycorrhizal species. Gamiet and Berch (1992) included ectomycorrhizal fungi in their survey of old growth forest in the Vancouver area. Gamiet (personal communication) also continues her extensive research on the genus *Cortinarius*, perhaps the most diverse genus in this region of the PNW. Peterson et al. (2000, unpublished report) studied the effect of forest burn history on the production of *Cantharellus formosus* on the Queen Charlotte Islands. Roberts (personal communication) continues to work on the taxonomy of *Russula*, another ubiquitous genus on Vancouver Island. Berch et al. (2001) reports ectomycorrhizal fungi from the pilot survey of the EP571 forest plantations, previous to my research in these plots.

As already mentioned, some data are available on ectomycorrhizal communities of different conifer species, including Sitka spruce, Douglas-fir, and western hemlock. In contrast, no reports have been made for any ectomycorrhizae on the roots of cedar species so far (Roth, 1990). It is therefore reasonable to assume that the western red cedar forms only vesicular-arbuscular mycorrhizae (VAM). The effect of various nutrients on ectomycorrhizal fungi has been studied in the past, although, unfortunatelly, more

frequently in artificial conditions, than in controlled experiments in the field (Lilleskov et al., 2001).

It is hypothesised that conifer species and site characteristics (moisture level and soil nutrient level) affect communities of ectomycorrhizal fungi in terms of species composition, species diversity, and friut body abundance. The hypothesis has been tested using monoculture forests of Sitka spruce, Douglas-fir, western red cedar, and western hemlock, at three different sites: moist and rich (Upper Klanawa), fresh and medium rich (Sarita Lake), and fresh to dry, nutrient poor (Fairy Lake).

Results

1. General findings

The two-year study yielded a total of 87 species of fungi known to be ectomycorrhizal (Table 4.1). This number includes the species observed in some of our cedar plots (Table 4.2), most likely associated with young rogue hemlocks in the understory (western red cedar is not known to form ectomycorrhizae). With the observations in cedar excluded, the overall ectomycorrhizal diversity amounted to 83 species, belonging to 18 genera, and 10 families (Table 4.3). Thirty six species, thus 43%, were recorded on one occasion only. The largest proportion of the species (41%) belonged to the family *Cortinariaceae*, with 34 species from the genera: *Cortinarius, Inocybe, Dermocybe, and Phaeocollybia*,

in descending order of their species diversity. In terms of abundance, *Inocybes* were more numerous then *Cortinarii* (81 vs. 36 observations), with *Inocybe sororia* being the most common one. *Cortinariaceae* were closely followed by *Russulaceae* (33%), with 14 species of *Lactarius* and 13 species of *Russula. Russulaceae* exceeded *Cortinariaceae* in terms of abundance with almost twice as many observations recorded (242 vs. 127), due mainly to the high frequency of *Lactarius hepaticus*. The 117 observations of this fungus constituted 13% of the entire ectomycorrhizal population, the second highest frequency. The most frequently occurring ectomycorrhizal fungus was, undoubtedly, *Cantharellus formosus*, the Pacific Golden Chanterelle. We have recorded the chanterelle as many as 296 times, which represents 33% of the total abundance of the ectomycorrhizal macrofungi. Other common species included: *Craterellus tubaeformis*, *Russula atropurpurea*, *Russula fragilis*, *Hydnum repandum*, *and Chroogomphus tomentosus*, in descending order. Table 4.4 lists the ectomycorrhizal fungi found in each conifer habitat according to their frequency.

2. Conifer effect

The highest number of ectomycorrhizal macrofungi was associated with western hemlock, *Tsuga heterophylla*, with cumulative total of 47 species. Douglas-fir, *Pseudotsuga menziesii*, supported 36 species and was followed by Sitka spruce, *Picea sitchensis*, with 32 species. The lowest diversity of ectomycorrhizal macrofungi was found with western red cedar, *Thuja plicata* (22 species). Most of the species in cedar

came from plots 123 and 116 in Sarita Lake and plot 23 in Fairy Lake. These plots were considerably overrun by competing juvenile hemlock. Fourteen of these species were also found under hemlock. *Cantharellus formosus* had the total cumulative abundance of 17 and the majority of the other species occurred only once or twice (Table 4.2). The ranking order for species number was: hemlock, Douglas-fir, spruce, and cedar (Table 4.5). The same ranking order was calculated for the four conifers with respect to abundance of ectomycorrhizal macrofungi. The respective total and average numbers of observations were: 322 (53.67), 320 (53.33), 189 (31.5), and 62 (10.33), for hemlock, fir, spruce, and cedar (Table 4.5). Analysis of variance (ANOVA) showed a significant difference in diversity ($P = 0.006698$) and abundance ($P = 0.00187$) of ectomycorrhizal sporocarps between the western red cedar and the other conifer species (Table 4.6). With western red cedar excluded, there was no significant effect of conifer species (between Sitka spruce, Douglas-fir and western hemlock) on the number of mycorrhizal fungus species fruiting and on the abundance of mycorrhizal fungi (Table 4.7).

3. Site and plot differences

With western red cedar included, Analysis of Variance (ANOVA) shows that site differences have significant effect on the abundance (but not diversity) of ectomycorrhizal species ($P = 0.003021$). The highest values for both variables are recorded in site 3, Fairy Lake – the poorest and driest), and the lowest in site1, Upper Klanawa (the richest and wettest).

Comparisons of the sites with cedar plots excluded shows that the number of ectomycorrhizal species was very similar between the three sites. Significant difference was only recorded for their abundance (P = 0.007366), which was consistently lowest in Upper Klanawa (the nutrient richest and wettest), and highest in Fairy Lake (the nutrient poorest and driest).

Variation in soil characteristics, topography, and microclimate existed amongst plots of the same conifer species, between, as well as within sites. Figures 4.1 and 4.2 exemplify differences in ectomycorrhizal fruiting for all the individual plots, reflecting perhaps the microsite influences. The bigest differences are the number of species in western red cedar plots compared to all other plots (Figure 4.1), and the increasing fruit body abundance of macrofungi along the nutrient gradient, from lowest abundance in UK (moist and rich) to highest in Fairy Lake (dry and poor) in Figure 4.2.

Ordination of plots, species, and nutrient data, using Detrended Correspondence Analysis (DCA; DECORA) throws further light on site induced patterns.

In Figure 4.3., plots of Sitka spruce, Douglas-fir, and western hemlock are ordinated on a joint plot based on soil nutrient data (loaded into both the main and the second matrices). This graph and the subsequent overlays in Figures 4.4. – 4.10. show nitrogen (N) and phosporus (P) negatively correlated with calcium (Ca), potassium (K), magnesium (Mg), and pH, along both axis 1 and axis 2. Humus content (t/th) shows negative correlation

with axis 2. The distribution of conifer plots is nutrient and site specific. For example, Upper Klanawa plots are rich in nitrogen and organic matter.

With ectomycorrhizal species in the second matrix (Figure 4.11.), a joint plot reveals presence of possible relationships between some fungal species and various microsites. Overlays of selected individual species are shown in Figures 4.12 – 4.17 (all the other species did not show any trends, unless stated otherwise). *Cantharellus formosus* and *Inocybe sororia* are positively correlated with axis 1 and axis 2 (i.e. their abundance is highest in the upper right quarter of the graph – the area in which any point plotted has both X and Y coordinates as positive values). It also means these two fungi are correlated with low nitrogen and phosporus (compare with Figures 4.5 and 4.6). *Lactarius luculentus* is negatively correlated with axis 1 and axis 2 (high nitrogen), and *Lactarius hepaticus* shows weakly negative relationship with axis 2 (high nitrogen, phosphorus, and organic matter). *Lactarius luculentus* var. *laetus* and *Russula atropurpurea* are negatively correlated with axis 1.

Cluster analysis (Euclidean Distance, Ward's method) of plots based on abundance of their fungal communities shows 11.70 percent chaining which suggests some patterns. The two most distinguishable groups are plots with a high number of chanterelles (*Cantarellus formosus*) and plots with low numbers of chanterelles. These are further subgrouped based , it seems, on their macrofungus diversity (Figure 4.18).

Three diversity measures were calculated for each plot:

- species richness S = number of nonzero elements

- species evenness E : H` / ln(richness)

and Shannon-Wiener function H`: $- S (p_I * \ln (p_I))$

Plots with highest diversity based on Shannon –Wiener function were:

DF 101, HW 83, HW 95 from Upper Klanawa;

SS 111, DF 126, and HW 121 from Sarita Lake,

and HW 22 from Fairy Lake (Table 4.8.).

No clear patterns emerge beyond the western hemlock and Douglas-fir high diversities.

4. Chanterelles (*Cantharellus formosus*)

The fruiting season for chanterelles, *Cantharellus formosus*, began in July in both years, and extended well into late October, with 1998 being a slightly more productive year (Table 4.9). Chanterelles were consistently three times as abundant in Fairy Lake (50% - 54% of observations) as they were in Upper Klanawa plots (9% to 13%). The variation within the Fairy Lake site was fairly high, with the highest yield in hemlock Hw24 and Douglas-fir Fd 18. These plots are characterized by low values across all the nutrients, pH of 4.37-4.53, and a thin humus layer.

Discussion

Despite their importance in many ecosystem processes, little is understood about the variation in diversity of macrofungal communities between different habitats in North America. Several researchers looked at community structure in hardwood forests versus coniferous ones. Bills et al. (1986) found 35 ectomycorrhizal species, including many rare ones, in a heterogenous hardwood stand, and 27 species in homogenous red spruce stand, which tended to be dominated by a few ubiquitous fungi. In contrast to my study, however, they included in their estimates sporocarps of species whose ecological role is uncertain, such as *Clavulina cristata*, *Entoloma* spp., *Cystoderma amianthinum*, or *Hygrophorus cantharellus* (here treated as *Hygrocybe cantharellus*, associated saprophytically with cedar habitat). Villeneuve et al., (1989) report similar results, commenting also on the clear dominance of ectomycorrhizal species from the *Cortinariaceae*, *Russulaceae*, and *Boletaceae*. Our results are consistant with the above studies in terms of overall diversity and community structure. Countess (2001) reports that the macrofungal mycota consisted of 48% ectomycorrhizal macrofungi from immature Douglas-fir dominated stands on Vancouver Island. The generally lower proportions reported here (20% for Douglas-fir plots) could be related to differences in nutrient resources.

Intensive work has also been done on hypogeous ectomycorrizal sporocarp production in the American Northwest (Hunt and Trappe 1987; Luoma et al., 1991). Durrall et al.

(1999) compared species richness in cutblocks of different sizes in the interior cedar-hemlock forest, and O'Dell et al. (1992) looked at young, managed, and old growth Douglas-fir stands. Kranabetter et al. (1999) reported an average of 52 morphotypes per tree species after examining ectomycorrhizal communities on 4- year old seedlings of lodgepole pine, white spruce and subalpine fir. His and similar studies (Roth and Berch, 1992) are difficult to relate to the present sudy to, due to the fact that considerable transitions in mycorrhizal associations occur during tree development (Dighton and Mason, 1985). Additionally, labelling ectomycorrhyzal taxa with various codes and descriptive names, without a reference to a known macrofungal species (a common practice among mycologists due to the limited knowledge) makes studies like the one reported here, entirely based on sporocarp observation, quite incompatible.

The work reported here is the first North American study of epigeous ectomycorrhizal community structure, in which same age conifer forests of different species and different soil types are compared.

In many ways there are a lot of similarities between ectomycorrhizal communities found in this study and those reported from Scandinavia, especially in comparing species of Cortinariaceae (Dalberg et al., 1997; Sastad, 1995). It is well worth looking through the taxonomic literature from these countries while studying fungi in British Columbia.

It is tempting to add to Trappe's lists (Trappe, 1962) a number of 'new' fungal symbionts of Sitka spruce, Douglas-fir, and western hemlock, especially when very few local fungi are on the list (most associations listed by Trappe are based on research in Europe). Indeed, only 6 out of 50 species listed by Trappe with Douglas-fir were 'confirmed' in my survey. The numbers for western hemlock and Sitka spruce are 3 out of 21, and 1 out of 21, respectively. Nevertheless, I consider my observations of the relationships to be anecdotal, as I did not examine them at the root/fungus interphase. In an attempt to reduce the presumptive, and therefore possibly erroneous nature of my research, I decided to limit the category of ectomycorrhizal macrofungi to only the classic genera that have been well documented in the literature (Harley and Smith, 1983). I cannot be sure, however, that within these genera, a species or two was not in fact associated with an understory shrub rather than the conifer tree. I did not include *Clavulina cristata*, or any of the Entolomas (they will be covered in the next chapter). Yet it is possible, that some of these are mycorrhizal as well.

Three main issues have been addressed in this part of the project. Western red cedar, as non-ectomycorrhizal host, was investigated in its ability to support some fruiting of ectomycorrhizal fungi, with juvenile rogue western hemlock in the understory. Influence of conifer species (with the focus on Sitka spruce, Douglas-fir, and western hemlock) on ectomycorrhizal macrofungus species composition, diversity, and their fruit body abundance were analysed. Effects of site differences in soil moisture and nutrients on same parameters were studied.

As many as twenty- two ectomycorrhizal fungi were found fruiting in the predominantly *Thuja plicata* forests, accounting for the cumulative total of 62 positive subplots. *Cantharellus formosus* fruiting bodies formed 27% of this mycota, and 63% of the total was concentrated in the Cw23 plot in the Fairy Lake site. This plot was particularly problematic, with lots of understory vegetation, forcing us to lay the sampling area out along its boundary. Two western hemlock plots in the vicinity of the Cw23 plot were most likely responsible for its high number of ectomycorrhizal sporocarps. Four species occurred in two different cedar plots: *C. formosus, Lactarius hepaticus, Lactarius mucidus,* and *Lactarius pseudomucidus*. Two *Suillus* species were observed: *Suillus brevipes* and *Suillus punctatipes*. *Suillus brevipes* along with *Gomphidius glutinosus, Lactarius kaufmanii,* and *Lactarius mucidus* var. *fuscogriseus* were not found in any other plots. Many collections of ectomycorrhizae in the Pacific Northwest are taken from forests reported to have a significant cedar component (Goodman et al., 1996) and ectomycorrhizal relationships have been documented for other genera of *Cuprecaceae* (Trappe, 1962). Yet, I am reasonably certain that western red cedar is non-ectomycorrhizal and the incidental status of the fungal symbionts found there is the result of direct correspondence to the density of understorey shrub vegetation (especially juvenile hemlock). Evidence in the literature exists only for arbuscular mycorrhiza formation on the roots of western red cedar.

Differences in experimental design and focus are responsible for large variation in reported numbers of ectomycorrhizal species from other types of forests. Garbaye and LeTacon (1982) collected 40 species in a spruce forest in France, and calculated that ectomycorrhizal species formed 35% of the total mushroom crop. Others claim diversity of anywhere between 1 and over 230 species and the guild size of 10% to 96% (Carroll and Wicklow, 1992). I have found 87 ectomycorrhizal species, with the total abundance = 893 'positive' (3m x 3m) subplots, over the two-year survey, in the area of 3456m^2. Without the cedar plots the overall diversity of 83 species (in 2592m^2) corresponds to 3.2 species per 100m^2 of coniferous forest. It is interesting to note, that although the proportion of the ectomycorrhizal guild for the whole study is 29%, this percentage differs within each conifer species. It is as low as 15% in Sitka spruce and as high as 32.31% in western hemlock, with Douglas-fir in between at 20.5%. Differences in foliar content of nitrogen, tannins, lignin, or other compounds might be a factor (Taylor et al., 1991; Prescott, 1996). Though I was able to rank western hemlock as the richest ectomycorrizal habitat, and Sitka spruce as the poorest, I did not find statistically significant differences in diversity and the abundance of sporocarps among the three conifers. This could be the result of the wide host range of the fungi in question, as well as the wide range of symbionts of the conifers involved. A relatively small plot size, proximity of other stands, problems with juvenile hemlock encroachment, and animal browsing, are amongst possible sources of error. I feel reasonably confident, however, in my results as they have been fairly consistent across the replicate plots and from year to year. The point to consider is that Douglas-fir, frequently discussed as the most important

host of ectomycorrhizal fungi of the Pacific Northwest, can be in fact second to western hemlock, at least in immature stands in the CWHW biogeoclimatic zone. However, the differences in ectomycorrhizal diversity and abundance between the two conifers were not statistically significant. Also, an important group of ectomycorrhizal macrofungi, the hypogeous species (Smith et al., 2002), were not considered in this study. Therefore, the ranking observed here can only be considered a trend at present.

Similarly, no distinct gradient or pattern emerged to reflect differences in site soil quality from rich and moist in Upper Klanawa, to poor and dry in Fiary Lake, with regards to ectomycorrhizal diversity. ANOVA analysis did not yield any significant results. The sites differed in ectomycorrhizal fungus community composition, but accommodated similarly rich mycota. This is not a surprise to me, considering the wide range of nutrient, moisture, temperature, and pH requirements of ectomycorrhizal fungi (Mexal and Reid 1973; Littke et al., 1984; Dennis, 1985), and the omnipresent demand for symbiotic partnership. It seems, that so long as there is a niche it will be filled, as environment selects for competitive, adapting, or new species everywhere and at all times. However, we have observed a significant effect of site characteristics on the total abundance of ectomycorrhizal fungi. Fairy Lake produced three times as many sporocarps as Upper Klanawa. This could be the result of low levels of nitrogen, potassium and organic matter at Fairy Lake, as well as the more open canopy of its stands - the result of its higher slope, and slower conifer growth. Some evidence exists in the literature that more mycorrhizal sporocarps of threatened species can be found on drier

and base-rich soils (Rydin et al., 1997), and on poorer and drier sites (Ohenoja and Koistinen, 1984). High nitrogen inhibition of ectomycorrhizal fruiting has been documented (Lilleskov et al., 2001; Baxter et al., 1999), as was the negative impact of a thick humus layer (Barr and Kuyper, 1993). A closer look at the nutrient data collected from the sites by Prescott et al. (2000), opened the door to more speculations. It is clear, from the analysis of soil pit samples, that Upper Klanawa is characterized by a considerably thicker humus layer, higher nitrogen and phosphorus, and by lower magnesium, calcium, and potassium (see Appendix 2B). The pH values varied from plot to plot with no apparent stimulating or inhibitory role. Joint plot ordination of the whole ectomycorrhizal community against the nutrient background does not reveal any affinities. Individual fungus overlays explain that the general picture was obscured because different fungi show different environmental preferences, many contrasting with each other. For example *Cantharellus formosus* was most abundant in plots with low nitrogen, phosphorus, and organic matter, *while Lactarius hepaticus* var. *laetus* preferred the oposite. This is consistent with my previous statement about filling the niche, and has some support in the literature (Nauta and Vellinga, 1993; Bruns, 1995). Additionally some species in my study, such as various species of *Cortinarius* or *Russula*, seemed to show a very broad spectrum of acceptable nutrient parameters. Unfortunately, speculation on the vast majority of the ectomycorrhizal species is not possible at this point due to their low overall abundance.

Overall, *Cantharellus formosus* was the second most common fungus in our survey of macrofungi in EP 571 sites. It was fairly evenly distributed among all three ectomycorrhiza forming hosts studied: Sitka spruce, Douglas-fir, and western hemlock (Table 4.9). The abundance of chanterelles in each of these habitats seemed moderate in comparison to that found in a recent study on Queen Charlotte Islands, with comparable stand age and site history (Peterson et al., 2000, unpublished report).

Cantharellus formosus Corner, as a taxon, is a recent addition to British Columbia mycoflora. Redhead et al. (1997) re-described the Pacific Northwest most common chanterelle and renamed it (from the previous *Cantharellus cibarius*, the European species).

Chanterelles are choice edible mushrooms and have been harvested commercially in Europe for decades and on the west coast of Canada and the United States for at least 20 years. Numerous publications have been written about the ecology, productivity, cultivation, and biochemistry of this species. Annotated literature review can be found in Peterson et al. (2000, unpublished report).

Chanterelles seem to fruit more prolifically in drier and sandier locations, with southern or south-eastern aspect, in mature (but not old) forests (Peterson et al., 2000, unpublished report). From the results of this study, it also seems that, they fruit more prolifically in areas with low nitrogen and /or phosphorus. I am also inclined to conclude that stands on

slopes, with good drainage and more exposed mineral soil are more productive, even if salal is present. In fact, the abundance of salal is correlated to the influx of light through the open or semi-open canopy, the stage which this fungus favours. Higher light level means warmer soil and increased photosynthesis, thus allocation of carbohydrates to the ectomycorrhizal fungus. There is also enough evidence to suggest that partially managed forests, habitat disturbance, or even destructive forest floor trampling, may stimulate sporocarp production of chanterelles (Norvell, 1995; Peterson et al., 2000, unpublished report; and Burova and Trapido, 1975, respectively). Undisturbed, closed canopy conifer stand combined with low pH, periodic flooding, and cool summers (all characteristic of the valley bottom Upper Klanawa site), leads to a thick build-up of undecomposed litter, which may be further detrimental to chanterelle growth.

Overall, the widely scattered and highly abundant distribution of chanterelle resemble that of a successful facultatively ectomycorrhizal species (such as *Paxillus involutus* suggested by Nauta and Vellinga 1993), capable of also existing as a saprotroph. I would not be surprising to find that *Cantharellus formosus* and *Lactarius hepaticus*, frequently found on decomposing logs, and sometimes on Douglas-fir and hemlock cones, could also live as saprotrophs at times.

On the other hand, Rangel-Castro (2001) examined carbon and nitrogen utilization of the European chanterelle, *Cantharellus cibarius* Corner, and determined that it more closely resembles other ectomycorrhizal fungi that have been studied and not a saprobe. He also

suggested that the huge numbers of *Pseudomonas* bacteria might be able to break down the complex nitrogen and carbon sources, making simple forms more available to the fungus.

Overall, communities of ectomycorrhizal fungi in EP571 appear to show great resilience, adaptability, and efficiency in sharing resources, independently of conifer species. More studies are needed on the *in situ* relationship between the below-ground processes and above ground fruiting patterns. We still do not know exactly what environmental factors are responsible for huge clusters of certain ectomycorrhizal mushrooms in one spot of the forest, and why some other seemingly suitable areas yield low fruit body production. More than likely some environmental factors we just havn't looked for are responsible. The fruiting patterns might also be correlated with other organisms not yet catalogued. Species and strain specificity are an important issue to consider in research on ectomycorrhizal macrofungi, as are their soil nutrient preferences, especially in designing experiments on seedlings inoculated with the symbionts.

Tables and Figures

Table 4.1. Cumulative list of ectomycorrhizal macrofungi found in Ep571 plots during the two-year survey. Abundance = number of observations. Frequency (%) = proportion of the total macrofungus abundance.

Ectomycorrhizal fungus	Abundance	Frequency
Amanita farinosa	3	0.06
Amanita vaginata	9	0.19
Boletus mirabilis	1	0.02
Boletus piperatus	1	0.02
Cantharellus formosus	313	6.67
Chroogomphus tomentosus	20	0.43
Cortinarius acutus group	1	0.02
Cortinarius alboviolaceus	1	0.02
Cortinarius castaneus group	1	0.02
Cortinarius cotoneus	1	0.02
Cortinarius decipiens	1	0.02
Cortinarius gentilis	2	0.04
Cortinarius glaucopus	3	0.06
Cortinarius junhuhnii	1	0.02
Cortinarius obtusus	3	0.06
Cortinarius renidens R.O. 332	1	0.02
Cortinarius scaurus group	2	0.04
Cortinarius sect. telemonia	17	0.36
Cortinarius semisanguineus	1	0.02
Cortinarius sp. affin. azureus	1	0.02
Cortinarius traganus gr.	1	0.02
Cortinarius vibratilis	2	0.04
Craterellus tubaeformis	75	1.60
Dermocybe crocea	1	0.02
Dermocybe idahoensis	2	0.04
Dermocybe sp. R.O. 348	1	0.02
Dermocybe sp. R.O. 349	4	0.09
Gomphidius glutinosus	1	0.02
Gomphidius smithii	1	0.02
Gomphidius subroseus	11	0.23
Hydnum repandum	22	0.47
Hygrophorus bakerensis	8	0.17
Hygrophorus pratensis	3	0.06
Inocybe calamistrata	16	0.34
Inocybe cookei	1	0.02
Inocybe eutheles	5	0.11
Inocybe fastigiata	7	0.15

Ectomycorrhizal fungus	Abundance	Frequency
Inocybe geophila	1	0.02
Inocybe idahoensis	1	0.02
Inocybe napipes	7	0.15
Inocybe ovatocystis	2	0.04
Inocybe sect. inocybium	2	0.04
Inocybe section cortinatae	2	0.04
Inocybe sororia	34	0.72
Inocybe sp. *affin. tigrina*	5	0.11
Inocybe *sp. R.O. 186*	1	0.02
Laccaria bicolor	2	0.04
Laccaria lacata	2	0.04
Lactarius alnicola	1	0.02
Lactarius deliciosus	2	0.04
Lactarius fallax	1	0.02
Lactarius hepaticus	120	2.56
Lactarius kaufmanii	1	0.02
Lactarius ligniotus var. *canadensis*	1	0.02
Lactarius luculentus	6	0.13
Lactarius luculentus var. *laetus*	10	0.21
Lactarius mucidus	5	0.11
Lactarius mucidus var. *fuscogriseus*	1	0.02
Lactarius olivaceo-umbrinus	1	0.02
Lactarius pallescens	1	0.02
Lactarius pseudomucidus	11	0.23
Lactarius rufulus	2	0.04
Lactarius scrobiculatus	10	0.21
Lactarius uvidus	5	0.11
Phaeocollybia phaeogaleroides	2	0.04
Phellodon atratus	3	0.06
Phellodon nigrea ? R.O. 334	1	0.02
Phylloporus rhodoxanthus	7	0.15
Russula adusta	1	0.02
Russula albonigra group	1	0.02
Russula arenicola	1	0.02
Russula atropurpurrea	38	0.81
Russula bicolor	8	0.17
Russula brevipes	1	0.02
Russula crassotunicata	1	0.02
Russula cremicolor	1	0.02
Russula cyanoxantha	1	0.02
Russula farinipes	1	0.02

Ectomycorrhizal fungus	Abundance	Frequency
Russula fragilis	32	0.68
Russula nigricans	2	0.04
Russula occidentalis	1	0.02
Suillus brevipes	1	0.02
Suillus punctatipes	2	0.04
Tricholoma imbricatum	1	0.02
Tricholoma pessundatum	2	0.04
Tricholoma sp. affin. *apium*	3	0.06
Tricholoma sp. R.O. 118	1	0.02
TOTAL	893	19.04

Table 4.2. Ectomycorrhizal macrofungi found in western red cedar plots (assumed to be associated with western hemlock scattered in the understory). Note only 1 ectomycorrhizal fungus in almost pure cedar plots in Upper Klanawa.

Fungus species	UK Cw 84	UK Cw100	SL Cw116	SL Cw123	FL Cw23	FL Cw32	Total Abundance
Amanita farinosa				2			2
Cantharellus formosus					16	1	17
Chroogomphus tomentosus					1		1
Cortinarius glaucopus	2						2
Cortinarius sect. Telemonia			1				1
Gomphidius glutinosus			1				1
Gomphidius subroseus				4			4
Inocybe eutheles						2	2
Inocybe fastigiata						1	1
Laccaria bicolor				1			1
Laccaria laccata				1			1
Lactarius hepaticus				2	1		3
Lactarius kaufmanii					1		1
Lactarius luculentus var. *laetus*					2		2
Lactarius mucidus				1	1		2
Lactarius mucidus var. *fuscogriseus*					1		1
Lactarius pseudomucidus			2		3		5
Phylloporus rhodoxanthus					3		3
Russula atropurpurrea					8		8
Russula fragilis					2		2
Suillus brevipes			1				1
Suillus punctatipes			1				1
Total	2	0	6	11	39	4	62

Table 4.3. List of families of ectomycorrhizal fungi, with numbers of genera and species (excluding those found in cedar).

Family	Number of genera	Number of species
Amanitaceae	1	2
Boletaceae	2	3
Cantharellaceae	2	2
Cortinariaceae	4	34
Gomphidiaceae	2	3
Hydnaceae	2	2
Hygrophoraceae	1	2
Paxillaceae	1	1
Russulaceae	2	27
Tricholomataceae	2	6

Table 4.4. Ectomycorrhizal macrofungi found in each conifer habitat, sorted by their relative frequency (as % of total macrofungus abundance within each conifer habitat).

Sitka spruce	% Fr.	Douglas-fir	% Fr.	western hemlock	% Fr.
Cantharellus formosus	6.35	*Cantharellus formosus*	6.6	*Cantharellus formosus*	11.46
Lactarius hepaticus	3.1	*Lactarius hepaticus*	4.59	*Craterellus tubaeformis*	2.31
Inocybe sororia	1.43	*Craterellus tubaeformis*	3.17	*Russula atropurpurea*	2.31
Inocybe calamistrata	0.48	*Inocybe sororia*	0.91	*Russula fragilis*	2.31
Inocybe fastigiata	0.32	*Inocybe calamistrata*	0.45	*Hydnum repandum*	2.11
Inocybe sp. affin. tigrina	0.32	*Russula atropurpurrea*	0.45	*Chroogomphus tomentosus*	1.91
Lactarius luculentus	0.32	*Inocybe napipes*	0.39	*Cortinarius sect. Telemonia*	0.9
Craterellus tubaeformis	0.24	*Russula bicolor*	0.39	*Lactarius scrobiculatus*	0.9
Cortinarius sect. Telemonia	0.24	*Russula fragilis*	0.39	*Lactarius hepaticus*	0.7
Hygrophorus bakerensis	0.24	*Gomphidius subroseus*	0.32	*Amanita vaginata*	0.6
Lactarius deliciosus	0.16	*Cortinarius sect. Telemonia*	0.26	*Lactarius pseudomucidus*	0.6
Lactarius luculentus var. *laetus*	0.16	*Phylloporus rhodoxanthus*	0.26	*Hygrophorus bakerensis*	0.5
Russula bicolor	0.16	*Amanita vaginata*	0.19	*Lactarius uvidus*	0.5
Amanita farinosa	0.08	*Hygrophorus pratensis*	0.19	*Dermocybe* sp. R.O. 349	0.4
Boletus piperatus	0.08	*Lactarius luculentus var. laetus*	0.19	*Inocybe calamistrata*	0.3
Cortinarius acutus group	0.08	*Inocybe fastigiata*	0.13	*Inocybe eutheles*	0.3
Cortinarius gentilis	0.08	*Inocybe sect. inocybium*	0.13	*Lactarius luculentus* var. *laetus*	0.3
Cortinarius obtusus	0.08	*Inocybe section cortinatae*	0.13	*Lactarius mucidus*	0.3
Cortinarius scaurus group	0.08	*Lactarius luculentus*	0.13	*Phellodon atrium*	0.3
Cortinarius sp. affin. azureus	0.08	*Lactarius rufulus*	0.13	*Cortinarius obtusus*	0.2
Gomphidius subroseus	0.08	*Russula nigricans*	0.13	*Cortinarius vibratilis*	0.2
Inocybe cookei	0.08	*Tricholoma sp. affin. apium*	0.13	*Inocybe ovatocystis*	0.2
Inocybe geophila	0.08	*Cortinarius decipiens*	0.06	*Inocybe sororia*	0.2
Inocybe napipes	0.08	*Cortinarius gentilis*	0.06	*Tricholoma pessundatum*	0.2
Laccaria bicolor	0.08	*Dermocybe crocea*	0.06	*Boletus mirabilis*	0.1
Lactarius pallescens	0.08	*Dermocybe* sp. R.O. 348	0.06	*Cortinarius alboviolaceus*	0.1

Sitka spruce	% Fr.	Douglas-fir	% Fr.	western hemlock	% Fr.
Lactarius scrobiculatus	0.08	*Gomphidius smithii*	0.06	*Cortinarius castaneus* group	0.1
Russula albonigra group	0.08	*Hydnum repandum*	0.06	*Cortinarius cotoneus*	0.1
Russula crassotunicata	0.08	*Inocybe idahoensis*	0.06	*Cortinarius glaucopus*	0.1
Russula farinipes	0.08	*Inocybe* sp. R.O. 186	0.06	*Cortinarius junhuhnii*	0.1
Russula fragilis	0.08	*Phaeocollybia phaeogaleroides*	0.06	*Cortinarius renidens* R.O. 332	0.1
Tricholoma sp. affin. *apium*	0.08	*Russula adusta*	0.06	*Cortinarius scaurus* group	0.1
	15.04	*Russula brevipes*	0.06	*Cortinarius semisanguineus*	0.1
		Russula cyanoxantha	0.06	*Cortinarius traganus* gr.	0.1
		Russula occidentalis	0.06	*Gomphidius subroseus*	0.1
		Tricholoma sp. R.O. 118	0.06	*Inocybe* sp. affin. *tigrina*	0.1
			20.5	*Laccaria laccata*	0.1
				Lactarius alnicola	0.1
				Lactarius fallax	0.1
				Lactarius ligniotus var. *canad.*	0.1
				Lactarius olivaceo-umbrinus	0.1
				Phaeocollybia phaeogaleroides	0.1
				Phellodon nigrea ? R.O. 334	0.1
				Russula arenicola	0.1
				Russula cremicolor	0.1
				Suillus punctatipes	0.1
				Tricholoma imbricatum	0.1
					32.31

Table 4.5. Total and average diversity (number of species) and abundance (number of observations) of ectomycorrhizal macrofungi within each conifer habitat, and total frequency (as proportion of the whole macrofungus community of a given conifer species).

	Sitka spruce	Douglas-fir	western red cedar	western hemlock
Total diversity	32	36	22*	47
Average diversity	9.33	11.17	4.33	12.83
Total abundance	189	320	62	322
Average abundance	31.5	53.33	10.33	53.67
Total frequency	15.4	20.5		32.31

* assumed to be associated with the understory western hemlock and possibly other vegetation

Table 4.6. Results of Analysis of Variance (ANOVA) for the effect of conifer species and site on ectomycorrhizal diversity and abundance. Ectomycorrhizal species found in cedar plots included. Significant tests in bold type.

Variable	Source of Variation	SS	df	MS	F	P-value	F crit
Diversity	Conifer species	243.5	3	81.16667	6.671233	**0.006698**	3.4903
	Site	63.58333	2	31.79167	2.613014	0.114282	3.88529
	Interaction	54.75	6	9.125	0.75	0.621244	2.996117
	Error	146	12	12.16667			
Abundance	Conifer species	7714.458	3	2571.486	9.298729	**0.00187**	3.4903
	Site	5409.333	2	2704.667	9.7803222	**0.003021**	3.88529
	Interaction	1573.667	6	262.2778	0.94842	0.497123	2.996117
	Error	3318.5	12	276.5417			

Table 4.7. Results of Analysis of Variance (ANOVA) for the effect of conifer species and site on ectomycorrhizal diversity and abundance. Ectomycorrhizal species found in cedar plots are excluded.

Variable	Source of Variation	SS	df	MS	F	P-value	F crit
Diversity	Conifer species	36.77778	3	18.38889	1.464602	0.28141	4.256492
	Site	28.44444	2	14.22222	1.132743	0.364096	4.256492
	Interaction	43.55556	6	10.88889	0.867257	0.519283	3.63309
	Error	113	12	12.55556			
Abundance	Conifer species	1936.333	3	968.1667	3.237414	0.087252	4.256492
	Site	5324.333	2	2.662.167	8.901913	**0.007366**	4.256492
	Interaction	1228.333	6	307.0833	1.026844	0.443928	3.63309
	Error	2691.5	12	299.0556			

Figure 4.1. Comparison of the numbers of ectomycorrhizal species amongst all the plots.

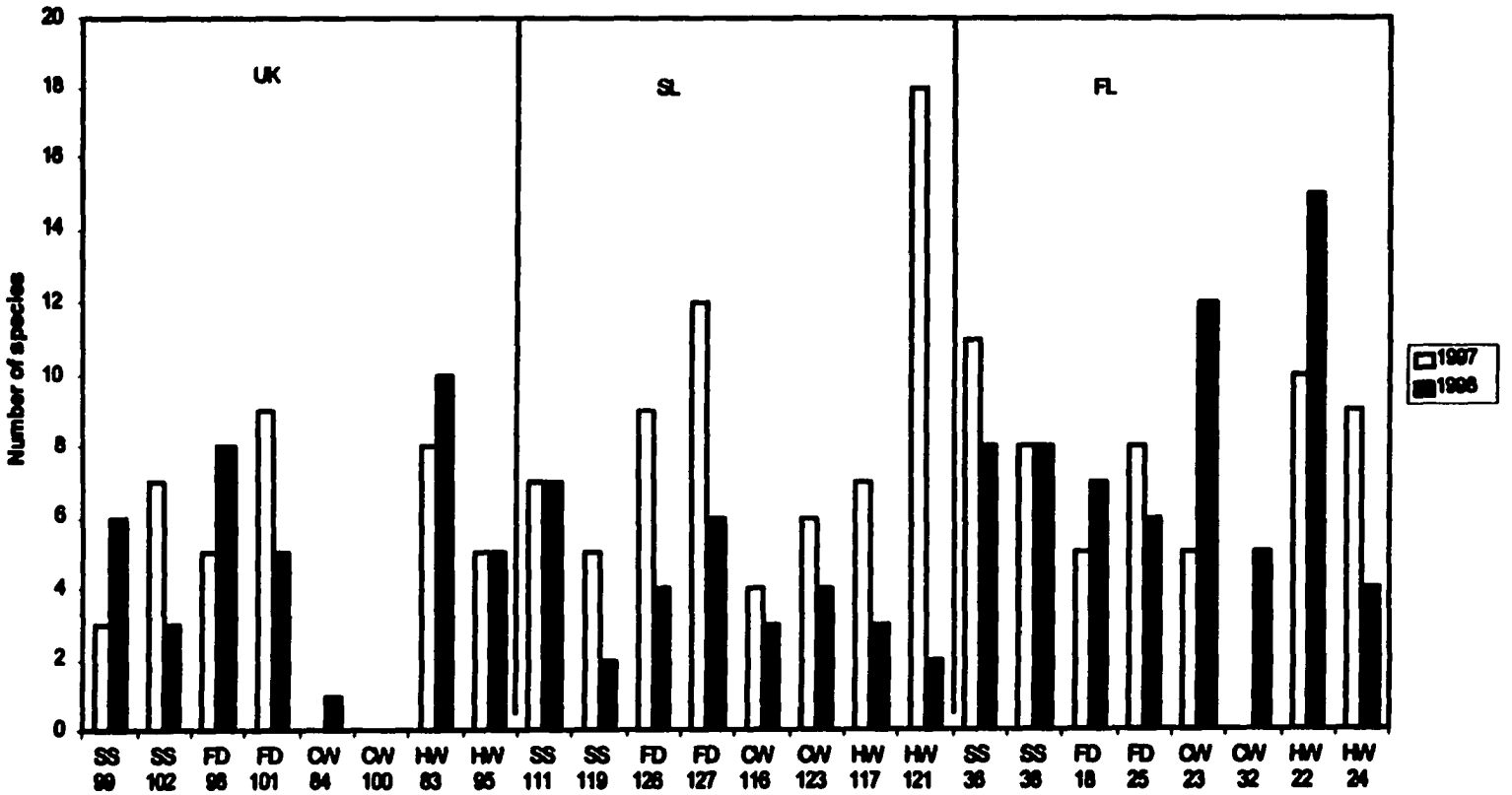


Figure 4.2. Comparison of the abundance of mycorrhizal macrofungi amongst all the plots.

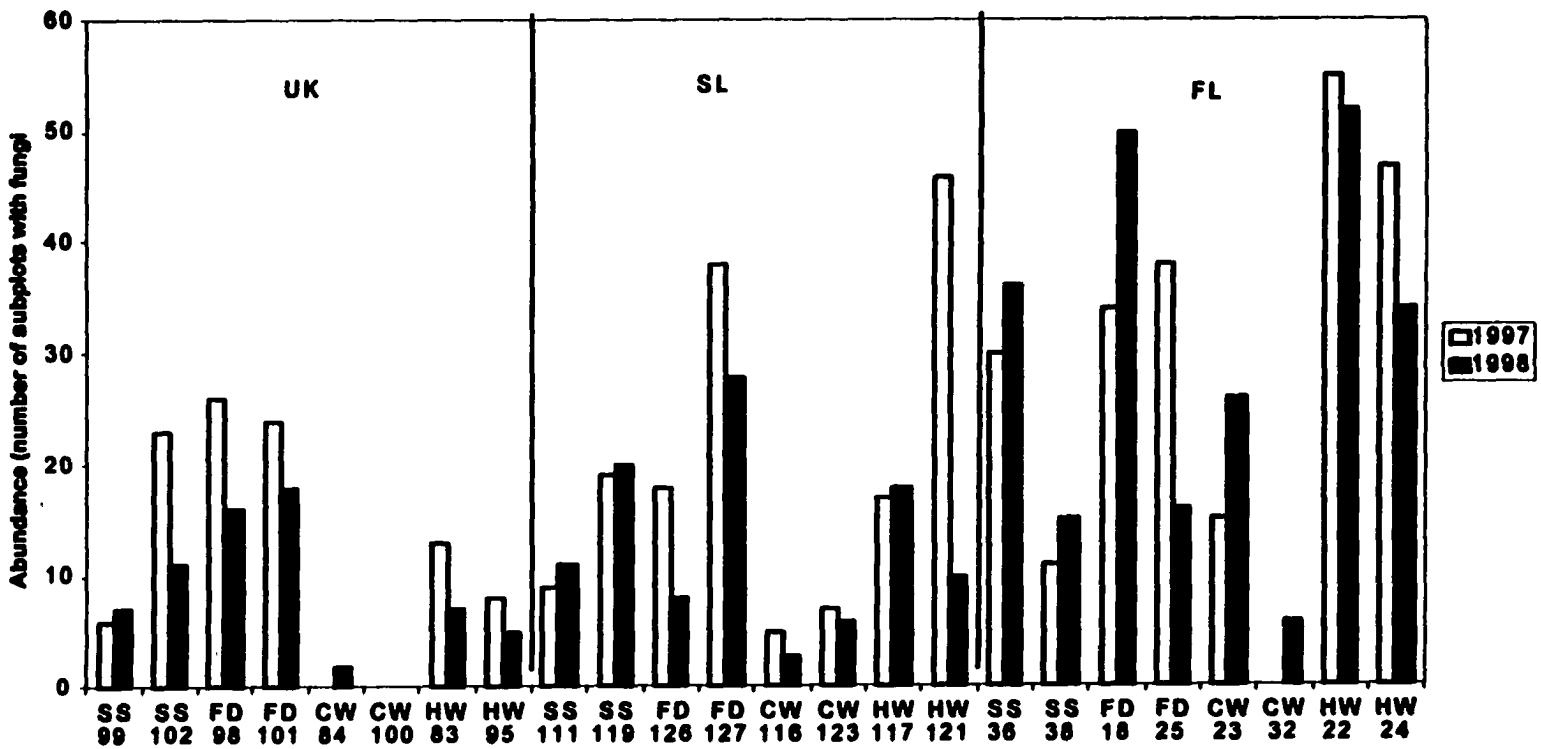


Figure 4.3. Detrended Correspondence Analysis. EP571 plots ordinated based on nutrient data for each plot. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

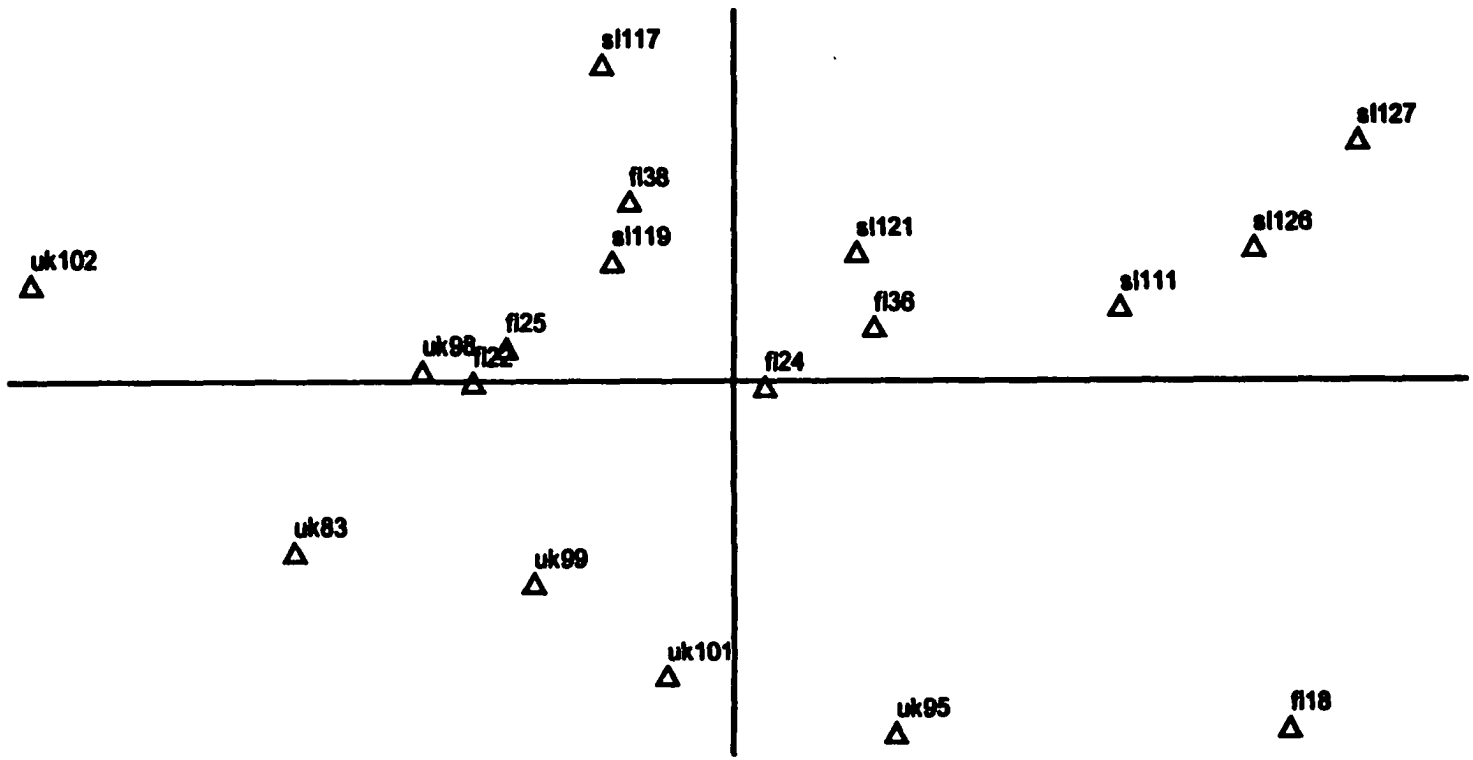


Figure 4.4. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of pH measurements. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

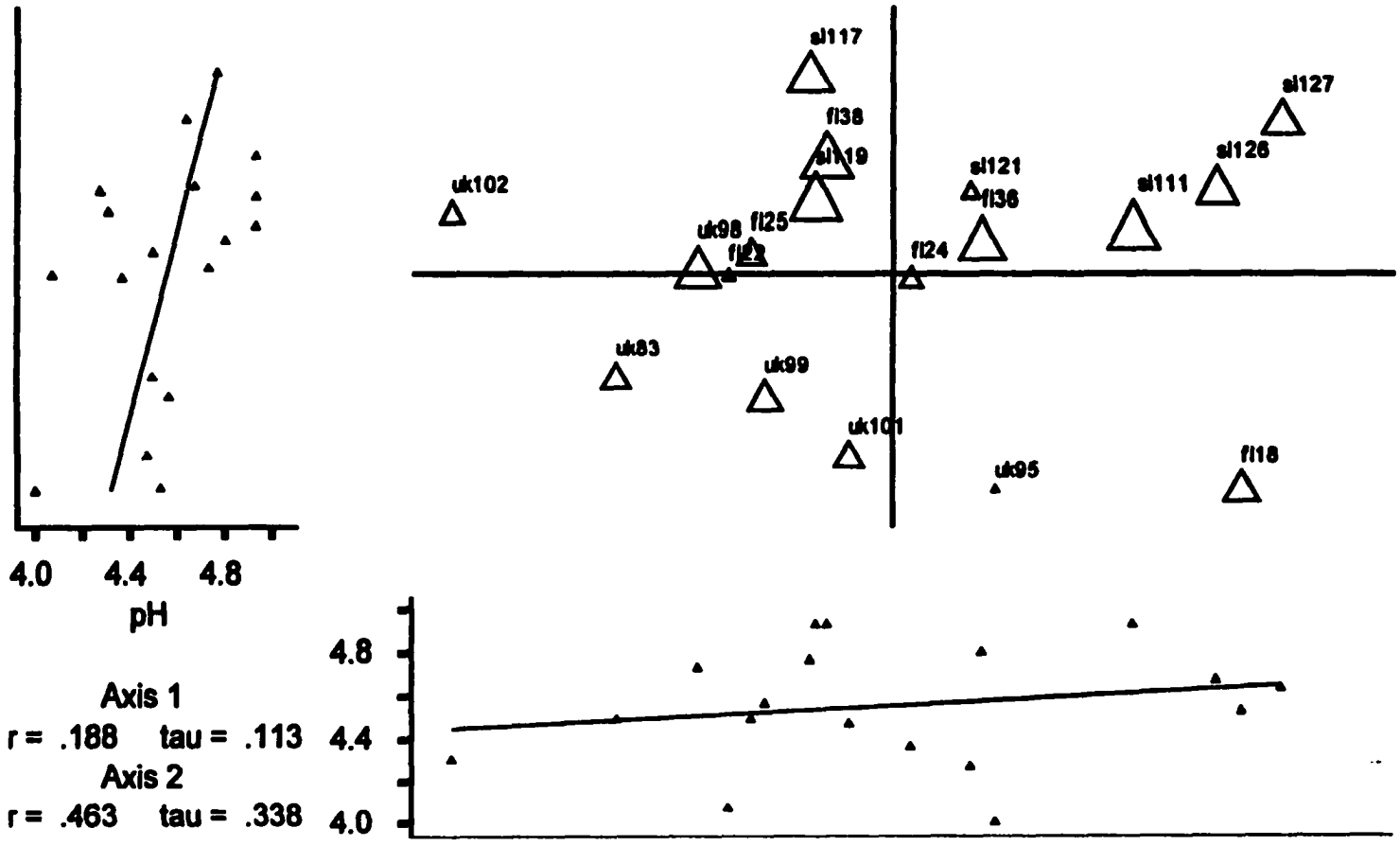


Figure 4.5. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of Nitrogen levels. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

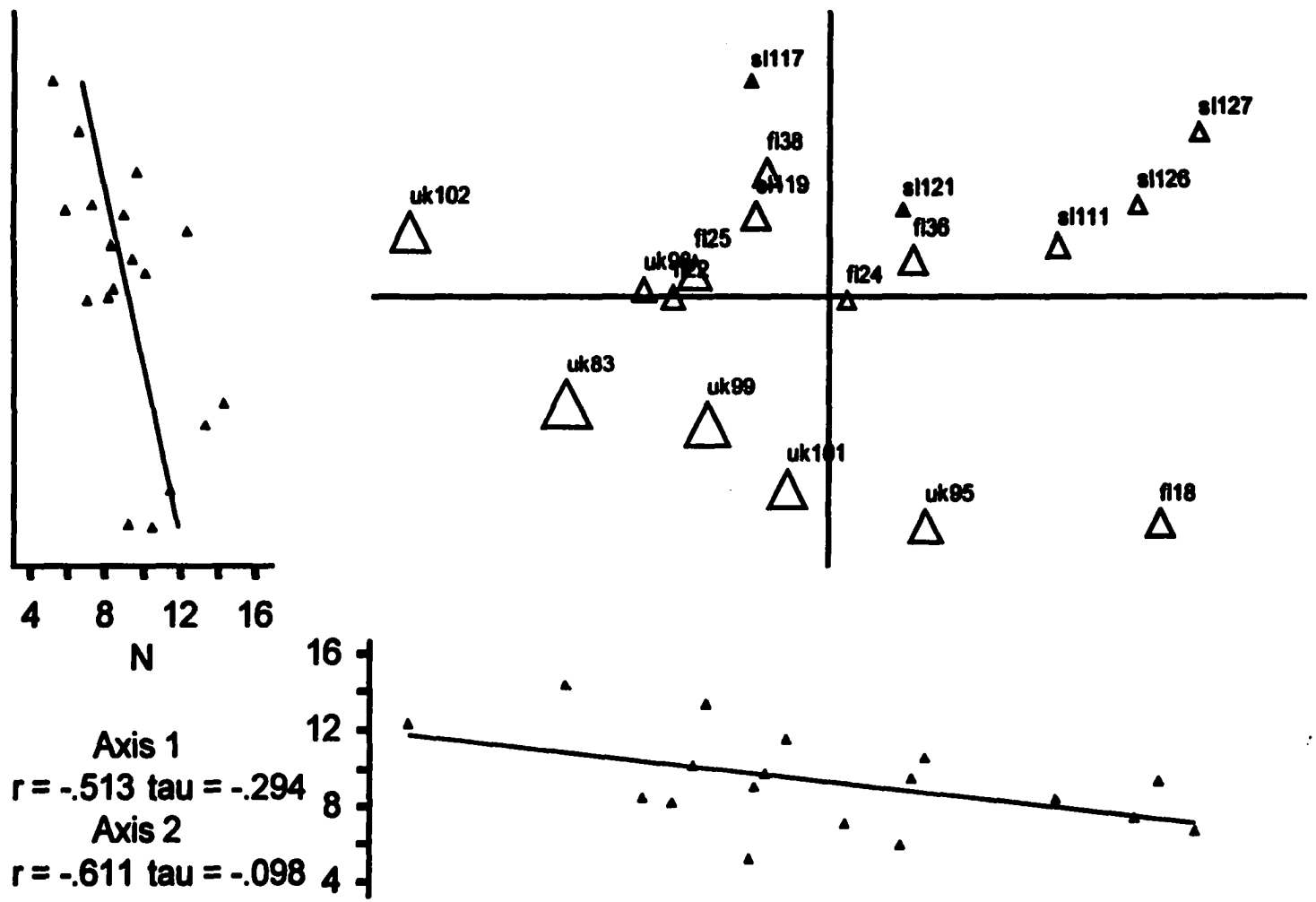


Figure 4.6. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of Phosphorus levels. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

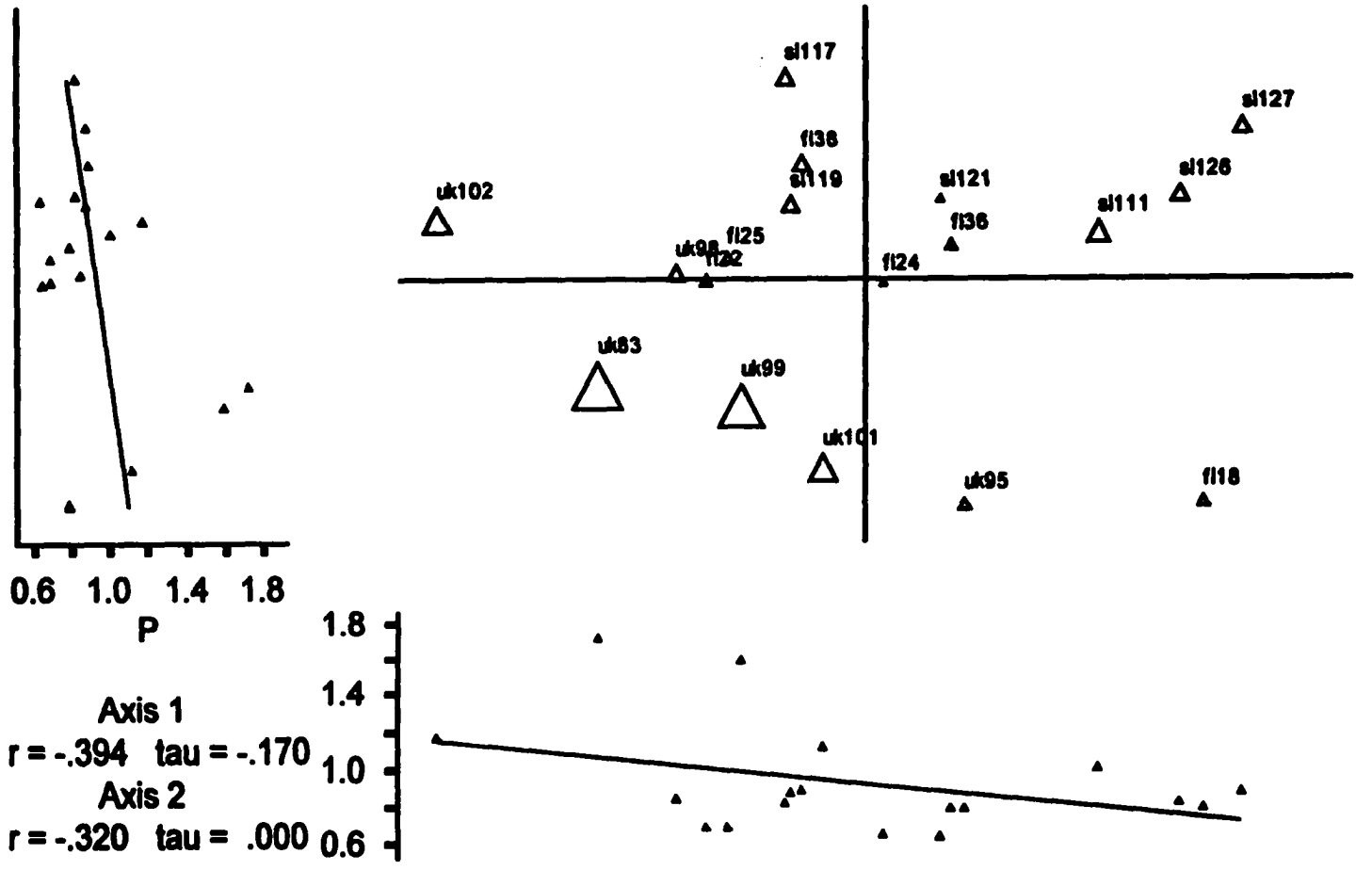


Figure 4.7. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of Calcium levels. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

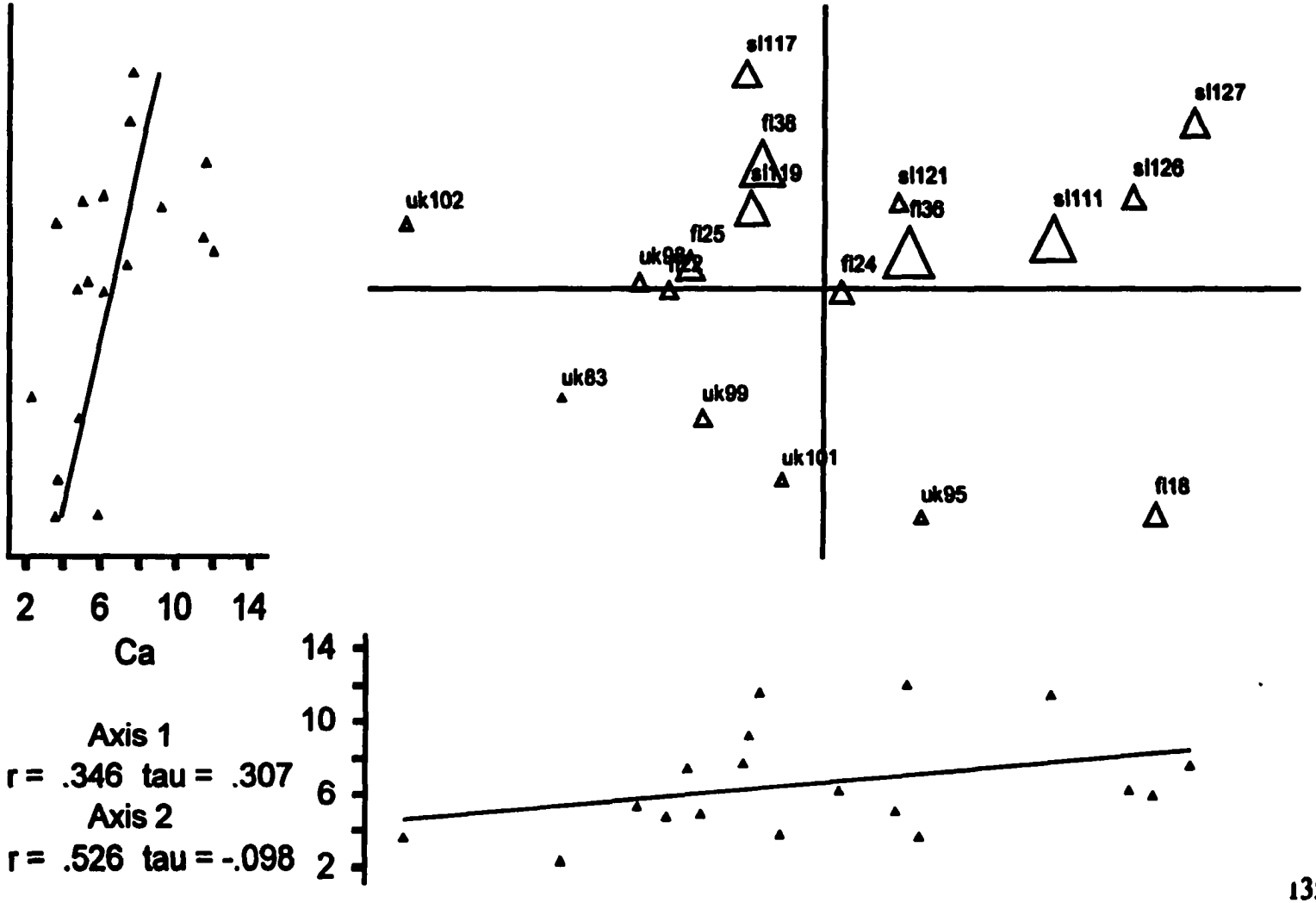


Figure 4.8. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of Potassium levels. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

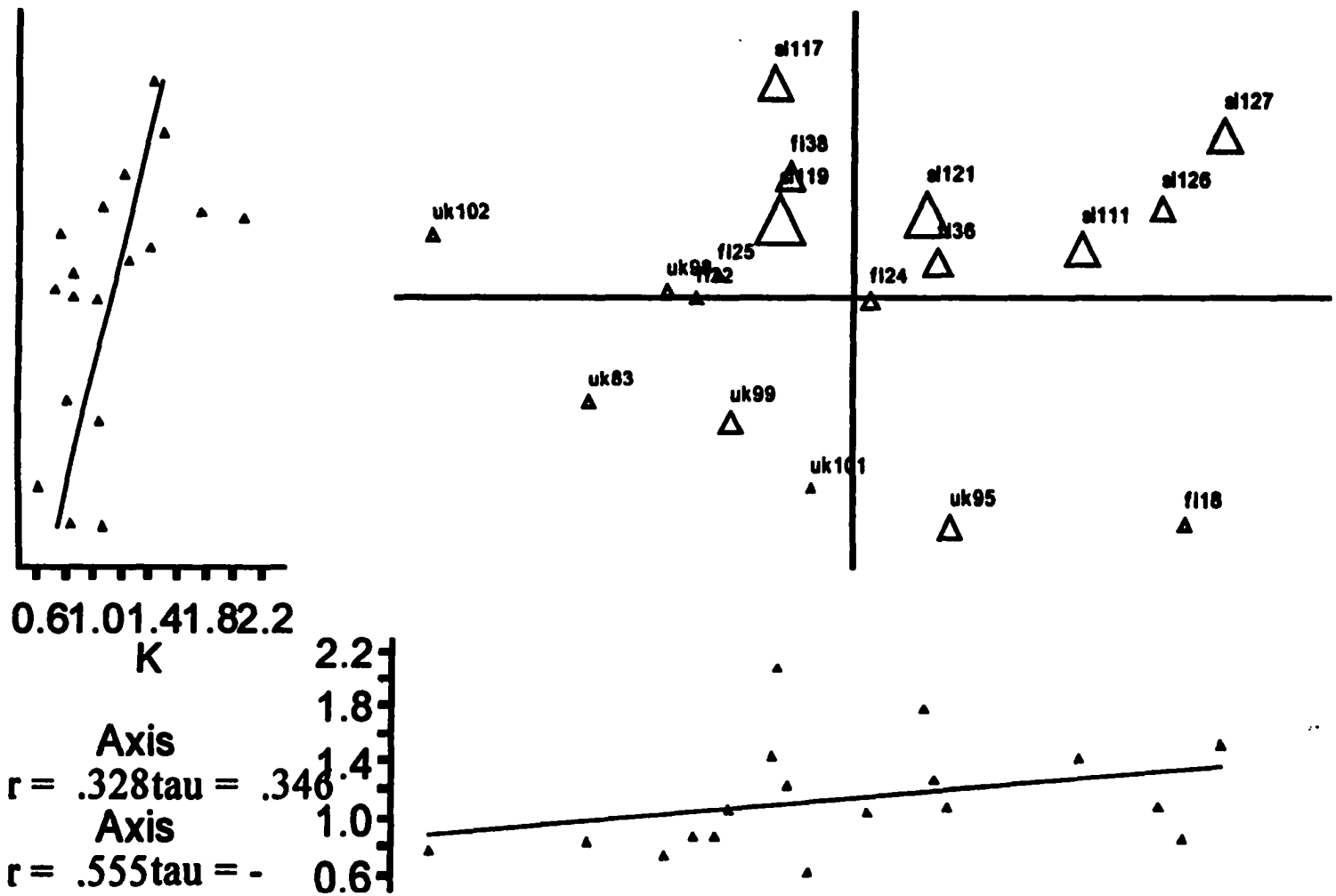


Figure 4.10. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of humus levels (ton/ha). The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

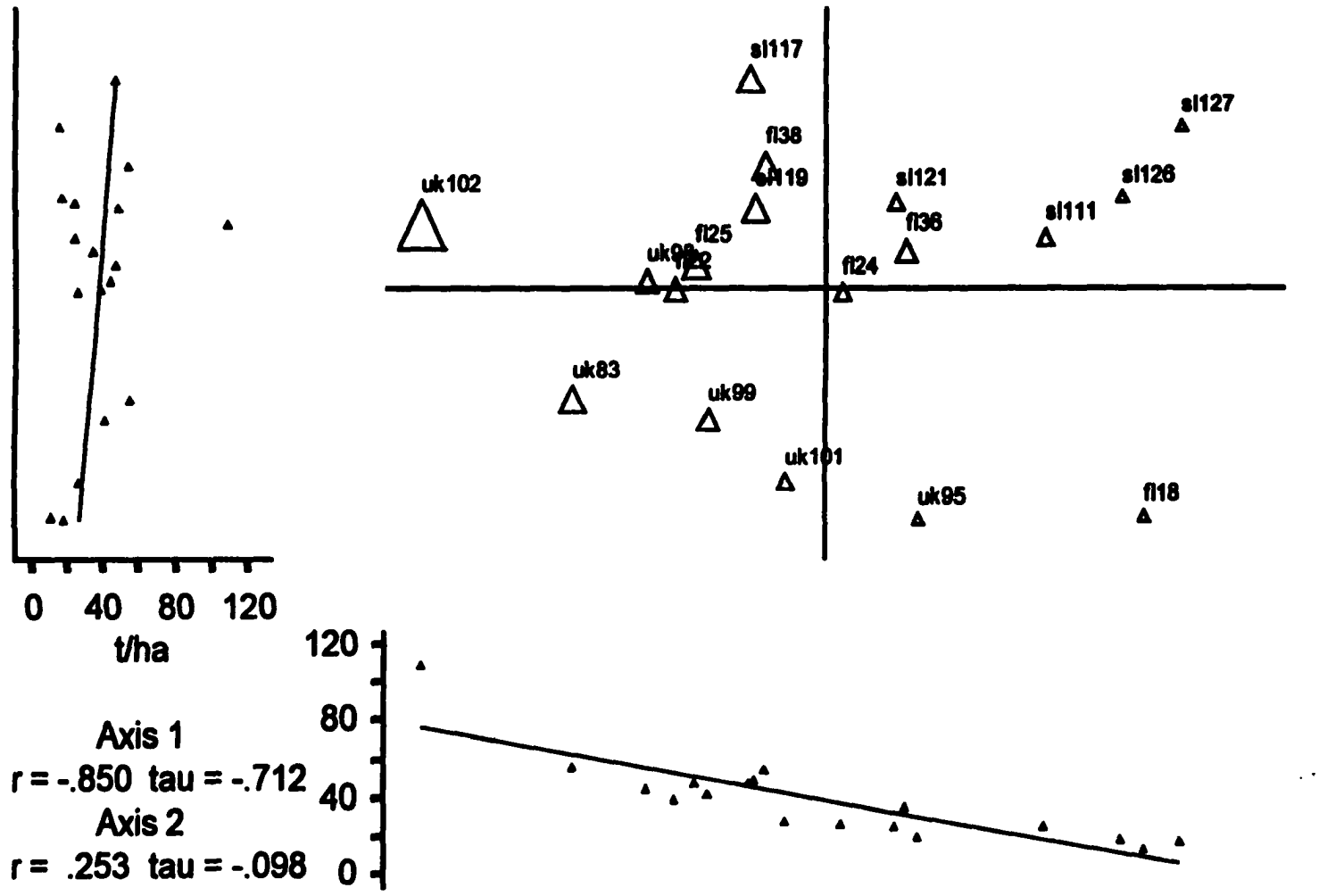


Figure 4.11. Detrended Correspondence Analysis (DECORA). Joint plot of nutrient and macrofungus data, showing possible relationship of the ectomycorrhizal fungi with microsites. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121.

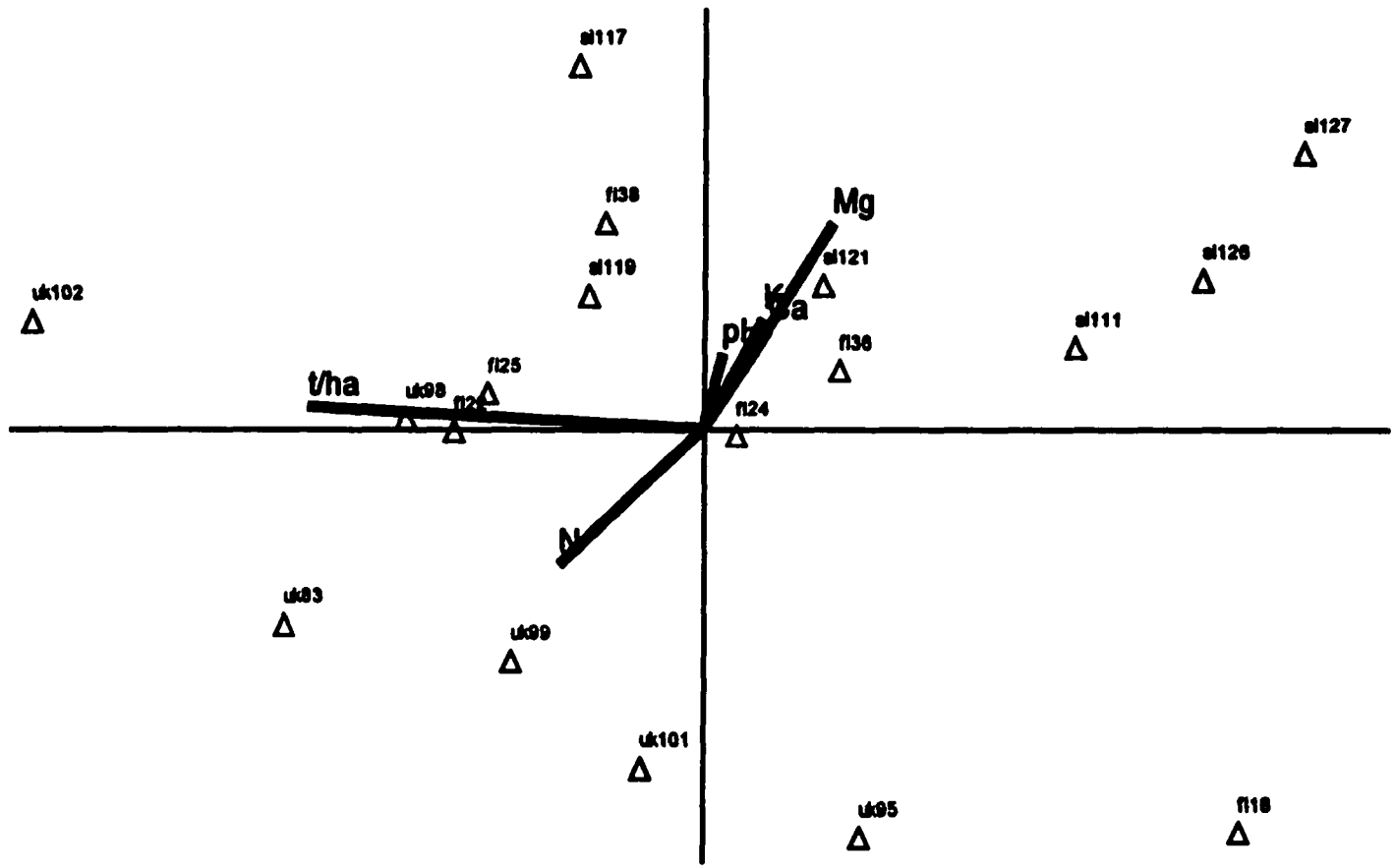


Figure 4.12. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Cantharellus formosus* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

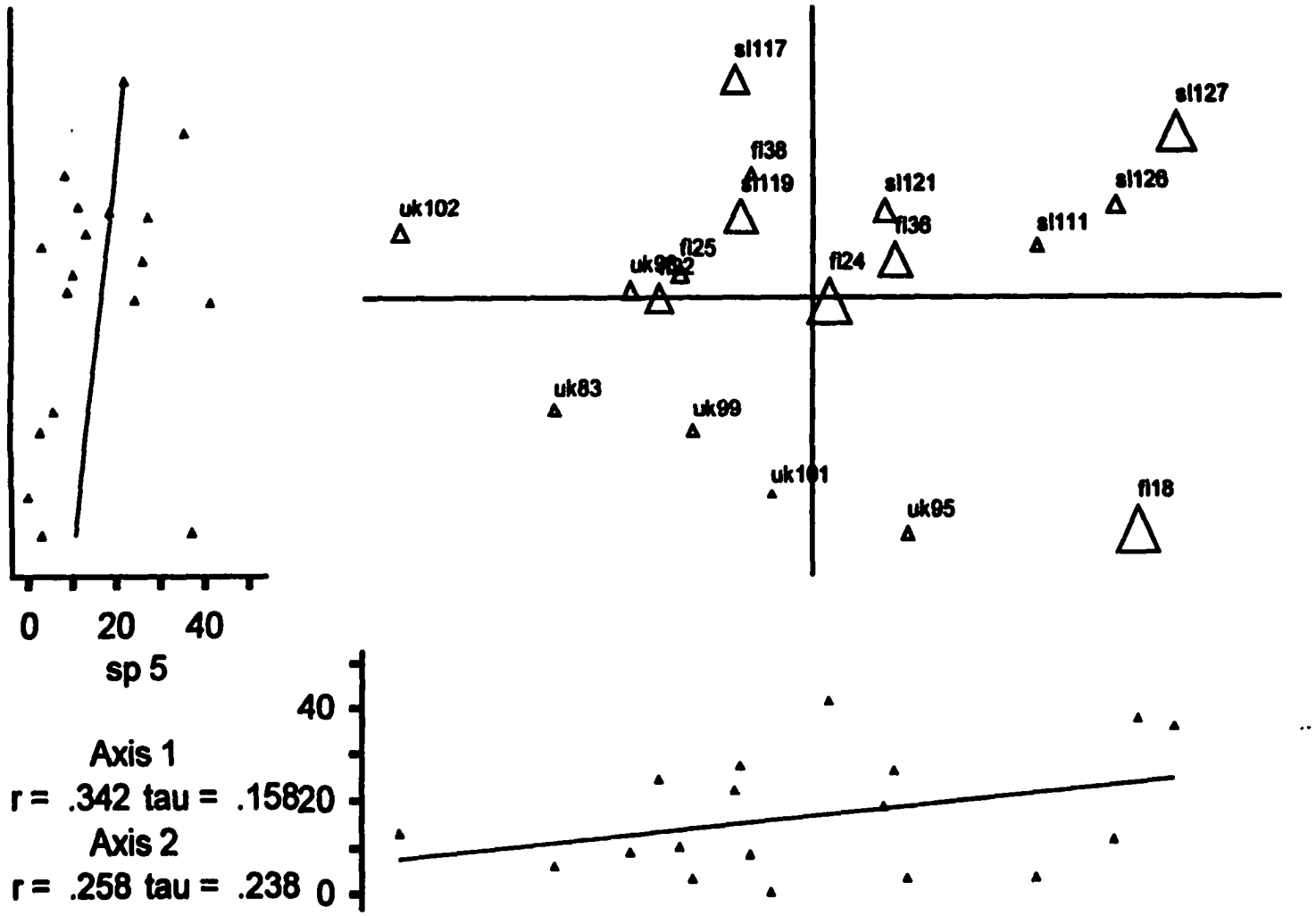


Figure 4.13. Detrended correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Inocybe sororia* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

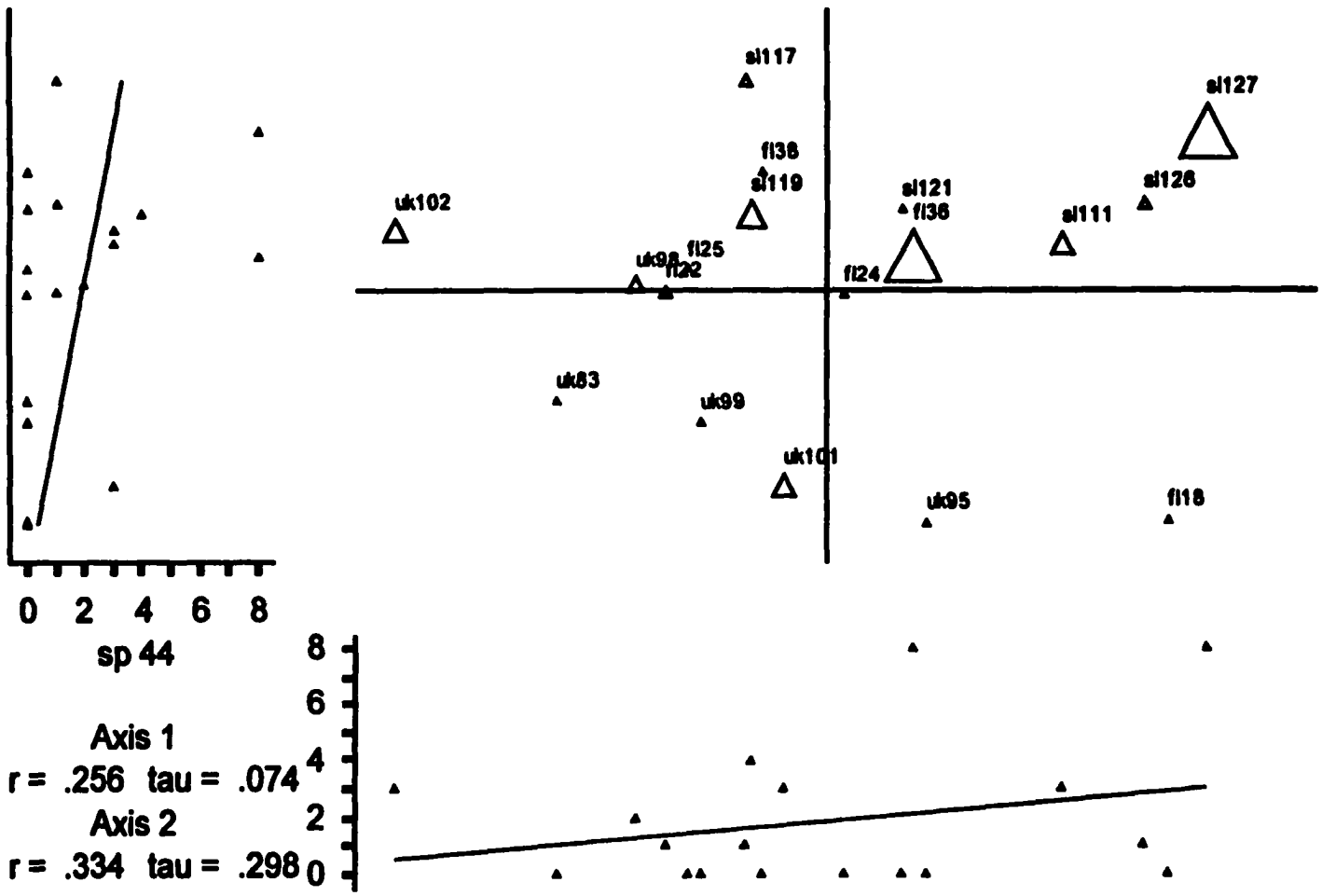


Figure 4.14. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Lactarius luculentus* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

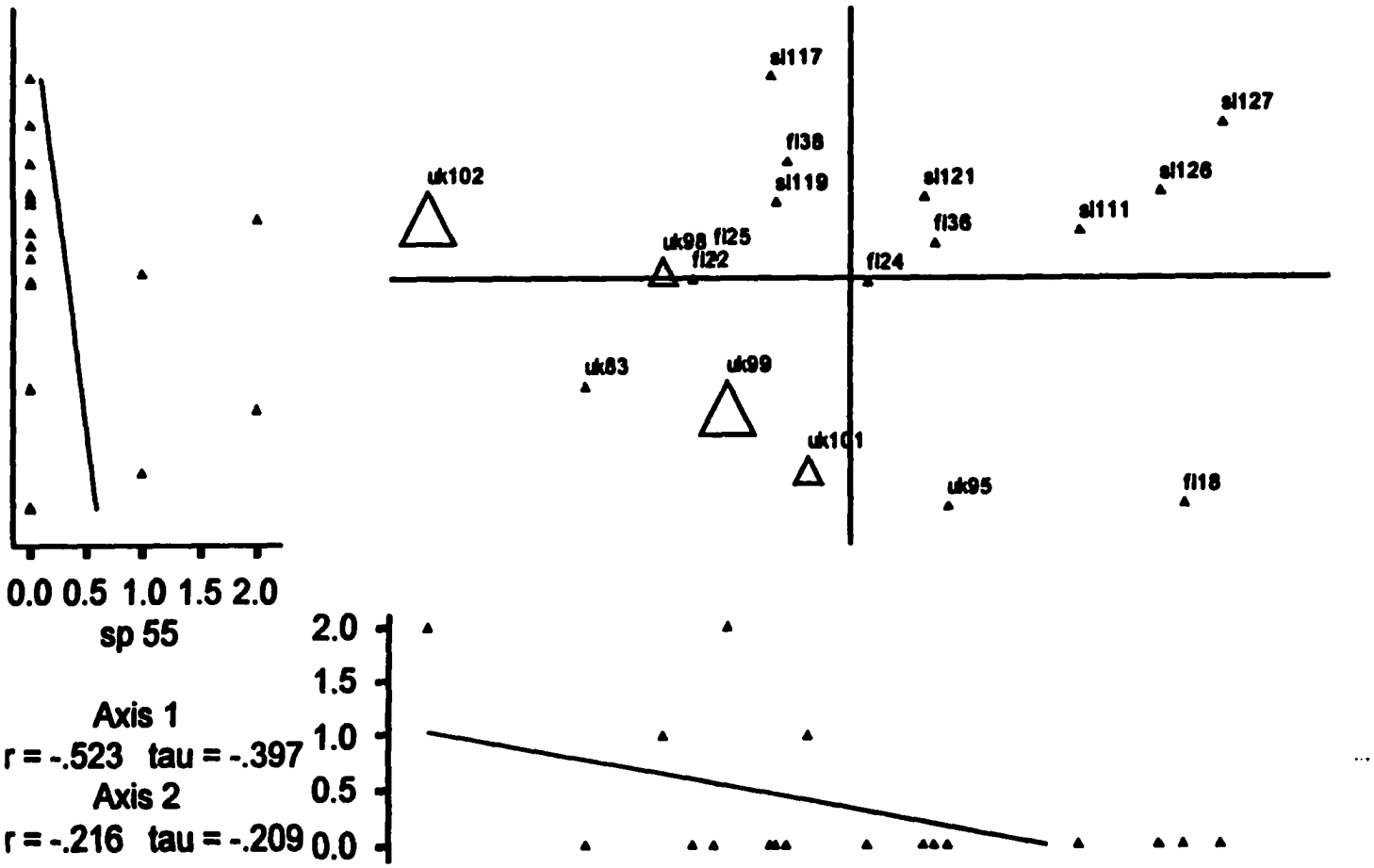


Figure 4.15. Detrended correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Lactarius hepaticus* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

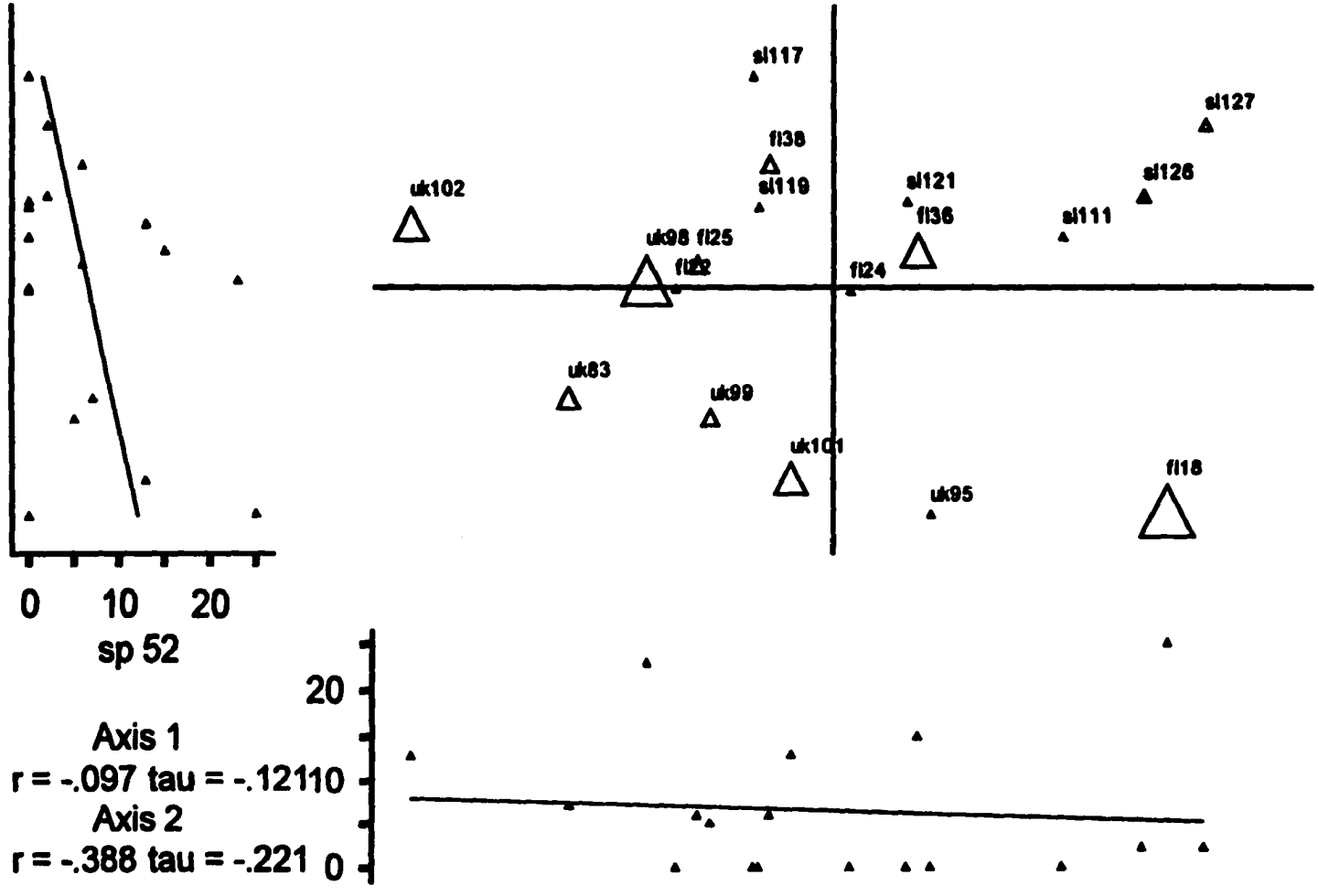


Figure 4.16. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Lactarius luculentus* var. *laetus* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

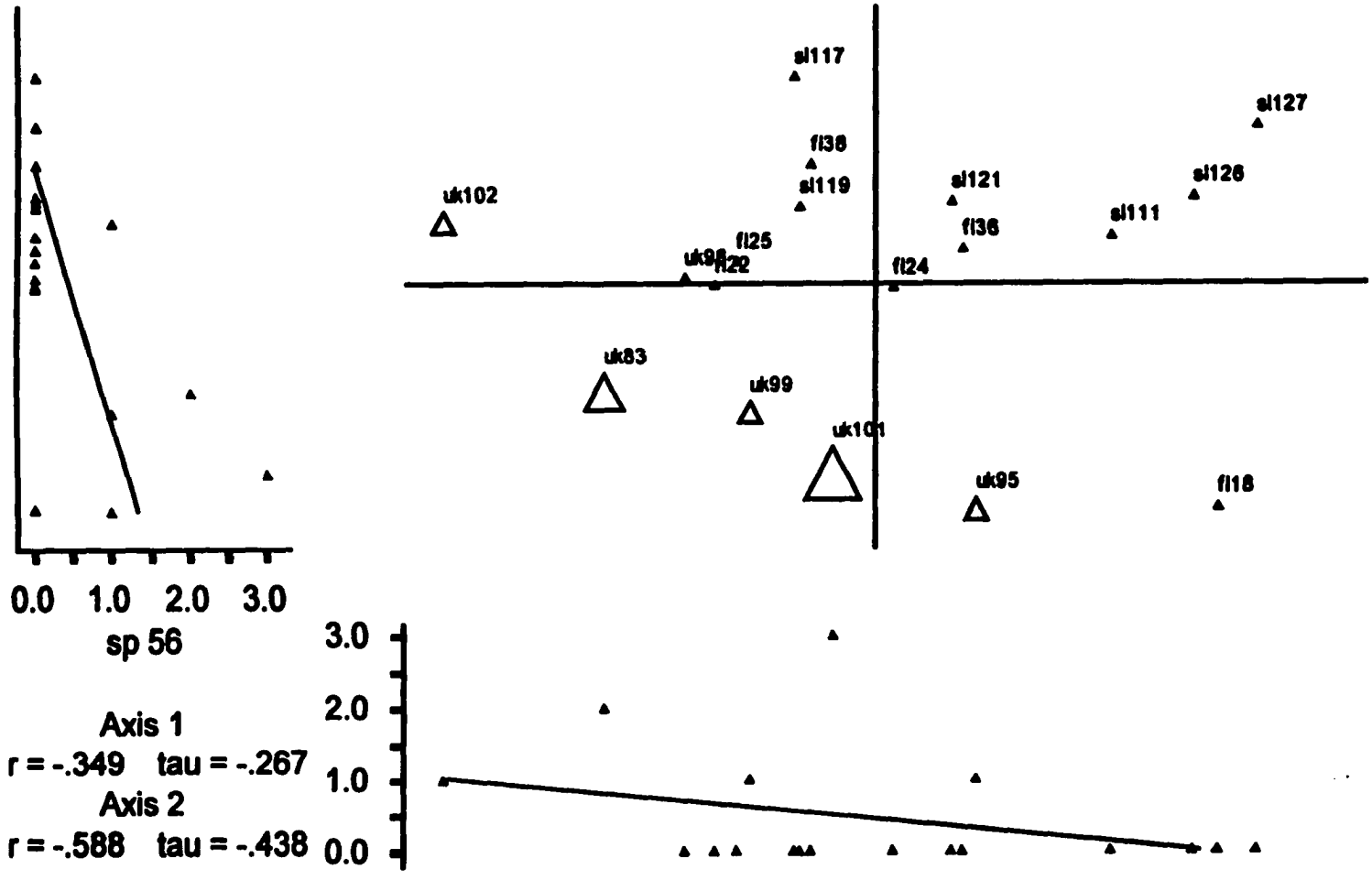


Figure 4.17. Detrended Correspondence Analysis (DECORA). Ordination of all the plots based on their nutrient status, with an overlay of *Russula atropurpurrea* abundance. The following plot numbers correspond to the following conifers: spruce - 36, 38, 99, 102, 111 and 119; Douglas-fir – 18, 25, 98, 101, 126, and 127; hemlock – 22, 24, 83, 95, 117, and 121. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

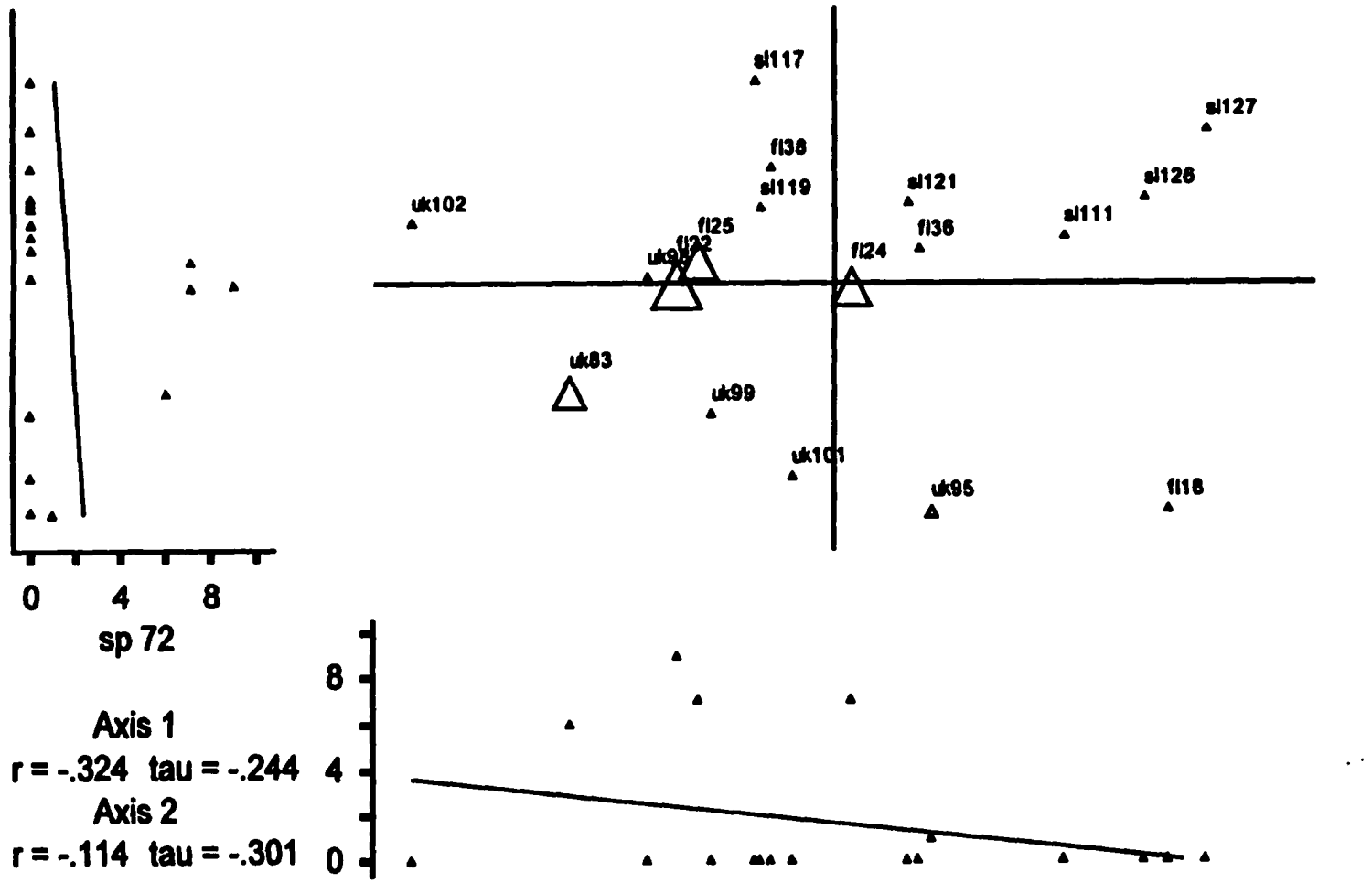


Figure 4.18. Cluster analysis (Euclidean Distance, Ward's method) of all the plots based on their ectomycorrhizal communities.

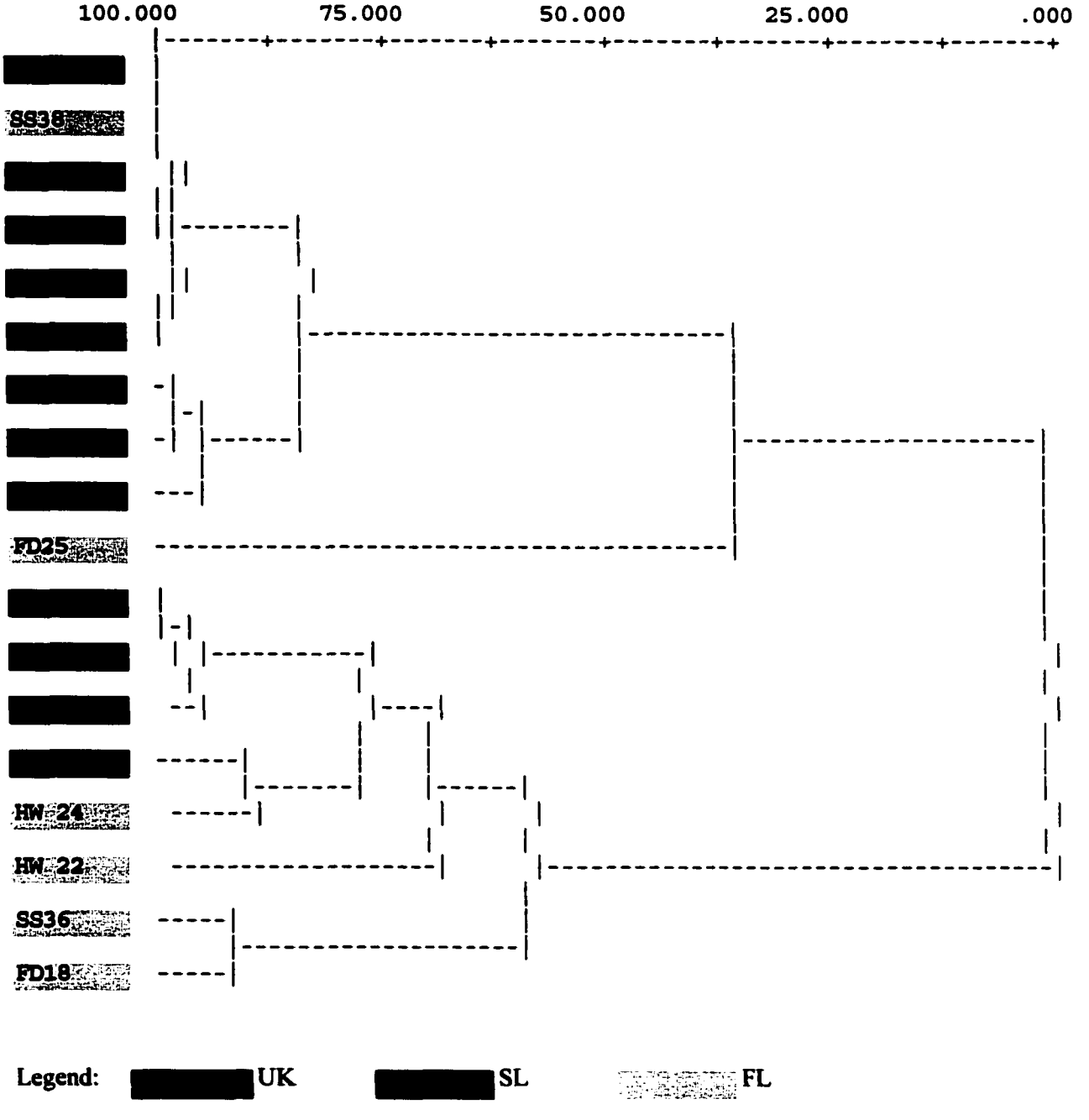


Table 4.8. Diversity indices: S = species richness, E = species evenness, and H' = Shannon- Wiener index, for each of the EP571 plots.

	Plot Name	S	E	H'
Upper Klanawa	SS 99	6	.885	1.586
	SS 102	7	.733	1.427
	FD 98	9	.639	1.405
	FD 101	12	.832	2.066
	CW 84	1	.000	.000
	CW 100	1	.000	.000
	HW 83	13	.873	2.238
	HW 95	9	.922	2.026
Sarita Lake	SS 111	12	.928	2.306
	SS 119	5	.538	.866
	FD 126	12	.840	2.087
	FD 127	15	.702	1.901
	CW 116	5	.970	1.561
	CW 123	6	.916	1.642
	HW 117	9	.611	1.343
	HW 121	19	.829	2.442
Fairy Lake	SS 36	15	.682	1.846
	SS 38	11	.825	1.979
	FD 18	9	.567	1.246
	FD 25	10	.642	1.479
	CW 23	11	.775	1.859
	CW 32	3	.946	1.040
	HW 22	16	.813	2.253
	HW 24	11	.671	1.610

Table 4.9. *Cantharellus formosus* - frequency of sporocarp observation in four different conifer habitats at three sites on south-western Vancouver Island.

Year	Conifer Habitat	Plot number	Site 1 – Upper Klanawa	Plot number	Site 2 – Sarita Lake	Plot number	Site 3 – Fairy Lake	**Frequency by conifer habitat**
1997	Sitka spruce	Ss 99	1	Ss 111	1	Ss 36	9	
		Ss 102	5	Ss 119	11	Ss 38	3	**20%**
	Douglas-fir	Fd 98	8	Fd 126	6	Fd 18	16	
		Fd 101	0	Fd 127	17	Fd 25	3	**34%**
	western hemlock	Hw 83	3	Hw 117	10	Hw 22	12	
		Hw 95	2	Hw 121	9	Hw 24	22	**39%**
	western red cedar	Cw 84	0	Cw 116	0	Cw 23	9	**6%**
		Cw 100	0	Cw 132	0	Cw 32	0	
	Frequency by site		**13%**		**37%**		**50%**	**100%**
1998	Sitka spruce	Ss 99	2	Ss 111	2	Ss 36	17	
		Ss 102	8	Ss 119	16	Ss 38	5	**30%**
	Douglas-fir	Fd 98	1	Fd 126	5	Fd 18	21	
		Fd 101	0	Fd 127	18	Fd 25	7	**31%**
	western hemlock	Hw 83	3	Hw 117	12	Hw 22	12	
		Hw 95	1	Hw 121	9	Hw 24	19	**34%**
	western red cedar	Cw 84	0	Cw 116	0	Cw 23	7	
		Cw 100	0	Cw 132	0	Cw 32	1	**5%**
	Frequency by site		**9%**		**37%**		**54%**	**100%**

Chapter five: The saprobic macrofungus community.

Introduction

Unlike ectomycorrhizae, saprobic macrofungal communities have not been studied extensively. Some general references exist to biology and ecology of fungal saprophytism (Frankland et al., 1982; Hudson, 1980). Literature on decomposition processes typically offers more thorough treatment of microfungal and bacterial agents and a brief comment on a few macrofungi (Dickinson and Pugh, 1974; Pugh, 1974; Caroll and Wicklow, 1992). Ingold and Hudson (1993) provide a good introduction to litter dwelling and wood rotting fungi from a variety of habitats, but, unfortunately, limit their coniferous wood coverage to five lignicolous species. Other authors focus on necrotrophic parasites or heart rot fungi. A few references exist to entomopathogenic species. Mushroom guide books usually indicate whether a fungus is ectomycorrhizal or saprobic, and frequently indicate substrate preferences (Phillips, 1991; Arora, 1986; Lincoff, 1981; Breitenbach and Kranzlin, 1984 - 1995). A good reference to the systematics and ecology of Basidomycete corticioid lignicolous fungi of North America can be found in Ginns and Lefebvre (1993). The common macrofungal saprobic genus *Mycena* has been extensively covered for the northern hemisphere by Maas Geesteranus (1992), and for North America by Smith (1947). They have been updated recently by Redhead (personal communication) with regards to thePacific Northwest. Detailed

requirements for inventorying British Columbia's macrofungi with special reference to the ecological niches of saprobic fungi are outlined by Redhead and Berch (1996).

Saprobic macrofungi have been listed in individual studies of various deciduous forests (Villeneuve et al., 1989; Schmit et al., 1999, Holec, 1992; Lange, 1993) and coniferous forests (Wasterlund and Ingelog, 1981; Dighton et al., 1986; Lange, 1993; Sastad, 1995; and Senn-Irlet and Bieri, 1999). Effect of soil type on diversity of litter and wood macromycetes was investigated by Lange (1993). Arnolds (1988) includes saprophytes in his discussion on the changing macromycete flora in the Netherlands. Soil saprobic macrofungi constitute the largest component on the lists of endangered macrofungi in Europe (Arnolds and de Vries, 1993). Generally, very little is known about the interaction within the guild, though complex competitive or inhibitory behaviour has been documented for some (Frankland, 1998; Ingold and Hudson, 1993).

Nutrient requirements and limiting factors are often discussed in reference to saprophytic community as a whole, though fungi are known to readily colonize unique or extreme environmental niches (Ingold and Hudson, 1993). Plant litter differs in quality and quantity depending on the species involved and environmental conditions (Dickinson and Pugh, 1974, Prescott et al., 2000). While various toxins produced by plants inhibit the growth of fungi, others attract and enhance particular species (Isaak, 1992, Ingold and Hudson, 1993).

Saprophytic macrofungal communities of coniferous forests have not been sufficiently researched, to make general predictions for occurences of specific fungi. Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) feature in most papers (Wasterlund and Ingelog, 1981; Sastad, 1995; Senn-Irlet and Bieri, 1999). Sitka spruce is compared with lodgepole pine (*Pinus contorta*) by Dighton et al. (1986), and Lange (1993) includes Sitka spruce, Douglas-fir, and Lawson's cedar (*Chamaecyparis lawsoniana*) in his survey of macromycetes on different soil types in Denmark.

I am aware of only two scientific surveys of macrofungi in British Columbia which separate the species into guilds. Countess (2001) researched Douglas-fir chronosequence plots on Vancouver Island. Berch (2001) reports on the pilot study of the Upper Klanawa site, preceeding my research in the EP 571 plantation forests. The guild structure used by Countess differed from the one used in this study and included the following groups: mycorrhizal, wood decay, litter decay, parasitic, fungicolous, and other saprobes. Berch placed all the species into four main functional groups: ectomycorrhizal, needle decomposers, wood decomposers, and general decomposers (not specific to wood or conifer needles), and placed a few parasitic species under the category 'other saprobes'.

This chapter elucidates some relationships between coniferous woods and saprobic (i.e. non-mycorrizal) macrofungi. The saprobic guild is divided into three groups: litter decomposers (growing on conifer needles, forest floor duff, soil, and insects), wood

decomposers (growin on logs, stumps, living trees, and fallen branches), and general decomposers (not specific to any of the two groups).

To some extent this research mimics and can be regarded as continuation of the work of others, as it mainly contributes a para-taxonomic list of species, from yet another set of habitats. Notwithstanding, I am not aware of any studies of coniferous plantations that parallel this work in the intensity and attention to the saprotrophic macrofungal component. The implications of this will be discussed.

Results

1. General findings

The survey yielded a total of 194 saprobic macrofungal species: 114 litter decomposers, 64 wood fungi, 14 general (substrate non-specific) saprobes, and 2 entomopathogenic fungi (parasitic on insects). Table 5.1 lists the more frequently observed species within the sub-guilds, with *Mycena* species removed. *Mycena* species are listed in Table 5.3. Overall, the saprobic community was represented by 31 families and 78 genera (Table 5.2). Seventy four species, thus 38%, were recorded on one occasion only. These infrequent species accounted for less than 2% of the total saprobic fungus abundance.

The largest proportion of the species (42%) belonged to the family *Tricholomataceae*, with 82 species from as many as 24 genera, the genus *Mycena* far outnumbering the others. The next largest family was *Cortinariaceae* with 10 out of 15 species in the genus *Galerina*, followed by *Entolomataceae*, and *Clavariaceae* (Table 5.2). Eight genera were outstanding in terms of their abundance: *Mycena* (1887 observations, 40.78% of the total macrofungus population, 49.68% of the saprobic fungi; see Table 5.3.), *Clavulina, Xeromphalina, Guepiniopsis, Galerina, Polyporus, Hygrocybe, and Plectania*, in descending order. Top ten saprobic macrofungi were *Mycena amicta* (323 observations, 6.98% of the total macrofungus population, 8.50% of the saprobic group), *Mycena metata* group, *Mycena rorida, Mycena aurantiidisca, Mycena galopus, Guepiniopsis alpina, Clavulina cristata, Mycena tenax, Mycena rosella, and Xeromphalina fulvipes.*

2. Conifer effect

Table 5.4. lists the saprobic species and their relative frequencies in each conifer habitat. The highest number of saprobic macrofungi was associated with Douglas-fir, *Pseudotsuga menziesii*, with a cumulative total of 106 species. Western red cedar, *Thuja plicata* supported 102 species, and was followed by Sitka spruce, *Picea sitchensis*, with 95 species. The lowest diversity of saprobic macrofungi was found in western hemlock, *Tsuga heterophylla* (only 76 species). The average numbers of species per plot were: 40.00, 34.00, 34.67, and 29.17, for Douglas-fir, cedar, spruce, and hemlock, respectively (Table 5.5).

The ranking order of the four conifers with respect to abundance followed that of average diversity. The respective total and average numbers of observations were: 1226 (204.33), 1070 (178.33), 829 (138.17), and 673 (112.17), for Douglas-fir, Sitka spruce, western red cedar, and western hemlock. Sitka spruce had the highest frequency of saprobic macrofungi (as proportion of the whole macrofungus community within its habitat), at 84.99%, and hemlock's saprophytic macrofungus component was the lowest at 57.59% (Table 5.5).

Analysis of variance (ANOVA) showed no significant difference in diversity (P = 0.064811) among the conifer habitats. The effect of conifer species on abundance of saprobic fungi was significant at P = 0.006903 (Table 5.6).

ANOVA was performed on data for the *Mycena* genus only, and yielded significant conifer effect for both diversity (P = 0.025839) and abundance (P = 0.001125), with Sitka spruce ranking the highest, and western hemlock the lowest (Table 5.7).

3. Site and plot differences

Analysis of Variance (ANOVA) shows that site differences have significant effect on the diversity (P = 0.049996), but not abundance (P = 0.358592) of saprobic species. The

highest values for both variables were recorded in site 3 (Fairy Lake– the poorest and driest), and the lowest in site 1 (Upper Klanawa – the richest and wettest).

Comparisons of the sites with only *Mycena* genus taken into account shows that there were no significant differences among the three sites. The respective probability values for diversity and abundance were P = 0.385103, and P = 0.10485.

Variation in soil characteristics, topography, and microclimate existed amongst plots of the same conifer species, between, as well as within sites. Figures 5.1. and 5.2. exemplify differences in saprobic fruiting for all the individual plots, reflecting perhaps the microsite influences.

Ordination of plots, species, and nutrient data, using Detrended Correspondence Analysis (DCA; DECORA) throws further light on site induced patterns. In Figure 5.3, plots of Sitka spruce, Douglas-fir, western red cedar and western hemlock are ordinated based on their saprobic macrofungus community, with an overlay of total available nitrogen distribution. The graph shows negative correlation of nitrogen with both axes, as well as two distinct groups of plots: Sitka spruce plots and UK plots, both positioned more or less were Nitrogen is highest. The remaining plots show wider scatter, with the Fairy Lake cedar plot Cw 116 being most isolated.

Ordination of nitrogen in Fig. 5.3. is almost mirrored by the distribution of *Mycena amicta* in Fig. 5.4., suggesting a strong relationshionship. To a lesser degree, *Clavulina cristata* (Fig. 5.5.) also shows a possible dependence on nitrogen availability. Distribution of *Mycena tenax*, overlayed on plot ordination in Figure 5.6., reveals strong affinity of this saprobic macrofungus to Sitka spruce. *Mycena aurantiidisca* (Fig.5.7.), and a few other *Mycena* species, not shown here, show some degree of this association as well.

In contrast, distribution of *Plectania melastoma* (Fig. 5.8), does not correspond to any of the nutrient ordinations, nor to any of the conifer habitats, but reflects spatial auto-correlation, being limited to several neighbouring plots within the Sarita Lake site. Similar distribution patterns (not shown here) are exibited by *Neournulla pouchetti, Mycena rubromarginata, Clitocybe incomis* (also in Sarita Lake), and *Polyporus badius* (in Upper Klanawa).

Cluster analysis (Euclidean Distance, Ward's method) of all the plots based on their *Mycena* communities shows three discernible groups: 1) Sitka spruce plots, 2) mostly Upper Klanawa plots, and 3) the remaining plots (Figure 5.8), which parallels the ordination of plots in Fig. 5.3.

Three diversity measures were calculated for each plot:

- species richness S = number of nonzero elements

- species evenness E : H' / ln(richness)

and Shannon-Wiener index H`: - S (p_i * ln (p_i))

Plots with highest diversity were:

HW 83 from Upper Klanawa;

FD 126, and CW 123 from Sarita Lake,

And CW 23, FD 18, and FD 25 from Fairy Lake (Table 5.8.).

This suggests a gradient of saprobic macrofungus diversity from the lowest at nutrient rich and moist Upper Klanawa to the highest at nutrient poor and dry Fairy Lake.

Discussion

The main distinction between saprobic and mycorrhizal fungi is in their feeding mode. While the former acquire nutrients by extracellular digestion of cellulose and lignin containing organic matter, the latter group lost the ability, according to Ingold and Hudson (1993), and has to rely on a host organism for the supply of organic carbon . One would expect, therefore, to see a tighter connection of saprophyte diversity and abundance with environmental factors, than with the presence and features of live hosts.

The results of this research show that type of conifer habitat did not have a significant effect on species richness. Sitka spruce, Douglas-fir, western red cedar, and western hemlock harboured equally diverse communities of saprobic macrofungi, and comparable sub-guild structure with regards to growth substrate. Differences existed in fungal species composition, and some taxa have emerged as possible habitat indicators (see Table 3.10).

Our findings are fairly consistant with those of Countess (2001), Berch (2001), Breitenbach and Kranzlin (1984 - 1995) in terms of the observed substrate preferences, and with Countess (2001), Lodge (1997), Lange (1993), and Arnolds (1988) with regards to the proportions of sub-guild mycota within the saprobe community. Studies dealing with mature and old growth forests generally report higher ratio of wood decomposers to litter decomposers (Gamiet and Berch, 1992; Holec, 1992; Villeneuve et al., 1989).

We found that the overall abundance and proportion of saprobic macrofungi relative to ectomycorrhizal fungi is much higher in EP 571 plantation forests than that reported elsewhere (Senn-Irlet and Bieri, 1999; Salo, 1993; Villeneuve et al. 1989; Ohenoja, 1978; Dennis, 1985), but similar to that described by Countess (2001), and Lange (1993). Schmit et al. (1999) compare their estimates of macrofungal diversity in a North American oak forest with the work of others, and conclude that 'mixed and coniferous forests generally have more mycorrhizal species but fewer species from the other guilds'. Carroll and Wicklow (1992) review some research from North America and Europe, and state that 'mycorrhizal fungi are probably more common than saprobic fungi in

coniferous forests', but admit that 'very few studies have separated sporocarps produced by mycorrhizal and saprobic fungi'. Further reading of their review suggests to me that there might be some general misconception of the relative proportions of these two groups of fungi, caused by their differences in biomass production.

The analysis of this survey strongly suggests that in coniferous woods, the mycorrhizal macrofungal community is a smaller component of the total mushroom biota than the saprobic one, the ratio being 30.32% to 69.68 % for species richness, and 18.28% vs. 81.72% for species abundance. Within specific conifer habitats the ratio can be even more extreme, for example in Sitka spruce habitat where the frequency of occurrence of mycorrhizal fungi amounted to a mere 15% of total mushroom abundance.

Conifer species were found to significantly influence the total abundance of saprobic macrofungi. Douglas-fir plots had the highest readings, primarily due to preferential fruiting of *Clavulina cristata*, but also a substantial *Mycena* mycota. Hemlock plots had the lowest frequency counts of saprobes, in contrast to the highest ectomycorrhizal community in this forest type. Suggestions have been made in the literature that some ectomycorrhizal fungi can inhibit the growth of other fungi in the immediate neighbourhood of the rhizosphere (Millar, 1974; Ingold and Hudson, 1993).

Two non-mycorrhizal genera, *Mycena* and *Galerina* contributed significantly to the overall diversity with 45 and 12 species, respectively. To my knowledge, no ecological

study of temperate forests reports such high numbers of species within these genera. This could be the result of very specific habitats chosen for this project, or a reflection of mycological interests of macrofungus researchers. Similar observations were made by Arnolds and de Vries (1993), in the discussion on conservation of fungi in Europe. *Mycena* deserves a closer look in this study, so I should like to elaborate.

Mycenae were without a doubt, the most frequently encountered mushrooms in this survey. These fragile, soft, and typically small macrofungi (ranging in height from 0.1 to 5.0 cm), often grow in large troops, as single fruiting bodies, or in clusters. In mycological terminology 'mycenoid stature' refers to the shape of the pileus, which is usually conic or umbonate (but can be merely convex or slightly depressed), often transparent-striate over the plane or decurved margin. Micro-characters include smooth spores, cystidia (sterile, distinct, variously shaped cells within the hymenium or pellis), a layer of inflated cells just under the cylindric hyphae of the pileipellis, and staining reactions of the various tissues. With some experience *Mycenae* can be distinguished easily in the field and one can avoid confusing it with other small macrofungi such as *Marasmius*, *Collybia*, or *Omphalina*. Species differentiation in the field has always been a challenge when working with this genus. Thorough and patient microscopic examination, with the use of appropriate stains is often required to confirm a *Mycena* species, especially those belonging to the section Typicae (Smith, 1947).

We found that while some Mycena species fruit on old stumps, fallen twigs, bark etc., the majority of the ubiquitous types can be seen growing on the needle covered forest floor, sometimes colonizing only individual needles as is the case with the minute, orange *Mycena oregonensis*. The gregarious forest species include the more robust species *Mycena tenax*,and the colourful *M. rosella* and *M. aurantiidisca*, all three thriving on spruce litter. On a smaller scale, cluster forming (but not always) *Mycenas* were: milk exuding *M. galopus*, ash coloured *M. metata*, and the very viscid, yellowish *M. epipterygia*. Though *Mycena amicta*, a brownish tall species, with a characteristic minutely pruinose (frosted look) stem, and a brilliant turquoise base (the blue colour in the cap is not always present), was the most frequently recorded species in our plots, it does not appear to form gregarious fructifications. Rather, its frequency results from the production of sporocarps on a wide range of substrates, in different host ecotypes, beginning with early summer, and continuing until late October (and possibly longer).

It is interesting to note that the most abundant *Mycenae* (9 species; including those showing preference for spruce habitat), were the ones which are not restricted to a single tree host, and were, in fact, found with all four conifers. Four of those species also show flexibility with respect to the substrate material. These wide distributional patterns could be the result of diversifying (recombinatorial) type of reproduction, which allows fungal organisms to vary functional role when faced with habitat heterogeneity. The general strategy of higher basidiomycetes is a move to obligate outcrossing. Needless to say,

tropolones (Minore, 1983). I think it is fair to say that, based on Prescott's analysis, spruce needles contain a relatively high average % of nitrogen, and relatively low amounts of tannin. Faced with a lack of evidence, I would like to speculate only at this point, that this particular combination of properties might be especially advantageous for the growth and fruiting of some saprobic macrofungi, such as *Mycenae.* The high lignin content of spruce needles (Johansson, 1995) might also translate into more sucsessful establishment of white rot fungi, such as *Mycena.* Other factors which might stimulate the growth of *Mycena* under Sitka spruce are mounding of the forest floor formed by the arched root system of this conifer, and the resulting pockets of unique microclimate of favourable pH, temperature, nutrient concentration, and above all moisture content (Frankland, 1998).

Nitrogen content of litter was found to play an important role in macrofungal ecology in this project, and the patterns observed were consistent with those described in the literature (Frankland, 1998; Lange, 1993; Dickinson and Pugh, 1974). While the ectomycorrhizal fruitings were diminished where high nitrogen prevailed, most saprobic taxa were dependent on its availability. This was exemplified by the distribution patterns of the most abundant and generic decomposer, *Mycena amicta*, or by that of a larger species, *Clavulina cristata.*

Following this train of thought, the analysis of site influence on saprobic populations brought some unexpected results. While abundance values were comparable between the three sites, species diversity was significantly higher in Fairy Lake (the driest and the poorest), than in Upper Klanawa (with richest soil and highest moisture content). A couple of reasons might offer some explanation of this seemingly contradictory situation. Upper Klanawa site is flooded during periods of persistent precipitation, which prevents the fragile saprobic species from fruiting, if not suffocates their mycelia entirely. Secondly, the numbers of fallen logs and old stumps, as well as density of course woody debris and the undergrowth vegetation are noticably lowest at the Upper Klanawa instalation. Positive relationship between vascular plant diversity, spatial heterogeneity and saprotrophic fungi has been discussed by Sastad (1995), and Villeneuve et al. (1989). Prescott et al. (2000), who studied decomposition rates in EP 571 sites, made similar comments about the enhancing role of the understory vegetation.

Fungi are thought to respond to nutrient limitation by producing sporocarps, perhaps as a way of escaping the unfavourable conditions (Carrol and Wicklow, 1992). Since we surveyed the forests for macrofungus fruit bodies only, it is also possible that the mycelium of some macrofungi was present in the plots, but the species were not recorded, or that the actual abundance and distribution patterns under the ground were different from those observed above the fround.

Ordination of all the plots, using Detrended Correspondence Analysis, showed some evidence of spatial auto-correlation with regards to abundance of saprobic macrofungi. Large cluster forming habit of some species, for example *Plectania melastoma*, *Clitcybe incomus*, *Neournulla pouchetti*, *Mycena rubromarginata*, or *Polyporus badius*, resulted in their simultaneous appearance in several neighbouring plots, regardless of conifer type.

A major obstacle in my interpretation of the saprobic macrofungal fruiting patterns at the sub-guild level, is the considerable presence of the left-over stumps and logs from the original mixed species old growth forest in the EP571 sites. These tree remnants have undergone advanced decay, but are still quite productive sources of wood rotting fungi, and, unfortunately, are not readily identifiable to species. Consequently, and because wood decomposers were a minor component of the macrofungus mycota, I decided not to separate wood decomposers from litter decomposers in my data analysis of saprobes. I think it is fair to say, that results of such analysis and conclusions that one might be tempted to draw from them would be 'guaranteed' for conifer habitat as a whole, but not necessarily for the individual conifer habitats.

In closing, I think an interesting avenue to pursue, would be to research further the reasons for proportionally higher diversity and abundance of saprobic macrofungi in the coniferous forests of the Pacific Northwest and the much lower numbers in Europe. Are the differences real? If so, is the impoverishment of saprobes in Europe caused by some inherent soil attributes, e.g. base-status, or by higher pollution in Europe, and other

anthropogenic factors, such as compaction of forest floor and woody debris removal. A closer look should also be given to the ecological dynamics between saprobic macrofungi and other decomposer organisms, between ectomycorrhizal and saprobic livestyles, as well as possibly very complex interspecific relationships within the saprobic macrofungus community.

Tables and Figures

Table 5.1. Frequencies of macrofungal species within the saprophytic community. Excluded are all *Mycena* species (see Table 5.3.) and taxa with only one observation.

Litter decomposers	%	Wood decomposers	%	General decomposers	%
Clavaria sp. cf. *acuta*	<1	*Ascocoryne sarcoides*	<1	***Galerina vitaeformis***	1.1
Clavaria vermicularis	<1	*Bondarzewia montana*	<1	*Guepiniopsis alpina*	3.5
Clavulina cinerea	1.3	*Callistosporium luteo-olivaceum*	<1	*Gymnopilus sapineus*	<1
Clavulina cristata	3.8	*Calocera cornea*	<1	*Hygrophoropsis aurantiaca*	<1
Clavulina ornatipes	<1	*Calocera viscosa*	<1	*Nolanea holoconiota*	<1
Clavulina rugosa	<1	*Clitocybe ditopus* gr.	<1	*Panellus longuinquus*	<1
Clavulinopsis fusiliformis	<1	*Cudonia grissea*	<1	*Podostroma alutaceum*	<1
Clavulinopsis laeticolor	<1	*Cudonia monticola*	<1		
Clitocybe incomus	<1	*Dacrymyces chrysocomus*	<1		
Collybia confluens	<1	*Fomitopsis pinicola***	<1		
Collybia dryophila	<1	*Galerina mammilata*	<1		
Coltricia perennis	1.0	*Ganoderma oregonensis***	<1		
Conocybe sp. affin. *sulcatipes*	<1	*Ganoderma tsugae* **	<1		
Conocybe plicatella gr.	<1	*Gymnopilus bellulus*	<1		
*Cordyceps militaris**	<1	*Heterobasidion annosum***	<1		
*Cordyceps myrmecophila**	<1	*Hypholoma capnoides*	<1		
Floculina granulosa	<1	*Hypholoma fasciculare*	<1		
Galerina atkinsoniana	<1	*Kuhneromyces lignicola*	<1		
Galerina badipes	1.4	*Laetiporus gilbertsonii***	<1		
Galerina emmentensis	<1	*Omphalina ericetorum*	<1		
Galerina sect. *Calyptrata*	<1	*Pholiota astragalina*	<1		
Geoglossum c.f. *umbratile*	<1	*Pleurocybella porrigens*	<1		
Hemimycena albicolor	<1	*Pluteus cervinus*	<1		
Hemimycena basipedes	<1	*Polyporus badius*	1.8		
Hemimycena delectabilis	<1	*Polyporus elegans*	1.0		
Heyderia abietis	<1	*Pseudoarmillaria ectypoides*	<1		

Hygrocybe cantharellus	<1	*Pseudohydnum gelatinosum*	<1
Hygrocybe laeta	1.7	*Tricholomopsis rutilans*	<1
Hygrocybe miniata	<1	*Tyromyces caesius*	<1
Hygrocybe virginea	<1	*Vibrissea truncorum*	<1
Lycoperdon foetidum	<1	*Xeromphalina campanella*	2.0
Lycoperdon pyriforme	<1	*Xylaria hypoxylon*	<1
Lycoperdon perlatum	<1		
Lyophylum semitale	<1		
Macrotyphula filiformis	<1		
Marasmius sp. affin. *wynnei*	<1		
Micromphale foetidum	<1		
Micromphale perforans	<1		
Neournulla pouchetti	<1		
Nolanea cetratum	<1		
Otidia kauffmanii	<1		
Plectania melastoma	2.0		
Podophacidium xanthomellum	<1		
Pseudoplectania nigrella	<1		
Richnella fibula	<1		
Xeromphalina fulvipes	2.3		

* Insect parasite

** Tree pathogen

Table 5.2. List of families of saprophytic fungi, with numbers of genera and species.

Family	Genera	Species
Agaricaceae	1	1
Bolbitiaceae	1	4
Bondarzewiaceae	1	1
Clavariaceae	6	15
Clavicipitaceae	1	2
Coprinaceae	1	2
Coriolaceae	6	8
Cortinariaceae	4	15
Dacrymycetaceae	2	3
Dermacetaceae	1	1
Entolomataceae	3	14
Exidiaceae	1	1
Ganodermataceae	1	2
Geoglocaceae	2	4
Hyaloscyphaceae	1	1
Hygrophoraceae	1	5
Hygrophoropsisdaceae	1	2
Hymenochaetaceae	2	2
Hypocreaceae	1	1
Leotiaceae	2	2
Lycoperdaceae	1	3
Otidiaceae	1	1
Plutaceae	1	2
Polyporaceae	1	2
Ramariaceae	1	2
Sarcosomataceae	3	3
Strophariaceae	4	10
Tremellaceae	1	1
Tricholomataceae	24	82
Vibricaceae	1	1
Xylariaceae	1	1

Table 5.3. *Mycena* species collected from all the plots over the two- year period.

Mycena species	Frequency	Habitat	Substrate
Mycena abramsii	0.09	Ss, Fd	Litter
Mycena acicula	0.04	Fd, Cw	Litter
Mycena adonis	0.11	Fd, Cw	Litter
Mycena alcalina	2.08	Ss, Fd, Cw, Hw	Litter and wood
Mycena sp.affin. *alnetorum*	0.02	Fd	Wood
Mycena alnicola group	0.04	Fd	Wood
Mycena amabillisima	0.02	Cw	Litter
Mycena amicta	6.93	Ss, Fd, Cw, Hw	Litter and wood
Mycena archangelina	0.02	Ss	Wood
Mycena atroalboides	0.02	Ss	Litter
Mycena aurantiidisca	4.36	Ss, Fd, Cw, Hw	Litter
Mycena aurantiomarginata	0.09	Ss, Fd	Litter
Mycena citrinomarginata	0.04	Ss, Fd	Litter
Mycena clavicularis	0.02	Ss	Litter
Mycena elegantula	0.07	Ss, Cw, Hw	Litter
Mycena epipterigia	0.72	Ss, Fd, Cw, Hw	Litter
Mycena filopes	0.39	Ss, Fd, Cw, Hw	Litter
Mycena flavoalba	0.02	Ss	Litter
Mycena fusco-occula	0.09	Ss, Fd	Litter
Mycena galericulata	0.02	Cw	Wood
Mycena galopus	4.08	Ss, Fd, Cw, Hw	Litter and wood
Mycena hematopus	0.17	Ss, Fd, Cw	Wood
Mycena latifolia	0.02	Ss	litter
Mycena leptocephala	0.02	Fd	Litter and wood
Mycena longesita	0.02	Fd	Litter
Mycena maculata	0.02	Ss, Cw	Litter
Mycena metata group	5.97	Ss, Fd, Cw, Hw	Litter
Mycena mirata group	0.04	Ss	Wood
Mycena murina	0.85	Ss, Fd, Cw, Hw	Litter
Mycena olivaceo-brunnea	0.07	Cw	Litter
Mycena oregonensis	0.02	Ss	Litter
Mycena pseudoinclinata	0.04	Ss,	Wood
Mycena pura	1.02	Ss, Fd, Cw, Hw	Litter and wood
Mycena pura f.alba	0.02	Fd	Litter and wood
Mycena purpureo-fusca	0.07	Fd, Cw	Litter and wood
Mycena rorida	4.95	Ss, Fd, Cw, Hw	Litter
Mycena rosella	2.56	Ss, Fd, Cw, Hw	Litter
Mycena rubromarginata	0.11	Fd, Hw	Wood
Mycena sanguinolenta	0.09	Fd, Cw, Hw	Litter
Mycena sp. sect *Typicae*	0.07	Ss, Fd	Litter
Mycena sp., *praecox* goup	0.02	Ss	Litter and wood
Mycena strobilinoides	0.02	Ss	Litter
Mycena subcana	0.04	Ss, Fd	Wood
Mycena tenax	3.02	Ss, Fd, Hw	Litter
Mycena tenax gr.	0.02	Ss	Litter
Mycena tenerimae	0.04	Hw	Litter
Mycena vulgaris	0.15	Ss, Fd, Hw	Litter

Table 5.4. Saprobic macrofungi found in each conifer habitat, sorted by their frequency (% of total macrofungus abundance within each conifer).

Sitka spruce	Freq. (%)	Douglas-fir	Freq. (%)	western red cedar	Freq. (%)	western hemlock	Freq. (%)
Mycena tenax	10.64	*Clavulina cristata*	7.63	*Mycena amicta*	13.99	*Mycena metata* group	7.84
Mycena aurantiidisca	10.17	*Mycena amicta*	7.31	*Hygrocybe laetus*	9.53	*Mycena rorida*	5.53
Mycena rosella	7.07	*Mycena metata* group	7.24	*Mycena rorida*	6.27	*Xeromphalina fulvipes*	4.72
Mycena galopus	6.99	*Mycena rorida*	4.59	*Galerina badipes*	5.91	*Guepiniopsis alpina*	4.52
Guepiniopsis alpina	5.32	*Guepiniopsis alpina*	4.53	*Mycena galopus*	4.95	*Mycena galopus*	3.42
Mycena amicta	5	*Clavulina cinerea*	3.69	*Mycena metata* group	4.7	*Micromphale perforans*	3.22
Mycena rorida	4.77	*Mycena alcalina*	2.59	*Polyporus badius*	4.22	*Mycena amicta*	3.12
Mycena metata group	4.29	*Xerompalina campanella*	2.39	*Plectania melastoma*	3.98	*Mycena aurantiidisca*	3.12
Clavulina cristata	3.02	*Coltricia perennis*	2.26	*Hemimycena albicolor*	3.62	*Polyporus badius*	2.51
Mycena alcalina	2.54	*Mycena aurantiidisca*	2.2	*Xeromphalina fulvipes*	3.5	*Xerompalina campanella*	2.21
Podoph. xanthomellum	1.99	*Mycena galopus*	2.13	*Mycena aurantiidisca*	2.9	*Micromphale foetidum*	2.01
Plectania melastoma	1.75	*Clitocybe incomus*	1.81	*Xerompalina campanella*	2.65	*Mycena alcalina*	1.71
Lycoperdon foetidum	1.51	*Mycena pura*	1.75	*Hypholoma fasciculare*	1.93	*Clavulina cristata*	1.61
Xerompalina campanella	1.03	*Galerina vitiformis*	1.68	*Galerina vitiformis*	1.81	*Plectania melastoma*	1.61
Xeromphalina fulvipes	1.03	*Mycena rosella*	1.55	*Mycena alcalina*	1.81	*Clitocybe incomus*	1.51
Lycoperdon pyriforme	0.95	*Plectania melastoma*	1.49	*Polyporus elegans*	1.57	*Polyporus elegans*	1.41
Mycena murina	0.95	*Xeromphalina fulvipes*	1.36	*Mycena metata, strigose*	1.45	*Pseudoplectania nigrella*	1.41
Mycena pura	0.95	*Vibrissea truncorum*	1.16	*Mycena murina*	1.45	*Coltricia perennis*	1.31
Panellus longuinquus	0.95	*Mycena epipter.* var. *lig.*	1.1	*Hygrocybe miniata*	1.21	*Entoloma trachyospermum*	1.11
Polyporus elegans	0.79	*Omphalina ericetorum*	1.1	*Pleurocybella porrigens*	1.21	*Mycena rosella*	1.11
Gymnopilus bellulus	0.71	*Polyporus badius*	1.1	*Hemimycena basipedes*	0.97	*Hypholoma fasciculare*	0.8
Mycena filopes	0.71	*Mycena murina*	0.91	*Laetiporus sulphureus*	0.97	*Entoloma cetrata*	0.6
Nolanea holoconiota	0.64	*Mycena metata, strigose*	0.84	*Panellus longuinquus*	0.97	*Galerina vitiformis*	0.6
Mycena epipter. var. *lig.*	0.56	*Nolanea holoconiota*	0.78	*Heterobasidion annosum*	0.72	*Mycena epipter.* var. *lig.*	0.6
Neournulla pouchetti	0.56	*Galerina badipes*	0.71	*Mycena pura*	0.72	*Neournulla pouchetti*	0.6
Polyporus badius	0.56	*Mycena tenax*	0.71	*Nolanea holoconiota*	0.72	*Marasmius* sp. c..f.. *wynnei*	0.5
Lycoprdon perlatum	0.4	*Polyporus elegans*	0.71	*Geoglossum* c.f. *umbratile*	0.6	*Nolanea holoconiota*	0.5
Mycena vulgaris	0.4	*Clavulina ornatipes*	0.65	*Cordyceps myrmecophila*	0.48	*Calocera cornea*	0.4
Clavulina ornatipes	0.32	*Cudonia monticola*	0.65	*Entoloma cetrata*	0.48	*Calocera viscosa*	0.4
Clavulina rugosa	0.32	*Gymnopilus bellulus*	0.65	*Galerina mammilata*	0.48	*Ganoderma tsugae*	0.4
Cudonia grissea	0.32	*Pseudohydnum gelatinos.*	0.58	*Mycena rosella*	0.48	*Heterobasidion annosum*	0.4
Lyophyllum semitale	0.32	*Entoloma cetrata*	0.52	*Omphalina ericetorum*	0.48	*Lycoperdon foetidum*	0.3
Calocera viscosa	0.24	*Marasmius* sp.cf. *wynnei*	0.52	*Clavulinopsis fusiliformis*	0.36	*Mycena metata, strigose*	0.3

Entoloma cetrata	0.24	*Mycena filopes*	0.52	*Cordyceps militaris*	0.36	*Mycena murina*	0.3
Galerina vitiformis	0.24	*Collybia conflueuens*	0.39	*Ganoderma oregonensis*	0.36	*Pholiota astragalina*	0.3
Hemimycena albicolor	0.24	*Hypholoma fasciculare*	0.39	*Guepiniopsis alpina*	0.36	*Tyromyces caesius*	0.3
Laetiporus sulphureus	0.24	*Pholiota astragalina*	0.39	*Hygrocybe cantharelloides*	0.36	*Clavulina cinerea*	0.2
Mycena abramsii	0.24	*Clitocybe* sp.*ditopus* gr.	0.32	*Hygrocybe virginia*	0.36	*Galerina atkinsoniana*	0.2
Mycena fuscodisca	0.24	*Collybia dryophila*	0.32	*Micromphale perforans*	0.36	*Galerina mammilata*	0.2
Pluteus cervinus	0.24	*Pseudoplectania nigrella*	0.32	*Mycena adonis*	0.36	*Gymnopilus bellulus*	0.2
Vibrissea truncorum	0.24	*Calocera cornea*	0.26	*Mycena epipterigia* var. *lig.*	0.36	*Hemimycena albicolor*	0.2
Xylaria hypoxylon	0.24	*Cudonia grissea*	0.26	*Mycena filopes*	0.36	*Hypholoma capnoides*	0.2
Clavaria vermicularis	0.16	*Galerina atkinsoniana*	0.26	*Mycena hematopus*	0.36	*Mycena filopes*	0.2
Conocybe affin. *sulcat.*	0.16	*Gymnopilus saponeus*	0.26	*Mycena olivaceo-brunnacea*	0.36	*Mycena pura*	0.2
Entoloma verna	0.16	*Heterobasidion annosum*	0.26	*Pseudoarmillaria ectypoides*	0.36	*Mycena rubromarginata*	0.2
Galerina mammilata	0.16	*Laetiporus sulphureus*	0.26	*Bondarzewia montana*	0.24	*Mycena tenax*	0.2
Gymnopilus saponeus	0.16	*Lycoperdon foetidum*	0.26	*Calocera viscosa*	0.24	*Mycena tenerimae*	0.2
Hemimycena delectabilis	0.16	*Podophas. xanthomellum*	0.26	*Clavaria vermicularis*	0.24	*Otidia kauffmanii*	0.2
Heterobasidion annosum	0.16	*Ganoderma tsugae*	0.19	*Clavulinopsis laeticolor*	0.24	*Panellus longuinquus*	0.2
Mycena hematopus	0.16	*Micromphale foetidum*	0.19	*Collybia dryophila*	0.24	*Clavulina ornatipes*	0.1
Mycena mirata	0.16	*Mycena aurantiomargin.*	0.19	*Flocculina granulosa*	0.24	*Clavulinopsis fusiliformis*	0.1
Podostroma alutaceum	0.16	*Mycena hematopus*	0.19	*Galerina atkinsoniana*	0.24	*Clitocybe sclerotoidea*	0.1
Tyromyces caesius	0.16	*Mycena rubromarginata*	0.19	*Galerina* sect. *calyptrata*	0.24	*Collybia dryophila*	0.1
Ascocoryne sarcoides	0.08	*Panellus longuinquus*	0.19	*Ganoderma tsugae*	0.24	*Cyptotrama chrysopeplum*	0.1
Baeospora myosum	0.08	*Ricknella fibula*	0.19	*Gymnopilus bellulus*	0.24	*Entoloma sinuatum (lividum)*	0.1
Callistos. luteo-olivaceum	0.08	*Tyromyces caesius*	0.19	*Mycena sanguinolenta*	0.24	*Entoloma verna*	0.1
Chrysomph. chrysophila	0.08	*Xylaria hypoxylon*	0.19	*Pseudoplectania nigrella*	0.24	*Fomitopsis pinicola*	0.1
Clavaria atkinsoniana	0.08	*Clavaria cf. acuta*	0.13	*Ricknella fibula*	0.24	*Galerina autumnalis*	0.1
Clavaria purpurea	0.08	*Clitocybe sp., olive /wood*	0.13	*Vibrissea truncorum*	0.24	*Galerina badipes*	0.1
Clavulina cinerea	0.08	*Galerina mammilata*	0.13	*Armilaria ostoye*	0.12	*Gymnopilus terrestris*	0.1
Clitocybe incomus	0.08	*Macrotyphula juncea* gr.	0.13	*Callistosporium luteo-olivacum*	0.12	*Hygrophoropsis aurantiaca*	0.1
Conocybe plicatella gr.	0.08	*Micromphale perforans*	0.13	*Calocera cornea*	0.12	*Lyophylum decastes*	0.1
Conocybe sp. R.O. 335	0.08	*Mycena adonis*	0.13	*Clavulina cristata*	0.12	*Macrotyphula juncea* group	0.1
Conocybe subg. piliferae	0.08	*Mycena alnicola* group	0.13	*Clavulinopsis subtilis*	0.12	*Mycena elegantula*	0.1
Dacrymyces chrysocomus	0.08	*Mycena purpureo-fusca*	0.13	*Clitocybe incomus*	0.12	*Mycena sanguinolenta*	0.1
Dacrymyces stillatus	0.08	*Mycena* sect. *Typicae*	0.13	*Clitocybe lignitalis* group	0.12	*Mycena vulgaris*	0.1
Entoloma livido album	0.08	*Neournulla pouchetti*	0.13	*Collybia racemosa*	0.12	*Omphalina ericetorum*	0.1
Entoloma trachyosperm.	0.08	*Pleurocybella porrigens*	0.13	*Cudonia grissea*	0.12	*Phaeollus schweinitzii*	0.1
Galerina emmentensis	0.08	*Psathyrella* sp. R.O. 220	0.13	*Dacrymyces chrysocomus*	0.12	*Pluteus cervinus*	0.1
Ganoderma oregonensis	0.08	*Ascocoryne sarcoides*	0.06	*Entoloma sp., scurfy stipe*	0.12	*Ramaria flavobrunescens*	0.1

Heyderia abietis	0.08
Hydropus marginellus	0.08
Hygrophoropsis olida	0.08
Hypholoma fasciculare	0.08
Lachnellula c.f. *calycifor.*	0.08
Mycena atroalboides	0.08
Mycena aurantiomargin.	0.08
Mycena citrinomarginata	0.08
Mycena clavicularis	0.08
Mycena elegantula	0.08
Mycena flavoalba	0.08
Mycena latifolia	0.08
Mycena metata, strigose	0.08
Mycena oregonensis	0.08
Mycena pseudoinclinata	0.08
Mycena sect. *Typicae*	0.08
Mycena strobilinoides	0.08
Mycena subcana	0.08
Nolanea sp. R.O.68	0.08
Nolanea sect. pseudonol.	0.08
Omphalina ericetorum	0.08
Pholiota astragalina	0.08
Pleurocybella porrigens	0.08
Pluteus sp. R.O. 326	0.08
Tremella sp.	0.08
	84.99

Clavaria vermicularis	0.06
Clitocybe affin. *pseudodec.*	0.06
Clitocybula abundans	0.06
Conocybe plicatella group	0.06
Cordyceps militaris	0.06
Cordyceps myrmecophila	0.06
Cudonia circinans	0.06
Cystoderma amianthinum	0.06
Entoloma trachyospermum	0.06
Fomitopsis pinicola	0.06
Galerina cerina	0.06
Galerina philipsii	0.06
Heyderia abietis	0.06
Hemimycena albicolor	0.06
Hygrophoropsis aurant.	0.06
Hypholoma capnoides	0.06
Lyophyllum semitale	0.06
Mycena abramsii	0.06
Mycena acicula	0.06
Mycena alnetorum ?	0.06
Mycena citrinomarginata	0.06
Mycena fuscodisca	0.06
Mycena leptocephala	0.06
Mycena longesita	0.06
Mycena sanguinolenta	0.06
Mycena subcana	0.06
Mycena vulgaris	0.06
Nolanea proxima	0.06
Nolanea sp. R.O.68	0.06
Nolanea sect. endochrom.	0.06
Pholiota flavida	0.06
Pholiota terrestris	0.06
Psathyrella hirta group	0.06
Resinomycena saccharif.	0.06
Strobilurus trulisatus	0.06
Tricholomopsis rutilans	0.06
	79.30

Entoloma trachyospermum	0.12
Entoloma verna	0.12
Fomitopsis pinicola	0.12
Galerina emmentensis	0.12
Galerina pteridicola group	0.12
Hemimycena pseudoscripula	0.12
Hohenbouhelia sp.	0.12
Hygrocybe conica	0.12
Hygrophoropsis aurantiaca	0.12
Hymenochaete sp. R.O. 223	0.12
Hypholoma capnoides	0.12
Hypholoma dispersum	0.12
Kuhneromyces lignicola	0.12
Leptonia albinella	0.12
Mycena acicula	0.12
Mycena amabilissima	0.12
Mycena archangelina	0.12
Mycena elegantula	0.12
Mycena galericulata	0.12
Mycena maculata	0.12
Mycena purpureo-fusca	0.12
Naucoria affin. *pseudoamares.*	0.12
Neournulla pouchetti	0.12
Nolanea sp. R.O. 122	0.12
Nolanea staurospora	0.12
Omphalina luteicolor	0.12
Pholiota decorata	0.12
Pholiota scamba	0.12
Pluteus cervinus	0.12
Pseudohydnum gelatinosum	0.12
Psilocybe pelliculosa	0.12
Ramariopsis sp. R.O. 229	0.12
	93.04

Ramaria sp. R.O. 191	0.1
Ricknella fibula	0.1
Trametes hirsutum	0.1
Trametes versicolor	0.1
Tricholomopsis rutilans	0.1
Tyromyces chioneus	0.1
	57.59

Table 5.5. Total and average diversity (number of species) and abundance (number of observations) of saprobic macrofungi within each conifer habitat, and total frequency (as proportion of the whole macrofungus community of a given conifer species).

	Sitka spruce	Douglas-fir	western red cedar	western hemlock
Total diversity	95	106	102	76
Average diversity	34.67	40.00	34.00	29.17
Total abundance	1070	1226	829	673
Average abundance	178.33	204.33	138.17	112.17
Total frequency	84.99	79.30	93.04	57.59

Table 5.6. Results of Analysis of Variance (ANOVA) for the effect of conifer species and site on saprobic diversity and abundance. Significant tests in bold type.

Variable	Source of Variation	SS	df	MS	F	P-value	F crit
Diversity	Conifer species	253.7917	3	117.9306	3.148313	0.064811	3.4903
	Site	291.0833	2	145.5417	3.885428	**0.049996**	3.88529
	Interaction	381.5833	6	63.59722	1.697812	0.204815	2.996117
	Error	449.5	12	37.45833			
Abundance	Conifer species	30324.17	3	10108.06	6.61558	**0.006903**	3.4903
	Site	3417.75	2	1708.875	1.118435	0.358592	3.88529
	Interaction	24121.58	6	4020.264	2.631206	0.072568	2.996117
	Error	18335	12	1527.917			

Table 5.7. Results of Analysis of Variance (ANOVA) for the effect of conifer species and site on *Mycena* diversity and abundance.

Variable	Source of Variation	SS	df	MS	F	P-value	F crit
Diversity	Conifer species	112.8333	3	37.61111	4.424837	**0.025839**	3.4903
	Site	17.58333	2	8.791667	1.034314	0.385103	3.88529
	Interaction	39.41667	6	6.569444	0.772876	0.605972	2.996117
	Error	102	12	8.5			
Abundance	Conifer species	19491.46	3	6497.153	10.50965	**0.001125**	3.4903
	Site	3384.75	2	1692.375	2.737548	0.10485	3.88529
	Interaction	5256.917	6	876.1528	1.417245	0.285372	2.996117
	Error	7418.5	12	618.2083			

Figure 5.1. Comparison of the numbers of saprobic macrofungus species amongst all the plots.

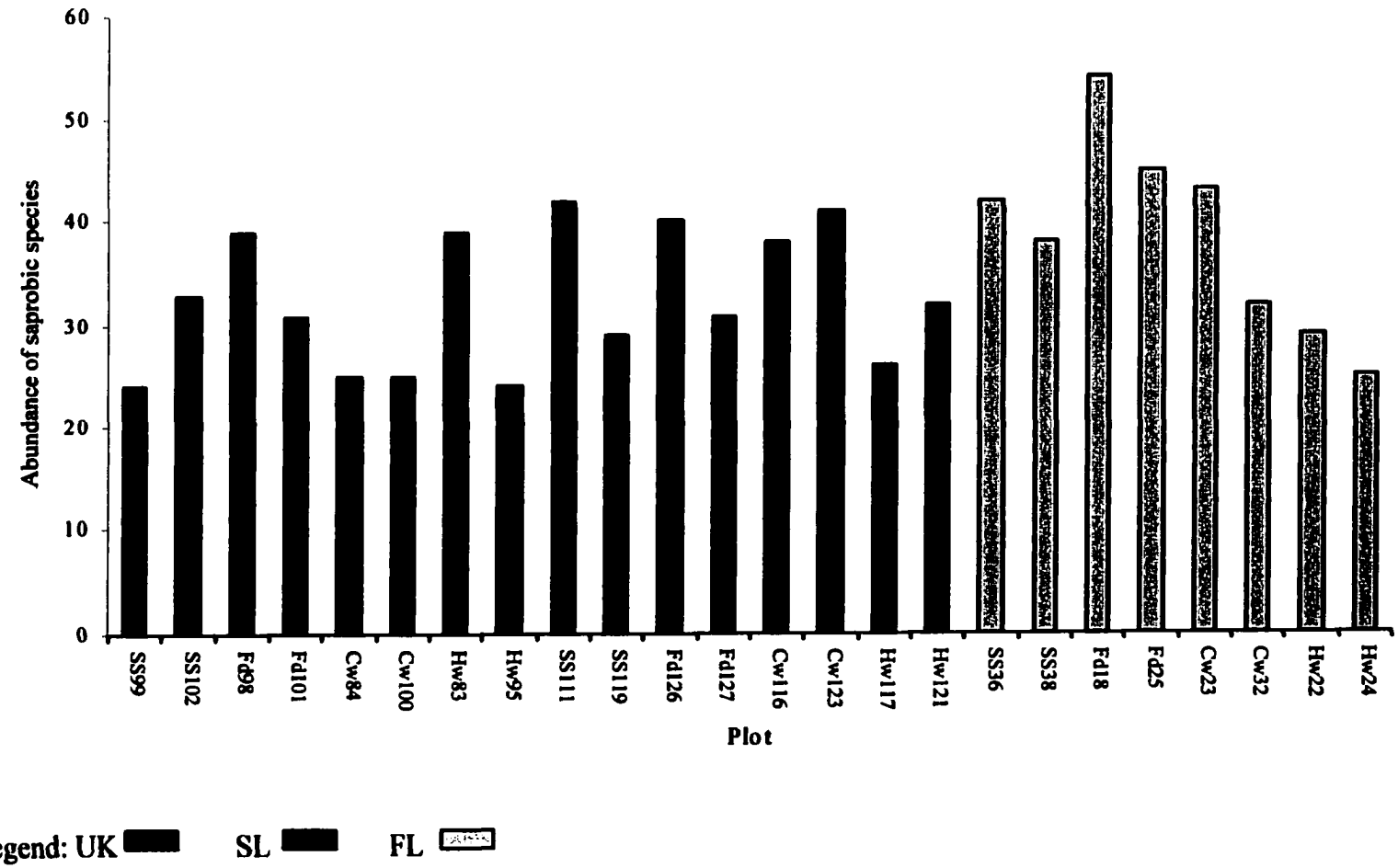


Figure 5.2. Comparison of the abundance of saprobic macrofungi amongst all the plots.

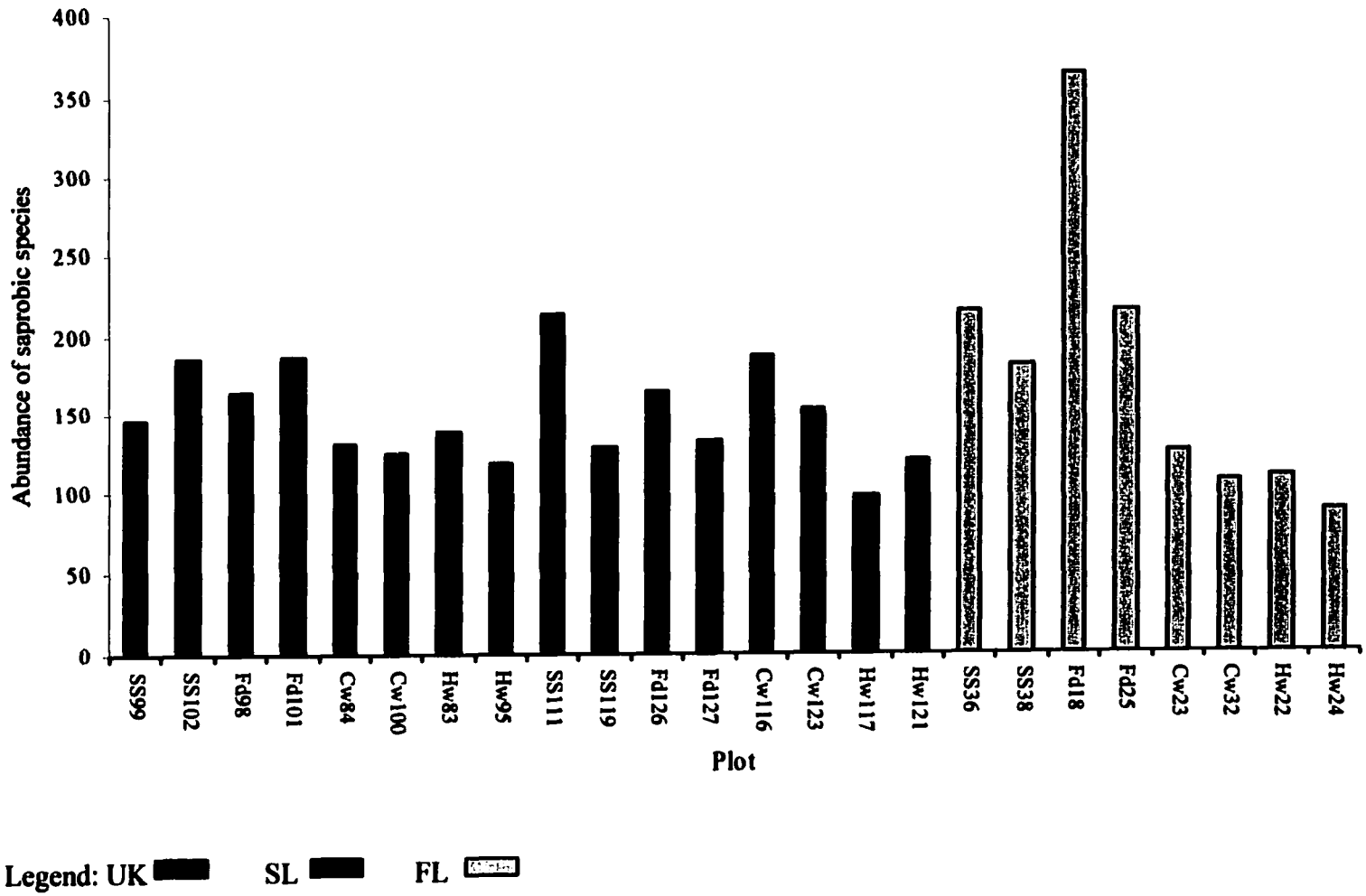


Table 5.8. Saprobic macrofungi - Diversity indices: S = species richness, E = species evenness, and H' = Shannon- Wiener function, for each of the EP571 plots.

	PLOT	S	E	H'
Upper Klanawa	SS99	24	0.827	2.63
	SS102	33	0.807	2.822
	Fd98	39	0.799	2.925
	Fd101	31	0.813	2.792
	Cw84	25	0.821	2.644
	Cw100	25	0.802	2.583
	Hw83	39	0.873	3.197
	Hw95	24	0.825	2.622
Sarita Lake	SS111	42	0.806	3.013
	SS119	29	0.848	2.855
	Fd126	40	0.901	3.325
	Fd127	31	0.869	2.983
	Cw116	38	0.751	2.732
	Cw123	41	0.846	3.142
	Hw117	26	0.84	2.736
	Hw121	32	0.865	2.998
Fairy Lake	SS36	42	0.828	3.093
	SS38	38	0.843	3.068
	Fd18	54	0.827	3.3
	Fd25	45	0.858	3.265
	Cw23	43	0.906	3.406
	Cw32	32	0.862	2.986
	Hw22	29	0.864	2.908
	Hw24	25	0.824	2.652

Figure 5.3. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of Nitrogen distribution. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

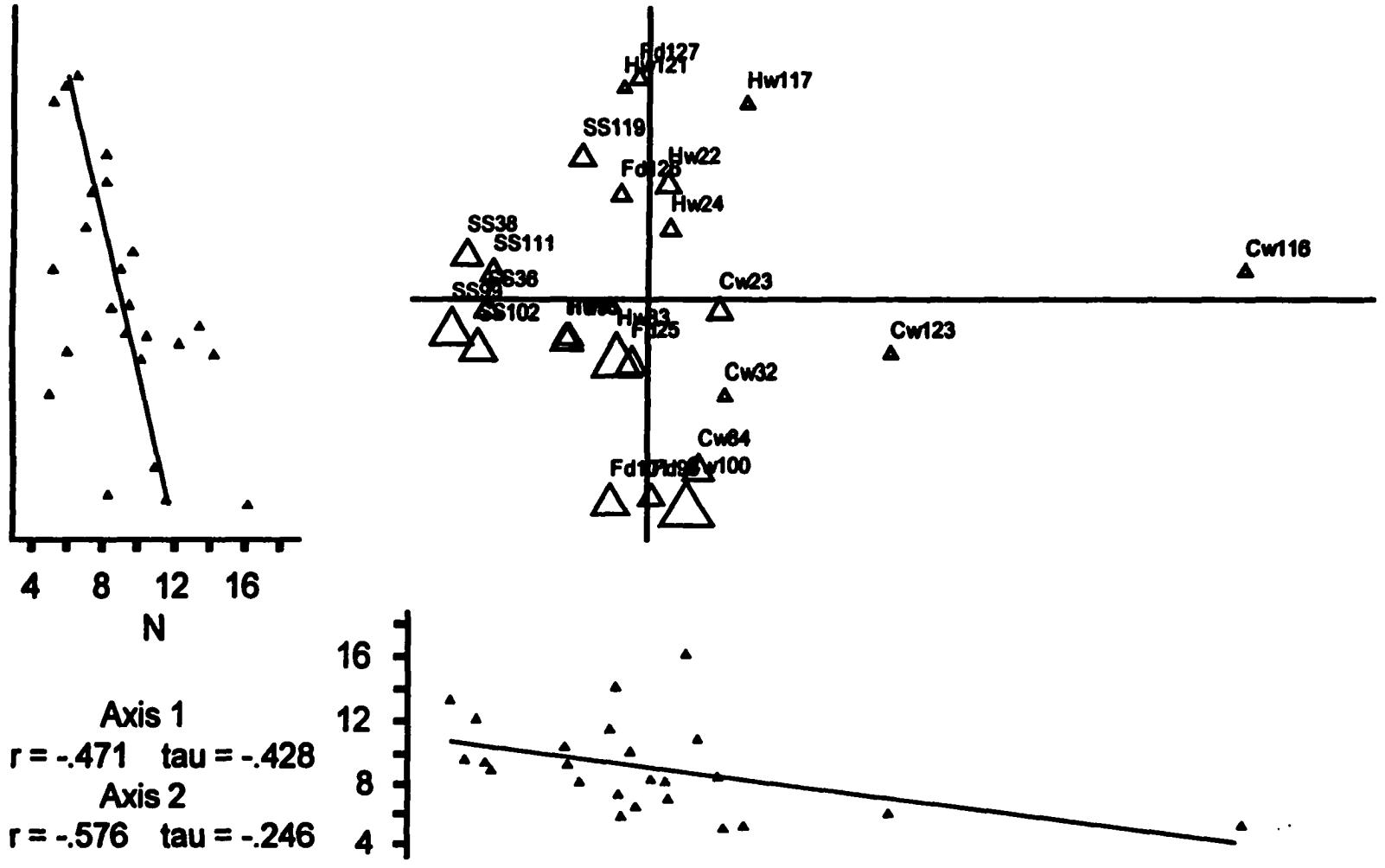


Figure 5.4. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of *Mycena amicta* distribution. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

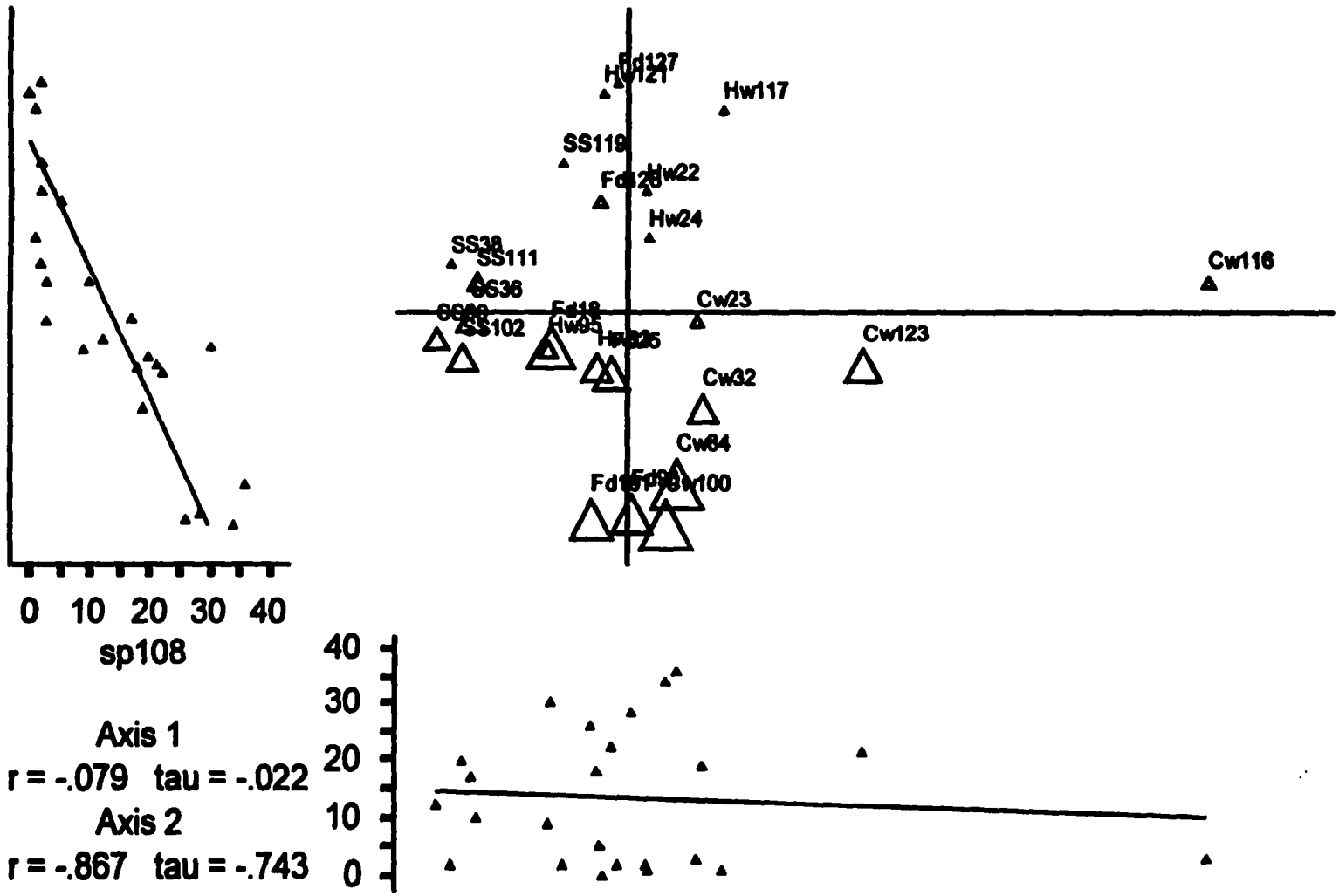


Figure 5.5. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of *Clavulina cristata* distribution. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

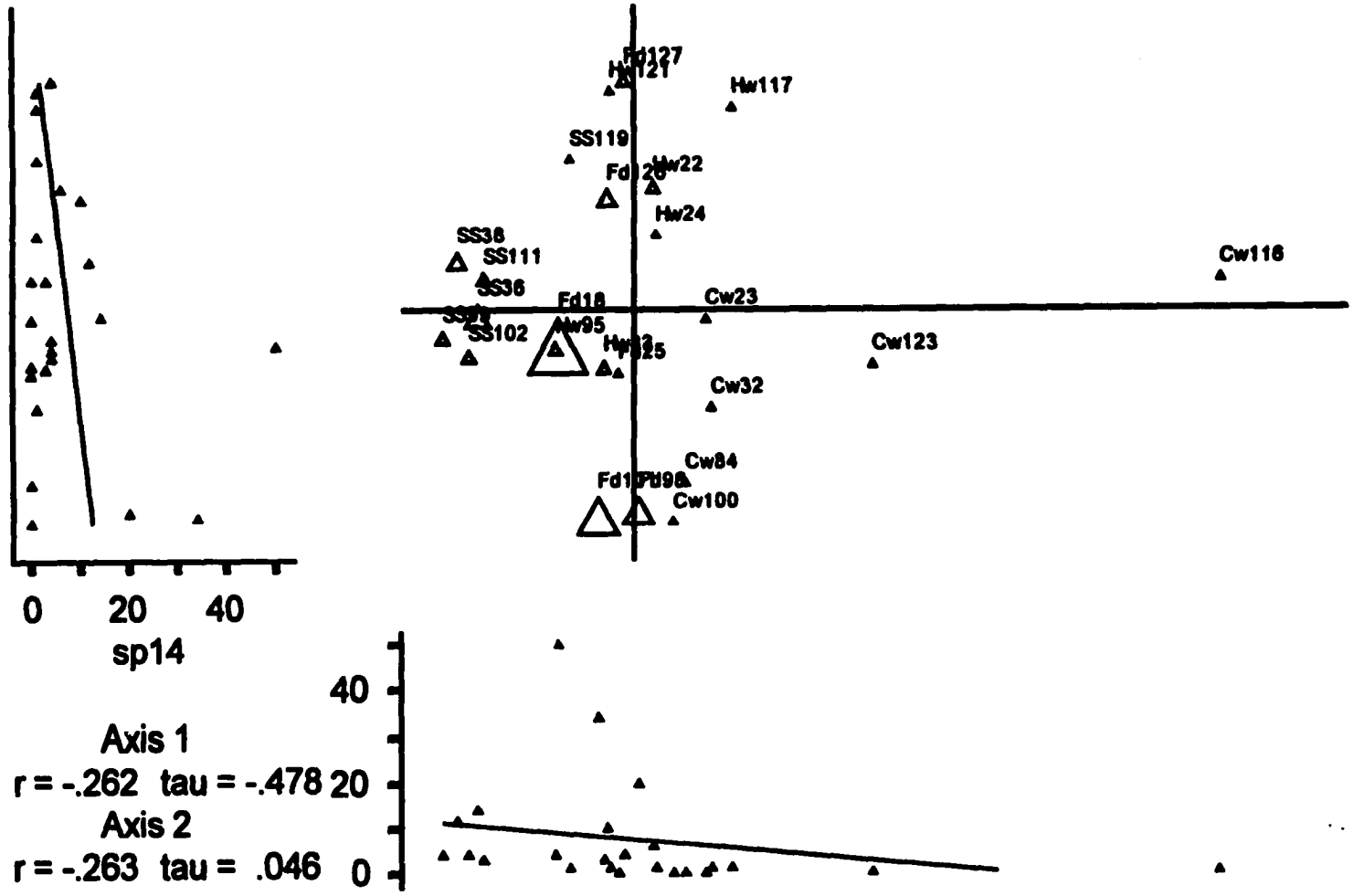


Figure 5.6. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of *Mycena tenax* distribution. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

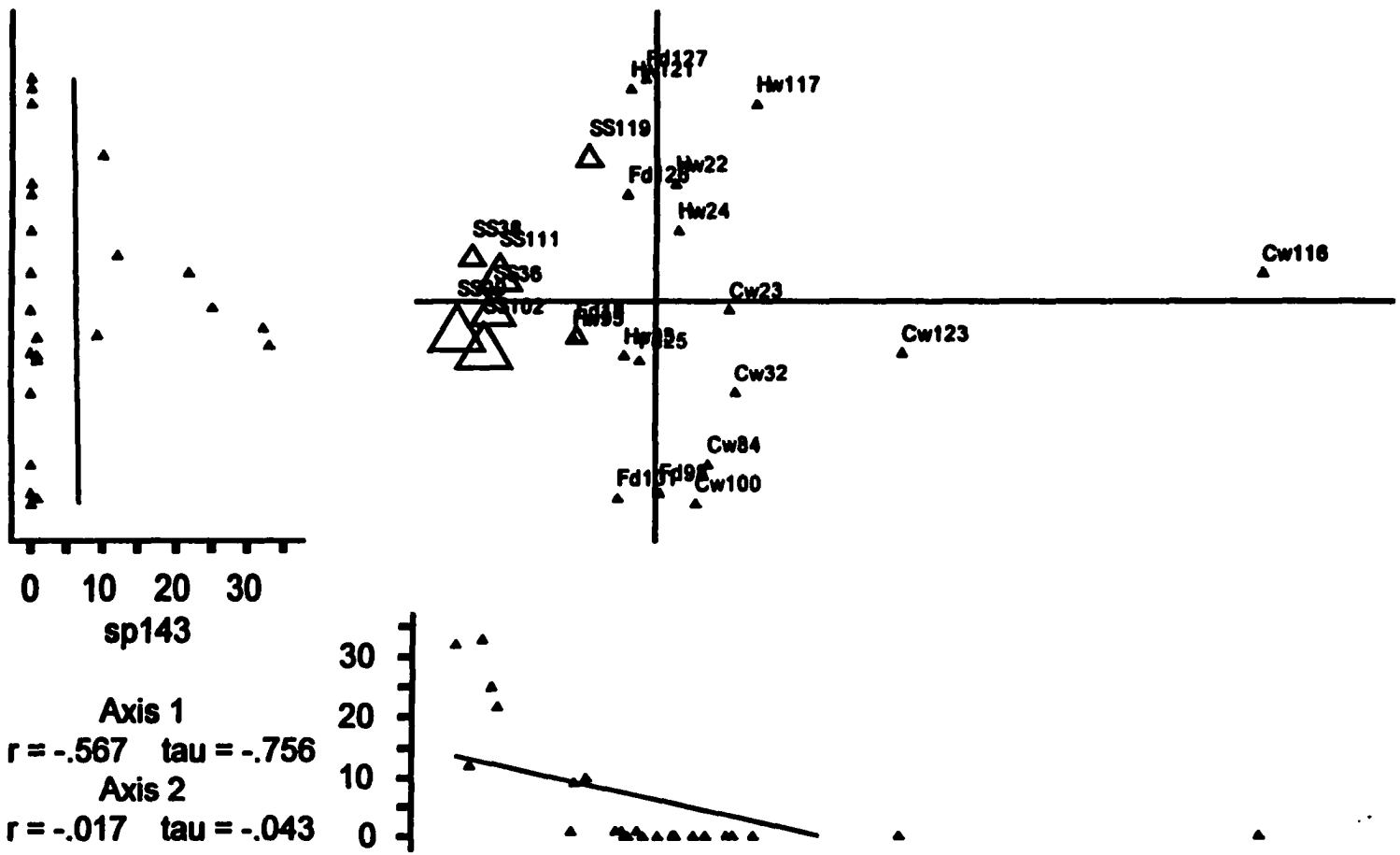


Figure 5.7. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of *Mycena aurantiidisca* distribution. r ranges 0 – 1; r = 1 corresponds to 100% correlation.

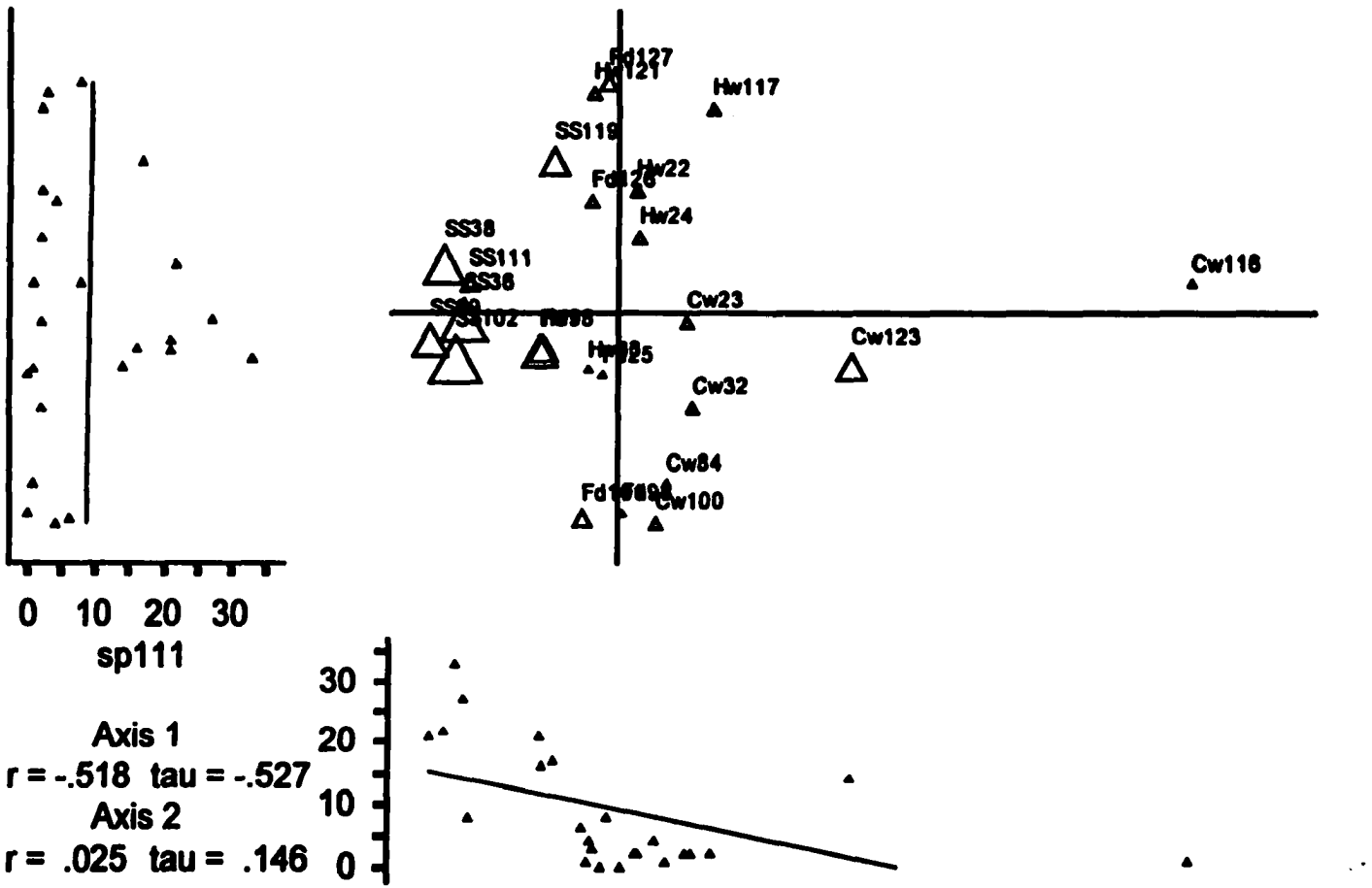


Figure 5.8. Detrended Correspondence Analysis (DECORA). Ordination of EP571 plots based on their saprobic macrofungus community with overlay of *Plectania melasoma* distribution.

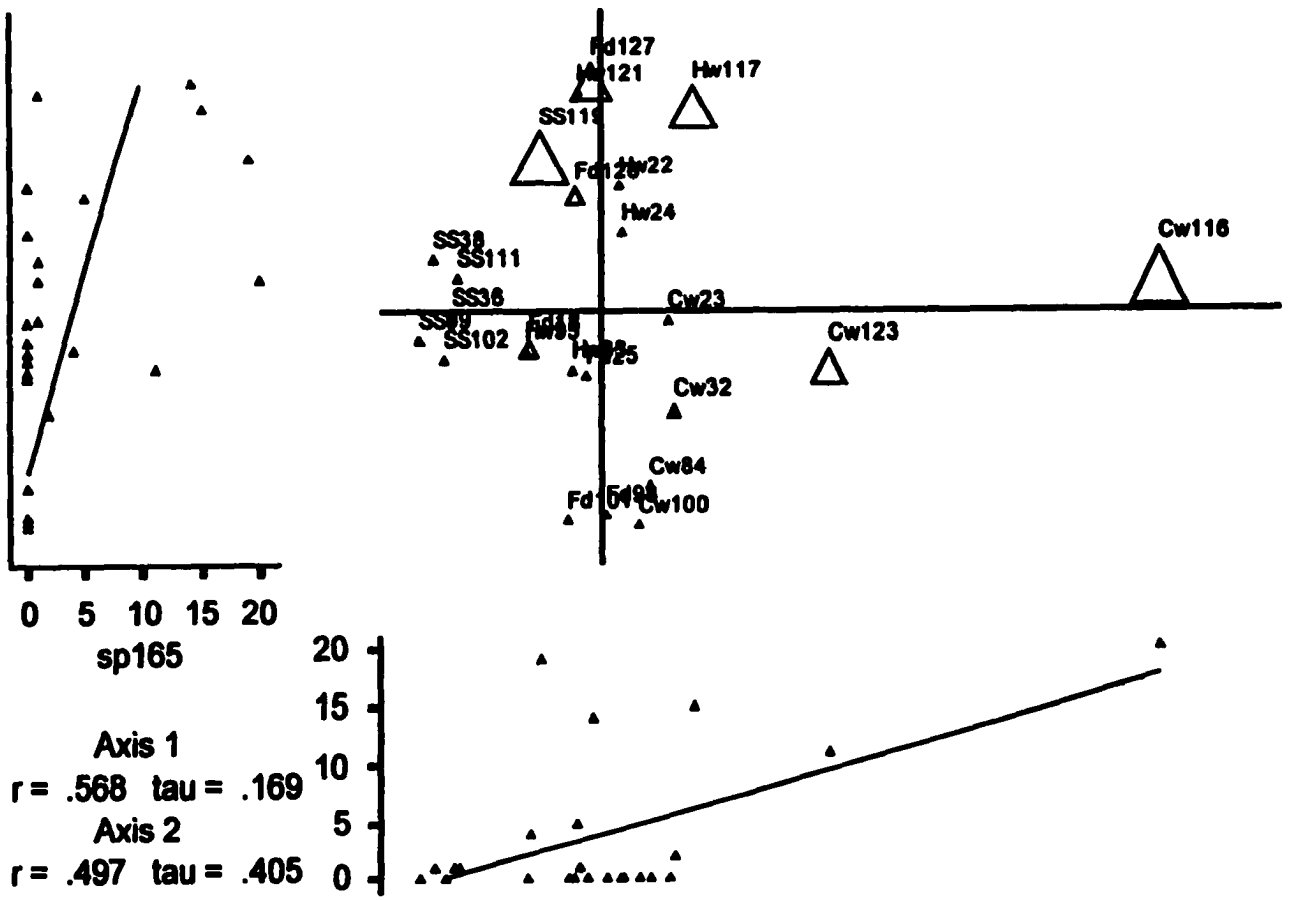
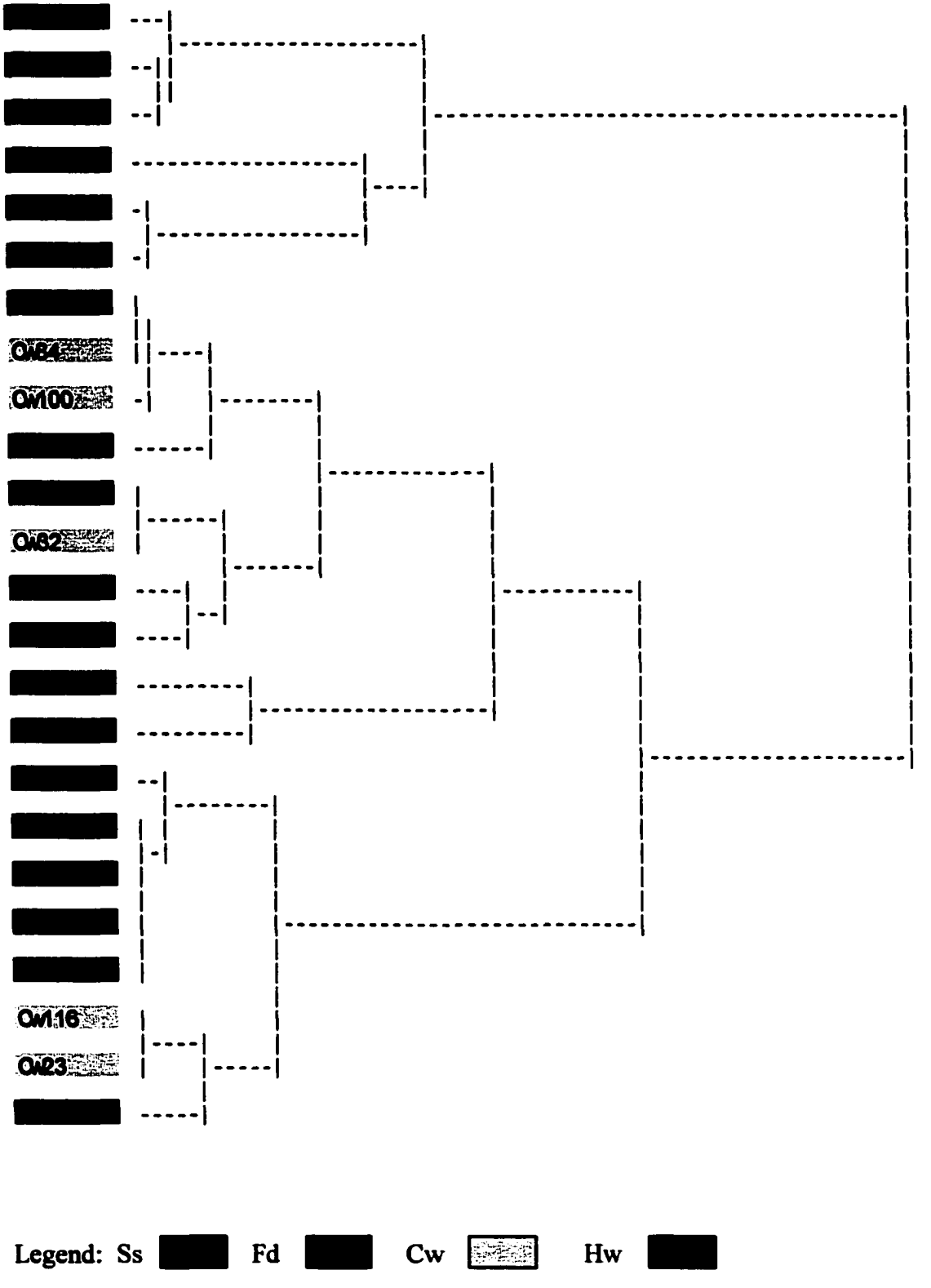


Figure 5.9. Detrended Correspondence Analysis (DECORA). Cluster analysis (Eucledean Distance, Ward's method) of EP571 plots based on their *Mycena* distribution.



Chapter Six : General Discussion and Conclusions

1. The species

Close to 80% of macrofungus species found in this study could be considered rare on south Vancouver Island., based on the fact that only one observation of their fruiting was recorded. Similar criteria, or that of only one or few known localities, have been used in the past to determine species rarity and the need for its protection in the Pacific Nortwest region and in Europe (Castellano et al.,1999; Molina et al., 2001; Arnolds and de Vries, 1993). Redhead (1997) recently published an update on the status of our knowledge on the taxonomy of macrofungi in British Columbia, including detailed notes on species occurrence within various ecological subzones, collection data, and lists of taxa perceived to be at risk. Based on these lists and other publications, some macrofungi identified in this study would qualify as "new" to British Columbia. It was beyond the scope of this study to pursue the various taxonomic and biogeographic analyses. Thus, species nomenclature contained herein should be regarded as para-taxonomic, and comments on rarity as tentative.

Suffice it to say, that in the absence of better knowledge about these fungi, it is prudent to assume that they might be rare and/or endangered (the two concepts should not be automatically equated), and care should be taken to preserve the various forest types which provide habitat for these fungi.

We should, however, also keep in mind the extreme scarcity and "patchiness" of data about the distribution of macrofungi in British Columbia. "For more than 90% of the province there has been documentation of less than 1% of the macrofungal flora in any systematic study " (Redhead 1997). What other statement could more undermine speculations about species rarity or endangered status? The might at first appear as rare could become common once we are atuned to looking for them. A relativistic scale with appropriate search parameters is required. Until then caution is the best approach.

Prescott et al. (1998) make an important point in support of protecting fungi. They believe that rich fungal flora represents a long -term solution to managing forest soil productivity. Any manipulation of forest humus which reduces fungi (the slow decomposers) and enhances bacteria (the fast decomposers), will only work in the short term, by providing a quick release of inorganic N and other nutrients. In the meantime the recalcitrant lignin and other compounds (which only certain fungi can break up) will build up, leading to stagnant, *mor*-dominated problematic humus. Hence, the concern about potential dangers to forest fungi and the need for their protection.

2. Spatial and temporal linkages

Judging by the age of the forests and the relatively high number of species we found in most plots, it seems that the fungal communities in these stands have reached, are approaching, or have just passed a peak in biodiversity. This assumption would not violate the existing knowledge on the subject. Evidence accumulates that fungi can

follow sequential occupation of a given site or substrate (Cooke and Rayner 1984, Dighton and Mason, 1985; Last et al. 1987). In general, independent of ecosystem type, fungal succession seems to follow a pattern of gradual rise, followed by a gradual fall. The highest diversity of macrofungi during sand dune development was observed when pioneer and late seral stage vegetation overlapped (Brown, 1958). In first generation forests diversity of mycorrhizal fungi increased until tree canopy closed, then declined (Dighton and Mason, 1985). On the other hand, other studies show greatest or equal diversity in old growth forests (Smith et al., 2002).

Typically, in young forests, the predominant ectomycorrhizal species, such as *Hebeloma* spp, or *Laccaria* spp., have broad host range and lower demand for host carbohydrates. Climax forests, characterised by the accumulation of nutrient impoverished litter, are colonized by more host selective and more competitive taxa, for example *Amanita muscaria*. However, these sequential events are drastically altered in second generation forests, planted after clear felling, or when non-mycorrhizal seedlings are planted among mature trees, with the aged, nutrient poor humus already in place (Carroll and Wicklow, 1992).

The second generation forests (or more accurately, single species plantations), which we investigated in this project, were not only planted after clear felling, but were also preceded by the slash burning method of site preparation. The burning must have been incomplete, as evidenced by the many remnant stumps from the old growth forest, which most likely resulted in heterogeneity of soil nutrient loading on the sites.

Additionally, due to varied topography and differing tree growth performance, young conifer seedlings and broadleaf vegetation were frequently present in the understory. All these factors undoubtedly contributed to the complexity and diversity of the fungal populations.

It is interesting that the more homogenous site, Upper Klanawa, with the "purest" stands, the least undergrowth, and the best tree performance, was also inhabited by the lowest diversity and biomass of fungi. Perhaps its fungal succession has reached a later stage compared to the other sites, or perhaps more macrofungal species are actually present there, but are not fruiting.

The succession of non-mycorrhizal fungi in temperate forest monocultures has not been well studied. Physiological advantages, such as growth rate and production of enzymes and antibiotics, as well as competitive inoculum potential, e.g. propagule densities, were proposed as the keys to success in colonization of dead organic matter (Garrett 1950). Fungal spore colonization of stumps and other decaying wood on forest floors has been investigated by Meredith (1959) and Carruthers and Rayner (1979). Generally, while spore dispersal is viewed as more passive and unpredictable, the mycelial invasion of new substrates, though highly effective, depends on resource continuity.

Goodman (1995) suspected that the ectomycorrhizal community in his mature plots of Douglas-fir may have been enriched by the presence of some old growth legacy of

large stumps and logs. I find it difficult to speculate on the likelihood of such influence in our study, but I do not exclude the possibility. More studies are needed on the survival of mycorrhizal propagules in tree stumps or buried wood. Notwithstanding, I believe that, the proximity of "freshly" fallen branches, twigs, and other plant material to the old rotting stumps from the original old growth forest, must have significantly influenced the composition of the saprophytic macrofungus flora at least.

3. Sampling methodology

The frequency of species in contiguous quadrats (here subplots), a well established method in ecology for measuring abundance of organisms with hard to delineate physical boundaries, is well suited for studying forest macrofungi. With the exception of really small species, confined in their growth to a single conifer needle or a tiny twig, the mycelium (and thus the actual body) of most macrofungi is hidden well beyond our perception. It permeates the substrates with hyphal networks of unforseeable shape or extent and the fragile texture of a cobweb. Such constraints, coupled with the inherent variation amongst macrofungi in the intensity of fruiting, diminish the usefulness of the absolute counts of fruiting bodies in studies such as this one. Bills et al., (1986) studied ectomycorrhizal communities in red spruce versus hardwood forests, and also concluded that species frequency in small contiguous quadrates is more appropriate than the actual sporocarp density in the occupied quadrats, for comparison of ubiquity of fungal species in plot studies.

Sampling intervals used in studies on mushroom sporocarp production vary considerably, from 2-3 times a year to 2-3 times a week (Vogt and Bloomfield, 1992). Similarly, sporocarp lifespan estimates show little consistency, even for the same species (Hora 1959, Richardson 1970). Fruit body longevity can range from 1-3 days for *Mycena* and *Galerina* , 17-20 days for *Boletus* or *Hygrophorus* (Richardson 1970), and up to 24 days for *Dermocybe* (Kotilova-Kubickova et al., 1990). For these reasons, we cannot exclude the possibility of errors in our data with regards to species abundance and frequencies. Similarly, our findings do not necessarily represent the actual biodiversity potential of the sites studied, as some short-lived species have been undoubtedly missed. Several species on our list can be categorized as relatively long-lived, e.g. *Polyporus, Ganoderma, Trametes,* or *Coltricia*, and efforts have been made to avoid double counting. The overall frequency of these genera was sufficiently low, and we feel fairly confident that errors due to double counting are minimal. However, we had to exclude the tiny *Nidula candida*, which formed persistant fruiting bodies on *Vaccinium* sp. twigs and other woody litter, from our calculations, as its ubiquity in several plots (especially those in site 1 – Upper Klanawa), would have significantly altered our results.

Perhaps the weakest part of our sampling methodology, was the duration of the entire survey. Extreme examples of a 97% decrease in sporocarp biomass from one year to the next have been recorded (Mehus, 1986), and Tofts and Orton (1998) claim that even after 21 years of macrofungus monitoring, the species number curve did not level off. Hering (1966) felt that a minimum of 8 years of fieldwork is needed for an accurate

estimate of mushroom diversity of a site. Based on our results, I think that the two years of monthly sampling, coupled with the replication of conifer plots in 3 distinct sites, yielded a fairly reliable set of data to sufficiently characterize the ecological fuction (i.e. guild) of macrofungus flora in the various microhabitats. The actual abundance and diversity, however, might be higher than the ones observed.

The results of this research have direct implications for two, generally conflicting, forest use strategies: ecosystems conservation measures and silvicultural practices management.

Clear-cutting and monoculture reforestation (Silviculture Interpretations Working Group, 1992) are widely used in forest industry of British Columbia. Combined with short rotation periods, these practices can have a serious impact on macrofungus species composition and abundance, and in the long term may lead to various changes in soil nutrient reserves, tree growth, and overall soil biological activity.

Our observations of site influenced differences in macrofungus diversity confirm the well documented fact that factors, such as soil nutrient status, temperature or moisture availability, can have a profound effect on diversity of soil organisms. It is hard to make generalizations, however. For example, some macrofungal species prefer high nitrogen and phosphorus levels, while other species perform best in nutrient poor soils. Similarly, while sufficient moisture is a prerequisite for the survival and production of

mushroom sporocarps, clearly too much moisture in the substrate is detrimental (Millar, 1974).

More importantly, however, we have found, that conifer species can have a significant effect on species diversity, composition, and sporocarp formation of macrofungi. In comparing the four types of habitat, according to these categories, western red cedar consistently ranked lowest (despite its still substantial saprophytic mycoflora). This can be explained by its lack of ectomycorrhizal associations, as well as its well known antifungal properties. Thus; one might speculate that, repeated, large scale monocultures of this conifer species could lead to impoverishment of soil mycoflora, and via food chains etc. to an overall decrease in soil productivity. Natural pure cedar forest stands are rather rare and not that extensive. It is more usual to find the mixtures of western red cedar and other tree species, e.g. western hemlock or arbutus, which form ectomycorrhizae.

It is generally assumed that in coastal forests of British Columbia, soil productivity is limited by the availability of nitrogen, which in turn depends on the rate of decomposition and nitrogen mineralization (Prescott et al., 2000). Since fungi are decomposer organisms and a major component of woods litter, one would expect to see a clear relationship between the number of fungi and soil productivity. However, according to Berg (1998) high nitrogen can be limiting (i.e. detrimental) in later stages of decomposition. Scheu (1992) adds that some microorganisms, the few that can degrade lignin and phenolic compounds, have requirements for readily available carbon

and low nitrogen, thus may be inhibited by the activity of soil invertebrates. Where these requirements are not met (i.e. where nitrogen is high and carbon is low), decomposition is inhibited and accumulation of humus occurs (Prescott et al., 1998). This school of thought might not be supported by Eviner and Chapin (1997), who believes that, if faced with carbon shortages, microorganisms will use N-compounds as a source of both carbon and nitrogen. Clearly, the issue of nutrient cycling in forest ecosystems is still unclear.

Notwithstanding, the above facts might be of particular relevance to conifer plantations (high lignin and cellulose content of the wood), especially, in the context of spruce ecology, as spruce needles are highly recalcitrant (Millar, 1974). Additional challenges in decomposition of recalcitrant material are met by a group of highly versatile saprophytic fungi, such as species of *Mycena*.

In view of all the results from Experimental Project 571, as well as available literature, I believe that the growing concern about conifer monocultures and their potential impact on soil productivity is not unsubstantiated. Many studies indicate that reducing competition between plants by mixing compatible species leads to overall increase in site stability and productivity.

Spatial stratification of foliage is often the key to reduction in competition. Various plantation studies in Europe showed that mixtures of shade tolerant species with less shade tolerant trees were consistantly more productive than monocultures of either one

(Kelty, 1992). Similar results were obtained for various species by North American (Wierman and Oliver, 1979) and tropical climate (Enright 1982) comparisons of natural stands.

Some work has been done on tree root competition in mixtures as compared to monocultures. It is known that tree species differ in rooting structure and depth (Spurr and Barns, 1980; Eis, 1978). Stability of mixed stands against windthrow, and increased resistance to pests and fungal diseases, are factors considered very important in some silvicultural systems (Kelty et al., 1992). However, it is not clear whether differences in rooting depth correspond to functional separation in nutrient or water uptake (Lyford, 1980, Berish and Ewel, 1988), especially as the stands age (Vogt et al., 1981). Even in situations where spatial separation of roots does not occur, differential uptake of nutrients (as shown for ammonium and nitrate by Waring and Schlesinger, 1985) may lead to more efficient utilization of soil resources. However, no studies link these characteristics with forest production increases.

Fungi play significant roles in nutrient cycling, food webs, forest diseases, and mutualisms. They increase seedling survival, tree growth, ond influence overall forest health (Molina et al. 2001). Mixed forest plantations are important to fungal diversity, function, and to ecosystem productivity. Amaranthus and Perry (1989) found that hardwoods share mycorrhizal species with conifers, frequently acting as their nurse crop. Perry et al. (1989) showed that ectomycorrhizae can reduce competition among

conifer seedlings, concluding that the shared mycelium contributed to the more even allocation of the soil resources among plants.

Both agriculture and forestry use mixed plantations to facilitate nitrogen availability to crop species. The two basic ways of achieving this are via increased nitrogen to carbon ratios in hardwood-conifer mixtures (leading to faster rates of litter decomposition by fungi and bacteria) (Matthews, 1989), and by including tree species that fix atmospheric nitrogen through symbiotic association with *Rhizobium* or *Frankia* (Binkley et al., 1984).

Richardson (1970) reported higher production of macrofungi in coniferous versus broadleaf forests. However, in a study by Bills et al. (1986) mixed hardwood forests yielded higher diversity and abundance of macrofungi than did single species conifer stands.

Based on the results of my study, there is some overlap in macrofungus community composition between Sitka spruce, Douglas-fir, western red cedar, and western hemlock. There are enough differences, however, that most likely a mixture of the four conifer species would significantly increase the overall macrofungus diversity.

4. Conclusions

Conifer species as well as site differences (soil nutrient and moisture content) were found to affect the structure, diversity, and abundance of macrofungal communities in single species plantations. The magnitude of the effect, especially with regards to sites, can vary from year to year.

Douglas-fir creates the most favourable conditions for fruiting of macrofungi in general. The most common fungi growing in its habitat are: *Clavulina cristata, Mycena amicta, Mycena metata,* and *Cantharellus formosus.*

Western hemlock is the leading host of ectomycorrhizal fungi, but has the poorest saprobic macrofungus flora. It is likely that the two ecological groups have an adverse effects on each other, though perhaps not in direct competition for resources.

The Sitka spruce forest floor is characterized by uniquely dense fruitings of fungi from the genus *Mycena*, with the most outstanding species being *Mycena tenax*. Low tannin, but high nitrogen and lignin content of spruce litter, might be responsible for the relationship. The ectomycorrhizal component of Sitka spruce mycobiota is relatively low.

Western red cedar habitat differs from that of other conifers. It has the lowest number of macrofungi in general. It can support sporadic fructifications of ectomycorrhizal fungi, e.g. *Cantharellus formosus*, with ectomycorrhizal hosts in its understory.

Coniferous forests of Vancouver Island show a lot of similarity in species composition to those of other Pacific Northwest coniferous forests, and to those of Europe, especially Scandinavia. Relative proportion of ectomycorrhizal macrofungi is similar for coniferous habitat as a whole, but the ectomycorrhizal component of individual species analysed here is lower than that reported elsewhere.

There are significantly more saprobic than ectomycorrhizal macrofungi in the local forests, the overall ratio being 7: 3. Second growth plantations show a lower percentage of wood decomposing fungi than that reported for mature and old growth forests.

Diversity of macrofungi, analysed for the four conifers separately and together, shows some similarities and overlap, but also elucidates fungi potentially restricted to a given habitat. A mixture of the four conifer species would probably be significantly more productive than the single species plantations.

This research contributed significant and useful information about the much understudied mycoflora of various forest habitats in British Columbia. Its main drawback was the relatively short duration of the project. More long -term studies are needed on single species plantation, as well as other silvicultural practices, and their effect on forest macrofungi.

Literature Cited

Ainsworth, G. C., and Sussman, A. S. (editors). 1965 - 1973. The Fungi , an Advanced Treatise. 1965, vol.1: The Fungal Cell; 1966, vol.2: The Fungal Organism; 1968, vol.3: The Fungal Population; 1973 (with F. K. Sparrow), vol.4: Taxonomic Review with Keys, A (Ascomycetes, Fungi imperfecti), B (Other groups). Academic Press, New York.

Allen M.F. 1991. The Ecology of Ectomycorrhizae. Cambridge University Press, Cambridge, England.

Allen, M.F., (editor). 1992. Mycorrhizal Functioning. An Integrative Plant Fungal Process. Chapman & Hall, New York, London.

Amaranthus, M. P., and D. A. Perry, 1989. Interaction effects of vegetation type and Pacific madrone soil inocula on survival, growth, and mycorrhiza formation of Douglas-fir. Can. J. For. Res. 19: 550-556.

Arnolds, E., and B. de Vries. 1993. Conservation of fungi in Europe. In: Fungi of Europe: Investigation, Recording and Conservation. Peggler D.N., L. Boddy, B. Ing, and P.M. Kirk (editors) pp. 211-230. Royal Botanic Gardens, Kew.

Arnolds, E. 1988. The changing macromycete flora in the Netherlands. Trans. Brit. Mycol. Soc. 90: 391-406.

Arnolds, E. 1991. Decline of ectomycorrhizal fungi in Europe. Agriculture, Ecosystems and Environment. 35:209-244.

Arora, D. 1986. Mushrooms Demystified. Ten Speed Press, Berkeley, Calif.

Ashton, P.S. 1992. The structure and dynamics of tropical rain forest in relation to tree species richness. In: The Ecology and Silviculture of Mixed-Species Forests. Kelty, M.J., B.C. Larson, and C.D. Oliver (editors). Kluwer Academic Publishers. Netherlands.

Bain, J. 1981. Forest monocultures - How safe are they? An entomologist's view. N.Z. Journal of Forestry 22: 37-42.

Bandoni, R. J., and A. F. Szczawinski. 1976. Guide to common mushrooms of B. C. rev. colour ed. B. C. Prov. Mus. Handb. No. 24.

Bandoni, R. J., and A. F. Szczawinski. 1964. Guide to common mushrooms of B. C. B. C. Prov. Mus. Handb. No. 24.

Barr, J., and Th. W. Kuyper. 1993. Litter removal in forests and effect on mycorrhizal fungi. In: Fungi of Europe: Investigation, Recording and Conservation. Pegler, D.N., L. Boddy, B. Ing, and P. M. Kirk (editors) Royal Botanic Gardens, Kew. pp. 275-286.

Bas, C. Th.W. Kuyper, M.E. Noordeloos and E.C. Vellinga. 1995. Flora Agaricina Neelandica. Volume 3, A. General part, B. Taxonomic part, C. Tricholomataceae (2). A.A. Balkema Publishers, Brookfield, VT. pp. 183.

Baxter, J.W., S.T.A. Pickett, M.M. Carreiro, and J. Dighton. 1999. Ectomycorrhizal diversity and community structure in oak forest stands exposed to contrasting anthropogenic impacts. Can. J. Bot. 77:771-782.

Berch, S. 1998. Impacts of forest soil disturbance on growth and ectomycorrhizae of conifer seedlings. . In: Ecology and Management of Northern Forest Soils Proceedings. University of Northern British Columbia. pp.112

Berch, S., B. Baumbrough, J. Battigelli, P. Kroeger, N. Strub, and L. de Montigny. 2001. Preliminary assessment of selected soil organisms under different conifer species. B.C. Min. For., Res. Br., Victoria, BC. Res. Rep. 20.

Berch. S.M. and A.M. Wiensczyk. 2001. Ecological description and Classification of some Pine Mushrooms (*Tricholoma magnivelare*) habitat in British Columbia. Ministry of Forest. Southern Interior Forest Extension and Research Partnership. Report 19. 61 pp.

Berg, B. 1998. Litter decomposition and organic matter turnover in northern forest soils. In: Ecology and Management of Northern Forest Soils Proceedings. University of Northern British Columbia. pp. 37-51.

Berish, C. W., and J. J. Ewel. 1988. Root development in simple and complex tropical successional ecosystems. Plant and Soil 106: 73-84.

Bigelow, H.E. 1982. Noth American species of *Clitocybe*. Part I. Beih. Nova Hedwigia 72:1-280.

Bills, G. F., G. I. Holtzman, and O. K. Miller, Jr., 1986. Comparison of ectomycorrhizal - basidiomycete communities in red spruce versus northern hardwood forests of West Virginia. Can. J. Bot. 64: 760-768.

Binkley, D., J. D. Lousier, and K. Cromack, Jr. 1984. Ecosystem effects of Sitka alder in a Douglas-fir plantation. For. Sci. 30: 26-35.

Bormann, F.H. and S.R. Kellert. 1991. Ecology, Economics, Ethics – The Broken Circle. Yale University Press, New Haven & London. 233 pp.

Breitenbach, J. and F. Krunzlin. 1984 –1995. Fungi of Switzerland. A contribution to the knowledge of the fungal flora of Switzerland. Vol. 1 Ascomycetes, Vol. 2 Non gilled fungi, Vol. 3 Boletes and agarics 1st part, and Vol. 4 Agarics 2nd part. Edition Mykologia Lucerne, Switzerland.

Brown, J.C. 1958. Soil fungi of some British sand dunes in relation to soil type and succession. J. Ecol. 46:641-664.

Bruns, T.D. 1995. Thoughts on the processes that maintain local species diversity of ectomycorrhizal fungi. Plant and Soil 170:63-73.

Burova, L.G. and I.L. Trapido. 1975. Mycological features of a birch forest of the *Carex pilosa* type in relation to prolonged recreational usage. Lesovedenie, No.1:49-55.

Carroll, G.C. and D.T. Wicklow. 1992. The Fungal Community. Its Organization and Role in the Ecosystem. 2nd edition, Vol.9 of Mycology Series, edited by P.L. Lemke. Marcel Dekker, NY. 976pp.

Carruthers, S.M. and A.D.M. Rayner. 1979. Fungal communities in decaying hardwood branches. Trans. Brit. Mycol. Soc. 72:283-289.

Castellano, M.A., J.E. Smith, T. O'Dell, E. Cazares and S. Nugent. 1999. Handbook to Strategy 1 Fungal Species in the Northwest Forest Plan. U.S.D.A. General Technical Report. PNW-GTR-476.

Castello, J.D., J.L. Donald, and P.J. Smallidge. 1995. Pathogens, patterns, and processes in forest ecosystems. BioScience 45: No.1:16-24.

Ciesla, W.M., editor. 1998. Non-wood forest products from conifers. Food and Agriculture Organization of the United Nations. European Forest Institute. Forest Service, Department of Agriculture. Rome.

Cooke, W.B. 1948. A survey of literature on fungus sociology and ecology. Ecology 29:376-382.

Cooke, R.C. and A.D.M. Rayner. 1984. Ecolgy of Saprotrophic Fungi. Longman, London.

Corner, E.J.H. 1966. A Monograph of Cantharelloid Fungi. Oxford Univ. Press, London, U.K.

Countess, R. 2001. Macrofungal diversity and communitiy structure in Douglas-fir dominated chronosequences of logging origin. M.Sc. Thesis. University of Victoria, B.C.

Cromack, K. Jr., R. L. Todd, and , D. C. Monk. 1975. Patterns of basidiomycete nutrient accumulation in conifer and deciduous forest litter. Soil. Biol. Biochem. 7: 265-268.

Dalberg, A., L. Jonsson, and J.Nylund. 1997. Species diversity and distribution of biomass above and below ground among ectomycorrhizal fungi in an old growth Norway spruce forest in south Sweden. Can. J. Bot. 75:1323-1335.

de Geus, P.M., 1995. Botanical Forest Products in British Columbia: An Overview. Integrated Resources Policy Branch, BC Ministry of Forests: Victoria, B.C. 44pp.

Delzenne-Van Haluwyn, Ch. 1972. Notes ecologiques sur les champignons superieurs, VII – le genre *Mycena*. Documents mycologiques. Fascicule 5. Lille.

Dennis, J.J. 1985. Effect of pH and temperature on *in vitro* growth of ectomycorrhizal fungi. Government of Canada, Canadian Forest Service Information Report BC-X-273. pp. 1-19.

Dighton, J., and P. Mason. 1985. Mycorrhizal dynamics during forest tree development. In: Developmental Biology of Higher Fungi. D. Moore, L. A. Casselton, D. A. Wood, and J. C. Frankland (editors). Cambridge University Press, Cambridge, England, pp. 117-139.

Dighton, J., J.M. Poskitt and D.M. Howard. 1986. Changes in occurrence of Basidiomycete fruit bodies during forest stand development: with specific reference to mycorrhizal species. Trans. Br. Mycol. Soc. 87 (1), 163-171.

Dickinson, C.H. and G.J.F. Pugh. (editors). 1974. Biology of Plant Litter Decomposition. Volumes 1 & 2. Academic Press. London and New York.

Durall, D.M., M.D. Jones, E.F. Wright, P. Kroeger and K.D. Coates. 1999. Species richness of ectomycorrhizal fungi in cutblocks of different sizes in the Interior Cedar-Hemlock forests of northwestern British Columbia: sporocarps and ectomycorrhizae. Can. J. For.Res. 29:1322-1332.

Egger, K.N. 1995. Molecular analysis of ectomycorrhizal fungal communities. Can. J. Bot. 73 (Supl. 1):S1415-S1422

Eis, S. 1978. Natural root forms of western conifers. Canada PFRC Repr. 15: 23-27.

Elton, C.S. 1958. The Ecology of Invasions by Plants and Animals. Chapman & Hall, London.

Enright, N.J. 1982. Does *Araucaria hunsteini* compete with its neighbors? Austral. J. Ecol. 7: 97-99.

Eviner, V. T. and F. S. Chapin. III 1997. Plant-microbial interactions. Nature 385: 26-27.

Ewel, J. J. 1986. Designing agricultural systems for the humid tropics. Annual Rev. Ecol. Syst. 17: 245-271.

Farrar, J.L. 1995. Trees in Canada. Fitzhenry & Whiteside Ltd. and the Canadian Forest Service. Markham and Ottawa, Ontario. 502 pp.

Fenger, M. A., E. H. Miller, J. F. Johnson, and E. J. R. Williams. (editors) 1993. Our Living Legacy: Proceedings of a Symposium on Biological Diversity. Royal British Columbia Museum, Victoria, B.C. 392 pp.

Fernando, A., F. Ring, D. Lowe, B.E. Callan. 1999. Index of Plant Pathogens, Plant Associated Micro-organisms and Forest Fungi of British Columbia. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C. Information Report BC-X-385.

Frank. 1887. Ber. Dtsch bot. Ges. 5:248. Sited in Ainsworth & Bisby's Dictionary of the Fungi, Hawksworth, D.L., P.M. Kirk, B.C. Sutton, and D.N. Pegler, 8th edition. International Mycological Institute. CAB International. Page 302.

Frankland, J. C. 1998. Fungal succession - unravelling the unpredictable. Mycol. Res. 102(1): 1-15.

Frankland, J.C., J.N. Hedger and M.J. Swift. 1982. Decomposer basidiomycetes: their biology and ecology. Symposium of the British Mycological Society held at Queen Mary College, London. pp. 1-347.

Gamiet, S. and S.M. Berch. 1992. Fungi of old-growth forests of British Columbia. Northwest Environmental Journal. Vol. 8:168-170.

Garbaye, J., and Le Tacon, F. 1982. Influence of mineral fertilization and thinning intensity on the fruit body production of epigeous fungi in an artificial spruce stand (*Picea excelsa* Link) in North-Eastern France. Acta Oecologia/Oecol. (*plant*). 3: 153-160.

Garrett, S.D. 1950. Ecology of the root infecting fungi. Biological Reviews. 25:220-254.

Gibson, I.A.S. and T. Jones. 1977. Monoculture as the origin of major forest pests and diseases. pp. 139-161 in Cherrett, J.M., G.R. Sagar, (editors), Origins of Pest, Parasite, Disease and Weed Problems. Blackwell Scientific Publications, Oxford. 413 pp.

Ginns, J. and M.N.L. Lefebvre. 1993. Lignicolous Corticioid Fungi of North America. Systematics, Distribution and Ecology. The Mycological Society of America Mycologia Memoir No. 19. APS Press.

Gochenaur, S.E. 1981. Response of soil fungal communities to disturbance. In: The Fungal Community: its organization and role in the ecosystem. Carroll G.C., and D.T. Wicklow (editors). Marcell Dekker, New York. pp. 459-479.

Goodman, D.M. 1995. Diversity of Ectomycorrhizae in Old-growth and Mature Stands of Douglas-fir on Southeastern Vancouver Island. Ph.D. Dissertation, Department of Biology, University of Victoria, Victoria, B.C.

Goodman, D.M., D.M. Durall, J.A. Trofymow, and S.M. Berch. 1996. A Manual of Concise Descriptions of North American Ectomycorrhizae. Mycologue Publications. Victoria, BC.

Grainger, J. 1946. Ecology of the larger fungi. Trans. Brit. Mycol. Soc. 29: 52-63.

Groves, J.W. 1979. Edible and Poisonous Mushrooms of Canada. Addendum by S.A. Redhead. Biosystematics Research Institute, Ottawa, Ontario. Research Branch Agriculture Canada Publication 1112. Canadian Government Publishing Centre, Hull, Quebec.

Grubb, P. J. 1977. The maintenance of species-richness in plant communities: The importance of the regeneration niche. Biol. Rev. 52: 107-145.

Hakkila, P. 1974. By-effects of the harvesting of logging residues. Folia For. 210: 3-24.

Hardy, G. A. 1946. Some mushrooms and other fungi of British Columbia. B. C. Prov. Mus. Nat. Hist. Anthropol. Handb. No. 4.

Harley, J.L. and S.E. Smith. 1983. Mycorrhizal Symbiosis. Academic Press, London.

Harmon, M.E., J.F. Franlin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.E. Lienkaemper, K. Cromack Jr., K.W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133-302.

Harvey, A. E., D. C. Larsen and M. F. Jurgensen. 1976. Distribution of ectomycorrhizae in a mature Douglas-fir/larch forest soil in western Montana. For. Sci. 24: 203-208.

Hawksworth, D. 1991. The fungal dimension of biodiversity: magnitude, significance, and conservation. Mycol. Res. 95:641-55.

Hawksworth, D. L., P. M. Kirk, B. C. Sutton and D. N. Pegler. 1996. Ainsworth & Bisby's Dictionary of Fungi. International Mycological Institute. CAB International.

Hering, T. F. 1966. The terricolous higher fungi of four lake district woodlands. Trans. Brit. Mycol. Soc. 49: 369-383.

Hesler, L.R. & A.H. Smith. 1979. North American Species of *Lactarius*. Ann Arbor: Univ. of Michigan Press, Michigan.

Hesler, L.R. & A.H. Smith. 1963. North American Species of *Hygrophorus*. Knoxville: Univ. of Tennessee Press.

Hill, J. and Y. Shimamato. 1973. Methods of analysing competition with special reference to herbage plants. J. Agric. Sci. 81: 77-88.

Holec, J. 1992. Ecology of macrofungi in the beech woods of the Sumava mountains and Sumava foothills. Ceska Mykologie 46:163-202.

Hora, F. B. 1959. Quantitative experiment on toadstool production in woods. Trans. Brit. Mycol. Soc. 42: 1-14.

Horton, T.R., T.D. Bruns and V. Thomas Parker. 1999. Ectomycorrhizal fungi associated with *Arctostaphylos* contribute to *Pseudotsuga menziesii* establishment. Can. J. Bot. 77:93-102.

Hudson, H.J. 1980. Fungal Saprophytism. Arnold, London.

Hunt, G. A., and Trappe, J. M. 1987. Seasonal hypogeous sporocarp production in a western Oregon Douglas-fir stand. Can. J. Bot. 65: 438-445.

Ingold, C.T. and J.J. Hudson. 1993. The Biology of Fungi. 6th Edition. Chapman & Hall. London. 224 pp.

Isaac, S. 1992. Fungal-Plant Interactions. Chapman & Hall, London. 418pp.

Johansson, M.B. 1995. The chemical composition of needle and leaf litter from Scots pine, Norway spruce and white birch in Scandinavian forests. Forestry 68(1):49-62.

Kelty, M. J. 1992. Comparative productivity of monocultures and mixed-species stands. In: Ecology and Silviculture of Mixed-Species Forests. Kelty, M. J., B. C. Larson and C. D. Oliver (editors). Kluwer Academic Publishers, Netherlands. pp.125-141.

Kelty, M. J., B. C. Larson, and C. D. Oliver (editors). 1992. The Ecology and Silviculture of Mixed-Species Forests. Kluwer Academic Publishers, Netherlands.

Kendrick, B. 1992. The Fifth Kingdom. Focus Texts, Focus Information Group, Inc., Newburyport MA.

Kenkel, N.C. and T. Booth. 1992. Multivariate Analysis in Fungal Communites. In: The Fungal Community. Its Organization and Role in the Ecosystem. 2nd edition, Carrol, G.C. and D.T. Wicklow (editors). Vol.9 of Mycology Series, edited by P.L. Lemke. Marcel Dekker, NY. pp. 209-227.

Kennedy, A. C. and V. L. Gewin. 1997. Soil microbial diversity: present and future considerations. Soil Science 162(9): 607-616.

Kernaghan, G., S. Berch, and R. Carter. 1995. Effect of urea fertilization on ectomycorrhizae of 20-year-old *Tsuga heterophylla*. Can. J. For. Res. 25:891-901.

Klinka, K., R.N. Green, P.J. Courtin, and F.C. Nuszdorfer. 1984. Site diagnosis, tree species selection, and slashburning guidelines for the Vancouver Forest Region. B.C. Min. For., Forest Service Internal Report No. 25.

Kotilova-Kubickova, L., J.P. Ondok and K. Priban. 1990. Phenology and growth of *Dermocybe uliginosa* in a willow carr. III. Fruit-body growth and biomass production. Mycol. Res. 94: 771-780.

Kranabetter, J.M. and P. Kroeger. 2001. Ectomycorrhizal mushroom response to partial cutting in a western hemlock-western redcedar forest. Can J. For. Res. 31:978-987.

Kranabetter, J.M., S. Hayden, and E.F. Wright. 1999. A comparison of ectomycorrhiza communities from three conifer species planted on forest gap edges. Can. J. Bot. 77:1193-1198.

Kranabetter, J.M. and T. Wylie. 1998. Ectomycorrhizal community structure across forest opening on naturally regenerated western hemlock seedlings. Can. J. Bot. 76:189-196.

Krebs, C. J. 1989. Ecological Methodology. Harper Collins Publishers. 654pp.

Laiho, O. 1970. *Paxillus involutus* as a mycorrhizal symbiont of forest trees. Acta For. Fen. 79: 1-35.

Lange, M. 1993. Macromycetes under twelve tree species in ten plantations on various soil types in Denmark. Opera Bot. 120:1-53.

Largent, J. 1994. Entolomatoid fungi of the western United States and Alaska. Mad River Press. 486 pp.

Larson, B. C. 1992. Pathways of development in mixed-species stand. In: Ecology and Silviculture of Mixed-Species Forests. Kelty, M. J., B. C. Larson and C. D. Oliver (editors). Kluwer Academic Publishers, Netherlands. pp. 3-10.

Last, F.T., P.A. Mason, J. Pelham, and K. Ingleby. 1984. Fruitbody production by sheathing mycorrhizal fungi: effects of 'host' genotypes and propagating soils. For. Ecol. Manage. 9:221-227.

Last, F.T., P.A. Mason, R. Smith, J. Pelham, K.A. Bhoja Shetty, and A.M. Mahmood Hussian. 1981. Factors affecting the production of fruitbodies of *Amanita muscaria* in plantations of *Pinus patula*. Proc. Indian Acad. Sci. (Plant Sci.) 90:91-98.

Last, F. T., Pelham, J., Mason, P. A., and K. Ingleby. 1979. Influence of leaves on sporophore production by fungi forming sheathing mycorrhizas with *Betula* spp. Nature 280: 168-169.

Last, F.T., J. Dighton and P.A. Mason. 1987. Successions of sheathing mycorrhizal fungi. Trends Ecol. Evol. 2: 157-161.

Lilleskov, E.A., T.J. Fahey, and G.M. Lovett. 2001. Ectomycorrhizal fungal aboveground community change over an atmospheric nitrogen deposition gradient in Alaska. Ecological Applications 11:397-410.

Lincoff, G. 1981. The Audubon Society Field Guide to North American Mushrooms. Alfred Knopf, New York.

Littke, W.R., C.S. Bledsoe, and R.L. Edmonds. 1984. Nitrogen uptake and growth in vitro by *Hebeloma crustuliniforme* and other Pacific Northwest mycorrhizal fungi. Can. J. Bot. 62:647-652.

Lodge, D.J. 1997. Factors related to diversity of decomposer fungi in tropical forests. Biodiversity and Conservation 6: 681-688.

Luoma, D.L., R.E. Frenkel, J.M. Trappe. 1991. Fruiting of hypogeous sporocarps in Oregon Douglas-fir forests: seasonal and habitat variation. Mycologia 83:335-353.

Lussenhop, J. 1992. Mechanisms of Microarthropod - microbial interactions in soil. Advances in Ecological Research 23: 1-33.

Lyford, W. H. 1980. Development of the root system of northern red oak (*Quercus rubra* L.) Harvard Forest Pap. No. 21. 30 pp.

Maas Geesteranus R.A. 1992. Mycenas of the Northern Hemisphere. Vol.1 & 2. Koninklijke Nederlandse Akademie van Wetenschappen Verhandenelingen, Afd. Natuurkunde, Tweede Reeks, deel 90. North-Holland, Amsterdam, Oxford, New York, Tokyo.

Magurran, A.E. 1988. Ecological Diversity and its Measurement. Princeton University Press. Princeton, N.J. USA. pp. 179.

Malloch, D.W., K.A. Pirozynski and P.H. Raven. 1980. Ecological and evolutionary significance of mycorrhizal symbioses in vascular plants (a review). Proceedings of the National Academy of Sciences. U.S.A. 77:2113-2118.

Marks, D. and B. Kozlowski (editors) 1973. Ectomycorrhizae, their Physiology and Ecology. Academic Press, London and New York.

Mason, P. A., J. Wilson and F. T. Last. 1984. Mycorrhizal fungi of *Betula* spp.: factors affecting their occurrence. Proc. Roy. Soc. Edinb. 85B: 141-151.

Matthews, J. D. 1989. Silvicultural Systems. Clarendon Press, Oxford. 284pp.

McCune,, B., and M.J. Mefford. 1995. PC-ORD. Multivariate Analysis of Ecological Data, Version 2.0. MjM Software Design, Glenenden Beach, Oregon, USA.

Mehus, H. 1986. Fruit body production of macrofungi in some North Norwegian forest types. Nord. J. Bot. 6: 679-701.

Mehmann, B., I. Brunner, and G.H. Braus. 1994. Nucleotide sequence variation of chitin synthase genes among ectomycorrhizal fungi and its potential use in taxonomy. Appl. and Envir. Microbiology 60(9): 3105-3111.

Meidinger, D.and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Min. For., Victoria, B.C. Spec. Rep. Ser. No. 6.

Menge, J. A. and L.F. Grand. 1978. Effect of fertilization on production of epigeous basidiocarps by mycorrhizal fungi in loblolly pine plantations. Can. J. Bot. 56:2357-2362.

Meredith, D.S. 1959. The infection of pine stumps by *Fomes annosus* and other fungi. Ann. Bot. (London) [N.S.] 23: 455-476.

Mexal, J. and C.P.P. Reid. 1973. The growth of selected mycorrhizal fungi in reponse to induced water stress. Can. J. Bot. 51:1579-1588.

Millar, C.S. 1974. Decomposition of coniferous leaf litter. In: Biology of Plant Litter Decomposition. Vol. 1. Dickenson, C.H. and G.J.H. Pugh (Ed.) Academic Press. London and New York. pp. 105-128.

Miller, R. E. and M. D. Murray. 1978. The effects of red alder on growth of Douglas-fir. In: Utilization and management of alder. D. G. Briggs, D. S. DeBell, and W. A. Atkinson (eds.), USDFA For. Serv. Gen. Tech. Rep. PNW-70. pp. 283-306.

Miller, S. L. 1995. Functional diversity in fungi. Can. J. Bot. 73 (Suppl. 1): S50-S57.

Minore, D. 1983. Western redcedar – a literature review. Gen. Tech. Rep. PNW-150. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 70 pp

Molina, R. 1979. Pure culture synthesis and host specificity of red alder mycorrhizae. Can. J. Bot. 57: 1223-1228.

Molina, R. and J.M. Trappe. 1982. Patterns of ectomycorrhizal host specificity and potential among Pacific Northwest conifers and fungi. Forest Sci. 28 (3):423-458.

Molina, R., T. O'Dell, M. Amaranthus, [and others]. 1993. Biology, ecology, and social aspects of wild edible mushrooms in the forests of the Pacific Northwest: a preface to managing commercial harvest. Gen. Tech. Rep. PNW-GTR-309. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Molina R., D. Pilz, J. Smith, S. Dunham, T. Dreisbach, T. O'Dell, and M. Castellano. 2001. Conservation and management of forest fungi in the Pacific Northwestern United States: an integrated ecosystem approach. In: Fungal Conservation Issues and Solutions. A Special Volume of the British Mycological Society. Moore D., M. M. Nauta, S. E. Evans, and M. Rotheroe (editors). Cambridge University Press.

Moser, M. 1983. Keys to Agarics and Boleti. Roger Phillips, London. 535pp.

Murdoch, W. W. 1975. Diversity, Complexity, Stability and Pest Control. pp. 795-807.

Naeem, S. and L. Shibin. 1997. Biodiveresity enhances ecosystem reliability. Nature 390: 507-509.

Namkoong, G. 1997. Biodiversity measurement: Where are we? Workshop on Biodiversity in B. C., University of British Columbia.

Nauta M. and E. C. Vellinga. 1993. Distribution and decline of macrofungi in the Netherlands. In: Fungi of Europe: Investigation, Recording and Conservation. Pegler D.N., L. Boddy, B. Ing & P. M. Kirk (editors.) Royal Botanic Gardens, Kew. pp. 21-46.

Newell, S.Y. 1992. Estimating Fungal Biomass and Productivity in Decomposing Litter. In: The Fungal Community. Its Organization and Role in the Ecosystem. 2nd edition. Carroll, G.C. and D.T. Wicklow (editors). Vol.9 of Mycology Series, Marcel Dekker, NY. pp. 521-562.

Norvell, L. 1995. Loving the Chanterelle to Death? The Ten Year Oregon Chanterelle Project. McIlvainea 12:6-24.

Norvell, L. 1998. The biology and taxonomy of Pacific Northwest species of *Phaeocollybia* (*Agaricales, Cortinariaceae*). Ph. D. Thesis. University of Washington, Seattle, 391pp.

Norvell, L. 2002. *Phaeocollybia* in western North America 3: Two new species with notes on the *Phaeocollybia festiva* complex. Mycotaxon 81: 95-112.

O'Dell, T.E., J.F. Ammirati, and E.G. Schreiner. 1999. Species richness and abundance of ectomycorrhizal basidiomycete sporocarps on a moisture gradient in the *Tsuga heterophylla* zone. Can. J. Bot. 77:1699-1711.

O'Dell, T.E., D.L. Luoma, R.J. Molina. 1992. Ectomycorrhizal fungal communities in young, managed and old growth Douglas-fir stands. Northwest Environmental Journal. 8:166-168.

Ohenoja, E. 1978. Mushrooms and mushroom yields in fertilized forests. Ann. Bot. Fenn. 15:38-46.

Ohenoja, E. and R. Koistinen. 1984. Fruit body production of larger fungi in Finland. 2. Edible fungi in Northern Finland 1976-1978. Ann. Bot. Fennici 21:357-366.

Omule, S.A.Y. and G.J. Krumlik. 1987. Juvenile Height Growth of Four Species on Four Sites in the CWHb1 Variant. B. C. Ministry of Forests. Research Branch. Economic & Regional Development Agreement. Canada. British Columbia.

Peredo, H., M. Oliva, A. Huber. 1983. Environmental factors determining the distribution of *Suillus luteus* fructifications in *Pinus radiata* grazing-forest plantations. Pl. Soil 71: 367-370.

Perrings, C., C. Maler, C. Folke, C. S. Holling and B. Jansson. 1995. Biodiversity Loss, Economic and Ecological issues. Cambridge University Press.

Perry, D.A., Margolis, H., Choquette, C., Molina, R., and Trappe, J.M. 1989. Ectomycorrhizal mediation of competition between coniferous tree species. New Phytologist 112:501-511.

Peterson, M.J., R. Outerbridge and J. Dennis. 2000. Chanterelle Productivity on Burned and Unburned Regeneration Sites in the Vicinity of Skidegate Lake on Moresby Island. Report submitted by Applied Forest Science Ltd. to the South Moresby Forest Replacement Account. pp. 37. Unpublished report.

Phillips, R. 1991. Mushrooms of North America. Little, Brown and Company, London.

Pilz, D. and R. Molina. 2002. Commercial harvests of edible mushrooms from the forests of the Pacific Northwest United States: issues, management, and monitoring for sustainability. Forest Ecology and Management 155:3-16.

Pilz, D. and R. Molina (editorss). 1996. Managing forest ecosystems to conserve fungus diversity and sustain wild mushroom harvests. General Technical Report PNW-GTR-371, U. S. Department of Agriculture, Forest Service.

Pojar, J. and A. MacKinnon (editors). 1994. Plants of Coastal British Columbia, including Washington, Oregon & Alaska. British Columbia Ministry of Forests and Lone Pine Publishing Co. Canada. Pp. 527.

Pomerleau, R. 1980. Flore des champignons au Quebec et regions limitrophes. Les editions la presse, Montreal, Quebec. 653pp.

Prescott, C.E., L. Vesterdal, J. Pratt, K.H. Venner, L.M. de Montigny, and J.A. Trofymow. 2000. Nutrient concentrations and nitrogen mineralization in forest floors of single species conifer plantations in coastal British Columbia. Can. J. For. Res. 30:1341:1352.

Prescott, C.E. 1996. Influence of forest floor type on rates of litter decomposition in microcosms. Soil Biol. Biochem. 28:1319-1325.

Prescott, C.E., D.G. Maynard and R. Laiho. 1998. Humus in boreal forests: friend or foe? In: Ecology and Management of Northern Forest Soils Proceedings. University of Northern British Columbia. pp. 3-20.

Pugh, G.J.F. 1974. Terrestrial fungi. In: Biology of Plant Litter Decomposition. Vol. 2. Dickenson, C.H. and G.J.H. Pugh (editors). Academic Press. London and New York. pp. 269-336.

Rangel-Castro, J.I. 2001. Eco-physiology of the ectomycorrhizal mushroom *Cantharellus cibarius*: carbon and nitrogen metabolism, and the interactions with bacteria and mycophagous invertebrates. Doctoral thesis, Acta Universitatis Agriculturae Sueciae, Silvestria 224. Swedish University of Agricultural Sciences, Uppsala.

Raven, P.H. and G.B. Johnson. 1986. Biology. Times Mirror/Mosby College Publishing. Missouri. 1198 pp.

Redhead, S. A. 1989. A biogeographical overview of the Canadian mushroom flora. Can. J. Bot. 67: 3005-3062.

Redhead, S.A. 1997. Macrofungi of British Columbia: Requirements for Inventory. Res. Br., B.C. Min. of For., and Wildl. Br., B.C. Min. Environ. Lands and Parks, Victoria, B.C. Work. Pap. 28/1997. 119 pp.

Redhead, S.A., L.L. Norvell, and E. Danell. 1997. *Cantharellus formosus* and the Pacific Golden Chanterelle Harvest in Western North America. Mycotaxon Vol. LXV, pp. 285-322.

Redhead, S. A. and S. Berch. 1996. Methodologies for inventorying British Columbia's macrofungi. Resources Inventory Committee, Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, B.C.

Richardson, M.J. 1970. Studies of *Russula emetica* and other agarics in a Scots pine plantation. Trans. Brit. Mycol. Soc. 55:217-229.

Roth, A.L. 1990. Mycorrhizae of outplanted conifer seedlings on eastern Vancouver Island. M.Sc. thesis, University of British Columbia, Vancouver.

Roth, A.L. and S.M. Berch. 1992. Ectomycorrhizae of Douglas-fir and western hemlock seedlings outplanted on eastern Vancouver Island. Can. J. For. Res. 22:1646-1655.

Rydin, H. M. Diekamann, and T. Hallingback. 1997. Biological characteristics, habitat associations, and distribution of macrofungi in Sweden. Conservation Biology 11(3): 628-640.

SAS Institute Inc. 1988. SAS/STAT User's Guide, release 6.03 edition. SAS Institute Inc. Cary, N.C.

Salo, K. 1993. The composition and structure of macrofungus communities in boreal upland type forests and peatlands in north Karelia, Finland. Karstenia, 33: 61-99.

Sastad, S.M. 1995. Fungi- vegetation relationships in a *Pinus sylvestris* forest in central Norway. Can. J. Bot.73:807-816.

Schalkwijk-Barendsen, H.M.E. 1994. Mushrooms of Northwest North America. Lone Pine Publishing Alberta, British Columbia and Washington. 415 pp.

Scheu, S. 1992. Decomposition of lignin in soil microcompartments: A methodical study with three different C-14-labelled lignin substrates. Biol. Fertil. Soils 13:160-164.

Schmit, J.P., J.F. Murphy and G.M. Mueller. 1999. Macrofungal diversity of a temperate oak forest: a test of species richness estimators. Can. J. Bot. 77:1014-1027.

Schlosser, W.E. and K.A. Blatner. 1995. The wild edible mushroom industry of Washington, Oregon and Idaho. Journal of Forestry. 93:31-36.

Senn-Irlet, B. and G. Bieri. 1999. Sporocarp succession of soil-inhabiting macrofungi in an autochtonous subalpine Norway spruce forest of Switzerland. Forest Ecology and Management 124: 169-175.

Silviculture Interpretations Working Group. 1992. Silviculture, British Columbia's Forests: Monocultures or Mixed Forests? British Columbia Ministry of Forests. 44 pp.

Smith, A. H. 1947. North American species of *Mycena.* Univ. Mich. Studies. Scientific Series. Vol. XVII. Univ. Mich. Press, Ann Arbor.

Smith, A.H. and R. Singer. 1964. A Monograph on the Genus *Galerina* Earle. Hafner Publishing Company. New York and London. 384 pp.

Smith, A.H., H.V. Smith, N.S. Weber 1979. How to Know the Gilled Mushrooms. The Pictured Key Nature Series. Wm. C. Brown Company Publishers, Dubuque, Iowa. 334 pp.

Smith, A.H., H.V. Smith, N.S. Weber 1981. How to Know the Non-gilled Mushrooms. The Pictured Key Nature Series. Wm. C. Brown Company Publishers, Dubuque, Iowa. 324 pp.

Smith, J.E., R. Molina, M.M.P. Huso, D.L. Luoma, D. McKay, M.A. Castellano, T. Lebel, and Y. Valachovic. 2002. Species richness, abundance, and composition of hypogeous and epigeous ectomycorrhizal fungal sporocarps in young, rotation-age, and old-growth stands of Douglas-fir (*Pseudotsuga menziesii*) in the Cascade Range of Oregon, U.S.A. Can. J. Bot. 80: 186-204.

Smitinand, T. 1995. Overview of the status of biodiversity in tropical and temperate forest. In: Measuring and Monitoring Biodiversity in Tropical and Temperate Forests. Proc. of a IUFRO Symposium held at Chiang Mai, Thailand. August 27th – September 2nd, 1994. Boyle, T.J.B. and B. Boontawee. Center for International Forestry Research, Bogor, Indonesia. 395 pp.

Spurr, S. H., and B. V. Barnes. 1980. Forest Ecology. John Wiley and Sons, New York. 687 pp.

Stark, N. 1972. Nutrient cycling pathways and litter fungi. Bioscience 22:355-360.

Taylor, B.R., C.E. Prescott, W.J.F. Parsons and D. Parkinson. 1991. Substrate control of litter decomposition in four Rocky Mountain coniferous forests. Can. J. Bot. 69:2242-2250.

Tedder, S., D. Mitchell and R. Farran. 2000. Seeing the Forest Beneath the Trees: The Social and Economic Potential of Non-Timber Forest Produkcts and Services in the Queen Charlotte Islands/Haida Gwaii. South Moresby Forest Replacement Account. Unpublished report.

Termorshuizen, A.J. 1991. Succession of mycorrhizal fungi in stands of *Pinus sylvestris* in the Netherlands. Journal of Vegetation Science 2:555-564.

Tofts, R.J. and P.D. Orton. 1998. The species accumulation curve for agarics and boleti from a Caledonian pinewood. Mycologist 12(3):98-102.

Trappe, J. M. 1962. Fungus associates of ectotrophic mycorrhizae. Bot. Rev. 28: 538-606.

Trappe, J.M. 1963. Some probable mycorrhizal associations in the Pacific Northwest. IV. Northwest Science 39(1):39-43.

Trofymow, T. 1998. Relative importance of litter quality and climate controls on short-term decomposition in Canadian forests. In: Ecology and Management of Northern Forest Soils Proceedings. University of Northern British Columbia. p. 84.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994a. Final Supplement Environmental Impact Statement of Management of Habitat for Late-successional and Old Growth Forest Related Species within the Range of the Northern Spotted Owl.

U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management. 1994b. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents within the Range of the Northern Spotted Owl.

Vandermeer, J. 1989. The Ecology of Intercropping. Cambridge University Press, Cambridge. 237 pp.

Varma, A. and B. Hoch (eds.) 1995. Mycorrhiza: Structure, Function, Molecular Biology and Biochemistry. Springer Verlag.

Veijalainen, H. 1976. Effect of forestry on the yields of wild berries and edible fungi. Ecol. Bull. (Stockholm) 21: 63-65.

Villeneuve, N., M.M. Grandtner, and J. Andre Fortin. 1989. Frequency and diversity of ectomycorrhizal and saprophytic macrofungi in the Laurentide Mountains of Quebec. Can. J. Bot. 67:2616-2629.

Vogt, K.A. and J. Bloomfield. 1992. Sporocarp production by basidiomycetes, with emphasis on forest ecosystems. In: The Fungal Community, Carroll G.C. and D. Wicklow (editors). Marcel Dekker, Inc. NY. pp. 563-81.

Vogt K. A., R. L. Edmonds, and C. C. Grier. 1981. Biomass and nutrient concentrations of sporocarps produced by mycorrhizal and decomposer fungi in *Abies amabilis* stands. Oecologia (Berlin) 50: 170-175.

Waring, R. H., and W. H. Schlesinger. 1985. Forest Ecosystems: Concepts and Management. Academic Press, New York. 340 pp.

Wasterlund, I., and T. Ingelog. 1981. Fruit body production of larger fungi in some young Swedish forests with special reference to logging waste. Forest Ecol. Manage. 3: 269-294.

Wierman, C.A., and C.D. Oliver. 1979. Crown stratification by species in even-aged mixed stands of Douglas-fir—western hemlock. Can. J. For. Res. 9:1-9.

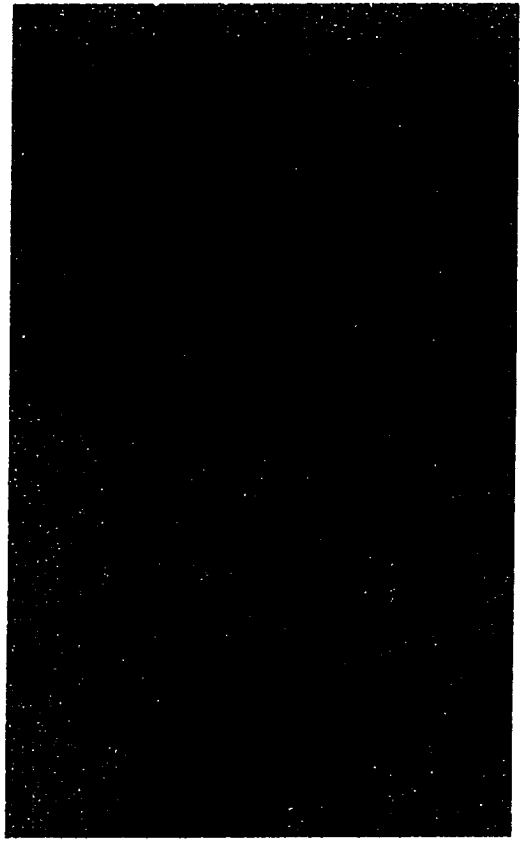
Wilkins, W. H., J. L. Harley, and G. C. Kent. 1938. The ecology of the larger fungi II. The distribution of larger fungi in part of Charlton Forest, Sussex. Ann. Appl. Biol. 25: 472-489.

Wilson, E.O. 1992. The Diversity of Life. The Belknap Press of Harvard University Press, Cambridge, Massachusetts. 424 pp.

Wilson, E. O. (Ed.) and F. M. Peter (Assoc. Ed.) 1988. Biodiversity. National Academy Press, Washington, DC. USA. 521 pp.

Zak, J.C. 1992. Response of Soil Fungal Communities to Disturbance. In: The Fungal Community. Its Organization and Role in the Ecosystem. 2nd edition, Carrol, G.C. and D.T. Wicklow (editors). Vol.9 of Mycology Series, edited by P.L. Lemke. Marcel Dekker, NY. pp 403-426.

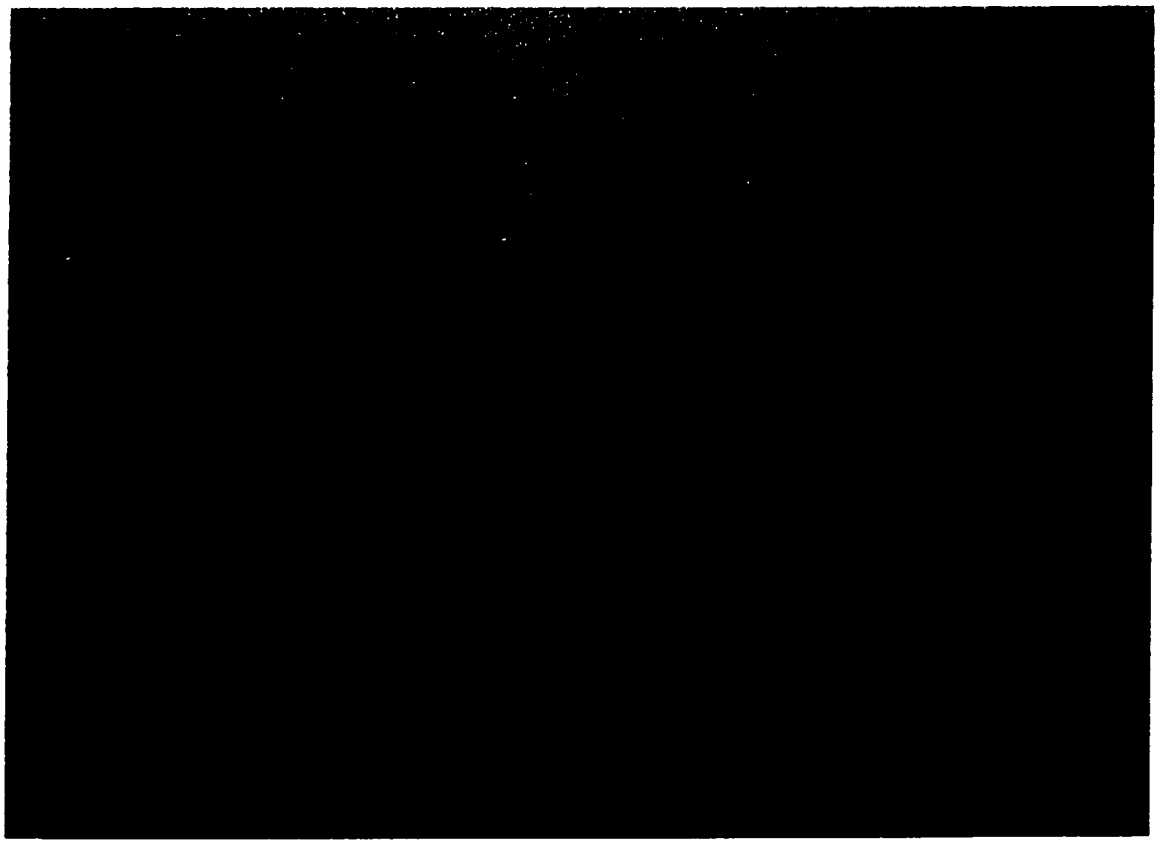
Colour Plates



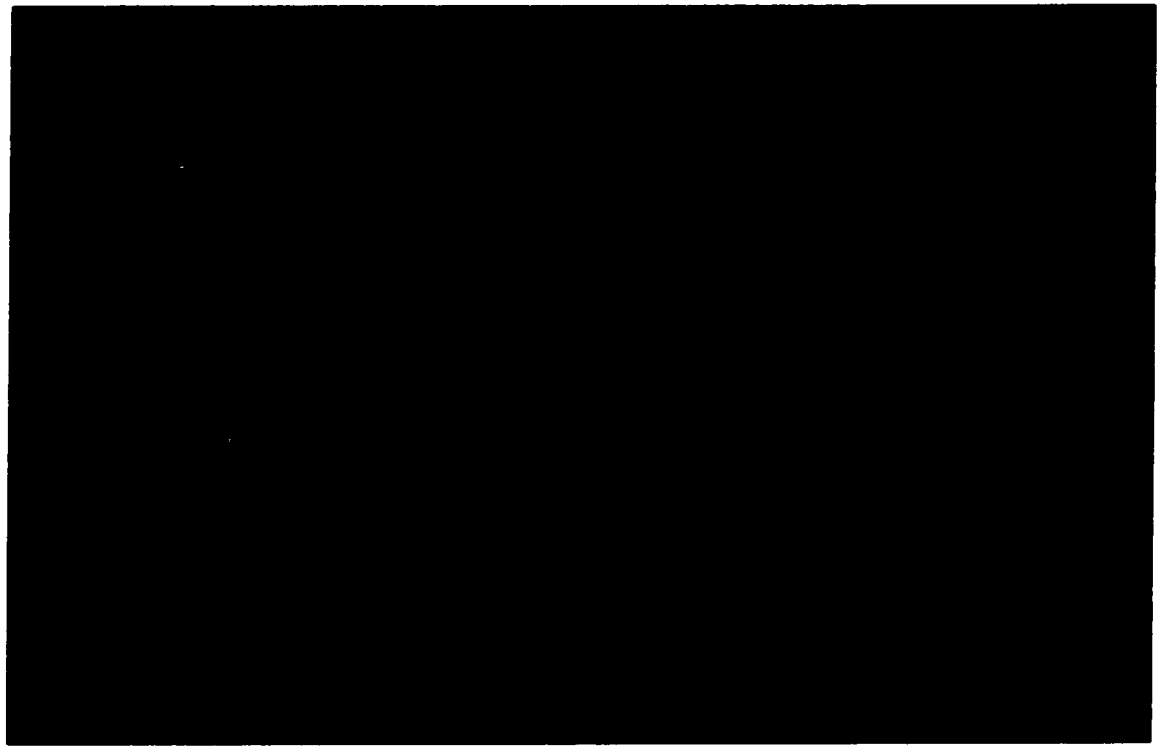
Colour Plate No 1. ***Mycena amicta***

Colour Plate No 2. ***Mycena tenax***

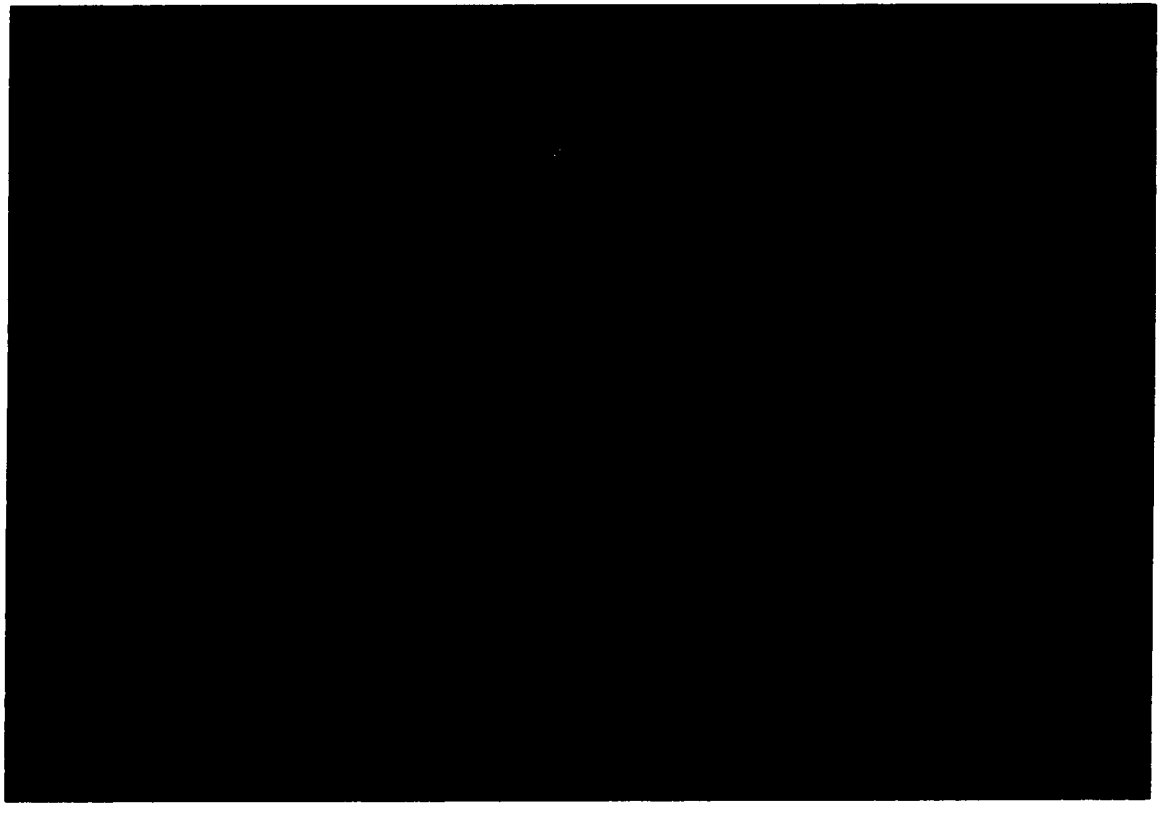
Colour Plate No 3. ***Mycena aurantiidisca***



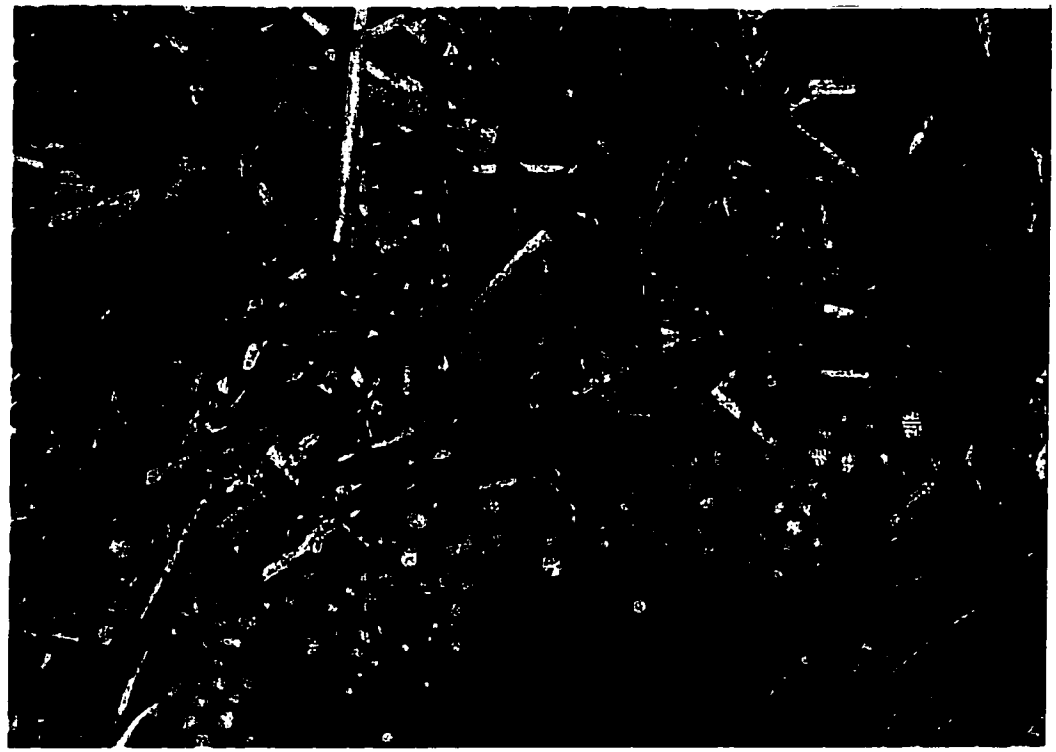
Colour Plate No 4. ***Mycena galopus***



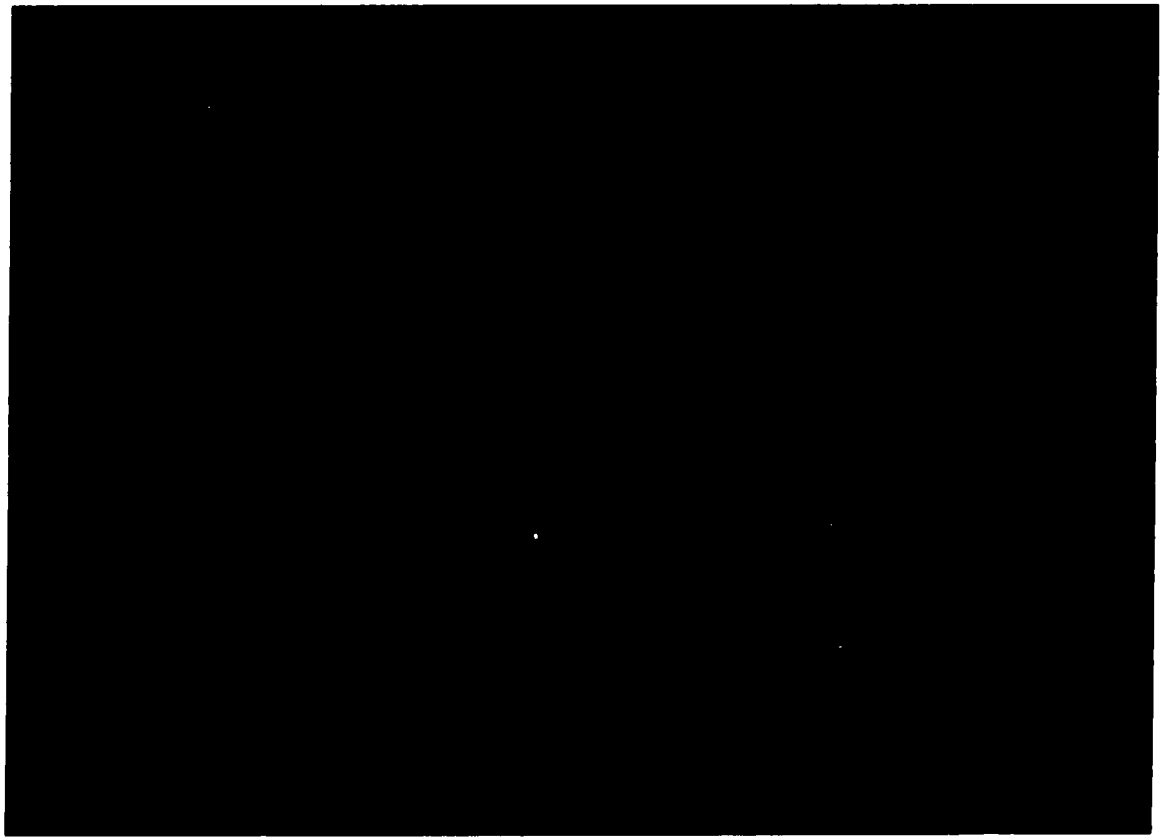
Colour Plate No 5. ***Mycena rosella***



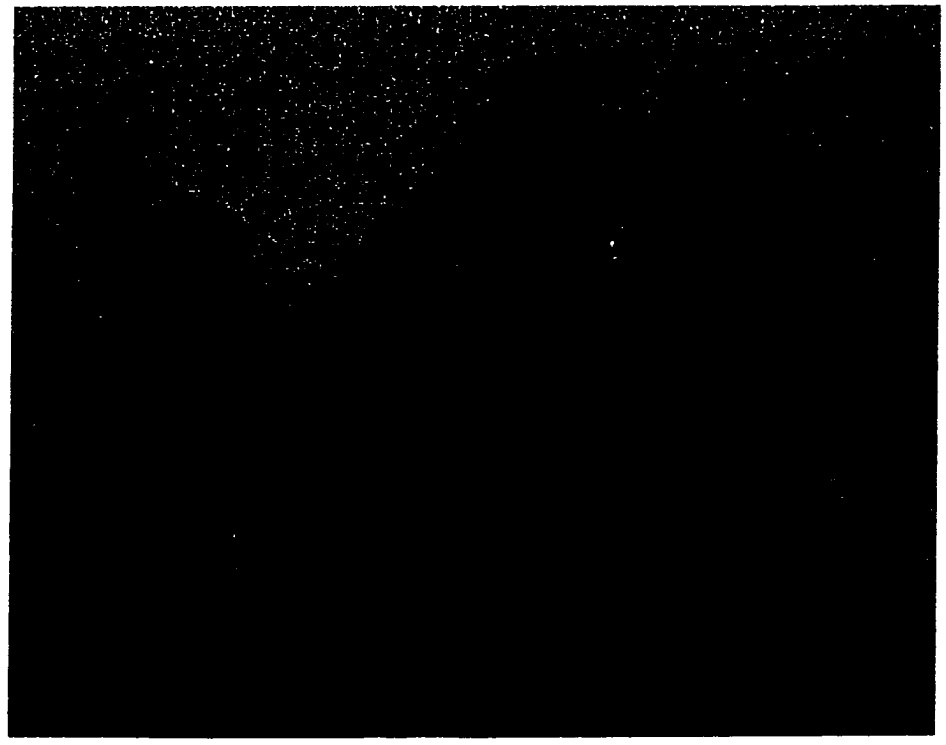
Colour Plate No 6. ***Mycena oregonensis***



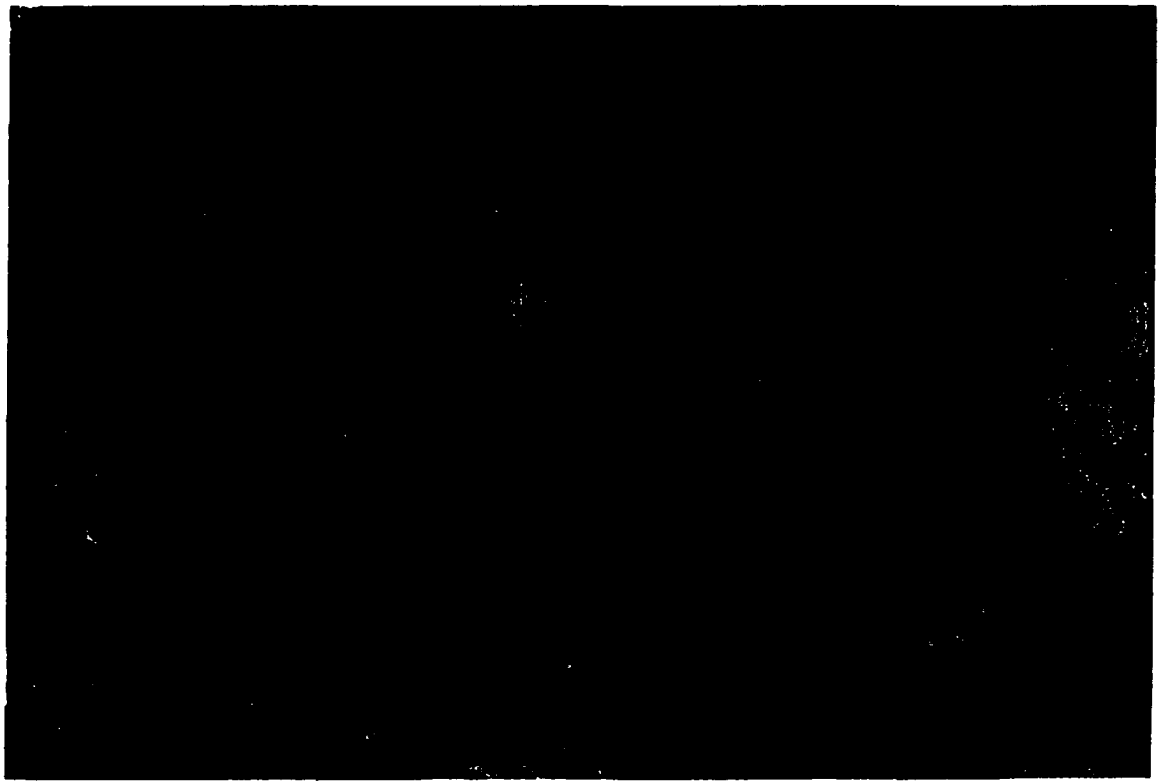
Colour Plate No 7. ***Podophacidium xanthomellum***



Colour Plate No 8. ***Galerina badipes***

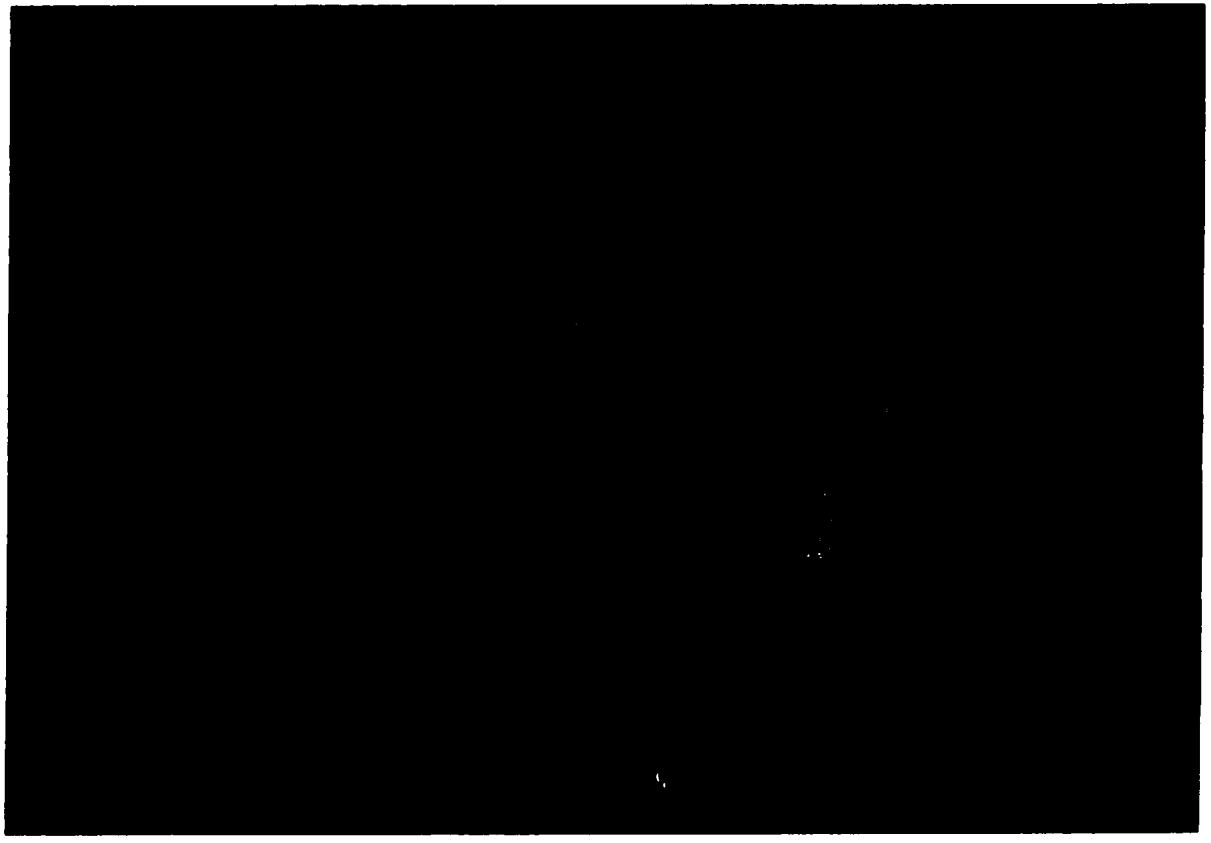


Colour Plate No 9. ***Galerina vitaeformis***



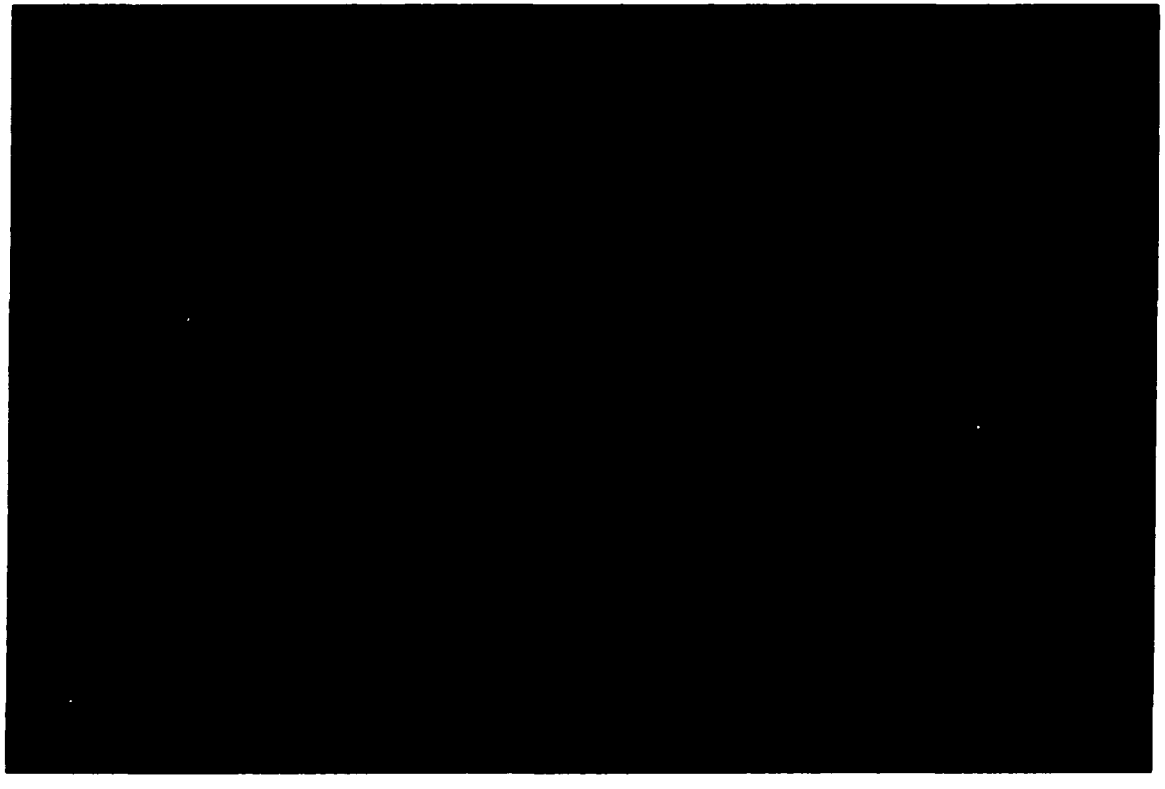
Colour Plate No 10. ***Cordyceps myrmecophila***

Colour Plate No 11. ***Clavulina cristata***

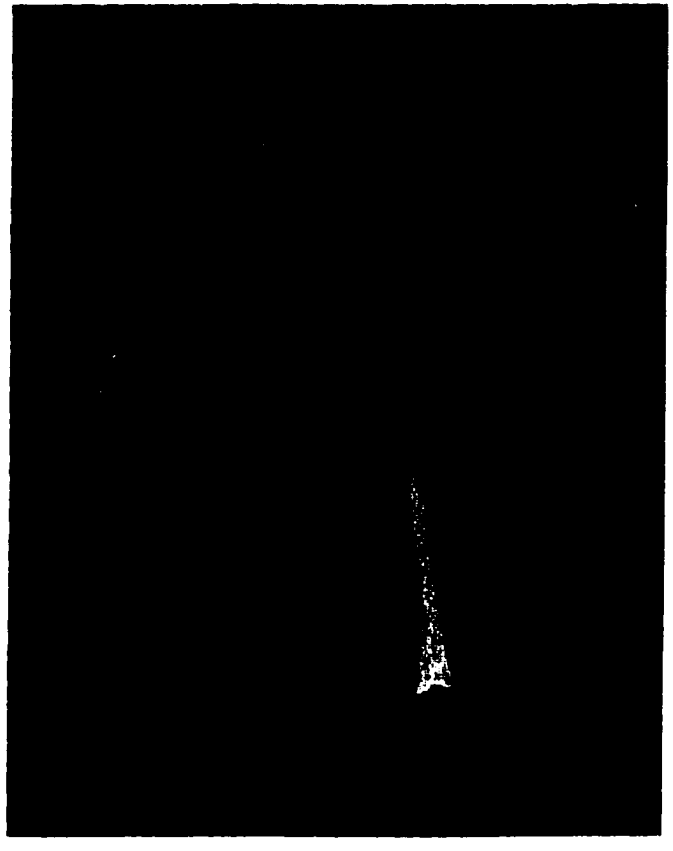


Colour Plate No 12. ***Cantharellus formosus***

Colour Plate No 13. ***Chroogomphus tomentosus***



Colour Plate No 14. ***Phaeocollybia phaeogaleroides***



Colour Plate No 15. ***Nolanea cetrata***

Appendix 1A.

Checklist of Macrofungus Characters. Macroscopic and Microscopic Features. After Kendrick (1992).

Habitat and Growth information

Locality:_____ Date:_____

Habitat notes: _____

Soil type: _____

Soil pH: _____

Vegetational community:

_____

Fruiting bodies growing:

Solitary_____ in troops_____ in rings_____ on ground_____

on wood _____ on living tree_____

other (describe) _____

Photograph, draw or preferably paint general view and vertical section of fruit-body.

Macroscopic Characters

Cap (Pileus): diameter: (range) _____-_____cm

Shape: convex _____ bell-shaped _____conical _____ umbonate _____ flat _____

depressed _____ umbilicate _____ funnel-shaped _____ cylindrical _____(when

young)_____ when mature _____

Colour: when immature _____ when mature _____

when wet _____ when dry_____

Surface: (circle one or more) dry * moist * greasy * viscid * glutinous * peeling easily * smooth * matt * polished * irregularly roughened * downy * zoned * velvety * scaly * splitting * shaggy * with volva fragments

Margin: (circle one or more) regular * wavy * upcurved * incurved * smooth * rough * furrowed * striate * split * shaggy * with veil fragments

Gills (or Tubes or Teeth): (circle as appropriate)

Remote * free * adnate * adnexed * sinuate * decurrent * crowded * distant * forked * anastomosing

Easily separable from the cap-tissue: Yes * No

Thick * thin

Consistency: brittle * pliable * fleshy * waxy

Colour: when immature _____ at maturity_____

Stipe: central * eccentric * absent * hollow * solid * stuffed * tapering upward * equal

Dimensions: length (range) ___-___ thickness ____-____

Colour: when immature _____ at maturity_____

Consistency: fleshy * stringy * brittle * leathery * cartilaginous * woody

Surface: fibrillose * dry * viscid * scaly * smooth

Characters of stipe base (e.g., swollen, rooting, etc.)

_____

Volva, if present: sheathing stem base * scurfy rings

Ring, if present: single * double * membranous * filamentous * persistent * fugacious * moveable * thick * thin * apical * median * hanging (skirt-like)

Flesh: colour: inside cap: when wet_____when dry_____

In stem: when wet_____when dry_____

Colour changes when exposed to air:_____

Milk-like latex: present * absent

Colour when extruded_____after exposure to air_____

Smell: before cutting_____after cutting_____

Microscopic characters

Basidiospores:

Colour: in mass (spore print)_____

under microscope_____

Shape: spherical * ovoid * elongate * angular * curved *

size _____-_____x_____-_____

Ornamentation: none * warty * rounded * pointed (spiny) * ridged * striate * net-like

Size and shape of germ-pore, if present_____

Iodine reaction of spore-mass: red-purple (dextrinoid) * blue-black to dark violet (amyloid) * yellow-brown or brown (non-amyloid)

Basidia: length/width ratio: less than 4:1 * more than 5:1

Number of sterigmata:_____

Cap Trama: types of cell present:_____

Gill-tissue (trama): type and arrangement of cells between adjacent hymenial faces (see Fig. 5.5 E-G): divergent * parallel * convergent * interwoven

Cap surface (pileipellis): cells of outer layer:

Filamentous * rounded

Sterile cells- - cystidia: present on:

Gill-face * gill-edge * cap * stipe

Shape:

Filiform * cylindrical * clavate * ventricose * branched

Size: ____-____x ____-____um

Thick-walled * thin-walled * hyaline * pigmented * other features_____

Appendix 2A.

Soil properties of each plot at the three sites. Based on Omule and Krumlik (1987).

Site	Plot	Soil classification		Soil class number
Fairy Lake	Ss 36	Fresh – Medium,	01 wm-sk	3
Fairy Lake	Ss 38	Fresh – Medium,	01 wm	3
Fairy Lake	Fd 18	Fresh – Medium,	01 wm	3
Fairy Lake	Fd 25	Fresh – Poor ,	01 ty	2
Fairy Lake	Hw 22	Fresh – Medium,	01 sk	3
Fairy Lake	Hw 24	Slightly dry – Poor	03 wm-sk	2
Fairy Lake	Cw 23	Slightly dry – Poor	03 wm-sk	2
Fairy Lake	Cw 32	Fresh – Medium,	01 wm-sk	3
Upper Klanawa	Ss 99	Moist – Rich,	07 ty	4
Upper Klanawa	Ss 102	Moist – Rich,	07 ty	4
Upper Klanawa	Fd 98	Moist – Rich,	07 ty	4
Upper Klanawa	Fd 101	Moist – Rich,	07 ty	4
Upper Klanawa	Hw 83	Moist – Rich,	07 ty	4
Upper Klanawa	Hw 95	Moist – Rich,	07 ty	4
Upper Klanawa	Cw 84	Moist – Rich,	07 ty	4
Upper Klanawa	Cw 100	Moist – Very Rich,	07 ty	6
Sarita Lake	Ss 111	Fresh – Medium	01 ty	3
Sarita Lake	Ss 119	Fresh – Medium	01 ty	3
Sarita Lake	Fd 126	Fresh – Medium	01 wm	3
Sarita Lake	Fd 127	Fresh – Medium	01 wm	3
Sarita Lake	Hw 117	Fresh – Medium	01 wm	3
Sarita Lake	Hw 121	Slightly dry – Medium	03 wm	2
Sarita Lake	Cw 116	Fresh – Medium	01 wm	3
Sarita Lake	Cw 123	Fresh – Medium	01 ty	3

Appendix 2B.

EP571 forest floor properities.
Based on data provided by Dr. Cindy Prescott, Uiversity of British Columbia. (also see Prescott et al., 2000). Nutrients in mg/g.

Plot	pH	N	P	K	Ca	Mg	t/ha
uk99	4.57	13.36	1.586	1.047	4.84	0.825	40.74
uk102	4.3	12.27	1.159	0.776	3.51	0.99	109.33
uk98	4.73	8.36	0.845	0.738	5.3	0.921	44
uk101	4.47	11.53	1.109	0.623	3.66	0.829	26.96
uk84	4.47	10.85	1.302	0.879	5.85	1.407	36
uk100	4.47	16.23	2.152	0.792	1.68	0.864	86.07
uk83	4.5	14.26	1.71	0.819	2.34	0.691	55.41
uk95	4	10.47	0.786	1.063	3.58	0.994	17.78
br119	4.93	8.93	0.875	2.063	9.21	2.091	47.51
br124	4.93	8.19	0.99	1.406	11.44	2.098	23.5
br126	4.67	7.28	0.815	1.075	6.11	4.114	16.46
br127	4.63	6.54	0.875	1.509	7.57	4.583	16.15
br116	5.1	5.09	0.468	0.805	12.75	1.605	42.07
br123	4.97	6.01	0.643	1.153	11.8	3.274	47.27
br117	4.77	5.2	0.807	1.431	7.6	4.242	46.67
br121	4.27	5.87	0.633	1.767	4.99	2.469	23.78
fl36	4.8	9.41	0.784	1.266	12.07	1.449	33.48
fl38	4.93	9.58	0.88	1.23	11.62	3.314	54.07
fl18	4.53	9.2	0.779	0.845	5.78	1.032	10.67
fl25	4.5	10.07	0.685	0.862	7.42	1.524	47.11
fl23	4.63	8.5	0.649	0.831	10.16	2.532	72.59
fl32	5.07	5.06	0.682	0.403	15.64	7.266	66.37
fl22	4.07	8.09	0.683	0.866	4.75	1.079	37.78
fl24	4.37	6.96	0.636	1.037	6.08	1.147	25.48

Appendix 3A.

Macrofungus species list with names of authorities.
Taxa of vague identification are accompanied by the collection number. Species marked with * occurred both years.

Species name	Authority
* *Amanita farinosa*	Schw.
* *Amanita vaginata*	(Bull. ex Fr.) Vitt.
Armilaria ostoyae	Romagn.
* *Ascocoryne sarcoides*	(Jacquin ex S.F. Gray) Groves & Wilson
Baeospora myosura	(Fr.:Fr.) Sing.
Boletus mirabilis	Murr.
Boletus piperatus	Bull. ex Fr.
Bondarzewia montana	(Quel.)Sing.
* *Callistosporium luteo-olivaceum*	(Bert & Curt.) Singer
Calocera cornea	(Batsch:Fr.) Fr.
* *Calocera viscosa*	(Pers.:Fr.) Fr.
* *Cantharellus formosus*	Corner
* *Cantharellus tubaeformis = Craterellus tubaeformis*	(L.:Fr.) Pers.
* *Chroogomphus tomentosus*	(Murr.) Miller
Chrysomphalina chrysophylla	(Fr.:Fr.) Clemencon
Clavaria atkinsoniana	Leather
Clavaria purpurea	Fr.
Clavaria sp. cf. *acuta*	Fr.
* *Clavaria vermicularis*	Fr.
* *Clavulina cinerea*	(Fr.) Schroet.
* *Clavulina cristata*	(Fr.) Schroet.
* Clavulina ornatipes	(Peck) Corner
* *Clavulina rugosa*	(Fr.) Schroet.
Clavulinopsis fusiliformis	(Fr.) Corner
Clavulinopsis laeticolor	(Berk. & Curt.) Petersen
Clavulinopsis subtilis	(Fr.) Corner
* *Clitocybe incomis*	
Clitocybe lignitalis group	(Pers.:Fr.) Karst.
Clitocybe sclerotoidea	(Morse) H.E. Bigelow
Clitocybe sp. affin. *pseudodicolor*	
Clitocybe sp., olive on wood, R.O. 431	
Clitocybe sp.affin. *ditopus*	(Fr. Ex Fr.) Gillet
Clitocybula abundans	(Peck.) Sing.
Collybia confluens	(Pers.:Fr.) Kumm.
* *Collybia dryophila*	(Bull.:Fr.) Kumm.

Collybia racemosa	(Pers.:Fr.) Quel.
* *Coltricia perennis*	(L.:Fr.) Murr.
* *Conocybe plicatella* group	(Peck) Kuhner
Conocybe sp. R.O. 335	
Conocybe sp. subgenus *piliferae*	
Conocybe sp.affin. *sulcatipes*	(Peck) Kuhner
* *Cordyceps militaris*	(L. ex St. Amans) Link
* *Cordyceps myrmecophila*	Ces.
* Cortinarius acutus *group*	(Pers.:Fr.) Fr.
Cortinarius alboviolaceus	(Pers. ex Fr.) Fr.
Cortinarius castaneus group	Fr.
Cortinarius cotoneus	Fr.
Cortinarius decipiens	Fr.
Cortinarius gentilis	(Fr.) Fr.
* *Cortinarius glaucopus*	(Schaeff. ex Fr.) Fr.
Cortinarius junhuhnii	(Fr.) Fr.
Cortinarius obtusus	Fr.
Cortinarius renidens	Fr.
Cortinarius scaurus group	Fr.
Cortinarius semisanguineus	(Fr.) Fr.
Cortinarius sp. affin. *azureus*	Fr.
* *Cortinarius* sp. sect. *Telemonia*	
Cortinarius traganus group	Fr.
Cortinarius vibratilis	Fr.
Cudonia circinans	(Pers.) Fr.
* *Cudonia grisea*	Mains
* *Cudonia monticola*	Mains
Cyptotrama chrysopeplum	(Berk. & curt.) Singer
*Cystoderma amianthinum (*var. *rugosoreticulatum)*	(Scop.:Fr.) Fay.
Dacrymyces chrysocomus	(Bull.:Fr.) Tul.
Dacrymyces stillatus	Nees.:Fr.
Dermocybe crocea = Cortinarius croceus	(Schaeff.)
Dermocybe idahoensis	
Dermocybe sp. R.O. 348	
Dermocybe sp. R.O. 349	
* *Entoloma cetratum*	(Fr.) Mos.
Entoloma cf. *lividoalbum*	(Kuhn. & Romagn.) Kubicka
* *Entoloma sinuatum*? (large, white)	(Bull. Ex Pers.:Fr.) Kumm.
Entoloma sp., scurfy stipe, R.O. 418	
Entoloma trachyospermum var. *purpureo-violaceum*	Largent
Entoloma verna (vernum ?)	Lundell
Flocculina granulosa	(Lange) Orton
Fomitopsis pinicola	(Schwartz ex Fr.) Karsten
* *Galerina atkinsoniana*	A.H. Smith

Galerina autumnalis	(Pk.) Smith & Singer
* *Galerina badipes*	(Fr.) Kuhner
Galerina calyptrata	P.D. Orton
Galerina cerina	A.H. Sm. & Singer ss. auct.
* *Galerina emmentensis*	Smith & Singer
* *Galerina mammilata*	(Murrill) Smith & Singer
Galerina philipsii	sp. nov.
Galerina pteridicola group	Smith sp. nov.
* *Galerina vitiformis*	(Fr.) Singer
Ganoderma oregonensis	Murr.
* *Ganoderma tsugae*	Murr.
* *Geoglossum* sp.affin. *umbratile*	Sacc.
Gomphidius glutinosus	(Schaeff.:Fr.) Fr.
Gomphidius smithii	Miller
* *Gomphidius subroseus*	Kauffman
* Guepiniopsis alpina	(Tracy & Earle) Bres.
* *Gymnopilus bellulus*	(Peck) Murrill
Gymnopilus saponeus	(Fr.:Fr) Maire
Gymnopilus terrestris	Hesler
* *Heideria abietis*	Fr. Link
* *Hemimycena albicolor*	
* *Hemimycena delectabilis*	(Peck) Singer
Hemimycena pseudocrispula	(Kuhn) Sing.
Hemimycena sp.	
* *Heterobasidion annosum*	(Fr.) Bref.
Hohenbouhelia sp.	
* *Hydnum repandum*	L.:Fr.
Hydropus marginellus	(Pers.:Fr.) Sing.
* *Hygrocybe cantharellus*	(Schw.) Murr.
Hygrocybe conica	(Scop.:Fr.) Kumm.
* *Hygrocybe laetus (laeta?)*	(Pers.:Fr.) Kumm.
* *Hygrocybe miniata*	(Berk. & Br.) Arnolds
Hygrocybe virginea	(Wulf.:Fr.) Ort. & Watl.
* *Hygrophoropsis aurantiaca*	(Wulf.:Fr.) Mre.
Hygrophoropsis olida	(Peck) Big.
Hygrophorus bakerensis	A.H. Smith & Hesler
Hygrophorus pratensis	(Pers.:Fr.) Kumm.
Hymenochaete sp. R.O.223	
Hypholoma capnoides	(Fr.:Fr.) Kumm.
Hypholoma dispersum	(Fr.) Quel.
* *Hypholoma fasciculare*	(Huds.:Fr.) Kumm.
* *Inocybe calamistrata*	(Fr.) Gillet
Inocybe cookei	Bres.
Inocybe eutheles	(Berk. & Br.) Quel.
* *Inocybe fastigiata*	(Shaeff. ex Fr.) Quel.
* *Inocybe geophila*	(Sow. ex Fr.) Kummer

Inocybe idahoensis	
* *Inocybe napipes*	Lange
Inocybe ovatocystis	Kuhner & Bours.
Inocybe sect. *Cortinata*, RO 67	
Inocybe sect. *inocybium*, RO 86	
* *Inocybe sororia*	Kauffman
* *Inocybe* sp. affin. *tigrina*	Heim
Inocybe sp., R.O. 186	
Kuehneromyces lignicola	(Peck) Jacobsson
* *Laccaria bicolor*	(Mre.) Ort.
Laccaria laccata	(Scop.:Fr.) Berk. & Br.
Lachnellula sp. c.f. *calyciformis*	(Willd. ex. Velen)
Lactarius alnicola	Smith
Lactarius deliciosus	(Fr.) S. F. Gray
Lactarius fallax	Smith & Hesler
* *Lactarius hepaticus*	Plowright
Lactarius kauffmanii	Smith & Hesler
Lactarius ligniotus var. *canadensis*	Smith & Hesler
Lactarius luculentus	Burl.
* *Lactarius luculentus* var. *laetus*	Smith & Hesler
Lactarius mucidus	Burl.
Lactarius mucidus var. *fuscogriseus*	Smith & Hesler
Lactarius olivaceo- umbrinus	Smith
Lactarius pallescens	Hesler & A. H. Smith
Lactarius pseudomucidus	Smith & Hesler
* *Lactarius rufus* group	(Scopp.:Fr.) Fr.
* *Lactarius scrobiculatus*	(Scopp.:Fr.) Fr.
Lactarius uvidus	(Fr.:Fr.) Fr.
* *Laetiporus sulphureus*	(Bull.:Fr.) Murr.
Leptonia albinella	Peck
* *Lycoperdon foetidum*	Bonord
* *Lycoperdon pyriforme*	Schaeff.:Pers.
* *Lycoprdon perlatum*	Pers.
Lyophyllum decastes	(Fr.:Fr.) Sing.
* *Lyophyllum semitale*	(Fr.) Kuhn.
Macrotyphula juncea group	(Fr.) Berthier
* *Marasmius* sp. cf. *wynnei*	Berk. & Broome
Marasmius sp., R.O. 442	
* *Micromphale foetidum*	(Sow.:Fr.) Sing.
* *Micromphale perforans*	(Hoffm.:Fr.) Sing.
Mycena abramsii	Murr.
Mycena acicula	(Schaeff.:Fr.) Kumm.
* *Mycena adonis*	Bull.:Fr.) Gray
* *Mycena alcalina*	(Fr.:Fr.) P. Kumm.
Mycena alnetorum	Favre
Mycena alnicola group	Smith

Mycena amabilissima	(Pk.) Saccardo
* *Mycena amicta*	(Fr.) Quel.
Mycena archangelina	Bres. Ap. Barsali
Mycena atroalboides	(Bolton.:Fr.) Grey
* *Mycena aurantiidisca*	Murrill
* *Mycena aurantiomarginata*	(Fr.) Quel.
Mycena citrinomarginata	Gillet
Mycena clavularis	(Bagsch. ex Fr.) Sacc. S. Kuhner non Lange.
* *Mycena elegantula*	Peck
* *Mycena epipterigia var. lignicola*	(Scop.:Fr.) Gray A.H. smith (var.)
* *Mycena filopes*	(Bull.:Fr.) Kumm.
Mycena flavoalba	(Fr.) Quel.
Mycena fusco-occula	Smith
Mycena galericulata	(Scop.:Fr.) Gray
* *Mycena galopus*	(Pers.:Fr.) Kumm.
* *Mycena haematopus*	(Pers.:Fr.) Kumm.
Mycena latifolia	(Peck) A.H. Smith
Mycena leptocephala	(Pers.:Fr.) Kumm.
Mycena longesita	Hohn
Mycena maculata	Cleland [& P. Karst.]
* *Mycena metata* group	(Fr.) Kumm.
* *Mycena metata* group, strigose	(Fr.) Kumm.
Mycena mirata group	(Peck) Sacc.
* *Mycena murina*	Murill
* *Mycena olivaceo-brunnacea*	Gillet
Mycena oregonensis	Smith
Mycena psuedoinclinata	(Fr.) Quel.
* *Mycena pura*	(Pers.:Fr.) Kumm.
* *Mycena purpureo-fusca*	(Peck) Sacc.
* *Mycena rorida*	(Scop.:Fr.) Quel.
* *Mycena rosella*	(Fr.) Kumm.
Mycena rubromarginata	(Fr.:Fr.) Kumm.
* *Mycena sanguinolenta*	(Alb. & Schw.:Fr.) Kumm.
Mycena sp. sect. *Typicae*	
Mycena strobilinoides	Pk.
* *Mycena subcana*	Smith
* *Mycena tenax*	Smith
Mycena tenerrima	(Berk.) Quel.
Mycena vulgaris	(Pers.: Fr.) P.Karst
Naucoria sp. affin. *pseudoamarescens*	(Kuhner & Romagn.) Kuhner & Romagn
* *Neournulla pouchetti*	
* *Nolanea holoconiota*	Largent & Thiers
Nolanea proxima	Largent
Nolanea sp., R.O. 122	
Nolanea sp., R.O. 68	
Nolanea sp. sect. *endochromonema*	

Nolanea sp. sect. *pseudonolanea*	
Nolanea staurospora	Bres.
* *Omphalina ericetorum*	(Fr.) Lange
Omphalina luteicolor	Murrill
Otidea kauffmanii	Kanouse
* *Panellus longuinquus*	(Berk) singer subsp. Pacificus S.D. Libonati-Barnes & Redhead
Phaeocollybia phaeogaleroides	Norvell
Phaeolus schweinitzii	(Fr.) Pat.
Phellodon atratus	Harrison
Phellodon niger	(Fr.:Fr.) Karst.
* *Pholiota astragalina*	(Fr.) Sing.
Pholiota decorata	(Murr.) Smith & Hesler
Pholiota flavida	(Fr.) Singer
Pholiota scamba	(Fr.:Fr.) Mos.
Pholiota terrestris	Overholts
* *Phylloporus rhodoxanthus*	(Schw.) Bres.
* *Plectania melastoma*	(Sowerby ex.Fr.) Fuckel
* *Pleurocybella porrigens*	(Pers.:Fr.) Sing.
* *Pluteus cervinus*	(Schaeff.) Kumm.
Pluteus sp., R.O. 326	
* *Podophascidium xanthomellum*	(Pers.) Kavina
* *Podostroma alutaceum*	(Pers. ex Fr.) Atk.
* *Polyporus badius*	(Pers. ex S.F. Gray) schw.
* *Polyporus elegans*	Fr.
Psathyrella hirta group	Peck
Psathyrella sp., R.O. 220	
* *Pseudoarmillariella ectypoides*	
* *Pseudohydnum gelatinosum*	(Scop.:Fr.) Karst.
* *Pseudoplectania nigrella*	(Pers. ex Fr.) Fuckel
Psilocybe pelliculosa	(Smith) Sing. & Smith
Ramaria flavobrunescens var. *aromatica*	(Akt.) Corner
Ramaria sp., R.O. 191	
Ramariopsis sp., R.O. 229	
Resinomycena saccharifera	
* *Ricknella fibula*	(Bull.:Fr.) Raith.
Russula adusta	Fr.
Russula albonigra group	(Krombh.) Fr.
Russula arenicola	
Russula atropurpurrea group	(Krombh.) Britz. non Pk.
Russula bicolor	Burlingham
Russula brevipes	Pk.
* *Russula crassotunicata*	Singer
Russula cremicolor	
Russula cyanoxantha	(Schw.) Fr.
Russula farinipes	Romell

* *Russula fragilis*	(Pers. ex Fr.) Fr.
Russula nigricans	Fr.
Russula occidentalis	Singer
* *Strobilurus trullisatus*	(Murr.) Lennox
Suillus brevipes	(Pk.) Kuntze
Suillus punctatipes	(Pk.) singer
Trametes hirsutum (*hirsuta*?)	(Wulf.:Fr.) Pil.
Trametes versicolor	(Fr.) Pil.
Tremella sp.	
Tricholoma imbricatum	(Fr.:Fr.) Kumm.
Tricholoma pessundatum	(Fr.) Quel.
Tricholoma sp. affin. *apium*	J. Shaff.
Tricholoma sp., R.O. 118	
Tricholomopsis rutilans	(Shaeff.:Fr.) sing.
Tyromyces caesius	(Schrad. ex Fr.) Murrill
Tyromyces chioneus	(Fr.) Karst.
Tyromyces subceasium	David
* *Vibrissea truncorum*	Fr.
* *Xeromphalina campanella*	(Bat. ex. Fr.) Kuhner &Maire
* *Xeromphalina fulvipes*	(Murr.) Smith
* *Xylaria hypoxylon*	(L. ex Hooker) Grev.

Appendix 3B.

List of macrofungus species collected as voucher specimens.
Presently held at B.C. Ministry of Forest Research Station at North Rd., Victoria, B.C., ultimately to be deposited in the Pacific Forestry Herbarium, Natural Resources Canada,Victoria, B.C.

Accession number	Identification	Collection Date	Location
R.O. 9	*Xeromphalina fulvipes*	5/05/97	FL,Hw24,s12
R.O. 10	*Cortinarius* sp.	5/05/97	FL,Hw22,s15
R.O. 11	*Cordyceps myrmecophila*	5/05/97	FL,Cw23,s2
R.O. 12	*Mycena rorida*	5/05/97	FL,Hw24,s2
R.O. 13	*Polyporus elegans*	5/05/97	FL,Hw22,s5,s13
R.O. 14	*Vibrissea truncorum*	5/05/97	FL,Cw32,s16
R.O. 15	*Clavulina rugosa*	5/05/97	FL,Ss38,s2
R.O. 16	*Polyporus elegans*	5/05/97	FL,Cw23,s5
R.O. 17	*Micromphale perforans*	5/05/97	FL,Fd18,s14
R.O. 18	*Micromphale perforans*	5/05/97	FL,Hw22,s11
R.O. 19	*Polyporus elegans*	5/05/97	FL,Hw24,s2
R.O. 20	*Marasmius* sp.	5/05/97	FL,Fd25,s15
R.O. 21	*Mycena alnicola* group	5/05/97	FL,Fd18,s6
R.O. 22	*Mycena alnicola* group	5/05/97	FL,Fd18,s11
R.O. 23	*Mycena alcalina*	5/05/97	FL,Fd25,s1
R.O. 24	*Xeromphalina campanella*	12/05/97	UK,Cw100,s4,s6
R.O. 25	*Cortinarius cotoneus*	12/05/97	UK,Hw83,s8
R.O. 26	*Entoloma* sp.	12/05/97	UK,Cw100,s6
R.O. 27	*Lactarius hepaticus*	12/05/97	UK,Fd101,s4
R.O. 28	*Polyporus elegans*	12/05/97	UK,Cw83,s16
R.O. 29	*Cortinarius scaurus* group	5/05/97	FL,Ss38,s13
R.O. 30	*Tremella* sp.	5/05/97	FL,Fd25,s14
R.O. 31	*Nolanea holoconiota*	13/05/97	Br167,Hw121,s2
R.O. 32	*Omphalina ericetorum*	13/05/97	Br167,Cw116,s16
R.O. 33	*Nolanea holoconiota*	13/05/97	Br167,Fd126,1
R.O. 34	*Omphalina ericetorum*	12/05/97	UK,Fd98,s4
R.O. 35	*Mycena amicta*	13/05/97	Br167,Cw123,s7
R.O. 36	*Coltricia perennis*	13/05/97	Br167,Hw121,s12
R.O. 37	*Mycena sanguinolenta*	12/05/97	UK,Hw83,s7
R.O. 38	*Polyporus elegans*	12/05/97	UK,Cw84,s16
R.O. 39	*Plectania melastoma*	13/05/97	Br167,Cw123,s4
R.O. 40	*Neournula pouchetti*	13/05/97	Br167,Ss119,s2
R.O. 41	*Pseudoplectania nigrella*	12/05/97	UK,Fd101,s5
R.O. 42	*Mycena alnicola* group	12/05/97	UK,Fd98,s4
R.O. 43	*Nidula candida*	12/05/97	UK,Ss99,s3

R.O. 44	*Inocybe napipes* group	24/05/97	
R.O. 45	*Inocybe napipes* group	24/05/97	Br167,Fd127,s12
R.O. 46	*Clitocybe* sp.	?	?
R.O. 47	*Collybia dryophila*	24/05/97	Br167,Cw116,s5
R.O. 48	*Clitocybe costata*		
R.O. 49	*Cudonia grisea*?	26/05/97	FL,Ss36,s1
R.O. 50	*Cordyceps myrmecophila*	26/05/97	FL,Cw,s14
R.O. 51	*Phyloporus rhodoxanthus*	26/05/97	FL,Cw23,s5
R.O. 52	*Clitocybe* sp.	24/05/97	Br167,Fd127,s6
R.O. 53	*Cortinarius* sp., subg. *Seriocybe*?	24/05/97	Br167,Ss119
R.O. 54	*Dacrymyces chrysocomus*	24/05/97	Br167,Fd127,s1
R.O. 55	*Heterobasidion annosum*	24/05/97	FL,Fd25,s10
R.O. 56	*Elaphomyces granulosus* group	24/05/97	UK,Hw83,s4
R.O. 57	*Elaphomyces muricatus* group	24/05/97	UK,Ss102,s5
R.O. 58	*Kuehneromyces mutabilis*	24/05/97	?
R.O. 59	*Kuehneromyces lignicola*	24/05/97	?
R.O. 60	*Mycena acicula*	9/06/97	FL,Cw32,s6
R.O. 61	*Psathyrella hirta* group	9/06/97	FL,Fd25,s16
R.O. 62	*Collybia dryophila*	9/06/97	FL,Fd18,s13
R.O. 63	*Collybia dryophila*	9/06/97	FL,Fd18,s13
R.O. 64	*Coltricia perennis*?	9/06/97	FL,Fd18,s1
R.O. 65	*Kuehneromyces lignicola*	9/06/97	FL,Fd18,s12
R.O. 66	*Flocculina granulosa*	9/06/97	FL,Cw32,s6
R.O. 67	*Inocybe* sp. sect. *Cortinatae*	12/06/97	UK,Fd101,s9
R.O. 68	*Nolanea* sp.	12/06/97	FL,Cw84
R.O. 69	*Kuehneromyces lignicola*	12/06/97	UK,Cw100,s13
R.O. 70	*Mycena pura*	12/06/97	UK,Ss102
R.O. 71	*Inocybe* sp. sect. *Cortinatae*	12/06/97	UK,Fd101,s12
R.O. 72	*Inocybe* sp.	12/06/97	UK,Hw83,s10
R.O. 73	*Nolanea* sp.	12/06/97	UK,Ss99,s12
R.O. 74	*Mycena aurantiidisca*	12/06/97	UK,Ss102,s6
R.O. 75	*Plectania melastoma*	13/06/97	Br167,Ss111,s11
R.O. 76	*Inocybe* sp.	13/06/97	Br167,Hw117,s3
R.O. 77	*Clitocybe* sp.	13/06/97	Br167,Fd126,s1
R.O. 78	*Hygrophorus pratensis* group	13/06/97	Br167,Fd127,s14
R.O. 79	*Lyophyllum* sp.	13/06/97	Br167,Hw117,s16
R.O. 80a	*Hygrocybe cantharellus*	13/06/97	Br167,Hw116,s3
R.O. 80b	*Mycena olivaceobrunnea*	13/06/97	FL,Cw116,s8
R.O. 81	???	13/06/97	Br167,Hw121,s16
R.O. 82	???	9/06/97	FL,Ss38,s12
R.O. 83	*Entoloma nidorosum*?	21/07/97	
R.O. 84	*Collybia dryophila*	21/07/97	UK,Cw84,s8
R.O. 85	*Clitocybe lignitalis*?	21/07/97	UK,Cw84,s9
R.O. 86	*Inocybe* sp.sect. *Inocybium*	21/07/97	UK,Fd101,s13
R.O. 87	*Russula fragilis*	21/07/97	UK,Hw83,s15
R.O. 88	*Clavulina cristata*	21/07/97	UK,Fd101,s4

R.O. 89	*Marasmius* sp.	21/07/97	UK,Ss102,s4
R.O. 90	*Ricknella fibula*	21/07/97	UK, Fd101,s8
R.O. 91	*Kuehneromyces lignicola*	21/07/97	UK,Fd98,s12
R.O. 92	*Cordyceps militaris*	21/07/97	UK,Cw100,s7
R.O. 93	*Clavulina cristata*	22/07/97	Br167,Fd126,s2
R.O. 94	*Mycena metata* group	22/07/97	Br167,Fd126,s2
R.O. 95	*Hygrocybe laeta*	22/07/97	Br167,Cw116,s1
R.O. 96	*Amanita farinosa*	22/07/97	Br167,Ss111,s3
R.O. 97	*Trametes hirsutum*	22/07/97	Br167,Hw121,s15
R.O. 98	*Inocybe* sp. sect. *Inocybae*	22/07/97	Br167,Fd127,s2
R.O. 99	*Xeromphalina fulvipes*	22/07/97	Br167, Hw117,s3
R.O. 100	*Mycena metata* group	22/07/97	Br167,Hw121,s1
R.O. 101	*Cudonia circinans*	22/07/97	Br167,Fd126,s14
R.O. 102	*Xeromphalina fulvipes*	22/07/97	Br167,Fd18,s7
R.O. 103	*Russula fragilis*	22/07/97	Br167,Hw121,s13
R.O. 104	*Cortinarius* sp.	22/07/97	Br167,Ss111,s4
R.O. 105	*Hygrocybe laeta*	22/07/97	Br167, Hw116,s7
R.O. 106	*Clavaria purpurea*	22/07/97	Br167,Ss111,s11
R.O. 107	*Clitocybula abundan*?	21/07/97	UK,Fd98,s10
R.O. 108	*Inocybe fastigiata*	21/07/97	UK,Fd101,s14
R.O. 109	*Phaeocollybia phaeogaleroides*	21/07/97	UK,Fd98,s8
R.O. 110	*Psathyrella* sp.	21/07/97	UK,Cw84,s12
R.O. 111	*Marasmius* sp.or *Collybia* sp.	25/07/97	FL,Ss36,s4
R.O. 112	*Lycoperdon foetidum*	25/07/97	FL,Ss38,s12
R.O. 113	*Mycena rorida*	25/07/97	FL,Cw32,s5
R.O. 114	*Omphalina ericetorum*	25/07/97	FL,Ss38,s13
R.O. 115	*Conocybe* subg. *Piliferae*	25/07/97	FL,Ss38,s14
R.O. 116	*Kuehneromyces lignicola*	25/07/97	FL,Cw23,s8
R.O. 117	*Mycena filopes*	25/07/97	FL,Ss36,s3
R.O. 118	*Tricholoma* sp.	25/07/97	FL,Fd18,s13
R.O. 119	*Collybia confluens*	25/07/97	FL,Fd25,s8
R.O. 120	*Hydnum repandum*	25/07/97	FL,Hw22,s8
R.O. 121	*Galerina pteridicola* group	25/07/97	FL,Cw32,s3
R.O. 122	*Nolanea* sp.	25/07/97	FL,Cw32,7
R.O. 123	*Galerina badipes*	25/07/97	FL,Cw32,s9
R.O. 124	*Lactarius hepaticus*	25/07/97	FL,Cw36,s10
R.O. 125	*Kuehneromyces lignicola*	25/07/97	FL,Hw24
R.O. 126	*Galerina badipes*	25/07/97	FL,Cw32,s14
R.O. 127	*Fomitopsis pinicola*	26/05/97	FL,Cw23,s6
R.O. 128	*Amanita vaginata*	26/08/97	UK,Hw83,s6
R.O. 129	*Russula albonigra* group	28/8/97	FL,Ss38,s5
R.O. 130	*Mycena filopes*?	26/8/97	UK,Df101,s2
R.O. 131	*Inocybe fastigiata*	28/8/97	FL,Ss36,s15
R.O. 132	*Cantharellus ignicolor*?	27/8/97	Br167,Df126,s5
R.O. 133	*Inocybe fastigiata*?	26/8/97	UK,Ss102,s13
R.O. 134	*Mycena filopes*?	28/8/97	FL,Ss36,s3

R.O. 135	*Clavulinopsis vermiculata*?	26/8/97	UK,Df98,s11
R.O. 136	???	27/8/97	Br167,Df126,s5
R.O. 137	*Nidula candida*	26/8/97	UK,Cw100,s12
R.O. 138	*Tyromyces chioneus*?	26/8/97	UK,Hw83,s15
R.O. 139	*Pseudoarmillaria ectypoides*	26/8/97	UK,Hw83,s1
R.O. 140	*Mycena* sp.	27/8/97	Br167,Cw116,s4
R.O. 141	*Mycena* sp.	26/8/97	UK,Ss102,s9
R.O. 142	*Pleurocybella porrigens*	26/8/98	UK,Cw100,s13
R.O. 143	*Nolanea cetrata*?	26/8/97	UK,Df101,s15
R.O. 144	*Mycena* sp.?	28/8/97	Br167,Cw123,s16
R.O. 145	*Mycena filopes*?	28/8/97	FL,Hw22,s15
R.O. 146	*Mycena purpureofusca*	26/8/97	UK,Df101,s2
R.O. 147	*Pseudoarmillaria ectypoides*	27/8/97	Br167,Cw123,s5
R.O. 148	*Hygrophorus laetus*	27/8/97	Br167,Cw123,s8
R.O. 149	*Chroogomphus tomentosus*	28/8/97	FL,Hw22,s3
R.O. 150	*Nolanea staurospora*	26/8/97	UK,Cw84,s3
R.O. 151	*Clavulina cristata*	26/8/97	UK,Df101,s1
R.O. 152	*Oligoporus caesius*	28/8/97	FL,Df18,s12
R.O. 153	*Gymnopilus bellulus*?	28/8/97	FL,Df25,s9
R.O. 154	*Mycena alnetorum*?	28/8/97	FL,Df25,s1
R.O. 155	*Mycena* sp.	28/8/97	FL,Df25,s15
R.O. 156	*Mycena* sp.	28/8/97	FL,Cw23,s13
R.O. 157	*Cordyceps militaris*	28/8/97	FL,Df25,s10
R.O. 158	*Conocybe plicatella*?	28/8/97	FL,Ss38,s11
R.O. 159	*Nolanea* sp.	28/8/97	FL,Cw32,s11
R.O. 160	*Micromphale perforans*	26/8/97	UK,Hw95,s9
R.O. 161	*Micromphale perforans*	26/8/97	UK,Hw95,s7
R.O. 162	*Calocera viscosa*	26/8/97	UK,Hw83,s9
R.O. 163	*Hygrophorus laetus*	27/8/97	Br167,Cw116,s14
R.O. 164	*Nolanea* sp.	12/5/97?	UK,Cw100,s9
165 - 178		Specimens	missing
R.O. 179	*Gymnopilus bellulus*	24/9/97	FL,Ss36,
R.O. 180	*Nolanea* sp.	24/9/97	FL,Df25,s13
R.O. 181	*Mycena tenax*	28/9/97	UK,Ss99,s6
R.O. 182	*Lactarius ligniotus* var.*canadensis*	28/9/97	UK,Hw83,s9
R.O.183 a.	*Nolanea holoconiota*?	28/9/97	UK,Cw84,s8
R.O.183b.	*Nolanea* sp.	28/9/97	UK,Hw83,s4
R.O. 184	*Calocera viscosa*	28/9/97	FL,Fd125,s10
R.O. 185	*Mycena galopus*	28/9/97	UK,Cw100,s2
R.O. 186	*Inocybe* sp.	28/9/97	UK,Fd101,s14
R.O. 187	*Galerina* sp.	28/9/97	UK,Fd101,s14
R.O. 188	*Macrotyphula filiformis*?	28/9/97	UK,Fd125,s2
R.O. 189	*Galerina badipes*	28/9/97	UK,Cw100,s11
R.O. 190	*Lactarius rufulus*	29/9/97	UK,Fd101,s3
R.O. 191	*Ramaria* sp.	28/9/97	UK,Cw83,s6
R.O. 192	*Mycena metata* group	28/9/97	UK,Ss102,s5

R.O. 193	*Clavulina ornatipes*	28/9/97	UK,Fd101,s14
R.O. 194	*Hydropus marginellus*?	28/9/97	UK,Ss99,s3
R.O. 195	*Lactarius scrobiculatus* var.*can.*	15/10/97	FL,Hw22,s2
R.O. 196	*Lyophylum* sp.	15/10/97	FL,Hw22,s2
R.O. 197	*Russula farinipes*?	15/10/97	
R.O. 198	*Callistosporium luteo-olivaceum*	15/10/97	FL,Ss38,s11
R.O. 199	*Pholiota astragalina*	15/10/97	FL,Fd25,s10
R.O. 200	*Mycena subcana*	15/10/97	FL,Cw23,
R.O. 201	*Hygrocybae laeta*	15/10/97	FL,Cw23,
R.O. 202	*Lactarius pallescens*	15/10/97	FL,Ss38
R.O. 203	*Lactarius pseudomucidus*	15/10/97	FL,Cw23,s19
R.O. 204	*Mycena rubromarginata*	15/10/97	FL,Fd18,s4
R.O. 205	*Panellus longuinquus*	15/10/97	FL,Ss38,s11
R.O. 206	*Inocybe calamistrata*	15/10/97	FL,Fd25,s4
R.O. 207	*Mycena galopus*	15/10/97	FL,Cw32,s11
R.O. 208	*Clavulinopsis fusiliformis*	15/10/97	FL,Cw23,s1
R.O. 209	*Ramaria* sp.	15/10/97	FL,Ss36
R.O. 210	*Mycena metata* group	15/10/97	FL,various
R.O. 211	*Lactarius mucidus* var.*fuscogriseus*	15/10/97	FL,Cw23,s11
R.O. 212	*Dermocybe Idahoensis*?	15/10/97	FL,Fd25,s11
R.O. 213	*Gymnopilus bellulus*?	15/10/97	FL,Cw32,s13
R.O. 214	*Mycena amabilissima*	15/10/97	FL,Fd25,s9
R.O. 215	*Tricholoma pessundatum s.l.*	15/10/97	FL,Hw24,s1
R.O. 216	*Lyophylum semitale*	15/10/97	FL,Ss38,s13
R.O. 217	*Hygrocybe miniata cf.*	15/10/97	FL,Cw23,s13
R.O. 218	*Mycena filopes*	15/10/97	FL,Fd18,s12
R.O. 219	*Mycena* sp. *(tenerimae)*	15/10/97	FL,Hw24,s2
R.O. 220	*Psathyrella* sp.	15/10/97	FL,Fd25,s9
R.O. 221	*Lactarius mucidus* var.*fuscogriseus*	15/10/97	FL,Hw22,s8
R.O. 222	*Galerina* sp.section *Calyptrata*	15/10/97	FL,Cw32,s1
R.O. 223	*Hymenochaete* sp.	15/10/97	FL,Cw32,s12
R.O. 224	*Mycena epipterigia*	15/10/97	FL,Ss36,s3
R.O. 225	*Mycena pura*	15/10/97	FL,Cw32,s11
R.O. 226	*Mycena rubromarginata*	15/10/97	FL,Fd18,s12
R.O. 227	*Hygrocybae miniata*	15/10/97	FL,Cw23,s13
R.O. 228	*Nolanea* sp. section *Endochromonema*	15/10/97	FL,Fd25,s4
R.O. 229	*Ramariopsis sp*?	15/10/97	FL, Cw23,s13
R.O. 230	*Laccaria bicolor*	15/10/97	FL,Ss36,s13
R.O. 231	*Macrotyphula juncea*	15/10/97	FL,Fd25,s14
R.O. 232	*Cortinarius* sp.	15/10/97	FL,Hw24,s12
R.O. 233	*Lycoperdon foetidum*	15/10/97	FL,Ss36,s13
R.O. 234	*Pholiota flavida*?	15/10/97	FL,Fd18,s6
R.O. 235	*Clitocybe* sp. *(affin.pseudodicolor ?)*	15/10/97	FL,Fd18,s4
R.O. 236	*Cortinarius vibratilis*	15/10/97	FL,Hw22,s2
R.O. 237	*Panellus longuinquus*	15/10/97	FL,Cw32,s13
R.O. 238	*Galerina* sp.section *Calyptrata*	15/10/97	FL,Cw32,s16

R.O. 239	*Cortinarius gentilis*	15/10/97	FL,Fd25,s3
R.O. 240	*Galerina* sp.section *Calyptrata*	15/10/97	FL,Cw32,s16
R.O. 241	*Hemimycena cf.albissima*	15/10/97	FL,Hw24,s2
R.O. 242	*Lactarius palescens*	15/10/97	FL,Ss38,s4
R.O. 243	*Mycena metata* group	15/10/97	FL,Cw23,s11
R.O. 244	*Mycena tenax*	15/10/97	FL,Ss36,s2
R.O. 245	*Galerina cerina* ?	15/10/97	FL,Hw24,s3
R.O. 246	*Russula fragilis*	15/10/97	FL,Hw22,s1
R.O. 247	*Galerina* sp.	15/10/97	FL,Cw32,s2
R.O. 248	*Mycena galericulata*	15/10/97	FL,Ss38,s12
R.O. 249	*Mycena metata* group	15/10/97	FL,Ss38,s9
R.O. 250	*Lactarius* sp.*cf.carbonicola*	15/10/97	FL,SS36,s7
R.O. 251	*Podophascidium xanthomellum*	15/10/97	FL,SS36,s11
R.O. 252	*Galerina vitaeformis*	15/10/97	FL,Fd25,s4
R.O. 253	*Collybia cf. Confluens*	15/10/97	FL,Fd25,s8
R.O. 254	*Podostroma alutaceum*	15/10/97	FL,Ss36,outside
R.O. 255	*Russula* sp.	15/10/97	FL,Fd25,s10
R.O. 256	*Mycena alcalina ss Smith s.l.*	15/10/97	FL,Fd25,s8
R.O. 257	*Inocybe* sp.	15/10/97	FL,Fd18,s4
R.O. 258	*Cortinarius acutus*	15/10/97	FL,Ss36,s4
R.O. 259	*Cortinarius junhuhnii*	15/10/97	FL,Hw22,s14
R.O. 260	*Cortinarius* sp.	15/10/97	FL,Ss36,s15
R.O. 261	*Nolanea* sp.section *Endochromonema*	15/10/97	FL,Ss36,s1
R.O. 262	*Clitocybe* sp. *(affin.pseudodicolor ?)*	15/10/97	FL,Ss38,s9
R.O. 263	*Oligoporus* sp.	15/10/97	FL,Ss36,s4
R.O. 264	*Nolanea* sp.	15/10/97	FL,Fd25,s8
R.O. 265	*Oligoporus* sp.	15/10/97	FL,Fd25,s1
R.O. 266	*Nolanea* sp.	15/10/97	FL,Hw22,s7
R.O. 267	*Mycena rubromarginata*	15/10/97	FL,Cw32,s3
R.O. 268	*Lactarius pallescens*	21/10/97	Br167,Hw117,s11
R.O. 269	*Geoglossum sp*	21/10/97	Br167,Cw116,s8
R.O. 270	*Hygrocybae miniata*	21/10/97	Br167,Cw116,s16
R.O. 271	*Mycena rosella*	21/10/97	Br167,Fd126,s8
R.O. 272	*Mycena epipterygia* var. *lignicola*	21/10/97	Br167,Cw116,s5
R.O. 273	*Naucoria pseudoamarescens*	15/10/97	FL,23,s14
R.O. 274	*Amanita farinosa*	21/10/97	Br167,Cw123,s9
R.O. 275	*Russula* sp.	15/10/97	FL,Fd18,s11
R.O. 276	*Amanita vaginata* group	20/10/97	UK,Hw95,s11
R.O. 277	*Mycena* sp.	15/10/97	FL,Fd18,s10
R.O. 278	*Mycena vulgaris*?	15/10/97	FL, Ss36,s11
R.O. 279	*Mycena* sp.	15/10/97	FL,Hw22,s7
R.O. 280	*Mycena* sp.	15/10/97	FL,Cw23,s3
R.O. 281	*Mycena* sp.	15/10/97	FL,Ss36,s3
R.O. 282	*Mycena* sp.	15/10/97	FL,Ss36,s3
R.O. 283	*Pholiota astragalina*	15/10/97	FL,outside
R.O. 284	*Mycena* sp.	15/10/97	FL,Cw32,s1

R.O. 285	*Hemimycena* sp.	15/10/97	FL,Cw32,s8
R.O. 286	*Hemimycena* sp.	15/10/97	FL,Ss36,s13
R.O. 287	*Resinomycena saccharifera* sp.	15/10/97	FL,Fd25,s3
R.O. 288	*Galerina* sp.	15/10/97	FL,Fd25,s5
R.O. 289	*Mycena flavoalba*?	15/10/97	FL,Ss36,s8
R.O. 290	*Mycena* sp.	15/10/97	FL,Cw32,s3
R.O. 291	*Mycena flavoalba*	15/10/97	FL,Ss36,s6
R.O. 292	*Galerina atkinsoniana*	20/10/97	UK,Hw83,s9
R.O. 293	*Clitocybe incomis*	21/10/97	Br167,Fd127,s1
R.O. 294	*Hemimycena delectabilis*	21/10/97	Br167,Ss111,s16
R.O. 295	*Gomphidius subroseus*	21/10/97	Br167,Cw23,s5
R.O. 296	*Mycena leptocephala*	21/10/97	Br167,Fd127,s8
R.O. 297	*Suillus punctatipes*	21/10/97	Br167,Hw121,s7
R.O. 298	*Phaeocollybia phaeogaleroides*	20/10/97	UK,Hw95,s7
R.O. 299	*Hygrophorus bakerensis*	21/10/97	Br167,Fd127,s1
R.O. 300	*Mycena adonis*	20/10/97	UK,Fd98,s4
R.O. 301	*Mycena tenax*	21/10/97	Br167,Ss111,s3
R.O. 302	*Lactarius luculentus* var.*laetus*	20/10/97	UK,Ss102,s5
R.O. 303	*Mycena* sp.	15/10/97	FL,Ss36,s15
R.O. 304	*Mycena* sp.	15/10/97	FL,Cw32,s2
R.O. 305	*Nolanea* sp.; *small, brown, striated*	21/10/97	Br167,Fd127,s2
R.O. 306	*Heyderia abietis*	20/10/97	UK,Fd98,s4
R.O. 307	*Ramaria flavobrunescens* var. *aromatica*	21/10/97	Br167,Hw121,s7
R.O. 308	*Clavaria atkinsoniana*	21/10/97	Br167,Ss111,s9
R.O. 309	*Clavaria purpurea*	21/10/97	Br167,Ss119,s15
R.O. 310	*Lactarius mucidus*	21/10/97	FL,Cw23,s9
R.O. 311	*Clavulinopsis subtilis*?	21/10/97	UK,Cw23,s14
R.O. 312	*Inocybe* sp.	20/10/97	UK,Hw83,14
R.O. 313	*Pholiota scamba*	20/10/97	UK,Cw100,s12
R.O. 314	*Lyuphylum semitale*	20/10/97	UK,Ss102,s4
R.O. 315	*Nolanea cetrata*	20/10/97	UK,Cw100,s11
R.O. 316	*Mycocalia duriaena*	20/10/97	UK,Hw83,outside
R.O. 317	*Tremella* sp.	21/10/97	Br167,Fd127,s2
R.O. 318	*Gomphidius smithii*	21/10/97	Br167,Fd127,s2
R.O. 319	*Galerina badipes*	21/10/97	Br167,Fd126,s2
R.O. 320	*Dermocybe crocea*	21/10/97	Br167,Fd127,s4
R.O. 321	*Hemimycena affin.pseudoscripula*	15/10/97	FL,Cw23,s1
R.O. 321a	*Clavulinopsis* sp.	15/10/97	Br167,Cw23,s11
R.O. 322	*Mycena oregonensis*	21/10/97	Br167,Ss111,s5
R.O. 323	*Russula adusta*	21/10/97	Br167,Fd127,s4
R.O. 324	*Mycena metata* group	21/10/97	Br167,Fd127,s2
R.O. 325	*Mycena atroalboides*	21/10/97	Br167,Ss119,s5
R.O. 326	*Pluteus* sp.	20/10/97	UK,Ss102,s11
R.O. 327	*Mycena aurantiomarginata*	21/10/97	Br167,Fd126,s12
R.O. 328	*Baeospora myosura*	21/10/97	Br167,Ss119,s3
R.O. 329	*Ascocoryne sarcoides*	21/10/97	Br167,Fd126,s5

R.O. 330	*Lycoperdon foetidum*	21/10/97	Br167,Ss111,s13
R.O. 331	*Clavulinopsis laeticolor*	21/10/97	?
R.O. 332	*Cortinarius renidens*	21/10/97	Br167,Hw121,s6
R.O. 333	*Mycena longiseta*	21/10/97	Br167,Fd127,s2
R.O. 334	*Phellodon niger*	21/10/97	Br167,Hw121,s6
R.O. 335	*Conocybe* sp.	21/10/97	Br167,Ss119,s5
R.O. 336	*Hygrocybe virginea*	21/10/97	Br167,Cw116,s11
R.O. 337	*Laccaria laccata*	21/10/97	Br167,Cw23,s8
R.O. 338	*Gymnopilus bellulus*	20/10/97	UK,ss102,s1
R.O. 339	*Cortinarius* sp.	21/10/97	Br167,ss119,s9
R.O. 340	*Dacrymyces stillatus*	20/10/97	UK,ss102,s13
R.O. 341	*Galerina atkinsoniana*	21/10/97	Br167,Hw121,s13
R.O. 342	*Cortinarius* sp.	21/10/97	Br167,Fd127,s5
R.O. 343	*Pseudoarmillaria ectypoides*	21/10/97	Br167,Cw123,s5
R.O. 344	*Cortinarius obtusus*	20/10/97	UK,Hw83,s5
R.O. 345	*Mycena metata* group	20/10/97	UK,Fd98,s15
R.O. 346	*Cordyceps militaris*	20/10/97	UK,Cw100,s16
R.O. 347	*Geoglossum with a Hypomycete*	21/10/97	FL,Cw23,s12
R.O. 348	*Dermocybe* sp.	21/10/97	Br167,Fd127,s10
R.O. 349	*Dermocybe* sp.	21/10/97	Br167,Hw121,s5
R.O. 350	*Mycena sp?*	20/10/97	UK,Fd98,s4
R.O. 351	*Mycena sp?*	21/10/97	Br167,Fd127,s6
R.O. 352	*Mycena tenax*	19/9/98	UKHw83s14
R.O. 353	*Strobilurus* sp.	19/9/98	UKCw84s3
R.O. 354	*Galerina* sp.	19/9/98	UKFd98s6
R.O. 355	*Mycena metata*	19/9/98	UKHw83s13
R.O. 356	*Cyptotrama chrysopepla?*	19/9/98	UkHw83s5
R.O. 357	*Lachnellula* sp. c.f. *calyciformis*	19/9/98	UkSs99s14
R.O. 358	*Galerina* sp. c.f. *vittaeformis*	19/9/98	UKFd98s6
R.O. 359	*Cordyceps militaris*	19/9/98	UKCw100s8
R.O. 360	*Pseudoarmillariella ectypoides*	19/9/98	UKCw84s4
R.O. 361	*Pleurocybella porrigens*	19/9/98	UKSs102s16
R.O. 362	*Cortinarius* sp.	16/9/98	FLHw22s8
R.O. 363	*Inocybe* c.f. *geophylla*	16/9/98	FLCw32s14
R.O. 364	*Lycoperdon* sp.	16/9/98	FLSs38s16
R.O. 365	*Tyromyces* sp.	16/9/98	FLFd18s3
R.O. 366	*Russula occidentalis*	25/7/98	Br167Fd127s11
R.O. 367	*Lyophyllum* sp.?	16/9/98	FLHw22s1
R.O. 368	*Cantharellus tubaeformis*	25/7/98	FLHw22s8
R.O. 369	*Tyromyces albellus*	27/8/98	UKHw83s14
R.O. 370	*Inocybe calamistrata*	27/8/98	UKHw95s16
R.O. 371	*Clitocybe sclerotoidea*	27/8/98	Br167Hw117s1
R.O. 372	*Bondarzewia montana*	27/8/98	UKCw84s5
R.O. 373	*Mycena*, on fern	22/10/98	nearBr167Cw116
R.O. 374	*Conocybe* sp.	26/7/98	UKCw100s8
R.O. 375	*Mycena* sp.	20/10/98	FLSs36s1

R.O. 376	*Mycena* sp.	20/10/98	FLSs38s7
R.O. 377	*Galerina emmentensis*	20/10/98	FLSs36s7
R.O. 378	*Mycena alcalina s.l.*	21/10/98	UKCw84s13
R.O. 379	*Amanita gemmata*	26/7/98	UKFd98s7
R.O. 380	*Russula atropurpurea*	25/7/98	Br167Hw117s6
R.O. 381	*Entoloma* sp.	25/7/98	Br167Cw116s6
R.O. 382	*Lactarius olivaceo-umbrinus*	26/7/98	UKHw83s7
R.O. 383	*Entoloma* sp.	26/7/98	UKFd98s1
R.O. 384	*Entoloma cetratum*	27/7/98	FLCw32s7
R.O. 385	*Inocybe* sp.	26/7/98	UKFd101s11
R.O. 386	*Mycena aurantiomarginata*	20/10/98	FLFd25s11
R.O. 387	*Mycena* sp.	20/10/98	FLSs36s1
R.O. 388	*Mycena epipterygia*	20/10/98	FLFd25s5
R.O. 389	*Mycena mirata* gr.	20/10/98	FLSs38s7
R.O. 390	*Mycena metata* gr.	20/10/98	FLSs36s6
R.O. 391	*Mycena arcangelina*	27/7/98	FLCw23s10
R.O. 392	*Amanita vaginata*	26/7/98	UKHw83s16
R.O. 393	*Mycena haematopus*	20/10/98	FLFd18s5
R.O. 394	*Mycena* sp.	27/7/98	FLFd18s8
R.O. 395	*Leptonia albinella*?	25/7/98	Br117Cw116s6
R.O. 396	*Galerina badipes* c.f.	20/10/98	FLCw32s11
R.O. 397	*Mycena tenax*	20/10/98	FLFd25s7
R.O. 398	*Chrysomphalina chrysophylla*	25/7/98	Br167Ss111s11
R.O. 399	*Mycena* sp. *Precox* gr?	20/10/98	FLSs36s1
R.O. 400	*Conocybe* sp.	20/10/98	FLSs38s14
R.O. 401	*Leptonia* sp.	20/10/98	FLFd25s11
R.O. 402	*Entoloma trachyospermum* var. *purpureoviolaceium*	20/10/98	FLHw22s8
R.O. 403	*Amanita farinosa*	22/10/98	Br167Ss111s3
R.O. 404	*Clavulina rugosa*	20/10/98	FLSs36s3
R.O. 405	*Gymnopilus bellulus*	20/10/98	FLFd25s16
R.O. 406	*Panellus longuinquus*	20/10/98	FLSs36s6
R.O. 407	*Inocybe euteles*	20/10/98	FLCw32s3
R.O. 408	*Cortinarius semisanguineus*	20/10/98	FLHw22s8
R.O. 409	*Clavulinopsis laeticolor*	20/10/98	FLCw32s8
R.O. 410	*Clavulinopsis laeticolor*	20/10/98	FLCw23s16
R.O. 411	*Entoloma* c.f. *lividoalbum*	20/10/98	FLSs38s9
R.O. 412	*Entoloma* c. f. *sinuatum*	20/10/98	FLHw22s2
R.O. 413	*Entoloma trachyosp.* var. *purpureoviol.*	20/10/98	FLSs38s14
R.O. 414	*Cortinarius castaneus* gr.	20/10/98	FLHw22s1
R.O. 415	*Corinarius* sp.	20/10/98	FLFd25s13
R.O. 416	*Inocybe napipes*	20/10/98	FLSs38s11
R.O. 417	*Lactarius kaufmanii*	20/10/98	FLCw23s10
R.O. 418	*Entoloma* sp.	22/10/98	Br167Cw116s6
R.O. 419	*Russula atropurpurea*?	16/9/98	FLCw23s1
R.O. 420	*Inocybe* sp.	22/10/98	Br167Ss111s8

R.O. 421	*Boletus piperatus*	22/10/98	Br167Ss111s12
R.O. 422	*Inocybe fastigiata*	22/10/98	Br167Ss111s11
R.O. 423	*Otidea kauffmanii*	22/10/98	Br167Hw117s4
R.O. 424	*Gomphidius glutinosus*	22/10/98	Br167Cw116s13
R.O. 425	*Calocera viscosa*	21/10/98	UKHw83s8
R.O. 426	*Heyderia abietis*	21/10/98	UKSs102s3
R.O. 427	*Lactarius fallax*	21/10/98	UKHw95s10
R.O. 428	*Podostroma alutaceum*	22/10/98	Br167Ss111s11
R.O. 429	*Cystoderma amianthinum* var. *rugosoreticulata*	21/10/98	UKFd98s11
R.O. 430	*Clavaria* sp. c.f. *acuta*	21/10/98	UKFd98s11
R.O. 431	*Clitocybe* sp.	20/10/98	FLFd18s2
R.O. 432	*Lactarius uvidus*	22/10/98	Br167Hw117s5
R.O. 433	*Russula atropurpurea*	16/9/98	FLFd25s16
R.O. 434	*Inocybe napipes*?	25/7/98	Br167Fd127s10
R.O. 435	*Tricholoma sp*?	27/7/98	FLSs38s5
R.O. 436	*Galerina* c. f. *autumnalis*	22/10/98	Br167Hw121s6
R.O. 437	*Inocybe ovatocystis*?	21/10/98	UKHw83s5
R.O. 438	*Psilocybe pelliculosa*	21/10/98	UKCw84s6
R.O. 439	*Galerina vitaeformis*	21/10/98	UKFd98s4
R.O. 440	*Mycena aurantiomarginata*	22/10/98	Br167Ss111s1
R.O. 441	*Conocybe* sp. c.f. *sulcatipes*	22/10/98	Br167Ss119s13
R.O. 442	*Marasmius* sp.	21/10/98	UKFd98s3
R.O. 443	*Unknown Ascomycete*	21/10/98	UKFd101s12
R.O. 444	*Mycena haematopus*	21/10/98	UKFd101s4
R.O. 445	*Mycena* sp.?	5/5/98	FLCw23s16
R.O. 446	*Cordyceps myrmecophila*	30/5/98	UKFd98s8
R.O. 447	*Inocybe ovatocystis*	27/8/98	Br167Hw117s7
R.O. 448	*Hygrocybe cantharellus*	27/6/98	Br167Cw116s4
R.O. 449	*Mycena basipedes*	27/6/98	Br167Hw117s10
R.O. 450	*Hemimycena delectabilis*	22/10/98	Br167Ss111s4
R.O. 451	*Mycena olivaceobrunacea*	22/10/98	Br167Cw116s13
R.O. 452	*Entoloma sericeum*	24/6/98	FLSs38s5
R.O. 453	*Clitocybe ditopus*?	21/10/98	UKFd98s10
R.O. 454	*Cudonia grissea*	28/5/98	FLSs38s12
R.O. 455	*Mycena mirata* gr.	20/10/98	FLSs38s9
R.O. 456	*Cordyceps myrmecophila*	27/6/98	Br167Cw123s7
R.O. 457	*Galerina philipsii*	21/10/98	UKFd98s3
R.O. 458	*Mycena purpureofusca*	21/10/98	UKFd98s8
R.O. 459	*Mycocalia duriaena*	21/10/98	outside UK
R.O. 460	*Russula bicoor*	20/10/98	FLSs36s12
R.O. 461	*Russula purple-green*	20/10/98	FLFd25s11
R.O. 462	*Russula greenish-purple*	20/10/98	FLHw22s6
R.O. 463	*Gymnopilus bellulus*	27/7/98	FLFd18s11